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THE INVENTOR AND HIS WORLD

THE INVENTOR AND HIS WORLD

BY

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CONTENTS

CHAP.		PAGE
I.	WHAT IS INVENTION?	1
II.	THE INVENTOR	23
III.	THE PRACTICE OF INVENTION	50
IV.	WORKING OUT AND FINANCING AN INVENTION	71
V.	THE DIRECTION OF INVENTIVE EFFORT	98
VI.	MECHANICAL INVENTION	114
VII.	CHEMICAL INVENTION	131
VIII.	ELECTRICAL INVENTION	156
IX.	PSYCHOLOGICAL INVENTIONS	169
X.	INVENTION AND THE TRANSFORMATION OF ENERGY	187
XI.	BIOLOGICAL INVENTION	215
XII.	PATENT LAW AS IT IS AND AS IT SHOULD BE	230
	BIBLIOGRAPHY	255
	INDEX	265

THE INVENTOR AND HIS WORLD

CHAPTER I

WHAT IS INVENTION ?

MAN is commonly said to owe his position as Lord of Creation to his ' brains '.

It is only quite recently that this generally accepted notion has been subjected to close scrutiny. In former times, man's mastery over animate and inanimate nature was supposed to be due to his power of exercising intelligent thought. Animals are endowed by nature with elaborate instincts, with bodies possessing the most varied means for offence and defence, and with powers of digestion, resistance to weather, and endurance of adverse conditions, which far exceed the unaided powers of man. But man possesses a gift found only in a very rudimentary form in animals. He can envisage a situation, foresee the course of events a little, picture in his mind's eye a desirable outcome, and devise means which will cause events to take a certain course. Each of us, all day and every day, is conscious of exerting this power. We are frequently confronted with situations new to some extent in our experience, and are obliged to ' think out ' measures of dealing with them.

Some people are said to be ' clever ' ; they think quickly and accurately, and act successfully. Others

are said to be 'stupid'; their powers of grasping a situation and its implications, and devising appropriate action, are very limited, though far greater than those of the cleverest animals.

Human progress was formerly regarded as due solely to the steady accumulation of the results of cleverness throughout the ages. Give a chimpanzee in a cage a couple of bamboos, and put a banana outside the cage, and beyond the reach of his arm. He will try to reach it with one of the bamboos. If this is too short, and he is a clever chimp, he will attempt to fit two bamboos together, and even nibble the end of one so as to make it fit into the other. He is clearly seen to consider what to do. Man is not only immensely superior when wearing the 'considering cap', but also in regard to memory, powers of observation, and aptitude for learning.

These latter characteristics are also exhibited in a less degree in the animal kingdom. Many animal habits are not transmitted by instinct, but by tradition; and many more require the example and precept of the parents to develop properly. This is true of the song of many birds, which is identically the same in the same district from generation to generation, but differs in different parts of the world. Untaught, the young birds sing very imperfectly, or not at all.

In recent times, our views on these subjects have changed very greatly. We have been reluctantly compelled to admit that the man in the street (nay, even in the Board Room) is not as clever, or at any rate as ingenious, as he once imagined himself. Normally, he possesses a greater or less number of standard tricks and dodges, which he has learned, and his whole equip-

ment for dealing with situations and attaining ends consists in the power of arranging and executing suitable combinations of these tricks and dodges. But he can no more add to their number than he can grow wings or a tail. In the language of modern psychology, he is a mass of conditioned reflexes, and nothing more.

Until modern times, therefore, the question which heads this chapter was not asked. But for the reasons we have just given and many others as well, it has come to be asked with increasing insistence by philosophers of many schools, by lawyers, and by biologists. The philosophers have perceived that the human mind exhibits what is called creative activity, and that this activity is different in kind from that of intelligent adaptiveness, the useful or pleasurable employment of known expedients. It alone produces new methods and new experience.

Nowhere is this seen more clearly than in the sphere of art. As art became more and more recognised as a separate and important field of human activity, a clearer and clearer distinction was seen to exist between original, creative artists, and those, however skilful, who merely make use of known forms. No amount of musical education will enable a person not endowed with creativeness to compose a single original melody ; the highest executive ability, the utmost enthusiasm, the finest taste, limitless industry—all these together will not suffice to produce a single unforgettable popular tune, let alone a deathless opera or symphony. In Wagner's famous phrase, *Kapellmeistermusik*, ' conductor's music ', the stringing together of notes and harmonies either meaningless or reminiscent, is the only product. The analogous case is true in every other

branch of human endeavour. Creation often comes from persons endowed with none but the most mediocre mental powers. When the great creative personality exhibits some or all of the qualities we have enumerated, we repeatedly get the impression that they are secondary, and acquired under the urge of the creative drive; not primary, as in the highly accomplished, but uncreative.

But before the philosophers had really got to grips with the problem, a curious, half-fortuitous, half-instinctive development of our British legislation, a single clause in the Statute of Monopolies of 1624, led to this same problem attracting the attention of our judicature. Parliament directed that Royal Grants of Monopoly were to cease, excepting only to the " true and first inventor " of a new manufacture. Though in all probability our legislators meant no more by these words than the person who set up any kind of manufacture not at the time being carried on by any one in the country, the judicature decided that patents were only to be granted for *inventions*, as distinguished from new manufactures involving no addition to man's stock of useful expedients and devices. A new manufacture consisting of no more than a collection or aggregation of the latter, such as any intelligent trained person could make, was not considered to be good subject matter for a patent.

Present-day law of patents, as built up through the centuries by decisions of the Courts, is based upon the fact that in every branch of technology, there are persons " skilled in the art " (as the phrase goes), and that these persons, in the daily exercise of their occupation, are aften called upon to apply their knowledge to

practical ends. Their power freely to apply their skill and knowledge must not, so say the Courts, be interfered with by the State. Hence it is not sufficient for a manufactured article, or a method of manufacture, to be actually new to the world, for a valid patent to be granted for it ; it may be nothing more than the use of known means or methods to attain known ends.

For instance, at some not distant past date, some one must have been the first to install a lift in a motor garage. The result was a building of a new, useful, and unique character. Yet no patent could have been obtained for it ; that is to say, no valid patent. You can actually obtain a patent in Great Britain for almost anything, and its strength can only be tested by an appeal to the House of Lords. And not even the House of Lords has power to declare a patent unconditionally valid.

The judges would say that putting a lift in a garage did not involve invention. They would say that a lift maker developed and offered his product for lifting anything, and that the first garage proprietor or architect who hit upon the idea of calling for his services should not be allowed to monopolise lifts for garages, and so prevent lift manufacturers and garage proprietors from carrying on their legitimate business freely, and employing all available means for the purpose. They would say that to put a lift in a garage did not involve the exercise of *inventive power*, since it was obvious that a lift was designed for lifting, and could be as well used to lift a motor car as human beings or goods.

When the validity of a patent is challenged in the Courts on this ground, the evidence is taken of inde-

pendent persons " skilled in the art ". They are asked to say whether, if presented with the problem which is solved by the patent, they would themselves have thought of the same solution. If they answer in the negative, the law assumes that some power or quality which went beyond the ingenuity of the normal technologist must have been displayed by the mind of the inventor. In many cases, the presence or absence of ' invention ' is extremely difficult to determine. The new idea may be of so simple a character as to appear obvious once it is stated. The persons skilled in the art, however, may be able to tell the Court that the problem solved by the patent has been before the technical world for many years, and that other and less satisfactory methods of solving it have been proposed or actually employed, or even that it has been regarded as insoluble.

In such cases the Courts will uphold the patent as containing this mysterious element of invention, whereas if circumstances do not allow of such a history being brought forward in evidence, the inventor will be very likely to lose his patent. Nevertheless, even if it is shown that the invention is the result of pure accident, the Courts will uphold the patent, precisely as if the invention was the result of the inventor's mental powers. It is recognised that a new technical form or expedient has been born into the world, and that the patentee is responsible, if not as parent, then as foster-parent or obstetrician.

We see from the foregoing that the law has been compelled to assume the existence of a special faculty, which nevertheless cannot be proved to exist either by an examination of its supposed possessor, or by an

objective test of the product. The more this special faculty is examined the more elusive and mysterious it appears. So far from its being simply the outcome of the highest degree of normal intelligence, it appears to be possessed by persons whose general intelligence is not of a high order. The ' master-mind ' equipped with an intimate knowledge of the best practice in art, science, or technology, able to grasp the essentials of a problem, and envisage exactly the results of applying known and tried methods to its solution—in short, those minds upon whom the continued existence and stability of civilised life depend, are not usually inventive or creative. The inventor is quite frequently a person of distinctly low general intelligence, with a limited mind and outlook, and an incapacity for practical grasp and decisive, effective action.

Meanwhile, an entirely different branch of research has again led to the same conundrum. As E. E. Free says in the *Encyclopaedia Britannica* (article ' Inventions and Discoveries ') : " The history of invention begins before that of mankind. Many inventions have unquestionably been made by animals ; for example, nests, a crude use of tools, the beginnings of language . . . it is customary and justifiable for evolutionists to speak of the invention of the backbone by some species of primitive worm which developed the ability to stiffen itself against the flowing water of ancient streams."

No dividing line can be drawn at any point between the highest development of human invention and the invention by other forms of life of devices which are of a useful, and sometimes even of a purely pleasurable character. Invention is a phenomenon exhibited by all

manifestations of life, from the simplest to the most complicated. It forms the central problem of the origin of living species, of the gradual differentiation of the immense variety of past and present living creatures, which have perhaps arisen from a single primordial form. This development has been accomplished by the invention of an enormous number of expedients and devices; bodily forms, and structures, chemical processes, habits, and instincts which are no doubt themselves forms of organisation of the central nervous system.

The naturalist and the archaeologist, indeed the man in the street, are perfectly accustomed to recognise both forms of matter, and behaviour, which bear the stamp of living agency. There may be border-line cases, as the canals of Mars or the earliest chipped flints; but no one would fail to recognise a fossil shell, a neatly finished flint implement, or the antics of a 'jumping bean', as the products of a force or purpose strange to inorganic existence, to crystalline forms however harmonious or elaborate, to mountains however beautiful, to the moods and tides of the sea however mysterious. If the swordfish were unknown to us, and a traveller brought home only the sword of one, we might be puzzled for a moment to tell whether it was part of an animal or a piece of human handicraft; but we should never mistake it for a product of inorganic nature.

Yet here again our ideas have recently changed greatly. Darwin's idea of the slow, automatic modification and adaptation of organisms in the struggle for existence has been more or less abandoned. Every race of living creature normally continues to repro-

duce itself unchanged from generation to generation. If it meets with adverse conditions or new enemies it generally succumbs, and is wiped out. It fails to invent new means to cope with them ; and like the normal human being or human race, when confronted with conditions which cannot be dealt with by the stock of expedients which it possesses, it perishes.

Nevertheless, throughout the hundreds of millions of years of organic life upon earth, countless inventions have been made. The giraffe's neck did not grow longer and longer by imperceptible degrees, as Darwin thought. While other short-necked beasts and bovines perished when food was short, someone among the ancestors of the giraffe grew a long neck, and he and his long-necked progeny survived. ' Nature ' produced a ' sport ' or ' mutation ', and a very useful one to boot.

It is clear that opinions in this field must always contain a large element of pure speculation, but the conviction is gaining ground that these inventions and moves forward in organic development are, and have been, offensive and not defensive in character, at any rate to a very large extent. Fish colonised the land, bats and birds conquered the air, not because they were pushed out of the sea or off the land, but by a kind of *élan* akin to our own inventive drive. At first blush, such a statement savours of mysticism. Still entangled in the notion that inventions are thought out, and assuming the first mice or reptiles which flew to have been devoid of the power of conscious thought, we seem to be calling in a *deus ex machina*, a planning Providence, to do the inventing and launch the mice or reptiles into the air. But modern psychology has

taught us that our own inventing, even our own normal everyday action, is largely unconscious. Our consciousness is only a spectator, or at best, a critic of the impulses and suggestions springing from our unconscious minds. All creative work, at any rate, takes place in the unconscious.

The human animal, like all others, is a creature of habit; it differs only from the lower animals by the fact that it requires to be taught its habits, and does not receive them in an instinctive form. Many birds, however, require to be taught to fly by their parents; others, as well as many animals, need to be taught where to find food, and how to master it. Particularly such creatures as have acquired new habits in contact with man inherit nothing but, perhaps, a certain aptitude for learning how to live as they must. The human being who is put in the witness box in a patent case to give evidence as a person skilled in the art, is really taken as a normal member of the species, who has been taught certain habits by the persons responsible for his training. The same is of course true of every human being whatsoever. The anthropologist is able to tell us of the social and technical habits of a very large number of races, and how these habits are transmitted by precept and example from generation to generation. The psychological mechanism is that of the conditioned reflex, and the superiority of humanity is due, in the first instance, to its power of acquiring an enormous number of conditioned reflexes, and of grasping a situation in such a way as to cause appropriate behaviour to take place.

The maintenance of these habits from generation to generation is the normal state of affairs. Their change

only occurs at certain epochs, and then only among a limited range of races. This change is called the rise and development of a civilisation.

This entirely mysterious impulse appears to seize hold of a race or a number of associated races living in a certain geographical area. A limited number of individuals conceive entirely new forms of behaviour and put these into practice. The rest of their fellows react variously, some exhibiting an unbending conservatism, while others eagerly acquire the new form. The new forms are of every kind, forms of thought about the universe, which have a religious character ; forms of social and military organisation ; artistic forms in painting, sculpture, literature, and music ; architectural forms, and finally, particularly in the case of our own civilisation, technical forms.

The central question of the whole matter is the meaning of this word ' form '. It is seen in its simplest aspect in music, to which we have already referred. Originality here consists solely in producing new arrangements of a limited number of notes ; or if we include orchestration, of a further limited number of tone-qualities. Nothing could possibly be simpler than melodies such as the Marseillaise, ' O God our Help in ages past ', or *Voi che sapete* ; yet almost anyone will identify these melodies at once from the first half-dozen notes. Most of us, certainly all trained musicians, have tried to compose such melodies, and all of us suffer daily from dreary and meaningless sequences of the same few notes. Here is the problem of the creation of original form in its most elementary aspect ; but the case of mechanism in technical invention is of almost equal simplicity.

We are concerned in this book only with technical inventions. The technical invention (and perhaps all other invention) is fundamentally a set of directions for behaviour addressed to certain persons who wish to obtain a certain end; it *is* the patent specification. The word is of course often applied to the result of this behaviour, a new form of matter, a tool, or other useful object. But it also applies to a process of manufacture of some well-known article or material. Its essence lies in these directions for the solution of a practical problem.

Every single method we use, every single form we construct, has at some time or another been new to the world, and in an epoch of progress such as our own, new methods are being continually developed, and when developed, applied more or less universally.

If we take, for example, a great electric power station, we may find that it has been designed by a skilled engineer. This skilled engineer, however, will, generally speaking, and if he is a wise man, have only followed in every detail the best current practice known to him. On the other hand, the whole station represents a collection of inventions, most of which can be traced to original minds such as Watt, Parsons, Ferranti, and so on, over a long but not unlimited list. The whole affair, as innumerable writers have remarked, bears the closest analogy to a living creature; it is a complicated mass of interrelated parts and devices, and performs a certain function when fed with coal, water, and oil. That it can neither feed itself nor reproduce itself without outside assistance are peculiarities which it shares with many organisms. Annex to it the necessary workshops, supply it with the necessary food

(steel, copper, and so on) and the required human assistance, and reproduction occurs.

How did this creature come into existence ? We have seen that it was born, along with countless other forms of all kinds, of that mighty urge forward known as modern European civilisation. We are all of us engulfed in that flood ; some swimming lustily, others dragged along complainingly and unwillingly, gasping for breath ; many, alas, going down for the third and last time. These inventions are the offspring of our own minds. Surely we can get at the heart of the mystery by studying them ? Samuel Butler, in his *Life and Habit*, says : " I would, therefore, strongly advise the reader to use man, and the present races of man, and the growing inventions and conceptions of man, as his guide, if he would seek to form an independent judgment on the development of organic life. For all growth is only somebody making something."

When we look into our own minds, we find at the outset a very curious fact. These new technical forms of ours fall into groups; to which we have given names : mechanical, chemical, electrical, engineering, and so on throughout the whole range of our intellectual activity. And we find that our own adolescents fell into similar groups likewise ; that one has an aptitude for mechanism, another for chemistry, another for electricity, another for some branch of art, and so on. It is not a matter of intelligence : a youngster, by no means bright, will often manipulate mechanism or wireless with much greater skill and facility than his more intelligent elder brother. We say that he ' gets the hang of it instinctively '. Right behind everything

else is this ' hang ' which, in colloquial parlance, is ' got ' only by persons with an inborn aptitude. Without that ' hang ', a person may know all about the matter to the extent of scoring 100 per cent of marks in a *written* examination, and yet be a hopeless dunce at applying the knowledge in a practical case, or even a practical examination strictly confined to the syllabus.

The construction and running of our electric power stations, for example, depend entirely upon a supply of persons with a natural aptitude for the various mechanical and electrical jobs involved. If the supply of such persons were to fall short, so would our supply of ' juice '. Nothing could be sillier or more fallacious than the notions of some theoretical educationists, who maintain that anybody can be taught anything, provided it is done properly. Every travelled and experienced engineer knows that races differ greatly as regards various aptitudes, and that the success of the Russian experiment, for instance, demands, as a *sine qua non*, that Russians should possess sufficient inborn technical aptitude of all kinds. Of primitive races which have never developed or used any but the most crude contrivances, some show the most remarkable ability to handle our own machines, etc., while others are utterly unteachable. The Eskimo, for instance, take watches apart for fun, and put them together again quite successfully, a feat entirely beyond most Europeans.

When we trace the history of our own modern inventions, we find that this fundamental ' hang ', this general notion of the nature and possibility of new classes of forms, is born in the brains of the very greatest and most remarkable originative geniuses.

Mechanisms have existed from the earliest dawn of civilisation. Some primitive form of lathe, loom, water-wheel, windmill, pump, and so on, are found almost everywhere. The Greeks and Romans possessed quite respectable engines of war for hurling projectiles and for other offensive and defensive purposes, and mechanical clocks of a sort. But the endless possibilities inherent in mechanism, the essential nature of it, were never recognised until they dawned upon the mind of Leonardo da Vinci. He proceeded to fill notebooks with designs which in many cases have hardly been improved upon till to-day. It then appeared that a sufficiency of his contemporaries and successors were capable of assimilating the new notion, very many to the point of constructing and using the machines he designed, a few to the point of creating new mechanical forms. But as all of us know, there are numbers of people to-day who, in spite of living among endless machines of all sorts, have no power whatever of ' getting the hang ' of them.

There can be little doubt that the whole development of human civilisation has taken the same course. At some distant period, humanity came into possession of the general notion of voluntarily producing physical and chemical changes in matter. The chimpanzee will nibble a bamboo to make it fit into another bamboo, but it never acquires the notion that all kinds of useful material constructions, buildings, ships, weapons, and so on, can be planned. Before the Greeks, the nature of static equilibrium and static forces was not understood ; and not until Galileo lived was an understanding of motion and inertia born into the world. In the same way, the true inwardness of chemistry was first

revealed to Dalton, and that of electricity to Faraday. So difficult did the latter prove to grasp, that even to-day, misguided persons are trying to explain electricity by mechanical analogies, as in Lodge's famous book *Modern Views of Electricity and Magnetism.* On the other hand, we nowadays find it easier to grasp very subtle and difficult mechanical processes, such as the working of the ordinary gramophone, by translating them into electrical analogies. The modern 'wireless fan' never thinks in terms of the hydrostatic and mechanical analogies to be found in popular books; the nature of electrical phenomena is directly present to him.

It would seem that de Broglie's conception of wave mechanics represents the most recently born notion of the kind; perhaps the first arrival since Faraday's conception of the electric and magnetic field. The relativity theory is probably in a different category.

