

**UNIVERSAL  
LIBRARY**

**OU\_212629**

**UNIVERSAL  
LIBRARY**

212629

OSMANIA UNIVERSITY LIBRARY

Call No.

824108/J13T

Accession No.

14613

Author

Jackson Jones W. P.

Title

Scientific Age 1930

This book should be returned on or before the date last marked below.

---



THIS SCIENTIFIC AGE

**BY DUGALD C. JACKSON, JR.  
AND W. PAUL JONES**

---

**This Scientific Age**

Essays in Modern Thought and Achievement. 5 } by 8 inches; 353 pages.

**The Profession of Engineering**

Essays Edited by DUGALD C. JACKSON, JR.,  
and W. PAUL JONES. 5 by 7¼ inches; 124  
pages.

---

Published by

**JOHN WILEY & SONS, Inc.**

**NEW YORK**

# THIS SCIENTIFIC AGE

*Essays in Modern Thought  
and Achievement*

EDITED BY

DUGALD C. JACKSON, JR., S.M.

*Head of Department of Electrical Engineering,  
University of Kansas*

AND

W. PAUL JONES, PH.D.

*Associate Professor of English, Speed Scientific School,  
University of Louisville*

NEW YORK

JOHN WILEY & SONS, INC.

LONDON: CHAPMAN & HALL, LIMITED

1930

COPYRIGHT, 1930,  
BY DUGALD C. JACKSON, JR.  
AND  
W. PAUL JONES

*All Rights Reserved*  
*This book or any part thereof must not*  
*be reproduced in any form without*  
*the written permission of the publisher.*

PRINTED IN U. S. A.

PRESS OF  
BRAUNWORTH & CO. NC.  
BOOK MANUFACTURERS  
BROOKLYN, NEW YORK

## PREFACE

In preparing this volume we have tried, not merely to produce another anthology, but to make a book for which there is a real need. None of the many volumes of readings recently available for the use of college classes in English was especially planned for students in technical schools. The anthologists seem usually to have had in mind students in the arts colleges; consequently some of their selections are quite unsuitable for prospective engineers, architects, and scientists.

In making this volume, however, we have had such students in mind at every step. We have asked ourselves, first, whether a particular essay would attract and hold the interest of students in technical schools, and second, whether it contained material of real educational value. Furthermore, we have subjected each essay to the test of actual usage in classes of engineering students.

The book is adapted for use, therefore, in English classes or orientation classes made up of students of technology. Since, however, it presents non-technical aspects of "this scientific age," it is suitable for use with any group of students interested in the modern world. Nor is it adapted solely for use in classes; individuals of all sorts, we hope, will find the book worth their attention.

Although the arrangement of essays in the book is more or less arbitrary, it is not entirely haphazard. **The reader will find** the following evident divisions :



VULCAN <sup>1</sup>

JOSEPH HUSBAND

Though Joseph Husband is president of an advertising agency, Husband and Thomas Company, New York, he is better known as an author. After graduating from Harvard in 1908 he took a job as an unskilled workman in a soft-coal mine of the Middle West, "with the intention of learning the 'operating end' of the great industry." His experiences during the year that he spent there are vividly described in his first book, *A Year in a Coal Mine*. The success of this book led to his making further studies of American industries, published under the titles *America at Work* and *The Story of a Pullman Car*. In 1918 and 1919 he served in the navy in French waters, and recorded his experiences in *A Year in the Navy* and *On the Coast of France*. Other books are *Americans by Adoption*, biographical sketches of immigrants who have risen to fame, and two novels, *High Hurdles* and *Citadel*.

Ten years ago the low dunes, a desert of yellow sand and beach-grass, stretched unbroken from the foot of Lake Michigan south to the headwaters of the Kankakee. Since the early days when the good Father Marquette was paddled slowly around the curving beach line to die finally on the Michigan shore, they have remained—a desert of soft colors in the summer, a sleet-swept tract in winter. A few miles north, on the western edge of the lake, a vast city in a single century was born and thrust its towers high against the horizon. Then, suddenly, came an instant transformation. Other cities, filled with the

<sup>1</sup> Reprinted from *America at Work* (1915) by permission of the author and by arrangement with Houghton Mifflin Company.

men of every nation, flattened the dunes into level streets. Along the lake shore strange structures of steel, reeking with smoke and blackness, streaked the sky with a cloud by day and a glare of furnaces by night. From a hundred meshing tracks the clamor of locomotives rose above the murmur of the city's streets. Steel, Vulcan, had usurped the wastes of sand and wiry beach-grass. Progress and industry stained the blue Indiana sky with the smoke of a thousand chimneys.

The long concrete slip slashed the beach lines. Beyond its mouth the lake, a brilliant ultramarine, pounded in before the north wind; but inside, the quiet water was tawny with riled sand and the stain of iron. Against the nearest dock an ore steamer rested its long low body beneath the shadow of a steel trestle that reached out, far above it. With sudden motion a grab-bucket swung down on slender cables from the trestle and disappeared in the waist of the ship. In an instant it lifted on tightened cables, heavy with ore, and swung ashore with grinding vibration of wheels and electric motors, to drop its contents on the ore pile that ran parallel with the dock. Like a mountain range the vermilion peaks of ore piled up above me, from the mouth of the harbor far inland, so high that behind them only the tops of the tallest furnaces appeared against the sky. From the scarred hills of northern Minnesota, down the length of Lake Superior and Lake Michigan, other steamers were bringing fresh food for the hungry furnaces. The reverberation of the mills rose sharp above the even cadence of the surf.

Like strange Martian creatures the blast furnaces squatted beyond the ore piles. Ample-waisted, they flanked them, and between their huge structures the long row of "stoves," high as modest skyscrapers, lifted their

slender domes in even line. Beyond, a vast pile of coal reared black against white heaps of broken limestone.

Inside the steel structure which inclosed the furnace a score of blackened, half-naked men were molding huge troughs of sand to receive the surplus iron which would pour forth when later they "cast the furnace." Hot, and enormous in girth, the furnace filled the building. Inside, under forced draft and at a temperature of thirty-five hundred degrees, layers of coke, limestone, and iron ore were undergoing their vital transformation. By the heat of the consuming coke the iron was filtering down in liquid flood, purified and refined by the flux of melted limestone.

From beneath the furnace a squat locomotive dragged a string of curious cars across a desolate field to the steel mills. On low trucks the ladles, like inverted cones, carried the liquid metal—so hot that four hours might elapse before it solidified.

In the twilight of a long corrugated building the brick ovens of the open hearths stretched away into almost indefinable distance. Heat, fresh consuming heat, choked the air. And from chinks in the hearths a white light of indescribable intensity pierced my eyeballs.

The trainload of molten metal had arrived before us. Already a big-lipped ladle had been dragged by an electric engine into the gloom of the building, and up to the hearth-mouth.

The doors of the hearth were thrown suddenly open. A blinding whiteness streaked with saffron, and heat almost beyond endurance, made me draw back behind a column. A workman thrust a pair of deep-blue glasses in my hand. Slowly the great ladle bent forward. From its spout a trickle of fluid iron poured faster and faster until the white cascade, at full flood, seethed into the

hearth-bath. A shower of sparks, strange flowery pyrotechnics, shot high into the gloom. Through the blue glass I peered into the hearth. Like an infernal lake it swirled and eddied, a whirlpool of incandescent flame. Leaping tongues of pink and lavender danced in the blue darkness. Shielding their goggled faces from the heat, the workmen cast lumps of rich ore into the hearth-mouth—black silhouettes of men against the blue glare of an uncanny firelight.

Behind the long row of open hearths huge cranes rumbled back and forth on their tracks beneath the roof, the operators, concealed somewhere on their rivet-studded frames, directing the swinging cables that lifted and carried weights inconceivable. High in the dark vault a great crane swung over us.

"They're going to tap a heat," shouted the assistant superintendent in my ear, his voice sounding faint and fragmentary above the steady roar that filled the building.

On the floor below, an electric motor trundled an empty ladle into place beneath the rear of one of the hearths.

Then from the hearth, with a mad daze of brilliancy, fifty-six tons of molten steel began to disgorge itself. Once more I put on the blue glasses. Against the deep purple gloom of the building the stream of metal shot forward and bent in the soft curve of running water. Like pale moonbeams the sunlight rays from glassless windows pierced the darkness, and sharp across them leaped the avalanche of steel, a flood of brilliant pink and blue that showered the room with a constellation of falling stars.

For a brief minute I took off the glasses. In the terrible glare of light all background disappeared. Gone

were the dark shapes of the toilers beneath; gone the uncanny moonlight. Yellow, tawny, brilliant as the contact of an electric arc, the swirling metal scorched my vision. A halo of flame seemed to envelop the ladle.

It was full. Through the glass again, it boiled soapy and seething, the crest of its wave-tossed surface crimson and blue. Slowly from the crane above, two great hooks like bent fingers caught the handles on its sides, lifted it, and with a hail of sparks and a glare of heat against our faces, swung it far above us. Then, with grinding reverberation, it moved past, far down the long gallery, to be poured into ingots in the waiting molds.

In the "blooming mill" there was the continuous rumble of mighty thunder. Cherry-red against the darkness, the incandescent ingots of steel shot back and forth between giant fingers that pressed and worked them at every passing; for like dough that must be kneaded to acquire a certain consistency, steel must be worked to obtain those qualities which its ultimate purpose will demand.

Into a great plank a hundred feet long the solid ingot flattened resistlessly between the stroking rollers. Then, finished, it shot abruptly beneath a knife that snipped it lightly into even bars of manageable weight.

In the structural mill the billets of steel, still malleable with glowing heat, rumbled noisily back and forth on the metal floor, propelled invisibly by countless whirling rollers that shot them with incredible speed and certainty of direction.

As I looked down the length of the gloomy building, the glare of the moving bars of metal contrasted so sharply with the black floor that they alone were visible,

like strange illuminated bodies that floated and swam on a sea of inky water. Through devious channels they navigated, palpably changing, narrowing, lengthening, until at last, in the far end of the building, the finished angle-bar or I-beam was deposited, a perfect thing, of cooling lead-gray steel.

And still more buildings; parallel with each other; equally vast; filled with darkness and tumult, the shifting shapes of giant roof-hung cranes, and the red glow of heated metal. Like paste from a tube, a thin rope of white-hot steel emerged from a shapeless machine that crouched squat on the iron floor, and with a breath of heat disappeared in the breast of another monster that trembled with the reverberation of a hundred hammers. And faster than the hand of my watch could count the seconds, a hail of railroad spikes, still glowing, leaped finished from its thundering womb. Bolts, spikes, nuts, and rivets, madly, with the tumult of clashing steel, poured finished from the vitals of the uncouth machines.

Plates of steel for the flanks of ships which will some day transport the wares of a trading world. Rails and spikes to carry high over mountain passes the flitting trains that make distant cities one. Bolt, rivet, and girder for the towering building. Steel, steel for its multifold destinies, here it is born in heat and labor. Steel for an age of steel.

In the twilight of the late summer afternoon the world seemed strangely quiet and at peace. Sharp and black against the yellow sky the roofs and stacks of the mills rose like the sky-line of a ruined city; and in an occasional opening the blue lake gleamed with the brilliant light of sapphire. In the gathering darkness electric lights began

to glimmer. Flares of dull-red gas-flame burst out like volcanoes and suddenly were gone.

Loud and metallic a hurdy-gurdy lifted the rippling cadence of a Neapolitan air in a distant street. Beyond the mill-yard gates the saloon window shone gayly and arc lights trembled into life. Day was over.

BUILDING A SKYSCRAPER<sup>1</sup>

COLONEL W. A. STARRETT

W. A. Starrett, one of the founders of Starrett Bros., Builders, Inc., has had charge of the construction of some of America's greatest skyscrapers. After graduating from the University of Michigan he entered the construction business with the George A. Fuller Company. In 1900, with others, he formed the Thompson-Starrett Company, which engaged in extensive construction enterprises throughout the United States. He was in the World War from beginning to end, starting as a rookie at Plattsburg and finishing as Colonel in the Quartermaster's Corps and Chairman of the Emergency Construction Committee, Council of National Defense, in charge of the army building program in this country. He has contributed to magazines and is the author of *Skyscrapers*, which narrates his own experiences and those of other pioneers in the building of skyscrapers and describes in detail the construction of tall buildings.

It is a fascinating game, building these great skyscrapers, and to those of us who stay in it year after year it's like strong drink; we get so that we just cannot do without the strenuous activity of it all. And it is a compelling thing too; a man gets his pride up over it, pride of accomplishment, pride in making good on prediction and forecast. "It can't be done" carries a challenge that the died-in-the-wool builder sometimes too eagerly accepts. So our business casualties are high—all too high for the sweat and toil that go into the game.

Building skyscrapers is the nearest peace-time equiva-

<sup>1</sup> Reprinted from *Skyscrapers and the Men Who Build Them*, copyright 1928 by Charles Scribner's Sons, by permission of the author and the publishers.

lent of war. In fact, the analogy is startling, even to the occasional grim reality of a building accident where maimed bodies, and even death, remind us that we are fighting a war of construction against the forces of nature. And the spirit of the Crusader is there, not only in the daring and courage, but also in the grief that ensues on these occasional terrible accidents, for they do happen in spite of the millions that are spent annually to prevent them. But the analogy to war is the strife against the elements. Foundations are planned away down in the earth alongside of towering skyscrapers already built. Water, quicksand, rock, and slimy clays bar our path to bedrock. Traffic rumbles in the crowded highways high above us, and subways, gas and water mains, electric conduits, and delicate telephone and signal communications demand that they be not disturbed lest the nerve system of a great city be deranged. Yet we venture down and do it, and from that inaccessible bedrock or hardpan we turn back upward, with accurately laid and adequate foundation structures to support the incredible weights that the columns of the skyscraper will impose; for it is not uncommon to have a thousand tons on a single column and a hundred separate columns and footings are not over-many as we build skyscrapers nowadays. All this is done without settlement or movement of so much as an inch, and with accuracy of position that regards a variation of an eighth of an inch as the very limit of allowable error.

Before these things are done, nice calculations have to be made of the weight of the building—just how much loading will be carried on each column; and then the ground is studied and soil conditions are analyzed. Not content with all of this, borings are taken and test-pits dug—the reconnaissance of a combat attack on an opponent

entrenched from geological eras and having all the mighty forces of nature in alliance to resist and oppose any disturbance of its age-long somnolence.

And with the foundations completed, only the first trenches have been carried, for the superstructure allies itself with gravitation and wind-pressure to resist the accomplishment; the same gravitation that, in its resistance, serves to make stable and everlasting the great skyscrapers that the battle is fought to produce. Rain, snow, and sleet repeatedly attack, sometimes with rushing tornadoes, sometimes with the long protracted attrition of rainy seasons or continued blizzard and cold. Even after the steel of the structure is up and the walls are well toward completion, as if to make their last violent sortie, blizzards rage in those dizzy heights, numbing the bodies and hands of the intrepid workmen at their tasks away up aloft, while in the streets the busy throngs muffle themselves in warm clothing or gather around cheerful radiators, rejoicing that civilization has so far advanced to mitigate the terrors of an adverse climate. Yet civilization has done all these things, and away up there where the icy winds sweep unrelentingly, the forge fires of the riveters hiss and glow while numb hands buck up with cold steel dolly-bars, and jack-hammers rattle and clatter defiance to the elements. These are the outposts fighting nature back, that nature may be made subservient to our common need. Building skyscrapers epitomizes the warfare and the accomplishment of our progressive civilization.

Even the organization closely parallels the organization of a combatant army, for the building organization must be led by a fearless leader who knows the fight from the ground up; who is familiar with the hazards of deep

foundations and the intricacies of all the complex trades that aid in completing the structures ; who has had experience with the equipment of construction, the hoists and derricks that raise the heavy steel and set the massive stones one on another, the mixers and chutes; who knows what equipment and materials may be made to do, where forcing must cease and daring must be curbed, where materials come from and how long it takes to prepare the different kinds; who knows what to allow for contingencies of temporary defeat, and how to consolidate the gains. Ever pressing forward, that leader with his lieutenants and they with their sub-lieutenants plan and do, ever prevailing over inertia, animate and inanimate, until the great operation fairly vibrates with the driving force of the strong personalities that direct the purposes of everything, seen and unseen, that makes for the swift completion of the work in hand.

The obtaining of materials near and far and the administration of all those thousands of operations that go to make up the whole are the major functions of the skyscraper builder. Knowledge of transportation and traffic must be brought to bear that the building may be built from trucks standing in the busy thoroughfares, for here is no ample storage space, but only a meagre handful of material needing constant replenishment—hour to hour existence. Yet it all runs smoothly and on time in accordance with a carefully prepared schedule; the service of supply of this peace-time warfare, the logistics of building, and these men are the soldiers of a great creative effort.

Marshaling this chaos into order is the commanding field-officer of the builder's troops, the job superintendent. The first building on the site will have been his shanty

and there he will be found workday, holiday, and Sunday, until the architect signs the certificate of completion. He knows how to be vice-president in charge of operations, master mechanic, superintendent, train master, and chief dispatcher keeping the traffic of a four-track road moving on time through the bottle-neck on a single pair of rails. He may be a jack of all trades and a master of many, but he is no superintendent unless he knows how to organize and how to delegate. Emergencies pound at his door day and night, and he must know the answer without looking in the book. Back of him stands the master builder who has traveled the same road and who has equipped him with everything necessary to the job except the know-how and the driving power; these he must supply himself. A poor superintendent often is felt on the job before the cost sheets and the slipping time schedule reveal his incompetence utterly.

As the young engineers come out of college and enlist as clerks and time-keepers, their goal after a year or two of apprenticeship is to be an assistant superintendent, or, as he is inadequately called in the trade, a job-runner. These assistants are not, as their name implies, the superintendent's lieutenants, but liaison officers between builder, architect, and sub-contractors. While the skyscraper gets under way they are in the architect's office asking how this detail is to be built, how that, and carrying the information to the sub-contractors who make their shop drawings therefrom. For each sub-contractor must be prepared to take up his own special task in order, and few items come in stock sizes.

While the steelwork is nearing completion away up in the upper reaches of the skyscraper and we break out with our masonry on one of the upper floors, where the

substantial brickwork of the building as it rises above the slender, exposed columns of the lower floors makes the structure look a bit ludicrous, many things are happening, not only in the complicated interior of the building, but at the shops, in the mills, and, in fact, far and near throughout our great industrial centers; for they all minister to the building of a skyscraper. Organized forethought translates itself into active organization. Here in a manufacturing plant a thousand miles from the job, an expeditor from the builder's office is checking up on a great blower of special capacity and dimensions, designed by the ventilating engineers while the job is still merely on paper, to fit in a certain cramped location away down in the bowels of the building. It is about ready for shipment and is needed because the sidewalk beams cannot be set until the blowers arrive. The steel erectors are about to finish, away up aloft, and the job superintendent knows that it is important to have the sidewalk beams completed while the erectors are still on the job. Moreover, the time schedule calls for it; that schedule prepared long ago before the wrecking commenced.

In New England, another expeditor is arranging for the loading of the granite, checked off piece by piece, for every piece has a separate cutting diagram, not only showing each stone as an integral part of the design, but also showing how that granite must be cut away on the back to fit securely on those same sidewalk beams that are giving the man in Detroit so much concern. Inside, plumbers, steamfitters, electricians swarm over the job getting in their piping, for pipes are everywhere, while down in the depths, now brightly lighted day and night, sheet metal workers hang great ducts that twist and turn and dodge pipes and squeeze between girders, that fresh

air in ample volume may be conducted to those depths by the fan that Detroit is making. Drawings, always drawings, depict all of this ; those same drawings that the engineers were preparing when the site still held the old buildings now demolished. When that granite arrives, it will be set to align perfectly with the masonry of those walls started away up there while yet the stone was being cut. In all of this, and, in fact, throughout the whole conduct of the job, the column-centers on the architect's and structural engineer's drawings control all matters of exact location.

Thus, the steel columns must have been set true and plumb; plumb by a special crew after the erectors have left the floor and before the riveting on that floor is started, for the erectors only hastily bolt their work as they forge ahead; yet the riveting must follow close behind, for the masonry floor arches are also pressing from below in this race to reach the top. How it all dovetails! One trade following and intermingling with another, yet all in orderly fashion and all in accordance with the schedule. It is the job superintendent who controls this great piece of teamwork, and as the succeeding trades are marshaled and embark upon their work, the whole job becomes imbued with his driving force, and every one on it senses the quality of leadership that guides it all. Here again the analogy to a combatant army is striking, for we all know that our fighting forces are only as good as the officers who lead them. Yet in the main office, the skill and experience of the master builder control. In spite of much that we see going on in this building game that gives discouragement, and sets men of life-long training and devotion to wondering, building is a great and inspiring calling, and the master

builder is still supreme. Quality in building still asserts itself, and our great national pride, the skyscraper, still holds bounteous opportunity for the exercise of the builder's art and forethought.

The spectacular work of excavating, shoring, and foundations, particularly where steam shovels are employed and heavy derricks lift great weights, has a fascination for the public to the extent that the crowds of spectators on the sidewalk would actually block progress, not to say endanger their own lives, if they were encouraged to loiter; hence the forbidding fences that the builder puts around the lot as soon as he can. As the structure rises, steel setting is perhaps even more spectacular, but here the point of vantage is anywhere in the street, and the public sees it and has learned to understand it better. Setting of exterior stonework has but a meager fascination after the spectacular feats of the steel workers, and bricklaying is almost prosaic, except that we like to note the progress from day to day and admire the speed with which a great structure is enclosed. A story of brickwork a day is a usual accomplishment for the well-organized builder. Then follows the glazing, and all of a sudden the building seems to stop, for it loses its spectacular interest.

Very different is the situation within those four walls, where to the builder's eye the major part of the operation is still to be done. The floor arches have been finished and the piping for the electric, plumbing, and heating work has all been done. Then comes the bustle of building partitions, always of fireproof material accurately laid, with doorways located and minute attention to floor plans, because already the renting agents have been renting space and there are many special layouts and arrangements

upon which leases have already been closed. All the special locations of electric outlets, baseplugs, and telephone outlets, if the layout has been carefully made, must be indicated for the guidance of the builder, and they are taken care of as these masonry partitions are being built.

The plumber's "risers" and piping must be tested before they are built in. If the building is a tall one, this test is carried on in sections of ten to fifteen floors at a time, thus avoiding too long delay in the partition work. Joining and following all of this comes an army of carpenters, metal lathers, sheet metal workers, marble and tile workers, cement floor finishers, elevator constructors, and what not—all marching in interlocked procession, for the sequence is complex.

In the superintendent's temporary office down on the bridge, daily conferences are held, either the foremen or representatives of the various sub-contractors attending, all intent upon working to the common plan which the superintendent has set, the same plan that was devised in the builder's main office away back when the time schedule was made and the builder planned the execution of it all.

The completion of plastering is the goal of the builder toward the finished work, as the completion of the steel is the goal on the exterior. The enormous amount of rubbish and dirt incidental and seemingly necessary to plastering stops all consideration of the finish, such as painting and carpentry where interior woodwork is used, and indeed, even marble and tilework; for, while marble and tile are sometimes set close on the heels of plastering and sometimes even before the plastering is finished, these two items appeal to the visual satisfaction which, in the

last analysis, must be the criterion of the builder's art. He may build with the conscience of a saint and the integrity of a trustee, but if in the finished building plaster surfaces are not true and straight, if expensive marble is cracked, tilework chipped, and painting marred, condemnation pursues him.

It is for this reason that the expert builder still clings to craftsmanship, and encourages it, for in spite of the standardization and pre-construction which have inevitably followed high wages and the division of labor, we cannot get away from the necessity of craftsmanship. This necessity has prompted the New York Building Congress to establish as one of its most important functions the awarding of craftsmanship certificates and tokens. This custom, although young, has already seized the imagination of the building industry and the architectural profession.

The initial move in the process of awarding these certificates arises when a special board of the Congress selects some notable building under construction where craftsmanship of high order may be expected. Representatives of the owner, of the architect, of the builder, and of labor make a study of the work for a period of several weeks prior to the award. On the appointed day, there is an appropriate ceremony and *one* craftsman in each trade to be considered is given his diploma, together with a lapel button, not necessarily for greatest productive effort, nor yet for minute skill, but, as the word implies, for general craftsmanship and high ability. Needless to say, such awards are highly prized by the men and have a significance beyond the mere token presented. It is the effort of the building industry in all its

interests to return to that spirit which guided the great structures of old and from which we seem unhappily to be parted in the mad mechanical application of our new-found instrumentalities of building construction.

We Americans always like to think of things in terms of bigness; there is a romantic appeal in it, and into our national pride has somehow been woven the yardstick of bigness. Perhaps that is one of the reasons we are so proud of our structures; they are big, very big, certainly the tallest and certainly the most complex and the most compelling the world has ever seen. They fairly personate the hustle and bustle of our modern accomplishment and postulate our ideal of efficiency, and they are our national pride because they are so completely American. So the bigness of the business as a whole we enjoy gasping over. Just think of it—over six billion dollars a year are spent on recorded structures in cities and towns that have official records on such matters. And that is not all, because throughout the length and breadth of the land, in hamlets, on the plains, in the mountains, everywhere there is sure to be building of some sort—always the spontaneous products of a virile and progressive people, always the token of a progressive nation. One enthusiast puts the unrecorded building at another six billion, but no matter—one six billion is enough to cloy the mind and give sufficient warrant for our claim that we are the greatest builders the world has ever seen.

Billions roll off the tongue so easily that to come back to millions seems like a humbling of our thoughts. Yet the spending of a few paltry millions in a single structure, all within the compass of a year, may still hold an interest; and when one views it as a great and complicated operation involving skill and daring, with a wealth of

adventure and the joy of fulfillment of a hard task well done, the scale of bigness may again grip the imagination, and in the story of how it is all done may yet be held the romance of a triumph no less stirring than the victory of battle, or the leading of a nation into the paths of peace and prosperity.

THE HOUSE OF A THOUSAND MARVELS <sup>1</sup>

M. K. WISEHART

M. K. Wisehart is primarily a journalist. After graduating from Hamilton College at Clinton, N. Y., in 1911 he went into newspaper work, serving as Washington correspondent of the *New York Evening Sun*, European correspondent of *Leslie's Weekly*, and member of the editorial, later of the contributing, staff of the *American Magazine*. From 1920 to 1929 he engaged in more or less continuous study of the work of certain American scientists, William D. Coolidge, Alexander Silverman, etc., and of American research and industrial organizations, such as the General Electric Company, the Westinghouse Electric and Manufacturing Company, and the Bureau of Standards. In 1929 he undertook similar studies abroad. His observations are partially presented in *Marvels of Science*, from which the present chapter about the Bureau of Standards is taken.

On the outskirts of Washington, D. C., occupying twenty buildings on a forty-three-acre tract is an institution known as the Bureau of Standards. Our national laboratory, it functions under the jurisdiction of the United States Department of Commerce. Organized twenty-five years ago for the purpose of maintaining and constructing "standards" for use in industry and commerce, it has become Uncle Sam's great clearing-house, probably the greatest anywhere in the world, for scientific information of all kinds. Every American is a shareholder in its discoveries and achievements. In innumerable ways we all profit from the wealth it produces,

<sup>1</sup> Reprinted from *Marvels of Science* (1928) by permission of the author and of The Century Company.

whether this wealth comes about through improvements in automobile tires and brake linings, or from research with regard to the sun and the stars, the weight of the earth, or the pressure of high winds against tall buildings.

More than seven hundred experts—chemists, physicists, and engineers—are employed by the Bureau of Standards. There are more than a hundred laboratories. More than ten curious, interesting, marvelous things in each laboratory. A thousand marvels? Literally tens of thousands! Let's see.

If ever you make a trip to our capital city and visit this institution you will enjoy a fascinating experience. You will find yourself hearing about or looking at just one wonderful thing after another!

For one thing you will be shown the laboratory of the mass section. Here is kept the apparatus which is used to check and govern all weighing in the country. The balances are exceedingly delicate. I wonder if you can imagine *how* delicate !

Suppose you wanted to weigh a slip of paper three or four inches long and half an inch wide. That would be easy. Now write your name on this slip of paper, and the balances will tell you what your signature weighs when written in ink! Write it with a pencil, and you can learn the difference between the weight of your name when written with ink or with lead! Did you forget to dot the " i " in your name? Dot it. Weigh your signature again, and you will learn how much the dot weighs.

Passing through another room, you will be told that an expert employed there recently devised means for ruling twenty-five thousand or more lines to one inch ! These lines are straight and parallel, with no error in the spacing between them that amounts to as much as one mil-

lionth of an inch. Can such precision as this serve any useful purpose? You will be told that such a ruled surface has the power to analyze a ray of light from a star or an atom, to tell what it is made of, to measure the light waves, and to disclose the structure of the atom!

That same expert has just completed measuring an almost incredibly fine bit of micro-writing on glass. The writing had been done so minutely that the Lord's Prayer occupied a space too small to be visible to the naked eye!

A swish! A roar! A giant propeller is revolving to the tune of an electric motor of more than two hundred horsepower. An airplane? You happen at this moment to be inspecting one of the bureau's three wind-tunnels, the so-called "caves of the wind," where hurricanes are made to order. In the teeth of winds ranging from twenty to a hundred and eighty miles an hour, models of airplanes, flying-boats, dirigibles, bombs, projectiles, motor-cars—everything that has to pass through the air with speed and efficiency—are tested. Their resistance to the air is measured by weighing the force required to keep them still in a wind whose speed is accurately known. To equal the velocity that can be mechanically created in these tunnels the speed of the typhoon would need to be doubled!

Off there, under the brow of a hill, is a curious-looking structure, a shed of extraordinary length. It houses a concrete water-tank four hundred feet long and about six feet wide. Above the tank, on steel rails at each side, is a platform on wheels, a kind of car which is driven by electricity. The mechanism operating the car is so precise and is subject to such exact control that the car can be run over the track at any desired speed, varying from two inches to twenty feet a second.

Attached to the rear of the car and dipping in the water is a metal device with revolving parts, something which at first glance might look to you like an airplane bomb. It is a water-current meter of the kind used by engineers in measuring the speed of small streams or big rivers.

Such a meter gives information of great importance in controlling rivers at flood time. Of course it must give accurate results, and the big tank and the electric car were devised as a means of checking the accuracy of such meters. Since a meter stationary in moving water and a meter moving in standing water yield exactly the same result, the water-current meter, after a trip down the long tank behind the car, should record exactly in proportion to the speed at which the car was run. It is in this way that errors in water-current meters can be corrected, and engineers furnished with an accurate basis for their estimates of water supply and flood hazard.

Recently a department of the Government sought from the Bureau of Standards information bearing upon the killing effect of light on the typhoid germ and other intestinal germs; for example, the *colon bacterium*. It was observed that ultra-violet rays of wavelengths lying between one hundred seventy and two hundred eighty billionths of a meter have the most powerful lethal action.

When science knows the frequency and the dose of ultra-violet light required to kill a specific organism, what may not be the future uses of such knowledge? One scientist suggests this: Suppose we want to disinfect a room; instead of using present-day types of disinfectants, might we not give the room a bath of ultra-violet rays for the purpose? It would seem almost impossible to overestimate the applications of such an achievement as this

to antiseptis, not only in disinfecting rooms but perhaps even wounds.

Is this probable near-discovery of the lethal dose for a colony of bacteria the beginning of what imaginative persons sometimes refer to as the death-ray—a ray that might annihilate animal life at a distance, in a flash? I say animal life, not human life, for that thought is appalling, and the zeal that prompted bureau scientists in their discovery was not the devastation but the betterment of mankind.

However, what I have said as yet does not begin to tell the story. The business of standardizing, of *measuring* everything under the sun, is a romance of human zeal, a magic story of infinitesimal things. The bureau is sometimes called the "house of accuracy." The home of ultra-precision! Here experts weigh to one part in a billion; talk and work to the millionth of an inch, the millionth of a second, or the billionth of an ampere!

Their interest is in anything under the sun—or beyond it!—that needs to be measured exactly. With how to keep your attic cool in summer—with the quantity and quality of light emitted by that most efficient of all lighting devices, the firefly—with the temperature of the continents and snowfields on the planet Mars!

In their pursuit of definite knowledge about the infinitely little, these scientists are continually producing big results of immediate practical value. Literally thousands of discoveries have been made by the bureau's experts which have to do with every kind of convenience and invention we commonly use.

But what does it all come down to in the end? In short, from what point of view can we discuss all the wonderful things that are being done here? And my

answer is this: *Science has reached such a stage that the millionth part of an inch is of more importance than a yard in the everyday life of us all.*

Now, strange as that statement may sound, I believe it to be true. Scarcely any man of vision would question the facts which can be called forth in support of it. Let me see if I can make clear just what I mean.

At first glance the diversity of the bureau's work seems to conceal the fact that its one main purpose is standardization. But standardization involves the measurement of phenomena and things. Progress in science and industry depends upon these measurements. First, the *need* is measured; then the product is *made to order* to meet the need. Underlying every invention and convenience that we commonly use—the telephone, the automobile, the radio—are measurements of all kinds, many so minute that we can scarcely grasp them. Any understanding of the importance of excessively small measurements is really the place to start, if one is to grasp what is going on in the world of science today.

So, as you follow this narrative through, I think you will realize that it is a kind of scientific idyl, and that this game of measuring a thing precisely is about the most fascinating pursuit in the world. You have heard of the seven wonders of our globe? This might be called the story of the millionth wonder! The millionth part of an inch! An infinitesimal thing, to be sure; but I think you will come to see that the stature of this hero of mine is greater than that of the legendary giants who stalked through fairy tales.

To begin with, suppose we make a brief visit to a remote California valley sixty miles east of Fresno. A device—the interferometer—which has been used in a'

rather spectacular experiment out there, was adapted in the Bureau of Standards for the particular purpose it was to serve. After a brief glance at this distant enterprise we shall come back to see what this same device means in the work of the Bureau and in our own homes.

In this valley I speak of, across Stevenson Creek, a tributary of the San Joaquin River, an experimental dam costing a hundred thousand dollars was erected in order that it might be destroyed and at the same time determine a few scientific principles. Among engineers many different theories are held regarding the construction of dams. In recent years a type of construction known as the arch dam has come into use. It can be built at much less cost, and may assure the full measure of safety obtained by other types. Hence, an experiment by the Engineering Foundation with the arch-type dam was planned.

This dam may give way with a roar of falling masonry and descending water, or the great mass of water behind it may merely crack and rend the masonry. At all events, the result is expected to settle definitely the maximum resistance of this type of dam, a very important thing in the development of our national water-power. The knowledge thus gained may make it practicable to construct dams in remote places where costs have hitherto been prohibitive.

A number of the instruments to be used in this test had to be designed to meet special conditions. The interferometer, which in one form or another has been in use for years, was one of these. The instrument for use out there is in such a form that it can be placed against the wall of the dam. By looking into the eyepiece, the observer can detect the slightest deflection of the dam

wall as the water pressure rises behind it. Looking into the eyepiece, he can *see* when, at any point, the dam wall yields as much as one millionth part of an inch! A dial attached to the instrument would record when the dam has yielded one ten-millionth of an inch! Thus, optically, the yield of the dam can be detected long before this could be ascertained by any other method of measuring.

It is a fairly simple apparatus, consisting of mirrors and plates, with all the parts fitting very exactly. By bringing about an interference of two trains of light waves from the same source it produces shadow lines. These shadow lines are observed through the eyepiece.

Suppose you put the interferometer on a steel axle six inches thick. Look into the eyepiece. Press the steel bar with your finger, exerting a force of, say, ten pounds. You see concentric shadow lines, an eighth of an inch apart, moving out from the center. Each step-up of the shadow lines represents a yield or bend of the axle of one one-hundred-thousandth of an inch.

For the novice, of course, it is an uncanny thing to see the quivering streaks of light and dark reveal that a six-inch steel axle, or a wall of masonry more than five feet thick, yields one one-hundred-thousandth or more under the pressure of one hand! By this same optical means you can *see* the "bending" of tool-steel shafting three and a half inches thick under the weight of a visiting card.

If you go into your home kitchen you will probably have little difficulty in finding dishes with numerous cracks in the glazed surface. Why are they cracked or "crazed"? Because the body upon which the glaze was applied expands and contracts to a different degree from the glaze itself when the dish is heated. Recently, the interferometer has been used in researches to determine

just how much various materials expand and contract under varying conditions. The result is that chemists now know how to match the expansion and contraction of the glaze with that of the body to which it is applied. By using this information in the ceramic industry the crazing of chinaware, porcelain, etc., will be greatly reduced.

In the same way can be measured the expansion of gold and of the amalgams used by dentists in filling teeth. As you doubtless know, such fillings expand or contract when subjected to heat or cold. As a result of researches in which the interferometer played an important part, the manufacturers of dental supplies now know the kind of amalgam which is affected *least* when, at the end of your dinner, you drink hot coffee and at the next moment eat ice-cream !

Presently I shall speak of methods of making measurements of an entirely different kind, which are more delicate even than those possible with the interferometer; but first I want to make sure we understand the great variety of ways in which we all profit by the use of this device.

Think for a moment of the important part that exact measurements play in the manufacture of automobiles. In the making of a car, thirty thousand or more measurements may be necessary. You will readily understand that the better the parts fit, the more efficient and smooth-running the mechanism. The same thing is true in the making of ordnance. The better the projectile fits the gun the more accurate the fire. In making an ordinary shell some two hundred accurate measurements are necessary—in making a Browning gun two thousand two hundred and sixty-two ! What about the trigger action in small arms? They must fit to one ten-thousandth of an inch! How are these things accomplished?

In the shops the dimensions of all parts that must fit together are controlled by gages. These gages consist of flat rectangular-shaped pieces of steel, one dimension of these having the precious precision that determines the effectiveness of the product. There may be a hundred or more gages in a complete set, ranging from one millimeter up to one meter, or from five-hundredths of an inch to thirty-six inches, in thickness. These can be combined, of course, into almost any number of different sizes.

Gages of sufficient accuracy for use in the manufacture of ordnance were not made in the United States up to the time when America entered the last war. They were imported from Sweden, where they were made by a secret process. When the scientist who made them was asked what methods he used, his answer was to the effect that his main ingredient was "infinite patience."

That certainly was a very truthful answer, as was found when the problem of producing these gages for the Ordnance Department was put before the Bureau of Standards. In three weeks' time, however, working day and night, the Bureau's experts perfected methods by which gages could be made accurate to three-millionths of an inch. They used not only infinite patience but the interferometer as well.

The first step in the making of such accurate gages is to develop what is known as the "flat." This is a piece of glass or quartz which has been ground until its surface is accurate in "flatness" to one ten-millionth of an inch. Patience and the interferometer, you see! The flat must be tested and retested until the interferometer shows that every point in the surface lies in the same plane within one ten-millionth of an inch.

Now, when a new gage is made, one that is a milli-

meter in length, say, it is tested by putting it on this "flat" alongside another gage of the same dimension and of *known* length. A similarly accurate "flat" is placed on top of the two gages. The interferometer is adjusted. By looking into the eyepiece one can see the shadow lines which measure the difference between the two gages to the millionth part of an inch. Thus, if the gage is accurate enough for the use required, it can be sent to the shop; if it is oversize it can be made accurate by further grinding.

I have been trying to impress upon you the fact that science is today dealing with quantities that are inconceivably small. Let me illustrate that in another way: As you know, the microphone is used in all telephones and loud speakers to amplify the received wavelength into audibility. Now it is estimated that the energy required to heat a thimbleful of water one degree is sufficient to run a telephone disk audibly for ten thousand years! At present, of course, the telephone disk consumes many times this amount of energy, and yet so little that the reduction of this waste is not a vital problem of the day. To perfect this device, and still get audibility, it will be necessary to measure as fine as the statement I have just made indicates.

Every radio enthusiast knows that his aerial picks up a certain wave, which is used as a pattern current to produce, control, and modulate a larger current. But I wonder if the average listener-in has any idea of the infinitesimal amount of energy that is picked up from the air to be used as a pattern for the loud-speaker device? How shall I put this? Take the ordinary small set, for example: a crystal set. It has been estimated that the walking of a fly up the wall for one second, or the dis-

tance of an inch, say, would accomplish work equivalent to the amount of energy received through space by a crystal set operating continuously for twenty-five years! That, I think, should give you some idea of the infinitely small quantities which science is now controlling.

Probably the most sensitive instrument in use at the Bureau of Standards is the Coblentz thermocouple. It is sensitive enough to register the heat that would be required to raise the temperature of your finger-tip one degree in a million years; so delicate, indeed, that it could register the heat of a candle several hundred miles away.

This instrument was devised by Dr. Coblentz, one of the leading physicists of the Bureau. With it he has measured the temperature of a hundred and ten stars, planets, and satellites, including the surface of Mars and of the moon. His observations were made during several months of the summer of 1924, on a mountain top at Flagstaff, Arizona. As a result, we definitely learned for the first time that at least one planet, Mars, has a temperature at which life of some kind may be possible. At noon, during the summer season, Mars has a temperature as high as sixty degrees, while at night, owing to air conditions, the temperature drops to ninety-four degrees below zero.

Can a creature of any kind live on a planet whose night-time temperature is so low? About that we can only speculate, of course.

What kind of a device is it that can measure the temperature of a body millions of miles away? It consists of a tiny weld of two metals, bismuth and silver, with a circuit of fine wires connecting the two metal parts of the joint. In this circuit is placed a delicate electric meter, which detects and measures the infinitesimal flow that

develops in the joint whenever it is heated. The image of the distant body whose temperature is to be measured is thrown upon the joint by a telescope. The electric current created by the rays turns a tiny mirror in the meter. The angle of the turn measures the current, and the current measures the energy of the ray. Then it is a simple matter of mathematical calculation to state the energy in the terms of temperature.

Scientific devices developed for purposes which to many seem remote from everyday affairs almost invariably prove of value for immediate and practical ends. This thermocouple has been used to measure the radiation of the sun on the leaves of plants, as an aid in research concerning the method of plant growth, and to measure the radiation and absorption of heat in different materials.

Some time ago the Bureau was advised by the United States Army that the heat within the soldiers' tents on the Texas border was unbearable. Could the bureau suggest means of keeping the sun's heat from penetrating the tents? The answer, tested by the thermocouple, was that white paint outside and aluminum paint inside would reduce by *80 per cent*, the amount of the sun's heat coming through the tent. This knowledge could, of course, be applied by all of us. To reduce heat radiation, ice-wagons, golf-caps, and attics might be treated in the same way as tents—white paint outside and aluminum paint inside. On the other hand, on our radiators we should use *not* aluminum paint, which radiates least and absorbs most heat, but pigment paints, which absorb least and radiate most.

Of the scientist who developed the thermocouple it has been said that he hitched his wagon to a star and forth-

with gave the world knowledge which improves the habitability of tents and attics and increases the efficiency of ice-wagons and radiators!

Let me tell you about another curious experiment in making fine measurements. Under one of the Bureau buildings is a cave thirty-five feet below the level of the ground. Here, without artificial heat, the temperature does not vary one degree a year. The device in use in this room is so delicate that it would be disturbed by the force of attraction of the body of a person who came within ten feet of it. The scientist (Dr. Heyl) at work there observes the delicate mechanism through a telescope fifteen feet away! An automobile coming within thirty feet of the apparatus might upset the calculations. Hence, the experiment is being conducted underground.

This apparatus is a miniature system representing the earth and a body near its surface. In part, it consists of a steel cylinder weighing a hundred and forty pounds and an eight-inch rod of aluminum, which carries at each end a platinum ball weighing an ounce and a half, the balls being suspended by a tungsten filament. Slowly this rod swings back and forth in a small arc as it is affected by the attraction of the steel cylinder. The time of swing is half an hour in each direction.

What's it all about? A scientist is weighing the earth! By repeated observations, he is determining the force of attraction between the bodies of his miniature system. Once this force has been accurately ascertained, the results can be applied so that he can calculate the mass of the globe.

Here we have the extremes of measurement, bigness and littleness. The enormous mass of the earth is being determined by measuring a force so small that only the

most delicate pendulum known can detect it. The force of attraction which this mass of steel weighing a hundred and forty pounds (representing the earth) has for the ball of platinum weighing an ounce and a half (representing a body near the earth's surface) is measurable only in millionths of a grain—about one thousandth of a kilogram!

Of course, we already know something about the weight of the earth. It's a pretty large figure. Write down "six" and twenty-one ciphers. There you have it! Six thousand million million million tons!

Science can do even a little better by you than that. It can give you the three figures that come after the six. But what about the fourth figure? Nobody knows. If all goes well, the work now going on in Dr. Heyl's cave will produce the fourth figure so that the weight of the earth can be stated more accurately than heretofore.

Off and on, Dr. Heyl has been at work on this experiment for two years. He has many notebooks filled with data. It took eleven months to build the apparatus required. Maybe, in six or eight months more the result will be known.

And now we may ask ourselves why anyone should take all this trouble to find out what this fourth figure is? Of what use can it be? It is of great use to astronomers, of course. The mass of the earth is a starting point from which are obtained the masses of the moon, the sun, and the other planets of the solar system. Again, a knowledge of the earth's mass enables scientists to learn something about the interior of the earth. Computations regarding the earth's density have suggested to scientists that the core of the earth is a great ball of iron! About

that, scientists will never be satisfied until they feel that they *know*.

Again, this experiment may furnish a new measure of the force of gravitation, universal in all matter. That will be of practical importance to navigators, who will use it in locating their positions at sea. It will make possible more accurate predictions of the rise and fall of tides years in advance. So, in future, the sailing time of vessels, which must ride out of harbors on the crest of the tide, may be determined by the work that is now being done in this cave !

# IV

## METALS, OLD AND NEW<sup>1</sup>

EDWIN E. SLOSSON

When Edwin E. Slosson graduated from the University of Kansas, in his native state, he was initiated into both Phi Beta Kappa and Sigma Xi, literary and scientific honorary societies. The combined abilities recognized there he retained throughout his life; no man has written more interestingly about science. As Edison once wrote, "Slosson is a 'Star' in lucidity." For thirteen years he was professor of chemistry at the University of Wyoming and the Wyoming Agricultural Experiment Station. Then he was on the editorial staff of the *Independent* in New York, and finally became Director of Science Service, the institution for the popularization of science. His lectures as well as his books give abundant evidence, first, of his desire to know, and, second, of his ability to tell the other person what he has found out. The present essay, originally a chapter of *Creative Chemistry*, was revised especially for this volume by Dr. Slosson, shortly before his death in October, 1929. Other interesting books of his are *Chats on Science*, *Snapshots of Science*, *Keeping Up With Science*, *Sermons of a Chemist*, and *Easy Lessons in Einstein*,

Gold is for the mistress—silver for the maid—  
Copper for the craftsman cunning at his trade.  
"Good!" said the baron, sitting in his hall,  
"But Iron—Cold Iron—is master of them all."  
—*Kipling*.

The primitive metallurgist could make use of only such metals as he found free in nature, that is, such as had not been attacked and corroded by the ubiquitous oxy-

<sup>1</sup> Reprinted from *Creative Chemistry* (1919), Chapter XIV, by permission of the author and of The Century Company, with revisions made by the author in 1929.

gen. These were primarily gold or copper, though possibly some original genius may have happened upon a bit of meteoric iron and pounded it into a sword. But when man found that the red ocher he had hitherto used only as a cosmetic could be made to yield iron by melting it with charcoal, he opened a new era in civilization, though doubtless the ochre artists of that day denounced him as a utilitarian and deplored the decadence of the times.

Iron is one of the most timid of metals. It has a great disinclination to be alone. It is also one of the most altruistic of the elements. It likes almost every other element better than itself. It has an especial affection for oxygen, and, since this is in both air and water, and these are everywhere, iron is not long without a mate. The result of this union goes by various names in the mineralogical and chemical world, but in common language, which is quite good enough for our purpose, it is called iron rust.

Not many of us have ever seen iron, the pure metal, soft, ductile, and white like silver. As soon as it is exposed to the air it veils itself with a thin film of rust and becomes black and then red. For that reason there is practically no iron in the world except what man has made. It is rarer than gold, than diamonds; we find in the earth no nuggets or crystals of it the size of the fist as we find of these. But occasionally there fall down upon us out of the clear sky great chunks of it weighing tons. These meteorites are the mavericks of the universe. We do not know where they come from or what sun or planet they belonged to. They are our only visitors from space, and if all the other spheres are like these fragments we know we are alone in the universe. For they contain

rustless iron, and where iron does not rust man cannot live, nor can any other animal or any plant

Iron rusts for the same reason that a stone rolls down hill, because it gets rid of its energy that way. All things in the universe are constantly trying to get rid of energy except man, who is always trying to get more of it. Or, on second thought, we see that man is the greatest spend-thrift of all, for he wants to expend so much more energy than he has that he borrows from the winds, the streams, and the coal in the rocks. He robs minerals and plants of the energy which they have stored up to spend for their own purposes, just as he robs the bee of its treasured honey and the silkworm of its cradle.

Man's chief business is in reversing the processes of nature. That is the way he gets his living. And one of his greatest triumphs was when he discovered how to undo iron rust and get the metal out of it. In the four thousand years since he first did this he has accomplished more than in the millions of years before. Without knowing the value of iron rust man could attain only the culture of the Aztecs and Incas, the ancient Egyptians and Assyrians.

The prosperity of modern states is dependent on the amount of iron rust which they possess and utilize. England, United States, France, Germany, all nations are competing to see which can dig the most iron rust out of the ground and make out of it railroads, bridges, buildings, machinery, battleships, and such other tools and toys, and then let them relapse into rust again. Civilization can be measured by the amount of iron rusted per capita, or better, by the amount rescued from rust.

But we are devoting so much space to the considera-

tion of the material aspects of iron that we are likely to neglect its aesthetic and ethical uses. The beauty of nature is very largely dependent upon the fact that iron rusts and, in fact, all the common compounds of iron are colored. Few elements can assume so many tints. Look at the paint pot canons of the Yellowstone. Cheap glass bottles turn out brown, green, blue, yellow, or black, according to the amount and kind of iron they contain. We build a house of cream-colored brick, varied with speckled brick and adorned with terra cotta ornaments of red, yellow, and green, all due to iron. Iron rusts, therefore it must be painted; but what is there better to paint it with than iron rust itself? It is cheap and durable, for it cannot rust any more than a dead man can die. And what is also of importance, it is a good, strong, clean looking, enduring color. Whenever we take a trip on the railroad and see the miles of cars, the acres of roofing and wall, the towns full of brick buildings, we rejoice that iron rust is red, not white or some less satisfying color.

We do not know why it is so. Zinc and aluminum are metals very much like iron in chemical properties, but all their salts are colorless. Why is it that the most useful of the metals forms the most beautiful compounds? Some say, Providence; some say, chance; some say, nothing. But if it had not been so we would have lost most of the beauty of rocks and trees and human beings. For the leaves and the flowers would all be white, and all the men and women would look like walking corpses. Without color in the flower what would the bees and painters do? If all the grass and trees were white, it would be like winter all the year round. If we had white blood

in our veins like some of the insects it would be hard lines for our poets. And what would become of our morality if we could not blush?

As for me, I thrill to see  
The bloom a velvet cheek discloses!  
Made of dust! I well believe it,  
So are lilies, so are roses.

An etiolated earth would hardly be worth living in.

The chlorophyll of the leaves and the hemoglobin of the blood are similar in constitution. Chlorophyll contains magnesium in place of iron, but iron is necessary to its formation. We all know how pale a plant gets if its soil is short of iron. It is the iron in the leaves that enables the plants to store up the energy of the sunshine for their own use and ours. It is the iron in our blood that enables us to get the iron out of iron rust and make it into machines to supplement our feeble hands. Iron is for us internally the carrier of energy, just as in the form of a trolley wire or of a third rail it conveys power to the electric car. Withdraw the iron from the blood as indicated by the pallor of the cheeks, and we become weak and faint, and finally die. If the amount of iron in the blood gets too small the disease germs that are always attacking us are no longer destroyed, but multiply without check and conquer us. When the iron ceases to work efficiently we are killed by the poison we ourselves generate.

Counting the number of iron-bearing corpuscles in the blood is now a common method of determining disease. It might also be useful in moral diagnosis? A microscopical and chemical laboratory attached to the courtroom would give information of more value than some of the evidence now obtained. For the anaemic and

florid vices need very different treatment. An excess or a deficiency of iron in the body is liable to result in criminality. A chemical system of morals might be developed on this basis. Among the ferruginous sins would be placed murder, violence, and licentiousness; among the non-ferruginous, cowardice, sloth, and lying. The former would be mostly sins of commission; the latter, sins of omission. The virtues could, of course, be similarly classified: the ferruginous virtues would include courage, self-reliance, and hopefulness; the non-ferruginous, peaceableness, meekness, and chastity. According to this ethical criterion the moral man would be defined as one whose conduct is better than we should expect from the per cent of iron in his blood.

The reason why iron is able to serve this unique purpose of conveying life-giving air to all parts of the body is because it rusts so readily. Oxidation and de-oxidation proceed so quietly that the tenderest cells are fed without injury. The blood changes from red to blue and vice versa with greater ease and rapidity than in the corresponding alternations of social status in a democracy. It is because iron is so rustable that it is so useful. The factories with big scrap-heaps of rusting machinery are making the most money. The pyramids are the most enduring structures raised by the hand of man, but they have not sheltered so many people in their forty centuries as our skyscrapers that are already rusting.

We have to carry *on* this eternal conflict against rust because oxygen is the most ubiquitous of the elements and iron can only escape its ardent embraces by hiding away in the center of the earth. The united elements, known to the chemist as iron oxide and to the outside world as rust, are among the commonest of compounds and their

colors, yellow **and** red like the Spanish flag, are displayed on every mountainside. From the time of Tubal Cain man has ceaselessly labored to divorce these elements and, having once separated them, to keep them apart so that the iron may be retained in his service. But here, as usual, man is fighting against nature, and his gains, as always, are only temporary. Sooner or later his vigilance is circumvented and the metal that he has extricated by the fiery furnace returns to its natural affinity. The flint arrowheads, the bronze spearpoints, the gold ornaments, the wooden idols of prehistoric man are still to be seen in our museums, but his earliest steel swords have long since crumbled into dust.

Every year the blast furnaces of the world release 75,000,000 tons of iron from its oxides and every year a large part, said to be a quarter of that amount, reverts to its primeval forms. If so, then man after five thousand years of metallurgical industry has barely got three years ahead of nature, and should he cease his efforts for a generation there would be little left to show that man had ever learned to extract iron from its ores. The old question, "What becomes of all the pins?" may be as well asked of rails, pipes, and threshing machines. The end of all iron is the same. However many may be its metamorphoses while in the service of man it relapses at last into its original state of oxidation. To save a pound of iron from corrosion is then as much a benefit to the world as to produce another pound from the ore. In fact it is of much greater benefit, for it takes four pounds of coal to produce one pound of steel, so whenever a piece of iron is allowed to oxidize it means that four times as much coal must be oxidized in order to replace it.

And the beds of coal will be exhausted before the beds of iron ore.

If we are ever to get ahead, if we are to gain any respite from this enormous waste of labor and natural resources, we must find ways of preventing the iron which we have obtained and fashioned into useful tools from being lost through oxidation. Now there is only one way of keeping iron and oxygen from uniting and that is to keep them apart. A very thin dividing wall will serve for the purpose, for instance, a film of oil. But ordinary oil will rub off, so it is better to cover the surface with an oillike linseed, which oxidizes to a hard elastic and adhesive coating. If with linseed oil we mix iron oxide or some other pigment we have a paint that will protect iron perfectly so long as it is unbroken. But let the paint wear off or crack so that air can get at the iron, then rust will form and spread underneath the paint on all sides. The same is true of the porcelain-like enamel with which our kitchen iron-ware is nowadays coated. So long as the enamel holds, it is all right, but once it is broken through at any point it begins to scale off and gets into our food.

Obviously it would be better for some purposes if we could coat our iron with another and less easily oxidized metal than with such dissimilar substances as paint or porcelain. Now the nearest relative to iron is nickel, and a layer of this of any desired thickness may be easily deposited by electricity upon any surface however irregular. Nickel takes a bright polish and keeps it well, so nickel plating has become the favorite method of protection for small objects where the expense is not prohibitive. Copper plating is used for fine wires. A sheet of iron dipped

in melted tin comes out coated with a thin adhesive layer of the latter metal. Such tinned plate commonly known as "tin" has become the favorite material for pans and cans. But if the tin is scratched the iron beneath rusts more rapidly than if the tin were not there, for an electrolytic action is set up, and the iron, being the negative element of the couple, suffers at the expense of the tin.

With zinc it is quite the opposite. Zinc is negative toward iron, so when the two are in contact and exposed to the weather the zinc is oxidized first. A zinc plating affords the protection of a Swiss Guard, it holds out as long as possible and when broken it perishes to the last atom before it lets the oxygen get at the iron. The zinc may be applied in four different ways. (1) It may be deposited by electrolysis as in nickel plating, but the zinc coating is more apt to be porous. (2) The sheets or articles may be dipped in a bath of melted zinc. This gives us the familiar "galvanized iron," the most useful and when well done the most effective of rust preventives. Besides these older methods of applying zinc there are now two new ones. (3) One is the Schoop process by which a wire of zinc or other metal is fed into an oxygen-hydrogen air blast of such heat and power that it is projected as a spray of minute drops with the speed of bullets, and any object subjected to the bombardment of this metallic mist receives a coating as thick as desired. The zinc spray is so fine and cool that it may be received on cloth, lace, or the bare hand. The Schoop metallizing process has been improved by the use of the electric current instead of the blowpipe for melting the metal. Two zinc wires connected with any electric system, preferably the direct, are fed into the "pistol." Where the wires meet, an electric arc is set up and the melted zinc is

sprayed out by a jet of compressed air. (4) In the Sherardizing process the articles are put into a tight drum with zinc dust and heated to 800° F. The zinc at this temperature attacks the iron and forms a series of alloys ranging from pure zinc on the top to pure iron at the bottom of the coating. Even if this cracks in part, the iron is more or less protected from corrosion so long as any zinc remains. Aluminum is used similarly in the calorizing process for coating iron, copper, or brass. First a surface alloy is formed by heating the metal with aluminum powder. Then the temperature is raised to a high degree so as to cause the aluminum on the surface to diffuse into the metal, and afterwards it is again baked in contact with aluminum dust, which puts upon it a protective plating of the pure aluminum, which does not oxidize.

Another way of protecting iron-ware from rusting is to rust it. This is a sort of prophylactic method like that adopted by modern medicine where inoculation with a mild culture prevents a serious attack of the disease. The action of air and water on iron forms a series of compounds and mixtures of them. Those that contain least oxygen are hard, black, and magnetic like iron itself. Those that have most oxygen are red and yellow powders. By putting on a tight coating of the black oxide we can prevent or hinder the oxidation from going on into the pulverulent stage. This is done in several ways. In the Bower-Barff process the articles to be treated are put into a closed retort and a current of superheated steam is passed through for twenty minutes followed by a current of producer gas (carbon monoxide), to reduce any higher oxides that may have been formed. In the Gesner process a current of gasoline vapor is used as the reducing

agent. The blueing of watch hands, buckles, and the like may be done by dipping them into an oxidizing bath such as melted saltpeter. But in order to afford complete protection the layer of black oxide must be thickened by repeating the process, which adds to the time and expense. This causes a slight enlargement, and the high temperature often warps the ware so it is not suitable for nicely adjusted parts of machinery, and of course tools would lose their temper by the heat.

A new method of rust-proofing which is free from these disadvantages is the phosphate process invented by Thomas Watts Coslett, an English chemist, in 1907, and developed in America by the Parker Company of Detroit. This consists simply in dipping the sheet iron or articles into a tank filled with a dilute solution of iron phosphate heated nearly to the boiling point by steam pipes. Bubbles of hydrogen stream off rapidly at first, then more slowly; and at the end of half an hour or longer the action ceases, and the process is complete. What has happened is that the iron has been converted into a basic iron phosphate to a depth depending upon the density of articles processed. Anyone who has studied elementary qualitative analysis will remember that when he added ammonia to his "unknown" solution, iron and phosphoric acid, if present, were precipitated together, or, in other words, iron phosphate is insoluble except in acids. Therefore a superficial film of such phosphate will protect the iron underneath except from acids. This film is not a coating added on the outside like paint and enamel or tin and nickel plate. It is therefore not apt to scale off and it does not increase the size of the article. No high heat is required as in the Sherardizing and Bower-Barff processes, so steel tools can be treated without losing their temper or edge.

The deposit consisting of ferrous and ferric phosphates mixed with black iron oxide may be varied in composition, texture, and color. It is ordinarily a dull gray, and oiling gives a soft mat black more in accordance with modern taste than the shiny nickel-plating that delighted our fathers.

The phosphate bath is not expensive and can be used continuously for months by adding more of the concentrated solution to keep up the strength and by removing the sludge that is precipitated. Besides the iron the solution contains the phosphates of other metals such as calcium or strontium, manganese, molybdenum, or tungsten, according to the particular purpose. Since the phosphating solution does not act on nickel it may be used on articles that have been partly nickel-plated so there may be produced, for instance, a bright raised design against a dull black background. Then, too, the surface left by the Parker process is finely etched, so it affords a good attachment for paint or enamel if further protection is needed. Even if the enamel does crack, the iron beneath is not so apt to rust and scale off the coating.

These, then, are some of the methods which are now being used to combat our eternal enemy, the rust that doth corrupt. All of them are useful in their several ways. No one of them is best for all purposes. The claim of "rustproof" is no more to be taken seriously than "fireproof." We should rather, if we were finical, have to speak of "rust-resisting" coatings as we do of "slow-burning" buildings. Nature is insidious and unceasing in her efforts to bring to ruin the achievements of mankind and we need all the weapons we can find to frustrate her destructive determination.

But it is not enough for us to make iron superficially

resistant to rust from the atmosphere. We should like also to make it so that it would withstand corrosion by acids; then it could be used in place of the large and expensive platinum or porcelain evaporating pans and similar utensils employed in chemical works. This requirement also has been met in the non-corrosive forms of iron, which have come into use within the last five years. One of these, "tantiron," invented by a British metallurgist, Robert N. Lennox, in 1912, contains 15 per cent of silicon. Similar products are known as "duriron" and "Buflokast" in America, "metilure" in France, "ileanite" in Italy, and "neutraeiscn" in Germany. It is a silvery-white close-grained iron, very hard and rather brittle, somewhat like cast iron but with silicon as the main additional ingredient in place of carbon. It is difficult to cut or drill but may be ground into shape by the new abrasives. It is rustproof and is not attacked by sulfuric, nitric, or acetic acid, hot or cold, diluted or concentrated. *It* does not resist so well hydrochloric acid or sulfur dioxide or alkalies.

The value of iron lies in its versatility. It is a dozen metals in one. It can be made hard or soft, brittle or malleable, tough or weak, resistant or flexible, elastic or pliant, magnetic or non-magnetic, more or less conductive to electricity, by slight changes of composition or mere differences of treatment. No wonder that the medieval mind ascribed these mysterious transformations to witchcraft. But the modern micrometallurgist, by etching the surface of steel and photographing it, shows it up as composite as a block of granite. He is then able to pick out its component minerals, ferrite, austenite, martensite, pearlite, graphite, cementite, and to show how their abundance, shape, and arrangement contribute to the strength

or weakness of the specimen. The last of these constituents, cementite, is a definite chemical compound, an iron carbide,  $\text{Fe}_3\text{C}$ , containing 6.6 per cent of carbon, so hard as to scratch glass, very brittle, and imparting these properties to hardened steel and cast iron.

With this knowledge at his disposal the iron-maker can work with his eyes open and so regulate his melt as to cause these various constituents to crystallize out as he wants them to. Besides, he is no longer confined to the alloys of iron and carbon. He has ransacked the chemical dictionary to find new elements to add to his alloys, and some of these rarities have proved to possess great practical value. Vanadium, for instance, used to be put into a fine print paragraph in the back of the chemistry book, where the class did not get to it until the term closed. Yet if it had not been for vanadium steel we should have no Ford cars. Tungsten, too, was relegated to the rear, and if the student remembered it at all it was because it bothered him to understand why its symbol should be W instead of T. But the student of today studies his lesson in the light of a tungsten wire and relieves his mind by listening to a phonograph record played with a "tungstone" stylus. When I was assistant in chemistry an "analysis" of steel consisted merely in the determination of its percentage of carbon, and I used to take Saturday for it so I could have time enough to complete the combustion. Now the chemists of a steel works' laboratory may have to determine also the tungsten, chromium, vanadium, titanium, nickel, cobalt, phosphorus, molybdenum, manganese, silicon, and sulfur, any or ail of them, and be spry about it, because if they do not get the report out within fifteen minutes while the steel is melting in the electric furnace the whole batch of seventy-five tons may

go wrong. I'm glad I quit the laboratory before they got to speeding up chemists so.

The quality of the steel depends upon the presence and the relative proportions of these ingredients, and a variation of a tenth of one per cent in certain of them will make a different metal out of it. For instance, the steel becomes stronger and tougher as the proportion of nickel is increased up to about 15 per cent. Raising the percentage to 25 we get an alloy that does not rust or corrode and is non-magnetic, although both its component metals, iron and nickel, are by themselves attracted by the magnet. With 36 per cent nickel and 5 per cent manganese we get the alloy known as "invar" because it expands and contracts very little with changes of temperature. A bar of the best form of invar will expand less than one-millionth part of its length for a rise of one degree Centigrade at ordinary atmospheric temperature. For this reason it is used in watches and measuring instruments. The alloy of iron with 46 per cent nickel is called "platinite" because its rate of expansion and contraction is the same as of platinum and glass, and so it can be used to replace the platinum wire passing through the glass of an electric light bulb. Another new metal called "permalloy" is made by melting together about 80 per cent nickel and 20 per cent iron. When brought into the vicinity of an electromagnet it becomes more quickly magnetized and demagnetized than any metal hitherto known as the electric current varies. Such ease of magnetization and demagnetization is just what is desired in dealing with feeble currents as in telephoning and submarine cabling. When the cable between New York and the Azores was wrapped with permalloy tape the speed of signaling was

raised from two hundred and fifty words a minute to over nineteen hundred.

A manganese steel of 11 to 14 per cent is too hard to be machined. It has to be cast or ground into shape and is used for burglar-proof safes and armor plate. Chrome steel is also hard and tough and finds use in files, ball bearings, and projectiles. Titanium, which the iron-maker used to regard as his implacable enemy, has been drafted into service as a deoxidizer, increasing the strength and elasticity of the steel. The new "stainless" cutlery contains 12 to 14 per cent of chromium.

With the introduction of harder steels came the need of tougher tools to work them. Now the virtue of a good tool steel is the same as of a good man. It must be able to get hot without losing its temper. Steel of the old-fashioned sort, as everybody knows, gets its temper by being heated to redness and suddenly cooled by quenching or plunging it into water or oil. But when the point gets heated up again, as it does by friction in a lathe, it softens and loses its cutting edge. So the necessity of keeping the tool cool limited the speed of the machine.

But about 1868 a Sheffield metallurgist, Robert F. Mushet, found that a piece of steel he was working with did not require quenching to harden it. He had it analyzed to discover the meaning of this peculiarity and learned that it contained tungsten, a rare metal unrecognized in the metallurgy of that day. Further investigation showed that steel to which tungsten and manganese or chromium had been added was tougher and retained its temper at high temperature better than ordinary carbon steel. Tools made from it could be worked up to a white heat without losing their cutting power. The new

tools of this type invented by "Efficiency" Taylor at the Bethlehem Steel Works in the nineties have revolutionized shop practice the world over. A tool of the old sort could not cut at a rate faster than thirty feet a minute without overheating, but the new tungsten tools will plow through steel ten times as fast and can cut away a ton of the material in an hour.

If one nation alone possessed the secret of the modern steels, no other nation could compete with her in war or peace, in munitions or machinery. A slight superiority in metallurgy has been the deciding factor in many a battle. Those of my readers who have had the advantages of Sunday school training will recall the case described in I Samuel 13: 19-22.

By means of these new metals armor plate has been made invulnerable—except to projectiles pointed with similar material. Flying has been made possible through engines weighing no more than two pounds per horsepower. The cylinders of combustion engines and the casing of cannon have been made to withstand the unprecedented pressure and corrosive action of the fiery gases evolved within. Castings are made so hard that they cannot be cut—save with tools of the same sort. In the high-speed tools now used 20 or 30 per cent of the iron is displaced by other ingredients; for example, tungsten from 14 to 25 per cent, chromium from 2 to 7 per cent, vanadium from 0.5 to 1.5 per cent, carbon from 0.6 to 0.8 per cent, with perhaps cobalt up to 4 per cent. Molybdenum or uranium may replace part of the tungsten. One of the most effective ways of hardening the surface of steel for the working parts of automobiles is to heat them in an atmosphere of ammonia for a day or so at a temperature of a thousand degrees Fahrenheit.

The ammonia breaks up at this temperature into nitrogen and hydrogen and the nitrogen unites with the aluminum in the steel. Such nitralloys are harder than chromium vanadium steel and will cut glass or quartz like a diamond.

Some of the newer alloys for high-speed tools contain no iron at all. That which bears the poetic name of star-stone, stellite, is composed of chromium, cobalt, and tungsten in varying proportions. Stellite keeps a hard cutting edge and gets tougher as it gets hotter. It is very hard and as good for jewelry as platinum except that it is not so expensive. Cooperite, its rival, is an alloy of nickel and zirconium, stronger, lighter, and cheaper than stellite.

Before the war nearly half of the world's supply of tungsten ore (wolframite) came from Burma. But although Burma had belonged to the British for a hundred years they had not developed its mineral resources, and the tungsten trade was monopolized by the Germans. All the ore was shipped to Germany, and the British Admiralty was content to buy from the Germans what tungsten was needed for armor plate and heavy guns. When the war broke out the British had the ore supply, but were unable at first to work it because they were not familiar with the processes. In the United States before the war tungsten ore was selling at \$6.50 a unit, but by the beginning of 1916 it had jumped to \$85 a unit. A unit is 1 per cent of tungsten trioxide to the ton, that is, twenty pounds. Boulder County, Colorado, and San Bernardino, California, then had mining booms, reminding one of older times.

If tungsten ores were more abundant and the metal more easily manipulated, it would displace steel for many purposes. It is harder than steel or even quartz. It

never rusts and is insoluble in acids. Its expansion by heat is one-third that of iron. It is more than twice as heavy as iron and its melting point is twice as high. Its electrical resistance is half that of iron and its tensile strength is a third greater than the strongest steel. It can be worked into wire 0.0002 of an inch in diameter, almost too thin to be seen, but as strong as copper wire ten times the size.

The tungsten wires in the electric lamps are about 0.03 of an inch in diameter, and they give three times the light for the same consumption of electricity as the old carbon filament. The American manufacturers of the tungsten bulb have very appropriately named their lamp "Mazda" after the light god of the Zoroastrians. To get the tungsten into wire form was a problem that long baffled the inventors of the world, for it was too refractory to be melted in mass and too brittle to be drawn. Dr. W. D. Coolidge succeeded in accomplishing the feat in 1912 by reducing the tungstic acid by hydrogen and molding the metallic powder into a bar by pressure. This is raised to a white heat in the electric furnace, taken out and rolled down, and the process repeated some fifty times, until the wire is small enough so it can be drawn at a red heat through diamond dies of successively smaller apertures.

The first metallic filament used in the electric light on a commercial scale was made of tantalum, the metal of Tantalus. In the period 1905-1911 over 100,000,000 tantalus lamps were sold, but tungsten displaced them as soon as that metal could be drawn into wire.

A recent rival of tungsten both as a filament for lamps and hardener for steel is molybdenum. One pound of this metal will impart more resiliency to steel than three

## METALS, OLD AND

or four pounds of tungsten. The molbdenum steel because it does not easily crack, is said to be serviceable for armor-piercing shells, gun linings, airplane struts, automobile axles, and propeller shafts. In combination with its rival as a tungsten-molybdenum alloy it is capable of taking the place of the intolerably expensive platinum, for it resists corrosion when used for spark plugs and tooth plugs. The salts of this metal can be used in dyeing and photography.

Calcium, magnesium, and aluminum, common enough in their compounds, have come into use as metals only since the invention of the electric furnace. Now the photographer uses magnesium powder for his flashlight when he wants to take a picture of his friends inside the house, and the aviator uses it when he wants to take a picture of his enemies on the open field.

The addition of 5 or 10 per cent of magnesium to aluminum gives an alloy (magnalium) that is almost as light as aluminum and almost as strong as steel. An alloy of 90 per cent aluminum and 10 per cent calcium is lighter and harder than aluminum and more resistant to corrosion. An alloy of aluminum containing about 5 per cent of copper and one per cent or less each of manganese and magnesium, known as duralumin, has come into general use where lightness has to be combined with strength, as in skeletons of dirigible airships of the zeppelin type.

Lead is an unpretentious metal disesteemed by the artists and unpopular with the poets, who are captivated by the glitter of gold, the luster of silver, and the sheen of steel. Yet, if it were not for lead the artist would be deprived of some of his brightest colors and the poet could not put his verses into, print. The leaden bullet

has won more wars than the shining sword, yet history has less to say about it. And lead saves more lives in peace than it takes in battle since we depend upon it for our sanitation and protection against the most dangerous enemies of mankind, the microbes.

The beginner in chemistry is always puzzled to understand why lead should be designated by such strange initials as "Pb," neither of which letters occurs in its name as he spells it. Yet the Romans, who called it "plumbum," made use of it and have contributed many words to our vocabulary as evidence. A plumber is literally a "leader" whether he is heaving the lead in sea soundings, or employing the plumb-bob making a wall upright, or putting lead pipes into a building.

How often has the world missed by a narrow margin its greatest inventions. It is startling to see a piece of lead pipe, part of the plumbing of the baths of ancient Rome, bearing the name of the Emperor Vespasian and of the builder Callistus, in raised block letters, looking like the curved sheet of a stereotyped page prepared for the press. If only some Roman had happened to have been struck with the notion of inking the type and rolling it over a sheet of parchment or papyrus, printing would have been discovered over eighteen hundred years ago and the Dark Ages might have been prevented.

In the fantastic scheme of alchemists, lead is the metal of Saturn and truly it seems to partake of the double nature of its deity, who inspired both the "saturnine" disposition and the carefree "saturnalia." So lead is looked upon as a dull metal by those who have never seen it freshly cast from the melting pot, when it rivals silver in its sheen, or the rainbow in its colors.

It is to lead in its camouflage that we owe the dazzling

white of the wooden house or the gaudy red of the steel structure. Lead is ordinarily opaque, yet it is lead that gives to cut-glass tableware its brilliancy, and to optical glass its transparency and refractive power. It is through lenses and prisms made largely of lead that the faintest star may be brought within sight and forced to reveal in its spectrum the elements of which it is composed. Glass that is three quarters lead is particularly clear and brilliant.

Lead which seems to us so lifeless and dull may once have been the liveliest of elements. For lead is the corpse of radium. After that eruptive element gets over its fits of shooting out alpha, beta, and gamma rays, which it does in the course of several thousand years, it settles down to lead a quiet life as lead until the end of time. It has sown its wild oats, its electrons, helium nuclei, and X-rays, and it becomes as tame as any element. "Radium-G" is the genealogical name of lead and it is tenth in descent from radium and sixteenth in descent from uranium, mother of elements.

And having reached this calm and passive state, lead becomes the most impenetrable of armor for the protection of the X-ray operator against the rays of a sort similar to those which it used to emit in its fiery youth. The staunchest of conservatives is a reformed radical; witness Mussolini.

When platinum was first discovered it was so cheap that ingots of it were gilded and sold as gold bricks to unwary purchasers. The Russian government used it as we use nickel, for making small coins. But this is an exception to the rule that the demand creates the supply. Platinum is really a "rare metal," not merely an unfamiliar one. Nowhere except in the Urals is it found in

quantity, and since it seems indispensable in chemical and electrical appliances, the price has continually gone up. Russia collapsed into chaos just when the war work made the heaviest demand for platinum, so the governments had to put a stop to its use for jewelry and photography. The "gold brick" scheme would now have to be reversed, for gold is used as a cheaper metal to "adulterate" platinum. All the members of the platinum family, formerly ignored, were pressed into service, palladium, rhodium, osmium, iridium; and these, alloyed with gold or silver, were employed more or less satisfactorily by the dentist, chemist, and electrician as substitutes for the platinum of which they had been deprived. The points of our gold pens are tipped with an osmium-iridium alloy. It is a pity that this family of noble metals is so restricted, for they are unsurpassed in tenacity and incorruptibility. They could be of great service to the world in war and peace. As the "Bad Child" says in his "Book of Beasts":

**I shoot the hippopotamus with bullets made of platinum,  
Because if I use leaden ones, his hide is sure to flatten 'em.**

Along in the latter half of the last century chemists had begun to perceive certain regularities and relationships among the various elements, so they conceived the idea that some sort of pigeon-hole scheme might be devised in which the elements could be filed away in the order of their atomic weights so that one could see just how a certain element, known or unknown, would behave from merely observing its position in the series. Mendeleef, a Russian chemist, devised the most ingenious of such systems, called the "periodic law," and gave proof that there was something in his theory by predicting the properties of three metallic elements, then unknown but

for which his arrangement showed three empty pigeon-holes. Sixteen years later all three of these predicted elements had been discovered, one by a Frenchman, one by a German, and one by a Scandinavian, and named from patriotic impulse, gallium, germanium, and scandium. This was a triumph of scientific prescience as striking as the mathematical proof of the existence of the planet Neptune by Leverrier before it had been found by the telescope.

But although Mendeleef's law told "the truth," it gradually became evident that it did not tell the "whole truth and nothing but the truth," as the lawyers put it. As usually happens in the history of science, the hypothesis was found not to explain things so simply and completely as was at first assumed. The anomalies in the arrangement did not disappear on closer study, but stuck out more conspicuously. Though Mendeleef had pointed out three missing links, he had failed to make provision for a whole group of elements since discovered, the inert gases of the helium-argon group. As we now know, the scheme was built upon the false assumptions that the elements are immutable and that their atomic weights are invariable.

The elements that the chemists had most difficulty in sorting out and identifying were the heavy metals found in the "rare earths." There were about twenty of them so mixed up together and so much alike as to baffle all ordinary means of separating them. For a hundred years chemists worked over them and quarreled over them before they discovered that they had a commercial value. It was a problem as remote from practicality as any that could be conceived. The man in the street did not see why chemists should care whether there were two

didymiums any more than why theologians should care whether there were two Isaiahs. But all of a sudden, in 1885, the chemical puzzle became a business proposition. The rare earths became household utensils and it made a big difference with our monthly gas bills whether the ceria and the thoria in the burner mantles were absolutely pure or contained traces of some of the other elements that were so difficult to separate.

This sudden change of venue from pure to applied science came about through a Viennese chemist, Dr. Carl Auer, later and in consequence known as Baron Auer von Welsbach. He was trying to sort out the rare earths by means of the spectroscopic method, which consists ordinarily in dipping a platinum wire into a solution of the unknown substance and holding it in a colorless gas flame. As it burns off, each element gives a characteristic color to the flame, which is seen as a series of lines when looked at through the spectroscope. But the flash of the flame from the platinum wire was too brief to be studied, so Dr. Auer hit upon the plan of soaking a thread in the liquid and putting this in the gas jet. The cotton of course burned off at once, but the earths held together and when heated gave off a brilliant white light, very much like the calcium or limelight which is produced by heating a stick of quicklime in the oxy-hydrogen flame. But these rare earths do not require any such intense heat as that, for they will glow in an ordinary gas jet.

So the Welsbach mantle burner came into use everywhere and rescued the coal-gas business from the destruction threatened by the electric light. It was no longer necessary to enrich the gas with oil to make its flame luminous, for a cheaper fuel gas such as is used for a gas stove will give, with a mantle, a fine white light of

much higher candlepower than the ordinary gas jet. The mantles are knit in narrow cylinders on machines, cut off at suitable lengths, soaked in a solution of the salts of the rare earths, and dried. Artificial silk (viscose) has been found better than cotton thread for the mantles, for it is sold, not hollow, more uniform in quality, and continuous instead of being broken up into one-inch fibers. There is a great deal of difference in the quality of these mantles, as everyone who has used them knows. Some that give a bright glow at first with the gas-cock only half open will soon break up or grow dull and require more gas to get any kind of a light out of them. Others will last long and grow better to the last. Slight impurities in the earths or the gas will speedily spoil the light. The best results are obtained from a mixture of ninety-nine parts thoria and one part ceria. It is the ceria that gives the light, yet a little more of it will lower the luminosity.

The non-chemical reader is apt to be confused by the strange names and their varied terminations, but he need not be when he learns that new metals are given names ending in *um*, such as sodium, cerium, thorium, and that their oxides (compounds with oxygen, the earths) are given the termination *-a*, like soda, ceria, thoria. So when he sees a name ending in *-urn*, let him picture to himself a metal, any metal since they mostly look alike, lead or silver, for example. And when he comes across a name ending in *-a*, he may imagine a white powder like lime. Thorium, for instance, is, as its name implies, a metal named after the thunder god Thor, to whom we dedicate one day in each week, Thursday. Cerium gets its name from the Roman goddess of agriculture by way of the asteroid.

The chief sources of the material for the Welsbach

burners is monazite, a glittering yellow sand composed of phosphate of cerium with some 5 per cent of thorium. Since the monazite contains more cerium than thorium and the mantles made from it contain more thorium than cerium, there is a superfluity of cerium. The manufacturers give away a pound of cerium salts with every purchase of a hundred pounds of thorium salts. It annoyed Welsbach to see the cerium residues thrown away and accumulating around his mantle factory, so he set out to find some use for it. He reduced the mixed earths to a metallic form and found that it gave off a shower of sparks when scratched. An alloy of cerium with 30 or 35 per cent of iron proved the best and was put on the market in the form of automatic cigar lighters. A big business was soon built up in Austria on the basis of this obscure chemical element rescued from the dump-heap. There are many other pyrophoric (light-producing) alloys, including steel, which our ancestors used with flint before matches and percussion caps were invented.

There are more than fifty metals known and not half of them have come into common use, so there is still plenty of room for the expansion of the science of metallurgy. If the reader has not forgotten his arithmetic of permutations he can calculate how many different alloys may be formed by varying the combinations and proportions of these fifty. We have seen how quickly elements formerly known only to chemists—and to some of them known only by name—have become indispensable in our daily life. Any one of those still unutilized may be found to have peculiar properties that fit it for filling a long unmet want in modern civilization.

Who, for instance, will find a use for gallium, the metal of France? It was described in 1869 by Mendeleef

in advance of its advent and has been known in person since 1875, but it has not yet been set to work. It is such a remarkable metal that it must be good for something. If you saw it in a museum case on a cold day you might take it to be a piece of aluminum, but if the curator let you hold it in your hand—which he won't—it would melt and run over the floor like mercury. The melting point is  $87^{\circ}$  F. It might be used in thermometers for measuring temperatures above the boiling point of mercury were it not for the peculiar fact that gallium wets glass so it sticks to the side of the tube instead of forming a clear convex curve on top like mercury.

Another metal that is sitting idly in the unemployed office is beryllium, the base of the beautiful emerald. Yet anybody would suppose that a metal with such recommendations as beryllium can present could get a job, perhaps in the aviation business. It is lighter than aluminum by a third and much harder; four times as clastic as aluminum and one quarter more elastic than steel; not so easily corroded as aluminum; is a good mixer, forms promising alloys with iron, copper, or aluminum; and there is plenty of it in the United States.

Then there is columbium, the American metal. It is strange that an element named after Columbia should prove so impractical. Columbium is a metal closely resembling tantalum, and tantalum found a use as electric light filaments. A columbium lamp should appeal to our patriotism.

The so-called "rare elements" are really abundant enough considering the earth's crust as a whole, though they are so thinly scattered that they are usually overlooked and hard to extract. But whenever one of them is found valuable it is soon found available. A

systematic search generally reveals it somewhere in sufficient quantity to be worked. Who, then, will be the first to discover a use for indium, germanium, terbium, thulium, lanthanum, neodymium, scandium, samarium, and others as unknown to us as tungsten was to our fathers?

As evidence of the statement that, no matter how rare an element may be, it will come into common use if it is found to be commonly useful, we may refer to radium. A good rich specimen of radium ore, pitchblende, may contain as much as one part in 4,000,000. Madame Curie, the brilliant Polish Parisian, had to work for years before she could prove to the world that such an element existed and for years afterward before she could get the metal out. Yet now we can all afford a bit of radium to light up our watch dials in the dark. The amount needed for this is infinitesimal. If it were more it would scorch our skins, for radium is an element in eruption. The atom throws off corpuscles at intervals as a Roman candle throws off blazing balls. Some of these particles, the alpha rays, are atoms of another element, helium, charged with positive electricity and are ejected with a velocity of 18,000 miles a second. Some of them, the beta rays, are negative electrons, only about one seven-thousandth the size of the others, but are ejected with almost the speed of light, 186,000 miles a second. If one of the alpha projectiles strikes a slice of zinc sulfide it makes a splash of light big enough to be seen with a microscope, so we can now follow the flight of a single atom. The luminous watch dials consist of a coating of zinc sulfide under continual bombardment by the radium projectiles. Sir William Crookes invented this radium light apparatus and called it a "spinthariscopes," which is Greek for "spark-seer."

Evidently if radium is so wasteful of its substance it cannot last forever nor could it have forever existed. The elements then are not necessarily eternal and immutable, as used to be supposed. They have a natural length of life; they are born and die and propagate, at least some of them do. Radium, for instance, is the offspring of ionium, which is the great-great-grandson of uranium, the heaviest of known elements. Putting this chemical genealogy into biblical language we might say: Uranium lived 5,000,000,000 years and begat Uranium  $X_1$ , which lived 24.6 days and begat Uranium  $X_2$ , which lived 69 seconds and begat Uranium 2, which lived 2,000,000 years and begat Ionium, which lived 69,000 years and begat Radium, which lived 1850 years and begat Niton, which lived 3.85 days and begat Radium A, which lived 3 minutes and begat Radium B, which lived 26.8 minutes and begat Radium C, which lived 19.5 minutes and begat Radium D, which lived 16.5 years and begat Radium E, which lived 5 days and begat Polonium, which lived 136 days and begat Lead.

The figures I have given are the times when half the parent substance has gone over into the next generation. It will be seen that the chemist is even more liberal in his allowance of longevity than was Moses with the patriarchs. It appears from the above that half of the radium in any given specimen will be transformed in about 2000 years. Half of what is left will disappear in the next 2000 years, half of that in the next 2000 and so on. The reader can figure out for himself when it will all be gone. He will then have the answer to the old Eleatic conundrum of when Achilles will overtake the tortoise. But we may say that after 100,000 years there would not be left any radium worth mentioning, or in other words prac-

tically all the radium now in existence is younger than the human race. The lead that is found in uranium and has presumably descended from uranium, behaves like other lead but is lighter. Its atomic weight is only 206, whereas ordinary lead weighs 207.2. It appears then that the same chemical element may have different atomic weights according to its ancestry, while on the other hand different chemical elements may have the same atomic weight. This would have seemed shocking heresy to the chemists of the last century, who prided themselves on the immutability of the elements and did not take into consideration their past life or heredity. The study of these radioactive elements has led to a new atomic theory. I suppose most of us in our youth used to imagine the atom as a little round hard ball, but now it is conceived as a sort of solar system with an electropositive nucleus acting as the sun and negative electrons revolving around it like the planets. The number of free positive electrons in the nucleus varies from one in hydrogen to ninety-two in uranium. This leaves room for ninety-two possible elements and of these all but two are more or less certainly known and definitely placed in the scheme. The atom of uranium, weighing 238 times the atom of hydrogen, is the heaviest known and therefore the ultimate limit of the elements, though it is possible that elements may be found beyond it just as the planet Neptune was discovered outside the orbit of Uranus. Considering the position of uranium and its numerous progeny as mentioned above, it is quite appropriate that this element should bear the name of the father of all the gods.

In these radioactive elements we have come upon sources of energy such as was never dreamed of in our philosophy. The most striking peculiarity of radium is

that it is always a little warmer than its surroundings, no matter how warm these may be. Slowly, spontaneously, and continuously, it decomposes, and we know no way of hastening or of checking it. Whether it is cooled in liquefied air or heated to its melting point the change goes on just the same. An ounce of radium salt will give out enough heat in one hour to melt an ounce of ice and in the next hour will raise this water to the boiling point, and so on again and again without cessation for years, a fire without fuel, a realization of the philosopher's lamp that the alchemists sought in vain. The total energy so emitted is millions of times greater than that produced by any chemical combination such as the union of oxygen and hydrogen to form water. From the heavy white salt there is continually rising a faint fire-mist like the will-o'-the-wisp over a swamp. This gas is known as the emanation or niton, "the shining one." A pound of niton would give off energy at the rate of 23,000 horsepower; fine stuff to run a steamer, one would think, but we must remember that it does not last. By the fourth day the power would have fallen off by half. Besides, no one would dare to serve as engineer, for the radiation will rot away the flesh of a living man who comes near it, causing gnawing ulcers or curing them. It not only will break down the complex and delicate molecules of organic matter but will attack the atom itself, changing, it is believed, one element into another, again the fulfillment of a dream of the alchemists. And its rays, unseen and unfelt by us, are yet strong enough to penetrate an armor plate and photograph what is behind it.

But radium is not the most mysterious of the elements but the least so. It is giving out the secret that the other elements have kept. It suggests to us that all the other

elements in proportion to their weight have concealed within them similar stores of energy. Astronomers have long dazzled our imaginations by calculating the horsepower of the world, making us feel cheap in talking about our steam engines and dynamos when a minutest fraction of the waste dynamic energy of the solar system would make us all as rich as millionaires. But the heavenly bodies are too big for us to utilize in this practical fashion. And now the chemists have become as exasperating as the astronomers, for they give us a glimpse of incalculable wealth in the meanest substance. For wealth is measured by the available energy of the world, and if a few ounces of anything would drive an engine or manufacture nitrogenous fertilizer from the air all our troubles would be over. Kipling in his sketch, "With the Night Mail," and Wells in his novel, "The World Set Free," stretched their imaginations in trying to tell us what it would mean *to* have command of this power, but they are a little hazy in their descriptions of the machinery by which it is utilized. The atom is as much beyond our reach as the moon. We cannot rob its vault of the treasure.

## V

# THE VOICE OF RESEARCH <sup>1</sup>

MAURICE HOLLAND

Maurice Holland's title is Director, Division of Engineering and Industrial Research, National Research Council. A graduate of the Massachusetts Institute of Technology, he has also done special work at Lowell Institute, Harvard, University of Pennsylvania, Tufts College, and Columbia. He has had an unusually varied experience as an engineer, in the fields of civil, electrical, mechanical, aeronautical, and industrial engineering. During the War he was Lieutenant-Pilot in the U. S. Air Service, and later consulting aeronautical mechanical engineer to the Engineering Division, Air Service. His work as an industrial engineer has been especially varied, including studies of organization and management of research both in America and in Europe. He has also made studies of industrial technology in China and Japan. In addition to being a member of various important committees and of several professional societies he was organizer and Executive Secretary, American Committee, World Engineering Congress, Tokio, 1929. He is the author of various magazine articles on industrial research, and has written the book *Industrial Explorers*, interesting sketches of the lives and achievements of American scientists and inventors, from which the present chapters are taken.

If Arthur D. Little did nothing except talk, or write an occasional paper, he would still be contributing his share to the cause of scientific research. He is the despair and the envy of his associates for he possesses a gift desired by all of them, although many deny it. This is the ability to write clearly, smoothly, even with literary distinction. While other scientists are helpless unless they

<sup>1</sup> Reprinted from *Industrial Explorers* (1928) by permission of the author and of Harper and Brothers.

quote mathematical formulas, Little charms his readers by quoting the classics. He can explain how paper is made from wood pulp and do it so cleverly that the owner of a chain of newspapers, who uses tons of paper but knows nothing of its manufacture, can understand him. He can convince a group of bankers that an industry which encourages research is far more safe, financially, than one that does not, and can do it without once mentioning a chemical or physical process. Little can, and does, tease funds from multi-millionaires for scientific schools and colleges by persuading them that the future of mankind rests upon research or the study of technical subjects.

I do not mean that all the other leaders in the field of research are totally helpless with the pen or on the platform. We have seen that John A. Matthews<sup>2</sup> of the Crucible Steel Company is more than moderately skilled, and there are others who can write and speak so that their readers and hearers have an even chance of knowing what they are talking about. But Little, the founder of Arthur D. Little, Incorporated, chemists, engineers, and managers, of Cambridge, Massachusetts, is the acknowledged master. In view of his attainments in the field of science, one pays him a dubious compliment, perhaps, to say that he is best known for his writings. But this, I think, is true. He is almost certainly the only important person engaged in industrial research who is frequently asked to contribute articles and book reviews to that most erudite of all popular magazines, *The Atlantic Monthly*.

To forestall any hastily formed conclusion that Little is merely a dilettante writer or speaker, it is well to point

<sup>2</sup> John A. Matthews was referred to in a previous chapter of *Industrial Explorers.—Editors*.

out that he is a chemical engineer, attended the Massachusetts Institute of Technology, and is a holder of the honorary degree of Doctor of Chemistry from the University of Pittsburgh. He is the inventor of processes for the manufacture of chrome-tanned leather, artificial silk, electrolytic manufacture of chlorates, and, with his associates, of methods for the production of a long line of alcohols and special products from petroleum. He is a specialist of international reputation in the chemistry of cellulose, paper making, process of fiber treatment, and gas and petroleum. His studies of industrial wastes have saved untold sums and have kept many a corporation from the ignominy of bankruptcy.

The esteem in which Little is held by the members of his own profession in this country is evidenced by the fact that he has served both as president of the American Chemical Society and as president of the American Institute of Chemical Engineers. That this esteem is international has recently been conspicuously demonstrated by his selection as president of the Society of Chemical Industry of Great Britain.

Among other scientific societies of which he is a member are the Chemical Society (London), La Societe de Chimie Industrielle (New York Section), American Academy of Arts and Sciences, American Institute of Mining and Metallurgical Engineers, and American Society of Mechanical Engineers. He is vice chairman of Engineering Foundation, the research agency of the four great national engineering societies.

He is a life member of the Corporation of the Massachusetts Institute of Technology and a member of its visiting committee for the Departments of Chemistry and Chemical Engineering. His interest in the Institute, as

well as in chemical education, was demonstrated some years ago when he submitted to its Corporation a plan for the cooperative course in which M. I. T. would unite with forward-looking manufacturing plants in the training of chemical engineers.

The essential novelty of the plan lay in its recognition of the fact that any process of industrial chemistry is merely a coordinated series of what Little termed "unit operations," which, when once mastered by the student, in all their variations, could be arranged in proper sequence to meet the requirements of any process. The proposed course was, therefore, one for the intensive study of these unit operations as conducted in the plants themselves. It was approved by the Corporation, but no funds for its establishment were available. Little thereupon went to Rochester and secured an interview with Mr. George Eastman, of Eastman Kodak Company, who quickly recognized the possibilities of the plan and provided the endowment of \$300,000 with which the school was started. It is now known as the school of Chemical Engineering Practice, and Little shares with Mr. Eastman the honor of its foundation. He is, however, insistent that the credit for bringing the school into effective, organized operation belongs to his friend and former partner, Dr. William H. Walker, then Professor of Chemical Engineering at M. I. T. It should be emphasized that the system differs in important respects from that found in many engineering colleges where the men merely obtain practical experience by working in industrial plants during vacations or for certain hours each day. Three field stations, where access to several plants is available, have been established. The men in the school devote all of their time, even when in the plants, to

educational work and therefore receive no pay from the companies which are cooperating. Most of the men are graduates either of M. I. T. or of other engineering colleges. Only *ten* or twelve students are in a group, with an assistant professor in charge.

So much for the professional standing of A. D. Little. His success as a consulting research chemist is due, primarily, to his technical ability. And the final factor is Little's personal presence. We have taken occasion to point out errors in the popular conception of industrial explorers, that they are *not* uniformly shabby, unkempt, vague gentlemen who stumble from their laboratories to find themselves incongruous figures in the sunlight—as conspicuous, for their lack of tailoring, as a farmer in town to sell his oats. And yet it cannot be denied that many of them are known as gentlemen despite their apparel. But Little, like L. H. Baekeland of Bakelite fame, is the motion picture director's idea of a prominent banker, suave, well-dressed, poised, at ease when addressing a dozen capitalists or five hundred members of a scientific society. No odors from his laboratories cling to his clothes. Whether he really does so or not, he seems to be the type who would always wear a dinner jacket after seven o'clock in the evening and who, like the traditional Englishman, would carry a bathtub in the heart of Africa. Although Little is sixty-four years old, no heaviness of middle age has caused his figure to sag. Of medium height, he holds himself erect. He smokes expensive cigarettes. His voice is low and well-bred, and his choice of words is good. Although he has lived in Boston most of his life, and on his father's side comes of an old New England family, he has not a trace of the ultra-refined, and so frequently synthetic, Boston

accent. He is, I should say, rather better-looking than most men of his age. White hair, almost beetling white eyebrows, a good mouth, further give the impression that he is a sophisticated clubman.

Little's interest in chemistry began more than fifty years ago and was the result of a rash investment on his part. He was born in Boston and spent the first year or two of his life within the walls of Fort Independence in that city. His father had been an artillery captain in the Civil War and had been given an easy assignment at the fort to recover from wounds he had received. After a few years the family moved to Portland, Maine, and Little first went to school in that city. One day, when he was about twelve years old, a boy seated behind him nudged him.

"Have you a dime?" the boy whispered.

Little fished through his pockets and discovered that he had just that and nothing more.

"Give it to me," the boy behind him went on, "and I'll show you some chemical experiments."

Little consented, and passed over his entire wealth. That afternoon the two boys stopped at a drug store and with the dime purchased a piece of glass tubing and five cents' worth of sulfuric acid. Reaching his classmate's home Little saw, for the first time, the miracle of sulfuric acid reacting upon zinc and producing hydrogen—only in this case the generator had been improperly set up and exploded, quite harmlessly, after a moment or two. He also witnessed a piece of marble hissing under the action of the acid, and found that blowing through lime water created a white deposit. That night, tremendously excited, he hurriedly sought his father.

"I'm going to be a chemist," he announced.

From that day the boy was definitely certain of his life calling. Everything that came into his hands was a subject for experimentation. He studied the stars with a concave mirror and one night announced, to the astonishment of a neighbor who knew something about astronomy, that he had discovered the moons of Mars." As this was a year before Hall, the neighbor was skeptical and it later developed that the tiny stars which Little had seen in his mirror, *one on* each side of the planet, were due to multiple reflection. It is easy to imagine that Little became a good deal of a nuisance as his interest in chemistry grew. Like every other boy consumed by his passion, he mixed together every chemical on which he could lay his hands, and the results were weird, odorous, and explosive. It is probable that the same gods which watch over drunkards, guard youthful chemists. At all events Little was never hurt and this despite the manufacture of hand grenades out of beer bottles. He filled the bottles with an explosive mixture and then tossed them over a fence, listening with anticipation for the crash of the explosion.

His family gladly cooperated in his desire to become a chemist but felt that he ought not neglect all other learning in preparation for science. So he began taking an academic course at the Portland high school. This did not hold his interest and he was only a mediocre scholar. Later, however, he came in contact with an excellent and discerning science teacher who gave him a great deal of individual attention. Little became a prize student and so proficient in chemistry that he became the proud assistant in charge of the apparatus for this teacher at public lectures. He went to the Berkeley School, in New York, to complete his preparatory education and made ready

to enter M. I. T., the school from which seven out of ten research directors appear to have been graduated.

At Tech. Little gave most of his time to his studies, although he participated in many student activities and was freshman editor and later editor-in-chief of the college magazine. Years afterward he founded the *Technology Review*, now one of the best magazines of its kind. Financial pressure caused him to leave college after three years, and he did not graduate with the class of 1885, as he had hoped to do. Instead, he took a summer course in paper manufacturing at Amherst and looked around for a job. His first position, which he has described as "part chemist and part clerk," was at a pulp and paper mill at Rumford, near Providence, Rhode Island. Six weeks later he was appointed superintendent of the pulp mill, the first in the country making sulfite wood pulp. During the winter of 1885 he was sent to Newbern, North Carolina, to start another sulfite mill and his place at the Rumford plant was taken by Roger B. Griffin, who the next year became a partner in Griffin and Little, of Boston, consulting chemists.

When the laboratory of Griffin and Little was opened in 1886 it was located in an ancient, dingy building on Milk Street. The landlord, Little recalls, attempted to insert a clause in their lease providing that all clients must walk down from the laboratory on the sixth floor. And although the landlord was persuaded out of this, his elevator service was erratic and unreliable and many of the first customers of the new firm found that they had to *climb* the entire six flights. Little is still wondering how much business he lost when the elevator was out of order. The entire capital possessed by the two young chemists was \$2500 and with this they bought what equipment they could afford. Certainly their outlook for suc-

cess was gloomy enough. There were six men in the city of Boston who were trying to make a living by the commercial practice of chemistry and each was pessimistic regarding its possibilities. One of them, a graduate of Harvard and of a German university, volunteered that he had not made \$700 during any one of the eleven years that he had been practicing. Not only in Boston, but generally in the United States, chemists were viewed with distrust. It was widely believed that their reports were framed to suit their clients. It was charged that they took commissions for recommending products, processes, and equipment. So underpaid were they that unless they enjoyed private incomes they could not usually maintain social contacts with important and wealthy members of the community, men who might be in a position to provide work.

In 1886, \$5 was the prevailing fee for a sanitary analysis of water, and with this analysis the chemist was expected to give an hour or so of advice on anything that happened to interest his client. Even experts, men who had been engaged in the practice of chemistry for years, were greeted with derision if they asked fees of more than \$25 a day for their services. The top price for analyzing a sample of sugar was seventy-five cents; and Griffin and Little abandoned sugar tests when, one morning, a composite sample representing 6000 tons was brought to them to be examined at this rate. Competition among the chemists in Boston was keen and their woes were increased by frequent price cutting.

Griffin and Little seem to have been insane optimists. As they opened their small laboratory with an office eight by twelve feet in size, they told each other that at least \$14,000 would be taken in during the first year. But at the end of the twelve months they discovered that their

income exceeded their expenses by only \$600. Somewhat sadly, the two young men took the \$600 and divided it. Their confidence was unshaken, however, and Little, who even then was a master salesman of research, hurried out to get additional clients.

"When I opened a laboratory in Boston," Little has recalled, "the street cars were drawn by horses, and I remember the clang of the first electric cars on Boylston Street and the consternation they caused among their equine competitors. From my window on Beacon Street 2000 bicycles an hour could be counted, where now more automobiles pass. I have seen the fishtail burner supplanted by the Welsbach mantle and the incandescent electric lamp develop from carbon to tungsten filaments through to the white light of argon-filled bulbs.

"When I first began the study of chemistry we were taught that there were certain permanent gases. They were called permanent because they could not be liquefied, but, almost before I had learned the lesson, Pictet and Cailletet had liquefied oxygen. There are now no permanent gases, and liquid air has become a commonplace of the laboratory and the raw material for great industries."

Little was "reminiscing" in this vein in an address a few years ago before the Division of Engineering and Industrial Research of the National Research Council, and much of what he said on that occasion demonstrates how very recent are most of the important developments in science. The American Chemical Society, for instance, had only 300 members against 15,000 in 1926. Students were taught that the atmosphere contained only oxygen, nitrogen, aqueous vapor, and a little carbon dioxide. But within a comparatively few years patient research in a

laboratory had uncovered five previously unknown gases : argon, helium, neon, krypton, and xenon.

"Even their names," the erudite Little explained, "carry interest and suggestions: argon, the lazy one, because it forms no compounds; helium, because the spectroscope had revealed its existence in the sun before its discovery on earth; neon, the new one; krypton, the hidden one; and xenon, the stranger. But already the lazy one has been put to work in incandescent lamp bulbs ; helium, with nearly the lifting power of hydrogen and noninflammable, has become the key to the safer navigation of the air by dirigibles; while neon tubes flash advertisements in shop windows and assist chauffeurs to locate engine trouble."

We seem, however, to have abandoned Little, the rising young chemist. The first few years were ones of bitter struggle during which his creditors could probably have plunged him into bankruptcy had they all asked for payment at one time. But the partners managed to scrape together enough capital to buy out one or two other consulting chemists and for a time, in addition to a miscellaneous practice, did the major portion of the sugar testing in Boston. This was arduous work and paid very badly. It was the custom to bring in samples at six o'clock in the evening and demand a report by nine-thirty o'clock in the morning. Thus the work had to be done at night.

By 1893 the young firm seemed to be making progress, with \$375 in business being recorded each month. But that year brought a grievous loss when Griffin, the senior partner, was killed by an explosion in the laboratory. Terribly shocked, and feeling that his personal loss was far greater than his professional one, serious as that was, Little determined to carry on alone. He did this from

1893 until 1900, and each year his income increased a little and his reputation a great deal. He made such progress by 1900 that Dr. William H. Walker of M. I. T. consented to the formation of a partnership, and for the next five years the firm was known as Little and Walker, Consulting Chemists and Engineers. In 1909 Dr. Walker withdrew, and the company known as Arthur D. Little, Inc., Chemists, Engineers, and Managers, was organized. Within two years the business volume was eight times what it had been in 1904. Meanwhile the laboratories and offices had been moved several times, always with additional space and finally with several floors. In 1917 the business was institutional in its character. Little had clients in all parts of the world and had piled up a moderate fortune. In that year he began work on the palatial building he now occupies. This is a large structure with three floors and a basement. It looks over the Charles River Basin and adjoins the grounds of M. I. T.

Institutions such as Arthur D. Little, Inc., occupy a unique position in the field of research. Many of their customers are hard-headed, so-called practical business men. Suspicious of research, inclined to be contemptuous of men who work with microscopes and test-tubes, these men not infrequently discover that they are falling behind in the competitive race, that their ledgers are showing an unaccountable number of red ink entries. Having attempted to spur sales by advertising, having discharged a few plant managers and hired new ones, having engaged efficiency experts, they are likely to turn, in the end, to men of Little's type. Obviously, he must be able to explain his methods in language that is nontechnical, clear, and convincing. And he requires

that his associates shall be able to do the same. Little is still the master salesman and he still finds that his most difficult task is to find among his scientist-subordinates men who can also tell the story of research. The laboratory on the banks of the Charles is notable for its non-technical atmosphere in the midst of the most technical activities. The layman visiting the Little laboratories feels less inferior, less out of place, than in probably any other laboratory in the country.

It is a rash visitor to Arthur D. Little, Inc., who insists that something cannot be done. It is the objective of Little and his associates to accomplish the impossible. Several years ago a client was holding forth on the uselessness of a certain raw material and remarked, without great originality, "You cannot make a silk purse out of a sow's ear." "Oh, can't I?" Little appears to have answered. And to prove that ancient sayings, apparent impossibilities, and tradition will not stand in the path of industrial research he proceeded to do just that, to make a purse out of a sow's ear. From the gelatin and tissues contained in a lady pig's ear his associates produced a red and blue tasseled purse, and today a prized exhibit in Little's museum is a board on which is mounted a sow's head. Beneath it are jars containing the materials taken from the ear, in the various stages of artificial silk manufacture. In a glass case at the bottom of the board is the purse and on each side of the exhibit are affidavits from packers attesting to the truth of it all. Needless to say, the layout has a powerfully chastening effect on skeptical industrialists inclined to insist that research cannot aid their failing concerns.

There are, of course, many and varied laboratories in the Little plant, and in addition to a large general scien-

tific library is another devoted to petroleum, gas, and coal. Probably the unique feature is the fact that much of the equipment is semicommercial in size. It includes a complete pulp and paper mill, and for special studies in petroleum there was built in the yard an oil refinery of semi-works size. The customers of Arthur D. Little, Inc., desire to see processes translated into industrial terms and to know whether laboratory methods can be adapted to plant operation. Little can demonstrate, before the eyes of his clients, that the process which works in the laboratory will, if he says so, be just as successful in the factory. An engineering department of the company makes available mechanical and civil engineers who will assist in the designing of plants and factories and assume full responsibility for them. Accountants are ready to make financial audits. They can do even more than this—make "chemical audits." These determine the efficiency of manufacturing processes, the quality of supplies and raw materials, the wastes and their prevention, the status of equipment, even the future of the business itself.

That Little has been able, to a degree probably unequaled by any other chemist, to translate the theoretical into the commercially practical is indicated by the brief summary of more recent developments. His laboratory has discovered processes for the manufacture of vegetable glue from starch, the recovery of turpentine and resin from yellow pine stumps, the extraction of zinc from complex ores, the separation of potash from complex saline deposits, the concentration of phosphate rocks. His laboratory staff developed a process for manufacturing a special mulching paper, used in Hawaiian sugar cultivation, from the waste products of sugar mills, and built a mill at Olaa, Hawaiian Islands. Elaborate studies have

been made in fuel processing and conservation, and both the Boston Elevated Railway Company and the Edison Electric Illuminating Company have been clients. The Little organization developed the dry mats—necessary when German imports ceased during the War—used in newspaper stereotyping and saved large sums for newspaper publishers. They have worked out many processes of paper manufacture and, most recently, a practical method for making newsprint paper from southern woods which, when operated on a large scale, promises to effect an important reduction in the cost of newsprint.

It must be clear that Little has been singularly successful in the profession which he selected, as a boy of twelve, back at school at Portland, Maine. The significance of Little, it seems to me, lies in his unusual talents as a salesman of the idea that prosperity must depend, in the long run, on research. Few could criticize Little if now, past sixty, he devoted all of his time to the business of which he is the head. Its responsibilities, with a payroll of more than \$1000 a day, are heavy. He has demonstrated on many occasions, however, that he is willing to preach the gospel of research, to give time to expounding its virtues and the necessities for it. His talents for doing so have earned him a wide audience.

Among all the addresses he has made there are two which are quoted from time to time, whenever research workers gather. One of these, "The Handwriting on the Wall," was made before the American Institute of Chemical Engineers in 1925. He told the story of Belshazzar's feast and the writing in which Daniel read the ruler's doom.

"I am willing," he said, "to interpret the handwriting which confronts our industry. It reads: *The price of*

*progress is research, which alone assures the security of dividends.* . . . The future of the shoe industry in New England has long been a matter of local concern, but it would be hard to find a New England shoe factory that could list among its assets even \$49.51 worth of laboratory equipment.

"But this failure to read the handwriting on the wall is by no means peculiar to New England. It is still, with a few conspicuous exceptions, characteristic of American industry as a whole. . . . In a situation so clear to us as chemists and chemical engineers, and so charged with peril to American industry, it is our imperative duty to translate the handwriting on the wall to those who mistake it for a mural decoration. . . . Let us . . . endeavor to educate the manufacturer to realize the opportunities before him, and let us teach the investor to appreciate the perils that confront those companies which ignore research."

Of the second address, "The Fifth Estate," I shall treat in a moment. It should first be said that Little believes that the cause of research is making headway, even if slowly, against the blindness of the manufacturer. He feels that bankers are more willing *to* listen to technical men, that science is constantly forging ahead. Young men contemplating research, he is confident, will find a place not only in the college laboratory, but in industry as well. They will make at least as much money, he promises, as their classmates "who go in for selling bonds."

It was this address made before the Franklin Institute on the occasion of its centenary celebration, and called "The Fifth Estate," which won for Little undisputed eminence as the voice of research. Though made

in 1924, it is still widely read. He is constantly called upon for reprints. In this speech, Little recalled the remark of Edmund Burke declaring journalists to be members of a Fourth Estate, more powerful than the lords spiritual, the lords temporal, or the commons. The Fifth Estate, "is composed of those having the simplicity to wonder, the ability to question, the power to generalize, the capacity to apply." Little went on to say:

"It is, in short, the company of thinkers, workers, exponents, and practitioners upon whom the world is absolutely dependent for the preservation and advancement of that organized knowledge which we call Science. It is their seeing eye that discloses, as Carlyle said, 'the inner harmony of things; what Nature meant.' It is they who bring the power and the fruits of knowledge to the multitude who are content to go through life without thinking and without questioning, who accept fire and the hatching of an egg, the attraction of a feather by a bit of amber, and the stars in their courses as a fish accepts the ocean."

One paragraph of "The Fifth Estate" establishes Little as a man of deep emotion, a scholar of rare learning, a man gifted with eloquence. In discussing W. R. Whitney of the General Electric, I have used Whitney's own words praising Langmuir to describe Whitney himself. The impulse to follow the same procedure here cannot be resisted. Little's tribute to Franklin might be, with the addition of a word here and there, an unconscious tribute to Little himself, a man of many parts. He said:

"Benjamin Franklin was not perhaps in all respects a paragon, but he was unquestionably a polygon—a plain figure with many sides and angles. . . . He was craftsman and tradesman; philosopher and publicist; diplo-

mat, statesman, and patriot. And he was, withal, a very human being. What concerns us particularly on this occasion is the fact that he was at once philosopher and man of affairs. His remarkable career should refute forever the fallacy, which, unfortunately, is still current, that the man of science is temperamentally unfitted for the practical business of life."

Little, too, is a "philosopher and man of affairs." He, too, is many-sided. He, too, refutes the theory that men of science cannot make themselves heard along with the journalists, the bankers, the politicians, and the lawyers.

## VI

# SCIENCE TAKES WINGS<sup>1</sup>

MAURICE HOLLAND

On a morning in the summer of 1911 most of the small boys of Shawnee, Okla., and not a few of the older ones, gathered at the edge of a small cliff on the outskirts of the town. A passer-by, seeing them, might logically have assumed that a circus was to pitch its tent on a nearby field. The theory was not entirely incorrect, but the circus, instead of being a vast affair with scores of performers, consisted of a single fifteen-year-old youth.

Calm and self-assured, the boy who was the center of attention shouted commands to a group of other boys who were carrying a huge contraption easily identified as a homemade monoplane-glider. William H. Miller, the hero of the moment, was Shawnee's leading aviation enthusiast. He had already pored over the existing literature on the science of aviation. He had studied diagrams and technical drawings in the *Scientific American* and other publications. And now he was ready to test his knowledge by sailing off from the cliff in the monoplane which he had built. As his glider was being carried toward the edge of the cliff one or two more cautious friends begged him not to make the attempt. The drop, they said, was at least twenty feet ! It was conceivable, to put as optimistic a front on the matter as possible, that the

<sup>1</sup> Reprinted from *Industrial Explorers* (1928) by permission of the author and of Harper & Brothers.

glider would not glide. Twenty feet constituted quite a drop. The monoplane was poised on the side of the cliff, with Miller propped on the framework, his feet on the ground. Two or three of his friends held the tail of the machine.