As we have seen, the power to make use of known expedients embodying the general notion, and even the power to operate apparatus successfully, can only be acquired by those capable of getting the hang of the whole matter. The non-mechanically minded can hardly drive cars, let alone design and construct them on orthodox lines. A mastery of any field of activity presupposes the assimilation of the general notion; it must be 'in the bones', as it were, not merely understood intellectually. Those who possess such a mastery know that, in their youth, something stirred within them when first they were introduced to the embodiments of the notion on which their subsequent activity was to be based. Something in them went out to meet it and grasp it; mechanism, chemistry, painting, music,

architecture—whatever it was, it 'came naturally'; a great deal was picked up without set teaching. In the brightest adolescent minds, thought is continually ahead of teaching, and reinvents forms already known.

If we are yet no nearer to understanding the innermost nature of invention, our analysis has now led us to an excellent criterion of creative mentality in the young. While the future 'master-mind' of wide and constructive grasp assimilates, usually quickly and easily, the whole science and technology of the subject, the born creative mind does not assimilate systematically but keeps leaping nimbly ahead. For this very reason, the average and minor inventor is usually an indifferent master of his branch of technology. The actual organ, the brain, is unequal to the task of assimilating everything, and also envisaging so clearly single problems, that actual creative results occur.

For that is as near as we can come to the essence of invention. We need a mind possessing very fully the aptitude for a certain general notion. Moving along the highway of established method, it comes across a hole, a bad spot. The journey is interrupted, and the deficiency is examined in all its bearings with the most intense interest. And then—out of the depths of the unconscious mind comes a suggestion, a vision, of a new form; one, perhaps, which seems paradoxical, absurd; but scrutiny or experiment shows it to be the sought-for solution and remedy.

The anecdotes of these 'flashes of inspiration' are endless. But there is no one who has not experienced exactly the same mental state. We seek in vain for a name or an expedient; we cudgel our brains without result. Finally we let the matter drop, and behold!

the name or other matter we had striven in vain to remember flashes into our minds, bringing with it sense of relief. Precisely thus does the long-sought solution visit the mind of the inventor, the new melody the mind of the musician, the original, personal phrase the mind of the writer. The process of creation is no more conscious than is the creation of new species or new mutations.

This fact has led to the facile adoption of an explanation of invention which at first sight appears very plausible. Modern psychology has familiarised us with the fact that a great deal of mental activity goes on in the unconscious mind; activity very largely of a kind precisely similar to that of which we may be fully conscious. At one time we may solve a problem in full consciousness of all the logical steps; at another, we may fail, only to have our unconscious work it out for us, and present the solution in a flash. Now in many cases, if not in all, a technical invention is nothing more than the correct and logical arrangement of parts, the known properties of which are utilised. Once it is stated, every competent technician can see that it will work; though the case is not uncommon in which the propounded solution strikes everyone at first sight as wrong, or at least as incomprehensible. It has therefore been maintained that our unconscious 'thinks out' the solution, even in the case where that solution is an original invention. The characteristic of the solution is, that sooner or later it convinces us of its rightness; in technical work, this conviction, if it does not follow upon an exact consideration of the proposition, is enforced by the test of experiment. In art, there is a sense of rightness which cannot be objectively demon-

strated, but which carries conviction sooner or later. Mozart's setting of *Voi che sapete* no doubt immediately satisfied his hearers when it was sung for the first time ; Isolde's Death Song baffled the writer completely on a first hearing, but now carries with it exactly the same sense of solving perfectly the problem of expression.

The view we are considering suggests that the creative mind manipulates with much greater facility, unconsciously, the available means (mechanical devices, or notes of the musical scale, as the case may be) and finds the solution. Furthermore, it is supposed that the Freudian ' censor ', which normally suppresses all inappropriate, unconventional, immoral, or otherwise objectionable matter put forward by the unconscious to the conscious mind, is more liberal in the creative person. Some people go so far as to assert that every human being is creative, but that our minds are so cramped by bad training that the creative power is suppressed.

There can be little doubt that there is some truth in this view. Some of the most capable masters of technique in science and art display an obvious and involuntary distaste when confronted with a new idea, and it is easy to suppose that their own well-stocked minds might well have unconsciously formulated the idea, and as unconsciously suppressed it. But this can only apply to a part of new ideas—those which, when first formulated, seem strange and bizarre, even to their creators. There are others which no one can fail to recognise instantly as heaven-sent. Furthermore, we have absolutely no evidence whatever of the assumed latent creativeness. ' Deep analysis ' and hypnotism enable us to delve in the depths of the unconscious, but treasures of originality never seem to come to light.

The 'messages from Mars' and other exploits of spiritualistic mediums are undoubtedly products of the unconscious; and rarely indeed do they reveal enough creative power to equip a newspaper reporter, let alone a writer of popular magazine stories.

Finally, this view in no way helps us to understand the distinction between 'thinking out' and creation. When conscious thinking out fails us, and later the sought for memory suddenly pops up, there is no creation. We may assume that thinking out is easier to the unconscious, which presumably has direct access to all memories. But this by no means explains creation by the unconscious.

So far we have considered the matter as if the purpose of the mind in seeking for a solution of a problem were an active force. The majority of biologists, however, have no use for the concept of purpose, except as a convenient descriptive term. We often think and talk of the steam in a boiler as *trying* to escape; but the engineer simply says that it *will* escape, if a hole is made in the boiler, *because* of its expansive force. The physicist will tell us that even the word *force* is another convenient anthropomorphic term, and not a real agent. The configurations of matter and energy which constitute the real world are there, and we come upon them as time progresses.[1]

This manner of thought applied to our present problem maintains that organic mutations are purely chance products, the useful ones being preserved by natural selection; in the same way, the inventive

[1] See J. W. Dunne, *An Experiment with Time*, for a very clear exposition of this view, coupled with some very remarkable experiments and theories of his own.

human mind is possessed only of a kind of idea-kaleidoscope, which occasionally produces a new and useful combination. The inventor obsessed by the problem of, say, variable mechanical transmission, has a mind in the unconscious part of which we are to imagine a kaleidoscope producing without end patterns constituted from the elements of mechanism, and an observer watching and criticising these patterns just as an engineer might criticise them consciously, by considering whether they make sense and would work. Whenever one appears which seems to pass muster, a picture of it is flashed into the consciousness of the inventor. The same explanation is given of the activity of the musical composer, into whose mind, when he is in good form for work, suitable melodies and harmonies flash, selected by his unconscious judgment from an enormous number of random combinations of notes.

This view cannot be disproved; it merely strikes us as extremely improbable, because it postulates a perfectly fabulous speed of operation by the hypothetical kaleidoscope and unconscious critic. If all Shakespeare's vocabulary were written on pieces of paper and put into the Dublin Lottery drum, it is possible, but extremely improbable, that the withdrawal of a successive number of slips might yield a poem better than he ever wrote. But such is the mechanistic picture of his creative activity.

The opposite, vitalistic school of thought, which sets up creative striving as the very essence of organic life, is very active and emphatic in its efforts to convince, but has failed to put forward a single suggestion as to how experimental proof of its views is to be had.

The truth seems to be that the self-maintaining and reproductive activities of organisms are extremely difficult, but not impossible, to picture on a mechanistic basis; while their creative production of new forms, a rare and sporadic activity, can only be pictured mechanistically as a matter of pure chance. The vitalists maintain that a mysterious purposefulness, impossible to picture in a machine, characterises normal organic activity. If we once admit this, we may readily look upon creativeness as resulting from a super-charge or super-efficiency of this vital force. But such an admission is a sad thing for a scientific mind.

To carry this discussion any further would be to embark upon metaphysics. Its purpose has been to make clear the fact that invention is a process by which new forms come into existence, step by step, through the agency of life, and not a gradual and inevitable advance resulting from the automatic selection by living agents of new forms from among myriads produced by pure chance.

New forms are created by individual minds, and advance in all branches of human activity depends, firstly, upon the application to the problems of the time of fertile minds; and secondly, upon the conservation and utilisation of their product. Organisation and education, important as they are, tend rather to fix and stereotype existing forms and methods. If national stagnation is not to result, it is essential that as much attention should be paid to the maintenance of freedom for change and growth, as is paid to the elaboration and improvement of the means used to conserve and consolidate our present stock of forms and methods.

CHAPTER II

THE INVENTOR

WHAT manner of man is the inventor ?

We might attempt to answer this question by surveying the personality of a great number of inventors. Or we may first consider what qualities are necessary to the making of an inventor, and then see whether these qualities are generally accompanied by others which, together, make up a distinctive type.

Let us attempt the latter course. It is obvious that the inventor must possess the distinctive gift of invention. Does he alone possess this power ? We know that very many highly gifted technicians do not possess it. Do others possess it without using it ? Is it something which in a few cases crowns the highest technical ability, or has it little or nothing to do with technical ability ?

In the last chapter I attempted to show that both technical ability and inventive power rest upon the gift of insight, upon the power to grasp the inwardness of some field of work. The accomplished technician bases upon this power a superstructure of thorough knowledge of existing practice. It is the perfections, and not the imperfections, of this practice which attract him and arouse his interest and power of concentration. If he is unambitious, he is happy when he can produce a

standard article or job to perfection ; if he is ambitious, adherence to standard practice, and consequent avoidance of mistakes, is the first counsel of worldly wisdom. The inventor, on the other hand, is bound to be a fault-finder, a discontented fellow. He is fascinated by the promise of achievement shown by existing practice, but not by its actual performances.

The divergence in type shows itself early. You can divide quite young children into ' actors ' and ' reactors ' ; those who learn readily and submissively the part they are to play in life, and those who react against the wise counsels of their elders, question everything they are told, and resist conditioning—to use the Behaviourist's term. The inventor is a reactor, a stubborn questioner, a rebel. If, as often happens, his reactiveness is confined to his technical work, the reason is that his interest is fully absorbed there. He has the good sense to know that reaction for the sake of reaction is merely waste of energy.

Let us continue this fascinating game of ' dichotomising ' humanity, to use the philosopher's term ; or, in biblical language, dividing the sheep from the goats. If we look over the bridges at the craft afloat on the river, we see that they are of two kinds : those possessing means of propulsion, and those adapted for being towed—the barges and the lighters. Mankind is divided into the same two classes, except that a considerable percentage of human lighters possesses engines rusting from lack of use, but often capable, when rocks and rapids are sighted in the tideway, of being started up and averting shipwreck.

The power and tendency to move of themselves, instead of waiting at moorings for a tug, characterise

creative minds ; and not only them, but a number of other types of mankind as well. But all ' self-starters ' together form but a small minority of the population ; a minority, I fear, which is rapidly diminishing. The initiative types are being bred out, as the Eugenists easily prove ; and as if that were not enough to ensure our national decay, the Legislature is untiring in its efforts to discourage in every way those that remain, and to protect the non-initiative. While money is poured out in educative efforts for the ungifted, and even the feeble-minded, patent royalties are classed as ' unearned income '.

Initiative generally shows itself at an early age. Edison as a boy of thirteen was already experimenting up to the limit of his energies and financial resources. In setting about writing this book, I felt that one thing at least was to be avoided, namely, references to Edison on every other page. But when I sought for other and less-known examples of equal typical perfection, I was baffled. Leonardo, Kelvin, Siemens, all of these were almost on his level—but not quite. Edison, of course, would never have been one of the founders of thermodynamics, but neither could Kelvin have invented the phonograph. Being offered the chance of acting as newsboy on a train, Edison took it, and set up a laboratory on the train, and also a printing press. He then started a business, in the large town which was the terminus of his route, for the sale of fruit and vegetables which he collected *en route*, paying nothing for freight, and getting another boy to sell for him in town. These enterprises were highly successful, and brought the young scientist plenty of cash to spend on his experiments. Whereas most people have to be forced or

persuaded into action, we here see the inventor as one who takes action spontaneously.

This characteristic, as we have said, he shares with many other types of men—and women. Nowadays young women seem often to equal and surpass their male contemporaries in this respect.

We have already, in the last chapter, considered another peculiarity of creative minds. They are not stereotyped, but flexible. Here again we have a perfectly recognisable division of humanity into two groups. Every mind worth while possesses a structure ; it is not a formless mass. But, in some, this structure is hard, impervious, bony, 'calcified', as the pathologist says of our bodily structures. In others it is living, flexible, organic, able to yield to admit ideas, and to modify itself so as to accommodate them.

Social conventionality (not conformity alone) is an infallible sign of this calcification. A really free and flexible mind suffers none of those acute pains from breaches of social consideration and convention, from contact with the bizarre or the ' not quite nice ', which afflict the stereotyped. A well-known incident in Faraday's early life well illustrates this point. Faraday was a social (and religious) conformist, but in his science —his only real interest—he was the most daring of questioners and original of thinkers.

In everyday life the freedom of his mind was only exhibited by his complete absence of interest in conventional points of view. When he was already recognised not only by his master Davy, but also by the scientific world at large, as a person of scientific consequence, he made a tour of Europe with Davy and his wife. Davy, with all his faults, treated Faraday with

every consideration, in spite of the fact that he had started his scientific career by washing Davy's apparatus. Lady Davy, however, was determined to regard Faraday as their servant, and also to economise on their usual practice of taking a valet with them, by assigning his duties to Faraday. Anyone in the circumstances might have accepted so much, but very few indeed would have remained cheerful under Lady Davy's crowning impertinence, in insisting that Faraday, as a servant, could not take meals with herself and her husband. Faraday, however, does not seem to have been affected ; or if he was, he did not show it.

In the extreme, and perhaps the happiest case, the self-determination of the creative mind is strictly limited to one particular matter from the first—the chosen science or art ; in all others, its possessor is glad to economise his energies by following accepted routine and convention, and even submitting without question to the authority of others. But in the most typical case, self-will, and refusal to be led, characterises the person all through. It is his fate, often a hard and bitter one, to stand alone. The simile of the river is not quite accurate. The mass of men move along by mutual aid ; their resources of power are pooled by the formation of organised bodies, and the general direction of the mass is the mean of a common tendency, partly their own, but mainly that of persons specially adapted by nature for leading the crowd.

Not only the creative minds, but many others, cannot fall in with the crowd. In particular, we have a large number who are born to trade on their own account, such as shopkeepers, and the inventors should have the warmest feeling of respect for this allied class—

the more so because the greatest of all inventors, Edison, owed his success in life very largely to the fact that he was born with a talent for retail trade, and hence could always make money when he needed it. Very often, indeed, the creation of a new type of business organisation exhibited originality of a high order.

So far, our inventor is a reactive, questioning fellow, a ' self-starter ' (to use an American expression), and a person of free and flexible mind. Let us attempt one more ' dichotomy ' ; a most important one. You can certainly divide people into those who find life too short, and those who find it too long : the unboreable, and the frequently bored. The vastness of the latter class is seen by the commercial importance of methods of killing time.

This line of division is by no means identical with that last considered. Any number of unboreable people do not possess the least initiative ; they are contemplative, satisfied with any simple task. ' Sometimes I sits and thinks ' says the yokel, in the well-known story, ' and sometimes I just sits.' Some factory workers are intolerably bored by monotonous tasks ; others prefer them. The boreable, on the other hand, develop on occasion the most furious initiative in their efforts to escape boredom. The more strenuous types of social activity are largely due to this cause. Needless to say, the inventor is of the unboreable.

This class, as a whole, possesses a positive life-feeling, a love of life—that is their secret. Life is always interesting, and this interest may develop into passionate enthusiasm. They can take fire. They may never do so ; their temperature may never rise beyond a gentle

warmth. But they are as different from their boreable fellows as warm-blooded animals from cold.

It is unfortunate for the inventor that his co-members of all three classes include a number of social nuisances. There are non-creative reactors—captious critics, grousers, pessimists, Puritans, and haters of joy. Likewise non-creative initiators—go-getters, exploiters, criminals, interferers, minders of everybody's business, agitators, politicians, organisers of all the infinitely tiresome organisations with which we are cursed. Even non-creative enthusiasts—bores with misplaced objectives, runners after every new thing—can sometimes be very trying.

But let us remember valuable and acute criticism, indispensable to progress; initiative as possessed by the best types of business leader; and above all, discriminating enthusiasm for genuine progressive work, without which the creators could not live.

Let us consider for a moment, in a general way, this matter of enthusiasm, about which the psychologists have surprisingly little to say, in view of its importance. Almost all human progress arises ultimately out of the fact that a minority of people become imbued with a passionate interest in some field of human activity, large or small. How can such apparently impersonal and intellectual matters come to obsess a person like sex, or hate, or jealousy, or greed of power? Yet so it is; and not only our 'self-starters' are affected in this way. Very fortunately, the large inert mass of the pulled and pushed, the led and driven, is leavened by 'fans' and enthusiasts of all kinds. Often one is quite astonished that so much enthusiasm can be compatible with so strong a bias for the orthodox. While the inventor

is struggling along in his garret or cellar, experimenting along pioneering lines with the most inadequate means, many an enthusiast for the same branch of art or science is collecting or building elaborate, expensive, but quite useless models of standard, or even archaic design. But the ' fan ' loves the subject for its achievements, the inventor for its potentialities.

The passion of the great creative minds for their art or science hardly needs the emphasis of example, so well known is it. There is nothing cold and bloodless about it : it can cause the eyes to shine, the heart to beat, the skin to glow, fully as well as the most genuine of those commoner passions which Hollywood counterfeits on celluloid. It is at once the glory and the undoing of those whom it affects. It drives them as with a whip ; once aware of their own creative gift, however modest, life is simply worthless and devoid of honour if it is not exercised. Shaw wrote *The Doctor's Dilemma* around this theme. I have elsewhere [1] put the matter as one of that self-feeling, that sense of the right to live, of which we must all maintain a credit balance in our own moral account. While for the majority of men and women the self-feeling is founded upon their possessions, and their credit as being members of certain moral or social classes, in the creative individual it is maintained dynamically. His sole justification to himself for his own existence rests upon his active pursuit of his life's work. This accounts for the fact that such types, at any rate when young, commonly exhibit a disregard for the sources of self-feeling which other people seek so eagerly—money, family life, social status and approbation, and generally

[1] *The Conquest of Thought by Invention.* London, 1930.

speaking all such distinction as is conferred by being a member of a certain class of persons recognised by society at large as honourable or useful.

This is one of the sources of the freedom of mind which characterises creative types. I like Edison in his early years. He graduated from his newsvending and publishing and greengrocering into the great Bohemian fraternity of skilled telegraph operators of that day—a band of jolly, drunken, wandering rascals, sure of a job everywhere, though they were the reverse of ideal and well-conducted employees. Edison wandered thus all over the States for several years, but while his colleagues were usually ' fired ' for drunkenness and consequent damage, he was as regularly fired for experimenting—and consequent damage. While his friends tore the instruments down and made matchwood of the switchboard, he crept into the dark instrument-room to experiment, and so upset a carboy of acid which ate its way through the floor to the manager's office. It is a remarkable fact, by the way, that Edison's deafness, which was then already quite pronounced, did not shut him off from this cheery existence, and that he was very popular with the crowd.

There is much more in these *Wanderjahre* of Edison than meets the eye. That young man was a person of limitless energy, of the highest practical address and readiness of resource, with a passion for electricity and its practical development, and no doubt also, with some personal ambition. Yet instead of striving after social and academic respectability, he wanders up and down the States, the associate of ne'er-do-wells, whose only resource in life is their skill as operators. All the time his wonderful power of going straight to the

practical end—never equalled since Leonardo—is developing.

Leonardo came to mechanics as Edison came to electricity : each had made a notion new to humanity part of his fundamental thinking power. Leonardo's freedom of mind was nourished, or at least maintained, by his artistic side, his life as a painter. In him we see the close affinity between art and technical invention. In each a new form is born into the world. What is the essential difference between the inventor of the Prize Song in *Die Meistersinger* and the inventor of, say, champagne ? Wagner and Dom Perignon ? Each consists ultimately in a prescription for human behaviour (in the one case addressed to an orchestra and tenor, and in the other to a vintner) by which certain means can at any time be brought into being for intoxicating and pleasing the human soul. And if at these two points these two branches of human creative activity almost coincide, we can certainly link up the rest. Indeed, in architecture we have a blend of art and science which is certainly one, and not two, and in which the artistic basis of technical creation, and the technical basis of artistic creation are one and the same.