"Ready?" the pioneer called.

"Set !" his assistants answered. And Miller ran a few steps into the breeze and jumped off the cliff. His calculations, alas, had been at fault and the glider did not sail into the breeze according to schedule. Instead, it dropped like a plummet to the field below and when the boys above got down they found Miller, miraculously unhurt, extricating himself from the mass of sticks, cloth, and wire.

"Go back to your singing !" one of the boys yelled—a most unkind remark based on the fact that Miller was the village tenor and was being urged by his parents to follow a musical career.

He did not do so. Instead, he went back to his studies of the theory of flight. He has been at them ever since and today, not much more than thirty years old, he is director of research for the Curtiss Aeroplane and Motor Company of Garden City, L. I. No small part of the astonishing advance which has been made in aviation is due to his careful, painstaking work in transforming theories into facts. The boy who tumbled off the cliff far out in Oklahoma has become an enthusiastic, dynamic, earnest individual who grows irritated when uninformed critics suggest that aviation is limping along on the "trial and error" method, that its engineers are really merely mechanics, and that as an exact science it is just a little beyond the pale. Miller silences these critics by taking them through the Curtiss laboratories, showing them the

wind tunnel where numerous complicated tests are made, asking them to glance at a few sheets of calculations regarding "drift," "propellor-thrust," aerodynamic coefficients, and other mysteries. He concludes his argument by pointing out that the automobile industry, whose engineers evolved many of the first airplane motors, are now turning for advice to aviation. The infant industry is beginning to pay back its debt and automobile designers, seeking "streamline" effects which will cut down wind resistance, are experimenting with models in the wind tunnels which Miller has built.

It is appropriate that Miller should be a young man, for aviation is one of the newest of sciences in an age when hardly a year passes without the birth of something startling and different in transportation, communication, or industry. He looks, perhaps, even younger than he is—not unlike a junior assistant in some university or technical school. But he is, withal, impressive enough, particularly when he is surrounded by the scientific apparatus down at the Curtiss plant or when such elderly grizzled pilots of the air as the famous "Casey" Jones of the Curtiss testing staff drop down from the clouds and call upon him for advice. Miller is rather short and stocky, although far from stout. He wears his hair neatly parted and brushed, neckties that are a little collegiate, and suits that are conservative. His eyes are keen and show an occasional flash of humor. He is popular among his subordinates, enough of a salesman to obtain appropriations for his work from practical-minded executives, enough of a mechanic to build his own models. Miller, whose study of aviation began with theory and who did not learn to fly for years, is practical enough to reduce his theories to a working basis. And yet he does not permit his connec-

tion with an industrial concern to dwarf his interest in the studies which he began as a boy out in the West.

Aviation is a young man's game and it is not without interest that two of the men who have aided materially in its development were small boys when the Wright brothers rose from the ground in December of 1903 in their crude heavier-than-air machine. The younger (he was not quite two years old), Charles A. Lindbergh, lived in Minnesota. The other, William H. Miller, was in Texas. Lindbergh was destined to do the flashier thing, to fly from New York to Paris, to win headlines, to dramatize the conquest of the air. Miller was to become the patient laboratory worker who would test theories with the instruments of an exact science. In 1914, while Lindbergh was dreaming of the day when he would fly, an eighteen-year-old Miller was writing an article for *Aero and Hydro* under the erudite title "Locating the Center of Lift on a Biplane." It was the first of many technical articles that Miller has written and it is, of course, unnecessary to record that it thrilled him more than any other. He still has the issue of August 29, 1914, in which it appeared.

Miller was born in Paris, Texas, in 1896, spent his earlier boyhood on the farm of his grandparents near Clarksville in the same state and moved to Shawnee, Okla., when he was eleven years old. He received his first schooling in Texas and also had his first chance to experiment with tools. His grandmother, he recalls, permitted him to make kites, windmills, model engines, and sailboats as long as he would also build chicken coops and repair fences. He also found time to devise traps for the birds and small animals of which there was great abundance in eastern Texas. By the time he had moved

with his father to Oklahoma, Miller was skilled in the use of tools and by then, too, he had become absorbed in the new science of aviation.

"I became interested," he remembers, "from reading of the exploits of the Wright brothers, Glenn H. Curtiss, and others. Pictures of their machines which appeared in the *Scientific American* inspired me to build the glider which was wrecked when I was fifteen years old."

Miller was fortunate in that his elders, while somewhat dubious regarding the hobby of aviation, did not discourage his bent towards the scientific. By the time he had reached his senior year in high school he had gained a fair knowledge of elementary physics, and his father, who was in the cotton business, bought him most of the aviation textbooks of the period. Among those over which he pored was an English translation of Gustav Eiffel's *The Resistance of the Air and Aviation* and the ponderous volume had a profound influence on his life. His father also permitted him to subscribe to most of the early aviation magazines, and a high school mathematics teacher whom he recalls with gratitude, a Miss Ella Mansfield, gave him much encouragement in his aeronautical studies. It was at about the time Miller graduated from high school that he told his father of his intention to become an airplane designer and engineer.

The elder Miller, while sympathetic, still felt that his son should take advantage of the very rich tenor voice which he possessed and during the summer after his graduation he was required to study singing with a local teacher. The publication of the technical article in *Aero and Hydro* was impressive, however. And the magic of seeing his name in print was enough to make Miller lose interest in music. Probably the father, too, was dazzled

by this brilliance. At all events, before the end of the summer, he consented to enrollment at the Oklahoma Agricultural and Mechanical College at Stillwater as a freshman in mechanical engineering.

Miller's education was interrupted, because of financial reverses, after he had been at college for a year. During this period he taught carpentry and woodworking in an Indian school at Seminole, Okla., and also when twenty-one years old, was married to Mary Davis of St. Louis, who had been a co-ed at Oklahoma A. & M. Miss Davis seems to have been a thoroughly modern young woman, for she enabled her husband to save enough to enter Missouri State University the following fall and then obtained a job for herself. Miller was made a student instructor and somehow they managed to get along. During his junior year he was requested to design an air propeller for a boat and thus became interested in the propulsion of airplanes. With the assistance of Dr. Earle Raymond Hedrick, now at the University of California at Los Angeles, he worked out a complete mathematical and physical theory for the air propeller. This served later as the basis for a master's thesis at M. I. T. (Miller, like so many of the other directors of research, eventually attended that school), and even today the material in it is useful to him in his laboratory.

The World War interrupted Miller's studies and he served in the Engineers' Reserve Corps. But in June of 1920 he was graduated from Missouri with the degree of Bachelor of Science in Engineering. After graduation Miller accepted a position with the Westinghouse Electric and Manufacturing Company and worked on the "Mica" propeller for airplanes. This is the propeller fashioned from a laminated form of Bakelite and is the

type used by Maitland and Hegenberger on their flight

Hawaii. The education of Miller was not yet completed, however. While at the Westinghouse plant at East Pittsburgh, he wrote to M. I. T. regarding post-graduate courses in aeronautical engineering and was astonished, after he had supplied data regarding his qualifications, to be offered an assistantship in the department of aeronautical engineering. The post paid \$1200 for the school term. Mrs. Miller felt certain that she could find employment in Boston for herself, and Miller's father, by now entirely convinced that his son had chosen the right calling, announced that he was again financially able to be of some assistance. Consequently, overjoyed at the full measure of good fortune, the Millers set out for M. I. T. He entered as an assistant and student in the graduate department of aeronautical engineering under Professor Edward P. Warner, later Assistant Secretary of the Navy for Aviation, and now editor-in-chief of *Aviation*. He remained at the Institute for two years and while there designed and supervised the construction of the two *new* wind tunnels built during 1921 and 1922. The larger of these has since been moved into the Guggenheim School of Aeronautics at the Institute, dedicated in June, 1928.

By 1922, the year he received a degree as Master of Science in Aeronautical Engineering, Miller was already widely known in technical aviation circles. Among those who had heard of his work were the executives of the Curtiss Aeroplane and Motor Company, of Garden City, and they asked him whether he would assume direction of the company's research laboratory. Feeling that the opportunity was exactly what he needed, Miller accepted and when he arrived at the plant was informed that the

company desired to develop a racing plane which would break the world's speed record by a wide margin.

Why speed? Was the Curtiss Company merely seeking publicity, anxious only for headlines in the newspapers? Was this merely another indication that the twentieth century had gone mad in its effort to obtain speed? Not at all. The Curtiss people wanted to develop fast racing ships so that the knowledge gained in making them could be used, if war came, for fighting ships which would dive on an adversary at terrific speed and dart away. By building machines for the Pulitzer air races the company would force its research, design, and motor staffs to extend themselves to the utmost degree. Thereby the development of aviation would be more rapid. The twentieth century is, of course, the age of speed. Each night, it has been said, there are shipments aggregating tons vitally needed in distant parts of the nation. Business men stand ready to pay almost any sum to have them delivered within a few hours. In time, the airplane will do this. Each year the Curtiss Company has turned out faster ships, motors that are more powerful for their weight, planes that are stronger. In 1849 it took a wagon train six months to cross the continent but on June 23, 1924, Lieutenant Russell L. Maughan flew from New York to San Francisco between dawn and dusk.

Miller, taking over the Curtiss aerodynamical laboratory, was given a part-time assistant, Michael Watter, who has since become design engineer for the Chance M. Vought Company. He found it necessary to install a large amount of new apparatus, to recalibrate and explore the air stream of the wind tunnel, and to develop new methods of testing bodies with low resistance. He had, in fact, to start far down among the fundamentals, for in building

racing planes the company had to know before the ship had been completed, even during the preliminary stages of design, what its performance in the air would be. What was the use of going on with some design that would not develop higher speed or be perfectly safe? So scores of wings were built, often of "plaster of Paris" by a secret process so that they could be fashioned and refashioned quickly. Fuselages were made of wax or plasticene so that their shape could be varied in the laboratory. Scores of models were tested in the wind tunnel—for resistance and for control.

In general, the problem was divided into two parts: the development by the airplane engineer of a machine of low weight, great strength, and, above all, low resistance; second, the development by the motor expert of an engine of great reliability which would exceed all others in power output per pound of weight. It was work that required vast technical knowledge. First the formulas were developed in the laboratory under the direction of Miller. Then the engineers evolved a little model, mathematically perfect, which represented the design produced by research on the motor, wings, fuselage, landing gear, controls. This model was mounted on the top of an extremely sensitive balance in the wind tunnel where atmospheric conditions and pressures could be simulated at will. Finally, careful records were made and checked against formulas and design specifications. The result was an astonishingly accurate forecast not only of speed, but of control and other characteristics of the finished plane to be built from the wind tunnel model.

Many important facts were developed as a result of the numerous tests. The resistance of the undercarriage of airplanes, for instance, was found to be a large propor-

tion of the total drag against the wind and in consequence a vastly simplified landing gear was developed. The conventional water-cooled engine radiator also offered great resistance and was finally eliminated from racing planes by developing a covering for the wings made of two thin corrugated copper sheets between which the water could be pumped. The resistance of the landing wheels, even, had to be greatly reduced, and new streamline designs were fashioned. The wind tunnel experiments further disclosed that a powerful rudder was a most important safety factor and that designers, using the old rule-of-thumb method, had generally been making them too small. The Curtiss aerodynamic laboratory developed new data governing the size of control surfaces.

So much for technicalities. In developing the Pulitzer racers the final design of the racer was each time worked out and a one-twelfth size model tested. From this test the speed of the machine was predicted *within less than one per cent.* In 1922, Miller's first year with the Curtiss Company, Lieutenant Maughan piloted the racing plane at 222 miles per hour against a predicted speed of 221.

In 1923 the company had succeeded in stepping up this speed to 248 miles per hour. Back of each mile added to that record, the fastest speed at which a human had ever traveled, were months of patient work of the laboratory staff, first in theoretical calculations and design layout on drawing boards, then with miniature models tested in the wind tunnel, and finally building the "mock up," or full-scale model of the racer in skeleton form. In the design of each new racer, the laboratory staff were fighting a battle of compromise between speed and the factors of safety and control. Test pilots, practical mechanics from the factory and flying field, contributed their

bit, all members of a team playing against those ancient rivals of speed—air resistance and old man Time.

The "mock up" of the 1925 model had been pruned down until air resistance was cut to a minimum—in fact, it looked more like a winged projectile than anything else. The model was then turned over to the shops, the factory rushed out the finished job, and another "mystery" ship was slipped into its hangar under the cover of darkness. There expert mechanics tuned up the engine for speed trials to be run over a measured course in the still air of a morning, just after dawn.

It is a thrilling scene, the first trials of a new racing airplane. The ship is trundled out of the hangar just as day is breaking; speed trials are made in undisturbed morning or evening air. The pilot, after inspecting struts, wires, and control, warms up the engine at the cry of "contact" as the mechanics spin the propeller; the slim racer pulls at the blocks.

Timers, starters, and instrument men are in the pylons, standing like sentinels at the markers at each end of the course, where electrically synchronized stop watches have been set up. Miller and his staff dart about, assisting in the last minute technical preparations for the great event. The laboratory staff are kept busy to relieve the tension while waiting for the timers to turn in their figures after the run. The speed trial figures will tell the final story of the success or failure of their efforts. The fruit of months of labor stands on the runway ready to take the air. The slim graceful racer starts down the field and, like a bird poised for flight, waits for the starter's signal for the take-off. At the wave of a flag, the pilot "gives her the gun" and the plane, gathering speed, literally jumps into the air, out of a cloud of dust. The pilot

circles the field a couple of times and then straightens out for the first run down the speed course with the wind. As he passes the pylon, the pilot zooms to kill speed at the finish of the run, makes a turn and a reverse run down the course against the wind. Several runs are made in each direction with and against the wind, if there is any, and the average of the runs is taken as the mean speed. The trial runs over, Miller, his staff, the pilot, mechanics, even executives of the company, rush pellmell back to the flying office where, after instrument calibrations and other corrections are made, the average speed is announced—264 miles an hour! The 1925 Curtiss racer has more than lived up to expectations and confirmed the predictions of her designers.

A five-year record of the Curtiss racers in the Pulitzer Trophy Race, the speed classic of aviation, was first and second place in each successive annual event from 1921 to 1925. There's a record for you! A record which bears testimony to the achievement of aeronautical science, to the skill of pilots in the mastery of air, to the practical knowledge of the craftsmen in the shop, mechanics of the flying field, and last, but not least, of the justification of the faith in their men, which company executives like C. M. Keys and Frank Russell demonstrated when real backing with generous appropriations for the work was required.

Miller's story is important, it seems to me, partly for the reason that he has demonstrated the value of fundamental research in an industry just beginning to grow. He feels, himself, that his best work with the company has been in connection with the improvement of design theory and methods. Soon after taking his position he consented to serve as a contributing technical editor of *Aerial Age*,

one of the journals he had read so eagerly as a boy. In this capacity he has written many technical articles dealing with stability, performance, wind tunnel theory, and propellers. These have been of great value to the entire industry. By now, of course, Miller is an experienced pilot. He knew the theory of aviation before coming to the Curtiss Company and had been up a great many times. In 1922 he was taught to fly at the Curtiss school and learned to solo in three hours, a remarkable record.

When, with the entry of the United States into the World War, the army and navy demanded huge air fleets, it was the engineers of the automobile industry who offered their services. The names of such outstanding automotive engineers as Vincent, Marmon, Ford, Hall, Kettering, and many others are linked with those days and among their contributions to war time aviation were the Liberty and Hall Scott engines, Delco ignition, the Mircarta propeller, and a number of accessories. The debt is now being repaid, for streamline models of automobiles are now being tested in the wind tunnel and research looking toward the reduction of wind resistance in motor cars is being carried on.

Miller, like some of his older brothers in the field of research, is a pioneer. The Curtiss Company was the first concern to begin a thorough research program. That it has paid, in money, is demonstrated by the present standing of the company and by the fact that Curtiss planes in 1928, all developed in their early stages in the laboratory, had captured seven world's records. In the future, it is certain, research is to play an even greater part in the further conquest of the air.

The Daniel Guggenheim Aeronautical Laboratory, established at M. I. T., started to function with its dedi-

cation. A vital part of the equipment of the new laboratory there is one of the world's largest wind tunnels designed by Miller in his student days at the Institute. Who knows but the same adventurous spirit of the pioneer and the explorer in the unknown realms of aeronautic science is welded into that piece of apparatus through the painstaking labors of its youthful designer. There in that institution of learning it may serve as an inspiration to the workers of the future who, in building the foundation of a new industry in the bedrock of scientific research, will leave the record of their achievements—milestones on the road of industrial progress—as Miller has done, buried under a mass of technical data—in laboratory notebooks.

## VII

# A SERBIAN AT COLUMBIA<sup>1</sup>

MICHAEL PUPIN

In 1874 Michael Pupin, a Serbian boy sixteen years old, landed in New York from an immigrant ship with but five cents in his pocket and with no knowledge of English or of any Americans except Franklin, Lincoln, and Harriet Beecher Stowe. Nine years later, he graduated with honors from Columbia University, and went abroad to do advanced work at the universities of Cambridge and Berlin. In 1889 he came back to New York to join the faculty of Columbia University in the newly organized Department of Electrical Engineering. In the years since then Dr. Pupin has been a pioneer in the fields of electrical science and engineering, with many inventions to his credit. He holds honorary degrees from several colleges and universities and is a member of various scientific societies. His book *From Immigrant to Inventor*, from which the present selection is taken, not only narrates vividly the events of his own career but also presents a history of the growth of knowledge of electricity.

During the last week of September of that year (1879) I presented myself at Columbia (College) for entrance examinations. They were oral and were conducted by the professors themselves and not by junior instructors. The first two books of the Iliad, excepting the catalogue of ships, and four orations of Cicero, I knew by heart. My leisure time at my Passaic River "villa" had permitted me these pleasant mental gymnastics; I wanted to show off before Bilharz<sup>2</sup> with my

<sup>1</sup> Reprinted from *From Immigrant to Inventor*, copyright 1922 by Charles Scribner's Sons, by permission of the author and the publisher.

<sup>2</sup> Bilharz was a fellow worker who tutored him in the classics.—  
*Editors,*

Greek and Latin quotations, to say nothing of the wonderful mental exhilaration which a young student gets from reading aloud and memorizing the words of Homer and Cicero. The professors were greatly surprised and asked me why I had taken so much trouble. I told them that it was no trouble, because Serbs delight in memorizing beautiful lines. The Serbs of Montenegro, for instance, know by heart most of the lines which their great poet Nyegosh ever wrote, and particularly his great epic "The Mountain Glory." I told them also of illiterate Baba Batikin, the minstrel of my native village, who knew most of the old Serbian ballads by heart. Besides, I assured the professors, I wanted to do in Greek and Latin as well as I possibly could, so as to gain free tuition. For the other studies I was not afraid, I told them, and they assured me that my chances for free tuition were certainly good. The other examinations gave me no trouble, thanks to my training with Bilharz and with the lecturers in the evening classes at Cooper Union. A note from the Registrar's office informed me a few days later that I was enrolled as a student in Columbia College with freedom from all tuition fees. There was no person in the United States on that glorious day happier than I!

The college atmosphere which I found at Columbia at that time gave me a new sensation. I did not understand it at first and misinterpreted many things. The few days preceding the opening of the college sessions I spent chasing around for a boarding house, while my classmates were hanging around the college buildings, making arrangements to join this or that fraternity, and also solidifying the line of defense of the freshmen against the hostile sophomores. There was a lively process of organization going on under the leadership of groups of boys

who came from the same preparatory schools. These groups led and the others were expected to follow without a murmur. Insubordination or even indifference was condemned as lack of college spirit. This spirit was necessary among the freshmen particularly, because, as I was informed later, there was a great common danger—the sophomores! I saw some of this feverish activity going on, but did not understand its meaning and hence remained outside of it, as if I were a stranger and not a member of the freshman class, which I heard described, by the freshmen themselves, as the best freshman class in the history of Columbia. The sophomores denied this in a most provoking manner; hence the hostility. Nobody paid any attention to me; nobody knew me, because I did not come from any of the preparatory schools which prepared boys for Columbia. One day I saw on the campus two huge waves of lively youngsters beating against each other just like inrolling waves of the sea lifting on their backs the returning waves which had been reflected from the cliffs of the shore. The freshmen were defending a cane against fierce attacks of the sophomores. It was the historic Columbia cane rush, I was told by Michael, the college janitor, who stood alongside of me as I looked on. It was not a real fight resulting in broken noses or blackened eyes, but just a most vigorous push-and-pull contest, the sophomores trying to take possession of a cane which a strong freshman, surrounded by a stalwart bodyguard of freshmen, was holding and guarding just as a guard of fanatic monks would defend the sacred relics of a great saint. This freshmen group was the center of the scrimmage, and it stood there like a high rock in the midst of an angry sea. Coats and shirts were torn off the backs of the brave fighters, some attacking and others defending the

central group, but not a single ugly swearword was heard nor did I see a single sign of intentional bloodshed. Members of the junior and senior classes watched as umpires. Michael, the janitor, who knew everybody on the college campus as a shepherd knows his sheep, was not quite certain about my identity. He asked me whether I was a freshman, and when I said "yes," he asked me why in the world I was not in the rush, defending the freshmen bodyguard. He looked so anxious and worried that I felt sure of being guilty of some serious offense against old Columbia traditions. I immediately took off my coat and stiff shirt and plunged into the surging waves of sophomores and freshmen and had almost reached the central bodyguard of freshmen, eager to join in its defense, when a sophomore, named Frank Henry, grabbed me and pulled me back, telling me that I had no business to cross the line of umpires at that late moment. I did not know the rules of the game and shoved him aside, and we clinched. He was the strongest man in Columbia College, as I learned later, but my kindling wood operations on the banks of the Passaic River had made me a stiff opponent. We wrestled and wrestled and would have wrestled till sunset like Prince Marco and the Arab Moussa Kessedjia in the old Serbian ballads, if the umpires had not declared the cane rush a draw. The main show being over, the side show which Henry and I were keeping up had no further useful purpose to serve, and we stopped and shook hands. He was glad to stop, he admitted, and so was I, but he told my classmates that "if that terrible Turk had been selected a member of the freshmen bodyguard the result of the cane rush might have been different." I told him that I was Serb and not a Turk, and he apologized, saying that he could never

draw very fine distinctions between the various races in the Balkans. "But, whatever race you are," said he, "you will be a good fellow if you learn to *play the game*" Splendid advice from a college boy! "*Play the game,*" what a wonderful phrase! I studied it long, and the more I thought about it the more I was convinced that one aspect of the history of this country with all its traditions is summed up in these three words. No foreigner can understand this country who does not know the full meaning of this phrase, which I first heard from a Columbia College youngster. No foreign language can so translate the phrase as to reproduce its brevity and at the same time convey its full meaning. But, when I heard it, I thought of the bootblacks and newsboys who, five years previously, had acted as umpires when I defended my right to wear a red fez. To "play the game" according to the best traditions of the land which offered me all of its opportunities was always my idea of Americanization. But how many immigrants to this land can be made to understand this?

Some little time after this incident I was approached by the captain of the freshman crew, who asked me to join his crew. I remembered young Lukanitch's opinion about oarsmanship at Columbia, and I was sorely tempted. [Young Lukanitch was the son of a Slovene living in New York who had known Pupin's father in Serbia.] But, unfortunately, I had only three hundred and eleven dollars when I started my college career, and I knew that if I was to retain my free tuition by high standing in scholarship and also earn further money for my living expenses I should have no time for other activities. "Study, work for a living, no participation in college activities outside of the recitation-room! Do you call that college train-

ing?" asked the captain of the freshman crew, looking perfectly surprised at my story, which, being the son of wealthy parents, he did not understand. I admitted that it was not, in the full sense of the word, but that I was not in the position to avail myself of all the opportunities which Columbia offered me, and that, in fact, I had already obtained a great deal more than an immigrant could reasonably have expected. I touched his sympathetic chord, and I felt that I had made a new friend. The result of this interview was that my classmates refrained from asking me to join any of the college activities for fear that my inability to comply with their request might make me feel badly. I had their sympathy, but I missed their fellowship, and therefore I missed in my freshman year much of that splendid training outside of the classroom which an American college offers to its students.

At the end of the freshman year I gained two prizes of one hundred dollars each, one in Greek and the other in mathematics. They were won in stiff competitive examinations and meant a considerable scholastic success, but, nevertheless, they excited little interest among my classmates. Results of examinations were considered a personal matter of the individual student himself and not of his fellow classmen. The prizes were practically the only money upon which I could rely to help carry me through my second year. The estimated budget for that year, however, was not fully provided for, and I looked for a job for the long summer vacation. I did not want a job in the city. My kindling-wood activity of the preceding summer suited me better, and after some consultation with my friend Christopher, the kindling-wood peddler of Rutherford Park, I decided to accept a job on a contract of his to mow hay during that summer in the

various sections of the Hackensack lowlands. No Columbia athlete ever had a better opportunity to develop his back and biceps than I had during that summer. I made good use of it and earned seventy-five dollars net

When my sophomore year began I awaited the cane rush which, according to old Columbia custom, took place between the sophomores and freshmen at the beginning of each academic year, and I was prepared for it; I knew also what it meant to "play the game." This time my class had to do the attacking and I helped with a vengeance. The muscles which had been hardened in the Hackensack meadows proved most effective and the result was that I shortly had the freshmen's cane on the ground and was lying flat over it, covering it with my chest. The pressure of a score of freshmen and sophomores piled up on top of me threatened to squeeze the cane through my chest bone, which already, I imagined was pressing against my lungs, my difficult breathing leading me to think that my last hour had come. Fortunately, the umpires cleared away the lively heap of struggling boys on top of me, and I breathed freely again. Some freshmen were found stretched alongside of me with their hands holding on to the stick. An equal number of sophomores held on, and, consequently, the umpires declared the rush a draw. Nobody was anxious to have another rush, and it was proposed by the freshmen to settle the question of class superiority by a wrestling-match, two best out of three falls, catch as catch can. They had a big fellow who had some fame as a wrestler of great strength, and they issued a defiant challenge to the sophomores. My classmates held a meeting in order to pick a match for the freshman giant, but nobody seemed to be quite up to the job, Finally I volunteered, declaring

that I was not afraid to tackle the freshman giant. "Do you expect to down him with Greek verses and mathematical formulas?" shouted some of my classmates, who had grave doubts about the muscle and the wrestling ability of a fellow who had won Greek and mathematical prizes. They knew nothing about my strenuous mowing in the Hackensack meadows during three long months of that summer. The captain of the class crew approached me, felt my biceps, my chest, and my back, and shouted, "All right !" The wrestling-match came off, and the freshman giant had no show with a boy who had learned the art of wrestling on the pasture-lands of Idvor, and had held his own against experienced mowers in the Hackensack meadows. The victory was quick and complete, and my classmates carried me in triumph to Fritz's saloon, not far from the college, where many a toast was drunk to "Michael the Serbian." From that day on my classmates called me by my first name and took me up as if I had been a distinguished descendant of Alexander Hamilton himself. My scholastic victory in Greek and mathematics meant nothing to my classmates, because it was a purely personal matter, but my athletic victory meant everything, because it was a victory of my whole class. Had I won my scholastic victory in competition with a representative of another college, then the matter would have had an entirely different aspect. *Esprit de corps* is one of those splendid things which American college life cultivates, and I had the good fortune to reap many benefits from it. He who pays no attention to this *esprit de corps* in an American college runs the risk of being dubbed a "greasy grind."

The sophomore year opened auspiciously. Eight of my classmates formed a class, the Octagon, and invited

me to coach them in Greek and in mathematics, twice a week. The captain of the class crew was a member of it. I suspected that he remembered my reasons for refusing to join the freshman crew and wanted to help. The Octagon class was a great help in more ways than one. I gave instruction in wrestling also to several classmates, in exchange for instruction in boxing. This was my physical exercise, and it was a strenuous one. Devereux Emmet, a descendant of the great Irish patriot, was *one* of these exchange instructors; he could stand any amount of punishment in our boxing bouts, which impressed upon my mind the truth of the saying that "blood will tell." Before the sophomore year was over my classmates acknowledged me not only a champion in Greek and in mathematics, but also a champion in wrestling and boxing. The combination was somewhat unusual and legends began to be spun about it, but they did not turn my head, nor lull me to sleep, not even when they led to my election as class president for the junior year. This was indeed a great compliment, for, because of the junior promenade, the dance given annually by the junior class, it was customary to elect for that year a class president who was socially very prominent. A distinguished classmate, a descendant of three great American names, and a shining light in New York's younger social set, was my chief opponent and I begged to withdraw in his favor; a descendant of Hamilton inspired awe. But my opponent would not listen to it. He was a member of the most select fraternity and not at all unpopular, but many of my classmates objected to him, although he was the grandson of a still living former Secretary of State and chairman of the board of trustees of Columbia College. They thought that he paid too much attention to the fashion

plates of London, and dressed too fashionably. There were other Columbia boys at that time who, I thought, dressed just as fashionably, and yet they were very popular; but they were fine athletes, whereas my opponent was believed to rely too much upon the history of his long name and upon his splendid appearance. He certainly was a fine example of classical repose; his classmates, however, admired action. He was like a young Alcibiades in breeding, looks, and pose, but not in action.

Some of the old American colleges have been accused from time to time of encouraging snobbery and a spirit of aristocracy which is not in harmony with American ideas of democracy. My personal experience as student at Columbia gives competency to my opinion upon that subject. Snobs will be found in every country and clime, but there were fewer snobs at Columbia in those days than in many other much less exalted places, although Columbia at that time was accused of being a nest of dudes and snobs. This was one of the arguments advanced by those friends of mine at the Adelphi Academy who tried to persuade me to go to Princeton or Yale. The spirit of aristocracy was there, but it was an aristocracy of the same kind as existed in my native peasant village. It was a spirit of unconscious reverence for the best American traditions. I say "unconscious," and by that I mean absence of noisy chauvinism and of that racial intolerance by which the Teutonism of Austria and the Magyarism of Hungary had driven me from Prague and from Panchevo. A name with a fine American tradition back of it attracted much attention, but it was only a letter of recommendation. He who was found wanting in his make-up and in his conduct when weighed by the best Columbia College traditions—and they were a part

of American traditions—had a lonely time during his college career, in spite of his illustrious name or his family's great wealth. Foreign-born students, like Cubans and South Americans, met with a respectful indifference so long as they remained foreigners. Needless to say, many of them adopted rapidly the attractive ways of the Columbia boys, but nobody would have resented it, or even paid any attention to it, if they had retained their foreign ways. A hopeless fellow became a member of that very small class of students known at that time as "muckers." They complained bitterly of snobbery and of aristocracy. I do not believe that either the spirit of plutocracy, or of socialism and communism, or of any other un-American current of thought could ever start from an American college like Columbia of those days, and bore its way into American life. That type of aristocracy which made the American college immune from contagion by un-American influence existed; it was very exacting, and it was much encouraged. But when American college boys, accused of bowing to the spirit of aristocracy, have among them a Hamilton, a Livingston, a DeWitt, and several descendants of Jay, and yet elect for class president the penniless son of a Serbian peasant village, because they admire his mental and physical efforts to learn and to comply with Columbia's traditions, one can rest assured that the spirit of American democracy was very much alive in those college boys.

## VIII

# LOUIS PASTEUR, AND LENGTHENED HUMAN LIFE <sup>1</sup>

OTIS W. CALDWELL

Otis W. Caldwell, after securing a B.S. degree at Franklin College and a Ph.D. degree at the University of Chicago, became a teacher of botany and a writer of textbooks in botany and general science. His interest in educational problems brought him into administrative work. In 1913 he became Dean of University College, University of Chicago, and later Professor of Education in Teachers College, Columbia University, and Director of Lincoln Experimental School and of the Division of School Experimentation of the Institute of Educational Research. The present essay is from the book *Science Remaking the World* (a series of essays by various writers suggesting the meaning of science in various aspects of modern life and thought and indicating the place of science in modern social and industrial relations), in the writing and editing of which he collaborated with Edwin E. Slosson. Though now engaged largely in educational work, Professor Caldwell has kept his interest in science and has done much to increase the popular understanding of scientific achievements.

When Louis Pasteur was sixteen years old his father, anxious about his education, decided to send him from the home town of Arbois to Paris. The boy was to have the advantage of instruction in the *École Normale*, a school in which the father thought there would be an exceptionally good opportunity for his boy since the *Ecole Normale* had been established to train men for college positions. This was in 1838, when schools were not generally as

<sup>1</sup> Reprinted from *Science Remaking the World*, copyright 1922 and 1923 by Doubleday, Doran and Company, Inc., by permission of the author and the publisher.

good in France as they are **today**. **The elder Pasteur** did not have the privilege of much schooling **but had** gained a fair education for his time by personal industry and efforts. Like many a father of recent times, or today for that matter, Louis's hardworking father decided **that** poverty should not deprive his son of a good education, and thus planned family sacrifices in the name of the boy's education. That parental sacrifice does not guarantee an education was as true of Louis Pasteur as it has proved to be of many another boy or girl. No sooner did the boy find himself at the school in Paris than an old and honorable malady befell the boy—homesickness. It is honorable and eminently respectable to be homesick, even almost disgraceful not to be so on occasion; but succumbing to this worthy emotional illness is not so respectable.

Louis Pasteur's father was a tanner of hides, as had been his grandfather and great-grandfather. His home was near the malodorous tannery yard, and his childhood home street in Dole before his family moved to Arbois, was known as the "street of the tanners." From his birth in 1822 until he was almost sixteen years of age, his life had been more or less associated with the tannery. And now, as a lonesome boy in a distant school, in a great city one hundred leagues from home, he longed so earnestly "for a whiff of the old tannery" that genuine illness would have been welcome if it could have secured his return to his home. Hours were days to the boy, and he soon decided he could stand it no longer. His work was poor, he was miserable, and so wrote to his father. The father, with much depression, went to Paris and took the boy back to his Arbois home.

The halo over the home and playground is sometimes more easily seen one hundred leagues away than close at

hand. It was so with young Pasteur, for the halo evanesced and certain stern realities appeared. He soon announced his readiness to return to Paris, but the wise father replied that the schools of Arbois would suffice for the present. The boy became an outstanding pupil in drawing, so recognized by all. At night he went over all of his day's lessons with his father, not the lessons of the next day, as is so commonly done nowadays to make sure that pupils know their lessons; but the lessons of the preceding morning and afternoon, as the father desired to learn those things with which the son was dealing, and Louis became truly his father's teacher. Two years in the schools of Arbois, then two years in the college at Besancon not far from Arbois, brought to Louis recognition as a successful student and as a tutor of his fellows. Then, at twenty years of age, in 1842, he returned to Paris as a student in the Ecole Normale, soon to be widely recognized as a young man of industry, intellectual integrity, and earnest devotion to his studies.

In addition to other studies, Pasteur attended lectures at the Sorbonne and devoted much time to the study of the structure of crystals. He became widely known and highly respected as a student of chemistry, and on January 15, 1849, began an eight-year period of useful service as professor of chemistry at the University of Strassburg. A characteristic Pasteurism occurred in the early part of his stay at Strassburg. The rector of the University was most cordial to the newly arrived professor of chemistry and took him to his home, where Pasteur was introduced to the rector's wife and daughter. In two weeks Louis addressed a lengthy letter to the rector, serving notice that the elder Pasteur, according to the customs of the times, would soon appear and propose marriage between

**Louis and the daughter.** In this letter Louis informed the rector that, "as to the future, unless my tastes should completely change, I shall give myself up entirely to chemical research." The father came, the proposal was made and duly accepted, the marriage occurred in three months.

At the close of 1854 Pasteur left Strassburg for a professorship at the University of Lille, where he served for two years. Then he went back to Paris, which was the central location of his work for the rest of his life.

When Pasteur went to Lille he fully expected to continue his studies in chemical and physical problems relative to crystals. The brewers and wine makers about Lille were having great difficulty since they could not be certain to secure the kinds of fermentation specifically needed in different cases, in order to produce the different specific results they desired. The wine and beer "went wrong," fermentation could not be controlled, and the industry was suffering great financial losses, said to exceed \$20,000,000 yearly in certain years. Pasteur was known as a chemist, and as a manipulator of the crude microscopes of that day. The manufacturers appealed to him to solve their problems, and he reluctantly agreed to the temporary diversion from his chosen studies, for he saw in this study great possibilities of new knowledge. Through the studies of famous German students, much had recently been learned about the yeasts which produced fermentation and about certain bacteria, but application of these studies had not been made in the brewing industries. There was still extended belief that the living organisms of fermentation came into existence spontaneously (spontaneous generation of life, as it was called), and that such organisms spring into existence in **the wine and beer** because of "**a vital force of nature,**" and thus injure

it. Pasteur, and others even more than Pasteur, proved that if nutritive liquids are sterilized and constantly kept from contact with air and other unsterile substances, *no* organisms will develop within this nutritive liquid no matter how long the experiment is continued. There was recently exhibited in the United States (1922), a flask of beef broth which it is claimed, correctly *no* doubt, that Pasteur prepared over fifty years ago. The beef broth is still fresh-looking and clear, never having had the stopper removed from the glass flask in which the broth has been constantly kept. Small living things, like the larger ones which we readily see, come only from other living things of their own kind. The process of treating wines as recommended by Pasteur, known as pasteurization, has since been applied to milk in all civilized countries.

With previously gained facts in mind, Pasteur proceeded to separate single living yeast plants under his microscope, and then to grow pure cultures from these organisms thus separated. He not only found that they grew as pure culture, but that each kind of small organism produced its own peculiar kind of fermentative products in the nutritive liquids. He thus taught the brewers and wine manufacturers how to separate, grow, and use the particular kinds of living microscopic organisms which produced the kinds of wine and beer that they desired.

We are not keenly interested in the fact that such discoveries taught people how to save the alcoholic industries of France and Germany. What interests us most is that he isolated the microscopic organisms, grew them in pure cultures, and proved that microscopic living things, like the larger ones we readily see, each produces its own peculiar results as product of its life and growth.

We need to recall that when Pasteur was studying

fermentation the **human** race did **not know the causes of** human diseases. Causes had been suspected, **but** not proved. What we know today as the science of public health did not exist. The bacterial origin of diseases was merely suspected, and the idea generally ridiculed. If a person had been bold enough to assert as true even a small part of what we now know to be true, such a person would have been thought insane or foolish. It was then not uncommon to think that persons who became ill had been guilty of some gross wrong-doing, and that illness was sent upon them as punishment for their sins. Or it was sometimes said that the "humours of the body," of which the blood and the bile were two, in some way got into wrong proportions or became deranged and thus caused illness. It is now generally known that most, if not all, common diseases are caused by living microscopic organisms, either bacteria or small animal parasites. Though this knowledge is but a few decades old, it is so common that it is difficult to put ourselves back to the recent date when the human race did not possess this knowledge. It is of such untold importance that Louis Pasteur lived and accomplished what he did, that, as we read this chapter, we must imagine ourselves for a time moved back a little more than forty years in the history of man's desire and efforts to have better health. Then, as now, most people wished to live instead of to die, and while living wished to have the best possible health. Then, as now, there were some benighted people who would not do the things necessary to produce good health, even if knowledge of how to do them were available.

When Pasteur's yeast and spontaneous generation studies were almost completed, he was urged to go to southern France to try to discover why the silk worms

were sick. He tried to decline, saying: "I have never touched a silk worm in my life." Why did people urge Pasteur to do this? Why didn't they call a bacteriologist or a student of insect diseases? At that time there were no bacteriologists because there was no bacteriology. Of course there were bacteria, but since no one then knew the laws of bacteria, there was no bacteriology. Likewise there was no science of insect diseases, or science of diseases of men as we now understand those terms.

For many years the silk industry of France had suffered. Often the worms became sick and died, or, if they lived, they produced poor cocoons. Poor cocoons, or no cocoons, mean reduction or loss of the desired silk, which means poorer food for the people, poorer education for their children, and all the poorer things which accompany reduction or loss of a fundamental industry. So important was the silk industry in southern France, and so great the anxiety about the health of the silk worms, that one writer says the workers when meeting would salute one another by saying: "Good morning! How are the silk worms this morning?" What they desired was good healthy adult silk moths which laid good moth eggs; that these eggs should hatch into worms which might feed and grow healthfully upon their food, the mulberry leaves; that the full-grown worms might spin good cocoons from which the workers could unravel the desired silk; that enough good cocoons should be left to produce adult moths to continue production of new supplies of healthy eggs.

Pasteur began this study in 1865. He studied the eggs and found within some of them certain small bodies resembling the smallest animal cells. He called these bodies corpuscles, simply meaning "small bodies." He

noted that when eggs which contained the corpuscles hatched, the worms were sickly and usually died. Using his crude microscope, he separated the eggs which contained no corpuscles and caused them to hatch. The worms thus produced seemed to be healthy, and after careful work, Pasteur announced that people could produce healthy worms and good cocoons by selecting eggs which contained no corpuscles. When this was tried and failed, Pasteur patiently returned to his microscopic studies and found another small organism, a bacterium, and immediately concluded that the silkworms had two diseases instead of one. One, *pebrine*, was caused by the animal corpuscles; and the other, *flacherie*, caused by the bacteria. Through long and careful experiments he discovered that eggs selected so as to be free from corpuscles and bacteria would produce healthy worms; that such worms when grown upon fresh mulberry leaves would mature and produce good silk cocoons; but that even healthy worms when grown were likely to sicken and die. He thus concluded that the corpuscles and bacteria produce the diseases, and that diseases from sick worms may be transmitted to healthy worms by contact with the food in which sick worms have fed. It is *not* so important that Pasteur taught France how to save her silk industry as it is that he proved that the small organisms produce the diseases; that transmission of the organisms may transmit the disease; and that prevention of transmission prevents disease. We are not likely to over-estimate the importance of these discoveries to modern public and individual health.

Meantime the cattle and sheep industry of France and of other countries was suffering from a disease known as anthrax. So deadly was anthrax to human beings that

when once it was clear that a person had the disease, it was regarded almost as a death warrant. Fortunately and for reasons then unknown, the disease did not often attack human beings. Its destruction of cattle and sheep was enormous.

Other students had discovered the nature of the bacterium which causes anthrax and had definitely proved the causal relation of the organism. But since no preventive or cure had been discovered, people appealed publicly to Pasteur to attack the problem. No less than 3600 public officers and prominent citizens signed petitions to Pasteur to undertake to find a means of preventing the ravages of this dreaded disease. He responded and began the study. It is interesting and important to know that the so-called anthrax bacteria caused the disease anthrax; but if they cannot be kept from causing the disease what does the knowledge profit us? If cattle and sheep and men must die, there really isn't large comfort in mere knowledge of what caused this wholesale death. That knowledge was essential for the beginning of Pasteur's study, but was merely the beginning.

After many efforts, too many and too intensive to be related in this connection, Pasteur recalled an important discovery made by the Englishman, Jenner, in 1798. Jenner, working in England, noted that persons who milked cows which were ill with cowpox contracted a disease resembling human smallpox, and that thereafter such persons would not contract smallpox from human beings ill with that disease. Jenner devised means, now improved and known to everyone, for giving human beings generally the infection or vaccination which protects against smallpox. In recalling this situation, Pasteur argued that smallpox was caused by a living organism; that

the organism when it lived in cattle did not flourish, and that this organism when introduced from cattle into human beings was not vigorous enough to produce a bad case of smallpox; that the case produced was bad enough, however, to leave some kind of protection or immunity against an attack from organisms from persons who have a vigorous case of smallpox. This line of thought is most interesting when we recall that we do not yet possess satisfactory evidence as to just what kind of an organism causes smallpox.

Meantime Pasteur had been carrying on experiments with chicken cholera. He left cultures of chicken cholera germs in his laboratory, and went away for a short vacation. Upon his return he found that these old cultures would no longer produce chicken cholera when some of the cultures were injected into fowls. Most important of all, he found that after the fowls had been treated with these old cultures they would not take chicken cholera even when injected with fresh and virulent germs. Therefore partly by chance came the discovery of the process of vaccinating poultry against cholera by use of depleted cholera germs or possibly by use of the dead products remaining in old cultures of these germs.

Thus Pasteur began his efforts to reduce the vigor of anthrax germs so that perchance they might not produce anthrax of usual destructiveness. Many highly illuminating experiments were performed. Finally, by growing anthrax bacteria in beef broth at high temperatures, it was found that they flourished for a time, then slowly died out. By using some of these cultures when the bacteria were much depleted it was found that sheep could be given mild attacks of anthrax from which they recovered. After their recovery they were given fully active

anthrax germs, from which the sheep promptly developed bad cases of anthrax and died. Pasteur then tried a first vaccination of depleted bacteria, and when the sheep had recovered, gave a second mild attack by use of bacteria much less depleted than those first used, but far from normal vigor. The sheep and cattle upon which this experiment was tried took successive mild attacks of anthrax. Thereafter, fully virulent anthrax bacteria failed to produce the disease, and Pasteur announced his triumph in producing progressive vaccination with successful results.

So important was this discovery that Pasteur was challenged to make a public demonstration of his claims. The Agriculture Society at Melun, France, offered to provide sheep and cattle for the demonstration. Delegates were invited and came from many interested organizations and countries. Pasteur penned ten sheep to serve as controls to determine whether anthrax was in the food, air, or water given to them and to the other sheep and cattle. Twenty-five sheep and six cows were to be vaccinated, and twenty-three sheep, two goats, and four cows were not to be vaccinated but were to receive fully virulent anthrax bacteria at the same time as the vaccinated sheep and cattle. On May 5, 1881, the first vaccination was given to the twenty-five sheep and six cows. On May 17, 1881, the second vaccination was given to the same animals. On May 31, 1881, fully virulent anthrax germs were given to all vaccinated sheep and cows, to the four remaining cows, and to the twenty-three sheep and the goats. Pasteur told the delegates to return on June 2. This direction was unnecessary as most of them did not leave, so keenly did they appreciate the momentous importance of what was going on. Many were disbelievers and expected Pasteur's downfall. The results were tri-

umphant. On the morning of June 2, all of the non-vaccinated sheep and cows and the goats were dead, dying, or severely ill. Not a vaccinated sheep or cow or a control sheep died as a result of the treatment they had received. Since that day the human race has known how to avoid anthrax, if only it will do what is known as good to do. More than this, the idea of successive vaccination was proved, and this has been the foundation of many subsequent advances in prevention of diseases of several types.

Did Pasteur then retire from active labor, one man's gigantic work having been clone? Did he remind his co-workers that since 1868 half-paralysis had made his work very difficult? No! Rather he reminded his closest friends that his part-paralysis which he suffered in 1868 enabled him to make more cautious and effective use of those parts of his body not affected by his malady—a malady for which the answer is not yet at hand. Instead he turned now to his last and most spectacular achievement.

For many years the sympathies of this great founder of the science of bacteriology had been sorely tried because of the ravages of the awful disease rabies, or hydrophobia. It is doubtless true that the cry of "mad dog" has created human panic since the times of primitive men. No sane person who has witnessed death from hydrophobia will willingly do so a second time, unless he is needed in ministrations of assistance or mercy. For years Pasteur had studied the dreaded disease and performed experiments with rabbits and other animals in efforts to locate the causal organism and to find a preventive or cure. It almost belittles this gigantic task to go directly to results, omitting descriptions of many fruitless efforts, false hopes roused in the man whose heart

as well as mind was now devoted to his supreme task. However, one day, after many failures to locate any guiding arrow, Pasteur used for inoculation in a rabbit a piece of old and dry spinal-cord tissue previously taken from a rabbit that had died of rabies. He had previously oftentimes transmitted the disease by use of nerve tissue, but the diseases thus produced were violent and death-productive. This time, however, the desiccated nerve tissue produced a mild attack from which the rabbit recovered. Following this lead, a series of less and less dry nerve tissues were used to produce a cumulative series of mild attacks, after which the bite of a rabid animal failed to produce hydrophobia.

At this juncture one of the most striking events of all science occurred. Frau Meister, of Alsace, had a boy, Joseph, who two days before had been bitten by a rabid dog. Such an attack as that shown by the fourteen bites upon the unfortunate boy had been previously regarded as meaning almost certain death. The mother had heard of Pasteur, and at once started to Paris with her boy. The treatment had not been given to any human being; it was not known whether results would be similar to those obtained in lower animals; it was not known what series or gradation of treatments would be necessary for human beings; it had been proved that the treatment could be applied to animals after a rabid bite, and that protection could be secured. Frau Meister was obstinately insistent. Pasteur's advisers intimated that the boy's death would be upon Pasteur if he refused to treat him and the mother absolved him from responsibility if the treatment were given. Against advice from his friends, Pasteur began the experiment upon the boy, shortening the periods between treatments in efforts to secure

cumulative protective results. **The ignorant but beautiful** confidence of the mother and boy permitted them to sleep and rest between treatments; but the highly intelligent understanding and tremendous responsibility and hope of Pasteur made sleep and rest almost impossible for him until the crisis had passed, and he felt sure that the boy's life had been saved.

Soon Pasteur institutes appeared in available centers throughout the civilized world, and today it is very rarely that a human being need die from hydrophobia. Superstitious and ignorant fear of hydrophobia has given place to the intelligent guidance of modern science.

On Pasteur's seventieth birthday (1892, three years before his death) delegates from scientific societies and public bodies of the civilized world met in France, in the great theater room of the Sorbonne. The band of the Republican Guard of France played the triumphal march. The President of the Republic was the escort as down the aisle came one of the greatest heroes and benefactors in human history. Gounod directed a choir which sang his Ave Maria. Coquelin recited verses written by him especially for this occasion. The Minister of Public Instruction among other things said :

Who can now say how much human life owes to you and how much more it will owe you in the future. The day will come when another Lucretius will sing, in a new poem on Nature, the immortal Master whose genius engendered such benefits.

Joseph Lister, when called upon, said:

Your researches upon fermentations have thrown a powerful light which has illuminated the baleful darkness of surgery and has changed the treatment of wounds from an uncertain and too often disastrous empirical affair into a sure beneficent scientific art. Thanks to you, surgery has undergone a complete revolution which has robbed it of its terrors, and has enlarged almost without

limit its efficacious power. Medicine owes not less than surgery to your profound and philosophical studies. You have lifted the veil which had covered infectious diseases during the centuries you have discovered and demonstrated their microbial nature. Thanks to your initiative and, in many cases, to your own special work, there are already a large number of these pernicious maladies of which we now know the causes.

Then Pasteur rose and spoke quietly and feelingly of his hope that science would save men from their bodily ills; that men will be more useful when free from disease. Then turning to the delegates he said:

**And you, delegates from other nations, bring me the deepest joy that can be felt by a man whose invincible belief is that Science and Peace will triumph over Ignorance and War, that nations will unite, not to destroy, but to build, and that the future will belong to those who will have done most for suffering humanity.**

The foundations of the science which may remove from man all his bodily ills if only he will turn his mind to them long enough, with sufficient patience and unselfishness—that is the achievement of Louis Pasteur. Human life is now much lengthened because of the work of Pasteur, by the few others of his time, and by the many others since who have been stimulated and whose work has been made possible by him. Those who know and do what modern health science teaches are the ones whose lives are lengthened. It is they who are of most worth to the world. A man at forty has just learned how to work. To add ten or fifteen or twenty years to his life saves to the world a man who is equipped and ready. His added years may double his service to the world. Surely in an age when great warriors are still extolled, it is supremely important for our young people to appreciate that true heroes help men to live and serve rather than teach them to vanquish and destroy their fellows.

# IX

## LEEUVENHOEK<sup>1</sup>

PAUL DE KRUIF

Paul de Kruif is a bacteriologist, with B.S. and Ph.D. degrees from the University of Michigan. He had a wide reputation among scientists for his research work and his writing on highly technical subjects before he became known to the general public. During the World War he was in France as a Captain in the Sanitary Corps of the Medical Department of the United States Army, and did important work on the poison and antitoxin of the bacillus of gas gangrene. After the War he spent another year of research at the University of Michigan and then went to the Rockefeller Institute for two years. Since 1922, however, he has devoted considerable time to writing for a nontechnical audience. Because of his knowledge of French, German, and Dutch he has been able to go directly to original sources for his material. For example, in preparing to write the present essay on Leeuwenhoek he read Leeuwenhoek's letters to the British Royal Society in the original Dutch. In addition to many articles, both technical and nontechnical, he has written *Microbe Hunters*, the story of the adventures of fourteen pioneers of bacteriology in their fight against disease; *Hunger Fighters*, stories of little known heroes in man's struggle against nature to get food; and *Seven Iron Men*, his most recent book.

|

Two hundred and fifty years ago an obscure man named Leeuwenhoek looked for the first time into a mysterious new world peopled with a thousand different kinds of tiny beings, some ferocious and deadly, others friendly and useful, many of them more important to mankind than any continent or archipelago.

<sup>1</sup> Reprinted from *Microbe Hunters*, copyright 1926 by Harcourt, Brace and Company, Inc., by permission of the publishers.

Leeuwenhoek, unsung and scarcely remembered, is now almost as unknown as his strange little animals and plants were at the time he discovered them. This is the story of Leeuwenhoek, the first of the microbe hunters. It is the tale of the bold and persistent and curious explorers and fighters of death who came after him. It is the plain history of their tireless peerings into this new fantastic world. They have tried to chart it, these microbe hunters and death fighters. So trying they have groped and fumbled and made mistakes and roused vain hopes. Some of them who were too bold have died—done to death by the immensely small assassins they were studying—and these have passed to an obscure small glory.

Today it is respectable to be a man of science. Those who go by the name of scientist form an important element of the population, their laboratories are in every city, their achievements are on the front pages of the newspapers, often before they are fully achieved. Almost any young university student can go in for research and by and by become a comfortable science professor at a tidy little salary in a cozy college.

But take yourself back to Leeuwenhoek's day, two hundred and fifty years ago, and imagine yourself just through high school, getting ready to choose a career, wanting to know.— You have lately recovered from an attack of mumps, you ask your father what is the cause of mumps and he tells you a mumpish evil spirit has got into you. His theory may not impress you much, but you decide to make believe you believe him and not to wonder any more about what is mumps—because if you publicly don't believe him you are in for a beating and may even be turned out of the house. Your father is Authority.

That was the world three hundred years ago, when Leeuwenhoek was born. It had hardly begun to shake itself free from superstitions; it was barely beginning to blush for its ignorance. It was a world where science (which only means trying to find truth by careful observation and clear thinking) was just learning to toddle on vague and wobbly legs. It was a world where Servetus was burned to death for daring to cut up and examine the body of a dead man, where Galileo was shut up for life for daring to prove that the earth moved around the sun.

Antony Leeuwenhoek was born in 1632 amid the blue windmills and low streets and high canals of Delft, in Holland. His family were burghers of an intensely respectable kind, and I say intensely respectable because they were basket-makers and brewers, and brewers are respectable and highly honored in Holland. Leeuwenhoek's father died early and his mother sent him to school to learn to be a government official, but he left school at sixteen to be an apprentice in a dry-goods store in Amsterdam. That was his university. Think of a present-day scientist getting his training for experiment among bolts of gingham, listening to the tinkle of the bell *on* the cash drawer, being polite to an eternal succession of Dutch housewives who shopped with a penny-pinching dreadful exhaustiveness—but that was Leeuwenhoek's university, for six years!

At the age of twenty-one he left the dry-goods store, went back to Delft, married, set up a dry-goods store of his own there. For twenty years after that very little is known about him, except that he had two wives (in succession) and several children, most of whom died, but there is no doubt that during this time he was appointed janitor of the city hall of Delft, and that he developed a

most idiotic love for grinding lenses. He had heard that if you very carefully ground very little lenses out of clear glass, you would see things look much bigger than they appeared *to* the naked eye. . . . Little is known about him from twenty to forty, but there is no doubt that he passed in those days for an ignorant man. The only language he knew was Dutch—that was an obscure language despised by the cultured world as a tongue of fishermen and shop-keepers and diggers of ditches. Educated men talked Latin in those days, but Leeuwenhoek could not so much as read it and his only literature was the Dutch Bible. Just the same, you will see that his ignorance was a great help to him, for, cut off from all the learned nonsense of his time, he had to trust to his own eyes, his own thoughts, his own judgment. And that was easy for him because there never was a more mulish man than this Antony Leeuwenhoek!

It would be great fun to look through a lens and see things bigger than your naked eye showed them to you! But *buy* lenses? Not Leeuwenhoek! There never was a more suspicious man. Buy lenses? He would make them himself! During these twenty years of his obscurity he went to spectacle-makers and got the rudiments of lens-grinding. He visited alchemists and apothecaries and put his nose into their secret ways of getting metals from ores, he began fumblingly to learn the craft of the gold- and silversmiths. He was a most pernicky man and was not satisfied with grinding lenses as good as those of the best lens-grinder in Holland; they had *to* be better than the best, and then he still fussed over them for long hours. Next he mounted these lenses in little oblongs of copper or silver or gold, which he had extracted himself, over hot fires, among strange smells and fumes. Today

searchers pay seventy-five dollars for a fine shining microscope, turn the screws, peer through it, make discoveries—without knowing anything about how it is built. But Leeuwenhoek—

Of course his neighbors thought he was a bit cracked, but Leeuwenhoek went on burning and blistering his hands. Working forgetful of his family and regardless of his friends, he bent solitary to subtle tasks in still nights. The good neighbors sniggered, while that man found a way to make a tiny lens, less than one-eighth of an inch across, so symmetrical, so perfect, that it showed little things to him with a fantastic clear enormousness. Yes, he was a very uncultured man, but he alone of all men in Holland knew how to make those lenses, and he said of those neighbors: "We must forgive them, seeing that they know no better."

Now this self-satisfied dry-goods dealer began to turn his lenses onto everything he could get hold of. He looked through them at the muscle fibers of a whale and the scales of his own skin. He went to the butcher shop and begged or bought ox-eyes and was amazed at how prettily the crystalline lens of the eye of the ox is put together. He peered for hours at the build of the hairs of a sheep, of a beaver, of an elk, that were transformed from their fineness into great rough logs under his bit of glass. He delicately dissected the head of a fly; he stuck its brain on the fine needle of his microscope—how he admired the clear details of the marvelous big brain of that fly! He examined the cross-sections of the wood of a dozen different trees and squinted at the seeds of plants. He grunted "Impossible!" when he first spied the outlandish large perfection of the sting of a flea and the legs of a louse. That man Leeuwenhoek was like a puppy

who sniffs—with a totally impolite disregard of discrimination—at every object of the world about him !

## II

There never was a less sure man than Leeuwenhoek. He looked at this bee's sting or that louse's leg again and again and again. He left his specimens sticking on the point of his strange microscope for months—in order to look at other things he made more microscopes till he had hundreds of them!—then he came back to those first specimens to correct his first mistakes. He never set down a word about anything he peeped at, he never made a drawing until hundreds of peeps showed him that, under given conditions, he would always see exactly the same thing. And then he was not sure ! He said :

"People who look for the first time through a microscope say now I see this and then I see that—and even a skilled observer can be fooled. On these observations I have spent more time than many will believe, but I have done them with joy, and I have taken no notice of those who have said why take so much trouble and what good is it?—but I do not write for such people but only for the philosophical!" He worked for twenty years that way, without an audience.

But at this time, in the middle of the seventeenth century, great things were astir in the world. Here and there in France and England and Italy rare men were thumbing their noses at almost everything that passed for knowledge. "We will no longer take Aristotle's say-so, nor the Pope's say-so," said these rebels. "We will trust only the perpetually repeated observations of our own eyes and the careful weighings of our scales; we

will listen to the answers experiments give us and no other answers!" So in England a few of these revolutionists started a society called The Invisible College—it had to be invisible because that man Cromwell might have hung them for plotters and heretics if he had heard of the strange questions they were trying to settle. What experiments those solemn searchers made! Put a spider in a circle made of the powder of a unicorn's horn and that spider can't crawl out—so said the wisdom of that day. But these Invisible Collegians? One of them brought what was supposed to be powdered unicorn's horn and another came carrying a little spider in a bottle. The college crowded around under the light of high candles. Silence, then the hushed experiment, and here is their report of it:

"A circle was made with the powder of unicorn's horn and a spider set in the middle of it, but it immediately ran out."

Crude, you exclaim. Of course! But remember that one of the members of this college was Robert Boyle, founder of the science of chemistry, and another was Isaac Newton. Such was the Invisible College, and presently, when Charles II came to the throne, it rose from its depths as a sort of blind-pig scientific society to the dignity of the name of Royal Society of England. And they were Antony Leeuwenhoek's first audience! There was one man in Delft who did not laugh at Antony Leeuwenhoek, and that was Regnier de Graaf, whom the Lords and Gentlemen of the Royal Society had made a corresponding member because he had written them of interesting things he had found in the human ovary. Already Leeuwenhoek was rather surly and suspected everybody, but he let de Graaf peep through those magic eyes

of his, those little lenses whose equal did not exist in Europe or England or the whole world for that matter. What de Graaf saw through those microscopes made him ashamed of his own fame and he hurried to write to the Royal Society:

"Get Antony Leeuwenhoek to write you telling of his discoveries."

And Leeuwenhoek answered the request of the Royal Society with all the confidence of an ignorant man who fails to realize the profound wisdom of the philosophers he addresses. It was a long letter, it rambled over every subject under the sun, it was written with a comical artlessness in the conversational Dutch that was the only language he knew. The title of the letter was: "A Specimen of some Observations made by a Microscope contrived by Mr. Leeuwenhoek, concerning Mould upon the Skin, Flesh, etc.; the Sting of a Bee, etc." The Royal Society was amazed, the sophisticated and learned gentlemen were amused—but principally the Royal Society was astounded by the marvelous things Leeuwenhoek told them he could see through his new lenses. The Secretary of the Royal Society thanked Leeuwenhoek and told him he hoped his first communication would be followed by others. It was, by hundreds of others over a period of fifty years. They were talkative letters full of salty remarks about his ignorant neighbors, of exposures of charlatans and of skilled explodings of superstitions, of chatter about his personal health—but sandwiched between paragraphs and pages of this homely stuff, in almost every letter, those Lords and Gentlemen of the Royal Society had the honor of reading immortal and gloriously accurate descriptions of the discoveries made by the magic eye of that janitor and shopkeeper. What discoveries!

When you look back at them, many of the fundamental discoveries of science seem so simple, too absurdly simple. How was it men groped and fumbled for so many thousands of years without seeing things that lay right under their noses? So with microbes. Now all the world has seen them cavorting on movie screens; many people of little learning have peeped at them swimming about under lenses of microscopes; the greenest medical student is able to show you the germs of I don't know how many diseases—what was so hard about seeing microbes the first time?

But let us drop our sneers to remember that when Leeuwenhoek was born there were no microscopes but only crude hand-lenses that would hardly make a ten-cent piece look as large as a quarter. Through these—without his incessant grinding of his own marvelous lenses—that Dutchman might have looked till he grew old without discovering any creature smaller than a cheesemite. You have read that he made better and better lenses with the fanatical persistence of a lunatic; that he examined everything, the most intimate things and the most shocking things, with the silly curiosity of a puppy. Yes, and all this squinting at bee-stings and mustache hairs and what-not was needful to prepare him for that sudden day when he looked through his toy of a gold-mounted lens at a fraction of a small drop of clear rain water to discover—

What he saw that day starts this history. Leeuwenhoek was a maniac observer, and who but such a strange man would have thought to turn his lens on clear, pure water, just come down from the sky? What could there be in water but just—water? You can imagine his daughter Maria—she was nineteen and she took such care of

her slightly insane father!—watching him take a little tube of glass, heat it red-hot in a flame, draw it out to the thinness of a hair. . . . Maria was devoted to her father—let any of those stupid neighbors dare to snigger at him!—but what in the world was he up to now, with that hair-fine glass pipe?

You can see her watch that absent-minded wide-eyed man break the tube into little pieces, go out into the garden to bend over an earthen pot kept there to measure the fall of the rain. He bends over that pot. He goes back into his study. He sticks the little glass pipe onto the needle of his microscope. . . .

What can that dear silly father be up to?

He squints through his lens. He mutters guttural words under his breath. . . .

Then suddenly the excited voice of Leeuwenhoek: "Come here! Hurry! There are little animals in this rain water. . . . They swim! They play around! They are a thousand times smaller than any creatures we can see with our eyes alone. . . . Look! See what I have discovered!"

Leeuwenhoek's day of days had come. Alexander had gone to India and discovered huge elephants that no Greek had ever seen before—but those elephants were as commonplace to Hindus as horses were to Alexander. Caesar had gone to England and come upon savages that opened his eyes with wonder—but these Britons were as ordinary to each other as Roman centurions were to Caesar. Balboa? What were his proud feelings as he looked for the first time at the Pacific? Just the same that ocean was as ordinary to a Central American Indian as the Mediterranean was to Balboa. But Leeuwenhoek? This janitor of Delft had stolen upon and peeped into

a fantastic sub-visible world of little things, creatures that had lived, had bred, had battled, had died, completely hidden from and unknown to all men from the beginning of time. Beasts these were of a kind that ravaged and annihilated whole races of men ten million times larger than they were themselves. Beings these were, more terrible than fire-spitting dragons or hydra-headed monsters. They were silent assassins that murdered babes in warm cradles and kings in sheltered palaces. It was this invisible, insignificant, but implacable—and sometimes friendly—world that Leeuwenhoek had looked into for the first time of all men of all countries.

This was Leeuwenhoek's day of days. . . .

### III

That man was so unashamed of his admirations and his surprises at a nature full of startling events and impossible things. How I wish I could take myself back, could bring you back, to that innocent time when men were just beginning to disbelieve in miracles and only starting to find still more miraculous facts. How marvelous it would be to step into that simple Dutchman's shoes, to be inside his brain and body, to feel his excitement—it is almost nausea!—at his first peep at those cavorting "wretched beasties."

That was what he called them, and, as I have told you, this Leeuwenhoek was an unsure man. Those animals were too tremendously small to be true; they were too strange to be true. So he looked again, till his hands were cramped with holding his microscope and his eyes full of that smarting water that comes from too-long looking. But he was right! Here they were again, not

one kind of little creature, but here was another, larger than the first, "moving about very nimbly because they were furnished with divers incredibly thin feet." Wait! Here is a third kind—and a fourth, so tiny I can't make out his shape. But he is alive! He goes about, dashing over great distances in this world of his water-drop in the little tube. . . . What nimble creatures!

"They stop, they stand still as 'twere upon a point, and then turn themselves around with that swiftness, as we see a top turn round, the circumference they make being no bigger than that of a fine grain of sand." So wrote Leeuwenhoek.

For all this seemingly impractical sniffing about, Leeuwenhoek was a hard-headed man. He hardly ever spun theories; he was a fiend for measuring things. Only how could you make a measuring stick for anything so small as these little beasts? He wrinkled his low forehead: "How large really is this last and smallest of the little beasts?" He poked about in the cobwebbed corners of his memory among the thousand other things he had studied with you can't imagine what thoroughness; he made calculations: "This last kind of animal is a thousand times smaller than the eye of a large louse!" That was an accurate man. For we know now that the eye of one full-grown louse is no larger nor smaller than the eyes of ten thousand of his brother and sister lice.

But where did these outlandish little inhabitants of the rain water come from? Had they come down from the sky? Had they crawled invisibly over the side of the pot from the ground? Or had they been created out of nothing by a God full of whims? Leeuwenhoek believed in God as piously as any Seventeenth Century Dutchman. He always referred to God as the Maker of the Great

All. He not only believed in God but he admired him intensely—what a Being to know how to fashion bees' wings so prettily! But then Leeuwenhoeck was a materialist too. His good sense told him that life comes from life. His simple belief told him that God had invented all living things in six days, and, having set the machinery going, sat back to reward good observers and punish guessers and bluffers. He stopped speculating about improbable gentle rains of little animals from heaven. Certainly God couldn't brew those animals in the rain water pot out of nothing! But wait. . . . Maybe? Well, there was only one way to find out where they came from. "I will experiment!" he muttered.

He washed out a wine glass very clean, he dried it, he held it under the spout of his eaves-trough, he took a wee drop in one of his hair-fine tubes. Under his lens it went. . . . Yes! They were there, a few of those beasts, swimming about. . . . "They are present even in very fresh rain water!" But then, that really proved nothing; they might live in the eaves-trough and be washed down by the water. . . .

Then he took a big porcelain dish, "glazed blue within," he washed it clean, out into the rain he went with it and put it on top of a big box so that the falling rain drops would splash no mud into the dish. The first water he threw out to clean it still more thoroughly. Then intently he collected the next bit in one of his slender pipes; into his study he went with it. . . .

"I have proved it! This water has not a single little creature in it! They do not come down from the sky!"

But he kept that water; hour after hour, day after day he squinted at it—and on the fourth day he saw those wee beasts beginning to appear in the water along with

bits of dust and little flecks of thread and lint. That was a man from Missouri! Imagine a world of men who would submit all of their cocksure judgments to the ordeal of the common-sense experiments of a Leeuwenhoek !

Did he write to the Royal Society to tell them of this entirely unsuspected world of life he had discovered? Not yet ! He was a slow man. He turned his lens onto all kinds of water, water kept in the close air of his study, water in a pot kept on the high roof of his house, water from the not-too-clean canals of Delft, and water from the deep cold well in his garden. Everywhere he found those beasts. He gaped at their enormous littleness, he found many thousands of them did not equal a grain of sand in bigness, he compared them to a cheesemite and they were to this filthy little creature as a bee is to a horse. He was never tired with watching them "swim about among one another gently like a swarm of mosquitoes in the air. . . ."

Of course this man was a groper. He was a groper and a stumbler as all men are gropers, devoid of prescience, and stumblers, finding what they never set out to find. His new beasties were marvelous but they were not enough for him; he was always poking into everything, trying to see more closely, trying to find reasons. Why is the sharp taste of pepper? That was what he asked himself one day, and he guessed: "There must be little points on the particles of pepper and these points jab the tongue when you eat pepper. . . ."

But are there such little points?

He fussed with dry pepper. He sneezed. He sweat, but he couldn't get the grains of pepper small enough to put under his lens. So to soften it, he put it to soak for several weeks in water. Then with fine needles he pried

the almost invisible specks of the pepper apart, and sucked them up in a little drop of water into one of his hair-fine glass tubes. He looked—

Here was something to make even this determined man scatter-brained. He forgot about possible small sharp points on the pepper. With the interest of an intent little boy he watched the antics of "an incredible number of little animals, of various sorts, which move very prettily, which tumble about and sidewise, this way and that!"

So it was Leeuwenhoek stumbled on a magnificent way to grow his new little animals.

And now to write all this to the great men off there in London! Artlessly he described his own astonishment to them. Long page after page in a superbly neat handwriting with little common words he told them that you could put a million of these little animals into a coarse grain of sand and that one drop of his pepper-water, where they grew and multiplied so well, held more than 2,700,000 of them. . . .

This letter was translated into English. It was read before the learned skeptics—who no longer believed in the magic virtues of unicorn's horns—and it bowled the learned body over! What! The Dutchman said he had discovered beasts so small that you could put as many of them into one little drop of water as there were people in his native country? Nonsense! The cheesemite was absolutely and without doubt the smallest creature God had created.

But a few of the members did not scoff. This Leeuwenhoek was a confoundedly accurate man: everything he had ever written to them they had found to be true. . . . So a letter went back to the scientific janitor, begging him

to write them in detail the way he had made his microscope, and his method of observing. That upset Leeuwenhoek. It didn't matter that these stupid oafs of Delft laughed at him—but the Royal Society? He had thought *they* were philosophers! Should he write them details, or should he from now on keep everything he did to himself? "Great God," you can imagine him muttering, "these ways I have of uncovering mysterious things, how I have worked and sweat to learn to do them, what jeering from how many fools haven't I endured to perfect my microscopes and my ways of looking! . . ."

But creators must have audiences. He knew that these doubters of the Royal Society should have sweat just as hard to disprove the existence of his little animals as he himself had toiled to discover them. He was hurt, but—creators must have an audience. So he replied to them in a long letter assuring them he never told anything too big. He explained his calculations (and modern microbe hunters with all of their apparatus make only slightly more accurate ones!) He wrote these calculations out, divisions, multiplications, additions, until his letter looked like a child's exercise in arithmetic. He finished by saying that many people of Delft had seen—with applause!—these strange new animals under his lens. He would send them affidavits from prominent citizens of Delft—two men of God, one notary public, and eight other persons worthy to be believed. But he wouldn't tell them how he made his microscopes.

That was a suspicious man! He held his little machines up for people to look through, but let them so much as touch the microscope to help themselves to see better and he might order them out of his house. . . . He was like a child anxious and proud to show a large

red apple to his playmates but loath to let them touch it for fear they might take a bite out of it.

So the Royal Society commissioned Robert Hooke and Nehemiah Grew to build the very best microscopes, and brew pepper water from the finest quality of black pepper. And, on the 15th of November, 1677, Hooke came carrying his microscope to the meeting—agog—for Antony Leeuwenhoek had not lied. Here they were, those enchanted beasts! The members rose from their seats and crowded round the microscope. They peered, they exclaimed: this man must be a wizard observer! That was a proud day for Leeuwenhoek. And a little later the Royal Society made him a Fellow, sending him a gorgeous diploma of membership in a silver case with the coat of arms of the society on the cover. "I will serve you faithfully during the rest of my life," he wrote them. And he was as good as his word, for he mailed them those conversational mixtures of gossip and science till he died at the age of ninety. But send them a microscope? Very sorry, but that was impossible to do, while he lived. The Royal Society went so far as to dispatch Doctor Molyneux to make a report on this janitor-discoverer of the invisible. Molyneux offered Leeuwenhoek a fine price for one of his microscopes—surely he could spare one?—for there were hundreds of them in cabinets that lined his study. But no! Was there anything the gentleman of the Royal Society would like to see? Here were some most curious little unborn oysters in a bottle; here were divers very nimble little animals; and that Dutchman held up his lenses for the Englishman to peep through, watching all the while out of the corner of his eye to see that the undoubtedly most honest visitor didn't touch anything—or filch anything. . . .

"But your instruments are marvelous!" cried Molyneux. "A thousand times more clear they show things than any lens we have in England!"

"How I wish, Sir," said Leeuwenhoek, "that I could show you my best lens, with my special way of observing, but I keep that only for myself and do not show it to any one—not even to my own family."

#### IV

Those little animals were everywhere! He told the Royal Society of finding swarms of those sub-visible beings in his mouth—of all places: "Although I am now fifty years old," he wrote, "I have uncommonly well-preserved teeth, because it is my custom every morning to rub my teeth very hard with salt, and after cleaning my large teeth with a quill, to rub them vigorously with a cloth. . . ." But there were still little bits of white stuff between his teeth, when he looked at them with a magnifying mirror. . . .

What was this white stuff made of?

From his teeth he scraped a bit of this stuff, mixed it with pure rain water, stuck it in a little tube on to the needle of his microscope, closed the door of his study.—

What was this that rose from the gray dimness of his lens into clear distinctness as he brought the tube into focus? Here was an unbelievably tiny creature, leaping about in the water of the tube "like the fish called a pike." There was a second kind that swam forward a little way, then whirled about suddenly, then tumbled over itself in pretty somersaults. There were some beings that moved sluggishly and looked like wee bent sticks, nothing more, but that Dutchman squinted at them till his eyes

were red-rimmed—and they moved, they were alive, no doubt of it! There was a menagerie in his mouth! There were creatures shaped like flexible rods that went to and fro with the stately carriage of bishops in procession; there were spirals that whirled through the water like violently animated corkscrews. . . .

Everybody he could get hold of—as well as himself—was an experimental animal *for* that curious man. Tired from his long peering at the little beasts in his own mouth, he went for a walk under the tall trees that dropped their yellow leaves on the brown mirrors of the canals; it was hard work, this play of his, he must rest! But he met an old man, a most interesting old man: "I was talking to this old man," wrote Leeuwenhoek to the Royal Society, "an old man who led a very sober life, who never used brandy nor tobacco and very seldom wine, and my eye chanced to fall on his teeth, which were badly grown over, and that made me ask him when he had last cleaned his mouth. I got for answer that he had never cleaned his teeth in his whole life. . . ."

Away went all thought of his aching eyes. What a zoo of wee animals must be in this old fellow's mouth. He dragged the dirty but virtuous victim of his curiosity into his study—of course there were millions of wee beasties in that mouth, but what he wanted particularly to tell the Royal Society was this: that this old man's mouth was host to a new kind of creature, that slid along among the others, bending its body in graceful bows like a snake—the water in the narrow tube seemed to be alive with those little fellows!

You may wonder that Leeuwenhoek nowhere in those hundreds of letters makes any mention of the harm these mysterious new little animals might do to men. He had

come upon them in drinking water, spied upon them in the mouth; as the years went by he discovered them in the intestines of frogs and horses, and even in his own discharges; in swarms he found them on those rare occasions when, as he says, "he was troubled with a looseness." But not for a moment did he guess that this trouble was caused by those little beasts, and from his unimagination and his carefulness not to jump to conclusions modern microbe hunters—if they only had time to study his writings—could learn a great deal. For, during the last fifty years, literally thousands of microbes have been described as the authors of hundreds of diseases, when in the majority of cases those germs have been only chance residents in the body at the time it became diseased. Leeuwenhoek was cautious about calling anything the *cause* of anything else. He had a sound instinct about the infinite complicatedness of everything—that told him the danger of trying to pick out one cause from the tangled maze of causes which control life. . . .

The years went by. He tended his little dry-goods store, he saw to it the city hall of Delft was properly swept out, he grew more and more crusty and suspicious, he looked longer and longer hours through his hundreds of microscopes, he made a hundred amazing discoveries. In the tail of a little fish stuck head first into a glass tube he saw for the first time of all men the capillary blood vessels through which blood goes from the arteries to the veins—so he completed the Englishman Harvey's discovery of the circulation of the blood.

The most sacred and improper and romantic things in life were only material for the probing, tireless eyes of his lenses. Leeuwenhoek discovered the human sperm, and the cold-blooded science of his searching would have

been shocking, if he had not been **such a** completely innocent man!

The years went by and all Europe knew about **him**. Peter the Great of Russia came to pay his respects to him, and the Queen of England journeyed to Delft only to look at the wonders to be seen through the lenses of his microscopes. He exploded countless superstitions for the Royal Society, and aside from Isaac Newton and Robert Boyle he was the most famous of their members. **But** did these honors turn his head? They couldn't turn his head because he had from the first a sufficiently high opinion of himself! His arrogance was limitless—but it was equaled by his humility when he thought of that misty unknown that he knew surrounded himself and all men. He admired the Dutch God but his real god was truth:

"My determination is not to remain stubbornly with my ideas, but **I'll** leave them and go over to others as soon as I am shown plausible reasons which I can grasp. This is the more true since I have no other purpose than to place truth before my eyes so far as it is in my power to embrace it; and to use the little talent I have received to draw the world away from its old heathenish superstitions and to go over to the truth and to stick to it."

He was an amazingly healthy man, and at the age of eighty his hand hardly trembled as he held up his microscope for visitors to peep at his little animals or to exclaim at the unborn oysters. But he was fond of drinking in the evenings—as what Dutchman is not?—and his only ill seems to have been a certain seediness in the morning after such wassail. He detested physicians—how could they know about the ills of the body when they didn't know one thousandth of what he did about the build of the body? So Leeuwenhoek had his own theories—**and**

sufficiently foolish they were—about the cause of this seediness. He knew that his blood was full of little globules—he had been the first of all men to see them. He knew those globules had to go through very tiny capillaries to get from his arteries to his veins—hadn't he been the man to discover those wee vessels in a fish-tail? Well, after those hilarious nights of his, his blood got too thick to run properly from the arteries to the veins! So he would thin it! So he wrote to the Royal Society:

"When I have supped too heavily of an evening, I drink in the morning a large number of cups of coffee, and that as hot as I can drink it, so that the sweat breaks out on me, and if by so doing I can't restore my body, a whole apothecary's shop couldn't do much, and that is the only thing I have done for years when I have felt a fever."

That hot coffee drinking led him to another curious fact about the little animals. Everything he did led him to pry up some new fact of nature, for he lived wrapped in those tiny dramas that went on under his lenses just as a child listens open-mouthed with saucer eyes to the myths of Mother Goose. . . . He never tired of reading the same story of nature; there were always new angles to be found in it; the pages of his book of nature were thumbed and dog-eared by his insatiable interest. Years after his discovery of the microbes in his mouth one morning in the midst of his sweating from his vast curative coffee drinkings he looked once more at the stuff between his teeth—

What was this? There was not a single little animal to be found. Or there were no living animals rather, for he thought he could make out the bodies of myriads of dead ones—and maybe one or two that moved feebly, as if they were sick. "Blessed Saints!" he growled: "I hope

some great Lord of the Royal Society doesn't try to find those creatures in his mouth, and fail, and then deny my observations. . . ."

But look here! He had been drinking coffee, so hot it had blistered his lips, almost. He had looked for the little animals in the white stuff from between his front teeth. It was just after the coffee he had looked there.—Well?

With the help of a magnifying mirror he went at his back teeth. Presto! "With great surprise I saw an incredibly large number of little animals, and in such an unbelievable quantity of the aforementioned stuff, that it is not to be conceived of by those who have not seen it with their own eyes." Then he made delicate experiments in tubes, heating the water with its tiny population to a temperature a little warmer than that of a hot bath. In a moment the creatures stopped their agile runnings to and fro. He cooled the water. They did not come back to life—so! It was that hot coffee that had killed the beasties in his front teeth!

With what delight he watched them once more! But he was bothered, he was troubled, for he couldn't make out the heads or tails of any of his little animals. After wiggling forward in one direction they stopped, they reversed themselves, and swam backward just as swiftly without having turned around. But they *must* have heads and tails! They must have livers and brains and blood vessels as well! His thoughts floated back to his work of forty years before, when he had found that under his powerful lenses fleas and cheesemites, so crude and simple to the naked eye, had become as complicated and as perfect as human beings. But try as he would with the best lenses he had, and those little animals in his

mouth were just plain sticks or spheres or corkscrews. So he contented himself by calculating, for the Royal Society, what the diameter of the invisible blood vessels of his microbes must be—but mind you, he never for a moment hinted that he had seen such blood vessels; it only amused him to stagger his patrons by speculations of their unthinkable smallness.

If Antony Leeuwenhoek failed to see the germs that cause human disease, if he had too little imagination to predict the role of assassin for his wretched creatures, he did show that sub-visible beasts could devour and kill living beings much larger than they were themselves. He was fussing with mussels, shellfish that he dredged up out of the canals of Delft. He found thousands of them unborn inside their mothers. He tried to make these young ones develop outside their mothers in a glass of canal water. "I wonder," he muttered, "why our canals are not choked with mussels, when the mothers have each one so many young ones inside them!" Day after day he poked about in his glass of water with its slimy mass of embryos, he turned his lens on to them to see if they were growing—but what was this? Astounded he watched the fishy stuff disappear from between their shells—it was being gobbled up by thousands of tiny microbes that were attacking the mussels greedily. . . .

"Life lives on life—it is cruel, but it is God's will," he pondered. "And it is for our good, of course, because if there weren't little animals to eat up the young mussels, our canals would be choked by those shellfish, for each mother has more than a thousand young ones at a time!" So Antony Leeuwenhoek accepted everything and praised everything, and in this he was a child of his time, for in his century searchers had not yet, like Pasteur who

came after them, begun to challenge God, to shake their fists at the meaningless cruelties of nature toward mankind, her children. . . .

He passed eighty, and his teeth came loose as they had to even in his strong body; he didn't complain at the inexorable arrival of the winter of his life, but he jerked out that old tooth and turned his lens onto the little creatures he found within that hollow root—why shouldn't he study them once more? There might be some little detail he had missed those hundred other times! Friends came to him at eighty-five and told him to take it easy and leave his studies. He wrinkled his brow and opened wide his still bright eyes: "The fruits that ripen in autumn last the longest!" he told them—he called eighty-five the autumn of his life!

Leeuwenhoek was a showman. He was very pleased to hear the ohs and ahs of people—they must be philosophical people and lovers of science, mind you!—whom he let peep into his sub-visible world or to whom he wrote his disjointed marvelous letters of description. But he was no teacher. "I've never taught one," he wrote to the famous philosopher Leibniz, "because if I taught one, I'd have to teach others. . . . I would give myself over to a slavery, whereas I want to stay a free man."

"But the art of grinding fine lenses and making observations of these new creatures will disappear from the earth, if you don't teach young men," answered Leibniz.

"The professors and students of the University of Leyden were long ago dazzled by my discoveries; they hired three lens grinders to come to teach the students, but what came of it?" wrote that independent Dutchman.

"Nothing, so far as I can judge, for almost all of the courses they teach there are for the purpose of getting

money through knowledge or for gaining the respect of the world by showing people how learned you are, and these things have nothing to do with discovering the things that are buried from our eyes. I am convinced that of a thousand people not one is capable of carrying out such studies, because endless time is needed and much money is spilled and because a man has always to be busy with his thoughts if anything is to be accomplished. . . ."

That was the first of the microbe hunters. In 1723, when he was ninety-one years old and on his deathbed, he sent for his friend Hoogvliet. He could not lift his hand. His once glowing eyes were rheumy and their lids were beginning to stick fast with the cement of death. He mumbled :

"Hoogvliet, my friend, be so good as to have those two letters on the table translated into Latin. . . . Send them to London to the Royal Society. . . ."

So he kept his promise made fifty years before, and Hoogvliet wrote, along with those last letters: "I send you, learned sirs, this last gift of my dying friend, hoping that his final word will be agreeable to you."

So he passed, this first of the microbe hunters. You will read of Spallanzani, who was much more brilliant, of Pasteur, who had a thousand times his imagination, of Robert Koch, who did much more immediate apparent good in lifting the torments that microbes bring to men—these and all the others have much more fame today. But not one of them has been so completely honest, so appallingly accurate as this Dutch janitor, and all of them could take lessons from his splendid common sense.

## X

# THE AXE-HELVE<sup>1</sup>

"DAVID GRAYSON"

[RAY STANNARD BAKER]

Ray Stannard Baker's profession is journalism. He has been associate editor of both *McClure's* and the *American* magazines, and has published several volumes on political and economic subjects. But he is better known, perhaps, as "David Grayson," the author of several volumes of familiar essays and of a novel, *Hempfield*. The volumes of essays are mainly adventures in simple living, especially notable for their whimsical humor and homely philosophy. The present essay is a chapter from the first of these books, *Adventures in Contentment*, where the scene is a little New England farm, and the characters are his sister, who keeps house for him, and his neighbors, Farmer Horace, Carpenter Baxter, the Scotch Preacher, etc. Other books are *Adventures in Friendship*, *The Friendly Road*, *Great Possessions*, and *Adventures in Understanding*.

April the 15th.

This morning I broke my old axe-handle. I went out early while the fog still filled the valley and the air was cool and moist as it had come fresh from the filter of the night. I drew a long breath and let my axe fall with all the force I could give it upon a new oak log. I swung it unnecessarily high for the joy of doing it and when it struck it communicated a sharp yet not unpleasant sting to the palms of my hands. The handle broke short off at the point where the helve meets the steel. The blade was driven deep into the oak wood. I suppose I should

<sup>1</sup> Reprinted from *Adventures in Contentment*, copyright 1907 by Doubleday, Doran and Company, Inc., by permission of the author and the publishers.

have regretted my foolishness, but I did not. The handle was old and somewhat worn, and the accident gave me an indefinable satisfaction: the culmination of use, that final destruction which is the complement of great effort.

This feeling was also partly prompted by the thought of the new helve I already had in store, awaiting just such a catastrophe. Having come somewhat painfully by that helve, I really wanted to see it in use.

Last spring, walking in my fields, I looked out along the fences for a well-fitted young hickory tree of thrifty second growth, bare of knots at least head high, without the cracks or fissures of too rapid growth or the doziness of early transgression. What I desired was a fine, healthy tree fitted for a great purpose and I looked for it as I would look for a perfect man to save a failing cause. At last I found a sapling growing in one of the sheltered angles of my rail fence. It was set about by dry grass, overhung by a much larger cherry tree, and bearing still its withered last year's leaves, worn diaphanous but curled delicately, and of a most beautiful ash gray color, something like the fabric of a wasp's nest, only yellower. I gave it a shake and it sprang quickly under my hand like the muscle of a good horse. Its bark was smooth and trim, its bole well set and solid.

A perfect tree! So I came up again with my short axe and after clearing away the grass and leaves with which the wind had mulched it, I cut into the clean white roots. I had no twinge of compunction, for was this not fulfillment? Nothing comes of sorrow for worthy sacrifice. When I had laid the tree low, I clipped off the lower branches, snapped off the top with a single clean stroke of the axe, and shouldered as pretty a second-growth sapling stick as anyone ever laid his eyes upon.

I carried it down to my barn and put it on the open rafters over the cow stalls. A cow stable is warm and not too dry, so that a hickory log cures slowly without cracking or checking. There it lay for many weeks. Often I cast my eyes up at it with satisfaction, watching the bark shrink and slightly deepen in color, and once I climbed up where I could see the minute seams making way in the end of the stick.

In the summer I brought the stick into the house, and put it in the dry, warm storeroom over the kitchen where I keep my seed corn. I do not suppose it really needed further attention, but sometimes when I chanced to go into the storeroom, I turned it over with my foot. I felt a sort of satisfaction in knowing that it was in preparation for service: good material for useful work. So it lay during the autumn and far into the winter.

One cold night when I sat comfortably at my fireplace, listening to the wind outside, and feeling all the ease of a man at peace with himself, my mind took flight to my snowy field sides and I thought of the trees there waiting and resting through the winter. So I came in imagination to the particular corner in the fence where I had cut my hickory sapling. Instantly I started up, much to Harriet's astonishment, and made my way mysteriously up the kitchen stairs. I would not tell what I was after: I felt it a sort of adventure, almost like the joy of seeing a friend long forgotten. It was as if my hickory stick had cried out at last, after long chrysalis-hood:

"I am ready."

I stood it on end and struck it sharply with my knuckles: it rang out with a certain clear resonance.

"I am ready."

**I sniffed at the end of it. It exhaled a peculiar good smell, as of old fields in the autumn.**

"I am ready."

So I took it under my arm and carried it down.

"Mercy, what are you going to do?" exclaimed Harriet.

"Deliberately, and with malice aforethought," I responded, "I am going to litter up your floor. I have decided to be reckless. I don't care what happens."

Having made this declaration, which Harriet received with becoming disdain, I laid the log by the fireplace—not too near—and went to fetch a saw, a hammer, a small wedge, and a drawshave.

I split my log into as fine white sections as a man ever saw—every piece as straight as morality, and without so much as a sliver to mar it. Nothing is so satisfactory as to have a task come out in perfect time and in good order. The little pieces of bark and sawdust I swept scrupulously into the fireplace, looking up from time to time to see how Harriet was taking it. Harriet was still disdainful.

Making an axe-helve is like writing a poem (though I never wrote one). The material is free enough, but it takes a poet to use it. Some people imagine that any fine thought is poetry, but there was never a greater mistake. A fine thought, to become poetry, must be seasoned in the upper warm garrets of the mind for long and long, then it must be brought down and slowly carved into words, shaped with emotion, polished with love. Else it is no true poem. Some people imagine that any hickory stick will make an axe-helve. But this is far from the truth. When I had whittled away for several evenings with my drawshave and jackknife, both of which I keep

sharpened to the keenest edge, I found **that my work** was not progressing as well as I had hoped.

"This is more of a task," I remarked one evening, "than I had imagined."

Harriet, rocking placidly in her armchair, was mending a number of pairs of new socks. Poor Harriet! Lacking enough old holes to occupy her energies, she mends holes that may possibly appear. A frugal person!

"Well, David," she said, "I warned you that you could buy a helve cheaper than you could make it."

"So I can buy a book cheaper than I can write it," I responded.

I felt somewhat pleased with my return shot, though I took pains not to show it. I squinted along my hickory stick which was even then beginning to assume, rudely, the outlines of an axe-handle. I had made a prodigious pile of fine white shavings and I was tired, but quite suddenly there came over me a sort of love for that length of wood. I sprung it affectionately over my knee, I rubbed it up and down with my hand, and then I set it in the corner behind the fireplace.

"After all," I said, for I had really been disturbed by Harriet's remark—"after all, power over one thing gives us power over everything. When you mend socks prospectively—into futurity—Harriet, that is an evidence of true greatness."

"Sometimes I think it doesn't pay," remarked Harriet, though she was plainly pleased.

"Pretty good socks," I said, "can be bought for fifteen cents a pair."

Harriet looked at me suspiciously, but I was as sober as the face of nature.

For the next two or three evenings I let the axe-helve stand alone in the corner. I hardly looked at it, though once in a while, when occupied with some other work, I would remember, or rather half-remember, that I had a pleasure in store for the evening. The very thought of sharp tools and something to make with them acts upon the imagination with peculiar zest. So we love to employ the keen edge of the mind upon a knotty and difficult subject.

One evening the Scotch preacher came in. We love him very much, though he sometimes makes us laugh—perhaps, in part, because he makes us laugh. Externally he is a sort of human cocoanut, rough, brown, shaggy; but, within, he has the true milk of human kindness. Some of his qualities touch greatness. His youth was spent in stony places where strong winds blew; the trees where he grew bore thorns; the soil where he dug was full of roots. But the crop was human love! He possesses that quality, unusual in one bred exclusively in the country, of magnanimity toward the unlike. In the country we are tempted to throw stones at strange hats! But to the Scotch preacher every man in one way seems transparent to the soul. He sees the man himself, not his professions any more than his clothes. And I never knew anyone who had such an abiding disbelief in the wickedness of the human soul. Weakness he sees and comforts; wickedness he cannot see.

When he came in I was busy whittling my axe-helve, it being my pleasure at that moment to make long, thin, curly shavings so light that many of them were caught on the hearth and bowled by the draft straight to fiery destruction.

There is a noisy zest about the Scotch preacher: he

comes in "stomping" as we say, he must clear his throat, he must strike his hands together; he even seems noisy when he unwinds the thick red tippet which he wears wound many times around his neck. It takes him a long time to unwind it, and he accomplishes the task with many slow gyrations of his enormous rough head. When he sits down he takes merely the edge of the chair, spreads his stout legs apart, sits as straight as a post, and blows his nose with a noise like the falling of a tree.

His interest in everything is prodigious. When he saw what I was doing he launched at once upon an account of the methods of axe-helving, ancient and modern, with true incidents of his childhood.

"Man," he exclaimed, "you've clean forgot one of the preinciple refinements of the art. When you chop, which hand do you hold down?"

At the moment, I couldn't have told to save my life, so we both got up on our feet and tried.

"It's the right hand down," I decided; "that's natural to me."

"You're a normal right-handed chopper, then," said the Scotch preacher, "as I was thinking. Now let me instruct you in the art. Being right-handed, your helve must bow out—so. No first-class chopper uses a straight handle."

He fell to explaining, with gusto, the mysteries of the bowed handle, and as I listened I felt a new and peculiar interest in my task. This was a final perfection to be accomplished, the finality of technique!

So we sat with our heads together talking helves and axes, axes with single blades and axes with double blades, and hand axes and great choppers' axes, and the science of felling trees, with the true philosophy of the last chip,

and arguments as to the best procedure when a log begins to "pinch"—until a listener would have thought that the art of the chopper included the whole philosophy of existence—as indeed it does, if you look at it in that way. Finally I rushed out and brought in my old axe-handle, and we set upon it like true artists, with critical proscription for being a trivial product of machinery.

"Man," exclaimed the preacher, "it has no character. Now your helve here, being the vision of your brain and work of your hands, will interpret the thought of your heart."

Before the Scotch preacher had finished his disquisition upon the art of helve-making and its relation with all other arts, I felt like Peary discovering the Pole.

In the midst of the discourse, while I was soaring high, the Scotch preacher suddenly stopped, sat up, and struck his knee with a tremendous resounding smack.

"Spoons!" he exclaimed.

Harriet and I stopped and looked at him in astonishment.

"Spoons," repeated Harriet.

"Spoons," said the Scotch preacher. "I've not once thought of my errand; and my wife told me to come straight home. I'm more thoughtless every day!"

Then he turned to Harriet:

"I've been sent to borrow some spoons," he said.

"Spoons!" exclaimed Harriet

"Spoons," answered the Scotch preacher. "We've invited friends for dinner tomorrow, and we must have spoons."

"But why—how—I thought—" began Harriet, still in astonishment.

The Scotch preacher squared around toward her and cleared his throat.

"It's the baptisms," he said: "when a baby is brought for baptism, of course it must have a baptismal gift. What is the best gift for a baby? A spoon. So we present it with a spoon. Today we discovered we had only three spoons left, and company coming. Man, 'tis a proleefic neighborhood."

He heaved a great sigh.

Harriet rushed out and made up a package. When she came in I thought it seemed suspiciously large for spoons, but the Scotch preacher having again launched into the lore of the chopper, took it without at first perceiving anything strange. Five minutes after we had closed the door upon him he suddenly returned holding up the package.

"This is an uncommonly heavy package," he remarked; "did I say tablespoons?"

"Go on!" commanded Harriet; "your wife will understand."

"All right—good-bye again," and his sturdy figure soon disappeared in the dark.

"The impractical man!" exclaimed Harriet. "People impose on him."

"What was in that package, Harriet?"

"Oh, I put in a few jars of jelly and a cake of honey." . . .

It is prodigious, the amount of work required to make a good axe-helve—I mean to make it according to one's standard. I had times of humorous discouragement and times of high elation when it seemed to me I could not

work fast enough. Weeks passed when I did not touch the helve but left it standing quietly in the corner. Once or twice I took it out and walked about with it as a sort of cane, much to the secret amusement, I think, of Harriet. At times Harriet takes a really wicked delight in her superiority.

Early one morning in March the dawn came with a roaring wind, sleety snow drove down over the hill, the house creaked and complained in every clapboard. A blind of one of the upper windows, wrenched loose from its fastenings, was driven shut with such force that it broke a windowpane. When I rushed up to discover the meaning of the clatter and to repair the damage, I found the floor covered with peculiar long fragments of glass—the pane having been broken inward from the center.

"Just what I have wanted," I said to myself.

I selected a few of the best pieces and so eager was I to try them that I got out my axe-helve before breakfast and sat scratching away when Harriet came down.

Nothing equals a bit of broken glass for putting on the final perfect touch to a work of art like an axe-helve. Nothing will so beautifully and delicately trim out the curves of the throat or give a smoother turn to the waist. So with care and an indescribable affection, I added the final touches, trimming the helve until it exactly fitted my hand. Often and often I tried it in pantomime, swinging nobly in the center of the sitting-room (avoiding the lamp), attentive to the feel of my hand as it ran along the helve. I rubbed it down with fine sandpaper until it fairly shone with whiteness. Then I borrowed a red flannel cloth of Harriet and having added a few drops—not too much—of boiled oil, I rubbed the helve for all I was worth. This I continued for upward of an hour. At that

time the axe-helve had taken on a yellowish shade, very clear and beautiful.

I do not think I could have been prouder if I had carved a statue or built a Parthenon. I was consumed with vanity; but I set the new helve in the corner with the appearance of utter unconcern.

"There," I remarked, "it's finished."

I watched Harriet out of the corner of my eye: she made as if to speak and then held silent.

That evening friend Horace came in. I was glad to see him. Horace is or was a famous chopper. I placed him at the fireplace where his eye, sooner or later, must fall upon my axe-helve. Oh, I worked out my designs! Presently he saw the helve, picked it up at once and turned it over in his hands. I had a suffocating, not unhumorous, sense of self-consciousness. I know how a poet must feel at hearing his first poem read aloud by some other person who does not know its authorship. I suffer and thrill with the novelist who sees a stranger purchase his book in a bookshop. I felt as though I stood that moment before the Great Judge.

Horace "hefted" it and balanced it, and squinted along it; he rubbed it with his thumb, he rested one end of it on the floor and sprung it roughly.

"David," he said severely, "where did you git this?"

Once when I was a boy I came home with my hair wet. My father asked:

"David, have you been swimming?"

I had exactly the same feeling when Horace asked his question. Now I am, generally speaking, a truthful man. I have written a good deal about the immorality, the unwisdom, the shortsightedness, the sinful wastefulness of a lie. But at that moment, if Harriet had not been

present—and that illustrates one of the purposes of society, to bolster up a man's morals—I should have evolved as large and perfect a prevarication as it lay within me to do—cheerfully. But I felt Harriet's moral eye upon me: I was a coward as well as a sinner. I faltered so long that Horace finally looked around at me.

Horace has no poetry in his soul, neither does he understand the philosophy of imperfection nor the art of irregularity.

It is a tender shoot, easily blasted by cold winds, the creative instinct: but persistent. It has many adventitious buds. A late frost, destroying the freshness of its early verdure, may be the means of a richer growth in later and more favorable days.

For a week I left my helve standing there in the corner. I did not even look at it. I was slain. I even thought of getting up in the night and putting the helve on the coals—secretly. Then, suddenly, one morning, I took it up not at all tenderly, indeed with a humorous appreciation of my own absurdities, and carried it out into the yard. An axe-helve is not a mere ornament but a thing of sober purpose. The test, after all, of axe-helves is not sublime perfection, but service. We may easily find flaws in the verse of the master—how far the rhythm fails of the final perfect music, how often uncertain the rhyme—but it bears within it, hidden yet evident, that certain incalculable fire which kindles and will continue to kindle the souls of men. The final test is not the perfection of precedent, not regularity, but life, spirit.

It was one of those perfect, sunny, calm mornings that

sometimes come in early April: the zest of winter yet in the air, but a promise of summer.

I built a fire of oak chips in the middle of the yard, between two flat stones. I brought out my old axe, and when the fire had burned down somewhat, leaving a foundation of hot coals, I thrust the eye of the axe into the fire. The blade rested on one of the flat stones, and I kept it covered with wet rags in order that it might not heat sufficiently to destroy the temper of the steel. Harriet's old gray hen, a garrulous fowl, came and stood on one leg and looked at me first with one eye and then with the other. She asked innumerable questions and was generally disagreeable.

"I am sorry, madam," I said finally, "but I have grown adamant to criticism. I have done my work as well as it lies in me to do it. It is the part of sanity to throw it aside without compunction. A work must prove itself. Shoo!"

I said this with such conclusiveness and vigor that the critical old hen departed hastily with ruffled feathers.

So I sat there in the glorious perfection of the forenoon, the great day open around me, a few small clouds abroad in the highest sky, and all the earth radiant with sunshine. The last snow of winter was gone, the sap ran in the trees, the cows fed farther afield.

When the eye of the axe was sufficiently expanded by the heat I drew it quickly from the fire and drove home the helve, which I had already whittled down to the exact size. I had a hickory wedge prepared and it was the work of ten seconds to drive it into the cleft at the lower end of the helve until the eye of the axe was completely and perfectly filled. Upon cooling, the steel shrank the wood, clasping it with such firmness that nothing short

of fire could ever dislodge it. Then, carefully, with knife and sandpaper I polished off the wood around the steel of the axe until I had made as good a job of it as lay within my power.

So I carried the axe to my log-pile. I swung it above my head and the feel of it was good in my hands. The blade struck deep into the oak wood. And I said to myself with satisfaction:

"It serves the purpose."

## XI

# THE PATTERN-MAKERS<sup>1</sup>

WILLIAM MCFEE

William McFee is a unique combination of marine engineer and author; at both professions he has an international reputation. He holds his Extra Chiefs Certificate from the London Board of Trade and also his United States Chief's License; and he has written a number of books, both essays and fiction, and is a regular contributor to magazines. The present essay is part of a record of his training as a pupil-apprentice from 1897 until 1900 in "McMuirland's" engineering shops at Aldergate; it is printed in *Swallowing the Anchor*, "notes," as the title page says, "made by an engineer in the merchant service who secured leave of absence from his ship in order to investigate and report upon the superiority of life ashore." In 1915, after five years of general engineering experience, McFee was discharged for mixing up some mechanical drawings, and took a job as engineer on one of his uncle's ships. From then until after the World War he was a marine engineer, though a great deal of his time he managed to spend reading and writing. Since 1911 he has lived in America, and is a naturalized American citizen. Other books of his are *Aliens*, *Casuals of the Sea*, *Race*, and *Sunlight in the New Granada*.

It was a world within a world, and that again lost in the mighty maze of London, and I remember with affection the days I spent there.

Between us, up there in the pattern shop, which you had to reach by crossing the girder shop and the heavy machine shop and so up a staircase leading over the booming and murky smithy—between us and the boss in

<sup>1</sup> Reprinted from *Swallowing the Anchor*, copyright 1925 by William McFee, by special permission of the author and of the publishers, Doubleday, Doran and Company, Inc.

his great skylighted office, surrounded by telephones and rushing out at us sometimes in his shirt sleeves, there was not so much difference as you might imagine. Because, while there was nothing democratic in our relations, supposing that word to have any meaning at all, which I doubt, we knew all about him. It was true he had inherited the business of millwrights and engineers, or would do so when his remarkable old father gave up the ghost. But he was in the line of succession. The old man, the Senior, we called him, to distinguish him from the Junior, had inherited the concern from his father, who had served his apprenticeship with the man who invented the steam engine, Jamie Watt, no less, with his partner Boulton. So here you had what, to us, was almost apostolic succession, and more than that there had been some sort of ironworks and foundry there in that part of Clerkenwell for goodness knows how long, with a yard behind which had been used in the Great Plague to bury the poor folk in, as we found, very horribly, when we dug the big erecting pit deeper for a tall mill engine, and found skulls and so on. And the tavern at the corner is still called the Pit's Head, and in my time their ale was good enough. And never did I hear from the men any complaint that Junior should inherit from Senior, seeing their fathers before them had builded the business and gave us, anyhow, a decent living. Even in my time, and that followed a strike that was like a lot of brothers fighting, the men were tradesmen, which is to say, men cunning and skillful in their trade, and none more proud and considering than the pattern-makers. Which made us notice how the Junior, though he had more book knowledge than his father or grandfather, depended on the foreman to say just how a pattern would draw and how it could be cored.

I can remember once, when I asked him, he was stuck and could not tell me.

The pattern-makers, then, with their own union, and looking down on the carpenters and, in fact, everybody except the moulders were "toffs" in the mechanics' world. It was an interesting place to be. I've heard men say that it was the best fitted-up shop, for a journeyman, of any in London; and they had worked in them all, from Hunter and English at Bow, who made pumping engines, the same as we, to Gwynnes of Hammersmith and Peter Brotherhood's, who were more in the marine line and had a host of tricky castings to do. We had a band saw, a circular saw, a planing machine, and two lathes, one for big face work, and a small one, which I delighted to run, for prints and so on. For you must understand I did not go into that place an ignoramus, as do so many apprentices, so that their whole four years is none too much to get the rudiments. I had always had tools in my hands, and had a lathe with a treadle at home and could use a gouge and knife tool pretty well, so when I got to that lathe up in the corner of the pattern shop, driven by a belt from the great humming engine downstairs, I was loath to leave off. Even now, I could use a lathe all day.

But the journeymen, who had learned their trade before all these fine machines had been invented, did not believe in having apprentices use them. I can remember, when they put in a machine for slicing the end grain of a piece of wood true and square and as smooth as cheese, old Thompson, the foreman, would not let me to it. I had to go back to my bench and plane my work square and test it by hand. This was sound doctrine, though I didn't see it. For how can a craftsman learn to have his hand

and eye and brain all trained to work together if he depends more and more on the machine? And to show how they made us apprentices work until we knew what we were doing, I can tell the way I made my tool chest

There was another mark of distinction the pattern-makers had—the great number of tools each man had to buy. There were his big trying plane, a couple of jack planes, and as many as a half-a-dozen small smooth planes, some of which he had made himself out of a piece of beech he fancied, and bought the irons in Petticoat Lane of a Sunday morning. There were his hammers, two at least, and his gages, which were sometimes wonderful pieces of fancy work, in ebony or rosewood, though this latter stuff, pretty to look at, had a way of splitting. He had compasses, of course, and prickers, for no pattern-maker can work to a pencil line; he has to scribe it with a sharp blade. But above all he took pride in his chisels and gouges, all oiled and sharpened and with boxwood hafts shining like cloudy amber, a lovely sight in a well-stocked chest. His saws were perhaps three in number and as a rule he would lend neither saw nor chisel nor gouge. Find your own. And indeed I have seen three men in a row at the long bench by the windows and their chests were worth all of twenty pounds each, which was a lot of money in those days when one made only tenpence or a shilling an hour.

Well, the first thing we apprentices had to do was make a chest. If we couldn't do that, seeing it was only joinery, we couldn't be trusted to make patterns. So up we went to the loft with our bench-mate and picked the wood, eleven-inch boards of fair white pine about five eighths of an inch thick. A chest had to go under a bench, it had to be long enough to carry a rip saw in the lid, and

it had to be handy enough to lift to the man's shoulder when he went away to another town. This brought the chest to about three feet long by a foot wide and the same high. Inside, the tools lay in trays, such as I am going to tell about, like spoons and forks in these modern stiver cabinets, and there was a lock or two, and handles at each end, of brass. I can tell you, when you had made that chest and knew how to use all the tools it held, from the spoon gouges to the old woman's tooth, you could call yourself an improver, anyhow, and the old fellows in the shop would no longer worry you with their chat.

The box and the lid were all made in one, and then the lid was sawn asunder about three inches down between the dovetails. It was the dovetailing that tried the youngster, and even now I think of the failures, the "wasters" I made before I got the sides and ends good enough for old Thompson. Nothing but right would do him, and he pushed the crooked work through the band-saw so fast it screamed, and I had to begin again. For if you will look at a box or drawer that has been dovetailed you will see how nice the fitting must be. You have to saw with extreme care down the sides of the tails, leaving a shade to pare with a chisel, and when all of that particular corner is ready for a trial, set the male and female lightly together. I have seen men, working on the heavy mahogany cases that cover the malt rollers in a brewery, so skilled in dovetailing that the work drove together at the first shot, but they were master-joiners and doing such work year in, year out. For me, I was lucky, getting my four boards together at last, all ready for glueing and nailing.

Even this was a craft, for glue ill-made is no use at all, but a mere filling. We had a steamheated pot out-

side on the landing, and they taught me to leave the glue in cold water overnight and then, when it was like large pale slabs of jelly, to set it warming gradually, stirring it now and then as I was told. When all was ready the bench was cleared and the pot brought in. All the tails were glued quickly and tapped into place, the excess was wiped off with shavings, the pot put back, and then the nails put in. This nailing was so done that each nail added to the rigidity of the chest, they being driven in pairs away from each other and headed home with a punch. Then the top and bottom—each was a clean and beautiful single piece of fine pine—were nailed on and the whole thing was put up in the loft to dry.

The custom in my time was to leave it there while you made your trays. And if any apprentice had trouble with his chest, he could count on a miserable time with trays. These were generally three in number. One, the same size as the chest, went below. The other two lay end to end, flush with the opening, and were to carry the fancy chisels, bradawls, drill bits, and gouges. The trouble and care arose from their being only three eighths of an inch thick, or sometimes only a quarter of an inch, and since they were shellac-varnished, every flaw was visible. I think I made a good half-dozen top trays before old Thompson managed to bring himself to let me go on with the work. I hated him and his particularity then, but I wish, when I have some wood work to do now, that I could find someone with one tenth of his skill and honorable professional conscience. When the trays were made, then, and ready to be planed down to fit the chest exactly, the chest itself was a hard, strong, hollow affair that, as old Thompson said, "could be chucked out o' two story window an' take no 'arm." This was the

ideal we were supposed to work for, and cases have been known in the trade where a chest, locked and screwed, has actually had this misfortune and survived with only a bruised or splintered corner.

Taking it up again, then, the next thing to do was to put on the top and bottom moldings, which formed additional sturdiness and also made the thing near water-tight. The lid being sawn through, the inside was cleaned up and the hinges fitted. Some men had four hinges on their chests, long ones, after the manner of a piano lid, and often you would see two or three locks. Both hinges and locks took skill, for if you cut too much you could not replace it, and a badly fitting lock or hinge was a mark to carry with you all your days. Then came the trays, and they had to be shaved so that when you dropped them into place they floated softly down on the imprisoned air, and old Thompson would mumble, "Not so dusty," and turn his ponderous body toward his own bench. I can see him now, reddish mutton chops and bristling moustache, standing with one hand on his trying plane, his spectacles on the end of his nose and he looking over them, as I exhibited my handiwork. He was an authentic part of England.

Things went easier for the apprentice once he had his box hinged and locked. It was now *to* be painted, and that was interesting to do. Inside, a dozen coats of shellac varnish, very thin, made a fine dry bed for tools. Outside, for some reason or other, black was universal. Lampblack and shellac varnish were applied as often as twenty times, and finally varnish alone, until the thing had the glossy, satiny feel of a piano. This was not only for decoration, for well-covered wood is stronger and takes a dint better than the naked timber. And then came the

joy of putting on the handles, which had to be of heavy brass, and if he had a friend in the machine shop, it was considered good form to get the castings rough from the foundry and have them finished close at hand.

There was a general feeling among the pattern-makers that they, the molders and the smiths, were superior to the other tradesmen, whose combined efforts built an engine, because, in a manner or speaking, "they had nothing but the drawing to work to." A fitter, a turner, a machinist—for in England they are so infernally logical that a machinist is a man who operates a machine—all had a forging, a casting, or some sort of stock from which to work. But a pattern-maker or a molder when "striking out" large molds that had no patterns, had to "read the drawing" and in no small degree was a draftsman himself. It was for this reason that apprentices like myself, who were destined to become professional engineers rather than journeymen mechanics, began with pattern-making. Moreover, it was a remarkably clean occupation and we had fastidious craftsmen in the shop. I have seen a man whose name was Harry, a tall middle-aged person from the north of England and wonderfully skilled at large built-up "plate" patterns, who would dart behind the band-saw half-a-dozen times in a morning to wash his hands in a bucket of warm water he had there and dry them in the rich yellow sawdust before rubbing olive oil over them and wiping them again, to make them what he called "soople." And a bench-mate I had for a while, a chunky little sportsman named Jack, invariably wore a nice derby hat ail day and had a fresh starched white shirt with wide cuffs that I never saw turned down, every day of his life. Here was a striking example of that peculiar individual liberty that can be found nowhere else save in

England. None of his mates queried Jack's right to do this if he could afford it, and his wife liked to get the shirts up for him, yet none of them would have dreamed of imitating him. That is what I call liberty.