Closely allied with the interest of the inventor for his subject is his staying power. This, expressed in sheer facts and figures, is amazing. Edison worked for five days and nights on end at one period on his development of the phonograph ; but such intensive labour is so common in technical development work as hardly to excite notice. It is also quite certainly true that, as opposed to all the rules applied to ordinary labour, the work done under such high pressure is actually

better in quality. The hyper-excitement of the brain, usually intensified by such drugs as alcohol, coffee, and even stronger, seems to stimulate its creative power. At any rate, the force of the impression made upon the unconscious, which is the preliminary condition to the generation of new ideas, is stronger and deeper in such states of excitement.

The sheer mass of work accomplished by the great inventors is astonishing. In some cases, of course, they possess the power of communicating their enthusiasm to others. Edison would work on a problem with a few assistants, and all of them, for days on end, took both food and sleep in the laboratory, Edison himself lying down on a table with a few books as a pillow. Edison, in common with many great minds, required very little sleep, averaging four to five hours a day.

One of the most remarkable of modern inventors was Lord Kelvin. In very early youth he developed the keenest passion for pure science, and became Professor of Physics at Glasgow University at the age of twenty-six, when his genius was already fully recognised. He remained at Glasgow all his life, a fact characteristic of his peculiar temperament, so different from that of Edison. In all other matters than in science, he was a typically respectable, business-like Scotsman with a very keen sense of the value of money and the things that could be bought with it. It seems almost incredible that his demand for a laboratory when made Professor of Physics astonished the Senate; it was with some difficulty that he obtained very poor accommodation in the basement, his technical work being largely motivated at the start by a desire to make money so as to equip his laboratory.

Kelvin was almost unique in science. Leonardo is only the greatest representative of a class of men who have combined artistic gifts with technical invention—Morse, for instance, was a very good painter—but the combination of high achievement both in pure science and in technical invention is very rare indeed. There is thus much justification for the practical man's contempt for the professor's impracticability. Lord Kelvin, however, was one of the greatest theoretical physicists who ever lived, and at the same time an inventor of the highest acuteness of vision and ingenuity in design. His inventions were, of course, as regards their principles, the application of physics, and in some cases chemistry, to practical problems; but his power of accurately visualising practical needs, for instance in his many nautical inventions, shows that he was far from being wrapped up in pure theory. So remarkable a man was he, that it is almost a relief to find one thing that he did supremely badly to the end of his life, and that the very thing which was the first of his official duties as professor. He was the worst lecturer that it is possible to imagine, and there must be many thousands who will remember his lectures at the Royal Institution, which were illustrated by remarkable experiments. Kelvin limped nimbly around between the blackboard and the front of the lecture-table, all the time reciting a monologue of which none but a few of the audience could possibly make head or tail.

Sir Dugald Clerk has pointed out that of twenty-one presidents of the Royal Society, only four are known as inventors (Davy, Rosse, Kelvin, and Lister), while of 174 recipients of the Copley Medal, only twelve were inventors —Franklin, Smeaton, Rumford, Volta, Davy, Gauss,

Matteucci, Bunsen, Wheatstone, Kelvin, Lister, Dewar). Faraday himself attempted to make an 'electromagnetic machine' in 1832, a year after his discovery of electromagnetism. The Italian Pixii was the first to succeed in making an electric motor, and of the names prominent in the history of the dynamo (Clark, Nollet, Van Malderen, Siemens, Varley) none are of the scientific eminence of Kelvin. Yet even he devised an ingenious and elaborate mechanical device for regulating the voltage of a dynamo supplying light to his house, and entirely failed to see the perfectly simple solution given by Varley's compound winding.

Kelvin had a mind the sheer horsepower of which was many times that of the normal. This type of mind, which astonishes any normal person when brought into actual contact with it, is common among men of genius, but by no means universal, and it is also possessed by many men, such as politicians, whose work demands no more than very moderate mental capacity. It is indeed an almost indispensable qualification for success in the profession of politics where rivalry plays so large a part, since the man who is able to go on working when his rival is tired naturally will get there first, brains being neither here nor there. Kelvin used to tell his assistants that everyone should be capable of doing at least three things at once. He himself could dictate one letter, write another by hand, and carry on a discussion with his assistant, all at once.

It would take us too far to discuss at length the relationship between the mentality of the scientist and the inventor. Superficially regarded, the scientist is merely discovering what is there, while the inventor is creating what has never existed before. This view is

certainly wrong; no class of human mind bears more clearly the creative stamp than that of the scientific genius. He does not create the facts which he discovers, but every important step involves the creation of the means of discovery: the hypotheses which are the basis and guide in all advance, and the experimental methods and instruments, which are normal technical inventions. Dewar invented the vacuum flask, Einthoven the string galvanometer, Aston the mass spectrograph, Crookes the X-ray tube, quite 'by the way' in the course of pure research, and without any thought of the general utility of these instruments. The same is true of innumerable chemical methods. But the highest order of creative effort is exemplified in the great hypotheses which, in the last marvellous thirty years of science, have sprung from the brains of Einstein, Rutherford, Bohr, Planck, de Broglie, Heisenberg, Schrödinger, and others. These are tested, like technical inventions, by trying whether they will work. But it is obvious that an aeon of experimenting would not discover them in nature, but only result in a mountain of facts without any structure whatever.

A great deal of technical invention, however, comes from minds of a much smaller order of magnitude, minds often of a character verging on the pathological. The monomaniac pioneers have been the chief creators of modern technology. The motor-car, indeed the modern internal combustion engine, the sewing-machine, the telephone, and many other inventions of the highest importance, were developed by a succession of men who were remarkable only for the concentrated ferocity with which they attacked these difficult problems. The idea of solving them became an

idée fixe ; their persistence seems inhuman and insane to ordinary sensible persons.

It is frequently said to-day that the day of such inventors is past, and that advance in the future will come exclusively from the magnificently equipped research laboratories of the great Trusts and Corporations. There is no evidence of this except the *ipse dixit* of the Corporations themselves. We shall see later that ' corporation research ' is, in fact, decidedly unproductive. Let us first study the pioneers who have succeeded, and try and find out the reason.

In the first place, we must admit that their success is that of an ill-equipped and fanatical horde, storming positions before which nine-tenths of the attackers perish, while the tenth that wins through is generally robbed of the fruits of victory. But it would be wrong to attribute the success of those who survive to pure chance, to the fact that numbers must triumph. The fanatical enthusiasm is the outcome of a creative drive, the success is the result of certain essential elements of character.

The first of these is the capacity for resolutely facing unpleasant facts ; the fact that a cherished idea is unsound ; the fact that the wrong road has been taken, and must be retraced ; the fact that hard study and more knowledge are necessary ; the fact that to trust in sheer luck is to court damnation. We constantly see the man who fails in these respects, obstinately adhering to false views, refusing to be convinced ; ending, all too often, as a mere charlatan, whose power to misguide the unwary has been developed, in the first instance, by misguiding himself.

Let us glance at the career of one of the most famous

and most characteristic of monomaniac pioneers, Charles Goodyear, the inventor of vulcanisation of rubber. The remarkable properties of raw rubber had been discovered by civilised man about the year 1800, though they were known to the natives of Brazil and other tropical countries from time immemorial. In fact, it has been shown that a crude form of vulcanisation had actually been discovered.

Rubber shoes and raincoats were soon manufactured in the United States, and in Europe the chief pioneer was a Mr. Mackintosh, whose name we have preserved for the article which he first produced. But these early rubber shoes and coats were useless both in extreme cold and extreme heat ; in the one they became hard and brittle, in the other, soft as putty. Those who have used gutta-percha for making moulds of objects will know what are the properties of unvulcanised rubber.

There were a number of manufacturers of rubber articles in Connecticut and Massachusetts, in fact there had been a wild speculative rush to found companies of this kind. The problem of ' tanning gum ' as it was called, was thus a burning question. In fact, Goodyear's attention was drawn to the matter by his being told that the large capital invested in the rubber industry was in danger of being entirely lost for want of a curing process. Thenceforward, Goodyear trod a very thorny path indeed in quest of a solution.

In his own words : " I was blessed with ignorance of the obstacles I had subsequently to encounter, but soon learned that the difficulties attending the experimenter in gum elastic obliged him to await the return of both warm and cold weather, at least twelve months, and often much longer, before he could know with

certainty that his manufacture would not decompose. . . . I was encouraged in my efforts by the reflection that what is hidden and unknown, and cannot be discovered by scientific research, will most likely be discovered by accident, if at all, and by the man who applies himself most perseveringly to the subject, and is most observing of everything relating thereto."

We are at once struck with a signal proof of Goodyear's poor natural equipment for technical experimenting. Surely, even in his time, the use of freezing mixtures was not unknown, while the problem of testing the behaviour of an experimental product at summer temperature in winter could surely have been solved by the use of a very simple form of oven.

Goodyear was a studious, industrious, and sober-minded type of man. He had worked at the making of hand tools in his father's workshop, where a pioneering spirit had appeared in making forks of steel for agricultural purposes much lighter than the rough wrought-iron forks then in use. He was unwise enough, however, to open a hardware store, mainly stocked from his father's factory, and at the same time to continue his mechanical and constructive work. It is rarely that the aptitude for making things and for selling things is found in the same person, and Goodyear soon got into financial difficulties. He was several times imprisoned for debt, and earned money for the support of his wife and family by working when in prison.

It was quite definitely with the object of retrieving his fortunes that Goodyear began to play with rubber. He borrowed money for this purpose; soon, after a few months' work, his friends abandoned him, and his

wife earned their keep by spinning. Goodyear then went off to New York and found free lodgings with a friend, and a good-natured druggist, Silas Carle, was induced to supply him with chemicals.

From now on he pursued a course of trial and error with the greatest persistence, for of course there was no other possible road to success. What appears most strange to us is the slowness of his progress. His first actual advance, after obtaining indications of success with lime, was due to the use of nitric acid. He was soon actually able to produce cured rubber fabrics by this means. But one would suppose that so simple a reagent would have been found somewhat sooner, especially as he had his druggist friend to supply him, and might have tried in a week everything that such a shop could supply. His wife then came to New York to help him, and for a time they succeeded in doing much business in rubber thus cured with nitric acid. The financial panic of 1836 ended this prosperity of Goodyear and his partner with bankruptcy. He was soon without money and even without food; the very household tableware had been used up in manufacturing. He was obliged to return to New Haven, and to manufacturing shoes for winter use only.

Then came a remarkable incident. One Nathaniel Hayward, who had been foreman of a bankrupt rubber company, was carrying on manufacture in a very small way on a part of its premises. He told Goodyear that he had been bidden in a dream to combine sulphur with rubber, and expose the compound to sunshine. He tried this and found that the rubber was actually 'cured'. Goodyear persuaded him to patent the process, and then bought the patent from him. As a

matter of fact, a German had previously discovered the affinity of sulphur for rubber.

For some time Goodyear continued trying to work this sulphur-sun cure, and it is at this point one becomes most of all impatient with him. He even carried out a large contract for mailbags given him by the Post-master-General. These were to be of thick rubber, which he attempted to cure, as he had successfully cured thin rubber, by exposure to the sun after the addition of sulphur. Thereupon his enemy the summer arrived, and the mailbags decomposed, for only a thin outer layer had been cured. For this bad result he blamed the inorganic fillers which he had used!

He was now overwhelmed by the return from all sides of his imperfectly cured wares. "For four years I had attempted in vain to improve a manufacture that had entailed ruin on all concerned. It was generally agreed that a man who could proceed further in such a course fairly deserved all the distress brought upon himself, and was justly debarred from sympathy. I was not infrequently reminded that I could at any time improve my circumstances by returning to the hardware trade."

Instead, he went on experimenting. His manufacturing declined to zero; he was obliged to dismiss Hayward, whom he had paid to assist him. He was now cold and hungry, and reduced to one room. At this point he made, quite by accident, his fundamental discovery; one which seems to us four years late, or at least due as soon as the work on sulphur and sun began. The rubber only needed cooking at a moderate temperature with sulphur to turn into the compound which meets us at every turn to-day, ordinary soft vulcanised rubber

It is difficult for us to do justice to Goodyear in respect of the difficulties which he had to overcome. In particular his partial successes were with materials (lime, nitric acid) very different in chemical nature from sulphur. In this kind of purely empirical work the only good rule is to try everything you can lay your hands upon, at all possible temperatures, and in every possible proportion. Another fact in mitigation of Goodyear's slow progress is that artificial methods of reproducing natural conditions have only been developed very recently. Goodyear was working nearly a hundred years ago, but it would not be difficult to find many industries in which the principle of artificial reproduction of extreme natural conditions has only been applied within the last ten or fifteen years. This is true, for instance, as regards the regular testing of dyed fabrics in their resistance to light, and of fabrics, road-surfaces, tyres, paper, and many other products, as regards their resistance to wear. It is also true as regards the testing of ship models in troubled water; and testing such models by traction in tanks is itself so much of a novelty that popular newspaper articles appear about it from time to time.

Success brought with it the most desperate trouble of all. He had to resort to the pawnshop, the sale of his children's school-books, even to charity. An oven was built for curing rubber by the volunteer labour of his neighbours, but meanwhile the only stock of gum had become useless by fermentation. Borrowing a few dollars, Goodyear went to New York and succeeded in obtaining capital. But no sooner was commercial success in sight than his capitalist went bankrupt for other reasons. A common enough case this;

the capitalisation of a pioneer invention is often only brought about by its being someone's last desperate gamble to retrieve fortune.

Goodyear was then thrown into prison for debt. He says, in recording the years of trial: " Money is indispensable for the perfection of improvement, but it is trial and necessity chiefly that are effectual in bringing hidden things to light ".

Then at last came success, both commercially and in his patent litigation. He went to Europe, and in 1855 spent $50,000 on his exhibit at the Paris Exhibition. Once more he found himself in a debtor's prison, this time in Paris. His detention did not last long.

Perhaps the best description of this type of inventor is that given by the formula so often used of him— " mad on the subject of ——". When such people are successful, or even before, we often find them attempting all kinds of inventions outside their original field. But the root and origin of their trouble is the original fixed idea, which seems to lodge in the minds of all kinds of people; only when its host is a man of parts does anything result, as a rule.

The power of the fixed idea is seen in the case of such a man as Goodyear, obviously born and bred to be a steady, reliable, and successful father of a family; the kind of man who would husband his resources, keep a steady eye on the main chance, and avoid all wildcat schemes. Under the compulsion of this vision of vulcanised rubber, he endured infinite hardship, such extremes as others have endured for their religious or political convictions.

Of course, once the hunt is up, the effort required

to abandon it becomes increasingly greater the longer it continues. It is only the feeble-minded average type that tires as soon as trouble begins; especially if a little real or apparent success has been obtained, or labour and money has been spent; there is an investment of pride and determination which cannot be abandoned. Often enough these latter factors are almost solely responsible for the tenacity exhibited; the work has been begun quite idly and indifferently, and if a fixed idea can be said to exist, it has formed as time went on. A great many people are wise enough to refrain from embarking on such enterprises, because they fully realise that the fascination of a quest may lure them from the paths of safety. The fanatical inventor has generally a deficiency of foresight, coupled with an element of rashness in his character.

His so-called 'characteristic optimism' is usually a mere defence mechanism, a mark behind which he hides his grim conviction of his own folly. For he knows quite well that for one inventor who wins through to success, a dozen go under in the struggle; some because they get on the wrong track, others because they are before their time, others again because the hardship is too much for their mental or physical constitution.

When we turn from these 'mad' inventors to the sane, sensible, and highly trained members of the research staffs of the great firms and corporations, we find ourselves in a different atmosphere altogether. These men are the salt of the technical earth, and absolutely indispensable to the working of modern industry. Nevertheless, their output as regards first-class inventions is surprisingly low. In a tabulation

made by Dr. Grosvenor,[1] only twelve out of seventy-two outstanding inventions made since 1889 have been produced by ' corporation ' research. Into this period falls the invention by independent individuals of such first-rate things as monotype, case-hardening of steel, photogravure, moving pictures, dial-telephones, calcium carbide, Diesel engines, carborundum, wireless telegraphy and telephony, electric train control, electric car-starters, submarines, safety razors, aeroplanes, flotation process, bakelite, gyro-compasses, etc. etc. We may add to Dr. Grosvenor's list the auto-gyro, the triode valve, Haber's ammonia synthesis, Bergius's hydrogenation of coal, television, gaslight papers (offered by their inventor, Baekeland, to the greatest photographic corporation in the world, and refused by them, only to be afterwards purchased at great expense when Baekeland had made a success of them). On the other side, we have of course a number of achievements in organic chemistry, the half-watt lamp, the Coolidge tube, and an enormous amount of improvement in materials such as photographic emulsion, steel, light alloys, cellulose and its products, few of which can really be regarded as pioneering work.

The very latest example of the victory of individualism in invention is television, worked out by a young Scotsman with the slenderest resources, in a cellar in Soho.

The fact is that born inventors do not, as a rule, join the research laboratories of manufacturing firms; and even when they do, the conditions under which they work are not conducive to production. The

[1] W. M. Grosvenor, ' The Seeds of Progress ', *Chemical Markets*, 1929, 23, 24, 26.

results obtained admit of no other interpretation. Yet it seems impossible to convince those responsible for the initiation and constitution of such laboratories for corporative research that matters are as they are, and might easily be improved.

The procedure adopted is to appoint as director some person of scientific attainments, who is instructed to engage at low salaries young persons of either sex pronounced by their college professors to be bright and promising, bind them by very strict long-term agreements to assign all inventions to the company, and provide them with problems to work on, and facilities for work.

Unfortunately, people with original minds do not as a rule become employees on such terms unless they have little faith in themselves, or are driven by force of circumstances. If they do so, they resent very strongly being compelled to abandon the property in their own creative products which the law, in the first instance, guarantees to them. Everyone is perfectly familiar with this fact as regards creative work other than invention ; in matters of art, music, and literature, the term of contempt used is ' hack '. Work under the conditions of most industrial research laboratories is hack-work in this sense. Insight into the psychology of the matter is gained by noting that the artist, writer, or composer feels no shame in accepting the support of a patron, dealer, or publisher, during the production of work of his own conception. He is still a free man, and not a wage slave.

The mistake arises in the case of invention largely from confusion with the position of pure scientific research, where creative work is unsaleable as such, and is

maintained by paying its producers as teachers, and by grants-in-aid. The business man who learns that Einstein or Rutherford draw smaller salaries than his own managers, yet turn out original scientific work which is the wonder of the world, may be pardoned for supposing that if he catches their like young, by offering a little more than the academic rate of pay, they will turn out equally original work, but of a kind extremely profitable to his firm if protected by patents. The psychological errors involved in this view are too numerous to deal with here, but the business man's psychological powers are best adapted to dealing with his own kind, and often fail completely when applied to the mentality of other human types. For one thing, he entirely fails to appreciate the fundamental difference between the pursuit of pure knowledge, every bit of which is of imperishable value, and technical invention, the value of which is largely transient. A young architect may be content to devote his life at a low fixed salary to building a single cathedral, but he will certainly refuse, if he is a first-class man, to remain for longer than he can help in the office of a firm, at the same salary, designing shop-fronts. Another point is, that the professor is paid to teach, and only in that function is bound to perform certain tasks at certain hours. His research work is free in every way.