It is necessary here to explain more clearly why a pattern-maker's work is so important, and the manner in which it differs from joinery and even cabinet-making. A pattern, then, is the wooden model which goes to the foundry to form the hole in the sand into which the metal is poured. Now it will be perfectly obvious that the pattern must be of sufficient size to leave metal enough for machining, it must be made so that it will not warp with damp, and above all it must be so designed that it will come out of the mold, or "draw," after the latter is made. Here comes the craft of the trade. The pattern-maker must decide, by an attentive consideration of the tracing sent to him from the office, how that casting should come out. And if he has decided, then he must make the pattern with a taper downward. If there is a rib or boss in the way, then that part must be made with screws that can be reached through the sand and so released; and then, when the main body of the pattern has been drawn out, these extensions can be picked out with clever fingers, and the mold set aside for black-washing with plumbago and making ready for pouring.

Now there is another thing that must be made clear, and that is the way a pattern-maker lays out his work. You would notice at once that he uses a rule different from the fourfold, three-foot thing that joiners and carpenters fancy. The pattern-maker's rule is of box, of course, since no other wood has the same nature and fitness, but it is straight and two inches wide by two feet long. And if you take it up and examine it you will find

every edge is scaled in a different way. The pattern-maker, indeed, has not one inch but four. He has the standard inch for comparison, he has a cast-iron inch, a brass inch, and one for cast steel. And the reason is this—that if a thing is to be of cast iron, let us say, the pattern for it must be made so much larger because cast iron contracts in cooling about a quarter of an inch in two feet. So he calls his rule a contraction rule, and the young apprentice soon learns to scan the scale before he uses it, remembering from what metal, iron or bronze, the casting will be made.

Now this was an education, because it brought out what was in you, and left you free from theories, which are the habit-forming drugs of the colleges and not good for the young. You could see, if you were wide awake, that the boss in his office might need those fine explanations with long words; but the clever journeyman had very little book learning, and his skill at his trade was something else—his brain and his hand and his eye all worked together. And sometimes I think it would be better if a man learned his trade before he learned to read and write. He would pay more attention to the feel of things under his hand, and his eye would see shapes instead of lines and—a long word—superficies.

I have said that this shop where I worked was a millwright's shop. This is a very ancient trade and much of it in my time was gearing. I speak of a time before electricity was much thought of. In the pattern shop and drawing office it is true we had electric lights, but danger from fires was great and electric motors gave trouble. They could not be depended on like a steam engine and shaft, driving leather belts. England in those days was a country of leather belts. The men wore them, great

broad plastrons to hold their girth together. They wore leather suspenders, and all harness was leather. And every machine was driven by a leather belt. I can remember the first motor-cars and can hear now the *click-slap click-slap* of the belt on the cone pulleys under the seat. We are held together by leather belts, and the familiar threat to a youngster who was cheeky was "a good belting" or perhaps "a good hiding" which carried with it the idea of leather and was sometimes changed to "tanning your hide for you." This was part of the education, and a very useful one, too, because it was founded upon tradition. When old Thompson looked for respect from me and the other apprentices he was not thinking so much of himself as of his position as a master mechanic, as the foreman, as the father of young Thompson who was at the next bench to me and another young Thompson in the brass-finishers' shop downstairs. And I maintain that a respect for authority is an essential part of education of the young, even if you have to tan their hides to make them understand it. If there is nothing in achievement and climbing to the top of your trade or profession, and you deserve no respect when you get there, then children may as well be taught to be bandits and hold-up men at the beginning. The men whom I remember with most affection today are those who understood authority and made me understand it too. Liberty is a very fine thing indeed, but a love of liberty can very easily become a love of laziness, and out of this union will be born impudence, which is the dry rot of character.

Of millwright's work, then, we had a plenty, and the best and finest work of all was the making of mortise teeth on the great cogwheels which were used for the transmission of power. Everybody now is familiar with

gears grinding and making a noise; imagine, then, the terrific clamor wheels ten or fifteen feet in diameter would have made had they been entirely of iron. So one wheel of each pair was provided with teeth of wood, and the making of these teeth, the fitting of them into their sockets and the shaping of them to mesh truly with their mates, was a craft, almost I said an art, since the doing of it afforded a deep pleasure to the artisan and was a part of human life and effort. Moreover, some men were "dabs" at it, as we used to say, while others never got the trick of it.

Hornbeam was the timber used and it came in great boards three inches thick and a couple of feet wide, of a dirty yellowish gray texture, and very heavy. When the wheel came in from the turnery and was mounted on a temporary mandrel, old Thompson would bend his body over the drawing and do some rough figuring on a smooth piece of pine.

The first thing to do was to find out how many teeth there were and the overall sizes. Then the jig was got out and made over to suit that size of tooth. A jig was a rough box so made that you could fit your block of hornbeam into it and by turning it different ways over the circular saw, cut to the shape you required. Once the jig was set you could produce as many teeth as you wished. The contrivance looked rude and clumsy, but it contained in itself the whole principle of repetition work and quantity production. The difference was we used no long words. We called it a jig.

This, however, was only the beginning of the story. When you had your teeth with their roots roughsawn, each one had to be fitted with plane and chisel into a particular hole. So you numbered the holes and the teeth

and made a separate job of each. This fitting was a craft in itself, because there must be neither shake nor bind in it. If there was any shake your tooth would be out in a week. If you had the tenon too tight, flogging home a block of hornbeam could split your iron wheel rim and make a waster of the whole job. So each tooth was done cannily and tapped in a little way while you went on to the next. No shake and no bind. "Cogs in a wheel" are looked down upon these days as of no account, but I can tell you it is fine work and good fitting to have them all the same, without shake or bind. Once well in, you can begin to ease them with oil. You dip each point, well chamfered, into a can of linseed oil and tap it a little harder. The oil keeps the fibers from splitting, and by the time you are ready to flog all home, the tenons are yellow and polished like old ivory. Hornbeam is a beautiful wood, white like new ivory when planed, and as hard. It is a proud moment for a wheelwright when he has all set to batter his teeth down until the hammer rebounds from the wood hard up against the iron; and perhaps the boss stops, on his way to the pattern loft, to admire the half-finished wheel, the rough, unshapen blocks of hornbeam standing up from the iron rim and the roots peeping from the inner side as regular as can be, all ready for the pinning. It is like a story, if you like, each block a chapter, and ended with a hammer blow.

Now comes the pinning. Close up under the rim the workman bores a quarter-inch hole longways through the root of the tooth, and the smith sends up a basket of pins, iron rods about six inches long and a tight fit to the holes. These pins are used only in case the timber dries up in a hot place, however, and loosens a cog by accident. It is soon done, and now comes the real craft of

all, the fine and finicky work of shaping the teeth so that the wheel will gear with its mate.

Now, I know well enough that the curves of a wheel tooth are determined nowadays by theory, and I could give you that theory if it would be of any help to you, with many long words like *epicycloid*, and *involute*, and so on. I could explain what we mean by the Rolling Circle and how it traces out the shape of the tooth in its path round the imaginary Pitch Circle. All very scientific. But what I want you to notice is this: that these fine explanations, like a professor's analysis of a story or a novel, come after the thing has been done. The wheelwright made his template and cut his wheel teeth to it for generations before the theory got into a book. He got it from his mates in the shop. This is not to say he had no hand in it himself, any more than a navigator should be thought to need nothing of his own because he uses the charts some dead naval officer made before he was born. The artisan makes his template and marks off his wheel according to rule of thumb, but he guides his gouge and chisel as he pares the flanks of the cogs by experience and something else which you can call knack, or intuition, if you like. You might even call it inspiration since it comes from his knowing in his mind what the teeth have to do. He sees in his subconscious mind the imaginary rolling circle of the two revolving and engaging wheels very much as a man writing a story sees the end and so on before he has got more than the beginning of it down in words. For a story is like a wheel, I should say, made up of pieces shaped and fitted, without shake or bind.

Here was a picture, then, that can be seen no longer, since electricity has made it useless, of old Thompson making a wheel, seated on a trestle close up against it,

his big portly person surrounded by white slivers and shavings as the long sharp chisel scuffed and scalloped at the clean white hornbeam teeth, paring down to the scratched lines on the ends. Day after day would he sit there, working at flank after flank, till all were done, three, four, or even five score of them on a big wheel. That was good work and it was an education to watch him and the men around him. It was something like the old-time guild where all the craftsmen were members of a brotherhood and their knowledge and chance to become skilled were common to all. What a man did with them after was nobody's affair.

Perhaps what I have said about crafts and craftsmen is not yet clear in its intention, and I must go back again to the picture of all those men and apprentices, with an improver or two, working in that pattern shop over the smithy. For I would not have you see it in your mind as a factory where the operatives stood over machines for *ten* hours every day and were forbidden to speak or "take a spell." Men need as much play as boys and have as much right to it. And the social life of that shop was a thing to remember, being a tiny democracy of artisans. Their lives were open to each other, yet sacred. Their houses were castles and an invisible dragon of decent consideration defended them. They had humor and wit, too, and the immortal spirit of Mr. Samuel Weller hovered benignly over them. The day was a ritual of labor and relaxation, and there was nothing in life more wonderful than the sudden change when the ancient sweeper, peering Puck-like through the murky windows of the shop and seeing the form of old Thompson safely across the girder shop, would call out, like some sergeant major, "Lay on 'em, me lads!"

Then would planes and chisels be dropped, tool chests dragged from beneath the benches, and a joyous spell ensue for a few minutes. There would be wrestling between youngsters catch-as-catch-can style, young Thompson, a red-headed giant, acting as referee. Excitement would grow; one of us would be down under a bench, his mouth and nose buried in shavings, trying desperately to keep his shoulders from touching the floor, when the old sweeper would put his hand to his ear and cry aloud, "Up guards and at 'em!"

And tool chests would disappear in a flurry, planes would be gripped, and when old Thompson came puffing through the door all hands would be hard at it.

On Saturdays, at noon, it was the custom, dating from very early days, to give over the hour to cleaning up. But we, who disbanded for the week-end at one o'clock, would do our tidying in a very short time and then we would go into the great clear template room, on whose blackened floor the girders and cantilevers were marked out in chalk, and we would have a match of wrestling on horseback. That is to say, we apprentices, who were young and light, would mount on the backs of the younger journeymen, like young Thompson, and we would ride at one another and strive to pull one another down. I reckon this good sport, as who will not who has tried it? It brought out all the generalship of which a man was capable, it exercised all the muscles lying flaccid during a day at the bench, and it inculcated a *camaraderie* that made for sound understanding of the workman's mind.

Sometimes, too, we boxed, and I know nothing more stimulating for a youth who imagines he is superior in mind or in birth, than a couple of rounds with a lithe and trained young Cockney from Hoxton or Camberwell who

will bang his royal highness on the jaw and send him to the floor with a pretty right hook to the stomach.

But again, lest you should become suspicious that we who worked in that pattern shop were no more than skylarking loafers—in which case I would scarcely remember those days with pleasure and delight—there were talk, and, if you will believe it, literary allusions. It was there, indeed, I began to understand how great a man was Charles Dickens, seeing he had gotten a strangle hold of the heartstrings of the common people. There, too, I learned what the music hall could be, and many were the nights I would go down to the old Paragon in the Mile End Road and lie back helpless and aching with laughter at the exquisite mimicry of the artists of those days. For all their art was a taking-off of the joys and sorrows of working-class life. There was Marie Lloyd—what an artist, for all her vulgarity, that bright, fat lady could be! There was George Robey, prince of his line, who could come on dressed as anything, from Prehistoric Man to King Charles the Second, and keep the audience in a vortex of hiccupping, heart-stopping laughter. There was Phil Ray, shrewd satirist of snobbery and a lynx-eyed wonder for catching his cue from words or expressions in his audience. There was Wilkie Bard with his almost mystical hold upon the emotions of his turbulent admirers.

And these nights were reflected in the days, and the humors of Dickens would blossom into comical asides from young Thompson, who knew Pickwick by heart and could have passed a creditable examination in all the works. There was much singing at the benches, and each man had his avowed favorite songs. An expected courtesy was that you joined in the choruses. And behind all this was the social instinct overpassing the boundaries of

birth and breeding, demanding that you fit into your place in the world, like a cog in a wheel, without shake or bind.

For artisan or artist, this was a training the best possible, since this world of the pattern-makers, above the boom of the blowers, and the clang of plates and beams being fashioned into bridges, and the skeletons of giant buildings, was a model of the world in which the artist must eventually find his level. Here he found the rudiments of his calling, character and discipline: character in the making and divested of the difficult problems of sex. Here he could see exactly how men, as well as machines, worked. He saw clearly the elements of design, how one part must ever bear a strict relation to others and to the whole, and how no pretty-pretty business about love could be a substitute for a knowledge of the characters of men. For an apprenticeship to a trade is nothing less than a true beginning of life and a training for it, and out of that will grow, if a man have any aptitude for letters, a desire to write.

All this, you must observe, is indirect and apparently without purpose, yet from the beginning of this essay my intention has been to show how best an artist may be made, which is by artisanship and knowing a trade and its tradesmen well. There is a notion very much liked today that an artist, and especially a writer, must be coddled when young, and "encouraged," or his ambition will die away. That is one error; and the other is, that to learn his trade a writer should be fed with theories as to "structure," and that he should learn of men's natures from books. To these contentions I cannot agree. I would rather argue that the writings of the young should be allowed to die of exposure and ridicule, as were my own for a number of years, and their spirits indurated by the

cold winds of contempt. The encouragement a young writer wants is mainly the inspiration of masterpieces, and when he learns a trade he can be forever bringing those masterpieces to the touchstone of reality. Better than any rumble-bumble of philosophy and theory is the ring of steel on an anvil, the clean finish of a finely made pattern. The pattern is a symbol of what he is to do in the future. For what a man writes is no more than a pattern fashioned in the workshop of his soul, and goes out thence to be cast and cunningly fashioned for the public eye. He must allow for shrinkage and the passage of time. He must make it so all parts fit truly yet will draw from the mold with ease and smoothness. Above all, he must take heed never to use words that have no meaning, any more than he would put fillets and headings on a pattern no workman in the foundry could understand, and he will use clean, dry scantling, keeping his tools very sharp, so that part fits into part as I have shown, and his work will hold together, year after year, without shake or bind.

## XII

# THE EYE<sup>1</sup>

HENDRIK VAN LOON

**Though** Hendrik Van Loon has lived in America most of his life, he has always been loyal in spirit to his native country, Holland. He graduated from Cornell University in 1905. The next year he was in Russia reporting the revolution as a representative of the Associated Press. He took his Ph.D. at the University of Munich in 1911 and then lectured on history and the history of art at various universities in the United States until the outbreak of the World War. Then he served again as a war correspondent until 1918, with an interlude as lecturer in modern history at Cornell. Since the War he has been writing or teaching or editing: he was professor of history at Antioch College, Ohio, for a year and later associate editor of the *Baltimore Daily Sun*. In addition to books concerning Dutch and early American history he has written two histories primarily for children, *The Story of Mankind* and *The Story of the Bible*. *Man the Miracle Maker*, from which the present essay is taken, narrates the story of men's progress considered as a "very simple process of multiplying to an almost unlimited degree the powers that lay dormant in their minds and feet and eyes."

We spend our lives on the bottom of a vast ocean of air which is so deep that no one has ever been able to reach the surface. During certain hours of every day the whole of this vast air-sea is exposed to the rays of the sun. When that happens we say that it is light and that we can see. For we happen to belong to a species of living beings which is provided with a sense of vision and in the front of our head we carry two curiously shaped

<sup>1</sup> Reprinted from *Man the Miracle Maker*, copyright 1928 by Horace Liveright, by permission of the author and special arrangement with the publisher.

instruments which allow us to "see." What exactly this business of "seeing" is, I do not know. And for the moment it interests me no more than the fact that the color red is produced by 392,000,000,000 impulses per second on the retina while violet demands double that amount, or 757,000,000,000 impulses per second.

Nor do I want to discuss the allegation of certain famous physicians that the human eye is one of the most awkward of nature's many clumsy devices and that almost any first-rate manufacturer of optical instruments would have been able to give us something infinitely better and more serviceable.

Such little bits of scientific gossip are interesting (if true), but they lie outside of the realm of the present volume and shall receive no further attention.

Behold, therefore, our earliest ancestor gazing into space and in a vague and none-too-certain way wondering what it is all about.

He knew, of course, what his eyes were for. They allowed him to observe those objects that were within a comparatively short distance of his eyes.

He must have realized that the "power of observation and discernment" was located in the two round balls situated on both sides of the opening by means of which he was able to smell the track of wild animals, and right above the slit through which he could fill himself with food and which enabled him to utter those cries of warning which in times of danger allowed him to communicate his own fears to his friends.

What this power of observation was, he probably knew no better than we do, half a million years later. But that it must be situated in those two round balls in the front of the head was certain, since the closing of the

eyelids made a temporary end to all "seeing" and since those whose faces had been clawed by a tiger or a bear were so completely helpless that they had to be killed lest they make a nuisance of themselves and endanger the safety of the rest of the tribe.

One other thing must have penetrated to his consciousness: those two little round balls right above his mouth and his nose lost all usefulness the moment the sun had disappeared beyond the distant horizon.

It seemed that certain other animals were able to see even when it was dark, but the species to which man belonged did not enjoy that advantage. Hence when the day came to an end, human beings were forced to retire to their nests or their caves or wherever they happened to sleep and there await the first rays of the next morning.

As soon, however, as it had been discovered that one could not only keep a fire going that had been taken from a burning bush, but also that one could make fire by artificial means, the night lost a good many of its terrors. Thereafter the human eye was able to fortify itself with a substitute for the light of day in the form of a torch. But the torch was not an ideal instrument of illumination. It was a very important invention, but it was only a beginning. One after another, all the different materials that were in the least inflammable were used for purposes of illumination, but very little progress was made until it was discovered that one could put some fibrous material in a bowl of oil or grease and keep it burning as long as the oil or the grease lasted.

In that way the "lampas" or "torch" of the Greeks became the lamp of the modern world.

The heroes of Homer still feasted by the flickering flames of torches. But four hundred years later the

**temples of the gods were made resplendent with the soft radiance of innumerable small oil lamps** and a century afterward the oil lamp had become an integral part of every well-appointed household; and far underneath the ground, miserable slaves, chained to the side of the mine walls, were hacking away at the coal and copper by the uncertain light of portable lamps made out of lead or iron.

For almost a thousand years smoky and smelly oil lamps were all we had for purposes of illumination. Then the lamp began to change its shape and slowly grew into the candle, which is really a lamp in which the oil has been discarded for tallow, but in which the wick has been retained as before.

During the twelfth century the artificial "glowers" found their way across the Alps and by the middle of the thirteenth century they had come into general use. And thereafter they maintained themselves as the exclusive auxiliaries for the eye-in-the-dark for several hundred years.

During this time many experiments were made with substitutes for the traditional tallow, but the only material that would serve the purpose was beeswax, and as beeswax was very expensive, these candles were never found outside of churches and palaces.

Even there they could dispel only a few square yards of darkness, and when the living conditions of the masses began to improve and more and more people desired to keep awake a few hours after their horses and cows, there arose a demand for a better way of fighting the discomforts of night.

The problem was finally solved by tapping that same reservoir of prehistoric energy which just then was begin-

ning to set the wheels of a million engines going, but in a somewhat different fashion. The existence of certain invisible substances which had neither volume nor shape was perfectly well known to the Greek physicists who lived twenty-five centuries ago. But they regarded them with grave suspicion, as mysterious forces capable of great harm and small good and did not inquire whether they could be used for any practical purposes.

To the alchemists of the Middle Ages, this *pneuma* or *aura* or *spiritus* or whatever they liked to call it came as a veritable blessing. The queer flames they produced were of great assistance in wheedling money out of recalcitrant customers, and one old sinner specialized so successfully in the manufacture of "emanations" that quite by accident he happened upon the substance which nowadays we know as carbon dioxide, but which impressed him so deeply that he favored it with a new and imposing name, derived from no lesser source than the Greek word "chaos" and called it "gas."

The name stuck, although van Helmont himself has long since been forgotten. Today, however, when we say "gas" we usually mean that particular gas which is distilled from coal and is used for illuminating purposes. The burning propensities of coal-gas had been noticed as long ago as the seventeenth century. But the man who was responsible for that invention was ahead of his time. Pigs' bladders filled with gas and used for trick lighting stunts remained part of the side-shows of country fairs, but the average man continued to be dreadfully afraid of the dangerous effluvium which was supposed to pour out of a crack of Hades and would not have it in his house, lest he be suffocated in his own bed.

During the wars of the French Revolution, when bal-

loons suddenly gained great military virtue, a Belgian physicist tried the experiment *of* filling the large paper bags with gas instead of hot air, and having manufactured more of the stuff than he needed for aeronautical purposes, he used the surplus to light up his own apartment. People looked at this effort to turn the night into day with distinct disapproval and it was not until well after the Napoleonic wars that coal-gas began to be used in a general way for the purpose of illuminating houses and public thoroughfares. Even then thousands of people were bitterly opposed to this innovation and they found cordial supporters among the ecclesiastical authorities.

These worthy divines offered a variety of reasons for their disapprobation of the new lighting system. As a rule they based their interdicts upon that chapter in Genesis which explains how God made both the day and the night. From this they concluded that all efforts to improve upon God's handiwork by giving the eye a chance to see with perfect clarity after sundown were blasphemous expressions *of* human arrogance.

But the most brilliant excuse for keeping the lamp-lighter off his streets was given by the ruler of the good city of Cologne, who declared that the use of gas was not only unchristian but also unpatriotic. For people, so he reasoned, who lived in gas-lit towns would no longer be impressed by festive illuminations, and festive illuminations were an everlasting source of inspiration for an exalted form of patriotism and respect for the reigning dynasty.

Today all this sounds quite absurd. Gas as a substitute for the light of day has been adopted by all the world. It reigned supreme until some one invented a way of changing coal into electric energy. Since then a

single citizen, bright enough to throw a couple of switches, can light up an entire city.

At last the human eye had been set free from the curse of darkness. And people did what they will always do when they are suddenly given a great deal of liberty. They began to abuse their new freedom in a scandalous fashion. Eyes that had been given them that they might be used for seven or eight hours of the day were forced to read all through the night. The poor things could not stand the strain and soon began to show signs of wear and tear. It was necessary to reinforce them for those who were obliged to read or write for the greater part of every twenty-four hours. The difficulty was solved by the introduction of "spectacles" or "glasses."

Roger Bacon is usually named as their inventor. He may have been or not. We don't know. Bacon was one of the few independent minds of the thirteenth century, and as such got blamed for almost everything new that appeared above the horizon between the years 1214 and 1294. And anyway for a long time glasses were of very little practical use, as they were regarded primarily as a luxury and not as a necessity and therefore were a hindrance quite as often as a help. Yet thousands of people used them. For there is in every one of us a streak of vanity. During a period when ninety-five per cent of all the people could neither read nor write, it was quite a swanky thing to embellish one's nose with glasses. They proclaimed to the poor devils who were too poor to buy them: "Behold! I have spent so much time upon my studies that my eyesight has suffered from too close application to learning."

This widespread snobbishness caused an equally widespread prejudice against glasses and it lasted until very

recently. The substitute eyes made out of polished crystal were derided as an affectation unworthy of real men. As Heinrich Heine discovered when he called upon the oracle of Weimar and was told that he could not appear within the presence of the great and glorious Goethe without first removing his specs.

And now to more serious business, for we have not yet mentioned the very important efforts that have been made by man to multiply his power of vision in such a way that he should be able to cast his glance into the most hidden and inaccessible secrets of nature.

Electricity gave him opportunity to devise a long-distance eye called a searchlight, which permitted him to examine the sea or the air during the night as well as during the day. But searchlights are too intimately connected with warfare to be of any special use in time of peace.<sup>2</sup> There are two other varieties of the multiplied eye which are of much greater usefulness.

There are the heavens. Man, a humble prisoner on a small planet, has always been profoundly curious about the objects that surrounded his own domicile.

But in the beginning the eyes were all he had with which to study the stars. To judge by their achievements as astronomers, the Babylonians and the Egyptians and the Greeks seem either to have enjoyed excellent eyesight, or to have been possessed of a highly developed sense of observation. What they saw, they saw correctly, but their range of vision was necessarily limited. For they were obliged to rely upon the human eye unassisted by any of those artificial multiplications of the power of vision which are today at our disposal.

<sup>2</sup> The extended use of searchlights is very recent—*Editors*.

The learned Roger Bacon not only seems to have discovered our spectacles; he also described a method by which one could construct a "far-seer" or telescope. Whether he ever made such an instrument for his own amusement is uncertain. He was a busy man, and during the many years he was not allowed to put pen to paper he was as a rule much too poor to indulge in expensive optical experiments.

Anyway, nothing was done about the telescope until four hundred years after his death. Then the fury of the Reformation had at last spent itself and for a short while people could indulge their desire for scientific speculations. At the same time little ships were beginning to sail across every inlet and bay of the Seven Seas and their mariners were in great need of an instrument that should allow them to see-at-a-distance. Small wonder, therefore, that the telescope was invented by inhabitants of the Low Countries, where navigation had been elevated to the rank of a fine art.

From Holland telescopes were exported to every part of Europe. One of them fell into the hands of Galileo and the purpose for which he used it justified the decree of the general of the Franciscans when he had forbidden Roger Bacon to continue his dangerous studies in the realm of applied physics. For Galileo, with a far-seer of his own fabrication (a childish enough instrument when we compare it to one of our modern telescopes), enlarged the dome of heaven by so many thousands of miles that all the old notions about the importance of the Earth and its sister-planets and its fiery little Sun were completely upset, and that the whole of the universe came in for a thorough house-cleaning.

Rather than revise the comfortable opinion which they

had held since the Year One, the majority of the people preferred to call Galileo and his fellow astronomers dangerous radicals and perfidious fellows who should be prevented from teaching their outrageous doctrines to the younger generation.

In the end, as always, man's divine curiosity triumphed. He continued to increase his range of vision until today with the help of gigantic telescopes he is at last beginning to get a faint idea, not of where he is but at least of whither he is going.

Now while certain people were devoting themselves to the problem of seeing extensively, others were trying to discover a way of seeing intensively. For as soon as it had become clear that there was a world which existed outside of our range of observation, because it was situated so far away that it could not possibly be sensed by the naked eye, it was suspected that there might also be a world composed of creatures so infinitely small that they could not possibly be noticed without the assistance of a differently multiplied power of vision.

The Greeks were the first to have suspicions in this general direction. Without lenses of the proper sort, those suspicions could not be evaluated into actual knowledge.

The most the ancients could do to magnify the human eye was to look at an object through a hollow sphere filled with water, and that was little enough.

But once lenses had been invented, people were on the right track. Four hundred years were spent in making experiments and then, during the first half of the seventeenth century, some one in Holland by the name of van Leeuwenhoek combined a few lenses in such a way

that at last the human eye was able to detect the little organisms whose existence had been predicted thousands of years before.

The new instrument was aptly called a microscope or a "small-seer." The first microscopes were painfully primitive but they were rapidly improved, and half a century ago we at last made the acquaintance of some of our worst enemies—the microbes. Not all of them, for even after the introduction of the most powerful microscopes, several of the tribe have managed to keep themselves hidden from our gaze.

In a world in which we have learned to look "through" people with the help of Professor Roentgen's extraordinary invention, almost anything seems possible and most of the problems of existence become reduced to two simple words: "Courage!" and "Patience." . . .

# XIII

## EDITORIALS <sup>1</sup>

### STONE & WEBSTER JOURNAL

These editorials from the Stone & Webster Journal are fairly representative of the spirit of a vast amount of contemporary writing for which great industries are primarily responsible. Technical journals and trade magazines and even catalogs are attaining a standard of literary excellence that deserves much wider recognition.

The Stone & Webster Journal owes its existence to Charles A. Stone and Edwin S. Webster, founders in 1889 of the great firm of Stone & Webster, Inc., now devoted to designing, constructing, operating, reporting on, and financing industrial and public utility properties throughout the country. Both Mr. Stone and Mr. Webster graduated from the Massachusetts Institute of Technology in 1888, and have devoted themselves since then largely to the management of the business of the firm. Both men are directors of numerous corporations. But they are more than mere technicians or executives; they are men *of* wide interests and broad culture. Business for them, as for so many leaders in modern industry, is something more than a means for amassing fortunes; it is a means for the building of a worthy civilization. Their ideals are well embodied in the Journal of their organization.

### ON BEING A CRANK <sup>2</sup>

In a recent letter to the editor a correspondent writes, "Unfortunately most of us if we have a hobby get called cranks; only a few are even able to command the more respectful term eccentric." The interesting thing about this sentence is the use of the word "unfortunately." Is

<sup>1</sup> Reprinted by permission of the editor of the Stone & Webster Journal.

<sup>2</sup> Stone & Webster Journal for February, 1929.

it so unfortunate to be considered somewhat different from one's fellows? Usually the "crank," even if a person of one idea, dares to be himself and has an opinion of his own to express. He does not have to wait for the morning paper to tell him what he thinks of a new play, and he will tell you at once how he likes the book he has been reading without waiting to hear what his friend is saying about it. In other words, he is not one of a herd following the leader, but a person who thinks for himself. As such he is interesting, no matter how mistaken we may consider him.

A striking example of the herd instinct in all sorts and conditions of people was forced on our attention the other day at a concert of the Boston Symphony Orchestra. The program contained a symphony by a modern composer of some note, built up on themes taken from Indian melodies and negro spirituals, designed to express the spirit of America. At the end these themes were gathered into a song, sung by the orchestra, augmented by a chorus of men and women, and called by the composer "America." He expressed the hope in the program book that all audiences that heard it would stand and even sing with the chorus. Apparently the suggestion was enough; almost every person in the hall rose to his feet with the chorus, although there was really nothing inspiring in the music and absolutely no reason for them to do so, except the fact that their neighbors were standing. The few people who sat calmly in their seats and suspended judgment until they heard the whole were no doubt considered eccentric by the majority of the audience.

Indeed, history is hardly more than a biography of cranks. Galileo, Columbus, Newton, Darwin, Pasteur, to take names at random, were all laughed at for going

their separate ways. Even those aggravating people in every town meeting who refuse to agree with any majority are usually worth noting because their opinion is their own, and they know why they hold it. Sometimes they do keep the rest of us from making fools of ourselves. The Chinese seem eccentric to Western nations, because they like leisurely amusements, and can spend any amount of time just drinking tea and admiring the landscape or an old print. To them enough is as good as a feast and there is no point in working hard to achieve two beds when one is all you can sleep in.

Present day novelists are often blamed because their characters are so standardized. One has rather ingeniously defended himself on the plea that all people all over the world now look so much alike, and think so much alike that the writer, if he describes life as he sees it, is bound to be equally monotonous. We once knew a dreadfully eccentric little boy who would never do anything until he understood the reason why. When he did understand he was perfectly cheerful about complying with the wishes of his elders, but explanation is not always convenient, and sometimes it is disconcerting to find that there really isn't any rational explanation of the things we all do because it is customary.

Of course the worst of being a crank is that the life is rather lonely and apt to be expensive, too. It is a good deal easier to admire a crank than to be one. That is the reason that we do not say whether we rose or sat in our seat at the Symphony concert.

"THE FEET OF THE YOUNG MEN" <sup>3</sup>

We are living in the Age of Steel. Today we hardly recognize this. Except for a few office buildings and hotels in the large cities, the outward aspect of life is not so greatly changed as yet. But tomorrow we shall awaken to the fact, and it bids fair to revolutionize life for all of us. Already the architects and builders are learning to mold steel and concrete into structures of enduring beauty. We have only to compare the earlier rectilinear buildings of many stories put up a few years ago with the Barclay-Vesey telephone building in New York, the Cathedral of Learning in Pittsburgh, the Shelton Hotel in Chicago, the Church of Notre Dame de Raincy in France, to realize the new mastery of the architects and the fitness of steel and concrete to express in forms of beauty as well as utility the needs and the spirit of the present. There is nothing mannered or ephemeral in this new type. The Cathedral of Learning has its roots in the Gothic of our ancestors as surely as any beautiful chapel on any college quadrangle. But one is a dream of the future, and the other is a worship of the past. We are fast learning that an imitation flame on the end of a candlestick is neither an artistic nor an effective way to employ electricity; congestion in our cities has enforced a new type of architecture but we still cling to the stereotyped living-room—sun-porch—dining-room style of house, and we copy faithfully the furniture of our ancestors if we do not happen to possess the originals.

Our children will not do this. They are already trying out new ways in music, in painting, in decoration, as well as in architecture. They are going to demand a

<sup>3</sup> Stone & Webster Journal for April, 1929.

world in which everything suggests the fitness and clean economy of means seen in the automobile and the airplane. They will look for beauty in color and line rather than in external decoration. The ensemble idea is likely to dominate everything, and every detail that does not contribute to the ensemble will go into the discard. Some of us are going to feel decidedly uncomfortable when we wake up suddenly in this new world if we have made no attempt to understand it. As yet, it is still chaotic, and has not found itself save perhaps in special types of architecture. But these types are significant, and will well repay study.

In his latest play Eugene O'Neill causes his hero to search for God in the dynamo of a power-plant. He does not find Him there, but the search is significant of the direction in which the feet of our young men are turning.

#### COVERED BRIDGES<sup>4</sup>

The covered bridge seems fast disappearing from our New England landscape. A New York newspaper says that some one should write their history, and a New England paper retorts that such a historian would have to be "a country born poet, neurologist, Freudian architect—a man who, re-living his covered bridge days, can revise his old impressions of sounds, sights, smells, and fears."

All this reminded us of one characteristic of the covered bridge usually known only to children so that the historian would have to be child as well as all the other things. And we remembered that in the editorial files, which, like others of their kind, contain all sorts of unexpected information sure to be useful if one waits long

<sup>4</sup> Stone & Webster Journal for April, 1929.

enough, was a little picture of one of these bridges written by one who is neither a poet nor a child but who, nevertheless, is a little bit of each and quite preeminently fitted to write the history of the covered bridge. The picture is called

#### SAILING BRIDGES

Every night I walk home across one of the covered wooden bridges that still span the Housatonic River. This bridge is some 200 feet long and is lighted by four squares, cut out of the boards on either side at a convenient height to frame in bits of landscape for one to see as one walks by.

For the last two weeks a small boy has been at the second window on the down *side* of the river every night, leaning far out and gazing out over the river with rapt intentness, oblivious to any passer-by. Ordinarily he is still dirty and dusty from play. Sometimes if I am very late he is cleaned up for supper. But his face, so far as I can see it, and the pose of his head show him to be far away from this world living in the misty reaches of the imagination.

The pictures that I see through those windows as I go by are very lovely. But this small boy is not one I should suspect of being embryo artist or poet and likely to be rapt in the beauties of the scenery. Something more than that is fascinating him.

Today I came over the bridge at noon when small boys are at school and other folks are at dinner. So I stopped by the second window and leaned out to see what I could discover beyond the rushing steel-blue water, the brown fields near at hand, and the feathery green willows down the banks. I gazed down the river, marked the play of colors in the fields and woods on either side, admired the hemlock-covered hill that shut *in* the valley at the river's bend, marveled at the slope of Long Mountain, painted with the mingled tints of birch and poplar and soft maple, pricked out with spots of evergreen.

Then I looked down at the water rushing underneath, looked at it steadily for a moment, and then the bridge suddenly picked up its moorings and started upstream. The pointed stone pier *of*

the bridge was the stern which left the white streak of the rapids as a wake of foam. The banks on either side were a moving blur. If I looked at them closely they seemed to move with me. But if I saw them just out of the corner of my eye they might have been standing still while I swept by them up the mighty current of a South American river. I screwed up my eyes to get the best effect and I stood there savoring the oddity of the situation as enraptured as any small boy.

Quite by chance I have discovered what calls my small friend to the bridge window. Is it by chance that he will some day lift his eyes from the swirling waters and see the landscapes I admire now *in my* (to him) venerable old age?

#### DIFFERENCE IN ATTITUDE <sup>5</sup>

Among all the other defects of the American people some one has discovered that we have no critical faculty. Two Frenchmen, even humbly born, can discuss a book together and arrive at an intelligent estimate of its merit. Two Italian fruit vendors will know why they like one piece *of* music and dislike another. The foreign born in our midst flock to art museums and seem to enjoy them. But these things are only ways of passing the time to the native American, and one is as good a means as another of filling a gap between the closing of the stock market and the hour to get out the car for the week-end trip.

There is a good deal of truth in these statements, although as far as museums are concerned the foreign born are probably using them only as a stop gap, until such time as they also can take to the road in their own car. For there are still a few people in this broad land without automobiles, in spite of the slogans of the dealers and the American standard of living.

But to the average American, art is still more or less

<sup>5</sup> Stone & Webster Journal for May, 1929.

of a decoration, a grace added after everything else has been provided, not an integral part, and that the most essential, of the structure of living. For this reason, if for no other, it is difficult for the new world and old really to understand each other. It is not that the European has any greater capacity for enjoying music, or painting, or literature, but his attitude toward their place in the scheme of things is wholly different. What Michelangelo says about his own art expresses their feeling about all art:

I sometimes think and imagine that I can find among men but one art or science, that of drawing or painting, from which all the rest branch out. For *if* one considers well all that is done in this life, one will find that every man unconsciously is engaged in painting this world, both in creating new forms and figures, *in* dressing variously, *in* building and filling spaces with structures and houses, *in* cultivating fields and plowing the land into sketches and pictures, *in* sailing over the sea, *in* fighting and ordering an armed host, and finally in deaths and funerals, and all other movements and occasions. So that all human actions, if they are considered with understanding, will without doubt be found to be either painting or some part of painting.

We have still a long way to travel in this country before we complete the cycle and come back to Michelangelo's fashion of regarding life itself as an art.

#### SWITCHING OFF ELOQUENCE<sup>6</sup>

Extensions in the use of electricity are becoming so numerous that presently there are few acts of life that we shall perform without its aid. On the stage we are using it to give a third dimension to flat surfaces. In

<sup>6</sup> Stone & Webster Journal for July, 1929.

**Italy** it is bestowing a new lease on life on **the Vatican Library** by keeping the books from becoming damp. The French, however, with their usual flair for effect, have found the latest and most novel method of using the push button. The President of the French Chamber of Deputies has found that the usual means of curbing long-winded speakers by verbal requests or by passing small slips of paper are not very effective, so he has consulted the engineering experts. The result is an electrical machine designed especially for the shortening of speeches. Now, when the chairman wishes to warn a speaker that his time is almost up, all he has to do is to press a button and immediately brilliantly illuminated placards, carrying the words "Five Minutes" appear to right and left of the orator, impossible to be ignored. Five minutes more and the word "Finish" flashes out. If the debate waxes too eager and the speakers ignore both signs, the President presses still a third button and plunges the Chamber in total darkness. This last method seems a little doubtful to us. It is just as easy, in fact easier, to talk in the dark and very much more difficult for the auditors to escape if they are bored. We should think that an electrical robot who would automatically clap a gag over the mouth of the recalcitrant speaker would be more effective.

E. V. Lucas, in one of his airy causeries on nothing in particular, visited a strange land where all the public speakers sat down abruptly the moment they had delivered their point. The court of this country, it seemed, had employed a dwarf who quietly and unostentatiously passed behind the speakers, and when he considered that they had gone on long enough, twitched their coat tails and caused them to sit down. His title was "The Lord

Low Twitcher," and he was one of the most respected and popular members of the court

At all events, this is an interesting extension of the services of the electrical engineer, and in the hands of a discreet statesman probably does not savor so much of opera bouffe as appears in cold print.

#### NEW STANDARDS<sup>7</sup>

The time has passed when a spade may be called a spade and nothing else. Something more than mere efficiency is demanded of nearly everything we make today, whether it is an automobile or a stew pan. . . . Whatever the cause, one has only to watch current advertising, to say nothing of the things advertised, to be convinced that neither the largest power-house nor the humblest one-car garage can safely ignore this increasing demand for outward graces as well as innate usefulness. Of course, we all know that beauty is not a mere outward grace, that it must inhere in the structural design and reveal itself in perfect adaptation to use, but manufacturers as well as architects are learning this lesson every day.

Only yesterday, we heard a visitor in the art room of a well-known library ask the attendant where he could find some account of the influence which the modern study of cubes, triangles, and blocked masses had exercised on such manufactured products as automobiles. One could not imagine a similar question asked in such a place twenty, or even ten years ago.

One Sunday we were invited into a new, small factory, designed to turn out several types of a single machine. It

<sup>7</sup> Stone & Webster Journal for November, 1929.

was a truly beautiful place, from its well appointed offices, its admirable drafting room, its perfectly kept stock, to the workroom where machines in all stages of construction waited for the turn of the electric buttons next morning. The place was an example of perfect adaptation and the elimination of everything extraneous to its purpose. It suggested fleetness and grace, as truly as a race horse or a yacht.

It is true that immediately outside this factory the eye was greeted with all sorts and conditions of ugliness, but this only emphasized the fact that, after many generations, we are again becoming beauty-conscious, to use the slang of the moment. One has only to compare the towering office building of today with the skyscraper of ten years ago to realize the change. Those who always fear the future will see only the grotesque mistakes made in this new quest for beauty, but the rest of us will hope that it presages the real dawning of the twentieth century.

#### THE SOCIAL SIGNIFICANCE OF ENGINEERING<sup>8</sup>

In his address last June, as President of the Society for the Promotion of Engineering Education, Dexter S. Kimball, Dean of the College of Engineering of Cornell University, made some very interesting remarks concerning the economic and social significance of engineering. Since man for centuries has been denied most of the comforts of life, his philosophy has been based on the hope that he might enjoy some of them in another world.

It remained for a comparatively small group of humble engineers to change all this viewpoint. Suddenly out of a clear sky there came the Industrial Revolution, changing all of our ideas of

<sup>8</sup> Stone & Webster Journal for November, 1929.

production, opening up a vista of hope, and promise hitherto denied to humanity. Just exactly what this means as yet we do not know, but it—the Industrial Revolution—has opened up a hope that had never been thought of or dreamt of up to that time. Truly, as Bertrand Russell has said, if there have been poverty and want since the Industrial Revolution it has been because of ignorance and selfishness. I do not need to tell you the results of the Industrial Revolution. You are aware of them as well as I. It may be sufficient to say that at this present moment, for the first time, we are producing more than we can use. That condition is new in the history of civilization. The problems before Congress today are not those of finding enough to go round, but finding out, if they can, what to do with the surplus that we have. We grow more food than we can eat, and if we should turn all of our productive machinery to the task of producing the necessities of life, we would not know what to do with it all, so changed is the situation. For the first time we are within striking distance of the abolition of poverty and want.

The census of 1850 gives the per capita wealth of this country as \$383; the last preliminary census, in fact every census, shows that this has stepped up every year through good years and through bad years, through good times and through bad times, until the per capita wealth of this country has risen to about \$4000. The preliminary estimate of the census last year indicates that we are worth *in* this country over \$400,000,000,000, and the national income last year was \$90,000,000,000. No people have ever talked about such sums of money; no people have ever possessed such sums of money at such a rapid rate. Nothing like it has ever been known since time began. Not only that, but this wealth is more widely distributed than ever known before.

Of course such a startling change has not taken place without difficult adjustments, and storms of criticism, but the adjustments are being made, and we shall find that people are capable of a development that will keep pace with the changes. But

more important than any of these material things that have come to us is the idea of progress. The theologians and all the phi-

losophy of the last century taught us, and I was *so* taught and many of you were so taught, that the age of wisdom lay back of us; that back of us somewhere was a Utopian time, ancient Greece possibly or some other time when all men were wise and happy, and we should mend our ways and increase our wisdom by studying these old and reliable men who are long since gone; that there could not be anybody as wise as the ancients were. Now we know that *in* engineering and *in* science that is not so. We are looking forward and not backward. The idea of progress has become firmly embedded in our minds. We expect to go forward and we expect to make progress. Already that viewpoint is taking hold in many fields besides engineering.

As a symbol of man's dreams, which the engineer may yet turn into living realities, Dean Kimball quotes these lines from the Pied Piper:

For he led us he said to a glorious land  
Joining the town and close at hand,  
Where waters gushed and fruit trees grew  
And flowers put forth a fairer hue  
And everything was strange and new.  
The sparrows were brighter than peacocks here  
And their dogs outran our fallow deer  
And honey bees had lost their stings  
And horses were born with eagle's wings.

# XIV

## PRACTICAL PURPOSE <sup>1</sup>

SIR RICHARD GREGORY

In honor of his achievements as scientist, educator, author, and editor, Sir Richard Gregory was made a knight in 1919. After attending the Royal College of Science, he became Science Demonstrator in H. M. Dockyard School, Plymouth, then Computer to the Solar Physics Committee and an Oxford University Extension lecturer. He has been assistant editor and editor of *Nature* since 1893. He is a fellow of several learned British societies, Emeritus Professor of Astronomy, Queen's College, and has been president or secretary or member of council of many of the great scientific and educational organizations of Great Britain. In addition to several textbooks on physical geography, physics, and chemistry and a revision of Huxley's *Physiography*, he is the author of *The Vault of Heaven* and *Discovery, or The Spirit and Service of Science*, from which the present chapter is quoted.

Purpose directs energy, and purpose makes energy.—*C. H. Parkhurst.*

A life without a purpose is a languid, drifting thing.—*Marcus Aurelius.*

Still o'er the earth hastes opportunity  
Seeking the hardy soul that seeks for her.  
—*J. R. Lowell.*

The Time is great  
(What times are little? To the sentinel  
That hour is regal when he mounts on guard.)  
—*George Eliot.*

<sup>1</sup> Reprinted from *Discovery, or The Spirit and Service of Science* (1923), by permission of the author and of The Macmillan Company.

There are two distinct classes of men: first, those who work at enlarging the boundaries of knowledge, and secondly, those who apply that knowledge to useful ends.—*Prof. R. W. von Bunsen.*

Scientific investigations carried on with the single motive of acquiring new knowledge often lead, as we have seen, to results of great practical value. Such applications are, however, only incidental, and in the world of science they provide no test of the importance of the work done. The practical man judges scientific research from the point of view of its direct service to humanity, or that of money-making capacity; and he considers that people who devote their lives to studies having neither of these profitable objects in mind are wasting their time and abusing their intellectual faculties.

It comes as a surprise to most men to be told that in scientific circles usefulness is never adopted as the standard of value; and that even if not a single practical result is reached by an investigation, the work is worth doing if it enlarges knowledge or increases our outlook upon the universe. This proposition, of course, leaves the practical man cold; yet it is all that science desires to offer in justification of its activities. While the discovery of truth remains its single aim, science is free to pursue inquiries in whatever direction it pleases; but when it permits itself to be dominated by the spirit of productive application it becomes merely the galley-slave of short-sighted commerce. Almost all the investigations upon which modern industry has been built would have been crushed at the outset if immediate practical value had determined what work should be undertaken. Science brings back new seeds from the regions it explores, and they seem to be nothing but trivial curiosities to the people

who look for profit from research; yet from these seeds come the mighty trees under which civilized man has his tent, while from the fruit he gains comfort and riches.

Industrial research is concerned not with the discovery of truth but with the production of something which will be of direct service to man and from which pecuniary profit may be secured. It is the province of the inventor rather than that of the man of science. Such research and that carried on with no ulterior motive are complementary to one another. Science has done its part when it has made a new discovery; constructive engineering renders good service when it shows how the discovery may be chained to the chariot of industrial advance. To foresee the possibilities of a discovery, to transform a laboratory experiment into the mechanical plant of a large works, or to apply it to the needs of ordinary life require aptitudes not commonly possessed by the scientific investigator. The engineer usually has such practical purposes in mind; discoveries are to him things to be used and not ends in themselves, as they are to the man of science. He seeks not so much to know Nature as to circumvent her; and the research which he undertakes or organizes has for its object the artificial preparation of substances which are naturally rare, the production of a new process or the improvement of an old, the design of machines which will increase his power over her, and of instruments which will enable him to laugh at limitations of time and space.

Research is necessary for these advances, but the spirit in which it is carried on is essentially different from that of the scientific worker. The engineer or the inventor first of all perceives a need and then endeavors to devise a means of meeting it. If he is of a scientific type

of mind he will make an accurate analysis of the conditions to be fulfilled, and then design his machine or instrument to fulfill them ; but the usual way is to find practically what will perform the required functions, and to leave experience or scientific knowledge to indicate how improvements may be effected.

The two methods may be illustrated by the discovery of the safety-lamp for miners. With no access to scientific works, or intercourse with scientific men, George Stephenson constructed a safety-lamp which, like Davy's, depended upon the principle that the flame would not pass through tubes of small diameter and ignite explosive gases outside. Stephenson first made a lamp with a long chimney and a tube at the bottom to admit air for the flame. As this was found to give an unsteady flame, he corrected the defect by using several tubes of reduced diameter instead of a single tube, to supply the air. This lamp was found to burn better than the first lamp, and was used with safety in a dangerous mine early in November, 1815. A few weeks later he had a third lamp constructed in which small holes in metal plates took the place of the tubes, but in this device he was forestalled by Davy, who presented to the public on November 9, 1815, his safety-lamp having wire gauze surrounding the flame.

It is not our intention, however, to revive the angry controversy which arose over the respective claims of Stephenson and Davy as the discoverer of the miner's safety-lamp; all we wish to do is to use the invention to illustrate the different methods by which the same end may be reached. Stephenson made a lamp and then proceeded to test and perfect it; Davy, when he took up the problem of the cause and possible prevention of explosions in mines, first inquired into the nature of the explo-

sive gases and of flame, and was soon able to announce his discovery "that explosive mixtures of mine-damp will not pass through small apertures or tubes; and that if a lamp or lanthorn be made airtight at the sides, and furnished with apertures to admit the air, it will not communicate flame to the outward atmosphere." Davy discovered a principle and then constructed a lamp based upon it. Stephenson made a lamp and was led by it to a principle. Though there may be differences of opinion as to who was the inventor of the safety-lamp, the establishment of the principle of its construction was undoubtedly discovered by Davy, and was a notable advance of scientific knowledge. It was, however, left to practical men to devise the improvements which removed some of the defects of the lamp in its original form, and made it an efficient protection against the dangers of fire-damp in mines.

The combination of mechanical ingenuity with scientific genius is rare; two men in whom it was notably manifest were James Watt and Lord Kelvin. . . .

Thomas A. Edison is the embodiment of the method of specialized research with a practical purpose. By quickness of perception, fertility of resource, and persistent trial of everything until the best means of achieving his end has been found, he has become the leading inventor in the world. When he was endeavoring to find the best material to use for the filament of the incandescent electric lamp, he dispatched agents to search through China and Japan, to explore the American continent from the Atlantic to the Pacific, and to seek in India, Ceylon, and the neighboring countries for a vegetable fiber which could be carbonized most efficiently; and he finally used a strip of carbonized bamboo for the filament. He invented the phonograph in 1877, and from

the rough instrument then devised developed the perfect means of recording and reproducing sound represented in the many forms of talking machines. He constructed new forms of telephone transmitter and receiver, and from his fertile brain have come a system of multiple telegraphy, new methods of treating ores, and many other agents for the service and pleasure of man.

The phonograph and the kinematograph are, perhaps, the greatest of Mr. Edison's achievements, both in a scientific and in a popular sense. He was not the first to photograph and combine a series of moving pictures, but he was the inventor of the instrument by which this is now accomplished. So long ago as 1870, Dr. E. J. Marey in France, and a little later Mr. E. Muybridge in the United States, began the analysis of animal movements by means of photographs taken at very short intervals. A few years afterward, Mr. Muybridge arranged successive pictures on glass disks, and by rotating them in front of an optical lantern he was able to produce the visual impression of motion.

The invention of the celluloid ribbon enabled pictures to be taken on a continuous strip of film, instead of being arranged on a glass disk, and after careful attention Mr. Edison succeeded in doing this in 1893. The modern kinematograph pictures may be said to date from this development of the work of Marey and Muybridge.

In his first fantastic romance, Mr. H. G. Wells created a time-machine by means of which time could be accelerated or retarded, and a journey could thus be made into the past or the future. The kinematograph is a veritable time-machine, so far as the past is concerned. It can show the life of an insect or the life of a man in a period which is but a fraction of the true duration,

and the period of projection may be the same in each case. If the insect is imagined to be endowed with a mind, its life, though but a day, will seem as long as the three score years and ten of man, for the ultimate conception of time is in terms of duration of life. A thousand years may be but an hour to the time-machine which Mr. Edison has produced to delight and instruct the modern world.

To the engineer the fascination of experimental research lies, as Cap'n Cuttle would observe, "in the application thereof." He seeks to know; not from the pleasure to be derived from the acquisition of knowledge, but in order to bring that knowledge to bear upon everyday problems of life, labor, and economy. It must not be supposed that this spirit is necessarily foreign to the man of science. Robert Boyle, one of the most active originators of the Royal Society, refers particularly to practical use of the researches undertaken by himself and other pioneers of the experimental method of investigation in England. Writing in 1646, he alludes to his studies in "natural philosophy, the mechanics, and husbandry, according to the principles of our new philosophical college that values no knowledge, but as it hath a tendency to use."

A Chinese proverb states that he who holds the iron of the world will rule the world. This, however, is only a half truth; for China itself has probably as large deposits of iron ore as any part of the world, but it has not the scientific knowledge required to make the best use of them. The talents which that country possesses have been buried in the ground instead of being used to gain other talents. The masters of the world of iron must be those who understand best the properties of the metal,

whether now or in the future. As the result of a systematic study of the effects of adding to iron a special element other than carbon, Sir Robert Hadfield produced his famous manganese-steel, which is used extensively for all purposes where toughness as well as hardness is required, whether for arts of peace or purposes of war. Ten years' persistent research upon the influence which different percentages of manganese exert upon the properties of steel were required before that remarkable metal, manganese-steel, was discovered, and showed the way to the production of dozens of other alloys possessing qualities required in arts and industries.

It is much easier to accept things as they are than it is to inquire into them and decide whether they are capable of improvement. Throughout the world's history, progress has been accomplished by the men who were not content to do as their forefathers did, but were continually asking, "Why?", "Wherefore?", "Is that the best way?", "Is this the best possible thing?". Lord Kelvin [Sir William Thomson] was a brilliant example of this type of scientific mind, ever critical of defects, alert as to practical needs, and fertile with possible improvements. His views as to the practical value of science were definite and unmistakable :

The life and soul of science is its practical application; and just as the great advances in mathematics have been made through the desire of discovering the solution of problems which were of a highly practical kind in mathematical science, so in physical science many of the greatest advances that have been made from the beginning of the world to the present time have been made *in the earnest desire to turn the knowledge of the properties of matter to some purpose useful to mankind.*

When Lord Kelvin turned his attention to the mariner's compass, about 1870, that instrument had been in

use in much the same form by European navigators for about six hundred years, and by the Chinese long before. The compass in the simple form in which it was used for many centuries was in many respects unsatisfactory. In the Navy it was found to be useless during gun-fire, and to be affected so much by the rolling of the ships during stormy weather that little dependence could be placed upon it. These defects came directly under the notice of Lord Kelvin after he had undertaken to write an article for a magazine. "When I tried," he said in the article, "to write on the mariner's compass, I found I did not know nearly enough about it. So I had to learn my subject. I *have* been learning it these five years." He not only noted the defects of the existing instrument, but also set himself to devise a means of remedying them; and in the end he produced the compass which has made his name famous to every nautical man. The existing compasses were made with needles ten, twelve, or even fifteen inches in length, in order that, when shaken, their period of vibration or swing should be long. The card also was made large, with the view of keeping the compass steady; but the result was that, on account of the weight of the needles and card upon the pivot, the compass was apt to stick, and was always sluggish in its action.

Lord Kelvin first showed in a mathematical paper that steadiness of the compass at sea in stormy weather could be obtained by small needles and a light compass card instead of large needles and a heavy card, if certain conditions of construction were fulfilled. He took out the first patent for his improvements in 1876, but he had to wait thirteen years before the instrument was adopted as the standard compass for the Navy. The compass is now being supplemented by a new form in which the mag-

nets and card are immersed in a liquid which fills the compass-bowl, and by the gyro-compass, which is independent of magnetic conditions, but it was Lord Kelvin who made the first departure from the crude instruments which had been in daily use by thousands of practical men from early times without one of them suggesting any substantial improvement.

All sailors are grateful to Lord Kelvin for his inventions for the preservation of life at sea, notably by means of his compass and sounding machine. With these two aids to navigation a safe course can be followed with confidence in fog or darkness; and every sailorman can tell of disasters from which he was saved by them. A characteristic tribute to Kelvin from a sailor's point of view has been given by Admiral Sir W. R. Kennedy:

Some years ago I left a port on the coast of Patagonia in the *Ruby*. We shaped a course for Golfo Nuevo for the night. At 8 P.M. the navigating officer came into my cabin and showed me the position of the ship, well clear of the land and [in] 100 fathoms no bottom, marked on the chart. "All right," I said. "Get a cast of the lead." "Throw Thomson overboard" was the way I put it. The navigator looked at me to see if I was joking. "Why, there's no bottom at 100 fathoms, sir." "Well, heave Thomson over." He left the cabin, and presently I heard the whirr of the wire suddenly stop. I rushed on deck. Fifteen fathoms! Stop her, hard aport, leadsmen *in* both chains! Sure enough, 15 fathoms. I hove to all night, head off shore, and next morning steered for the gulf, which we reached without further *adventure*, but had we continued our course we should have been ashore before daylight. The navigating officer was not at fault, but the coast-line was not correctly charted. No wonder that we sailors bless the name of Lord Kelvin.

By his improvements of the two oldest aids to navigation—the compass and the sounding line—Lord Kelvin

earned profound gratitude from all who go to sea. He has been called the best friend the sailor ever had; and it is said that a blue-jacket was once overheard to remark, "I don't know who this Thomson may be, but every sailor ought to pray for him every night."<sup>11</sup>

Lord Kelvin's work for submarine telegraphy is another example of a practical problem solved by scientific knowledge. The first Atlantic cable was laid in 1858, but scarcely had the enthusiasm awakened by it begun to subside when the signals grew more and more feeble and in a few weeks the cable altogether ceased to transmit messages. This failure was sufficient to discourage most people, but Lord Kelvin encouraged a fresh attempt. "What has been clone," he said, "will be done again. The loss of a position gained is an event unknown in the history of man's struggle with the forces of inanimate Nature." Faith and courage were both required to attack the problem again. A new type of cable was designed, better adapted than previous kinds to bear the strain of laying, and in 1865 this cable had established telegraphic communication between England and America. The appliance, known as the siphon-recorder, invented by Lord Kelvin to register the electric impulses transmitted by the cable, still remains in universal use as the standard instrument in submarine telegraphy. It was scientific knowledge, and the spirit of converting difficulties into opportunities, that made transatlantic telegraphy possible.

When the first iron ships were built, it was found that the compasses were so greatly affected by the magnetism of the ships that accurate navigation was impossible. Long before Kelvin devised his instrument, a method of determining a ship's permanent and temporary magnetic conditions had been worked out, and a means of counter-

acting them had been found. No magnetic compass would be of any practical use if the effect upon it of the fixed and movable iron of a ship could not be compensated effectively.

The problem presented by the use of iron in ships was definite but complicated; and it could be solved only by scientific investigation. Mr. Archibold Smith, a Chancery barrister who devoted all his leisure hours to the application of mathematics to navigation, had this practical purpose in mind; and his work was recognized by the award to him, in 1872, of a gift of £2000 "for the long and valuable services which he had gratuitously rendered to naval science in connection with the magnetism of iron ships, and the deviation of their compasses." The chief credit must, however, be given to Sir George Airy, the Astronomer Royal, who, in 1838, was asked to undertake experiments on a ship—the *Rainbow*—for the purpose of discovering a correction for the deviation of the compass produced by the iron of which it was constructed. The deviation was so great that the compass of the ship was as much as fifty degrees out of the magnetic north and south direction.

Airy investigated the subject theoretically as well as practically, and calculated the strength of the magnetic action required to counteract the disturbance. In a month he had completed his inquiry. He took the necessary compensating magnets and iron correctors to Deptford, where the ship was lying, mounted them in their proper places, tried the ship, and the compass was then found to be sensibly correct. In the same year, another iron ship—the *Ironsides*—built at Liverpool, had her compass similarly corrected by Airy; in this case, as in the *Rainbow*, the disturbance was so great as to make the vessel

worthless without a mechanical means of correcting the effect due to the iron.

The success of the methods employed for the correction soon became widely known, and led immediately to extensive building of iron ships. Though some acknowledgment of an important service thus rendered to navigation might have been expected, the Admiralty refused to sanction any reward for it; possibly because the Government did not then possess a single iron vessel and was not disposed to urge the inquiry into the effect of a ship's magnetism upon the compasses. When Airy commenced the investigation, the whole subject was in darkness, yet by the application of a mechanical theory he brought it under control. Lord Kelvin made a great advance later by the use of short needles for the compass cards, but the method of correcting the compasses in iron ships, now adopted not only in the merchant service but also in the navies of all countries, is that worked out by Sir George Airy in 1839. Airy—mathematician and astronomer—has thus been justly called the father of the mode of mechanical compensation of the compass now followed throughout the civilized world.

Neither Airy nor Kelvin had any special knowledge of ships' compasses when they took up the problems which they solved with such complete success, but they knew that the best way to attain a practical purpose is to submit the conditions to scientific analysis before devising arrangements to meet them. This method may be tedious, but it is always the best in the end. No matter to what branch of human activity the subject belongs, the preliminary scientific investigation undertaken with the view of understanding it fully makes the surest foundation of advance. All work which has not this basis is of the em-

pirical, trial-and-error, rule-of-thumb kind; it is a shot in the dark, and though the target may be hit the chances are very much against it. When science is brought to bear upon a practical problem, it first discovers exactly what has to be done, and then seeks the most efficient way of doing it. . . .

The intention of technical research is not so much to contribute to scientific knowledge as to create new industries or develop old into higher or more productive forms. The country which neglects this pioneer branch of its industrial army cannot maintain an important position in the struggle for existence or supremacy in commercial life. Lord Beaconsfield once said that the condition of the chemical trade of a country is a barometer of its prosperity, and King George the Fifth accentuated this remark in a speech made at the opening of a Congress of Applied Chemistry in London in 1909. His Majesty said :

I fully appreciate the important part which chemistry plays in almost every branch of our modern industry. We all recognize that without a scientific foundation no permanent superstructure can be raised. Does not experience warn us that the rule of thumb is dead, and that the rule of science has taken its place, that today we cannot be satisfied with the crude methods which were sufficient for our forefathers, and that those great industries which *do* not keep abreast of the advance of *science* must surely and rapidly decline?

It would be easy to give many examples of the beneficial effects of the cooperation of scientific theory with practical methods. One of the most striking illustrations is afforded by the optical trade. About 1863, the firm of Carl Zeiss, of Jena, asked Ernst Abbe to assist them in the development of the microscope by investigating the

optical theory of the instrument. Abbe proved mathematically that with the glass then at the optician's disposal no great improvement in the optical parts of the microscope could be expected. Progress in the art of glass-making was necessary before any substantial advance could be made in microscopic or photographic lenses. Abbe himself, with Otto Schott, began, therefore, in 1881, to investigate the relation between the optical properties and the chemical composition of glasses. When they began their work, about six chemical elements were the constituents of glasses; and they tested by experiment the effect of adding definite quantities of other substances, as had been done previously in a small way by Canon W. V. Harcourt in England.

What had been a rule-of-thumb industry was thus reconstructed on a scientific basis. Glasses could be produced having particular properties for microscope lenses, for photographic lenses, for thermometers, or any other special purpose. Works were established at Jena, and they soon became the chief center of optical glass manufacture in the world. On account of the indifference shown to scientific theory by its manufacturers and state officials, England lost an industry in which it was once preeminent.

This not only has been the case with glass manufacture, but also is largely true of the construction of photographic lenses. The principles of the design of such lenses were worked out by Sir John Herschel, Sir William Hamilton, and Sir George Airy, but their significance was not appreciated by practical opticians in the country of their origin, and it was left to optical experts of another nation to apply them to practical needs. Empirical methods followed by British opticians have achieved some notable successes in optical instruments, but the guidance of theory is essential for steady advance, and scientific

knowledge is necessary to see any close relation between theory and practice. In originality and inventiveness, the English mind will compare favorably with that of any race, but its attitude to scientific theory is supercilious, and the nation suffers loss by it. If England does not lead in industrial development, it is not because of lack of new ideas, but on account of want of scientific insight among her manufacturers, and want of faith in the ultimate value of organized industrial research. We commend to the men who have the nation's future in their keeping the words of a president of the Royal Society:

*Scientia vincet*—whether it be on the field of battle, on the waves of the ocean, amid the din and smoke of the workshop, or on the broad acres under the light of heaven; and assuredly, in the future, even more than in the past, not only the prosperity, but even the existence of the Empire will be found to depend upon the "improvement of Natural Knowledge"—that is, upon the more complete application of scientific knowledge and methods to every department of industrial and national activity.

—*Sir William Huggins.*

It is commonly supposed that the marvelous development of aviation within recent years owes nothing to scientific work; indeed, the assertion is often made—unjustly so—that men of science declared the flight of an airplane to be a mathematical impossibility. Aviation engineers have certainly had few scientific principles to guide them in the design of their machines, and the improvements which have been effected have been by trial-and-error methods; but the error has unfortunately involved the sacrifice of many promising lives. Artificial flight has been achieved chiefly by these empirical methods; and in the absence of exact knowledge they are the only methods available, though they are expensive and wasteful.

As in other cases mentioned already, the problem of flight with heavier-than-air machines was approached by two separate roads of invention and science. Early in the nineteenth century, Sir George Cayley designed an airplane driven by an engine which used the explosive force of gunpowder; and the machine appears to have lifted itself from the earth. Nearly forty years later, W. S. Henson projected, and his friend J. Stringfellow constructed, model airplanes from Cayley's designs, driven by a light steam engine of about one-third horsepower; and the models are said to have been capable of free flight. About 1875 Alphonse Penaud, a French mechanic, constructed the well-known toy airplane with a propeller in the rear and driven by a rubber band, the machine thus utilizing motive energy which it carried with it.

Experiments with man-carrying machines were made about 1889 by Otto Lilienthal in Germany, Percy Pilcher in Scotland, and Octave Chanute in the United States. These machines were, however, only gliders, by means of which the experimenters could soar in the air for a hundred yards or so, after taking a short run against the wind, along the top of a hill or mound. In none of these cases was a motor used successfully to drive the wings of the airplane against the air and thus maintain it from falling. Sir Hiram Maxim built in 1894 a huge machine driven by a steam engine, and proved by it that the whole weight could be lifted slightly off the rails on which the machine ran by driving the planes against the air with sufficient velocity. A little later M. Ader, in France, traversed a distance of about fifty yards in his "Avion" airplane.

All these machines may be not inappropriately classi-

fied as devices of engineers to achieve flight by invention—call it practical experiment if you will—before the principles of dynamic motion had been studied. The practical man makes his machine first and lets experience decide whether its design is sound or not; the scientific man begins by investigating the principles involved in the problem, and then suggests how they may be met. The only satisfactory way to determine such principles is by experiment and calculations based upon the results. The possibilities of artificial flight were studied experimentally by a man of science at a time when anyone who gave attention to the subject received nothing but derision for his pains. Modern aviation was based upon the results he obtained, for he himself first showed that a system of planes could be sustained in the air if made to advance through it fast enough.

Until a few years ago, very little was known of the resistance offered to air by a body advancing through it. Sir Isaac Newton considered the subject, and came to the conclusion that the resistance opposed to a thing in rapid motion would be so great that enormous mechanical power would be required if artificial flight were to be accomplished. It was not a practical engineer or an aviator who undertook experiments to test the rule which Newton gave to calculate this power, but an American man of science—Samuel Pierpont Langley, secretary of the Smithsonian Institute of Washington.

Professor Langley commenced his experiments in 1887; and his work gave, for the first time, some accurate knowledge as to the resistance offered to planes moving through air at different speeds and inclinations. He proved that what had been called the Newtonian Law was wrong; and that it takes less power to support a plane moving

through air at high speed than at low. By simply moving a given weight fast enough in a horizontal plane, Langley found that it was possible to sustain the weight with less than one twentieth the power demanded by Newton's rule. His conclusion as to the relation of speed to power for a body in motion in air was as follows:

**These new experiments (and theory also when viewed in their light) show that if in such aerial motion there be given a plane of fixed size and weight inclined at such an angle and moved forward at such a speed that it shall be sustained in horizontal flight, then the more rapid the motion is, the less will be the power required to support and advance it.**

This rule, now known as Langley's Law, represented a definite advance of knowledge secured by the methods of exact science. The practical men who, in these days of rapid locomotion, might have been expected to investigate the laws of air resistance, left it to a man of science to prove that a rule which had been accepted for two hundred years was incorrect. His experiments demonstrated that relatively little power was required to sustain a given weight if the horizontal velocity reached a certain rate. All that was needed in order to make mechanical flight possible was a light motor capable of forcing a plane or set of planes through the air with sufficient velocity.

Guided by his results, Langley had a model airplane constructed, weighing about twenty-five pounds; and successful flights, each about half a mile in length, were made with it in 1896. His experiments were regarded, however, as the trivial amusements of a scientific man; and when, in 1903, his man-carrying airplane was wrecked, owing to an accident in launching it, so much ridicule was thrown upon the trials that he abandoned the subject and devoted himself to other things. Eleven years later, in 1914, the

same machine was used for flights with a pilot.<sup>2</sup> Langley did not live to see this success, but he never lost faith or confidence in the ultimate possibility of aerial flight with heavier-than-air machines. Concluding an account of his experiments in 1897, he said:

**I have brought to a close the portion of the work which seemed to be especially mine—the demonstration of the practicality of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it does not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened.**

How completely Langley's belief in flight by airplanes has been justified is known now to everyone, though his experiments are rarely mentioned. Faraday once said, referring to the electric dynamo, "I gave you this machine as an infant; you bring it back as a giant." Had Langley lived, the same remark could have been applied appropriately by him to the development of flying machines from his models. Purely scientific investigations gave the world the dynamo, and with the construction of this means of producing electricity there commenced a new era in engineering. In like manner, the work of a man of science opened a new epoch in the history of aerial navigation.

When, in May, 1896, Langley's power-driven model airplane flew over the Potomac River for a minute and a half (for which time only it was provided with fuel and water), and accomplished a flight of a little over half a

<sup>2</sup>The only changes made were the installation of a more powerful engine with a modern radiator and carburetor and the addition of floats,—*Editors.*

mile before it settled down upon the water with a gentle descent, the possibility of free dynamic flight was established. It was Langley, and no one else, who was the father of modern airplaning, both because he conducted researches to determine the scientific principles of air resistance and the work of the wind, and because he put the principles into practice by constructing a self-balancing heavier-than-air machine which would sustain itself in the air so long as the power driving it lasted. No one before Langley had succeeded in building an airplane capable of sustained free flight with a man as pilot.

When Wilber and Orville Wright commenced their experiments in artificial flight, the only exact experiments they could find as to the resistance of the air to machines driven at different velocities were those made by the man of science, S. P. Langley. They were the pioneers of sustained flight with man-carrying airplanes, and they have acknowledged that their confidence in the practical solution of the problem was derived from Langley and his work.

The knowledge that the head of the most prominent scientific institution of America believed in the possibility of human flight was one of the influences that led us to undertake the preliminary investigations that preceded our active work. He recommended to us the books which enabled us to form sane ideas at the outset. It was a helping hand at a critical time, and we shall always be grateful.—*Wilbur and Orville Wright.*

In December, 1903, the Wright brothers made the first actual flight with an airplane driven by a petrol motor. It is constantly stated that artificial flight would have been accomplished long before if engines light enough to drive them had been available, but that is not the case. Flights with two, three, or more passengers

show that lightness of the motor is not the only consideration, and motors with equivalent weights were available ten years before the Wrights designed their man-carrying airplanes. It was by following the scientific guidance of Langley, and using mechanical ingenuity to extend it, that they were able to give practical effect to the desire of man to rise above the clouds.

Though the Wrights were the first aviators to make successful flights with a heavier-than-air machine driven by its own power, little was known of their work for about two years after 1903. During this period they were engaged in perfecting their airplane until, in 1905, they were able to remain in the air for half an hour and cover a distance of about twenty-four miles. They did not give a public demonstration of their achievements until 1908—two years after a young Brazilian, M. Santos Dumont, had made a short public flight in France, using an airplane designed by him without any definite knowledge of what the Wrights had done. Since that period, the advance of dynamic flight has been rapid and marvelous.

The performances of the earlier machines depended very largely upon the pilots, who had to give close attention to different controls in order to keep the planes in a condition of stability in the air. The problem of producing a machine which is automatically steady in free flight is largely mathematical; and it involves the theory of small oscillations about a state of steady motion developed by Lagrange, Kelvin, Routh, and other men of science. Definite attention has been given to the mathematical conditions which have to be satisfied, in order to solve the problem of inherent stability, by G. H. Bryan and F. W. Lanchester; and their conclusions, with the results of experimental research on models at the National

Physical Laboratory, largely by L. Bairstow, led to the construction of the B. E. biplane, which is almost independent of the pilot except when near the ground, where personal control must be exercised.

Work in the laboratory and calculation in the study have determined the lines upon which a flying machine can be designed that may be launched into the air with as much confidence in its safety and inherent stability as a vessel can be trusted to leave the slips of the dockyard in which it has been built.

## XV

# MEN, ATOMS, AND STARS<sup>1</sup>

M. LUCKIESH

M. Luckiesh is Director of the Lighting Research Laboratory, National Lamp Works of the General Electric Company, Cleveland. He is both physicist and engineer, and has conducted many researches in color and light, with practical applications to modern lighting. For ten years he was a physicist in the Nela Research Laboratories; then for four years he was Director of Applied Science in the same laboratories before undertaking his present work in 1924. During the World War he was Chairman of the National Research Council Committee on Camouflage. He has been writing and publishing books more or less regularly since 1915, and has also to his credit more than two hundred articles in scientific and technical journals. Some of his books are entitled *Color and Its Applications*, *The Language of Color*, *Artificial Light*, *Lighting Fixtures and Lighting Effects*. The present essay is the first chapter of *The Foundations of the Universe*, a popular and systematic discussion of the present state of knowledge of the universe, from atoms to stars, and its laws.

My friend or your friend marvels nightly at the wonders of the latest scientific achievement which has swept over the civilized world. His radio "receiving set," without any material connection with the outside world, actually reproduces for him the music or speech which is delivered to a "sending set" located a thousand miles away. This to him is marvelous, perhaps awesome, and in most cases profoundly mysterious. But let us detach him from

<sup>1</sup> Reprinted from *Foundations of the Universe*, copyright 1925 by D. Van Nostrand Company, Inc., by permission of the author and of the publishers.

the radio and take him to a window. We point to that brilliant star, Sirius, and ask him if he sees it. Of course, he sees it, but "What of it?" he asks. Seeing the light of that star is even more wonderful than hearing music transmitted a thousand miles by "wireless." Let us see if we cannot convince him.

Sirius is 500,000 times farther away from us than the sun. It is at a distance of 54 million million miles. It takes light nearly nine years to travel the distance, and the velocity of light according to modern views is the highest attainable. Furthermore, the light that travels from Sirius to our eyes is electromagnetic energy in the form of waves similar to those intercepted by the radio set. The only difference is in wavelength or frequency. Off there at that almost inconceivable distance is Sirius, a station sending forth electromagnetic waves of such frequencies or wavelengths as are within the range for which our eyes—the radio receiving sets of the human body—are tuned. This is not a mere analogy. The two cases are practically identical from the physical viewpoint.

Minute particles of electricity—electrons—are playing a vital part in the radio tube. They are one link in the chain of reception and transformation of invisible electromagnetic radio waves into audible sounds. Out there at such a tremendous distance that it would take the fastest airplane 25 million years to travel that far, are electrons in the atoms of the elements of which Sirius consists. These are sending forth electromagnetic energy to be *seen* by us. Each atom operates exactly like any other of the same element, sending forth electromagnetic waves of the same frequencies. Here on earth by means of the spectroscope, we measure the wavelengths and tell what the elements are that are sending their wireless messages to

us. From the viewpoint of the physical world, signaling to Mars would be but a commonplace achievement.

All around us are wonders just as surprising. Most of them are passed by without interest because they are not understood or because they are commonplace experiences. However, the most wonderful and stupendous picture is the physical universe. Nothing can excel it in magnitude. Each detail is interesting in itself, but the dovetailing of the details gives us not only a picture of great magnitude but also one of surprising harmony, for there is unity in the whole.

Our interest in the physical world generally is not so much in itself, but in our relation to it. Atoms and stars, their compositions, properties, and relations, are the physical universe. Man is incidental and of no influence or consequence. He finds himself in this physical world and strives to learn something of the mechanism. He naturally desires to know what "makes it go" and wishes to understand its laws so that he may harness them to his advantage during his sojourn. What an insignificant mite he is and what an instant of time is occupied by his journey in this physical world!

But here, we are not so concerned with man's insignificance as we are with the confusion which he introduces into the universe, for man himself is the cause of much of the apparent complexity of the physical universe as it appears to him.

Man's contact with the physical world is complicated by the multiplicity of his senses and is limited by the capabilities of these sense-organs. We can see light; hear sounds; feel temperatures; experience weights and forces. The senses involved divide the physical phenomena into such branches as optics, acoustics, heat, and mechanics.

We have no special sense-organ for the phenomena of electricity and magnetism, which are more foundational from the viewpoint of the physical universe than light, heat, and mass. The picture of Nature that we obtain through our senses is a subjective one. It is not the real fundamental one. Although without these senses we would have no doorways from which to view the universe, they complicate matters by giving us a picture of a subjective world. We must eliminate the prejudices of these senses before we can develop a true picture of the objective or physical world.

As we look downward from the present heights of scientific achievement we cannot help wondering at the slow progress of science during the early centuries when civilization in many respects had attained great heights. The scientific achievements of the first quarter of the present century compare favorably with the aggregate of all the centuries preceding. The wonderful practical applications of electricity have nearly all appeared during the past fifty years. The science of electricity is only about a century old. It is true that earlier centuries had marvelous men who helped to lay the foundation upon which later men built, but much of the foundation was quicksand. A few men built well, considering the paucity of authentic data. Roger Bacon lived in the thirteenth century and Copernicus was of the fifteenth century. But it was the sixteenth century with such men as Gilbert, Tycho Brahe, Galileo, and Kepler that first witnessed a great deal of advancement in physical science that was to supply foundations of more or less permanency. Scientific achievement was ever gaining momentum, but it was still feeble and uncertain. There was too much speculation and too little experimentation, but fortunately the

proportion was to change in the seventeenth century with such experimenters as Toricelli, Boyle, Huygens, and Hooke appearing on the stage. Then came Isaac Newton, eclipsing all his predecessors.

There is no doubt that scientific achievement before Newton's time is insignificant compared with that which has accumulated since the sojourn of that great man. Naturally we wonder why the great minds of earlier centuries in Greece, in Rome, and elsewhere achieved so little in unraveling the mysteries of the physical universe. We cannot believe that there were not mighty intellects in those centuries and fortunately such an assumption is unnecessary. The reason for the slow progress in science up to Newton's time and for the rapid advances in the past century is not found in *mind*, but in *method*. Now we build theories only upon a reasonable foundation of facts. Experimentation is the watchword of modern science. This method yields knowledge of the physical world, which is used for building the solid foundations of theories. In earlier centuries the great minds theorized without many facts and the result was largely uncertain speculation. Science has learned a great and lasting lesson which would be beneficial to all given to theorizing without a "working knowledge." As we look backward we see that the earlier peoples cheated themselves out of many things we now enjoy, by misplaced faith, by scorning experimentation, and by trying to build without knowledge. What a relief the present age would enjoy if reformers, politicians, and many others would profit by what science has learned and would begin with facts instead of theory.

Let us not be misunderstood. Theory is the greatest tool that science has had. It even exceeds experimenta-

tion in value. The great epochs in scientific progress which have changed the course of thought and development have been theories built by mathematical treatment of the physical facts yielded by experimentation. For example, Newton contributed the theory of gravitation; Maxwell the electromagnetic theory of light or radiation; Planck the quantum theory of energy; Einstein the theory of relativity. These are conspicuous milestones along the highway of scientific progress.

Let us take a glimpse of scientific work as it is achieved in modern times. Here and there we have experimenters penetrating the unknown. These scouts bring back many authentic data. Various branches of physical science grow here and there. When enough data have accumulated some kind of unity may be constructed. Eventually a great mind comes along and erects a structure from these facts by arranging them systematically and cementing them together with philosophy and mathematics. If the facts are sufficiently authentic and complete, the structure is a theory. It remains so until all the gaps have been filled. Perhaps some alterations must be made to admit new data. If, as is often the case, the erected structure contains a great many gaps and some misfits, it is better named an hypothesis. It retains this name until it is safe enough to be termed a theory. The gaps in the structure are the predictions of the incomplete assembly and scientific men set about to ascertain their validity. For example, expeditions set out for the southern hemisphere in the midst of the World War in order to determine during a solar eclipse the validity of Einstein's prediction that light from a star would be bent from its path due to the gravitational force of the sun. It was. During the construction of a theory it is often necessary to

make alterations and to add final touches until finally we behold a beautiful structure of perfect unity of harmonized facts. Obviously, attempts at hypothesis and theory are necessary. Otherwise the data of experiments would merely accumulate without unification.

Many of the so-called theories which appeared in earlier centuries are misnamed. They were little more than speculations because of the scarcity of authentic observational data. Many of them are interesting and even fascinating. They prove that great minds and thoughtful men existed throughout the ages. Some of these speculations hit close to the truth as revealed by the facts garnered by later experimenters. But the hits were mere accidents for the most part. Just as the fertile imagination of Jules Verne pictured flying-machines and submarines, some of the earlier speculators pictured possibilities which are now known to be realities. It is a popular pastime among superficial writers to credit some *of* the early speculators with uncanny insight and foresight, but this is unwarranted. Given enough speculations, particularly when these are the products of great intellects, some of them are bound to strike close to the truth.

Thoughtful men of all times have recognized that the physical world is more likely to be simpler than it would appear to man with scanty knowledge of its mechanism and with several inadequate sense-organs. Simplicity appeared more likely than complexity. Harmonious cosmos appeared more likely than discordant chaos. Basing their speculations on these reasonable assumptions some of the earlier philosophers drew word-pictures that are quite close to the realities as we now know them. For example, Democritus (460-360 B.C.) developed certain principles which, after twenty-four centuries, can be made to fit the

facts by slightly modifying them. He concluded that the only existing things are atoms and empty space and that nothing existing can be destroyed. He struck close to the truth of the atomic and the electronic theories as they have recently been developed. He tried to construct a picture in which motion was the only physical phenomenon. While it now appears that physics cannot be reduced entirely to mechanics, some of the speculations of Democritus are substantially correct. However, it would be unfair to those modern philosophers such as Newton, Maxwell, and Einstein, who builded upon known facts and who coordinated authentic data by mathematical genius, to credit early philosophers with comparable achievements. The earlier ones speculated thoughtfully without being fettered by a multitude of facts. The modern ones must develop principles which harmonize a vast amount of data.

Another difficulty which has hindered man in forming a true picture of the objective world is that mixed blessing—egoism. In early centuries he could not escape from the false assumption of his own preeminent importance and these same shackles are still prejudicing the observations of most persons. Under this handicap it is not surprising to find man placing himself at the center of the universe. When he began to speculate in regard to the motion of heavenly bodies naturally he conceived them as in motion around the earth. The latter was the stationary center of the cosmos. Many brilliant men were to suffer persecution for striking at this bigotry when they attached less importance to man and the earth by giving to the latter a motion and an importance comparable with the other heavenly bodies.

Pythagorean philosophers suggested a system in which the earth was not the center of the universe. It was not

accepted, but the seed was sown which two thousand years later inspired Copernicus (1473-1543) to develop the system of planetary motions around the sun. This was destined to form the foundation of an accurate picture of our solar system. Galileo (1564-1642) was just the man to take up the Copernican theory. With the astronomical observations of Tycho Brahe (1546-1601), with better telescopes, with the friendship of Kepler (1571-1630), and with his own genius, it is not surprising that he placed the Copernican theory *on* a solid foundation from which it was never to be shaken.

Scientific men encountered obstacles in those days besides those naturally found in their physical researches. Throughout fifty years this great scientist successfully battled the churchmen and others. The controversy of Galileo with the Inquisition is famous. This searcher for truth was confronted by the hordes of bigotry and ignorance. Finally he was haled before the Inquisition, and the judgment of the court was that his claim to the effect that the sun was in the center of the solar system and that the earth was not the center of the world was "absurd, philosophically false, and formally heretical because it is expressly contrary to the Holy Scriptures." In appreciation of his great contribution to our knowledge of the foundations of the universe we cannot blame him when, finally confronted with the terrors of the Inquisition, he recanted his doctrines. But the latter were the truth and they lived until a time when they could be openly proclaimed.

The foregoing is introduced to show what hindrances were encountered by scientists of the past. Fortunately, bigotry and ignorance no longer hinder scientific progress. But the new world did not escape the final struggles of

that controversy. Perhaps it will shock some readers to learn that a half century ago a state university in the Middle West drove a young teacher of physics from the school because he dared by experimentation to lift the veil from Nature to view the "sacred realm." There is in print a record of this persecution and controversy which took place in the latter part of the nineteenth century. The young man lived to a moderate old age and passed away only recently after a successful life of contribution to physical science.

Although such bigotry and ignorance have ceased to handicap scientific research, man finds it difficult to step aside and view the physical world quite apart from himself. For this reason the distances in the stellar universe appear inconceivably large and those of atomic structure appear infinitely small. These difficulties are natural and man is wholly above criticism in this respect. Nevertheless, in order to obtain a proper view of this wonderful mechanism he must transport himself in his mind's eye to great distances and must contract himself into the atom. He will see wonderful systems of bodies in orderly motion in both cases. It is a good exercise to attempt to conceive limitless space bounded by nothingness which extends forever. Out in the stellar universe he finds a great void inhabited by heavenly bodies relatively "few and far between." In the atom he finds the same condition.

To the uninitiated person a glimpse of the night sky reveals what appears to be countless heavenly bodies scattered in confusion. Ask him to count the stars and he would be awed at what would appear an impossible task. Still, from a single viewpoint a person can see with the unaided eye only about three thousand stars. All the persons over the entire face of the earth from pole to

pole can see less than ten thousand stars. Galileo's telescope with its objective lens  $2\frac{1}{4}$  inches in diameter revolutionized human thought because it multiplied the number of visible stars a hundred times. Each increase in diameter of lens or reflector up to the 100-inch Hooker telescope at Mount Wilson Observatory has revealed many more stars. Add to those the records of long photographic exposures and we have a billion stars revealed. How many stars are still behind the veil, of course, is not known, but there are many no doubt.

Although the telescope has increased the complexity of our visible universe by revealing millions of its inhabitants, it is also simplifying the physical world by revealing the motions, the constituents, the relations, and the forms of the celestial bodies. Some of the experiments that the physicist would like to perform in the laboratory, but cannot owing to his inability to produce the proper conditions, are now daily and nightly performed by viewing the phenomena in those far-off celestial laboratories of nebulae, of comets, of glowing gaseous stars, of very hot suns, etc. The physicist now studies the spectra (the electromagnetic waves) emitted by elements at high temperatures as yet unattainable in man-made laboratories. He finds new elements in far-off stars before they are found on earth. He discovered helium in the sun twenty-eight years before its detection on earth. The telescope and its accessories, especially the spectroscope, have proved that the same elements are scattered throughout space; that all celestial bodies have a common origin. This is simplification indeed. And finally he is learning much of the evolution of matter from the myriad stars of all stages of evolution and levels of temperature.

If we reverse the telescope in our imagination, the

stellar universe or particularly our solar system gives us a rough model of the atom. The microscope fails us long before the smallness of molecules or atoms is reached, but by indirect methods a still smaller particle, the electron, has been isolated and measured. The atom is now known to consist of a positive nucleus—protons—and negative particles of electricity—electrons. Usually electrons are considered to revolve around the nucleus, the number varying with the element. Thus everywhere from stellar space to atomic space we find bodies in motion, and when we think of how small the protons and the electrons are, we can see that Democritus came close to the mark in his bold speculation which reduced physical phenomena to a single one—motion.

As we take these intimate peeps into the mechanism of the physical world perhaps we are reminded of an attitude which crops out here and there. The scientist by his cold analysis is often considered to be robbing us of the pleasure that awe and mystery give. The artist often shows this attitude plainly. But knowledge is safer than ignorance in our present civilization. This is one of the defenses of the scientist if he needs any. As for the validity of the contention that knowledge lays Nature bare, thereby robbing it of its beauty and us of the pleasure of awe and mystery, it falls down completely. To know the reason for colors does not rob us of the pleasure that color gives. As for awe, the disintegration of radium, the mechanism of the atom, the motions of the planets, the great torches of flame which shoot out from the sun, the plunging of our planetary system toward the galactic, and many other facts of the physical world are more awesome than any observations through the eyes of ignorance. As for mystery, plenty remains. With each

addition to the area of knowledge the horizon of the unknown grows larger. Science only replaces one mystery with another of greater magnitude. Some day possibly science will have revealed everything, but we have no need to worry on that score. We shall not see that day and if anyone ever does, it is quite likely that the compensation of knowledge will suffice for the disappearance of mystery. . . .

Mere human beings, insignificant and of no influence or consequence, we find ourselves with our familiar dimensions midway in a universe of magnitudes almost infinitely large and small. The constituents of the atom are only a millionth the size of the smallest object that our unaided eyes can see. Most of the bodies of the stellar universe that are visible to us are billions of times larger and most of their distances are billions of times greater than the dimensions with which we are usually concerned. Well may we wonder that man attempts to unveil the mechanism of the physical universe. Here we must thank our egoism, for, where it sometimes handicaps us, it is responsible for the incentive which makes us desire to know all that we can of the world of which we are apart rather than a part.

So man, who here seems principal alone,  
Perhaps acts second to some sphere unknown,  
Touches some wheel, or verges to some goal ;  
'Tis but a part we see, and not a whole.

—*Pope.*

## XVI

### A PARABLE OF WHEAT<sup>1</sup>

ALBERT EDWARD WIGGAM

Albert Edward Wiggam has had rather a colorful career. After obtaining a B.S. degree from Hanover College, in Indiana, he was successively chemist in a sugar factory, student of philosophy, assayer and mine superintendent, newspaperman, political campaigner, lyceum and Chautauqua lecturer, lecture manager, and journalist. In recent years he has been an enthusiastic advocate of eugenics, as evidenced by his books *The New Decalogue of Science*, *The Fruit of the Family Tree*, and *The Next Age of Man*. The last of these, from which the present excerpt is taken, is an interesting presentation of the thesis that (paraphrasing from the Preface) the naturally good, naturally sane, healthy, intelligent, and long-lived will in time, through the use of the new instrumentalities of science, constitute the main body of the population.

A certain man had two ears of wheat, the grains large in size, of equal vigor and freedom from disease. He planted the grains from one in rich, mellow soil, and from the other in hard, sterile soil. He gave them equal care and cultivation. They each received an equal amount of air, moisture, and sunshine. At the end of the season those planted in the rich soil yielded him both a richer harvest and much larger ears. He congratulated himself that he had discovered a simple and easy method of improving the *inborn quality* of his whole race of wheat, that is, the method of providing an improved environment.

<sup>1</sup> Reprinted from *The Next Age of Man*, copyright 1927, by special permission of the author and of the publishers, The Bobbs Merrill Company.

The results of the improved environment were so immediate and unmistakable that he failed to inquire what had gone on inside the plants themselves.

Being, however, of an experimental turn of mind, he saved all the grain from both lots for seed, just as we save all human beings for reproduction. He therefore planted all the wheat from both lots again in the same sort of ground as before, those from the rich soil back in the rich soil and the others in the poor soil.

At the end of a few seasons, however, he began to suspect that something was going wrong with his stocks. He found among those grown continuously in the rich soil an enormous number of little grains. He was unable to account for this, as he had started out only with large ones. True, there were still many good-sized grains from the rich soil, but what discouraged him was the increasing number of little ones. When he considered the general *average* size of this entire stock he found it greatly reduced from that of the original lot. He also found that disease had set in among them, while the ones from the poor soil seemed strangely unaffected by disease. He concluded that his *soil, not his seed*, was deteriorating, and also that he had not expended sufficient time and skill in cultivation.

He therefore bought expensive fertilizers, and redoubled his efforts at tillage. But his fertilizers brought him only a new disappointment. For a time they did give a few extraordinarily large specimens, but even these were not free from disease. Indeed, both the fertilizers and the extra efforts at cultivation seemed only to promote both the amount of disease in his rich-soil wheat and to increase the number of small, puny grains. One thing also that had struck him all along about his poor-soil

wheat was that, while at first the hard environment decreased its average size, yet the plants remained free from disease and, as time went on, gradually improved slightly in size and quality.

He now had two pictures before him. First, the rich soil had given him size and abundance, all mixed with disease and littleness, with a gradual tendency of his whole stock toward general degradation. On the other hand, the hard, forbidding soil had apparently preserved the vitality of his stock and kept it free from disease, but had given him very little in the way of food.

All this experience led our farmer to take a new tack. He selected a large, general *random* sample of his rich-soil wheat and planted the grains in the poor soil, and at the same time he transferred a similar sample from the lot bred in the meager ground to the rich and stimulating environment.

To his amazement, the whole picture was instantly reversed. The wheat from the poor soil, when transferred to the rich environment, leaped up at once to great size and vigor, and even exceeded its original size of years before, when he began his experiment. The seeds were practically all healthy and of good proportions, while, on the other hand, those taken from the comfortable environment and put into the hard, ruthless soil had become so weakened that they scarcely survived at all.

At last there dawned on his mind, from this expensive experience, a new idea. From the new lot, hardened by their long experience in sterile soil, which had weeded out their weaklings, their diseased, and their unfit, and which he had now tried for a season in his rich soil and found to respond magnificently to luxury and cultivation, he selected *not a random sample*, but the finest, healthiest, and

largest specimens he could find, and saved them for seed. The remainder he used for his own food or sent to the market.

The next season he planted his selected seeds in his most luxuriant soil and gave them every possible care and nourishment. When the harvest came he found himself richly rewarded for his use of intelligence. The crop from his selected seeds was the finest and largest and the freest from disease that he had ever grown. His fame went abroad and his neighbors came to purchase seed. The superstitious actually believed that he had been somehow blessed by Heaven or that some special god of wheat had bestowed his favors on this particular brand.

As a matter of fact, what the farmer had done in his first experiment was to defy Nature's laws by preserving all his weaklings for seed. He thus gave them as good a chance as the strong and healthy; in good soil they reproduced their weakness and spread it throughout the entire race. Thus, his very efforts to improve the environment had been the chief cause of his *racial* disaster. But in his second experiment the farmer had obeyed Nature's laws in two directions: first, he had selected his weaklings and prevented them from reproduction; and second, he had given those which he selected for seed the finest possible opportunity and encouragement for individual development. Still further he continued this educational process with the children and grandchildren. In this way he secured all the benefit of his best heredity and his wonderful environment combined.

Now, men are not different from wheat. Biologists can find very little difference either in the breeding mechanism or in the physiological processes of reproduction of wheat and of men. There are differences in detail

but none in general process. Every plant which the farmer had planted in stern, austere soil had had to fight for its life. The ones that were naturally more vigorous, those that possessed a superior heredity of strength or rapidity of growth or resistance to drouth or excessive rain or cold, won out. The small grains and the weaklings never got a proper start, or if they did they were killed off. But in the warm, opulent, and stimulating environment of the rich, mellow soil, all sorts of grains survived—the good, bad, and indifferent alike—and *unfortunately they also reared of spring*. In time the weak were crossed with the strong. Thus the weakness spread even to the largest and most robust specimens; the entire race became degraded, and feebleness and disease perpetuated themselves.

Just so it is when men are in a state of brute savagery. Strange and contradictory as it may seem, they progress constantly in their mental, moral, and physical qualities. For the jungle administers a racial discipline to man which is bound even today to excite the unqualified admiration and esteem of the most ardent advocates of eugenics. The weak and the witless quickly pay their debt to nature. The fool literally perishes by his own folly; the wages of sin and departure from tribal custom and morality is instant death. The beasts of the field, the birds, and the insects of the air make their hourly raids and select the less agile the less cooperative, and the less courageous. The microbial diseases take their yearly toll and leave only those who by nature lack a lethal susceptibility to these invisible and therefore mysterious enemies.

In a wonderful picture of these early days when man was beginning his long and toilsome journey from brutality to culture, Doctor Ales Hrdlicka, our American

anthropologist, says: "Humankind is the greatest accomplishment of this world. What is its meaning? . . . It had a long, laborious, and difficult infancy, reaching far back into the Ice Age. What almost endless sacrifices man was obliged to make before he became sufficiently apt to cope with adversities and have a sufficient surplus of progeny to enable him to multiply and to spread to the more distant parts of the earth! His progress, his evolution were hard earned, and every step was paid for to the full."

When we try to picture this helpless, naked creature in that day, and think of the long red gantlet of evolution which he has successfully run, following always the loftiest vision within him toward some unknown goal, there should certainly be no reluctance, to our imaginations, in picturing the heights of intelligence and character to which he yet may climb. Archeology and anthropology have made it a definite certainty and not a theory that man's life in that far-away time was simply a bare-handed fight against a whole universe which seemed hostile to his every step. Women who could not succeed at childbirth always died, and their offspring, who would naturally inherit this disability, perished with them. Today we keep such women alive and save their offspring by surgical interference with nature. The halt, the maimed, and the blind, instead of being invited to tribal feasts, had to rustle for themselves. Every man for himself and the devil take the hindmost, was the unmitigated law.

When we think today of our feeble efforts to make men good in their natural qualities by Sunday schools, jails, prohibitions, and copybook maxims, our strivings seem puny indeed compared with those gigantic and bloody methods by which nature disciplines a terrified and

foolish creature into organic courage and moral health. Vice constantly purified the race, because it killed its votaries. No fatted calf was prepared for the prodigal. He starved upon the husks of his own folly. Thieves, violators of sex morals, and those who defied the tribal law were executed without chance to appeal to any higher court. The anti-social man who would not cooperate with his fellows paid the penalty of his foolhardiness and died alone. There were no sentimental women to carry flowers to the murderer, and no sentimental governor, bidding for votes in the next election, to grant a reprieve. Nature lay in wait day and night to enter the weak spot in every man's armor and when she found it, without mercy she shot her shaft to the death. As Professor F. C. S. Schiller, the philosopher, of Oxford, has suggested, when you see in the museum today the adult skull of some prehistoric human being, you may feel considerable assurance that its original inhabitant was a pretty smart man, since, in the good old days of natural selection, probably no fool ever lived long enough to leave an adult skull.

But this new thing, civilization, at once reversed—just as the rich soil did with the wheat—nearly every purifying agency which had worked such amazing benefit upon the body, the mind, and the character of the savage. Particularly, under this new regime, the strong, the intelligent, and the sympathetic had to devote their time and energies to caring for the weak, the witless, and the incompetent. The naturally civilized thus expended their energies in taking care of the naturally uncivilized and in giving them a chance to breed, the very privilege which nature had denied them in the jungle.

By the very process by which morality and sympathy exercise their natural functions they bred immorality into

the race. **Indeed**, I think it highly probable **that the** greatest social as well as biological disaster which civilization has worked upon man's constitution, especially upon his moral health, has been that it caused the man of great powers of social cooperation and rich moral emotion to take care of the man with little cooperative interest and social passion—to such an extent that the cooperative man did not have enough surplus energy left to reproduce his generous nature in an abundant brood of children, while the non-social and the non-cooperative man was by this very process especially set up in business as a going, breeding concern. It was precisely as though the glorious throughbreds in some famous stable were put to the plow to do the labor of the fields, while the scrubs and mongrels were kept in luxurious idleness and given the privilege of reproduction. The very softness of human sympathy and cooperativeness, which have been two of the chief agencies in making civilization, are also two of the chief agencies in breeding out the hard, robust, and virile virtues. In this way gentleness keeps brutality alive, and the milk of human kindness congeals in the racial veins. If the reader has any doubt upon this point and believes that it is merely a fanciful theory, I beg him to contemplate the history of the Ishmaelite family in America as worked out by Doctor Arthur Estabrook of the Carnegie Institution. A few generations ago, down in Old Virginia, this family was composed of but two members, Old Man Ishmael and his wife, helpless, anti-social, thriftless incompetents. By the finest thing in civilization, kind-heartedness, the Ishmaelites were kept alive; not only that, they were given a better chance to reproduce their kind than the school teachers, preachers, business men, skilled mechanics, doctors, and

lawyers who tried to teach their empty brains, clothe and shelter their filthy bodies, and by expensive legal procedures, prevent them from being hanged. There were two of them then; there are nearly twelve thousand now!

Perhaps until modern times this tendency of cooperativeness to breed non-cooperativeness, of social coherence to breed social incoherence, has not had extensive sway; but since the rise of humanitarianism it has been one of the outstanding features of both social and racial evolution. Social capacity is caring on an immense scale for social incapacity and giving the latter nearly all the aces in the biological deck. Human sympathy is thus steadily waging war against itself and by its own exercise is steadily weeding out its own agents. At the very least, the modern stage is set for just such a biological fiasco.

Man has come, therefore, in these burgeoning years of the twentieth century to the point where a critical examination by the biologists, psychologists, educators, and statesmen, of the natural agencies which have made him what he is—and which, if they could only be understood and controlled might make him something better than he is or than he otherwise could be—seems one of the most worth while as well as adventurous enterprises to which the intelligence and social capacity which he has already attained could possibly devote themselves.

## XVII

# ARCHITECTURE AND DEMOCRACY<sup>1</sup>

CLAUDE BRAGDON

Claude Bragdon, after serving an apprenticeship in architecture, began practising the profession in Rochester, New York, in 1893, where he continued to live for over thirty years. His home is at present in New York City. He has won a number of medals in competition, the President's Medal of the Architectural League of New York three times, and has designed many notable buildings\*. But he is a poet, an essayist, a critic, and a philosopher as well as an architect. Most of his writing has\* been concerned with the philosophy and aesthetic\* of architecture, especially the volumes *The Beautiful Necessity*, *Four-Dimensional Vistas*, *Architecture and Democracy*, and *The New Image*. In philosophy he has been identified with the theosophists, has written a history of the theosophical movements, and has lectured in theosophical circles\*. As a specialist in color and light he has been art director of the theatrical productions of Walter Hampden. The present essay, from *Architecture and Democracy*, illustrates well his philosophical bent. Mr. Bragdon is a typical example of the best of modern technicians, whose interests are as broad as knowledge itself.

I

### *Before the War*

The World War represents not the triumph, but the birth of democracy. The true ideal of democracy—the rule of a people by its *demos*, or group soul—is a thing unrealized. How then is it possible to consider or discuss an architecture of democracy—the shadow of a shade?

<sup>1</sup> Reprinted from *Architecture and Democracy*, copyright 1926, by permission of the author and special arrangement with Alfred A. Knopf, Inc., authorized publisher.

It is not possible to do so with any degree of finality, but by an intention of consciousness upon this juxtaposition of ideas—architecture and democracy—signs of the times may yield new meanings, relations may emerge between things apparently unrelated, and the future, always existent in every present moment, may be evoked by that strange magic which resides in the human mind.

Architecture, at its worst as at its best, reflects always a true image of the thing that produced it; a building is revealing even though it is false, just as the face of a liar tells the thing his words endeavor to conceal. This being so, let us make such architecture as is ours declare to us our true estate.

The architecture of the United States, from the period of the Civil War to the beginning of the present crisis, everywhere reflects a struggle to be free of a vicious form of feudalism, grown strong under the very aegis of democracy. The qualities that made feudalism endeared and enduring, qualities written in beauty on the cathedral cities of medieval Europe—faith, worship, loyalty, magnanimity—were either vanished or banished from this pseudo-democratic, aridly scientific feudalism, leaving an inheritance of strife and tyranny—a strife grown mean, a tyranny grown prudent, but full of sinister power the weight of which we have by no means ceased to feel.

Power, strangely mingled with timidity; ingenuity, frequently misdirected; ugliness, the result of a false ideal of beauty—these in general characterize the architecture of our immediate past: an architecture "without ancestry or hope of posterity," an architecture devoid of coherence or conviction, willing to lie, willing to steal. What impression such a city as Chicago or Pittsburgh might have made upon some denizen of those cathedral-crowned

feudal cities of the past we do not know. He would certainly have been amazed at its giant energy, and probably revolted at its grimy dreariness. We are wont to pity the medieval man for the dirt he lived in, even while smoke grays our sky and dirt permeates the very air we breathe; we think of castles as grim and cathedrals as dim, but they were beautiful and gay with color compared with the grim, dim canyons of our city streets.

Lafcadio Hearn, in *A Conservative*, has sketched for us, with a sympathy truly clairvoyant, the impression made by the cities of the West upon the consciousness of a young Japanese samurai educated under a feudalism not unlike that of the Middle Ages, wherein was worship, reverence, poetry, loyalty—however strangely compounded with the more sinister product of the feudal state.

Larger than all anticipation the West appeared to him—a world of giants; and that which depresses even the boldest Occidental who finds himself, without means or friends, alone in a great city, must often have depressed the Oriental exile: that vague uneasiness aroused by a sense of being invisible to hurrying millions; by the ceaseless roar of traffic drowning voices; by monstrosities of architecture without a soul; by the dynamic display of wealth forcing mind and hand, as mere cheap machinery, to the uttermost limits of the possible. Perhaps he saw such cities as Dore saw London: sullen majesty of arched glooms, and granite deeps opening into granite deeps beyond range of vision, and mountains of masonry with seas of labor in turmoil at their base, and monumental spaces displaying the grimness of ordered power slow-gathering through centuries. Of beauty there was nothing to make appeal to him between those endless cliffs of stone which walled out the sunrise and the sunset, the sky and the wind.

The view of our pre-war architecture thus sketchily presented is sure to be sharply challenged in certain quarters, but unfortunately for us all, this is no mere matter

of opinion, it is a matter of fact. The buildings are there, open to observation; rooted to the spot, they cannot run away. Like criminals "caught with the goods" they stand, self-convicted, dirty with the soot of a thousand chimneys, heavy with the spoils of vanished civilizations; graft and greed stare at us out of their glazed windows—eyes behind which no soul can be discerned. There are doubtless extenuating circumstances; they want to be clean, they want to be honest, these "monsters of the mere market," but they are nevertheless the unconscious victims of evils inherent in our transitional social state.

Let us examine these strange creatures, doomed, it is hoped, to extinction in favor of more intelligent and gracious forms of life. They are big, powerful, "necessitous," and have therefore an impressiveness, even an aesthetic appeal, not to be denied. So subtle and sensitive an old-world consciousness as that of M. Paul Bourget was set vibrating by them like a violin to the concussion of a trip-hammer, and to the following tune:

The portals of the basements, usually arched as *if* crushed beneath the weight of the mountains which they support, look like dens of a primitive race, continually receiving and pouring forth a stream of people. You lift your eyes, and you feel that up there behind the perpendicular wall, with its innumerable windows, is a multitude coming and going—crowding the offices that perforate these cliffs of brick and iron, dizzied with the speed of the elevators. You divine, you feel the hot breath of speculation quivering behind these windows. This it is which has fecundated these thousands of square feet of earth, in order that from them may spring up this appalling growth of business palaces, that hide the sun from you and almost shut out the light of day.

"The simple power of necessity is to a certain degree a principle of beauty," says M. Bourget, and to these structures this order of beauty cannot be denied, but even

this is vitiated by a failure to press the advantage home: the ornate facades are notably less impressive than those whose stark geometry is unmitigated by the grave-clothes of dead styles. Instances there are of strivings toward a beauty that is fresh and living, but they are so unsuccessful and infrequent as to be negligible. However impressive these buildings may be by reason of their ordered geometry and their weight and magnitude, and as a manifestation of irrepresible power, they have the unloveliness of things ignoble, being not the product either of praise, or joy, or worship, but enclosures for the transaction of sharp bargains—gold-bringing jinn of our modern Aladdins, who love them not but only use them. That is the reason they are ugly: no one has loved them for themselves alone.

For beauty is ever the very face of love. From the architecture of a true democracy, founded on love and mutual service, beauty would inevitably shine forth; its absence convicts us of a maladjustment in our social and economic life. A skyscraper shouldering itself aloft at the expense of its more humble neighbors, stealing their air and their sunlight, is a symbol, written large against the sky, of the will-to-power of a man or a group of men—of that ruthless and tireless aggression on the part of the cunning and the strong so characteristic of the period which produced the skyscraper. One of our streets made up of buildings of diverse styles and shapes and sizes—like a jaw with some teeth whole, some broken, some rotten, and some gone—is a symbol of our unkempt individualism.

Some people hold the view that our insensitiveness to formal beauty is no disgrace. Such argue that our accomplishments and our interests are in other fields, where we

more than match the accomplishments of older civilizations. They forget that every achievement not registered in terms of beauty has failed of its final and enduring transmutation. It is because the achievements of older civilizations attain their apotheoses in art that they interest us, and unless we are able to effect a corresponding transmutation we are destined to perish unhonored on our rubbish heap. Before attempting the more genial and rewarding task of tracing, in our life and in our architecture, those forces and powers which make for righteousness, for beauty, let us look our failures squarely in the face, and discover if we can why they are failures.

Confining this examination to the particular matter under discussion, the neo-futile architecture of our city streets, we find it to lack unity, and the reason for this lack of unity dwells in *a divided consciousness*. The tall office building is the product of many forces, or perhaps we should say one force, that of necessity; but its concrete embodiment is the result of two different orders of talent, that of the structural engineer and that of the architectural designer. These are usually incarnate in two different individuals, working more or less at cross purposes. It is the business of the engineer to preoccupy himself solely with ideas of efficiency and economy, and over his efficient and economical structure the designer smears a frosting of beauty in the form of architectural style, in the archaeological sense. This is a foolish practice, and can but result in failure. In the case of a Greek temple or medieval cathedral, structure and style were not twain, but one; the structure determined the style, the style expressed the structure; but with us so divorced have the two things become that, in a case known to the author, the structural framework of a great office building was deter-

mined and fabricated and then architects were invited to "submit designs" for the exterior. This is of course an extreme example and does not represent the usual practice, but it brings sharply to consciousness the well-known fact that for these buildings we have substantially one method of construction—that of the vertical strut, and the horizontal "fill"—while in style they appear as Grecian, Roman, Renaissance, Gothic, Modern French and what not, according to the whim of the designer.

With the modern tendency toward specialization, the natural outgrowth of necessity, there is no inherent reason why the bones of a building should not be devised by one man and its fleshly clothing by another, so long as they understand one another and are in ideal agreement, but there is in general all too little understanding, and a confusion of ideas and aims. To the average structural engineer the architectural designer is a mere milliner in stone, informed in those prevailing architectural fashions of which he himself knows little and cares less. Preoccupied as he is with the building's strength, safety, economy; solving new and staggeringly difficult problems with address and daring, he has scant sympathy with such inconsequent matters as the stylistic purity of a facade, or the profile of a moulding. To the designer, on the other hand, the engineer appears in the light of a subordinate to be used for the promotion of his own ends, or an evil to be endured as an interference with those ends.

As a result of this lack of sympathy and coordination, success crowns only those efforts, on the one hand, in which the stylist has been completely subordinated to engineering necessity, as in the case of the East River bridges, where the architect was called upon only to add a final grace to the strictly structural towers; or those, on

the other hand, in which the structure is of the old-fashioned masonry sort and the architect, faced with a familiar problem, has found it easy to be frank, as in the case of the Manhattan Storage Warehouse, on 42nd Street, New York, or in the Bryant Park facade of the New York Library. The Woolworth Building is a notable example of the complete coordination between the structural framework and its envelope, and falls short of ideal success only in the employment of an archaic and alien ornamental language, used however, let it be said, with a fine understanding of the function of ornament.

For the most part, though, there is a difference of intention between the engineer and the designer; they look two ways, and the result of their collaboration is a flat and confused image of the thing that should be, not such as is produced by truly binocular vision. This difference of aim is largely the result of a difference of education. Engineering science of the sort which the use of steel has required is a thing unprecedented; the engineer cannot hark back to the past for help, even if he would. The case is different with the architectural designer; he is taught that all of the best songs have been sung, all of the true words spoken. The Glory that was Greece, and the Grandeur that was Rome, the romantic exuberance of Gothic, and the ordered restraint of Renaissance are so drummed into him during his years of training and exercise so tyrannical a spell over his imagination that he loses the power of clear and logical thought, and never becomes truly creative. Free of this incubus, the engineer has succeeded in being straightforward and sensible, to say the least; subject to it, the man with a so-called architectural education is too often tortuous and absurd.

The architect without any training in the essentials

of design produces horrors as a matter of course, for the reason that, as Buddha said, "All sin is ignorance." The architect trained in the false manner of the schools, on the other hand, becomes a reconstructive archaeologist, handicapped by conditions with which he can deal only imperfectly, and imperfectly control. Once in a blue moon a man arises who, with all the advantages inherent in education, pierces through the past to the present, and is able to use his brain as the architects of the past used theirs—to deal simply and directly with his immediate problem.

Such a man is Louis Sullivan, though it must be admitted that not always has he achieved success. That success was so marked, however, in his treatment of the problem of the tall building, and exercised subconsciously such a spell upon the minds even of his critics and detractors, that it resulted in the emancipation of this type of building from an absurd and impossible convention—the practice, common before his time, of piling order upon order, like a house of cards, or by a succession of strongly marked string courses emphasizing the horizontal dimension of a vertical edifice, thus vitiating the finest effect of which such a building is capable.

The problem of the tall building, with which his predecessors dealt always with trepidation and equivocation, Mr. Sullivan approached with confidence and joy. "What," he asked himself, "is the chief characteristic of the tall office building? It is lofty. This loftiness is to the artist-nature its thrilling aspect. It must be tall. The force of altitude must be in it. It must be every inch a proud and soaring thing, rising in sheer exultation that from bottom to top it is a unit without a dissenting line." The Prudential (Guaranty) Building in Buffalo represents

the finest concrete embodiment of his idea achieved by Mr. Sullivan. It marks his emancipation from what he calls his "masonry" period, during which he tried, like so many other architects before and since, to make a steel-framed structure look as though it were nothing but a masonry wall perforated with openings—openings too many and too great not to endanger its stability. The keen blade of Mr. Sullivan's mind cut through this contradiction, and in the Prudential Building he carried out the idea of a *protective casing* so successfully that Montgomery Schuyler said of it, "I know of no steel-framed building in which the metallic construction is more palpably felt through the envelope of baked clay."

The present author can speak with all humbleness of the general failure, on the part of the architectural profession, to appreciate the importance of this achievement, for he pleads guilty of day after day having passed the Prudential Building, then fresh in the majesty of its soaring lines, and in the wonder of its fire-wrought casing, with eyes and admiration only for the false romanticism of the Erie County Savings Bank, and the empty bombast of the gigantic Ellicott Square. He had not at that period of his life succeeded in living down his architectural training, and as a result the most ignorant layman was in a better position to appraise the relative merits of these three so different incarnations of the building impulse than was he.