But let the creative bird be caught in the net of the fowler, and duly caged. All experience goes to show that he rarely sings. Creative work is *over*-work; the steady round of 9 to 6, with lunch from 1 to 2.30, simply does not produce it. It needs sweating and worrying in the small hours of the night; it is monomania. The hope of fortune, the pressure of creditors,

nay, even the battle with insufficient means and appliances, are the spurs that are needed. Bad as is our patent law in many respects, it forces the pace by its insistence upon fixed periods of time : a year for the complete specification ; a year for the foreign patents. It is not that the big problems are solved more slowly when the attack has less impetus ; the vastly better facilities at the disposal of the large concerns would more than compensate for that. The atom is not split by an alpha-particle or proton possessing less than a certain energy ; the big problems are not solved at all by minds with less than a certain impetus.

Another fact that misleads is the sight of the first-rate inventor, when successful and in funds of his own making, equipped with a large laboratory and staff. But here, as in all analogous cases, the maintenance of success won by one's own efforts becomes a keener spur even than poverty. It is the tritest of truisms concerning all the independent professions that the early struggle is the making of the man or woman, and that to quit as soon as success is obtained is rare. An Edison, a Kelvin, a Baekeland finds the call on his energies increased, and not decreased, as his work expands, and such men respond to the call. But even when a large firm buys up a young but proven inventor body and soul, and makes him director of a research organisation, the result is usually disappointing. A stream of useful minor improvements in products and processes is the most that ensues. And curiously enough, such directors are often the first to insist on depriving their assistants of all rights to a share in the success of their work.

Finally, the business of evading or fighting trouble-

some patents of outside inventors is apt to play a considerable part in the work of such research laboratories. In some natures, resentment at their own bondage may lead to a certain gusto in respect of this task, but others find it merely depressing.

We will defer to the concluding chapter the question as to how matters might be otherwise arranged, so that industry would further the progress of invention to its own profit, and proceed to consider more practical matters ; matters of life and death to the person who is willing to venture on the thorny path of independent invention.

Chapter III

THE PRACTICE OF INVENTION

Our discussion of the nature of invention and inventors has prepared the way for a discussion of the actual practice of invention. Should anyone deliberately practise invention as a private individual? Or should we pray to be delivered from the infection as from the plague? If it be granted that invention may stand with art and science as a creative life-work, it has only recently been admitted to this position; not till the seventeenth century is there any recognition of it. Papin was probably the first full-time inventor on record. No one would dream even to-day of suggesting to a boy that he should choose invention as a profession. But the same is true of painting. A very wise man said, "an artist can live by his work—if not well, then less well"; meaning that a creative career calls for the devotion of all the energies to it. There are few indeed who can first devote themselves to securing a comfortable living by ordinary methods, and then turn to creative work of a high order. As a rule, the divine spark is out; the passion of youth cannot be recaptured, whereas it may be alive in old age in him who has never set it aside for the good things of the world.

Nevertheless, in the case of invention, whole-time

devotion is an impossibility unless the means of livelihood are otherwise provided for.

When one considers the history of modern civilisation, and particularly of this country, the part played by technical invention is so overwhelming, that the apparent indifference towards its encouragement appears at first sight incomprehensible. The ideas which have sprung from the brains of British inventors have played as large a part in the growth of our wealth and population as has the discovery and extraction of gold in that of South Africa. Yet the inventor still meets with very little encouragement in this country. Everywhere he meets with a variety of excuses when he seeks support. It is as though the directors and shareholders of a Rand gold mine, which in the past had been extremely profitable and the main source of their wealth, were to appear nevertheless almost indifferent to the working of the mine. If taxed with this indifference, they might reply with truth that winning gold from quartz is a hard and difficult business, and one beset with risks. The rock must be mined with the aid of elaborate machinery, and only contains a small percentage of the precious metal, the rest of the mass being absolutely worthless and indeed a nuisance. Long and difficult operations are necessary to extract the gold, and make it ready for sale. This involves the investment of immense capital in plant and machinery, and the chance is always there that the vein of gold may give out altogether.

Further, our imaginary apologist for inaction might plead the objections of many economists to the gold standard, an abandonment of which would lead gold to lose its value. Also, on the other hand, some clever

inventor may find a way of extracting it from sea-water or heaven knows what else, or even of making it outright.

Finally, in any case it is no blessing to mankind ; it has been the cause of war, private bloodshed, crime, and misery without end, and the world would be much better off without it. Undeniable as all these arguments are, the shareholders of a gold mine would make short work of a director who advanced them as an excuse for poor financial returns. He would certainly be invited to betake himself to a field of activity more in accordance with his personal tastes and views.

Ridiculous as such a situation appears when stated so explicitly, it occurs every day in a less obvious form. People do not actually give expression to their want of faith and interest in the fundamentals on which their lives are based, but it is betrayed by their otherwise inexplicable inertia. In fact, faith great enough to move even a moderately sized molehill is rather rare to-day.

In the matter of invention a further complication arises. There is, after all, a fair consensus of opinion among engineers as to how a gold mine should be worked for efficiency, but there is no corresponding class of persons who are able to give authoritative advice resting upon practical experience in the matter of invention.

Let us deal first of all quite shortly with the question : Is invention worth while ? We may consider this from two points of view, first absolutely, and secondly, relatively to our present position.

We have a number of writers who persistently decry industrial civilisation, and would have us return to a

much simpler way of living. These writers themselves rarely put their ideas into practice; and even an exponent such as Mr. Gandhi, though his actual domestic personal tastes may exhibit a highly superior simplicity, is not above making use at least of the medical advances of our time and of means of transport. The argument in favour of simplicity usually turns about the question of happiness, and its futility lies in the fact that there is no objective test by which the happiness of simply living people can be compared with that of those subjected to high industrial civilisation. It is probably true that the latter leads logically to extreme boredom for the majority of people, but this boredom is due to the fact that their minds have been awakened without being given any real satisfaction. The majority, on the other hand, of primitive people do not reflect at all upon their condition, and hence strictly speaking cannot be said to be happy or unhappy at all, since happiness is a state of conscious well-being. The general effect of modern civilisation is certainly to remove men's minds as well as their bodies farther from the animal state, and unless we agree with Walt Whitman in envying the animals because

> They do not sweat and whine about their condition.
> They do not lie awake in the dark and weep for their sins.
> They do not make me sick discussing their duty to God,
> . . . . . .
> Not one is respectable or unhappy over the whole earth.

we are obliged to admit that a negation of industrial civilisation is a negation of the course taken by humanity in all its past evolution.

Relatively to the time in which we live, there is more to be said against a further development of

invention. A distinguished ecclesiastic actually expressed this view recently in calling for a holiday from further technical advance, much as certain pacifists call for a holiday from further invention and construction in armaments. Indeed, our consideration of this subject at the present time is completely overshadowed by the fact that modern invention appears to be leading to the possibility of enslaving both the minds and the bodies of men in a manner hitherto quite impossible. In past times ploughshares could be beaten into swords, and tyrants could be literally pitchforked out. Nowadays the tyrant has not only physical means at his disposal which render ridiculous any kind of revolt against his tyranny ; he has also equally powerful means of influencing the minds of the mass to the point of their accepting his tyranny without even a wish for revolt. Every advance in invention adds to these means, and invention is not by any means confined in this respect to physical invention. If this book were devoted to a wider survey, one of its principal divisions would relate to the ingenious means for government and taxation by which so self-willed a people as our own, for instance, has been reduced to a sheep-like subservience almost without parallel in the history of the world. Furthermore, not only governmental and acknowledged power benefits by modern invention ; the gangster in America has exhibited equal aptitude for making use both of moral and physical invention to enforce his will.

Against all this we have the fact that invention has now given mankind the power to release itself entirely from servitude to labour. The future is essentially dependent upon the struggle between the forces oper-

ating in favour of this release being practically accomplished, and the fact that a minority rejoicing in the exercise of power, open or secret, is able to withhold these advantages from mankind.

Quite recently the effect of technical advance has been to redress the balance in favour of general freedom, and against the tyranny of individuals and ruling powers. More and more, the latter are becoming dependent upon psychological action as opposed to purely physical. This psychological action consists essentially in the power of deluding the mass in some way or another, and it has enjoyed in the past half-century very great triumphs. There are signs, however, that unless further invention in this respect takes place, the power of the spoken and written word upon the mass will decline, because it has been used, and still is used, for objects which too quickly demonstrate the nature of its appeal. In the very field we are considering we have had a recent example in the boosting, in 1928–29, of bogus or overestimated technical inventions for Stock Exchange purposes, with the result that at the moment capital for companies financing new inventions is unobtainable.

At present the situation is complicated by the fact that few thinkers see any hope of realising for mankind the physical advantages offered by technology without an organisation of society as rigid as that of Russian Communism, or some equally complete negation of individual freedom. The writer has put forward this view,[1] rather by way of warning than as an attack upon the principle of invention itself.

At the present time we have reached a point where

[1] *Conquest of Thought by Invention*, London 1930.

retreat is really impossible. We must go forward, first of all because we shall starve if we do not ; and secondly, because a way out is visible ahead, while no line of retreat is conceivable. If Mr. Gandhi could persuade the great majority of people that they would be happier by reverting to extreme simplicity, the only result of their doing so would be that a handful of determined men, making use of but a tithe of modern technical possibilities, could exploit a whole nation. I often think that the unconscious objective of the intellectual who adheres to this school of thought is really the slave-state of ancient Greece. There is from many points of view a very great deal to be said for such an organisation of society. But it is no argument for a cessation in the advance of technical invention. As a matter of fact, technical invention at the present time is developing in a way which would make such a slave-state very easy to form. Power is now available in small units, either from electric networks or from petrol motors. The telephone, and television when it comes, will abolish the isolation of persons living in rural surroundings, so that a new peasantry is possible, and is indeed growing up in Europe, whose life is more attractive and much more healthy than that of the town proletariat. The mass manufacture of cheap goods can be set up anywhere, and the goods which Europe will export can only be such as require great scientific skill to make. Most of these are capable of being made in small country workshops. Invention will and must develop on these lines, if Europe is to maintain its supremacy in the production of fine industrial products.

We will now turn to the question of education as affecting industrial invention. One of the worst features

of present-day education, especially secondary and higher education, is its technical as opposed to its scientific character. The universities are all developing the teaching of applied science and technology, and no systematic attempt is made to select or advise the students who enter for these courses. The result is that a great many students of high ability are taught the details of some technical subject, such as chemical, electrical, or mechanical engineering, without having first been thoroughly grounded in chemistry, physics, and mathematics. If students of this class were to devote their time to acquiring a thorough scientific grounding, the subsequent entrance into practical engineering, which is nothing but the application of the principles of science plus empirical experience, would be an easy matter. But their minds would not be biassed in favour of the particular methods taught at college ; they would be perfectly open to changes in these methods, if scientifically sound, and those who possessed creative talent would be fully qualified to exercise it.

On the other hand, a large number of less gifted students, perfectly competent to acquire the routine of technical work, have their minds overstrained in acquiring too wide a range of knowledge, which yet is only a knowledge of formulae, and not of principle. They would be better occupied in learning very throughly the practical details of one branch of technology, together with the commercial and other related matters which would be of use to them in management.

The first problem, therefore, is to select from among those students who definitely exhibit a strong interest in technology, those who should receive an education

in pure science. It is often difficult to persuade students or those responsible for their education, that pure science is not an academic matter, but one of practical value in the highest degree. The students may be divided quite definitely into those possessing a naturally practical turn of mind, and those possessing an interest in scientific research for its own sake. The latter class, as we have seen, may contain persons of the highest practical originative talent, such as those 'inventors-by-the-way' of whom we spoke in the last chapter. The practical bent will, however, be displayed very early in the form of invention, and the infallible sign of its existence is a tendency on the part of a student, when acquiring knowledge, to think ahead, and actually re-invent step by step what is already known in his particular subject, though not to himself.

Since this is practically the only possible objective proof of originative faculty in the student, no kind of formal examination that can be devised is of much value for revealing it. But it should be clear enough to anyone possessing the necessary insight and closely following the student's development. The unoriginal mind, no matter how brilliant and gifted otherwise, shows only the power of rapid comprehension and acquisition. The original type may even be deficient in these respects, but when it is following up a certain line with strong interest, it leaps ahead, and actually anticipates largely. This is well known as a characteristic of some of the greatest minds in pure science, particularly in mathematics. Gauss, Newton, Ampère, and others no sooner took up the study of Euclid when children, than their minds already formulated propositions far ahead of their reading ; and it is not possible

to conceive of more striking proof of the superiority of their mental powers as compared with those of the ordinary average schoolboy. He usually has to be pushed over the *pons asinorum* with the combined force of persuasion and threats, and remains incapable of making any use of what schoolmasters imagine to be his knowledge when he reaches the other side. This is not meant to deny that a dunce at mathematics may be a genius in some other line.

There is, however, another matter altogether closely bearing upon technical invention. If invention consisted solely in applying known science to technology, as Kelvin for instance applied it, the whole education of an inventor would consist in a grounding in pure science. But, as we have seen, a great deal of invention consists in the application or utilisation of natural fact which cannot as yet be stated scientifically, but is a matter of almost unconscious insight on the part of the inventor. The Vikings, when they built their ships, developed lines which can hardly be improved upon to-day, and the steam-engine preceded thermodynamics. The conclusion we must come to is that the student with the practical bent and original mind should devote his time of serious study to pure science, but at the same time should be immersing himself in the general atmosphere of the art in which he is interested by practising it in his spare time, and particularly by devoting himself to matters in which practice is in advance of theory. To take an example, the student interested in aviation and hoping to advance it by invention, should be studying only chemistry, physics, and mathematics, and his practical acquaintance with aviation should lie rather in a sport such as

gliding, than in the building and testing of engines. There is no more instructive case in the history of technology than the development of engineless flying. It is very doubtful whether Lilienthal, who advanced farthest along gliding lines before the advent of the motor-driven plane, ever dreamed of the possibility of flying without engines for hours on end. This development was in no way the result of the application of scientific principles, but simply of the growth of a feeling for the practical behaviour of planes in turbulent air, and might have been developed on Lilienthal's lines before suitable motors for aeroplanes were invented.

A very important matter for the full development of an originative mind is an early and varied experience of life. We have seen in the case of Edison how his own extraordinary adaptability to practical, and indeed very Bohemian life, led to his earliest years being spent in wandering all over the States. A remarkable feature of his case is the fact that deafness, which so often leads people into a morose seclusion, in no way prevented him from going around in the world. Too many creative types are afflicted with a natural shyness or nervousness which is greatly to their disadvantage, and they are very unfortunate if circumstances allow this tendency to be confirmed for life. In this respect the German university system is greatly superior to the English. There, every student if possible sees something of several universities, and is entirely thrown upon his own resources as regards his way of life, whereas in England, at any rate in the older universities, he is more or less in a position of tutelage. In pre-war Germany, also, military service was compulsory for all but those completely unfit physically, and this again,

I feel sure, very much contributed to the great practical adaptability to life shown by the younger generation of German inventors and technologists. In all ranks of English society, you will find people of extraordinary ability and originality, whose gifts have never found a proper outlet because they have shunned their fellows and developed into oddities.

There is, however, an increasing tendency, only checked at present by economic difficulties, for young people to move about the world and interchange ideas. Unfortunately, a great deal of this is rather a matter of herd activity, and people of an original type of mind are the last to join organisations, wear uniforms and badges, and generally to disport themselves according to plan. But every effort should be made by all persons interested in the education of youth to persuade those with a tendency to withdraw from the crowd not to withdraw into a shell, but rather to move around and see the world.

This matter has a great and important bearing upon the subsequent activity of one who must necessarily, if he is to be successful, apply his creative energies in a way which will be appreciated by the world. The romantic pioneer who is entirely misunderstood in his time and dies in poverty is, in creative art, a type that must exist and one whose work is not lost to the world. But the inventor who is ahead of his time, or at any rate fails to make an impression upon it, usually expends his energies in vain ; it is rarely that his work is finally discovered and continued from the point at which he left off. Usually it is entirely forgotten, and done over again by someone else. We may at this point consider generally the characteristics of a successful

invention, for anyone engaged in invention cannot do better than reconsider his work from time to time, rigorously applying tests to it which extend beyond its fundamental technical possibilities.

To put the matter shortly, a successful invention must be: (1) sound, (2) practicable, (3) workable, (4) producible, (5) having advantages which outweigh its disadvantages, (6) marketable.

Take first the question of fundamental soundness. This is meant in the sense that the idea must not conflict with the laws of Nature. No perpetual motion idea, for instance, can be sound. Since no person with a proper scientific training will dwell for long upon a fundamentally unsound idea, there is little more to be said, except to emphasise that a practical engineering training is by no means sufficient to save its possessor from falling into a scientific fallacy.

The question of practicability is quite separate from that of soundness. The idea of an internal combustion turbine is fundamentally sound, but it is not practicable because efficiency demands materials capable of standing temperatures beyond the range of all known materials. It is chiefly this question of material which nowadays decides matters of practicability, though we may also be met with limitations set by possible accuracy of workmanship to such matters as speeds of revolution, optical possibilities, and the like.

I use the term ' workable ' to cover the position of an invention imagined as actually carried out and put to its task. It is not workable if it involves for its use a degree of skill or special knowledge beyond that generally obtainable. For instance, in an ordinary cinematograph projector, the film is jerked forward,

held still, and flashed on the screen, with intervals of darkness between each jerk. An extremely ingenious machine in which the film moved continuously, one picture dissolving into the next without the screen being darkened, failed because its running required an operator of a type quite unobtainable in the ordinary way. In other cases we may have a cumulative error, or an effect of wear, which is self-aggravating, inherent in the design, so that when it has once started in ever so slight a degree, it gets worse at ever-increasing speed. Generally, however, the most important matter will be the question of material, and every invention, imagined as ideally carried out, should be considered in detail from this point of view, namely, what will happen when the material, which can never be perfect, begins to wear or otherwise deteriorate. The whole history of aviation is scattered with instances where this matter has played a decisive part.

The next question is whether an invention is producible. Of course any invention which has survived the three questions so far put must be capable of being produced, but it is a very different matter when we come to consider the problem of cost. For instance, cinematograph projectors of the type just mentioned have been devised and built and shown to function perfectly. But when it comes to their actual production, the accuracy required in some designs is such as to make their cost out of all proportion to the advantages gained. A fact that is very frequently forgotten, often by scientists, and even by engineers, is the fact that no two objects can ever be made identical by the hand of man. No matter how perfect the tools available, there is a limitation to their accuracy ; and when

we come to manufacture on a practical scale, we have to be content with considerably less perfection. Even the simplest stamping or pressing inevitably varies from piece to piece ; the material itself varies in composition and condition, and the tool is worn at each operation, thus producing a progressive change in the result. This accounts for the fact that even the highest class of interchangeable manufacture never produces identical results. Every car engine or aeroplane engine, for instance, is slightly different from every other of the same batch ; it differs in its initial performance, in its rate of wear, and in the nature of its final failure. Perhaps one of the most beautiful and remarkable inventions of recent times, the Constantinesco torque-converter applied to a motor-car, failed because at one point, which had nothing to do with the fundamental principle, it was impossible to produce, by any available means, the part required.

The next point is that the advantages of an invention must outweigh its disadvantages, especially if, as is nearly always the case, it has to compete with other methods of attaining a given end. It is at this point that self-criticism of inventors, and generally speaking the criticism of experts, is most liable to fail. On the one hand, a highly ingenious idea is liable to be over-estimated, especially if one or two striking advantages are attached to it, the corresponding disadvantages peculiar to it being overlooked or made little of. On the other hand, an unexciting idea, one perhaps involving an apparent reversion to simplicity, is liable to be under-estimated, especially if its advantages are rather of a negative character. No more striking instances of these facts are to be found than in the matter

of the transmission of power by gearing and its equivalents. The Constantinesco torque-converter is only one of very many instances in which the greatest ingenuity has been displayed, without success hitherto being obtained, to abolish the gear-change in motor-cars, and generally, to make an infinitely variable transmission. While all these brilliant and exciting attempts have been made at enormous cost, ordinary tooth-gearing, as well as transmission by belts and chains, have been the subject of gradual small improvements in methods and materials, and with very few exceptions, the motor-car of to-day is designed on the most primitive lines in this respect. It is instructive that even Ford himself adopted a type of gearing which, though he adhered to it, failed to find acceptance by others. At the very moment of revision of this MS., the news comes of the adoption by many motor-car makers of the Wilson gear, a serial system of epicyclic gearing invented long ago and first used on tanks in the war.

In this matter there is room for the exercise by the inventor and by critics, of every degree of imaginative insight. It is extraordinary that not only are probable disadvantages and troubles underestimated, but that others are overlooked altogether. At the same time, as in the case of the Wilson transmission, highly valuable inventions lie unused. There is room for a definite science of criticism in each branch of technology, so that these matters are not left to individual judgment, but made the subject of an analytical routine as strict as, for instance, the tests which are applied to material when purchased by contract for a given purpose.

Finally, an invention must be marketable. It must

fulfil an existing need, or be so attractive and useful as to create a need for it. It is here that we leave the province of scientific and technical knowledge altogether and have to rely largely upon the kind of insight into the public mind which makes the successful business man. History shows that it is here that insight is rarest; just as with literary works or music and painting, mistakes have been made again and again by those most qualified to form a judgment. It is surprising that no regular system has grown up for discovering, before a large amount of expense is incurred, whether an invention is likely to receive public support. At present there seems no other way than actually to produce the thing and see what happens, and here again very much depends upon the energy, persuasion, and finance put into marketing it.

Generally speaking, an invention is marketable if it falls into one of four classes. It may be better than anything existing at the time for fulfilling its purpose. This, as we have said, will not, or very rarely, be a question of absolute superiority; the existing thing and the new thing will have both advantages and disadvantages, and the fact that in many branches of technology there is lively competition between alternative possibilities shows that these advantages and disadvantages may be differently felt by different users.

An invention may also fulfil a need that is still unfulfilled. The phonograph is a supreme instance of such an invention. What usually surprises us is the slowness with which such inventions are made use of. It is far easier as a rule to introduce an invention against competition than to persuade people to adopt an entirely new thing which is not yet down on their list of

those things upon which it is necessary to spend money. This is least true in the case of labour-saving devices. On the other hand, the introduction of the cash register shows us what energy in salesmanship is able to effect in such a case.

It is needless to say that an invention which is cheaper than competing methods stands the best chance of all of being introduced. Sometimes, however, this principle may fail. For instance, an ingenious machine was devised for making egg-shaped briquettes from waste coal-dust, and this was applied to anthracite, the product being put on the market at half the price of pure anthracite nuts. Although it was fully as good as the anthracite, it failed to sell. When the price was raised to be slightly more than that of pure anthracite, it at once began to sell very well indeed.

The writer has had personal experience of a most amusing instance of this kind. A company was selling a certain apparatus used in large households for £40, the cost of manufacture being about £8, but the selling costs being very heavy. Very strong competition arose with a better-finished article of equal efficiency at a lower price. Whereupon the first firm called its travellers together, told them that the sales were falling off rapidly owing to competition, and that the price would now be raised to £45, the extra £5 to be taken by the traveller effecting the sale. On the other hand, if the sales did not increase by 20 per cent within the next month, the travellers would be dismissed. The anticipated increase in sales was more than realised.

One of the most difficult matters to estimate is the relation between the cheapness or dearness of a product and its relative advantages or disadvantages. As

a rule, we are never surprised when a cheaper article is commercially successful, even though its cheapness carries with it obvious disadvantages. But clever people have again and again made money by putting on the market an article very much dearer, but also very much better, than anything in existence. Everyone is now accustomed to the various types of pencil-sharpeners for offices which are made with all the perfection and precision of a high-class machine, and are correspondingly expensive, but the first man who embarked upon their manufacture must have had great courage when fairly efficient pencil-sharpeners could already be bought for a shilling or two.

Very likely his success was originally due in part to an entirely different factor. We can well imagine that prosperous business men looked upon so elaborate a machine for performing so simple an operation as something in the nature of an amusing ' stunt ', and bought one as a toy rather than an economy in time and pencils. This leads us to consider a fourth class of inventions, which sell largely or exclusively on this stunt value. It is obvious that anything that will surprise or amuse the public is capable of commercial success, provided that it is properly handled. A great deal of invention devoted to domestic and sporting matters is of this character, and these ingenious devices have usually very short lives. But this by no means excludes commercial success, and a return for the time and labour expended. The point is that such things should be handled quite differently from inventions where a permanent success is hoped for. For instance, the expenditure upon foreign protection for such stunt ideas is hardly worth while. Unfortunately, ideas essentially

of this character are often mistaken for things of permanent value, and instead of hay being made while the sun shines, the attempt is made to build up a permanent business.

What has been said above leads us very definitely to the conclusion that the inventor, to be successful, needs to combine in himself a great many diverse qualities. In the first place, he must be in love with invention, and either have faith in its value, or at least an abiding delight in it as a game. He must have an instinctive grasp of the fundamentals of the field in which he works, and on top of that, a sound scientific education, at least for many types of work. For others, the *sine qua non* is a thorough practical experience. And quite apart from all these qualities, and by no means usually associated with them, he needs a sound capacity for objective consideration of all the industrial pros and cons of a given problem and its possible solutions. If he possesses all these qualities, he will certainly never want for funds to live modestly and experiment in a restricted degree. The making and keeping of a small fortune calls for still further endowments; but unless he succeeds in this, he will never be able to devote himself wholly to invention.

Invention, like all other creative work, has one thing in its favour. When it goes well, the work is pure delight; when the task becomes hard the holder of the whip is still oneself, and not another. Even in the best-paid professions, the plain marks of the beast of burden generally appear in middle age, and only the prospect of being able to throw off in retirement the whole hateful grind keeps a spark of vitality alive, in very many cases. It is astonishing how different are

those who have never bent their necks to the yoke. While their hours have been far longer and laborious, and their fare and living far plainer than the others, they seem to wear decidedly better. Such, perhaps, is the only justification for recommending anyone to become an inventor.

Chapter IV

Working Out and Financing an Invention

The stages in the progress of practically every invention are four in number: (1) the idea, (2) the rough test, (3) the demonstrable model, (4) the marketable sample.

The second of these divisions is one which necessarily does not apply to all ideas. It is obvious, for example, that many mechanical inventions cannot be tested at all unless they are made with the greatest care. But it is in devising the means for testing satisfactorily at least the principles of an invention that the practical skill of the inventor is of the greatest use.

When an idea is conceived, there are two directions in which the imagination should be exercised with the highest intensity. One of these is to discover the greatest possible generality of the idea. Because an idea is devised for a certain end, and appears likely to fulfil it, it does not follow either that it is limited to that end, or that it is anything but one form of a more general idea which would serve the same end better when thrown into another form. Most ideas, of course, are examples of the application of known general principles to special purposes, but even if the known general principle which we find useful in one special form cannot be protected, there may be another form of its applica-

tion which is preferable to the one which has first occurred to us.

The second direction in which imagination must be exercised is that of finding all the assumptions involved in applying the idea. These assumptions may often be very difficult to discover by pure thought. Nearly all the difficulties which turn up when experiment begins are simply the demonstration that certain assumptions made when the idea was accepted as useful, were really unwarrantable. In the case of ideas of such a nature that a rapid and useful rough test is impossible, some at least of the assumptions involved may often be tested. For example, in the design of an elaborate automatic machine for packing powders or semi-powdered material, certain assumptions are involved as to the way in which the materials concerned —that is, the packing material and the material to be packed—will behave in the operation of the machine. When the machine is designed, the most careful consideration should be given, before proceeding further, to such matters as whether the packing material will actually fold in a certain way, or whether the substance to be packed will, under all practical conditions of temperature, moisture, and composition, feed into the machine and pack in the containers as expected. These points can readily be tested, but very frequently indeed such tests are neglected.

The psychology of Freud is becoming so well known that people are beginning to make practical use of it in everyday life ; and a business man will now realise that he is liable to forget important matters when they are connected with persons unpleasant to him. The inventor is not immune from this Freudian repression,

and has to be particularly on his guard against it. His tendency is to apply such tests to his ideas as are likely to exhibit their best features, and genuinely to forget to apply those tests which will exhibit their worst features. Without falling into that hypercriticism of one's own work which sometimes appears to paralyse persons of original powers, it is most important to keep the weak points of an invention in mind, and to subject them to practical tests. They will have to be dealt with sooner or later, and the earlier the mind is set to the task of dealing with them, the better.

We shall deal specifically in later chapters with the practice of experimenting in different fields, and will not go further at this point into the matter of rough testing, except to say that, generally speaking, every effort should be made to avoid relying for such investigations upon other people, excepting the inventor's own paid assistants. A few firms exist which have had some success in working out and testing ideas for inventors, but these quite rightly charge heavily for their services. Any inventor hoping to get this work done cheaply is mistaken. The firm undertaking it at a cheap rate can only give the work to a comparatively unskilled person, on whose wages the charges of the shop, management, and profit have to be laid. It is very much better in the end for the inventor to purchase the necessary equipment, which can often be done very advantageously second-hand, and then employ a suitable person to assist him. Very frequently he will be able to find highly skilled persons willing to assist in their spare time for payment ; and he will do well, if fortunate enough to obtain really valuable help of this kind, to bind such a person by a fair agreement, giving

him a share in the proceeds of success, and at the same time preventing him from running away and working on the same lines when matters are half developed.

As soon as work is well started and the results appear promising, the inventor should redouble his imaginative efforts to find out what he is really doing, and to think of alternatives. In every branch of invention there are certain common classes of alternatives, some of which have received recognition in legal decisions. We shall deal with these again under their headings. But in addition to considering such alternatives, the inventor will do well at this stage to picture to himself exactly where he will stand, in the most favourable case, when his invention is perfected. Here he has to put himself in the position of a user who is looking simply to his own advantage, and is in no way dazzled by the beauty or ingenuity of the invention. A labour-saving device, for instance, must not save labour by putting trouble and responsibility upon highly paid officials. This has been a great obstacle to the introduction of instruments, and especially recording instruments of all kinds. While it is agreed that they effect great economies, they have often caused so much trouble, by reason of a certain care and skill being needed (for however short a time) in their use, that they have been abandoned after trial. In the same field, the introduction of an entirely new instrument, no matter how obviously needed, is attended with much greater difficulty. The inventor and manufacturer can but demonstrate its perfect operation ; the economies and other advantages are a matter of prediction only. Hence instruments of the greatest value, such as those for indicating and recording the chemical composition

of furnace gases, softened water, effluents, and so forth, are introduced very slowly indeed. A manager can get a large coal bill of many thousands paid without question by his Board, and a saving effected by attention to furnace combustion or purity of boiler feed may be entirely masked by fluctuations in works output, quality of coal, and other causes. But the instrument is a separate item of expense, and every repair to it is the same; these have to be justified to the directors. Furthermore, the installation will require the attention of the manager, and the running will need the discovery in the works of some employee sufficiently intelligent to look after it without breaking it.

In the world as it is, the introduction of new inventions is almost entirely dependent upon the fact that a very few persons in positions of management have retained a schoolboy interest in novelties, and when this interest is combined with a sufficient degree of intelligence, such a man is finally able to justify himself to his peers by pointing out that he has, all his life, been well ahead of the rest of the world in his practice. This by no means leads to others following his example, since they may prefer to play golf rather than stay behind in their works anxiously watching over some new device in which they have not even any financial interest.

It is almost needless to say that any inventor who is able to induce a man in such a position to accept as a free gift a financial interest in his invention, will usually be doing well for himself.

The moment the idea appears quite definitely promising, the inventor should protect it by a provisional specification, which will cost £1 for the stamp fee, and

a further £3 or £4 for the services of an agent if one be employed. It is a perfectly easy matter for anyone possessing the faculty of straightforward exposition to draft a good specification, and in the last chapter we shall discuss this in greater detail. The ideal way is to file new provisional specifications at frequent intervals embodying everything you know, or can think of. The foreign patent must be filed within a year by the terms of the International Convention, and a year is a very short time in the development of an invention. Hence, if a new provisional specification has been filed every few weeks, it is possible to let the earlier ones drop, and base the foreign patents on the later ones. In view of the fact that foreign protection costs a great deal of money, most inventors will have to get others to pay for it, or do without it.

It is naturally desirable to be as secret as possible about the work, but secrecy bulks altogether too largely in the minds of many inventors. There have, of course, been some remarkable cases of theft in history ; one of the most flagrant being the way in which the American Fulton stole the idea of the steamboat from a Scotsman named Symington, who took him for a trip on the first steamboat ever made. But these cases go back to days when inventions were eagerly sought after. Nowadays, I fear, no one is likely to attempt to steal an invention, unless its introduction costs nothing and promises to yield immediate profit.

If the inventor can actually produce a marketable article by his own exertions and financial resources, he will be much better advised to make this his object, rather than to attempt to widen the applications and the field of his invention and to commercialise it on a

large scale. But he should not underestimate the enormous labour which is involved long after the invention has been brought to working perfection. The production of a single model by which the invention can be perfectly demonstrated is often difficult enough, and involves a great deal of work quite apart from the direct line of development. But the next step, that of producing the thing in a saleable form, involves work of a kind usually entirely foreign to the inventor's aptitude. In order to produce a feeling of confidence in possible customers, there must be no signs of amateurishness in his presentation of the invention. Every detail of literature, finish, packing, and so forth must approach as closely as possible the standard set by firms possessing all the resources of modern advertising and sale-pushing. Generally speaking, the inventor will have to confine himself to producing a model which will impress the business partner sought for. If the invention presents various possibilities, some of these will be easier to realise than others. Some of them, and not necessarily the easier ones, will be more commercially attractive than others. The inventor should attempt to strike a balance between these two desirable ends, and set to work to produce one single product, at once technically perfect and commercially attractive. It is here that most inventors fail. They do not resolutely adhere to a single line of development.

In demonstrating an invention, every effort should be made to make the demonstration convincing and impressive. It is usually a matter of impressing a man with money, and not a technician. The inventor is necessarily striving to impress not only the technical merits of the invention, but also of his own personal

merits upon his visitor. Now many business men are not good psychologists, though not a few are convinced that in this respect they are remarkable. It is a lesson to see such a man turning over with a complacent air the answers received to an advertisement for an employee. Almost invariably he is fully convinced that he is all but clairvoyant. When the applicants are interviewed, he examines their clothes, their collars, their nails, their boots; he is often the victim of the charlatans who profess to tell character from handwriting, physiognomy, and so on. The final choice, one usually finds, is decided by an instinctive preference for some physical or racial type, usually his own.

Now the business man likes things done in a business-like manner, and detests the slipshod and happy-go-lucky. An invention may actually be devised and constructed with a skill and efficiency far beyond anything needed for the conduct of an ordinary business; but if the mode of presentation of it is inefficient, the man to whom technical matters are a sealed book will, when he attends a demonstration, usually be less influenced by the technical result than by showmanship and staging. A few shillings spent in paint and paper—unobtrusively used—may make all the difference. The highest art is to conceal art. He should feel that what is shown him as a rough model is evidently a very neat and careful piece of work, and that if the inventor were given the opportunity he would make a very attractive job of it.

The greatest care should be taken that no hitch occurs; it is astonishing how careless some inventors are in this respect. If nevertheless an accident does happen, presence of mind will often entirely conceal the

fact. Above all, no attempt should be made as a rule to interest the non-technical man in the means employed; what appears perfectly plain and simple to the inventor is hopelessly beyond the comprehension of the layman. In the first place, this fact wounds his vanity, which is not to the inventor's advantage; and secondly, he feels that the whole matter is very complicated and hence liable to trouble.

A. N. Linley, who evidently knows from experience something of the average inventor, gives the following list of 'don'ts' for inventors in dealing with capitalists. Don't assume an aggressive manner, or talk about all the other ideas you have had at various times. Don't belittle other inventions; this is a rule well known to the advertising expert, and it rests upon the fact that what is well known and in use must have merit. To deny it all merit suggests, therefore, an absence of fairness and frankness. Don't send out long, and especially illegible, descriptions; every description should be confined to the barest essential set forth in a manner perfectly intelligible to a layman of average intelligence. Don't complain of the unfairness of the patent law, and generally be full of troubles, ailments, quarrels, and injustices done to you by individuals or by the law. Linley rightly points out that many inventors have a tendency to shut themselves up with their inventions, and when forced by circumstances or otherwise to approach outside persons, do so with an unconscious bias against the effort. He advises the inventor not to send out original drawings, but to make use as far as possible of perspective sketches neatly executed.

It is notorious that the genuine expert inventor is greatly at a disadvantage as compared with the char-

latan. In dealing with the business man, he is confronted with a type of mind totally different from his own, whereas the charlatan is dealing with a soul which is in some respects akin, though, of course, poles apart as regards honesty. Both are workers in mind, whereas the inventor works in matter. The ease with which business men are deluded by charlatans is often due to the fact that the latter make their nonsense appear infinitely simpler and more comprehensible than the sound scientific sense of genuine work.

The inventor should dwell upon the result, and the advantages, financial if possible, to the user; and on the other hand, the ease and cheapness of construction, and the large margin of profit. The inventor is wasting his time and even doing harm in striving to win admiration for his own technical ingenuity. The man whom the financier really respects is he who can spot a potential market where a large profit can be made. The inventor should convince himself for the moment, and so go a long way towards convincing the other man, that he (the inventor) is actuated solely by a desire for gain, and that his ingenuity has consisted, not in technical skill, but in actually discovering a profitable market. The fact that the capture of this market depends upon the introduction of a new invention is merely a nuisance. It would be much better from a business point of view if it could be effected by ' cornering ' some existing material, or securing a monopoly by some surer means than modern patents. All business men have a horror, quite natural from their point of view, of the man who invents for the pleasure, honour, or glory of inventing. So if the inventor has already made other inventions, he should refer only to those

which have actually become practical successes, and then only to their financial success. The fact that he is now appealing cap in hand for money is readily explained by his saying that he made a bad bargain ; whereupon the business man will hope that he will make yet another.

It is, I know, very much easier for me to say all this than for the inventor to do it. His business in life is to persuade matter to conform to his will, whereas in dealing with the launching of his invention, he is confronted with the task of influencing the *minds* of other men. One has only to talk politics to men of science and inventors, to realise that they know as little of the workings of the human mind as do the politicians of the workings of protons and electrons. Matter is logical ; if a machine does not work, there is a mechanical, and hence logical, error in its design. If the business man refuses to be convinced of the value of an invention, the fault may not be in the reasons given, or in the business man, but in the mode of presentation of the matter.

Business is not a matter of logic ; the doctrinaire in business, as in politics, is a ghastly failure. Intuition, instinct, call it what you like, must be the guide. It is the inventor, not the man of affairs, who is ' narrow-minded ' ; nine-tenths of the decisions needed every day in the world have to be taken illogically, instinctively, in matters infinitely too complicated for logical analysis.

If the man of finance is interested, he will usually send or bring a technical adviser whom he regards as capable of giving an expert opinion. Here the first rule for the inventor is to leave the talking to the expert, answering his questions as shortly as possible,

and trying to find out whether he knows more or less about the subject than the inventor. If he knows more, if he is obviously a first-rate expert, the inventor should throw himself on his mercy, ask him questions, and adopt the rôle of the fresh mind from outside, that has struck upon an idea which may perhaps seem somewhat unorthodox—and so on. In other words, assume that the expert is on your side and anxious to assist you. If, on the other hand, he is your inferior in knowledge, don't let him feel that you think so. Suggest ingeniously that you know a very great deal, and treat him as an equally expert colleague.

We have thus considered two characters, the Business Man and the Expert. But where are they to be found in the flesh ?