Since the Prudential Building there have been other tall office buildings, by other hands, truthful in the main, less rigid, less monotonous, more superficially pleasing, yet they somehow fail to impart the feeling of utter sincerity and fresh originality inspired by this building. One feels that here democracy has at last found utterance in

beauty: the American spirit speaks, the spirit of **the** Long Denied. This rude, rectangular bulk is uncompromisingly practical and utilitarian; these rows on rows of windows, regularly spaced and all of the same size, suggest the equality and monotony of obscure laborious lives; the upspringing shafts of the vertical piers stand for their hopes and aspirations, and the unobtrusive delicate ornament which covers the whole with a garment of fresh beauty is like the very texture of their dreams. The building is able to speak thus powerfully to the imagination because its creator is a poet and prophet of democracy. In his own chosen language he declares, as Whitman did in verse, his faith in the people of "these states"—"A Nation announcing itself." Others will doubtless follow who will make a richer music, commensurate with the future's richer life, but such democracy as is ours stands here proclaimed, just as such feudalism as is still ours stands proclaimed in the Erie County Bank just across the way. The massive rough stone walls of this building, its pointed towers and many-dormered chateau-like roof unconsciously symbolize the attempt to impose upon the living present a moribund and alien order. Democracy is thus afflicted, and the fact must needs find architectural expression.

In the field of domestic architecture these dramatic contrasts are less evident, less sharply marked. Domestic life varies little from age to age: a cottage is a cottage the world over, and some manorial mansion on the James River, built in Colonial days, remains a fitting habitation (assuming the addition of electric lights and sanitary plumbing) for one of our Captains of Industry, however little an ancient tobacco warehouse would serve him as a place of business. This fact is so well recognized **that**

the finest type of modern country house follows, in general, this or some other equally admirable model, though it is amusing to note the millionaire's preference for a feudal castle, a French chateau, or an Italian villa of the decadence.

The "man of moderate means," so called, provides himself with no difficulty with a comfortable house, undistinguished but unpretentious, which fits him like a glove. There is a piazza toward the street, a bay-window in the living-room, a sleeping-porch for the children, and a box of a garage for the flivver in the bit of a back yard.

For the wage earner the housing problem is not so easily nor so successfully solved. He is usually between the devil of the speculative builder and the deep sea of the predatory landlord, each intent upon taking from him the limit that the law allows and giving him as little as possible for his money. Going down the scale of indigence we find an itinerancy amounting almost to homelessness, or houses so abject that they are an insult to the very name of home.

Other aspects of our life which have found architectural expression fall neither in the commercial nor in the domestic category—the great hotels, for example, which partake of the nature of both, and our passenger railway terminals, which partake of the nature of neither. These latter deserve especial consideration in this connection, by reason of their important function. The railway is of the very essence of the modern, even though (with what sublime unreason) Imperial Rome is written large over New York's most magnificent portal.

Think not that in an age of unfaith mankind gives up the building of temples. Temples inevitably arise where the tide of life flows strongest; for there God

manifests, in however strange a guise. That tide is nowhere stronger than in the railroad, which is the arterial system of our civilization. All arteries lead to and from the heart, and thus the railroad terminus becomes the beating heart at the center of modern life. It is a true instinct therefore which prompts to the making of the terminal building a very temple, a monument to the conquest of space through the harnessing of the giant horses of electricity and steam. This conquest must be celebrated on a scale commensurate with its importance, and in obedience to this necessity the Pennsylvania Station raised its proud head amid the push-cart architecture of that portion of New York in which it stands. It is not therefore open to the criticism often passed upon it, that it is too grand, but it is the wrong kind of grandeur. If there is truth in the contention that the living needs of today cannot be grafted upon the dead stump of any ancient grandeur, the futility of every attempt to accomplish this impossible will somehow, somewhere, reveal itself to the discerning eye. Let us seek out, in this building, the place of this betrayal.

It is not necessarily in the main facade, though this is not a face, but a mask—and a mask can, after its kind, always be made beautiful; it is not in the nobly vaulted corridor, lined with shops—for all we know the arcades of Imperial Rome were similarly lined; nor is it in the splendid vestibule, leading into the magnificent waiting room, in which a subject of the Caesars would have felt more perfectly at home, perhaps, than do we. But beyond this passenger concourse, where the elevators and stairways descend to the tracks, necessity demanded the construction of a great enclosure, supported only on slender columns and far-flung trusses roofed with glass. Now

latticed columns, steel trusses, and wire glass are inventions of the modern world too useful to be dispensed with. Rome could not help the architect here. The mode to which he was inexorably self-committed in the rest of the building demanded massive masonry, cornices, moldings; a tribute to Caesar which could be paid everywhere but in this place. The architect's problem then became to reconcile two diametrically different systems. But between the west wall of the ancient Roman baths and the modern skeleton construction of the roof of the human greenhouse there is no attempt at fusion. The slender latticed columns cut unpleasantly through the granite cornices and moldings; the first century A.D. and the twentieth are here in incongruous juxtaposition—a little thing, easily overlooked, yet how revealing!

The New York Central terminal speaks to the eye in a modern tongue, with however French an accent. Its facade suggests a portal, reminding the beholder that a railway station is in a very literal sense a city gate placed just as appropriately in the center of the municipality as in ancient times it was placed in the circuit of the outer walls.

Neither edifice will stand the acid test of Mr. Sullivan's formula, that a building is an organism and should follow the law of organisms, which decrees that the form must everywhere follow and express the function, the function determining and creating its appropriate form. Here are two eminent examples of "arranged" architecture. Before organic architecture can come into being our inchoate national life must itself become organic. Arranged architecture, of the sort we see everywhere, despite its falsity, is a true expression of the conditions which gave it birth.

The grandeur of Rome, the splendor of Paris—what just and adequate expression do they give of modern American life? Then shall we find in our great hotels, say, such expression? Truly they represent, in the phrase of Henry James, "a realized ideal," and a study of them should reveal that ideal. From such a study we can only conclude that it is life without effort or responsibility, with every physical need luxuriously gratified. But these hotels nevertheless represent democracy, it may be urged, for the reason that every one may there buy board and lodging and mercenary service if he has the price. The exceeding greatness of that price, however, makes of it a badge of distinction which converts these democratic hostelries into feudal castles, more inaccessible to the Long Denied than if entered by a drawbridge and surrounded by a moat.

We need not even glance at the churches, for the tides of our spiritual life flow no longer in full volume through their portals; neither may the colleges long detain us, for architecturally considered they give forth a confusion of tongues which has its analogue in the confusion of ideas in the collective academic head.

Is our search for some sign of democracy ended, and is it in vain? No, democracy exists in the secret heart of the people, but it is a thing so new, so strange, so secret and sacred—the ideal of brotherhood—that it is unmanifest yet in time and space. It is a spiritual birth, and therefore it cannot perish, but will live to write itself in terms of beauty unlike any that the world has known.

## II

*After the War*

When the old world is sterile  
And the ages are effete,  
He will from wrecks and sediment  
The fairer world complete.

—*The World Soul: Emerson.*

He whom the World Soul "forbids to despair" cannot hope; and he who hopes tries ever to imagine that "fairer world" yearning for birth beyond this interval of blood and tears. Prophecy, to all but the anointed, is dangerous and uncertain, but even so, the author cannot forbear attempting some prevision of the architecture likely to arise from the wrecks and sediment left by the War. As a basis for this forecast it is necessary first of all briefly to classify the expression of the building impulse from what may be called the psychological point of view.

Broadly speaking, there are not five orders of architecture—nor fifty—but only two: *Arranged* and *Organic*. These correspond to the two terms of that "inevitable duality" which bisects life. Talent and genius, reason and intuition, bromide and sulphite are some of the names we know them by.

Arranged architecture is reasoned and artificial; produced by talent, governed by taste. Organic architecture, on the other hand, is the product of some obscure inner necessity for self-expression which is subconscious. It is as though Nature herself, through some human organ of her activity, had addressed herself to the service of the sons and daughters of men.

Arranged architecture in its finest manifestations is the product of a pride, a knowledge, a competence, a confidence staggering to behold. It seems to say of the works of Nature, "I'll show you a trick worth two of that!" For the subtlety of Nature's geometry, and for her infinite variety and unexpectedness, Arranged architecture substitutes a Euclidian system of straight lines and (for the most part) circular curves, assembled and arranged according to a definite logic. It is created but not creative; it is imagined but not imaginative. Organic architecture is both creative and imaginative. It is non-Euclidian in the sense that it is higher-dimensional—that is, it suggests extension in directions and into regions where the spirit finds itself at home, but of which the senses give no report to the brain.

To make the whole thing clearer it may be said that Arranged and Organic architecture bear much the same relation to one another that a piano bears to a violin. A piano is an instrument that does not give forth discords if one follows the rules. A violin requires absolutely an ear—an inner rectitude. It has a way of betraying the man of talent and glorifying the genius, becoming one with his body and his soul.

Of course it stands to reason that there is not always a hard and fast differentiation between these two orders of architecture, but there is one sure way by which each may be recognized and known. If the function appears to have created the form, and if everywhere the form follows the function, changing as that changes, the building is Organic; if on the contrary, "the house confines the spirit," if the building presents not a face but however beautiful a mask, it is an example of Arranged architecture.

The Gothic cathedrals of the "Heart of Europe"—now the place of Armageddon—represent the most perfect and powerful incarnation of the Organic spirit in architecture. After the decadence of medieval feudalism—synchronous with that of monasticism—the Arranged architecture of the Renaissance acquired the ascendant; this was coincident with the rise of humanism, when life became increasingly secular. During the post-Renaissance, or scientific period, of which the War perhaps marks the close, there has been a confusion of tongues; architecture has spoken only alien or dead languages, learned by rote.

But in so far as it is anything at all, esthetically, our architecture is Arranged; so if only by the operation of the law of opposites, or alternation, we might reasonably expect the next manifestation to be Organic. There are other and better reasons, however, for such expectancy.

Organic architecture is ever a flower of the religious spirit. When the soul draws near to the surface of life, as it did in the two mystic centuries of the Middle Ages, it *organizes* life; and architecture along with the other arts becomes truly creative—the informing force that comes not so much *from* man as *through* him. After the War that spirit of brotherhood, born in the camps—as Christ was born in a manger—and bred on the battle-fields and in the trenches of Europe, is likely to take on all the attributes of a new religion of humanity, prompting men to such heroism and renunciations, exciting in them such psychic sublimations, as have characterized the great religious renewals of times past.

If this happens it is bound to write itself on space in an architecture beautiful and new; one which "takes its shape and sun-color" not from the niggardly mind, but from the opulent heart. This architecture will of neces-

sity be organic, the product not of self-assertive personalities, but the work of the "Patient Daemon" organizing the nation into a spiritual democracy.

The author is aware that in this point of view there is little of the Scientific spirit"; but science fails to reckon with the soul. Science advances facing backward, so what prevision can it have of a miraculous and divinely inspired future—or for the matter of that, of any future at all? The old methods and categories will no longer answer; the orderly course of evolution has been violently interrupted by the earthquake of the War; igneous action has superseded aqueous action. The casements of the human mind look out no longer upon familiar hills and valleys, but on a stark, strange, devastated landscape, the plowed land of some future harvest of the years. It is the end of the age, the *Kali Yuga*—the completion of a major cycle. But all cycles follow the same sequence: after winter, spring; and after the Iron Age, the Golden.

The specific features of this organic, divinely inspired architecture of the Golden Age cannot of course be discerned by anyone, any more than the manner in which the Great Mystery will present itself anew to consciousness. The most imaginative artist can imagine only in terms of the already-existent; he can speak only the language he has learned. If that language has been derived from medievalism, he will let his fancy soar after the manner of Henry Kirby, in his *Imaginative Sketches*; if on the contrary he has learned to think in terms of the classic vernacular, Otto Rieth's *Architectur-Skizzen* will suggest the sort of thing that he is likely to produce. Both results will be remote from future reality, for the reason that they are so near to present reality. And yet some germs of the future must be enfolded even in the present

moment. The course of wisdom is to seek them neither in the old romance nor in the new rationalism, but in the subtle and ever-changing spirit of the times.

The most modern note yet sounded in business, in diplomacy, in social life, is expressed by the phrase, "Live openly!" From every quarter, in regard to every manner of human activity, has come the cry, "Let in the light!" By a physical correspondence not the result of coincidence, but of the operation of an occult law, we have in a very real sense let in the light. In buildings of the latest type devoted to large uses, there has been a general abandonment of that "cellular system" of many partitions which produced the pepper-box exterior, in favor of great rooms serving diverse functions lit by vast areas of glass. Although an increase of efficiency has dictated and determined these changes, this breaking down of barriers between human beings and their common sharing of the light of day in fuller measure is a symbol of the growth of brotherhood, and the search, by the soul, for spiritual light.

Now if this fellowship and this quest gain volume and intensity, its physical symbols are bound to multiply and find ever more perfect forms of expression. So both as a practical necessity and as a symbol the most pregnant and profound, we are likely to witness in architecture the development of the House of Light, particularly as human ingenuity has made this increasingly practicable.

Glass is a product still undergoing development, as are also those devices of metal for holding it in position and making the joints weather-tight. The accident and fire hazard has been largely overcome by protecting the structural parts, by the use of wire-glass, and by other ingenious devices. The author has been informed on

good authority that shortly before the outbreak of the War a glass had been invented abroad, and made commercially practicable, which shut out the heat rays, but admitted the light. The use of this glass would overcome the last difficulty—the equalization of temperatures—and might easily result in buildings of an entirely novel type, the approach to which is seen in the "pier and grill" style of exterior. This is being adopted not only for commercial buildings, but for others of widely different function, on account of its manifest advantages. Cass Gilbert's admirable studio apartment at 200 West 57th Street, New York, is a building of this type.

In this seeking for sunlight in our cities, we shall come to live on the roofs more and more—in summer in the free air, in winter under variform shelters of glass. This tendency is already manifesting itself in those newest hotels whose roofs are gardens, convertible into skating ponds, with glazed belvideres for eating in all weathers. Nothing but ignorance and inanition stand in the way of utilization of waste roof spaces. People have lived on the roofs in the past, often enough, and will again.

By shouldering ever upward for air and light, we have too often made of the "downtown" districts cliff-bound canyons—"granite deeps opening into granite deeps." This has been the result of no inherent necessity, but of that competitive greed whose nemesis is ever to miss the very thing it seeks. By intelligent cooperation, backed by legislation, the roads and sidewalks might be made to share the sunlight with the roofs.

This could be achieved in two ways: by stepping back the facades in successive stages—giving top lighting, terraces, and wonderful incidental effects of light and shade—or by adjusting the height of the buildings to the width

of their interspaces, making rows of tall buildings alternate with rows of low ones, with occasional fully isolated skyscrapers giving variety to the sky-line.

These and similar problems of city planning have been worked out theoretically with much minuteness of detail, and are known to every student of the science of cities, but very little of it all has been realized in a practical way—certainly not on this side of the water, where individual rights are held so sacred that a property owner may commit any kind of an architectural nuisance so long as he confines it to his own front yard. The strength of *is*, the weakness of *should be*, conflicting interests and legislative cowardice are responsible for the highly irrational manner in which our cities have grown great.

The search for spiritual light finds unconscious symbolization in a way other than this seeking for the sun. It is in the amazing development of artificial illumination. From a purely utilitarian standpoint there is almost nothing that cannot now be accomplished with light, short of making the ether itself luminiferous. The aesthetic development of this field, however, can be said to have scarcely begun. The San Francisco Exposition witnessed the first successful effort of any importance to enhance the effect of architecture by artificial illumination, and to use colored light with a view to its purely pictorial value. Though certain buildings have since been illuminated with excellent effect, it remains true that the corset, chewing-gum, beer, and automobile sky-signs of our Great White Ways indicate the height to which our imagination has risen in utilizing this Promethean gift in any but necessary ways. Interior lighting, except negatively, has not been dealt with from the standpoint of beauty, but of efficiency;

the engineer has preempted this field to the exclusion of the artist.

All this is the result of the atrophy of that faculty to worship and wonder that alone induces the mood from which the creation of beauty springs. Light we regard only as a convenience "to see things by" instead of as the power and glory that it inherently is. Its intense and potent vibrations and the rainbow glory of its color beat at the door of consciousness in vain. When we awaken to these things we shall organize light into a language of spontaneous emotion, just as music was organized from sound.

It is beside the purpose of this essay to attempt to trace the evolution of this new art form, made possible by modern invention, to indicate what phases it is likely to pass through on the way to what perfections; but that it is bound to add a new glory to architecture is sure. This will come about in two ways: directly, by giving color, quality, subtlety to outdoor and indoor lighting; and indirectly, by educating the eye to color values, as the ear has been educated by music, thus creating a need for more color everywhere.

As light is the visible symbol of an inner radiance, so is color the sign manual of happiness, of joy. Our cities are so dun and drab in their outward aspects, by reason of the weight of care that burdens us down. We decry the happy irresponsibility of the savage, and the patient contentment of the Oriental with his lot, but both are able to achieve marvels of color in their environment beyond the compass of civilized man. The glory of medieval cathedral windows is a still living confutation of the belief that in those far-off times the human heart

was sad. Architecture is the index of the inner life of those who produced it, and whenever it is colorful that inner life contains an inner joy.

In the coming Golden Age life will be joyous; and, if it is joyous, color will come into architecture again. Our psychological state even now alone prevents it, for we are rich in materials and methods to make such polychromy possible. In an article in a recent number of *The Architectural Record*, Mr. Leon V. Solon, writing from an entirely different point of view, divines this tendency, and expresses the opinion that color is again renascent. This tendency is so marked, and this opinion is so shared that we may look with confidence toward a color-evolution in architectural art. . . .

## XVIII

### AN AGE OF SPECIALIZATION<sup>1</sup>

H. G. WELLS

Perhaps it is not generally known that H. G. Wells took a degree in science at the University of London and taught biology for three years. He gave up teaching because of his growing interest in writing and his success as a journalist. Though he first wrote literary articles and criticisms, his first real success came as a result of his prophecies in romance of what the results of new discoveries in science would be. *The Time Machine*, *The War of the Worlds*, and *Tales of Space and Time* were of this type. But the variety of Mr. Wells's subjects shows that he is interested in everything. His socialistic tendencies are evident in such books as *A Modern Utopia*, *Men Like Gods*, and *The Dream*. He sees the present through the eyes of the future, and prefers to be regarded as a preacher and prophet rather than an artist. Even the *Outline of History* was written largely to embody his ideas of how history should be taught. Many of his novels are merely tracts in sugar-coated form, and he bluntly justifies his use of the novel for spreading propaganda. Perhaps his most enduring work, however, is in such novels as *Tono Bungay*, *Kipps*, and *The History of Mr. Polly*, where the story and the characters are their own justification. *Social Forces in England and America*, from which the present essay is taken, is a miscellaneous collection of articles, most of which were published first in magazines.

There is something of the phonograph in all of us, but in the sort of eminent person who makes public speeches about education and reading, and who gives away prizes and opens educational institutions, there seems to be little else but gramophone.

These people always say the same things, and say them in the same note. And why should they do that if they are really individuals?

<sup>1</sup> Reprinted from *Social Forces in England and America*, copyright 1914 by Harper and Brothers, by permission of the author.

There is, I cannot but suspect, in the mysterious activities that underlie life, some trade in records for these distinguished gramophones, and it is a trade conducted upon cheap and wholesale lines. There must be in these demiurgic profundities a rapid manufacture of innumerable thousands of that particular speech about "scrappy reading," and that contrast of "modern" with "serious" literature, that babbles about the provinces so incessantly. Gramophones thinly disguised as bishops, gramophones still more thinly disguised as eminent statesmen, gramophones K. C. B., and gramophones F. R. S. have brazened it at us time after time, and will continue to brazen it to our grandchildren when we are dead and all our poor protests forgotten. And almost equally popular in their shameless mouths is the speech that declares this present age to be an age of specialization. We all know the profound droop of the eminent person's eyelids as he produces that discovery, the edifying deductions or the solemn warnings he unfolds from this proposition, and all the dignified, inconclusive rigmarole of that cylinder. And it is nonsense from beginning to end.

This is most distinctly *not* an age of specialization. There has hardly been an age in the whole course of history less so than the present. A few moments of reflection will suffice to demonstrate that. This is beyond any precedent an age of change, change in the appliances of life, in the average length of life, in the general temper of life; and the two things are incompatible. It is only under fixed conditions that you can have men specializing.

They specialize extremely, for example, under such conditions as one had in Hindustan up to the coming of the present generation. There the metal worker or the cloth worker, the wheelwright or the druggist of yester-

day did his work under almost exactly the same conditions as his predecessor did it five hundred years before. He had the same resources, the same tools, the same materials; he made the same objects for the same ends. Within the narrow limits thus set him he carried work to a fine perfection; his hand, his mental character were subdued to his medium. His dress and bearing even were distinctive; he was, in fact, a highly specialized man. He transmitted his difference to his sons. Caste was the logical expression in the social organization of this state of high specialization, and, indeed, what else is caste or are any definite class distinctions but that? But the most obvious fact of the present time is the disappearance of caste and the fluctuating uncertainty of all class distinctions.

If one looks into the conditions of industrial employment, specialization will be found to linger just in proportion as a trade has remained unaffected by inventions and innovation. The building trade, for example, is a fairly conservative one. A brick wall is made today much as it was made two hundred years ago, and the bricklayer is in consequence a highly skilled and inadaptably specialist. No one who has not passed through a long and tedious training can lay bricks properly. And it needs a specialist to plow a field with horses or to drive a cab through the streets of Condon. Thatchers, old-fashioned cobblers, and hand workers are all specialized to a degree no new modern calling requires. With machinery, skill disappears and unspecialized intelligence comes in. Any generally intelligent man can learn in a day or two to drive an electric tram, fix up an electric lighting installation, or guide a building machine or a steam plow. He must be, of course, much more generally intelligent than the average bricklayer, but he needs far less specialized

skill. To repair machinery requires, of course, a special sort of knowledge, but not a special sort of training.

In no way is this disappearance of specialization more marked than in military and naval affairs. In the great days of Greece and Rome war was a special calling, requiring a special type of man. In the Middle Ages war had an elaborate technique, in which the footman played the part of an unskilled laborer, and even within a hundred years it took a long period of training and discipline before the common discursive man could be converted into the steady soldier. Even today traditions work powerfully, through extravagance of uniform, and through survivals of that mechanical discipline that was so important in the days of hand-to-hand fighting, to keep the soldier something other than a man. For all the lessons of the Boer War we are still inclined to believe that the soldier has to be something severely parallel, carrying a rifle he fires under orders, obedient to the pitch of absolute abnegation of his private intelligence. We still think that our officers have, like some very elaborate and noble sort of performing animal, to be "trained." They learn to fight with certain specified "arms" and weapons, instead of developing intelligence enough to use anything that comes to hand.

But, indeed, when a really great European war does come and lets loose motor-cars, bicycles, wireless telegraphy, airplanes, new projectiles of every size and shape, and a multitude of ingenious persons upon the preposterously vast hosts of conscription, the military caste will be missing within three months of the beginning, and the inventive, versatile, intelligent man will have come to his own.

And what is true of a military caste is equally true of

a special governing class such as **our** public schools<sup>2</sup> maintain.

The misunderstanding that has given rise to this proposition that this is an age of specialization, and through that no end of mischief in misdirected technical education and the like, is essentially a confusion between specialization and the division of labor. No doubt this is an age when everything makes for wider and wider cooperations. Work that was once done by one highly specialized man—the making of a watch, for example—is now turned out wholesale by elaborate machinery, or effected in great quantities by the contributed efforts of a number of people. Each of these people may bring a highly developed intelligence to bear for a time upon the special problem in hand, but that is quite a different thing from specializing to do that thing.

This is typically shown in scientific research. The problem or the parts of problems upon which the inquiry of an individual man is concentrated are often much narrower than the problems that occupied Faraday or Dalton, and yet the hard and fast lines that once divided physicist from chemist, or botanist from pathologist have long since gone. Professor Farmer, the botanist, investigates cancer, and the ordinary educated man, familiar though he is with their general results, would find it hard to say which were the chemists and which the physicists among Professors Dewar and Ramsey, Lord Rayleigh and Curie. The classification of sciences that was such a solemn business to our grandfathers is now merely a mental obstruction.

<sup>2</sup> The English "public schools," such as Eton, Harrow, and Rugby, are really rather exclusive institutions, corresponding somewhat to the expensive private "prep" schools in America.—*Editors.*

It is interesting to glance for a moment at the possible source of this mischievous confusion between specialization and the division of labor. I have already glanced at the possibility of a diabolical world manufacturing gramophone records for our bishops and statesmen and such-like leaders of thought, but if we dismiss that as a merely elegant trope, I must confess I think it is the influence of Herbert Spencer. His philosophy is pervaded by an insistence which is, I think, entirely without justification, that the universe, and every sort of thing in it, moves from the simple and homogeneous to the complex and heterogeneous. An unwary man obsessed with that idea would be very likely to assume without consideration that men were less specialized in a barbaric state of society than they are today. I think I have given reasons for believing that the reverse of this is nearer the truth.

# XIX

## THE MACHINE AND STANDARDIZA- TION<sup>1</sup>

RAYMOND B. FOSDICK

Raymond B. Fosdick is a lawyer, trained at Princeton and the New York Law School. He has been active in public affairs since 1918, when he was Commissioner of Accounts, City of New York. In 1913 he went to Europe as representative of the Rockefeller Bureau of Social Hygiene to study police organizations, and published the results of his study in *European Police Systems*. During the World War he held several responsible positions, among them the chairmanship of the Commission on Training Camp Activities of the War and Navy Departments. He was also special representative of the War Department in France in 1918-1919, and civilian aide to General Pershing. *Keeping Our Fighters Fit* and *American Police Systems* were published in 1918 and 1920. The present essay is from *The Old Savage in the New Civilization*, the theme of which is, as the preface states, "the new civilization into which modern machinery has plunged us and the struggle of mankind to keep abreast of it. Can the old savage be trusted with the tools which he has created?"

"I wholly disapprove of what you say and will defend to the death your right to say it."

—*Voltaire to Helvetius.*

The year 1776 was one of history's greatest turning points. It was marked by three events of almost immeasurable consequence: the Declaration of Independence, which opened a new chapter in the philosophy and practice of government; the publication of Adam Smith's *Wealth of Nations*, which laid the foundations of a new

<sup>1</sup> Reprinted from *The Old Savage in the New Civilization*, copyright 1928 by Doubleday, Doran and Company, Inc., by permission of the author and of the publishers.

economics; but chiefly, the invention by a man named Wilkinson of a cylinder that made Watt's new steam engine really work. It was this cylinder that changed the course of history and the destiny of man. The Age of Machinery stood beckoning on the threshold, and the human race walked into a revolution the termination of which we cannot foresee and the consequences of which we do not know how to measure.

For beginning with Watt's steam engine we have pressed excitedly from one invention to another, harnessing new forces to ever new mechanical appliances. In the first eagerness of our pursuit we did not know that we were following a one-way path along which there could be no retreat. Only within more recent years, as the machine process has fastened itself on every detail of our lives, have we sensed the difficulties into which we have so unwittingly wandered. We know now that we are not completely the masters of the machines we have created. Their pulsations we can control, but their consequences control us. They have risen like living things to dominate our entire civilization. They have called into being hundreds of millions of people who otherwise would not have been born. For these hundreds of millions they are the sole means of existence. Stop the machines and half the people in the world would perish in a month.

Modern industry has become a mechanical circle: we create machinery in order to increase production, only to find that increased production involves the necessity of creating more machinery. We produce in order that we may consume—and discover that we must consume in order that we may produce. In other words, the machine process has become both the means and the object of life. We are trapped by our own inventions. Our machinery

seems almost to be endowed with a soul—a vindictive life within itself: we must tend it or it will turn and rend us. The penalty of neglect is death.

It is this inescapable necessity of keeping the machines going that constitutes the great problem of modern economic life. Idle machines mean starvation to the millions of people whom they have brought into the world; active machines mean a surplus of goods beyond the immediate capacity of the race to consume. To this dilemma but one answer has been found: we have kept the machines going, and we have done it by whipping up the demand for their products, by stimulating new desires, by creating new wants. Our problem has become not how to make things but how to dispose of them; not how to produce goods but how to produce customers; not how to develop output but how to intensify consumption. Consumption must constantly keep ahead of production; the appetite for more things of every kind must be constantly stimulated. One desire must be used to breed another, and these new wants in turn must be fed and nourished so that other new wants may be born. As the editor of a New York newspaper recently remarked, the citizen's first importance to his country is no longer that of citizen but that of consumer. Thrift, which our fathers prized as one of the marks of wisdom, has become a virtue of doubtful social and economic value. If we would survive we must buy. "No matter how much the consumer who can afford to buy may resist," says Ralph Borsodi, "he must be made to eat more, to wear out more clothes, to take more drugs, to blow out more tires. He must consume, consume, consume, so that our industries may produce, produce, produce."<sup>2</sup> Says Garet Garrett: "To consume

<sup>2</sup> Ralph Borsodi, *The Distribution Age* (1927), p. 44.

more and more progressively—to be able to say in the evening: 'I have consumed more today than I consumed yesterday'—this now is a duty the individual owes to industrial society."<sup>3</sup>

Out of this solution of the dilemma with which the machine has confronted us have come all the phenomena of modern business: the pursuit of the buyer; the new science of advertising; the revolutionary methods in salesmanship involving the creation not only of new ways of wanting but of new habits of comfort and luxury; the cheapening of goods by mass production and distribution; the extension of credit systems; the development of new markets; the exploitation of backward races in an attempt to whet new appetites; and, finally, the struggle of rival imperialisms for new territories in which to sell.

By this necessity of disposing of the surplus product of the machine the life of our age is shaped and dominated. It motivates our political thinking and is the chief factor in controlling our social institutions. It gives rise to what is fast becoming the outstanding characteristic of our time—the standardization of life, the stereotyping of possessions and environment in terms of fixed molds. For if people are to be made to want what they have not wanted before, if sales are to be stimulated, goods must be cheap in price, and cheapness cannot be had without quantity production. The greater the quantity, the lower the cost. But quantity production makes *no* allowance for variation. The machine must be adjusted to turn out units that are exactly alike. The Ford machines in Detroit and elsewhere stamp out more than 2,000,000 auto-

<sup>3</sup>Garet Garrett, *Ouroboros* (1926), p. 32.

mobiles a year, more than 6000 a day, but within their types there is no difference between them. A single watch factory in the United States produces 1,260,000 watches annually, and they are always the same. One shoe manufacturer in New England turns out 4,000,000 pairs every year, that vary only by sizes. Cloth that comes from a given loom must be of one width, *one* color, and one texture; to vary these factors would add to the cost and thus discourage sales. Quantity production is necessary to keep the machine going, and the price of quantity production is the standardization of the product.

Toward this goal of standardization modern industrial methods are driving with determination. Standardization has indeed become one of the chief bulwarks of our economic life. It has been carried into every branch of industry. In the interests of economy we have standardized the sizes of bricks and blackboards and blankets. We have standardized the types and sizes of beds and mattresses and hotel chinaware. We have standardized bolts and nuts and milk bottles and bedsprings. The Department of Commerce is engaged in an effort to hasten the pace and widen the approach toward standardization, and commissions and committees, specially formed for that purpose, are now at work. Standardization is in the air. It even extends to standardized divorce laws and standardized building and plumbing codes.

How far this standardization has gone in altering the age-old habits and environment of mankind a moment's reflection will show. Indeed, it has world-wide implications. It touches human life everywhere. One sees with a feeling of dismay English caps adorning the heads of Chinese throughout their vast country. One sees them wearing European shoes and smoking European ciga-

rettes. What has happened is that by artificial stimulation the Chinese have been made to want something, the lack of which they have not previously appreciated. In order to keep the wheels moving in European factories, these new desires have been artificially created. Similarly Oriental civilization is rapidly taking to European clothing—so that we may look forward to seeing at least the masculine world arrayed in costumes which may possess a limited utilitarian value, but little else. So, too, the nations of the world are using the same breakfast foods, the same shaving soaps, and the same agricultural machinery. One hears the same music ground out from the same records by the same type of victrola in New York, Johannesburg, Calcutta, or Tahiti. Douglas Fairbanks, Charlie Chaplin, and the whole host of lesser notables are to be seen from Greenland to the south tip of New Zealand. If bathroom fixtures, ice cream sodas, and elevators represent an American contribution to the cultural life of mankind, then we can honestly say that our influence is spanning the world. No matter into what remote region he may travel, an American can scarcely get away from his own civilization. Even in out-of-the-way villages where the language is unfamiliar and the roofs are still thatched it follows him like a spectre, screaming of sewing machines, typewriters, collars, canned soups, cosmetics, and the products of five-and-ten-cent stores.

All around the world the habits and possessions of men are shaking down to fixed, common levels. In a country like the United States the process is even more pronounced. From east to west we eat the same kinds of food, wear the same styles of clothes, and live in the same types of houses or apartments. A hotel menu in San Francisco is exactly like a hotel menu in New York, just

as the suburbs of Portland, Oregon, look like the suburbs of Boston, Massachusetts, and the furniture and household utensils in New Orleans are identical with the furniture and household utensils in Minneapolis. The material side of life in America is fast developing a sameness, a uniformity, a monotony without parallel in history over so wide a geographical area. Quantity production, advertising, and the new methods of communication and transportation which modern machinery has created are breaking down the differences which hitherto have made of civilization a garment of many colors.

But it is not alone on the material side of life that standardization is developing. Out of this environmental uniformity is coming a spiritual and intellectual uniformity of far greater significance. Common physical surroundings and possessions seem invariably to foster common mental reactions. There is something about mass production and distribution of goods that suggests mass production and distribution of ideas. If standardization works in one field, why is it not applicable in another? If men have the same types of automobiles and food and furniture, why should they not have the same beliefs? If it promotes efficiency for men to dress alike and act alike, why does it not promote efficiency for men to think alike?

Whether or not there is a deliberate, conscious analogy between these two fields, certainly the same machine processes that have been employed in the one can be and are being employed in the other. The condition of our press furnishes an excellent illustration. The telegraph, the telephone, the wireless, the expensive up-keep of high-power machinery, the necessities of quantity production,

are revolutionizing the business of disseminating news. As one travels from east to west across the continent, picking up the local newspapers at the various stations where one stops, one realizes how far the processes of standardization have gone in enforcing a uniformity of taste and thought—the same comic strips, the same political cartoons, the same advice to the lovelorn, the same success hints, the same sermons, the same pictures, inspirational messages, recipes, health talks, and feature stories. More than all this froth, there are the same identically worded news items, syndicated from the same central point. Similarly, there are syndicated editorials on a great variety of topics, so that the whole country can hear the same thunder of applause or condemnation. If the papers are Republican in point of view, a common editorial emanating from Washington extols the virtues of the administration. If the papers are Democratic in persuasion, an editorial coming from the same city views with alarm the degenerate trend of events. From New York to San Francisco one cannot escape from syndicated opinion. On all sides there is the pressure for standardized thinking.

It is not only through the press, but through inventions like the radio that this development is being accentuated. Audiences of five and ten million people listening to the same voice are now almost daily phenomena. One station is linked with another, and the political, social, or moral ideas of one man travel with the speed of lightning from ocean to ocean, impressing their force with all the persuasive authority of the spoken word. And this single invention is merely in its infancy. The entire world will soon be linked together, so that the voices and opinions of men will search out the remote hiding places of the earth.

What is happening is that our machines—our power presses, our radios, our telephones, our telegraphs—are creating a mental propinquity from which the individual can scarcely escape. They are refining the technique of gregariousness. Solitude, physical and intellectual, has become a difficult achievement. Whether a man lives in a fishing village *on* the coast of Maine, or on a Nebraska farm, or on a ranch in the Sierra Nevadas, he lives in a crowd, preyed upon by the power of mass suggestion conveyed to him by the newspaper, the radio, the telephone, and other mechanical devices. For these instruments can re-create the psychology of crowds: they stimulate the collective consciousness; they speak with the authority of numbers; they shake down to a common level of intelligence; they override the critical judgment of the individual; they encourage group passion and hallucination. Through mechanical invention the vices of the crowd are being sown in wide fields. Intensified propinquity is accentuating and reinforcing the instincts of the herd.

This is the crux of the difficulty. As one of its curious consequences, the coming of machinery has clothed the opinions of the pack with a new authority. Man's natural instinct for uniformity, his distaste for intellectual individuality and independence, his habitual intolerance of variations from normal standards in the realm of habits and ideas, have taken on fresh sanctity as the machine process has knit together the members of the herd in a new unity. Consequently, conventional opinion tends to become more difficult to resist, and individual opinion more difficult to assert, as the development of science makes the collective judgments of the herd easier of ascertainment and expression. The step from mass production to mass thinking is, perhaps, shorter than we imagine.

Undoubtedly this development is accelerated by the necessities of the modern industrial state. As society grows more organic, more urban, under pressure of the machine, the processes of government acquire more importance. Because the individuals in the state are linked together in the production of goods, and the life of each depends upon the life of all, administration, regimentation, and organization take on an importance which they did not have in the pioneer or agricultural society. Consequently, in the machine age individual self-assertion is subordinated to collective action, and individual ideas and ideals give way to the ideas and ideals of the group. Whipped up by the community's instinct of self-preservation, mass opinion tends to override its minorities and crush out the lone voices.

One has only to watch the trend of our national life to appreciate the significance of this situation. Lynch law in the moral sense seems to be making a tremendous growth. Probably the war gave impetus to this development, for a nation in arms cannot tolerate the independent opinion of its minorities.

War requires a regimentation of the public mind into a flat uniformity of thought and feeling. From the moment that hostilities are declared, truth for its own sake is at a discount, and the concentrated massing of public opinion behind certain elemental ideas is as essential to success as ammunition and battleships. This involves the wholesale planting of selected news and opinion by a common method. It implies a public mind that is suggestible, receptive, uncritical, and unresisting. To accomplish the result every available and effective instrument is utilized:

pulpit, platform, moving pictures, and, especially, the press. The success of this propaganda process in the last war in shaping opinion and stimulating passion was startling. "Never before has the power of collective suggestion been wielded with so much deliberate skill. Individual opinion having been ruthlessly brushed aside, the public mind presented a smooth surface for common impressions." Here in the United States we are still too near 1917 to forget the methods by which, in the hour of crisis, the fighting instincts were aroused and the nation was welded into a single instrument of vengeance. "Man is subject to the passions of the pack in his mob violence and to the passions of the herd in his panics."<sup>4</sup>

Following the exhibition of mass emotion which the War presented, we have witnessed such phenomena as the organization and spread of the Ku Klux Klan, with its doctrine of mass hatred of Catholics, Jews, and negroes. We have seen the attempt to prohibit the teaching of evolution over wide areas and to enforce by law the acceptance of a biological principle to which an uneducated majority could subscribe—apparently on the theory that the ascertainment of truth is merely a matter of adding up voters. We have seen the weapons of the law used to impose particular standards of morality, to enforce particular codes of private conduct, to make the personal habits of the majority the personal habits also of the minority—in other words to standardize by threat of penalty the ideas and preferences of an entire nation. We have seen the passion for uniformity express itself in vast Americanization schemes whose avowed purpose has been the creation of a homogeneous mental type, citizens whose ideas about government, property, and the industrial proc-

<sup>4</sup>W. Trotter, *Instincts of the Herd in Peace and War* (1916), p. 115.

ess will conform to a standard acceptable to the majority. We have seen the authorities of industrial towns crushing peaceful strikes by the brutal use of police and sheriffs, invoking "public safety" as a justification for the denial of such elemental rights as assembly and free speech, gaining the support of the courts in their attempt to override minority opinion and make the world safe for industry. We have wearily followed the long procession of special days and special weeks set aside for mass contemplation and reverence, such as "Constitution Week," "Patriotism Day," "Flag Day," "For God and Country Day"—days in which (to quote from a pamphlet of instruction sent to school teachers) we "implant in the mind of every child the superiority of our government over all others and the sanctity of the principles and forms of government as originally planned by our forefathers." We have seen the scarehead pamphleteering of professional patriotic societies and the repressive tactics of various boards of education, colleges, and universities in their attempts to censor opinion and make the ideas of everybody measure up in Procrustean fashion to the standards to which the mass subscribes. "There seem to be some among us," said a recent spokesman of a so-called patriotic organization, "who are not satisfied with what the American people do and think. America is no place for knockers; and if these malcontents do not like our ideas and our ways of doing things, let them get out. The overwhelming majority of the American people is satisfied and that is enough."

Truly, majorities are in the saddle, and, as Walter Lippman says, "the rule of the majority is the rule of force. For while nobody can seriously maintain that the greatest number must have the greatest wisdom or the

greatest virtue, there is no denying that under modern social conditions they are likely to have the most power.<sup>0</sup>

We in this generation, therefore, face questions of great moment. They relate to the kind of world our children will inherit. How can we maintain the freedom of expression and initiative of the individual when the machine process is accentuating the old herd instinct for solidarity? How in the complex interrelations of our industrial civilization can we find room for the individual conscience? How far is it possible to combine the uniformity and large-scale operation which industrialism demands with the diversity, originality, and spontaneity which are the supreme contributions of the individual to society? Or, as Bertrand Russell phrases it, is it possible to have machinery in industry without having a mechanistic outlook in our thoughts and mental habits? Does the mass distribution of goods inevitably mean the mass distribution of ideas?

Let us say at once that we do not know how to answer these questions. The reconciliation of the group with the individual, of government with the individual, of government with liberty, has always defied solution. Mankind has always stoned its prophets and from Socrates through Servetus to the present time runs the long line of those who testify to the indestructible inheritance of intolerance. But these troublesome questions press with peculiar insistence in our generation, for the machine process which has accentuated the pack instinct for solidarity is reinforced by the enthusiasm of democracy for leveling human

<sup>5</sup> Walter Lippman, "Why Should the Majority Rule?" *Harper's Magazine* (March, 1926).

expression and imposing the measures of mediocrity. Democracy is "the apotheosis of the commonplace," the glorification of "the divine average." Its proud boast is that it makes all people equal and all life uniform. Its distinction is the absence of distinction. Too often, in Rodo's words, it is "an organized hunting party against everything that shows aptitude or daring wing to fly." Our generation, therefore, in attempting to find place for the individual conscience, is under double attack. All the forces of our time are driving toward standardization.

But although we can give no complete answer to the questions which face us, we can at least reassure ourselves as to the validity of the life lived from within, not forced into conformity to an external mechanism. We can reaffirm our faith in the principle that the state, the community, the family, and all other social institutions are merely a means to an end, and the end is the individual. We can repudiate, for ourselves at least, the Hegelian fallacy which has formed the basis of so large a part of our thinking in this generation: the belief "that the state, or the community as a whole, is capable of some different kind of good from that which exists in individuals, and that this collective good is somehow higher than that which is realized in individuals."<sup>6</sup> There is no social good apart from individual good. There is no such thing as collective happiness except as it comprises the happiness of individuals. We need a new definition of individualism in the interwoven complexities of our modern society. No one, of course, would subscribe to the *laissez faire* individualism of the nineteenth century with its emphasis upon acquisitive rights. Its day is gone, al-

<sup>6</sup> Bertrand and Dora Russell, *Prospects of Industrial Civilization* (1923), p. 262.

though its unhappy influence still persists. But the other extreme by which, in our thinking at least, we substitute a collective entity for the individual as an end to be served, is equally untenable. Somewhere in our scheme of things—indeed, at the very core of it—we must find place for the self-expression and spontaneity of persons. Somewhere we must lay the same emphasis upon the spiritual freedom of the individual in his pursuit of what he believes to be good, regardless of the opinion of the mass, that was laid by Buddha and Lao-tsze and Jesus of Nazareth.

But what about the majority? Our whole political system is based upon it. Reverence for it is interwoven with our thinking about democracy and government. It has acquired an authority that protects it from criticism. It has the same sanctity and infallibility that in medieval ages attached to the Church or the person of the king. For a hundred years or more people have grown up with the belief that deep within a fixed percentage of them there lay a sort of supernatural excellence, a divine judgment, a genuine gift of revelation. How can we talk of the right of the individual conscience when the opinion of the majority is hedged about with such hallowed traditions?

We need to be frank about this matter of majorities. Majority rule is a working plan by which we attempt in a rough way to determine policies of common concern. It is a political expedient by which, through the crude process of counting heads, we establish standards of action. It is acceptable because, as Lippman says, "we do not know any less troublesome method of obtaining a political decision." But to credit this clumsy device with a kind of centralized infallibility and to proclaim that the

voice of the people is the voice of God is to talk nonsense. More than that, it is vicious nonsense. Not only is it impossible to make virtue and wisdom dependent on fifty-one per cent of any collection of men, but the unintelligent mouthing of this old superstition serves to incite majorities against minorities on matters which do not pertain in any way to political decisions. Thus in recent years we have seen random majorities, collected and directed by organized propaganda, claiming jurisdiction over personal beliefs and personal habits, overriding minorities in fields where the collective judgment has no business to go. There is a silent referendum in the hearts and minds of men against which no impertinent pronouncement by a majority can stand. For knowledge, for truth, for a valid line between right and wrong, for an appreciation of spiritual values, one does not consult the greatest number. The coarse thumb and finger of mass opinion cannot shape to any given pattern the conscience and intellectual integrity of a man.

"No man," says George W. Martin, in a recent notable essay, "surrenders his whole being to the state. . . . The state is for him sovereign only when his conscience is not stirred against its performance. Whatever, therefore, concerns the conscience of a man, whatever brings its activity into operation, must, for the state, be sacred ground. As for the state itself, even where the opposition is small, it is probable that more is gained by the possession of that energy of character which is willing to offer challenge than by destroying it."<sup>7</sup> Said Lord Acton: "The great question is to discover, not what governments

<sup>7</sup>George W. Martin, "The Duty of Rebellion," *The Groton School Quarterly* (December, 1925).

prescribe, but what they ought to subscribe; for no prescription is valid against the conscience of mankind."

There is real truth in Herbert Spencer's observation that majorities are generally wrong. History is one long record of the scornful overturn of standards which the majority in the preceding generation had fought and died for. In Mr. Justice Holmes's classic phrase, "Time has upset many fighting faiths." It was the majority that stood behind the Spanish Inquisition. It was the majority that supported the burning of witches. It was the majority in America that upheld in election after election the institution of slavery and passed laws to suppress those who criticized it. It was the majority that rallied behind our unjust war on Mexico in 1845. It was the majority that prohibited the teaching of evolution in Tennessee. It was the majority on both sides that wallowed in blood from 1914 to 1918. It is perhaps the majority in the United States that is today opposing our entry into the League of Nations. Majorities are generally wrong. On all questions involving moral or ethical considerations they are pretty sure to be wrong. A people should be judged, said Emerson, not by its majorities, but by its minorities.

As a matter of fact, it is always the minorities that hold the key of progress. The still small voice speaking through the conscience of a man, bidding him choose obloquy and ostracism rather than conform, is, now and always, the hope of the race. It gave us Wycliffe and Huss and Savonarola and William Wallace and Bruno and Hugh Latimer and a host of heroes and prophets who challenged the mass judgments of their generations—

Lonely antagonists of destiny  
Who went down scornful before many spears.

What a glorious record it is, and how it relieves the drab and complacent pages of history! We see Socrates, on trial for his life, saying to his jury: "Athenians, either acquit me or do not acquit me; but be sure that I shall not alter my way of life, no, not if I have to die for it many times. . . . For no evil can happen to a good man in life or in death." We see John Hampden, who, when he drew his sword for liberty, "threw the sheath away," riding unafraid to his deathbed from Chalgrove Field with two bullet wounds in his shoulder. We see William Lloyd Garrison dragged through the streets of Boston with a rope around his neck, reaffirming in the next issue of his paper, the *Liberator*, the same pledge with which he began his work: "On this subject [of slavery] I do not wish to speak or write with moderation. I will not equivocate—I will not excuse—I will not retreat a single inch—and I will be heard." We see Theodore Parker in his pulpit in Boston thundering against the iniquity of our war on Mexico: "Your President tells us it is treason to talk so. Treason is it? I think lightly of what is called treason against a government. That may be your duty today, or mine. But treason against the people, against mankind, against God, is a great sin, not lightly to be spoken of." We see John Morley standing before a hostile, howling audience in Manchester, throwing back into its teeth his condemnation of the oncoming Boer War: "You may carry fire and sword into the midst of peace and industry: it will be wrong. A war of the strongest government in the world against this little republic will bring you no glory: it will be wrong. You may make thousands of women widows and thousands of children fatherless: it will be wrong. You may add a new province to your empire: *it will still be wrong.*" We

see Eugene Debs addressing his jury at Cleveland in words that Socrates might have used: "Gentlemen, I have no dispute with the evidence presented by the Government, no criticism of the counsel for the prosecution. I would not take back a word to save myself from the penitentiary. I am accused of obstructing the War. I admit it. I abhor war. I would oppose the War if I stood alone." We see Woodrow Wilson, not as the brilliant leader of a nation in arms, but as a grim, stricken man, leaning on a cane, saying to a group on his doorstep: "I have no anxiety for the League of Nations. It will take care of itself. My only anxiety is for the people of this country."

It is spirits like these that give dignity and worth and glory to human life. In the light of their high courage, Emerson's words take on a fresh significance: "Whoso would be a man must be a non-conformist."

Certainly a little more of this spirit of non-conformity would constitute a healthy admixture in American life. It would be a tonic to tone up the sluggish body politic. And it is sorely needed. For science has armed majorities with instruments of persuasion and coercion far more effective than any which they have previously wielded, and the individual must seek protection against the new usurpations of society. More completely than in the days of his grandfathers is he swallowed up in the collective mechanism; more menacing are the encroachments of the mass upon his inner freedom; more determined is the effort to establish the comfortable standard of the commonplace, and iron the intelligence, the emotions, and the will of everybody into a perfect smoothness. We need to

teach this new generation that "nothing is at last sacred but the integrity of their own minds." We need to say with Thomas Jefferson: "I have sworn upon the altar of God eternal hostility against every form of tyranny over the mind of man." We need to breed a skepticism of intellectual authority, a distaste for unruffled unanimities, a toleration of differences. We need to proclaim the glory of the Odyssey of the human spirit—the great adventures of thought, of passionate feeling, of aesthetic experience that constitute the birthright of mankind.

This is dangerous talk, some will say; these are wild and whirling words; this is the gospel of radicalism. On the contrary, it is thorough-going conservatism in the best sense of the term. For the enemies of society are not those who promote the processes of freedom, but those who try to block them. The danger to any civilization, or any living thing whatever, does not lie in progress, but in stagnation; not in growth, but in dry rot; not in change, but in the lack of change. The peril is that under pressure of entrenched and satisfied majorities we shall stone the prophets once too often. The danger is that we shall cling to the shell of our social and economic institutions too long after they have been outgrown, adhere to the husk and form of ideas too long after they are dead. For it is always to the outward symbol rather than to the inner principle that mass loyalty attaches itself, and the mob mind is quick to resent and if possible repress the lone voices that would call us back to reality. But these lone voices are the true conservatives. Their aim is not to destroy, but to preserve, not to kill the roots of the social order, but to prune the dead branches that sap its life. Says Clifford: "A race in proportion as it is plastic and capable of change may be regarded as young and

vigorous, while a race which is fixed, persistent in form, unable to change, is as surely effete, worn out, in peril of extinction." <sup>8</sup>

But our timid friends will not be satisfied. Change means unrest, they will say. Certainly it does. It is the business of man to be restless. It is the salvation of man that he is willing to "agitate" and "rock the boat." It is the glory of man that he is never satisfied, never content, eager for adventure in uncharted seas. Tranquillity is not life; it is stagnation. Not in hours of placidity do men build a Rheims Cathedral, or write a *Hamlet*, or push their boats across an unknown ocean to discover a new continent, but in hours of unrest. It is not security that develops the human spirit, but danger. "We must expect that the future will disclose dangers," says Professor Whitehead of Harvard in a striking passage in his recent book. "It is the business of the future to be dangerous. . . . The prosperous middle classes who ruled the nineteenth century placed an excessive value upon placidity of existence. They refused to face the necessities for social reform imposed by the new industrial system, and they are now refusing to face the necessities for intellectual reform imposed by the new knowledge. The middle class pessimism over the future of the world comes from a confusion between civilization and security. In the immediate future there will be less security than in the immediate past, less stability. It must be admitted that there is a degree of instability which is inconsistent with civilization. But, on the whole, the great ages have been the unstable ages." <sup>9</sup>

<sup>8</sup> Clifford, quoted by Frederick J. Teggart in *The Processes of History* (1918), p. 130.

<sup>9</sup> Alfred North Whitehead, *Science and the Modern World* (1926), p. 291.

We come, then, to an inevitable conclusion: in the realm of ideas standardization means death. Society cannot afford to stamp out variations from type; they are the biological steps by which the race advances. It is by the uniqueness, the differentiation, of a St. Francis, a Goethe, or a Darwin that we have any civilization at all. No society can be healthy which does not contain strong ingredients of non-conformity. No mass opinion has any claim to validity which is not continually challenged by the critical judgment of the individual.

In 1813 eighteen workman died on the gallows at York, England, on the charge of destroying machinery. They had resented the coming of the new civilization, they had feared the extension of its power, and they had struck out blindly to destroy it. It was a pathetic, foolish act. It was like trying to stop a glacier with a firecracker. Remorselessly and irresistibly the machine age has plowed its way across the life of man. Today we are in the complete grip of its gigantic force. Some of its consequences we know to be appalling: some we know to be good. In the midst of the revolution we can scarcely tell the good from the bad, so great is the upheaval. But this we know: that if as an incident of the machine process the opinion of the individual becomes more hampered in expression, and diversity and spontaneity are checked, then there are no compensatory advantages that can outweigh the disaster. Then, indeed, are we headed for spiritual bankruptcy. The things that make life worth preserving are not created by mechanism, nor are they born of organization, however efficient. They come only from the freedom of the human soul.

## XX

# SKILLS <sup>1</sup>

STUART CHASE

Among the many books that have appeared in the last decade attempting to appraise contemporary civilization, especially science and industry, two of the most widely read have been *Your Money's Worth*, by Stuart Chase and Frederick J. Schlink, and *Men and Machines*, by Stuart Chase. The latter is an attempt, based largely on statistics and first-hand observation, to judge the way machines are affecting civilization. The author, who attended college at the Massachusetts Institute of Technology and Harvard, was a partner in Harvey S. Chase Company, accountants, then an investigator of the meat industry and the packers under the Federal Trade Commission, and finally with the Labor Bureau, Inc., New York. He is a certified public accountant. *The Tragedy of Waste* is an earlier volume. In contrast to many modern prophets he is optimistic, and his style is cheerful, direct, and shrewdly humorous.

In a lonely spot in the Pacific, on the night of August 10, 1783, the ship *Antelope* drove on the rocks off Pelen Islands. The crew of fifty men, including sixteen Chinamen, all managed to get ashore. Before the *Antelope* had broken to pieces on the reef, an improvised dock-yard had been set up on the beach, and the construction begun of a schooner in which to escape. Three months from the time of the wreck, on November 12, the new ship was launched; and she put to sea with all the sometime castaways safely on board. So well was she built that she was later sold at Macao for 700 Spanish dollars.

It is doubtful whether any crew that sails the seas

<sup>1</sup> Reprinted from *Men and Machines*, copyright 1929 by The Macmillan Company, by permission of the author and of the publishers.

today could duplicate this performance. One fears that the sorriest kind of a craft, if indeed any craft at all, would be the result of its labors in as many months as you please. If the marooned contingent lost its radio, the chances are that it would stay marooned indefinitely. Nor in the circumstances, if food was scarce, would I elect to be a Chinaman.

The day of the all-around man has passed for dwellers in the Power Age. Certain work we can accomplish with a very pretty skill—aided by our instruments, with an incredible skill—but thrown on the resources of our bare hands and a few tools, few of us could ever build a schooner, or survive any serious predicament at all. Consider, again, the one hundred persons who landed from the *Mayflower*. They immediately established a community, a microcosm of the culture they had left. Disembark one hundred assorted shopkeepers, typists, plumbers, lawyers, factory hands, realtors, garage men, shipping clerks, upon a wild but fertile shore and what would happen? The results are too painful to contemplate. . . .

Instead of all-around skill, we have developed a great variety of special skills. This is admittedly to be deplored on desert islands, or in the event of a cosmic catastrophe—say the submergence of a continent—but who has set the date for the submergence? One does not wear a perpetual shroud because some day he must die. Why is it worse to live in a world of specialized skills if it means more peace, happiness, comfort, leisure, and no compensating psychic loss? Mr. Freeman<sup>2</sup> will say that there has been psychic loss, but biology does little to befriend him; he cannot prove it. Specialization forces men to be less

<sup>2</sup>Mr. Austin Freeman, author of *Social Decay and Regeneration* (1921).

anarchic and more cooperative, a clear gain economically, and, for all anybody knows, biologically as well.

Specialization can be carried to fantastic limits and become an active social disease. That it has been so carried, here and there in the modern world, is not to be denied, but this is no argument against specialization as such, but only against its misuse. In short, if I had to be wrecked on Pelen Island, I would choose the crew of the *Antelope*, but not confident of this disaster, I prefer to live in a suburb of New York, befriended by the experts who provide me with electric lights, a bathroom, and a furnace.