At the time of writing, it seems as if the independent business man ready to finance a new idea has completely disappeared. If the disappearance is permanent, the commercial future of this country is almost hopeless. For the large firms, growing larger every day, are absolutely useless from the point of view of the independent inventor. Since they do practically no real inventing themselves, industry will cease to advance in this country altogether, except in so far as new inventions are adopted from abroad. In fact we are already subject to a tribute of tens and perhaps hundreds of millions annually for inventions which were actually pioneered in this country, but developed abroad.

A typical inventor usually has a totally false picture of modern commerce. He is quite right in thinking that one of the essential elements in commercial success is to offer for sale a better article or a cheaper

article than one's competitors, or an article unobtainable from them. But he is quite wrong in supposing that every prosperous firm will welcome with open arms the offer of the right to add such an article to its catalogue. On the contrary, he will find that such firms are so rare as to be almost non-existent.

Since this elementary and demonstrable fact seems to be unknown not only to inventors, but also to otherwise quite sensible people, we must go into the matter a little more fully. Appearances are against me. Any inventor who writes a straightforward letter to almost any firm, saying that he has something in their line to show, will receive a call from a polite and knowledgeable official of the firm, who will be quite enthusiastic and encouraging. And there the matter will end—for the inventor at any rate.

If they are really interested, they will ask for the date of the patent, and a copy of the application or specification. This will be referred to their patent agent (or department in the case of a very large firm) and the inventor's further proceedings will be watched in the Patent Office Journal. If they are very interested, a careful search will be made as to the novelty of the invention. If there are good grounds for regarding the broad claims as invalid on account of previous publications, the technical officials of the firm will be informed, and will use what they have learned, if they wish to do so.

The independent inventor and the technical official are, unfortunately, inevitably related much as dog and wolf; as tame animal and wild animal. If this be regarded as too drastic a statement, let us admit that the technical official is, as a rule, thoroughly competent,

and that his experience of independent inventors is, that nine-tenths at least are thoroughly incompetent people, hiding a mentality incapable of hard work and steady application under a cloak of exaggerated self-complacency. But just because they are, as a class, so objectionable, the individual exception that cannot be despised tends to be feared.

Often the inventor has not the courage to apply personally; he meets some business man who claims to have personal access to one or more of these leviathans of modern business, and promises him a share if he will use his good offices. The end result is exactly the same; the very same minor official will appear and say the same things.

The inventor is no better and no worse off, unless he has committed the supreme folly of handing over his models to the official. The chances of anything eventuating from such a procedure are almost nil. Introductions to directors are worse than useless.

The reasons for this paradoxical state of affairs are simple. Most prosperous firms arose, not so very long ago, from small beginnings; from the partnership, usually in two skins, but sometimes in one, between technical invention and business acumen. There was a new and important technical advance and there was salesmanship to introduce it to the world. There was usually extremely little money. Such firms rise and prosper on the innovations they introduce. Then, as a rule, they continue to live for some time upon their reputations, while young and innovating firms are establishing themselves. Finally they die, or are absorbed into a new-comer.

Occasionally, however, a man of business and finan-

cial genius will enlarge the scope of such a firm until it covers one or more main branches of industry. This process is accomplished by the absorption of smaller firms. If the head of the large firm is merely clever, he absorbs paying businesses, generally at an inflated figure. If he is a genius, he buys for a song businesses which are based on inventions technically sound, but failing to make good for want of management.

Only in the very rarest cases would such a man be interested in an invention not already on the market. For as soon as a new invention is being actually manufactured and sold successfully (from the technical point of view) it becomes a suitable subject for the peculiar type of judgment possessed by men who manage businesses successfully. Before that, another type of mind is required to form an estimate of it, which estimate will in the best case be far more speculative.

But if these remarks are rather general, let us get down to particulars. Firms, after all, are aggregates of human beings : directors, managing director, technical staff, salesmen, and so on. The interest of the firm as a whole, and in the long run, of course imperatively demands that it should keep up to date and indeed be as far ahead as possible. But when the practical case arises of a new invention being offered, it will rarely be to the interest of any individual person in the firm to advocate its adoption. Only when the firm is ruled by someone with a definite forward policy, is anything likely to eventuate. No Board of Directors is capable of forming a decision. The Board consists of figure-heads, financiers, sometimes men who have come from the office of the firm, and only rarely first-

rate technicians. Often, of course, it will contain the very man whose inventive genius laid the foundation of the firm's prosperity. He is the only chance for the inventor, but as a rule, he will long ago have been gently but firmly barred from any say in technical matters. As soon as the scale of manufacture begins to grow, he is too often found quite incompetent to exercise proper control ; instead of attending to routine manufacture and quick delivery, he is liable to experiment on new developments. I could mention some astonishing cases of this kind, in which the very man whose name the firm bears is practically excluded from its workshops.

As we saw in the first chapter, technical production, from the managing director down to the youngest apprentice, necessarily consists in doing everything in just the right and well-tested way. One of the minor troubles of the highly competent inventor who finds himself in charge of a large works, is to deal with the infection which he causes in the personnel. He infects everyone with the mania to invent. He has found out by long and bitter experience how his job should be done ; nevertheless, everyone who is there to carry out his ideas begins to have ideas of his own, and to teach him his work.

Thus the successful works consists almost exclusively of people who do the right thing in the right way. The whole art of successful manufacture consists in turning out as uniformly as possible a product which is known for its good points, though its bad points are also known, both in the works and by customers. One of the main causes of failure in manufacturing consists in the neglect of this rule. If the neglect occurs from

sheer carelessness and want of system, whether in the buying of material or in the actual work, there is no excuse for it. But often the best intentions in the world lead to disaster. A change is made which appears obviously advantageous, and the fatal error is not discovered until it is too late. Such changes are often of the minutest description: in the material used at a certain point, or a supposed improvement in a certain process, and so on. In one famous recent instance, a certain process for the removal of sulphur compounds from petrol, widely used with success in America, was installed here in a large refinery. Probably the process was actually tested on the English petrol, and was found, quite correctly, to remove sulphur compounds perfectly. But when the petrol so refined was supplied to users, it turned out that it had suffered an obscure chemical change, peculiar to that particular petrol, and this led to cars using it gumming up completely.

How often, in the manufacture of electrical instruments, has a slight change in the insulation used, or even in the arrangement of the wiring, led to breakdown!

People who avoid all these errors, and so conduct manufacture successfully, are of two kinds. On the one hand they may be highly energetic and intelligent, fully open-minded as regards innovations, but yet wide-awake to all the manifold dangers connected with them. But such people are rare, and there are not enough to go round. The average type in charge of manufacture is just sufficiently intelligent, and is by no means energetic. He is there because he has never made mistakes, owing to the fact that he has found it safer and less trouble to stick closely to routine. He is of

course the last person in the world to be interested in new inventions.

While the inventor, if he is worth his salt, is not likely to be discouraged by the cold water thrown upon his ideas from such quarters, his financial backer, if he has one, is so liable. He very naturally assumes that the management of a big firm in a given industry is a better judge of the market for a new thing in that industry than anyone else could be ; he assumes that the position attained by these individuals is chiefly due to this imagined superiority of their judgment.

This, of course, is not the case. Only in those industries, such as fashion trades, where novelty is of the essence of the business, is a keen eye for coming change a passport to promotion. In all others, a technical man does best for himself to turn down all novelties offered from outside. If he picks a loser, his firm will never forget the greater or less loss for which he has been responsible ; if he turns down a winner, the fact will probably be completely forgotten by the time the winner has fought its way to recognition. And the directorate will always console itself with the thought that most likely, in their hands, it would not have turned out a winner at all.

In any case, a large firm can usually afford to wait and see, and buy up the new idea when it is proved, but still not victorious. Directors of large concerns are quite aware of these facts. They know that their large and cumbersome organisations are extremely badly suited to dealing with innovations. Few people who have not inside experience of large firms can have any idea of the time, trouble, and expense involved in innovation of any kind.

The most painful case for the inventor is when the technical officer of the large firm feels it incumbent upon himself to produce a report damning the invention fundamentally. I could cite some really astonishing cases of this kind, but they would carry no weight without details which it is, of course, impossible to give. In one case, the two head technical men of the appropriate department of a certain first-rate firm, having seen a certain machine performing its functions perfectly, departed without comment of any kind, and produced a report in which they proved by (wrong) mathematics that the machine could not work. This report would not have come to the knowledge of the inventor at all but for exceptional circumstances; but although he strained every nerve to prove the errors of its authors to their directorate, nothing could be done. It is best in such cases to content oneself with a simple good-tempered correction, and leave it at that.

In certain cases, it is possible for an inventor unaided to reach the point of actually selling the article he has invented, on no matter how small a scale. If he is then able to point to satisfied customers, the arguments brought against him by the average engineer fall to the ground. This suggestion, however, is Utopian as regards most inventors. The capacity to stand on one's own feet and do business independently and successfully, is one rarely found combined with the qualities which go to make successful invention. Sometimes early training, or close association with a relative or friend, may lead to the acquirement of the elementary principles; but as a rule what is acquired are only the tricks of a particular trade, and not the essential principles of business dealing.

These essential principles are obvious when stated, like the essential principles of all other human activities; the difficulty lies in the fact that they cannot be applied logically, but really form the background against which all the detail of everyday action takes place. If we were to try and formulate them they would be something as follows: first, be sure that every transaction is profitable, unless for good reason an exception is made. This involves a knowledge of costs, and particularly of those dangerous factors known as overheads, which are so easily neglected in a small and growing business. Second, give credit only to good and safe customers, and see that the credit terms are strictly stated and that customers are not allowed to exceed them without energetic protest. Third, Mr. Selfridge's maxim, 'the customer is always right'. Never show ill-temper in face of complaints or criticism, least of all attempt to make people accept and pay for what they do not want. Fourth, take care of the sidelines of money-making, which are available in most cases; the supplies and replacement of parts, and other maintenance charges. It is better to charge well for these and to be extremely efficient about supplying them. Fifth, observe strict order and routine in business matters. This is a hard saying for the average inventor, who is rarely very orderly in his habits, and in any case regards with impatience anything which does not bear directly upon his own technical problems. A common cause for the breach of this rule is the bringing into the business of relations, wives, sweethearts, old school friends, or the formation of such relationships. 'Business is business' is a rule subject to abuse, but of golden import; it is almost impossible to keep unless one is

dealing with people whose personal attitude accepts it. Sixth, keep your promises to customers, even at the cost of loss and overtime. Seventh, and perhaps most important of all, don't bite off more than you can chew, don't accept more work than you can finance. It seems at first sight quite absurd that a small firm may be ruined by a large order from a thoroughly good customer; but the execution of the order will involve heavy payments which have to be met before payment can be had, even in the best case when no hitch occurs. A small hitch, such as non-arrival of some essential part or ingredient, may delay delivery of the order, without delaying the maturing of major obligations.

I do not say that these few maxims exhaust the subject, but it would be difficult to find a failure in normal times where one of them had not been flagrantly transgressed. But to keep them intact requires unceasing vigilance, and the inventor is the last person to be vigilant in such matters. Far and away the best chance is to find a partner with capital and business instinct.

Any inventor of moderate powers of showmanship will find without any difficulty dozens of people who will offer to get capital for him. As a rule, such people begin by stipulating for a sole option on the invention for a certain period, and very rarely indeed are they willing to pay anything for this option. An inventor should never under any circumstances agree to such a proposition.

He should from the outset make a rule with regard to all agreements and arrangements of whatever description, namely, that they shall commit the other party to expenditure of money, or some equivalent activity. He should

never enter into an agreement which binds him to definite acts or restraints, but not the other side.

Nominally, a one-sided contract, in which one party receives no ' valuable consideration ', as the legal phrase runs, is invalid at law. This forms a good argument for refusing to sign such a contract, but a very bad one for signing it. An agreement however bad, or even invalid from the outset, cannot be simply ignored. Hence the difficulty attaching to vague clauses binding one party to advertise for sale and push sales, but not to any specific acts.

The inventor may feel quite sure that if he puts forward these arguments reasonably and tactfully, and they are received with coldness or even indignation, he is wasting his time. He is probably dealing with a type of man who is extremely commonly met with. This type possesses a source of income of some kind which leaves him a great deal of free time. It is frequently derived from matrimony, but may also be the result of past deals which were successful more by luck than by judgment. Secretly conscious of his own mediocrity, he has never jeopardised this source of income by speculation. He buys and sells stocks and shares with extreme caution, in accordance with such tips as he can collect from bigger men of his acquaintance. But he badly needs a sensation of being a man of affairs (which he never can be), and he obtains this sensation very cheaply by ' looking into propositions ', and taking up options, so long as they cost him nothing but the upkeep of an office and a little entertainment. Being a nobody, the somebodies take actually less notice of him than they would of the inventor himself. A man of this kind usually ' knows the very firm (or man)

for the job ' ; which means to say that he happens to have a friend or acquaintance holding a position of management, or even a directorship in some works or another. The inventor would obviously do far better, as regards firms already in the trade, to pick them out of a directory, and write a sensible letter stating simply and modestly the claims he makes for his invention. If he is able to find out the name of some technical or scientific person of authority in the company he should write to him by name.

Another trouble with these ' lookers-into ' of propositions is, that they almost invariably want to do a little inventing themselves, and will suggest all kinds of modifications, improvements, and new applications to the unfortunate inventor. He must, of course, consider carefully every suggestion, from whatever quarter ; but he should not be ' suggestible '. He will generally find that a suggestion which at first sight seems sound to him has a snag in it somewhere. Very rarely indeed, therefore, should he make new models and designs at the request of a negotiator. The position is different in dealing with the actual man who is to pay the piper ; he can hardly be prevented from having a say as to the tune. But the old rule holds of not giving something for nothing. If special models are called for, let them be designed, quoted for, ordered, and paid for. This attitude will command much more respect than a pathetic eagerness to please at all costs.

Altogether, the inventor should beware of everyone who is anxious to spend *his* money in a burst of enthusiasm over the merits of his invention. Real enthusiasm spends its own money. In the bad old days there were dozens of patent agents who would flatter

an inventor into patenting an obviously useless invention all over the world, but these have been handicapped by legislation promoted by the Chartered Institute, the members of which are beyond reproach. But there are still people anxious to take fees for promoting companies, making models, advertising, and so on. The inventor is a child in matters of business, as a rule, and he badly needs an injection of the business man's caution, which looks for a probable profit from every transaction.

The Institute of Patentees should be mentioned at this point. For a very modest fee of one guinea, he may exhibit at their annual London exhibition, and receive much help by way of introduction, legal advice, etc.

Another procedure is open to the inventor who wishes to make known his invention. Almost every branch of technology is now represented by some Institution, Society, or other organisation which holds regular meetings to listen to papers read, and in many cases there is an actual shortage of papers containing genuinely novel and interesting matter. Consequently, a well-written paper of such a standard is usually acceptable, and even if the inventor has no friend among the members, the secretary will often find him a sponsor. He should remember, however, that the paper will as a rule be submitted by the secretary to a referee, and hence should be very careful not to advance extravagant claims, or to decry present practice in the field of his invention.

This may be a road to fame, but it is not one to fortune. The paper will in due course be published or abstracted all over the civilised world, and if the ideas are good they will come to the notice of rivals and set them at work. For a paper of this kind can hardly be

written without saying ' why ' as well as ' how ' ; and anyhow it will be followed by a discussion in which the inventor will have to answer shrewd questions. The particular methods used by the inventor and protected by patents are thus laid open to a comparison with the principles on which they are based, and particularly, the inventor's analysis of the problem. Someone else may then think of an alternative outside the inventor's patent ; this may even be an alternative already rejected by the inventor, and left unprotected by him. But it may be better than he has judged it to be, and in the worst case, better than the method actually chosen by him. *It is a good rule in all publications, in patent specifications as well as in other descriptive matter, to give away as little as possible of one's fundamental analytical results ; in other words, to state how, but never why.*

By publishing your invention in this way before it is commercialised, you already expose yourself as unprotected financially, unless of course you are well known to be possessed of ample private resources. In any case, no records of commercial experience and practice can be given, and hence the invention is laid open to supposititious criticism which cannot be rebutted.

Worse still, other people may attempt to verify or disprove the work, without consultation with the inventor, and publish adverse reports concerning its principles.

It is very much to be deplored that our industries do not set up, in co-operation with the City, bodies fully competent to criticise and test new inventions. In many industries we now have Research Associations formed under the auspices of the Imperial Council for

Scientific and Industrial Research. These bodies are engaged in very valuable work on behalf of their respective industries, and wherever the invention is one which represents a step forward along the lines on which these bodies are working, it should certainly be submitted to them.

It will in most cases receive fair and sympathetic consideration. But in the case of inventions of a more novel and pioneering description, the Research Association can hardly do more than pass the inventor on to one of the firms under which it operates ; whereupon the inventor is again subject to all the difficulties connected with dealing with an established firm.

There is no machinery at present by which the inventor or financier can obtain an independent opinion concerning the fundamental soundness and utility of an invention, such as should be required before public subscription to a flotation is invited. The usual course is for the financial interests to obtain the services of a consulting engineer of established reputation, and it is needless to say that men of first-class reputation will not give ill-considered opinions. But the position of such a consulting engineer is very much like that of a doctor who is called in by a rich lady who believes herself to be worse than she really is. If he tells her that there is nothing much the matter with her, he loses a lucrative source of revenue ; he is much better advised to agree with the lady's diagnosis rather than his own. If a financier has got to the point of being interested in an invention, he is probably interested in it primarily as a subject for the promotion of a company. He wants from the consulting engineer a statement which will assist him in this object, and is not pleased

to be told that he has found a mare's nest. Also, if the company is promoted the consulting engineer may hope for a useful yearly retaining fee.

Finally, every inventor may be recommended to study very seriously the people who make a success of selling things. He will find that they put into the job every bit as much energy, enthusiasm, and time as he puts into working out his inventions. He is a fool if he thinks that he can sell his inventions without becoming a salesman ; instead of feeling resentment, let him study the art. There is no mystery about it ; it is taught every day to the most unlikely people by those who specialise in doing so. It demands good-humoured, patient, persuasive persistence in the face of rebuffs, and even insults ; bitter pills for the inventor who is offering for sale his own cherished creation, and not a mere ' new line ' of his firm. It is a job to which he has to force himself, in a way strange to him in his own work. He is like an inhabitant of the plains afoot in a hilly district ; a mild hill to climb seems to him Mount Everest itself.

Chapter V

THE DIRECTION OF INVENTIVE EFFORT

Let us attempt in this chapter to consider a matter which has been considered very many times before in every kind of handbook addressed to inventors; namely, what are the most promising directions to which inventive effort can be applied.

It is obvious that every branch of technology has, so to speak, a life and a logic of its own; it is developing almost as a thing of which its human agents are merely the servants. We all know that if an invention of importance is made to-day, the probability is that a number of people will have had the same or similar ideas, and of these, a certain proportion may be well advanced. Nevertheless, it is extremely difficult to peer even a short distance ahead as regards coming *practice*. It would be difficult to name a single important human need which has not several totally different sources from which it may be satisfied. Who can tell what course the development of power, of transport, of textiles, or mechanical amusement, of large scale chemical industry, will take in the next ten years? It is obvious that first-class inventions in any of these lines may be developed, only to find their *raison d'être* abolished by developments from an entirely different quarter. This has happened again and

again in recent years, and is one of the reasons why invention is regarded with less and less favour by the financial leaders of industry.[1]

Every branch of human, indeed zoological, activity is prodigal in wasted effort, and invention is no exception to the rule. It is quite futile to lay down any rules. None can say whether in one case honest effort will be entirely wasted, and certainly none can guarantee that in another it will prove valuable.

When we consider in retrospect the development by secondary inventions of any industry, it often seems that they could have been made without any originative effort at all, merely by drawing the logical conclusions from the existing state of affairs. The man actually at work in the industry, however, by no means has this bird's-eye view of his position. He is usually quite incapable of seeing even a short distance ahead. The solemn discussion of the directions in which advance is likely to take place often occurs between very eminent experts ; but if these same experts are called upon, as they often are, to lay down lines of activity for paid research workers, they generally fail completely. For this reason, the advances of moment usually come from single workers, not of course without a thorough knowledge of the technology in question, but generally somewhat aloof from the main scene of activity. Inspiration visits these workers in an erratic manner.