If skill *itself* has disappeared, the situation becomes far more serious. Were the old handiness to give way to nothing at all save a few simple repetitive motions, we should have plenty of cause for alarm. The muscles must be used, the hand and eye must have opportunity to coordinate, or something will surely go to smash.

The vast majority of medieval artisans merely followed designs made by master workmen—even as we find it in the Orient today. The level of monotonous work under machine technology for great classes of occupations is held by Mr. Beard<sup>3</sup> to be not worse but better than in the handicraft eras. Compare, he says, life in the latifundia of Rome or the cities of modern China with the life of a machine worker. "Those who are prepared to sacrifice the standard of living for millions to provide conditions presumably favorable to the creative arts, must assume a responsibility of the first magnitude."

Certainly many of the skills of England were ruptured

<sup>3</sup> Charles Austin Beard, author of *The Industrial Revolution* (1901) and *The Rise of American Civilization* (1927), and editor of *Whither Mankind* (1929).

when Watt's engines began to pound. Hand-loom weavers, chain and metal workers, tailors, cabinet makers, were driven first to reduce their prices, then to sweat the labor of all the members of their families, finally to the wall. "The destruction of the laborer's only capital, his skill, is one of the most pernicious effects of machinery, and when it happens, there is and can be no remedy; still if the changes are gradual, the evil consequences are not so great"—wrote Professor Nicholson in 1892. Skill in this connection means the loss of an opportunity to sell an acquired manual art at a price which would have obtained if machinery had never been introduced. The industrial revolution ruthlessly destroyed skill as so defined; nearly all the crafts were battered if not entirely undone.

But this only disposes of certain sorts of dexterity. Granted that they were ruined, did not others arise to take their places? They did. Consider the skilled intelligence needed to design, build, install, repair, and inspect the new engines and mechanical devices. The skilled machinist, boilermaker, toolmaker, engineer, fireman, plumber, electrician, made their first appearances on any stage. Meanwhile great numbers of the class which, in the earlier dispensation, would have been common laborers, diggers of ditches, went to work tending machines. Their tasks were repetitive and simple, but many observers believe that they took a step upward in the ladder. They had to know more than on the old job. "One odd thing," says the editor of the *American Machinist*, "about the introduction of machinery is that while it is designed primarily to accomplish the transfer of the skill of the expert hand operator to a mechanism<sup>1</sup>, and thus permit the employment of a less skilled and less expensive operator,

experience has shown that its introduction is accompanied by a general improvement in the type of worker. More brains are needed to keep the machine functioning than to handle a shovel." Meanwhile Henry Ford is convinced that the number of skilled craftsmen in proportion to the working population has greatly increased under the conditions brought about by the machine.

Barnett finds that certain inventions, far from being introduced gradually, come relatively very quickly, eliminating handwork in a few years. The stone-planer was fully introduced in seven years; the linotype in ten, the bottle-making machine in six. But the use of the machine, even at its maximum development, is always narrower than the entire handicraft; some marginal handworkers remain. . . .

We must remember that many of the articles produced by machines are new sorts of articles, unheard of in any other culture. They crowd in on top of the ancient family necessities of food, shelter, and clothing. In so far as this happens, the factory does not affect the handworker. He goes marching along, side by side with large-scale industry, doing his time-honored tasks of tailoring, house-building, metal-working, what not. Rabinowitz, writing in the *International Labor Review*, finds that in Europe today persons engaged in handicrafts far outnumber those in large-scale industry. "Not only is the number of handicraft workers still considerable, but it does not seem to have decreased, either absolutely or even relatively to population." His careful study makes it appear that the Jeremiahs have been talking through their hats when they bid us, with tears streaming down their faces, regard the dying artisan. There are more artisans today

**than** ever there were. This is certainly true of Europe, but more dubious for the United States—for which Rabinowitz has no figures.

Machines, strange to say, far from reducing the aggregate of handicraft work (again in Europe) have increased it. Their first effect was to reduce it, as the plight of the English artisans shows, but as the Power Age gained headway, inventing countless new processes and articles, additional tasks for the hand skills appeared. The factory machine does part of the work, leaving expert hand transformers, finishers, dressers, fitters to link the process together. Furthermore the factory has produced invaluable aids for handworkers in the form of sewing machines, knitting machines, motor-driven hand tools, and so stimulated the crafts. "Large-scale industry has provided certain old trades with the means of keeping alive and even of expanding. It has created and nurtured a large number of new handicrafts which flourish side by side with it, and which it has neither the will nor the power to absorb."

In short, regarding the whole field rather than one isolated trade, there is no conclusive evidence that the machine is seriously reducing the number of skilled handworkers. Rabinowitz looks for their survival for an incalculable period in the future.

Let us now turn to the new skills, never before seen on land or sea, which the industrial revolution has called forth. . . .

The following table serves as a rough indication of certain of the old skills which the machine displaced in part and the new skills which the machine has created. On the assumption that Rabinowitz is correct, and that there has been no net decline in handicrafts, is there any doubt

that the workers of the Power Age are, in the aggregate, more skilled, if more specialized, than the artisans of any previous culture?

*The old hand skills:*

Spinning	Stoneworking
Weaving	Pottery making
Smithing	Printing
Woodworking	Glass-blowing
Shipbuilding	The household arts

*The new Power Age skills:*

Engine driving	Machine printing
Track inspecting	Radio engineering
Chauffeurage	Laboratory research
Garage work	Prospecting and drilling
Steel construction work	Caisson work
Electric power servicing	Airplane making
Telephone and telegraph work	Flying
Camera and motion-picture work	Modern navigating
Production pre-planning	Modern tool-making
Sanitary engineering	Accounting
Medical, dental, and surgical work	Stenographic work
	Barbering and hairdressing
	Publicity work

The list of modern skills could be indefinitely extended, utterly overwhelming in volume and variety the skills which have declined. The principle often touched upon earlier applies here and with equal force. When the machine controls the man, his skill evaporates; when he guides or controls the machine—as in many of these new occupations—his skill remains, and may even be enhanced.

There is one department where it seems to me that skill has been lost with no offsetting compensation. We have taken many of the housewife's tasks into the factory

and left her to gossip, play bridge, buy more clothes than she needs, and make a sad spectacle of herself at so-called culture clubs. The poor woman has been left high and dry, after the children are big enough to dress and care for themselves—and there are not as many to dress as there used to be. The problem of the restless, neurotic middle-class woman is based on the fact that the machine has stripped her of her ancient skills, leaving nothing but boredom in their place. Nature has ever abhorred a vacuum.

For those gainfully employed there has obviously been no decline in skill. The robot class is relatively far smaller than that of the old-time slave or serf. The modern farmer must know more than his ancestors, and much of his new knowledge is enforced by the new machines—the tractors and the harvesters—he is called upon to operate.

The psychological effects of these new skills are a more dubious matter. As Simon Patten has pointed out in his theory of product and climax, the old artisan saw the product of his skill culminating immediately before his eyes. Satisfaction came as he worked. The modern designer may not see the tangible product of his labor for months; indeed he may never see it. Satisfaction is delayed, or completely *thwarted*. Similarly much specialized work of the highest skill is only one tiny part of a great process, and often the worker has no picture of the whole process, or where his task fits into it. The machine has thus operated to split the psychological unity of work and result, and to take away a greater or less amount of the craftsman's completed satisfaction. On this score the gloomy prophets have a case, but it needs far more investigation before we can know how serious it is.

## X XI

### W H A T I S S U C C E S S ? <sup>1</sup>

WILLIAM RALPH INGE

The Very Reverend William Ralph Inge, often called "the gloomy Dean" because of the pessimistic tone of much of his preaching, has been Dean of St. Paul's Cathedral, London, since 1911. His career has been that of student, lecturer, and great divine. He was a prize scholar and medalist at Cambridge, and then a master at Eton and fellow at King's College; later he became a fellow of Hertford College, Oxford, and in 1907 was made professor of divinity at Cambridge. He was Paddock Lecturer in New York in 1906 and Lyman Beecher Lecturer at Yale in 1925. The originality of his sermons and writings and his caustic criticisms of many modern tendencies are perhaps best illustrated in *Outspoken Essays* and *Lay Thoughts of a Dean. Labels and Libels*, from which the present chapter is taken, is a miscellaneous collection of essays on various aspects of modern life.

The word "success" is written on the heart of every good American, and floats as an ideal before the minds of most young Englishmen. "Be Christians and you will be successful," exclaimed the president of an American university to his students. It does not sound quite like the Beatitudes, but I daresay it helped the young men who heard it to live cleanly, to shun smuggled wood-alcohol, to work hard and render efficient "social service." There are many young people who are the better for being told that success is within their reach. Nothing distresses an English college tutor more than to see the young man with *two* talents preparing his napkin to hide

<sup>1</sup> Reprinted from *Labels and Libels*, copyright 1929 by Harper and Brothers, by permission of the author and of the publishers.

them in. Ambition may be the last infirmity of noble minds; but it is a splendid spur for the average man. This is why the Americans deliberately try to engender the *superiority* complex. The subject of it is sometimes a rather intolerable person; but he is ostentatiously happy, and he gets things done.

But what is success? We know what Samuel Smiles meant by it. The good apprentice comes up to London with half a crown in his pocket. By unremitting attention to his humble duties he wins the confidence of his employer, becomes a partner, marries his employer's daughter, and dies a peer and a millionaire. This is success, tangible and incontrovertible.

A prime minister is also unquestionably a successful man. A judge, an archbishop, a field-marshal, a "best-seller," is admitted to have been successful, in his own line. He would probably, most people suppose, have preferred to be a millionaire or a prime minister, if he had known how to do it, but he has played his cards well. There are no doubt other ways of spending one's life, which some people find attractive. But the world does not speak of success in connection with them. Robert Browning thought that the grammarian, who spent his life over the niceties of Greek syntax, had resolved to win "heaven's success or earth's failure," and that he therefore exclaimed once for all, to achieve a horrible rhyme, "Hence with life's pale lure." I have known several grammarians; I once wrote a Latin grammar myself; and I fear they are simply creatures of habit. They have no visions of unfading crowns; they would be miserable if they were separated for a day from their desks and their books.

Most people would assent to the saying that happiness

is "our being's end and aim"; and yet, curiously enough, they do not identify success with happiness. If they did they would have to revise their standards of success rather drastically. It has been said that the happy man has the best of reasons for being happy, namely, the fact that he is so. That may be true; but the contented man is severely handicapped in the race of life. He who wants nothing will get nothing. Ambition is occasionally the luxury of the fortunate, but it is more often the consolation of the unhappy. Borrow in *Lavengro* would even have us believe that a tendency to mental depression may be a man's best friend. "Thou wouldst be joyous, wouldst thou? Then be a fool. What great work was ever the result of joy, the puny one? Who have been the wise ones, the mighty ones, the conquering ones of the earth? The joyous? I believe it not."

The biographies of the great on the whole confirm Borrow's opinion, though it may be too rhetorically expressed. We generally find that in early life they have been unhappy; not merely impecunious and driven to fight hard for their own hands, but depressed and anxious beyond what the circumstances justified. And often, though not always, they have owned that the happiest period of their lives was the time of their first struggles and quite insignificant successes. Sometimes the big victories have brought only disillusionment. They have done something, but it was not what they meant to do. Their bodily organization, it may be, has broken down under the strain; or they have formed habits which prevent them from enjoying success, when it has come to them. We have met some successful men who seem to be happy. They have aimed at a rather low type of achievement, or after beginning with noble ambitions, they have come

to be content with the world's honors, which they have gained. But no one could maintain that the successful as a class are conspicuously happy.

Augustine Birrell, in one of the most famous of his *Obiter Dicta* essays, declares that most great men hate their greatness, because it is not of the kind which they most admire. Gray, an exquisitely finished poet and incidentally a college don, would have liked to be a successful general, but he wrote the *Elegy in a Country Churchyard*, and took no Quebec. Wolfe did take Quebec, and while he was doing it was heard to remark that he would rather have written Gray's *Elegy*. Carlyle, whose motto was "Blows, not words," sang the praise of silence in about thirty-six octavo volumes. Invalid men of letters—cripples like W. E. Henley or consumptives like Robert Louis Stevenson—let their imaginations run riot in scenes of violence and bloodshed. I think, however, that Mr. Birrell has made an amusing point rather than proved a general truth. Most great men have believed in the work of their choice, whether active or artistic or contemplative.

Putting aside the test of happiness, which clearly is no criterion, since those who have it seldom become great, and those who become great have either put happiness aside or are too busy to think whether they are happy or not, we find other troublesome questions waiting for an answer.

Why do we say, "All's well that ends well"? Why is the end of a man's career more important than the beginning? Are we to call a man successful who has spent an extremely strenuous and uncomfortable life in the pursuit of power or place or riches, and who at last gains his object only to have the cup snatched from his

lips by death, disablement, or domestic misfortune? Was St. Paul not a successful man, because he was beheaded? Or Napoleon, because he died at St. Helena? Or Raphael and Mozart, because their lives were cut short at thirty-six? Two men are in love with the same woman. One of them seizes her; the other writes a *Vita Nuova* about her. Which is the successful lover? Beatrice's husband probably found her a very ordinary young woman; Dante possessed the ideal Beatrice, with Gemma Donati to satisfy his less spiritual needs. However we may answer this last question, the saying, "Call no man successful before he dies," will not work. Many men have died rather early, and some rather miserably, after putting to their credit some great achievement for which posterity owns itself in their debt.

The question of posthumous fame as an ingredient in success remains rather difficult. Rogers believed himself a great poet, and thoroughly enjoyed his reputation; he is now forgotten. If Wordsworth had died at fifty, he would have received scarcely any recognition in his lifetime; he is now secure on his pedestal. The French Millet had not enough to eat; the English Millais made £30,000 a year. Which is the more successful, the painter of *The Angelus*, or the painter of the very creditable canvases which found so ready a market?

These problems, which cannot be solved with any precision, should lead us to look for a less external standard of success than those which we have suggested while following Samuel Smiles, a prophet of whom in these socialistic days we are becoming ashamed. Success, we shall agree, is something that a man is or becomes, not something that he takes or gets. We are brought back to the old question whether it is better to be or to seem,

which Socrates discusses in the first **book** of Plato's *Republic*. His conclusion of course is that it is better to be just than to be thought so, even if the pretender dies loaded with honors, and the truly just man, after suffering every kind of ill-usage is—crucified. To read that sentence, written in the fourth century before the Christian era, helps us to understand what Nietzsche meant when he said that Plato was a Christian before Christ. To be successful is to have made a right use of our life; to ask what we have got by it is irrelevant,

This new criterion will make some of Smiles's heroes, and some of the men whom Lloyd George delighted to honor, look rather foolish. The "self-made" man, as an American said, thereby relieves the Almighty of a very heavy responsibility. His success, on inspection, turns out to have been too dearly bought. Bacon, who was not too scrupulous himself, writes: "The rising unto Place is laborious; And by Paines men come to greater Paines; And it is sometimes Base; And by Indignities men come to Dignities. The standing is slippery, and the Regresse is either a downfall, or at least an Eclipse, which is a Melancholy Thing." The risk of a fall, however, is not the chief evil. Climbing and crawling are performed in much the same attitude.

It is astonishing how easily acts of baseness, if they are not discovered, are forgotten. The passions of youth, and the ambitions of middle-age, grant dispensations more readily than the most courtly father confessor. The things that pinch the conscience of the man of the world are his miscalculations and his gaucheries, not his pre-meditated crookednesses. But sins that are forgotten are not therefore forgiven; they are just the sins which are not forgiven. When a man has acted meanly and profited

by it *his* sense of values is perverted; a double heart, as a seventeenth-century divine says, makes a double head. The whole character of the successful worldling suffers a fatty degeneration; it becomes vulgar, narrow, and uninteresting. The Psalmist speaks of men to whom God gives their desire, and sends leanness withal into their souls. A lean soul in an overfed body is an unlovely spectacle, and not an unusual one.

But even if the conscience is not blunted by ignoble arts, the successful career is often an unjust and antisocial one. How large a part of success consists in choosing a line of work which by some accident is overpaid; in seizing an advantageous position, such as a temporary monopoly; in appropriating profits which cannot be said to have been earned; in tripping along unencumbered, while others have to carry the heavy baggage! It is this kind of social injustice which rouses the indignation of the less fortunate; and we can hardly deny that this kind of success is more praised, envied, and sought after than it should be. The man himself may not see that his career is open to criticism; but this crass kind of success is not good for the character. We can see that even without the warnings in the Gospels. Outside the field of commerce, very much of what the world calls success is won by adroitly annexing the credit which belongs to some one else, or which should be shared among many. Socrates's dilemma, to be or to seem, probes very deeply when we examine the foundation of what we usually consider success.

But another question suggests itself. If success consists in making the most and the best of our natural gifts, how is it compatible with specialization, and who can do anything great without specializing? We may

envy the harmoniously developed man, with his numerous interests, but these are not the men to whom the world owes most. It would be delightful to be a Sir John Lubbock, keen about everything from bees to banking, or an Andrew Lang, who could write equally well on golf and on folklore, besides translating Homer. But did not even the greatest of all universal geniuses, Leonardo da Vinci, fritter away some of his unrivaled talents by trying too many things and leaving them unfinished? My view about specializing is that if the object be mean, selfish, or unworthy, the success won by concentration has to be paid for, and at a high price. The character is warped, cramped, and stunted. But when a man deliberately resolves to limit himself for the sake of some worthy task to which he conceives himself to be specially called, the sacrifice is not so great as it appears to be, nor so great as he was willing to make it. The eternal values, Goodness, Truth, and Beauty, overlap one another, so that by faithfully following one of them, as the saint or the scientific worker or the artist does, we do not wholly forfeit what we might have learned from the other two. Every noble endeavor takes on a kind of universality, so that a broad mind is not much cramped by a narrow sphere. We penetrate further toward the heart of things by learning one subject thoroughly than by acquiring a smattering of many.

It is a truism that there can be no success without a unitary purpose in life. But most people have none. Men may be divided into those who have a plan for their lives, and those who have none. The plan may be a mean one—enough has been said of this; but those who have no purpose at all swell the ranks of the unsuccessful. It is less of a truism to add that for those who have an ideal

it is not the attainment of the purpose that makes success. "Everyone may win who tries, for the struggle is the prize,"<sup>71</sup> Success, for the man with an ideal, is nothing external, which chance may give and chance take away. It is no definite limited achievement, which we can enjoy or forget when we have won it. It is a growing and expanding life, which because it is spiritual in its nature, stretches into infinity, far beyond our knowledge, and even beyond our desire. The beatified spirit, in the words of Plotinus, is "always attaining and always aspiring." Or in the more familiar words of St. Paul, "I count not myself to have apprehended; but one thing I do; forgetting those things that are behind, and reaching forward to those things that are before, I press toward the mark for the prize of the high calling of God in Christ Jesus." There can be no boredom in such a life.

There can be no boredom; but failure is an ingredient in this kind of success. "Our business, in this world," wrote Stevenson, "is not to succeed, but to continue to fail in good spirits." He suggested for his epitaph, "Here lies one who meant well, tried a little, failed much," or "There goes another faithful failure." Browning's development of this thought in *Rabbi Ben Ezra* is too well known to quote. I will transcribe instead a few lines by the schoolmaster-poet, T. E. Brown:

The man, that hath great griefs I pity not;  
'Tis something to be great  
In any wise, and hint the larger state,  
Though but the shadow of a shade, God wot.  
To him the sorrows are the tension-thrills  
Of that serene endeavor  
Which yields to God for ever and for ever  
The joy that is more ancient than the hills.

Have I been too homiletic? Then let me in conclusion come back to earth, and ask what is the type of a successful life, not strictly from the religious point of view, but taking a higher and more rational standard than that of Samuel Smiles. Christ, in his great encomium of John the Baptist, implied that a great prophet is the greatest of all men born of women. So be it; but the prophet is a man inspired, and the spirit bloweth where it listeth. Next to a great religious genius, what is the most thoroughly satisfying type of success? If we are young enough to choose our line in life, how shall we set about it? First, we must choose some worthy and congenial task, the partial fulfilment of which may be within our reach. "Blessed is he who has found his work," says Carlyle; "let him seek no other blessedness." Then, we must devote ourselves to it, making our work our play, as any noble work may be and ought to be. An excellent example of a life wisely planned is that of a not wholly admirable character, Gibbon the historian. His immortal history was just within the compass of his genius; he had just time to finish it, and he finished it. But even more enviable, it seems to me, are the lives of Charles Darwin, Sir Francis Galton, and Pasteur. There is no finality about scientific discovery; the very greatest men, even a Newton and a Darwin, are proved in time not to be infallible. But we have argued that finality is no part of success. The man who has advanced the frontiers of knowledge has done all that a man can do in one life. More insecure and ephemeral are the achievements of the great "practical" men, the men of action, like Julius Caesar, Napoleon, and Bismarck. Their methods certainly, and their aims probably, are less pure than those of the scientific discoverers and men of learning. The voice of the

people would place them far above the students and thinkers; but so would not I. Such men usually take out of the common stock more than they put in, and they cause a great deal of human suffering. The time may come when our perverse fellow-men will come to honor their benefactors more than their destroyers and plunderers, and will think a skilled craftsman more worthy of respect than an emperor Napoleon, or a "Napoleon of finance." But this would involve such revolutionary changes in our estimates of success that I shrink from following up the subject any further.

## XXII

# DREAMS AND FACTS<sup>1</sup>

BERTRAND RUSSELL

It was inevitable that Bertrand Russell should be a nonconformist. His father, a son of Lord John Russell, wished him to be brought up as an agnostic; instead of being sent to school he was taught by governesses and tutors. At Cambridge, where he was a very shy undergraduate, he won distinction in philosophy and in 1895 was elected a fellow of his college. From then until the outbreak of the World War he was principally engaged in study and writing, especially in the fields of philosophy and mathematics. Occasionally he went abroad, and at times he dabbled in politics. When the War broke out, he became an active champion of conscientious objectors, was fined, and finally imprisoned for six months. Since the War he has traveled and lectured widely, in the United States in 1924 and 1927, and has twice stood for Parliament as a Labor candidate. With his wife, Dora Russell, also a well-known writer, he started in 1927 a school for young children. Some of his books are *The Analysis of Matter*, *An Outline of Philosophy*, and such popular expositions of science as *The A B C of Atoms* and *The A B C of Relativity*. *Skeptical Essays*, from which the present essay is taken, is a collection which illustrates vividly the author's unconventional opinions.

I

The influence of our wishes upon our beliefs is a matter of common knowledge and observation, yet the nature of this influence is very generally misconceived. It is customary to suppose that the bulk of our beliefs are derived from some rational ground, and that desire is only an occasional disturbing force. The exact opposite

<sup>1</sup> Reprinted from *Skeptical Essays*, copyright 1928 by W. W. Norton and Company, Inc., by permission of the author and of the publishers.

of this would be nearer the truth: the great mass of beliefs by which we are supported in our daily life is merely the bodying forth of desire, corrected here and there, at isolated points, by the rude shock of fact. Man is essentially a dreamer, wakened sometimes for a moment by some peculiarly obtrusive element in the outer world, but lapsing again quickly into the happy somnolence of imagination. Freud has shown how largely our dreams at night are the pictured fulfillment of our wishes; he has, with an equal measure of truth, said the same of day-dreams; and he might have included the day-dreams which we call beliefs.

There are three ways by which this non-rational origin of our convictions can be demonstrated: there is the way of psychoanalysis, which, starting from an understanding of the insane and the hysterical, gradually makes it plain how little, in essence, these victims of malady differ from ordinary healthy people; then there is the way of the skeptical philosopher, showing how feeble is the rational evidence for even our most cherished beliefs; and finally there is the way of common observation of men. It is only the last of these three that I propose to consider.

The lowest savages, as they have become known through the labors of anthropologists, are not found groping in conscious ignorance amid phenomena that they are aware of not understanding. On the contrary, they have innumerable beliefs, so firmly held as to control all their more important actions. They believe that by eating the flesh of an animal or a warrior it is possible to acquire the virtues possessed by the victim when alive. Many of them believe that to pronounce the name of their chief is such sacrilege as to bring instant death; they even go so far as to alter all words in which his name occurs

as one of the syllables; for example, if we had a king named John, we should speak of a jonquil as (say) a George-quil, and of a dungeon as a dun-george. When they advance to agriculture, and weather becomes important for the food supply, they believe that magical incantations or the kindling of small fires will cause rain to come or the sun to burn brightly. They believe that when a man is slain his blood, or ghost, pursues the slayer to obtain vengeance, but can be misled by a simple disguise such as painting the face red or putting on mourning. The first half of this belief has obviously originated from those who feared murder, the second from those who had committed it.

Nor are irrational beliefs confined to savages. A great majority of the human race have religious opinions different from our own, and therefore groundless. People interested in politics, with the exception of politicians, have passionate convictions upon innumerable questions which must appear incapable of rational decision to any unprejudiced person. Voluntary workers in a contested election always believe that their side will win, no matter what reason there may be for expecting defeat. There can be no doubt that, in the autumn of 1914, the immense majority of the German nation felt absolutely certain of victory for Germany. In this case fact has intruded and dispelled the dream. But if, by some means, all non-German historians could be prevented from writing during the next hundred years, the dream would reinstate itself: the early triumphs would be remembered, while the ultimate disaster would be forgotten.

Politeness is the practice of respecting that part of a man's beliefs which is specially concerned with his own merits or those of his group. Every man, wherever he

goes, is encompassed by a cloud of comforting convictions, which move with him like flies on a summer day. Some of these convictions are personal to himself: they tell him of his virtues and excellencies, the affection of his friends and the respect of his acquaintances, the rosy prospects of his career, and his unflagging energy in spite of delicate health. Next come convictions of the superior excellence of his family: how his father had that unbending rectitude which is now so rare, and brought up his children with a strictness beyond what is to be found among modern parents; how his sons are carrying all before them in school games, and his daughter is not the sort of girl to make an imprudent marriage. Then there are beliefs about his class, which, according to his station, is the best socially, or the most intelligent, or the most deserving morally, of the classes in the community—though all are agreed that the first of these merits is more desirable than the second, and the second than the third. Concerning his nation, also, almost every man cherishes comfortable delusions. "Foreign nations, I am sorry to say, do as they do do." So said Mr. Podsnap, giving expression, in these words, to one of the deepest sentiments of the human heart. Finally we come to the theories that exalt mankind in general, either absolutely or in comparison with the "brute creation." Men have souls, though animals have not; Man is the "rational animal"; any peculiarly cruel or unnatural action is called "brutal" or "bestial" (although such actions are in fact distinctly human); God made Man in His own image, and the welfare of Man is the ultimate purpose of the universe.

We have thus a hierarchy of comforting beliefs: those private to the individual, those which he shares **with** his family, those common to his class **or** his **nation**, and

finally those that are equally delightful to all mankind. If we desire good relations with a man, we must respect these beliefs; we do not, therefore, speak of a man to his face as we should behind his back. The difference increases as his remoteness from ourselves grows greater. In speaking to a brother, we have no need of conscious politeness as regards his parents. The need of politeness is at its maximum in speaking with foreigners, and is so irksome as to be paralyzing to those who are only accustomed to compatriots. I remember once suggesting to an untraveled American that possibly there were a few small points in which the British Constitution compared favorably with that of the United States. He instantly fell into a towering passion; having never heard such an opinion before, he could not imagine that any one seriously entertained it. We had both failed in politeness, and the result was disaster.

But the results of failure in politeness, however bad from the point of view of a social occasion, are admirable from the point of view of dispelling myths. There are two ways in which our natural beliefs are corrected: one the contact with fact, as when we mistake a poisonous fungus for a mushroom and suffer pain in consequence; the other, when our beliefs conflict, not directly with objective fact, but with the opposite beliefs of other men. One man thinks it lawful to eat pork, but not beef; another, beef but not pork. The usual result of this difference of opinion has been bloodshed; but gradually there is beginning to be a rationalist opinion that perhaps neither is really sinful. Modesty, the correlative of politeness, consists in pretending not to think better of ourselves and our belongings than of the man we are speaking to and his belongings. It is only in China that this art is

thoroughly understood. I am told that, if you ask a Chinese mandarin after the health of his wife and children, he will reply: "That contemptible slut and her verminous brood are, as your Magnificence deigns to be informed, in the enjoyment of rude health." <sup>2</sup>

But such elaboration demands a dignified and leisurely existence; it is impossible in the swift but important contacts of business or politics. Step by step, relations with other human beings dispel the myths of all but the most successful. Personal conceit is dispelled by brothers, family conceit by school fellows, class conceit by politics, national conceit by defeat in war or commerce. But human conceit remains, and in this region, so far as the effect of social intercourse is concerned, the myth-making faculty has free play. Against this form of delusion, a partial corrective is found in Science; but the corrective can never be more than partial, for without some credulity Science itself would crumble and collapse.

## II

Men's personal and group dreams may be ludicrous but their collective human dreams, to us who cannot pass outside the circle of humanity, are pathetic. The universe as astronomy reveals it is very vast. How much there may be beyond what our telescopes show we cannot tell; but what we can know is of unimaginable immensity. In the visible world, the Milky Way is a tiny fragment; within this fragment, the solar system is an infinitesimal speck, and of this speck our planet is a microscopic dot. On this dot tiny lumps of impure carbon and water, of complicated structure, with somewhat unusual physical

<sup>2</sup> This was written before I came to know China. It would not be true of the China that I saw.

and chemical properties, crawl about for a few years, until they are dissolved again into the elements of which they are compounded. They divide their time between labor designed to postpone the moment of dissolution for themselves and frantic struggles to hasten it for others of their kind. Natural convulsions periodically destroy some thousands or millions of them, and disease prematurely sweeps away many more. These events are considered to be misfortunes; but when men succeed in inflicting similar destruction by their own efforts, they rejoice, and give thanks to God. In the light of the solar system the period during which the existence of man will have been physically possible is a minute portion of the whole; but there is some reason to hope that even before this period is ended man will have set a term to his own existence by his efforts at mutual annihilation. Such is man's life viewed from the outside.

But such a view of life, we are told, is intolerable, and would destroy the instinctive energy by which men persist. The way of escape that they have found is through religion and philosophy. However alien and indifferent the outer world may seem, we are assured by our comforters that there is harmony beneath the apparent conflict. All the long development from the original nebula is supposed to lead up to man as the culmination of the process. *Hamlet* is a very well-known play, yet few readers would have any recollection of the part of the "First Sailor," which consists of the four words: "God bless you, sir." But suppose a society of men whose sole business in life was to act this part; suppose them isolated from contact with the Hamlets, Horatios, and even Guildensterns: would they not invent systems of literary criticism according to which the four words of

the "First Sailor" were the kernel of the whole drama? Would they not punish with ignominy or exile any one of their number who should suggest that other parts were possibly of equal importance? And the life of mankind takes up a much smaller proportion of the universe than the "First Sailor's" speech does of *Hamlet*, but we cannot listen behind the scenes to the rest of the play, and we know very little of its characters or plot.

When we think of mankind, we think primarily of ourself as its representative; we therefore think well of mankind, and consider its preservation important. Mr. Jones, the Nonconformist grocer, is sure that he deserves eternal life, and that a universe which refused it to him would be intolerably bad. But when he thinks of Mr. Robinson, his Anglican competitor, who mixes sand with his sugar and is lax about Sunday, he feels that the universe might well carry charity too far. To complete his happiness, there is need of hell-fire for Mr. Robinson; in this way the cosmic importance of man is preserved, but the vital distinction between friends and enemies is not obliterated by a weak universal benevolence. Mr. Robinson holds the same view with the parts inverted, and general happiness results.

In the days before Copernicus there was no need of philosophic subtlety to maintain the anthropocentric view of the world. The heavens visibly revolved about the earth, and on the earth man had dominion over all the beasts of the field. But when the earth lost its central position, man, too, was deposed from his eminence, and it became necessary to invent a metaphysic to correct the "crudities" of science. This task was achieved by those who are called "idealists," who maintain that the world of matter is unreal in appearance, while the reality is

Mind or Spirit—transcending the mind or spirit of the philosopher as he transcends common men. So far from there being no place like home, these thinkers assure us that every place is like home. In all our best, that is, in all those tasks which we share with the philosopher in question, we are at one with the universe. Hegel assures us that the universe resembles the Prussian State of his day; his English followers consider it more analogous to a bicameral plutocratic democracy. The reasons offered for these views are carefully camouflaged so as to conceal even from their authors the connection with human wishes: they are derived, nominally, from such dry sources as logic and the analysis of propositions. But the influence of wishes is shown by the fallacies committed, which all tend in one direction. When a man adds up an account, he is much more likely to make a mistake in his favor than to his detriment; and when a man reasons, he is more apt to incur fallacies which favor his wishes than such as thwart them. And so it comes that, in the study of nominally abstract thinkers, it is their mistakes that give the key to their personality.

Many may contend that, even if the systems men have invented are untrue, they are harmless and comforting, and should be left undisturbed. But they are in fact not harmless, and the comfort they bring is dearly bought by the preventable misery which they lead men to tolerate. The evils of life spring partly from natural causes, partly from men's hostility to each other. In former times, competition and war were necessary for the securing of food, which could only be obtained by the victors. Now, owing to the mastery of natural forces which science has begun to give, there would be more comfort and happiness for all if all devoted themselves to the conquest of Nature rather than

of each other. The representation of Nature as a friend, and sometimes as even an ally in our struggles with other men, obscures the true position of man in the world, and diverts his energies from the pursuit of scientific power, which is the only fight that can bring long-continued well-being to the human race.

Apart from all utilitarian arguments, the search for a happiness based upon untrue beliefs is neither very noble nor very glorious. There is a stark joy in the unflinching perception of our true place in the world, and a more vivid drama than any that is possible to those who hide behind the enclosing walls of myth. There are "perilous seas" in the world of thought, which can only be sailed by those who are willing to face their own physical powerlessness. And, above all, there is liberation from the tyranny of Fear, which blots out the light of day and keeps men groveling and cruel. No man is liberated from fear who dare not see his place in the world as it is; no man can achieve the greatness of which he is capable until he has allowed himself to see his own littleness.

## XXIII

### THE ART OF READING <sup>1</sup>

ERNEST DIMNET

The Very Reverend Abbe Ernest Dimnet is probably the only person alive who has written books in English, French, and Latin. Though a native Frenchman, he early became interested in English literature, and began to write for the English magazines in 1898. His biographical studies of the Bronte sisters and of Paul Bourget were published in English and gained him a wide reputation. He was Lowell Lecturer at Harvard in 1919 and French Lecturer at the Williamstown Institute of Politics in 1923. His book entitled *The Art of Thinking*, from which the present extracts on Reading are taken, has been deservedly a "best-seller." It is a wise and witty book, enriched by the mellow scholarship of a mind intimate with the world's history and literature, yet tempered with a broad sympathy for, and understanding of, human frailties.

Reading is supposed to help thinking; a man who reads simply borrows another man's thoughts, and this means a craving for thinking. A scarcity of books is understood to amount to intellectual fasting. Reading, Bacon says, makes a full man; and Dangeau, dining with Louis XIV, once answered a question of the King with the sentence: "Reading does to my mind what your Majesty's partridges do to my cheeks."

But there is reading and reading. The word, like "intelligent," like "wit," has been in service a long time and its fringe has gradually become different from what it used to be. Reading, in its earliest stage, cannot have been remote from a magical or a hieratic process and

<sup>1</sup> Reprinted from *The Art of Thinking*, copyright 1928 by Simon and Schuster, by permission of the author and of the publishers.

was a part of a rite. Our way of reading by just running our eye quickly along a page of type would have surprised and shocked the Ancients. Few people, in antiquity, knew how to read, and few possessed the bricks, stones, or rolls necessary for reading. So, like Herodotus at the Olympic games, they were expected to import to their less fortunate brethren something of the treasure in their hands. Reading out loud seems to have been the rule. It must have been the custom even in private reading, and the rustic who moves his lips as he reads is keeping up a tradition. Candace's eunuch, who was reading Isaiah on the Gaza road, would not have been overheard by Philip had he not read his book aloud. A biographer of Saint Ambrose also tells us that this learned archbishop was sorely tried in old age by having to renounce reading "because his throat was affected." So people would only take up a book for a purpose and with a gravity now reserved for reading the Bible or documents of a semi-sacred character. The whole soul was in requisition and its whole power, undiminished by distraction or by phantasms, was applied to the high task. Who can doubt that reading, under such conditions, must be effective? Legouve, a mere man of the world, once beat Cousin, a philosopher and a scholar, in the discussion of a doubtful passage of La Fontaine. Cousin asked the reason, and the other man said: "I always read La Fontaine out loud whereas you read the *Fables* as most people do; my voice tells me when there is a danger of misinterpreting a line."

So the quality of reading was excellent.

The quality of what was read was as good. Books were few and costly and there was no idea of accumulating them indiscriminately. Even the invention of printing

did not at first modify the composition of libraries: religious books, poets, and philosophers were the foundation; light reading was provided by Homer or by the historians. The libraries of kings and those of the rich monasteries seldom counted more than a few thousand volumes. Individual collections were naturally smaller. Spinoza possessed less than sixty volumes, of which we have a list. A hundred years later Kant collected three hundred, but half of this number were narratives of travel, for Kant had a frivolous side. . . . :

Today printing has gone mad and the world is in danger of being submerged by the ocean of books. Eleven thousand volumes are annually published in France alone to about seventy under Louis XIV. And who can think, without feeling dizzy and sick, of the billions of words deluging every Sunday morning the American towns? "Make your own choice!" the guilty editors would say. "Know what you want! We have it ready for you." A wise counsel, indeed, for the whole Art of Thinking is in it, but only the man who knows how to think can follow it. The others, millions of them, will be awed or bewildered by the formidable inroad of printed things upon them. In such a confusion, phantasms and inferiority complexes germinate like microbes in an active solution. The worst of them is probably the notion that one cannot have an opinion about every book, yet one must seem to have one. This gives a free field, and secures a multitude of slaves to slogans. People pretend they have read what they have not read and repeat anyhow somebody else's judgment. Nothing, of course, can be so destructive of thought and of the capacity for thinking. No such lever can wrench a man from out of his own soul.

When people do read, what do they read? Certainly

not Aquinas or the *Pandects*. Many pretend to read the Bible, but of how few it is true ! Three or four in a thousand read poets: they are regarded with the same surprise—not unmixed with mistrust—with which the poets themselves are considered. What is produced by the gross, what is constantly forced on our attention, trumpeted by publicity and magnified by criticism is fiction. Novels fill the bookshops and suffocate our bookshelves. What people read in the country where there is a little time to read is novels; what people pretend to read or skim through in town where there never is any time is novels. And the novels are not those great works of fiction which, since the sixteenth century, have added to our knowledge of mankind, or even their modern successors of such fame that we cannot ignore them; they are, and the readers know they are, pure and simple trash, the very titles of which will be forgotten in a week. "What are you reading?" I once asked an English friend, a woman of high character and no mean achievements—"Novel."—"Whom is it by?"—"Don't know." (*Semi-guilty, semi-apologetic little laugh.*)

Novels are read to kill time—the most sacrilegious phrase in modern languages. And the word "read," since the people of the past three or four generations have been weakened to death by fiction, not only has lost its former majesty but has changed its very meaning. It is now mentioned, along with smoking and playing cards, as a semi-physical relaxation; the notion of a definite purpose in giving one's self up to it is excluded. The real purpose hidden under the gregarious act of reading is NOT TO THINK. . . .

I remember once observing a man on the other side of the aisle between Philadelphia and New York. We

both had the *Philadelphia Ledger* across our knees. I made a few red marks on my copy and then began to notice the gentleman. He read the account of the swimming feat accomplished by some lady in the Hudson River. This was a story of some length which had to be continued on page 6, column 3. But the gentleman was unequal to the effort of turning three big sheets over; he was reading, not exerting himself.

So, leaving the grease-coated nymph, he went on to the cross-examination of the Pig Woman in the New Jersey case, and, dazed by the fusilade of irrelevant questions which the Pig Woman herself described in an immortal sentence as "talk, talk, chatter, chatter," he began alternately to fidget and yawn, but he never skipped a line. The whole mortal newspaper was read through in that way, on the brim of disgust or sleepiness, with occasional flickers of energy accompanied by a stiffening of the bust and a falcon glance at nothing through the window. In time the swimming lady reappeared in a corner, and the Pig Woman filled serried columns again, and there was a presidential message to Congress, and editorials, and news of the corn market, and shipping and sporting intelligence. All this was read on the same level, and with the same unfathomable disinterestedness till we neared the tunnel. Then the gentleman, all fagged and faint, showed a marvelous reflex; he flung down the crumpled sheets, jumped to his feet, and felt for his cigarettes. He had been reading.

Imagine the effects, in the long run, of a so-called intellectual process which consists in presenting to the mind a score of different objects in none of which any real interest is taken. If we remember that our most serious attempt at mastering what we read is constantly

hindered by adventitious images which we call distractions, leaving possibly two thirds of our consciousness available for what we read, we shall have little doubt that reading, as practiced by most people, is nothing but a method of not thinking. Let this go on for several years and the brain will become what is properly termed jellified. Now, this goes on through a whole lifetime with the majority of men and women. They leave school or college at eighteen or twenty-two. At that stage academic necessities have compelled them to read mostly serious books and to read them seriously. As far as education goes they were going in the right direction. The first thing the world and its so-called civilization do for them is to persuade them that masterpieces are tedious, textbooks or encyclopedias boresome, whereas light literature goes along with freedom. Henceforth reading will be one of the destructive forces, arrayed against them. The newspaper, above all, will bewilder them by its desultoriness or weaken them into faint-hearted common skepticism by its contradictions. They will be the joy of irresponsible headliners.

Here let me conjure up, only for an instant, the wistful face of the man immersed in business, thinking of intellectual culture as of a Paradise Lost, and able at most to devote half an hour a day to religious or philosophical reading or occasionally to a poet worth the name. How noble and pathetic this visage looks! How we bow to the often marvelous results produced by the thirty minutes set aside for thought! But how rarely we encounter the almost heroic person who will save himself from annihilation whereas millions happily plunge into it. The idea of such a thing as printing contributing to such a result is well-nigh unbearable. . . .

Reading, to most people, means an ashamed way of killing time disguised under a dignified name. Trifling with print in that manner quickly diminishes the resilience of the intellect. It goes directly against an Art of Thinking.

If you wish to use books as an adjuvant to thought, they must be books that will not merely amuse or put your mind to sleep, but, on the contrary, will keep it wide awake and alert.

What are those books?

What they are *you* know best, and I do not know in the least. A book, like a landscape, is a state of consciousness varying with readers. There exists some book, pamphlet, article in an encyclopedia, or possibly an old clipping from a newspaper that once set you thinking; there may be many; indeed you may be one of those rare beings with whom a few lines of print are food enough for thought because, as Lamartine says, their thoughts think themselves. The something evocative for you may be poetry, history, philosophy, the sciences, or moral sciences, i.e., the progress of mankind. Some people who go to sleep over a volume will be interested by a review which they think more condensed or better within their reach. Read reviews if they help you to think, that is to say, if they leave in your mind images that will go on living when you have forgotten where they came from; read a Shakespeare calendar at the rate of four lines a day, if Shakespeare quotations have on you the magic influence they have on some people; read algebra, read the lives of great inventors or of great business-men, read *that* kind of books which you and nobody else know to be thought-productive for you. . . .

Nobody can think our thoughts for us, and nobody

can tell us what will act as dew or sun on our thinking. The book that makes us think is the book we cannot shut again after we have read one page, because we are entranced by what it says to us; or it is the book we drop on our knee after reading one page, because what it says starts us irresistibly questioning, contradicting, or supplementing. No titles, no categories can be given to you by anybody but yourself, and what I am going to say hereafter should not intimidate you into doubting the wisdom of your answer to the entirely personal question: what books help me the best to think? . . .

And what books should we so read?

The principle which has never failed to confer superiority on a man's thinking activity is the well-worn precept: DO NOT READ GOOD BOOKS—life is too short for that—READ ONLY THE BEST. This simple recipe is as infallible as good air and good food are in physical hygiene. Yet it is a fact that nineteen out of twenty modern people quake away from it. "Masterpieces again," they groan, "the *Æneid*, the *Divina Commedia*, *Paradise Lost*, we have heard that before: rather be ordinary than bored."

The notion that masterpieces are boresome school-books interpreted by dull teachers, or examination stuff, is a marvelous product of education. Ignorance is assuredly less deadly, for it can create no such inferiority complex as the schoolboy's notion of his lack of kinship with the best literature. But this phantasm can easily be exorcised if we modify the above principle to: READ ONLY WHAT GIVES YOU THE GREATEST PLEASURE.

In the past century there lived in London a clerk of the retiring disposition behoving a man of little means,

yet with a turn for the brilliant in civilization, especially for the theater, for beautiful actresses, for talent and elegance. This man was a playgoer of course, but, in his leisure hours in the daytime, he would read plays, plays of all times and all countries, plays of any description, provided they gave him pleasure. No reader ever placed his own enjoyment more decidedly before any other consideration. We know his impressions, we can hardly be better informed about the mental background of anybody than about this absolute dilettante. Uniquely by his untiring application to pleasing himself and by his delight in analyzing his pleasure, this man achieved no mean originality. It is evident that, had he compelled himself to read famous sermons, as many of his contemporaries still did, he would have made his life not only less enjoyable but useless. His name was Charles Lamb. When we look into the kind of literature he used to read, we discover it was the pink of dramatic literature, and the prejudice against perfection left on us by the defects of teaching or teachers is so strong that immediately our chin falls and we know the familiar impression of disgust.

For all that, Lamb had a superb time all his life reading his sixteenth century dramatists, a much better time than trash, unhampered by any inferiority complex, can ever give even us.

A few years ago I traveled from Montreal down to Boston in a Pullman car which, strange to say, never contained more than three passengers till we reached our destination. Opposite me sat a McGill girl—a junior, I inferred from her conversation with two other girls who were seeing her off. On the other side of the aisle sat a young man, one of those handsome, perfectly well-tailored American youths, so attractive that you are will-

ing to ascribe genius to them as well as a host of minor perfections. This demi-god was reading. The McGill girl looked across at him for some time till their eyes met. "Reading?" she half queried, after an interval of mute presentation leading to a simultaneous smile. "Yes," a very uncultivated voice answered, "what I want a love story with a kid in it and lots of deviltry in him." The book was handed across the aisle and the girl began to read. The voice had been an anticlimax and so, evidently, was the book, yet the girl read on, skimming and skipping. After a while my professorial conscience smote me and bending over the love-and-kid-story I whispered: "Have you ever read *Vanity Fair*?" The girl looked up, flushed a little and answered: "Dickens?"—"No," I said, "Thack . . ."—"Oh! Thackeray, of course! No, it was not on our list."

What would I not have given to have *Vanity Fair* in my valise, open it at random and watch the girl's delight at Becky Sharp's introduction to Sir Pitt's townhouse and to his immortal charwoman!

"You have never read *Vanity Fair*, which is a wonderfully interesting book," I said, "and you waste an hour on a kid-and-love-story which bores you to death."

The girl certainly was bored to death but she was not convinced. As long as masterpieces appear as books "which are on our list," trash is sure to be preferred. Better be bored by it than excited by great books.

Assignments, examination papers, and the commentaries of pedants are largely responsible for this. For, the moment a great book is not supposed to be one, it recovers at once its original value as entrancing reading. Another train incident once gave me a tangible proof of this fact. I was in the Paris to Orleans train. Opposite

me an intelligent-looking but countrified man was sorting papers. In the corner, on my side of the compartment, his little daughter, a child of twelve in black, was reading a square little book also habited in black canvas by some amateur bookbinder. I never saw anybody read like that. It seemed as if the old-fashioned but pretty and dainty little figure were trying to lose itself in that book. In time my curiosity about a book that could be read with such intensity became irresistible. I made a brief feint of talking with the father and then suddenly turned to the little girl and asked: "What are you reading so delightedly?" The eager little face looked up, summoned, as it were, from far-away regions. "*Monsieur, c' est l'Histoire Romaine*" (brief pause) "*et je vais arriver a Jules Cesar!*"—"How do you know you are coming to Julius Caesar?"—"Oh ! I have read this book many times."

I have never forgotten the emphasis on: "*et je vats arriver a Jules Cesar!*" No prospect of Christmas, graduation, first European trip, or *debut*, ever produced emphasis of that quality. I visualized the background in an instant: a farm on the windy plain of wheatfields between long strips of grape vines, the *salle* with its big mantel-piece ; on the side ledge of this, below the ancestral powderhorns, the tiny library of three or four musty prayer-books, a gardening book, a cookbook, a surveyor's manual, a Family Lawyer, a Larousse *Dictionary*, a few old almanacs, and, in the far-away corner, the little black canvas *Histoire Romaine*. In a modern library of fiction or magazines the square squat volume would have been as forbidding to a child as a black old monk. Next to the Lawyer's or Surveyor's stuff, Roman History resumed its glamour and Julius Caesar became once more the romantic hero he was during so many centuries. Owing to an in-

credible chance the little girl summed up in herself the dreams, yearnings, and admirations of princesses. No wonder she looked distinguished.

This is what classics do when they are not killed by those who teach them, or, above all, when they are not juxtaposed with trash sure to make them look like the brown bread of Auvergne as compared to cheap sweets. None of the inferior stuff to which our children are treated, while we look on powerless, can ever give them the feeling of elation, nay, the amusement which great books naturally produce.

So, if you want to be vitalized into the power of thinking real thoughts, and if you want never to know one dull instant while reading, do what has been done by the best specimens of mankind since there have been books, resolutely leave out whatever is not of the best. If something in you rebels against this, you are not in the mood for reading this book, you care for no Art of Thinking, or you only want mental lozenges which I cannot produce, and so farewell. But let it not be till you have drawn up a list of the great books which do possess some attraction for you, and till a few months' experience has shown you which of these give you unmixed pleasure. Those twenty or thirty volumes will be *your* library, that is to say, your fountain of thought, your delight, and when you see people envying you your pleasure in them—they will be your pride.

Does this mean that we should give up contemporary literature, and live entirely in the monuments of the past? No indeed, for nothing helps like the *hic et nunc* questions, and if you do not belong to your own time what time can you belong to? We should read modern poets and modern novelists and follow art in its most advanced mani-

festations. There must have been toward 1840 suspicious old Londoners who refused to read the *Pickwick Papers* because the book was so unlike Mr. Addison's *Spectator*. These old fogeys were losers. It would be as foolish today to ignore Mr. Sinclair Lewis or Mr. Arnold Bennett, even if we suspect that, in eighty years, they will not appear like the Dickenses of the early twentieth century. On the other hand, if you try to keep up with the industrialized literary production of today you will be swamped and lost. Is there no way of making a selection?

There are dozens of ways, but here is an easy recipe. Nobody can twit you with an affectation of indifference to the present time if you leave out books which you find are forgotten three months, that is to say, twelve short weeks, after their publication. Do not read those. You will be surprised to see how few there will be left to read. People do not realize that the feverish excitement often produced on the publication of many books, and which the innocent public can hardly resist, is entirely commercial and artificially created by publishers. They imagine that the book itself does it all. But the book does not do it, and the publisher cannot do it longer than a week or two. When ten more weeks have put their dead weight on the little excitement it is more than forgotten. Draw up a list of the American writers whose works published several years ago are still on the shelves where the eye and hand occasionally travel. Those are the ones it would be unforgivable to desert, even for far superior reading, but you will see how few they are. Notoriety, high as it is above mere publicity, is still many degrees below fame. If a man reproaches you for ignoring books that have not made their author famous he is

speaking from publishers' blurbs and ought to be listened to accordingly.

All that has been said above applies to literature, and literature, especially the higher kind of poetry which ought to be the staple of every cultivated reader, certainly provides a man with the most accessible thought he needs. However, literature is not our only field. Philosophy, the sciences, contemporary history, and what are called the moral sciences, all put in our way explanations of the world and of man which are eminently thought-productive. In fact, they lead by a straight way to generalizations which are thought reduced to its most portable form. Now, it is true that philosophy, history, and the sciences have, as well as literature, their classics which cannot be ignored. Plato or Darwin cannot be absent from our library. Yet it is especially in that domain that it is not only permissible but imperative to look for the most up-to-date information, acquired through the most modern methods. The history of the past interests us only in so far as it illuminates the history of the present. The politics and economics of today, the characters and ideas of contemporary leaders, the tendencies of modern parties are what we must endlessly revert to. We must be able to take out a map of the world and read frontiers and their problems like a book.

The same can be said of philosophy. The position today of the eternal problems means more to us than their solutions even in the great past. Religious questions ought to be studied in their latest exponents. So, of course, should plans for social reforms. So above all, should the philosophy of the sciences.

Great books, great men, great problems, and great

doctrines, great facts and their lessons, all that is opposed to *'tits details* cannot but result in high thought. The busier we are, the more severe our selection should be. Many men absorbed in business show such a rare quality of culture that we are surprised at it. The reason invariably is partly because hard work and even the weariness it leaves carry a nobility with them, but also because there is no room in such lives for inferior mental occupation....

I have been tempted many times to annex Schopenhauer's maxim in his *Paralipomena* : "Do not read, think !" or to transform it into: NEVER READ, ALWAYS STUDY. A harsh saying ? Not if we realize that we should study nothing that does not interest us, and that studying applies only to the most enjoyable way of extracting from our reading what will interest us the most. In precisely the same way does an artist study a beautiful face instead of merely glancing at it. We can never repeat often enough that nothing intellectual can be achieved against the will of Minerva, that is to say, in a field that does not attract us. Working in our vein, without a sense of effort, and, on the contrary, with a sense of ease and freedom, is the fundamental condition of a healthy mental operation. Do not tackle algebra when you are attracted by comedies, and if farces attract you more than comedies leave comedies alone and study farces. Only STUDY them. You will not have done so long before discovering that there is more and deeper pleasure in studying *le Misanthrope* than in rehearsing *Scapin*.

This being laid down as a principle, how should you read ? As you please. If you please yourself by reading fast, read fast; if you read slowly and do not feel like reading faster, read slowly. Pascal does say that we are

apt to read too fast or too slowly, but he only blames an excess. (Levity is foolish to read too fast, but seriousness will be a gainer in many cases if it reads briskly.) Montaigne complains of a formal way of reading. "My thoughts go to sleep whene they are seated," he says, "so they and I walk." Honest industry merely jogs along, curiosity flies on Mercury's pinions. Passionate reading not only flies, it skips, but it only does so because it can choose, which is a high intellectual achievement. How do you read the time-table? You skip till you come to your place, then you are indifferent to the whole world and engrossed by your train, its departure, arrival, and connections. The same thing with a map which a motorist lends the anxious cyclist at the crossroads. The latter's whole soul is in his reading. The same thing with a financial tip in a letter which a friend is waiting for you to return. The same thing with any formula for the production of the philosopher's stone. Whatever we read from intense curiosity gives us the model of how we should always read. Plodding along page after page with an equal attention to each word results in attention to mere words. Attention to words never produces thought, but very promptly results in distractions, so that an honorable effort is brought to naught by its own ill-advised conscientiousness. . . .

Whatever we read we must first comprehend and, when we have comprehended, criticize.

Comprehension is the first and essential step in reading, but a vast majority of readers do not care to take it. They understand or think they understand what is obvious: the rest they regard as a mistake or a freak of the writer. I once tried a number of readers with that passage in *Aurora Leigh* in which Mrs. Browning defines

philosophy as "sympathy with God" (II, 293). Only one of them seemed to think there was anything arresting in this phrase. The others visibly were carried away by the rhythm or dazzled by the superficial abstraction of the passage. When invited to fix their attention on this "sympathy with God," most of them first said it was far-fetched but perfectly intelligible. But, being asked what these perfectly intelligible words meant, they had to admit they could not tell, and only two or three wished to hear. None ventured on any conjecture or tried to hit upon one. Their attitude was the uneducated one implying that if people use any except everyday language, they ought not to hope to be understood.

There is an abyss between people who want a poem to be as accessible as the morning paper and people in possession, or in search of, culture. Scholars often spend years over a retrieved fragment of a lost writer and read into it or infer from it the most interesting information. I have seen Angellier refuse after an hour's effort to give up an obscure passage of Herbert and succeed in making it appear laden with meaning yet clear to minds used to the rich language of poetry or philosophy. Certainly the habit of French lycee professors to devote a whole two hours to twenty lines of Seneca is first-rate intellectual training. Foreign visitors who, at first, wonder at this method ultimately appreciate it, and boys or girls compelled to use it are never slow in recognizing its merits. If you happen to know two languages, try your hand at really intelligent and artistic translation, were it only of four lines every day. The habit of complete comprehension will be a magnificent reward.

Too slow, you say, **and too hard. But are we not endeavoring to think?**

Criticizing is only another aspect of the effort to comprehend. The word in its etymology means "to judge," and in fact we think of a critic as a competent, not a carping, judge. The capacity to resist oral or printed affirmations, to have one's own opinion about an idea, a poem, a doctrine, or a work of art, and to see it clearly enough to give it forcible expression is an exception. Most people suspend their judgment till somebody else has expressed his own and then they repeat it. Common parlance alludes to this weakness in the frequently heard phrase: PEOPLE DO NOT THINK. These four words describe the mental cowardice or sluggishness which makes sheep of most people. Such passivity cannot be too early counteracted. If it is done methodically and intelligently it will never produce over-confidence, only the youthful mind will acquire strength during the all-important formative period. . . .