If a man is actually engaged in a given industry, and can find time and energy to devote to research and invention in that industry, he will often do well to devote

[1] It is curious that economists rarely stress this point, even those economists who are at pains to prove that nineteenth-century notions of industrial development are obsolete.

them to a branch of the industry other than that in which he is actually engaged ; for he will have a clearer and more unbiassed view.

Very often indeed, as is notorious, the greatest advances are made in industry by persons who come from other fields of technical activity into work new to them, and bring with them, in addition to a sound general foundation in scientific practice, a number of general ideas practically unknown to the industry in question. This process is one almost analogous to cross-fertilisation in biology. I believe that no two industries could be named, no matter how widely separated, without it being possible that each could in some way influence the other. We have the famous case of Bessemer who revolutionised the steel industry by a method which must have seemed ludicrous to others when he first proposed it.

This principle of cross-fertilisation should, however, be subjected to some reasonable modification. Technical invention is only one way in which humanity exercises creative imagination, but it includes within itself a number of types of mental activity which in many ways are almost as distinct in character as the difference between literature, painting, music, and sculpture. One great divergence is already visible in pure science ; there is a great fundamental difference in the natural aptitude for chemistry and for physics ; at one end of the scale you have the successful research worker in organic chemistry, and at the other the theoretical physicist. Nevertheless, we feel that the physical chemist is a person who combines in himself two different aptitudes, rather than an intermediate type.

In technical invention we may distinguish a considerable number of styles, each of which represents a type, temperament, or attitude of mind. Without attempting to be exhaustive, I think we may at least distinguish styles drawn to mechanics, chemistry, electricity, transformation of energy, treatment of natural materials such as fibres, leather, wood, etc., craftsmanship, and work depending upon a human factor. The technical and practical aptitude of any given individual will commonly exhibit predominantly one of these types; and this fact will, I firmly believe, be a matter of birth and not training; though I am speaking, of course, of persons of strong aptitude and interest, and not of the mass of skilled and trained workers, who though filled with a prejudice in favour of their own branch, owe it merely to the accident of being trained in that branch.

It is obvious that our classification of styles of mind must be related to some extent to the more general notions of which we spoke in the first chapter. But interest in a given practical industry often depends psychologically upon quite other matters, such as very early impressions.

The effect of this is that on the one hand industries fail to benefit from one another's progress as much as they should, but on the other hand an enormous amount of practical advance depends primarily upon work which can only be done by a person of the right type of mind. The main advances of chemical technology will be due to work which can only be done by persons possessing a chemical instinct or 'nose'; but this does not by any means exclude the possibility of most important developments arising from the

application of mechanical or electrical notions, or even experience and ideas still more remote.

It is quite common to-day for the physicist and the chemist to be associated in technical work, and for these again to combine with the power engineer and the electrical engineer. But when one actually goes into industry, one is continually surprised at the way in which enthusiastic research workers and inventors are often ignorant of the first elements of allied sciences and arts which could be of the greatest advantage to them. Indeed, all too often, disastrous failure occurs because of this fact. It is only quite recently that the electrical arrangements of motor-cars have been brought fully up to the standard of normal electrical engineering practice. The mechanical part of the car attained high perfection, while the electrical arrangements were on the level of amateur bell-wiring. Only very slowly is really good mechanical practice being introduced into chemical engineering. The textile industry, and many allied industries, do not yet sufficiently appreciate the advantages of instruments of all kinds, such as thermometers of special construction, automatic apparatus for indicating chemical composition, colour-indicating apparatus, and so forth. The craftsman, whose work is on the border-line between artistic and industrial invention, is very far, as yet, from using the immense resources which many industries place at his disposal. Here, however, the modern school of architecture, design, and decoration is in many ways bringing about a change.[1]

[1] Mention may be made of the new Building Centre in London, founded by the Architectural Association. Here every kind of material which may be useful in building is collected, together with information as to its uses and peculiarities.

There is one classification of invention which I mentioned above which will no doubt have arrested the reader's attention; I refer to the psychological. In this class I place quite a number of inventions the characteristic of which is not by any means the physical, chemical, or mechanical involved, but the fact that they are based on some peculiarity of human psychology. We shall consider them in a chapter by themselves.

For the reasons that we have just considered, many of the most successful and important inventions have been made by persons entirely new to their particular line of work. Werner Siemens was a lieutenant of artillery when he took out his first patent, which was for electrolytic gilding. He and his brother became the pioneers in Europe, not only of electrochemical invention, but also of electrical engineering; while Werner remained in Germany and became associated with Halske and Schuckert, Walter was sent to England, where Faraday's fundamental discoveries had hardly been developed technically, and set the same development going in this country.

Morse was a painter, and continued with his art even when his telegraph made him world-famous. Arkwright, the inventor of mechanical spinning, was a barber; Gramme, the first to correctly design a dynamo, and inventor of the modern armature, was a carpenter. He is a particularly striking instance of what was said earlier in regard to the absorption of a fundamental notion. It is striking and instructive that at this particular point he beat even Edison, who exhibited in his development of electric lighting and transmission a thorough grasp of the principles of the electric current, while making bad fundamental mis-

takes in his dynamo design. Not only did he imagine that he was saving copper loss in the fields of his dynamos by breaking the iron core up into parallel rods each wound with coils; he even supposed that magnetic leakage would be reduced by the use of zinc as a kind of magnetic insulator, since zinc is a diamagnetic metal.

It is natural, of course, that the pioneers of aviation were all other than aviators by training. Berblinger, of Ulm, one of the first well-attested inventors of gliders, made some fairly successful flights in 1811. He was a tailor. Chanute, who was born in 1832, was a railroad engineer. He published a book on Aerial Navigation in 1861, and made many hundreds of successful glides.

The chapter in history concerning pioneer invention is full of tragedy; indeed no one, I imagine, would devote himself to pioneering voluntarily. In fact, of course, all pioneer work, or nearly all of it, is done in the belief that there is an immediate need for the invention. This belief is usually quite correct; what the inventor fails to realise is that while the need is felt as an evil, the great majority of people regard taking a risk with an entirely new thing as a still greater evil. In this they are not by any means so wrong, from their own personal point of view, as the inventor imagines. The man in a responsible technical position has nothing to gain, as a rule, by adopting new methods and new inventions. If they are successful, he gets no great credit from his employers, and but little even from his colleagues. The credit goes to the inventor, as also does the financial profit. If they fail, or give a great deal of trouble before they are made to work properly,

not only has he a burdensome life himself, but a black mark is put against his name by his employers.

Some of the most important pioneer inventions were made at a surprising distance of time in advance of their general application. R. W. Thomson made a pneumatic tyre forty-seven years before Dunlop. He was born in 1822, and was an engineer connected with road locomotion. He was the first inventor of resilient tyres of all kinds. W. R. Sykes outlined in 1874 a perfect system of automatic signalling on railways. At that time the Board of Trade and the Directorate of the Railway Companies maintained that the personal care of the signalmen was much better than any automatic system. The thermostat was invented by Cornelius Drebbel in 1625, but it is only recently that its advantages have become generally recognised, and some modern cooking-stoves have been fitted with it. In modern times pioneer inventions have not taken so long to become generally used, as in the past. The cinematograph was first invented by an Englishman, Friese-Greene, who filed his patent in 1889. At that time Edison was also at work in this field, but the real development did not occur until some ten years later. Friese-Greene never derived any benefit from his pioneer work ; on the other hand the French pioneers Pathé and Gaumont both founded large concerns. This is almost characteristic of modern development in England, where most of the great and fundamental inventions of recent times have had their pioneer workers, who have received no recognition at all. Curiously enough, while England has refused to encourage her pioneers of native birth, she has taken two Italian pioneers, Ferranti and Marconi, to her heart, and

enabled them to develop long-distance high-tension transmission of electric current, and wireless telegraphy, respectively. Sir Charles Parsons, the inventor of the steam turbine, was, as the son of Lord Ross, in an exceptional position, but his basic patents had expired before his invention received practical recognition.

This mournful chapter concerning the fate of pioneer inventors, particularly of British nationality, could be extended to fill a whole volume, but the facts are so well known in a general way as to be commonplace. The reason why pioneers still continue to starve in garrets is that, generally speaking, they do not know that they are pioneers. To the inventor his invention appears something so obviously valuable and useful that he is entirely unable to comprehend the scepticism with which the average man meets it. The only exception to this scepticism occurs when the inventor holds out prospects which suggest a prospectus appealing to the most foolish and gullible types of investor. For this reason the charlatan and swindler are constantly able to obtain sums of money running into tens of thousands, while the genuine inventor, working on sound lines, is frequently unable to obtain funds for his work. Hardly a month passes, even in such times as the present, when money for development is practically unobtainable, without the columns of the daily press giving accounts of so-called inventions which are immediately ridiculed by every expert and by the technical press, but nevertheless attract large sums of money. At the moment of writing we have a gentleman who is promising to extract gold from lava, in which no assayer can find a trace of the metal; and he appears to be well supplied with spacious laboratories and

furnace equipment, and ample funds. It is true that he is a German, but even this glamorous fact hardly accounts for the faith which he arouses.

It is not surprising that the genuine and serious worker is sometimes led to take advantage of the appetite for sensation. In a case known to the writer, an inventor had produced a valuable chemical process, but was deprived almost entirely of any profit to himself by the astuteness of his financial backers. Realising the futility of protest, he pretended to be more than grateful for the small amount which he actually received, and after a period of mysterious labour in a humble workshop, announced that he had discovered a still more valuable process, by which crude grey beet-sugar crystals could be instantly transformed into perfect castor sugar. He invited his financial friends to see the apparatus and they were confronted with a large closed machine, at one end of which was a funnel into which the crude sugar could be poured, and at the other end an opening out of which the finest castor sugar was to issue. A switch being turned on, a deafening noise proceeded from the interior of the machine, and a workman then proceeded to shovel in crude sugar as fast as he could. Immediately all expectations were fulfilled by an enormous stream of white castor sugar pouring from the tail end of the machine. The financial gentlemen were naturally in ecstasies, though they did their best to conceal this fact, and proposed an agreement somewhat similar to the last. Thereupon the inventor proceeded to tell them in emphatic language exactly what he thought of the last agreement, and offered them the contents of the room and all rights in regard to it for £50,000 cash. The meeting then broke

up in some disorder, and the inventor locked up his workshop and waited. After a period of reflection, the financial gentlemen, finding that the inventor was entirely unmoved by persuasion, were unable to restrain their cupidity and paid the money. Whereupon the inventor disappeared. When the financiers opened the marvellous contrivance, they found an electric motor attached to a noise-making apparatus and two large bins, one containing the grey crystals which had been shovelled in, and the other with a further reserve of white castor sugar of the best quality.

We shall have something to say later regarding the possibility of dealing with pioneer invention. It is a subject peculiarly suitable for discussion at the present time, when the City is still painfully aware of the disasters which accompanied the backing of thoroughly unsound ideas, or the over-capitalisation of other inventions, in 1928. We all hope that money will again be available for the development of industry, and the City should certainly make up its mind to organise competent and entirely disinterested scientific and technical advice in the matter of new inventions.

In this country, pioneer invention seems likely to remain a matter for the independent individual. It is difficult to conceive exactly why large organisations, which in other directions exhibit extraordinary enterprise, and are quite willing to invest money in tens and hundreds of thousands very speculatively, should nevertheless be quite so unwilling to encourage pioneer invention. For reasons which we have already considered very fully, that encouragement would have to be divorced entirely from both technical manufacture and works research. But very few forms are known to me

which deliberately subsidise pioneer workers. When this is done with due care and caution, very profitable results accrue. But we will return later to this aspect of the matter.

The independent pioneer worker without ample resources should make it his first endeavour to find a business partner who possesses just those qualities in which he himself is almost certain to be deficient. It should be the task of the business partner to decide what application of the invention is most likely to yield practical success, no matter on how modest a scale, and the efforts of the partnership should be directed primarily to obtaining this degree of practical success. Very often the invention which is destined to revolutionise a whole industry may best be demonstrated convincingly by some quite small field of application being made use of for this purpose. For instance, a simple and cheap form of cinematograph projector having a continuous motion of the film would not have the slightest chance of being introduced into cinemas. Its advantage would lie in the absence of wear of the film, and the simpler arrangements for taking the sound in the case of talkies. Though the film wear is reduced about ten times, the cinematograph proprietor who buys the projector only hires the film, and hence does not care whether the latter are damaged or not, while he has a very natural objection to introducing an entirely new system to his operators, who are often by no means very skilful in handling the apparatus they are supposed to know. In the educational field, on the other hand, although there is little money available, the advantages of such an apparatus are very great ; the use of cinematograph for education will necessarily develop by schools and

institutions being offered an over-all yearly price for a projector and the use of a film library, and the reduced wear of the continuously moving projector will make all the difference to the finance of such a system.

A very striking recent development was that of mains working of wireless sets, where an inventor and a first-rate business man started in partnership with £50 capital a few years ago and now command a capital of £400,000.

To summarise the results of what we have said so far, we may lay down as follows the most promising approach to invention for anyone who is seriously intending to take it up. First let him decide what particular style of work is most suited to his powers. If he is of very high capacity he will probably be inclined to attempt main-line development in his particular field. If this takes the form, not of pioneering, but of moving just ahead of present developments, well and good, but pioneer work is very unlikely to bring anything but disappointment in its train.

By far the most likely road to success will consist in bringing his peculiar style of work to bear on a field the main style of which is another one. For instance, the person with mechanical ability will still find in many branches of electrical work, and certainly in chemical work, a large field for invention. The chemist similarly will find in every other field but his own the best opportunities of applying his special practice. Roughly speaking, these facts have been recognised generally only in the last twenty years, and the result has been an astonishing amount of progress. But this progress has been due rather to the efforts of salesmen than to those of inventors. The

chemist and metallurgist have turned their attention to alloys and other special materials, and the efforts made to market these new alloys are gradually causing the mechanically-minded technologists to realise that mechanical problems are necessarily linked with chemical problems, and that principles of design which held when iron, steel and brass were the main constructional metals, are entirely out of date now that materials of altogether other qualities are available. Similarly the instrument maker, in order to extend his business, has succeeded in persuading industries to adopt indicating and recording thermometers, hygrometers and similar instruments where no thought had ever been given to the matter at all. But there is still a large field for invention in the construction of special instruments ; especially recording instruments of all kinds, the moral effect of which is very great. An instance of this is found in the success of an absurdly simple device consisting of a recording drum upon which a number of pens in a row draw lines. Each pen may be slightly drawn aside by a small electromagnet, so that whenever a current is sent through the magnet a break appears in the line. These magnets, of which as many as twelve may be arranged to act upon a like number of pens writing on a single drum, may be electrically connected to contacts operated in all sorts of ways, as by machines when started or stopped, doors when opened or shut, maximum or minimum contact instruments, relays affected by light, and so on almost without end. An arrangement of this kind is thus a tell-tale which cannot lie, and may supply all kinds of information about the operation of a plant or works. It might easily have been constructed nearly a century

ago, and yet is only just coming into use. It forms one of the best possible illustrations of the dependence of invention upon pure psychological factors.

One of the characteristic fallacies of present-day popular philosophising is the belief that technical progress is bound to continue without end. It is supposed that the human mind will never be content to leave invention alone, but that no sooner is one problem solved than another will be attacked. This view entirely loses sight of the way in which technology actually lives.

The tendency in any branch of technology is to develop a final type of practice, and then to cease further advance. No better instance exists than that of the bicycle, which has gone through a process of evolution which appears now to be at an end. The same may almost be said of electrical power generation ; it is extremely unlikely that revolutionary changes will be brought about in this field. Technical advance takes place at present almost exclusively along lines of a spectacular description, such as flying, radio, television, and so forth.

Spectacular invention of this kind is able to find financial support, but it is already dependent almost entirely upon the sensation it is able to produce. On the other hand, the maintenance of technical work in general at its present standard of efficiency is also largely a question of the same class of publicity ; the newspaper which booms the latest advance in flying or television will also attack the telephone service for its inefficiency.

It is not at all difficult to imagine a change in economic organisation which would result in this whole

apparatus of publicity shrinking to much smaller proportions, while a movement of the mass mind, in a political or religious direction, might easily so distract attention from technical and scientific work as to depress recruiting among the rising generation below that necessary for the maintenance of efficiency. A Kelvin, a Leonardo, and even an Edison might very well not concern themselves with science at all; the only scientists and technicians, apart from those merely there to earn a living, would be true narrow-minded cranks, or if the word is too hard, persons with only one outlook in life.

Spengler predicts such a turning-away from science and technology as due to happen to ourselves within a century or two; and it is not difficult to imagine it taking place very much sooner than this in Russia, which has no natural appetite for our culture. For us, the urge towards material invention and power over matter is intimately bound up with our cast of mind; our God is the Great Artificer, the 'maker of Heaven and Earth'. Other civilisations have had their cosmogonies, their accounts of how the world came to be; but they have rarely regarded the Creator, to whom the pioneer invention of the Universe has been ascribed, as the important ruling power to be supplicated and conciliated. They seem, in fact, to have had a better insight than ourselves into the fate of pioneers.

CHAPTER VI

MECHANICAL INVENTION

As we said in Chapter I., progressive mechanical invention really began with Leonardo. Before his time the only mechanisms in the modern sense were clocks, and it is difficult to discover where these first developed But with Leonardo, mankind awakened to the fact that by means of an apparatus consisting of a number of rigid or elastic parts linked together in such a way as to have their motion completely predetermined, almost anything could be done ; and this idea took so strong a hold that in the nineteenth century, many very eminent minds occupied themselves with attempts to devise mechanisms which would explain the fundamental properties of the universe.

A curious thing about mechanism is the fact that a gift for it is found in quite primitive races, such as the Eskimo, while the white races, which have developed to such an extraordinary extent, still produce a large proportion of individuals incapable of grasping it. Numbers of these actually busy themselves with mechanical design, and the records of the Patent Office are full of their products. These are often the efforts of technicians of great experience and ability in other lines of work, who have realised that it would be remunerative to replace hand-work by mechanical de-

vices. Regarding mechanism as something which anyone can understand, they have set to work to construct machines for doing automatically, or at least facilitating, the hand operations familiar to them, quite overlooking the fact that though no one has so far succeeded in producing a general theory of mechanism which can be applied to solve problems, an enormous amount of practical experience has been accumulated, which must be made use of if success is to be attained.

From the point of view of the inventor, there are two distinct classes of mechanism, large and small. By a large mechanism, I mean one which can be designed upon the drawing-board, and, in the hands of a competent man can then be trusted to do its work without the need for any but minor modifications and adjustments, since not only can the compulsive and rigid interrelation of the parts be assured, together with sufficient absence of play and back-lash, but also the elastic forces involved can be known and allowed for. On the other hand, the small mechanism is in an entirely different category. Down to a certain limit it is possible to make a small mechanism with the same relative accuracy as that employed for large mechanisms, but in practice, cost usually rules this out. By far the largest class of small mechanisms are those in which cheapness is essential, and hence their design must be such that the accuracy required is that obtainable in the mass production of punched, drawn, capstan-turned, and similar parts. This necessitates their whole design being on different lines. An alarm clock is not merely a very cheaply made clock, similar in character to a large clock or even a turret clock ; it is a mechanism

designed on altogether different lines, and functioning with equal or even greater reliability.

No one who has not shown from early youth a strong mechanical bent should attempt to work in this field. Even so, a practical training is almost essential, though the training need not have been one in design. Indeed, a training in specific design is rather a drawback than otherwise, because in every field of mechanism certain methods are followed almost by tradition, since they have been found to be effective, whereas the inventor should be free to adopt principles of design from other mechanical fields. But unless he has a feeling for mechanism he will be certain to overlook the peculiarities of some particular type of device, and make a wrong use of it; or, again, he may become imbued with a prejudice against certain devices.

We will now consider large mechanisms more in detail. In no field of work is more money wasted than in this, where the cost of construction is heavy. The first essential is that very good and detailed drawings should be prepared. There are a number of designers who pride themselves on working from sketches, which is merely foolish in a field where accurate prediction of almost every force concerned is possible. Even when drawings are prepared, sufficient consideration is not given to the forces operating. Of course, a consideration of these is often an exceedingly complicated matter. The stresses due to the transmission of power, resistance of the work, and so on, are usually simple enough, but it is further necessary to consider the forces between sliding surfaces which may destroy lubrication, and also inertial forces, which in some cases may be very considerable indeed. In another category we have the

elastic yield of the parts, and this again may be affected by the inertial and frictional forces as well as by the direct stresses.

In very many cases motions may occur which cause the stress to become excessive in certain positions, and hence the design is not fully checked over until the whole cycle of operations of the mechanism has been considered point by point.

The next question that must receive consideration is the effect of wear. As far as possible, a mechanism should be designed so as to allow of a considerable amount of wear taking place without interference with the cycle of operations ; and the mistake is frequently made of overlooking the fact that a small amount of wear may introduce new and very powerful forces, for instance, where a reciprocating part of considerable inertia is moved.

Here very little wear starts a knock, and this again introduces very powerful forces which rapidly destroy the pin or other link concerned. An excellent illustration of the way in which the unexpected may turn up in mechanical design on a matter such as we have been discussing, is that of the well-known ratchet with steel balls, as illustrated in Fig. 1. When this is made accurately and concentrically, the balls are always arrested at the same point on the teeth, with the result that wear takes place with comparative rapidity. If, however, the outer ring is made slightly eccentric, the effect is that the balls are arrested over a considerable space on each tooth, and the wearing qualities of the device are increased many times. Possibilities of this kind should constantly be borne in mind in design, for a slight change in design may lead to a distribution of

wear or other stress very much more favourable to good operation.

If it is at all possible, the inventor should have his drawing looked over by an expert before starting to build a machine. The expert is almost certain to object to one thing or another, since experts usually

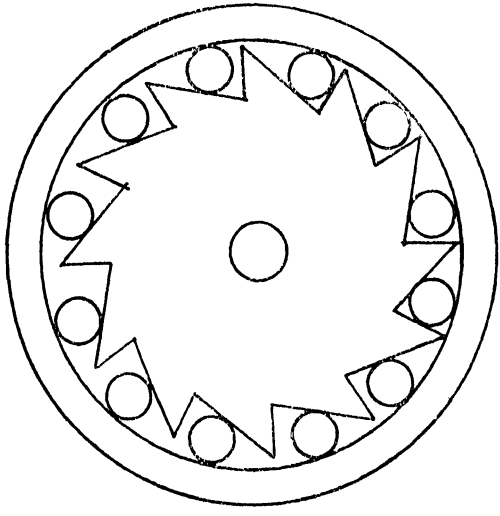


FIG. 1.

have very strong prejudices in favour of one type of design as against another. But a reasonable argument will usually lead to a decision between mere prejudice and more solid grounds. One can very easily picture the feelings of the engineer accustomed to the old Stevenson slide valve steam engine, when first confronted with a Corliss valve gear.

Another thing that should not be left out of account is the possibility of applying materials other than those

commonest in mechanical construction. In the motor-car this has been done with the most excellent results, especially in the fast-moving piston and connecting rod. The very latest pistons are, I believe, made of tinned cast-iron. The aluminium piston had a long vogue. Ford was the first to apply vanadium steel in certain parts, and there can be little doubt that the new materials which come forward almost every day will produce further changes in practice. It seems probable that in a great many other fields of mechanism, such as textile machinery, the application of the newer materials has not gone nearly far enough.

The most difficult problem, and one of the commonest, is presented by a mechanism which has to deal with material of a non-uniform or non-mechanical description. This applies to textile machinery, and the problems presented there by new artificial, and also natural, fibres have caused designers an immense amount of trouble. But other machines, such as those dealing with the conveyance, measurement, and packing of all kinds of granular materials, some of which not only vary greatly in size, but also in their physical qualities, are very difficult to design, and here experimenting is liable to be long and costly. But not nearly sufficient attention is devoted by designers to a preliminary examination of the qualities of the material to be dealt with. Innumerable machines have been designed, built, and even sold for dealing with powders and pastes, as well as with natural products, such as nuts, kernels, and the like, only to fail completely for want of the study of the raw material as it actually occurs in practice. For instance, a mixture of lime and soda is used to soften water on a large scale. By far the simplest plan

would be to dose this to the water mechanically in a dry form, and numerous machines exist which purport to do this. Unfortunately sufficient account has not been taken of the effect of moisture on different grades of these two materials, and the mixture of them, so that none of these machines is successful in Great Britain. The same applies to burners for powdered coal. Coal is a substance which varies very greatly in its properties, and when powdered, is also affected by moisture, and many systems have failed for want of attention to the actual material to be used in practice.

A great deal of such failure can be avoided by a careful preliminary study of the behaviour of the material. This involves obtaining real practical samples, and a series of these covering the whole range of the natural product. A second point is then to arrange to test out the effect of moisture, and this will usually have to be done by taking advantage of artificial conditions such as a damp cellar, and on the other hand, a very dry heated room. It is usually impossible to make quantitative observations of much value, and the designer can only construct models of the kind of device which he is proposing to fit to his machine to deal with the actual material—such things as scoops, gates, screw-conveyors—and try these on the material in its various states.

It is obvious that this field of invention offers a very large scope for practical ingenuity, since the commonest types of mechanical device are often quite useless for the purposes required.

It must next be borne in mind that the material dealt with may introduce all kinds of objectionable

substances into the machine. There are two general ways of avoiding this ; one is to design the machine so that their presence will not interfere with its working, and the other is to prevent their getting into the delicate parts. Not nearly enough is done, as a rule, in this latter respect. For instance, the writer has found that the principle of design well known to the electrical engineer, as ' petticoating ', by which an overhanging cover open at the bottom prevents moisture and dirt settling on a part, can be quite easily employed with a little ingenuity in all mechanism subject to trouble from this cause. Such a shield, while not of course being dustproof, will keep away nine-tenths of the dust, and all moisture falling from above ; while the part is freely ventilated, and therefore no condensation can take place.

If proper drawings are made, there is no difficulty in costing the job, and estimates can be obtained from various firms. If the apparatus is to be purely experimental, careful consideration of what is essential and what is not essential in finish may enable very considerable saving to be effected. The consideration of cost should be in the mind of the designer, of course, in preparing the drawing. He should have a list of available materials, especially such as do not require much finishing, and use these as far as possible. If he puts in standard sizes of steel and other materials which are already obtainable finished and polished so as to require very little work, a great saving will be effected, as against the use of odd sizes. Not only materials, but also a great many useful finished parts such as gears, bearings, slides, and the like, are now obtainable, and it often pays to buy new or second-hand a complete

machine of some kind, and incorporate it wholly or partly in the design.

A problem that frequently confronts the experimental designer is the choice between castings and built-up parts. It is always somewhat expensive, and a source of delay, to get castings made, but generally speaking the advantage of having castings is worth waiting for them, though it is a golden rule not to go to a cheap foundry for experimental work. But the writer has found it possible to obtain quite satisfactory castings of odd-shaped parts, presenting difficulties both to the draughtsman and the pattern-maker, by making models in plasticine of the parts in question, casting these in plaster of paris, hardening the plaster of paris by heating it, after thorough drying, in Carnauba wax. The result is a pattern good for more pieces than the average complicated wooden pattern, which very soon loses its shape in the sand. In experimental work aesthetic considerations should have no part at all, unless there are good reasons for wishing to produce a good-looking job. Otherwise every piece of unnecessary finish is pure waste of money.

The most difficult problem in experimenting is presented by pieces which are finally to be pressed from the sheet. Here the aid of the artistic craftsman may be called in with advantage. A good metal-worker, capable not only of beating metal but also hard-soldering it, should be able to produce a model very close to the final pressing which it is intended to use.

The designer should supervise the construction closely and not leave it to the maker. He should examine as far as possible each part before it is built in,

for nothing is more common than for a mistake to be rectified by illegitimate means, which would not be used in a job known to be intended for hard wear. A certain latitude may of course be allowed in this direction, but the judge of it is the designer, not the workman. Very often too, an experimental machine is called upon to work much longer hours than its designer anticipates.

It is a good rule to study and test parts of a machine separately before they are assembled. The cool and careful person will naturally do this, but others may feel inclined to wait until the whole affair is put together and ready to have the power turned on, in the optimistic hope that perfection will be attained at a bound. On the contrary, if the designer plays about with each part separately and endeavours almost to identify himself with the part and feel how it is going to operate when operating in the complete machine, his sense of the working of the whole will be very much more acute, and he will be much more likely to lay his finger immediately upon the cause of an unsatisfactory result when the machine is tried out as a whole. It is this getting inside the skin of a machine, as it were, that makes the successful inventor, and the one who is able not only to devise good principles, but also to complete a design which will work satisfactorily over a long period.

Fast-moving mechanism presents very great difficulty to the designer, because it is often troublesome if not impossible, to trace the source of defective working. Recently, the cinematograph has been made use of most successfully for this purpose; in an instance known to the writer, the last slight trouble in the work-

ing of a machine-gun firing twenty shots a second was cured by this means. There are substitutes for the cinematograph, in which an apparatus is employed for directly viewing the machine instantaneously at any part of its cycle ; these are readily obtainable and not expensive.

Rough finish of the machine should not prevent the possibility of very accurate measurement of all wearing parts before the machine is assembled. These measurements should be carefully recorded, and if satisfactory operation is found, the machine should then be run, of course with proper attention and lubrication, to allow of a wear test. If the machine is then taken down and the measurements repeated, the wear on each part can be estimated. Following this, the effect of adverse conditions likely to be met with in practice, such as wet, over-speeding, bad lubrication, should be tried. All these words of advice will seem trite to those working in fields, such as the motor-car trade, where competition is severe, and success depends upon reliability ; but in less strenuous areas they are frequently neglected with disastrous results.

We will now consider an entirely different field, one peculiarly the playground of the amateur inventor, and yet one of the most difficult of all—the field of small mechanisms. It is a curious fact that, in spite of the enormous practical importance of this field, practically no organised information exists to guide the designer. As far as I know, there is no department of any technical institution devoted to a general consideration of this subject. Its ramifications cover almost the whole field of technical work. In toys, we have small-scale imitations of all kinds of large machines ; in instru-

ments, especially the more elaborate type, we have mechanisms of extreme fineness and delicacy, with a gradual range up to systems of automatic control involving power up to a few horsepower. We have the whole range of coin-freed mechanisms, though many of these, such as weighing machines, are rather outside the scope of the following remarks.

The sewing-machine and typewriter, together with their numerous associated duplicating machines, are also on the border-line; and finally, we have clocks and watches, with their associated mechanisms such as time switches, striking mechanisms, and so on.

We might almost say that the difference between the large mechanism and the small is that the former can be designed on paper, whereas the latter cannot. Every maker of toys, model engines, and the like knows that successful operation, and especially manufacture, depends upon a variety of dodges found by experience, which do not apply to the large machines of which the models are copies.

The small mechanism is the field where, most of all, experience tells. I have met one or two men at the most in my life who were capable of designing an entirely new small mechanism, and making it, with the practical certainty that it would work in a commercially satisfactory form. These men would quote for such machines and succeed in making them profitably, whereas I have seen a large firm of apparatus makers, staffed with draughtsmen designers, ruined by attempting to do the same thing. In the latter case a really beautiful design would be evolved in the drawing office and made in the works at great expense, only to require weeks of experimenting to discover all the possible

ways in which it would go wrong. Unfortunately, when it was then sent out, a few further new and unexpected defects would usually turn up.

It is obvious that no small mechanism, with the exception of the most expensive class, can be made, or at least manufactured, with the same relative accuracy as a large mechanism. Hence, the first principle of designing small mechanism is that accuracy in construction should not be essential. Indeed, if it is attempted to attain this, failure will often occur, since a large bearing may be closely fitted and yet run no risk of seizing, whereas a small bearing, relatively as good a fit, will seize; in any case the same means cannot be employed to ensure its proper lubrication. On the other hand, parts of a small mechanism can be relatively extremely light; if they are called upon to move fast, they cannot be expected to wear, but they are not always required to do so. The great art in designing small mechanisms consists in making them so that loose-fitting may be employed everywhere. When this is impossible for any reason, it is often possible to avoid a bearing or link altogether by using a spring. Loose-fitting means, of course, that all back-lash must be taken up if wear is not to occur.

Since efficient lubrication of small mechanisms is often impossible, recourse may be had to an important principle, viz. that wear between unlubricated unlike materials is generally less than between like materials. Hence, in clocks, steel pivots are used in brass plates, and never two like metals. A still better combination is between metal and non-metal. Phosphor-bronze and ebonite, for example, will show no signs of wear under light load, for an almost indefinite period. The use of

bakelite-impregnated linen for gear-wheels, with steel pinions, is becoming very common.

It is very important to remember that friction is greatly reduced by vibration, and a mechanism which functions perfectly under test in a place where running machinery exists may fail altogether when set up in a perfectly still position. On the other hand, a clock movement subjected to vibration may well have its escapement overpowered owing to the diminution of friction in the train.

Small and light mechanism cannot transmit much power. It is fatal to cut down working power too far, and the whole aim should be to get all fast-moving parts as light and frictionless as possible. The use of tiny ball-bearings is not common enough. These may be very simple in design, and the balls may be of phosphor bronze, and so rustless. Such bearings are usually much to be preferred to the cone-and-point bearings generally fitted.

Small mechanisms are generally designed for manufacture in large quantities, and this should be borne in mind from the outset. One of the commonest mistakes is to overlook ease of assembly ; in fact, some designs on paper turn out to be incapable of assembly, and an otherwise good design is often spoilt by the inaccessibility of some important part. Space saved is, of course, material saved, as a rule ; but if the gain is made at the cost of increased labour in assembling, or in liability to trouble, it is illusory.

On the other hand, it is often a good plan to make small mechanisms, especially if they are for use by the general public, in such a way that they cannot be taken apart without special tools ; if they do not work pro-

perly, they must be returned to the maker. The exact cause of the trouble can then be diagnosed and, as a rule, a new machine will be given in exchange—a gesture which invariably results in a gain of kudos. If a member of the public is tempted to try and remedy a small defect, the maker may finally get back a mass of small and damaged parts, and often cannot tell what the original source of trouble was.

Far too many small nuts and screws are made use of in small mechanisms. These often work loose in transit, and in any case they incite the user to unscrew them. Soldering, of course, should be avoided like the plague in any final design, though marvels can be performed with it in experimenting. It is difficult to get a good experimental mechanic to make enough use of it—often he is very unskilful at it. But there are means of fastening small parts in regular manufacture which are very effective. One of these is the eyelet or tubular rivet, which is much easier to fasten than the solid rivet, and easier also to remove. Electric spot welding is very useful as applied to iron and steel. Split pins are invaluable, for they can never work loose. A careful study of modern mass-produced designs will reveal many neat devices capable of much wider application.

It is hardly necessary to mention die-casting as one of the most important aids to cheapness in production. It is a great pity that we are yet without a die-casting metal having the qualities of brass. Electrochroming of die-castings may be used to harden the surface, if the dimensions are not too finely cut.

The great field to-day for small mechanisms is in combination with electricity, and it is a field in which

the small, individual inventor can compete. But it is open only to very competent and experienced workers. When we remember that the most recently adopted mechanisms of this class, such as automatic telephones, railway signals, instrument control, and so on, depend upon principles which are nearly a century old, some idea can be formed of the practical difficulties involved. Nothing is easier than to design on paper, and construct, contraptions made up of magnets, contacts, detents, ratchets, etc. etc., capable of performing any desired operation, and nothing is more difficult than to render such a device free from mechanical and electrical trouble.

There are no good general books on the subject, but each type of these mechanisms, such as telephones, electric clocks, electric organs, instrument controls, and so on, is a small technology in itself. What could be simpler in principle than a clock, yet any text-book of ' horology ' will show us what a mass of refinements in principle and design exist in this field. Advances of the greatest importance are still being made in it, as witness the recent improvement in astronomical clocks of the highest precision.

In no field is the contrast between the ' fan ' or hobbyist, and the inventor, more remarkable. One sees at exhibitions models, made with the most marvellous skill, which are utterly useless except as show pieces, since they are far too valuable for toys. What might not the combination between such mechanical skill and inventive ability have produced in the way of new and useful devices ? Unfortunately, such a combination is rare among amateurs. Frequently, however, great things have been done by the association

between the proprietor of a small workshop and a scientific inventor. Such were Carl Zeiss and Ernst Abbé, and the firm has retained the name of the craftsman, not of the inventor.

Perhaps some highly skilled amateur mechanic may read these lines, and consider whether carrying out the ideas of an ingenious friend might not be more fun than making scale models of locomotives. One of the most easily saleable of all inventions is a small mechanical model, correctly designed for mass production, and functioning demonstrably, without need for apology.

Chapter VII

Chemical Invention

Under the term ' chemical invention ' we understand everything connected with the production of new homogeneous materials, the properties of which depend upon their chemical composition. In this field we have the strongest contrast of all between science and rule-of-thumb. On the one hand modern chemistry, including physical and electrochemistry, covers an enormous range of work in which the science of all that happens is thoroughly well known. On the other hand, there are large fields of invention in which scientific chemistry plays quite a subordinate part, and much good work is done by persons who have little or no knowledge of it. It is needless to say that this latter field is continually diminishing in extent, and that chemical and physical methods of investigation are being applied where not so long ago they were not of the slightest assistance. But the fact remains that their function is still very largely merely subsidiary, and that they offer little or no assistance as regards new developments. In cases such as paint, varnish, linoleum, and rubber manufacture, floor-covering compositions, and many classes of food-stuffs, invention still proceeds along the lines of trial and error, and the race is not to the scientifically educated, but to those possessing that

instinctive sense of the possibilities of certain materials of which we have spoken earlier. In other words, this branch of invention is simply cookery in a wider sense, and results are obtained rather by art than by science.

If we take scientific chemistry first, we have to recognise the fact that there is still a considerable gap between inorganic and organic chemistry. There is certainly such a thing as a born chemist, and among chemists there is certainly such a thing as a born organic chemist, who normally has hardly any feeling for physics or physical chemistry. While conversant with the complicated geometrical patterns upon which his own science is based, he still seems to proceed by a kind of instinct, for his science tells him only what is possible, and not what will happen. Thus it will tell him that a certain mixture when cooked up will result in the formation of a certain desired product, but it does not tell him what are the most favourable conditions for this cookery, nor what actual yield of the desired product will be obtained. As everyone is aware, who has had the misfortune to work at organic chemistry without being born with the necessary *flair*, the yield of material in the hands of an unskilful operator is often ludicrously small, while the skilled operator cannot state the principles upon which his success depends.

In organic and physical chemistry, matters are much more subject to our powers of prevision and control. Especially where physical chemistry and electrochemistry can be applied, we are able to say with some certainty what will be the result of subjecting given substances to given treatment. In this field of work there is now no room at all for anyone who has not had a thorough training in physics, chemistry, and

mathematics. Given this training, processes can be devised and calculated on paper, and tested in their essentials on quite a small scale in the laboratory. The further development on full scale, which invariably leads to a whole crop of fresh problems, is extremely costly as a rule, and the chances of finding support in this country are very small. Some of the most important modern developments, such as the Haber process for ammonia synthesis and the Bergius process for the hydrogenation of coal, have been worked out in Germany, after being tested on the laboratory scale. Such laboratory work demands the highest virtuosity in experimenting.

A new chapter in the history of chemical inventions can be foreseen as resulting from our most recent knowledge of the atom. This at present is entirely confined to the work of certain physicists, and it is impossible at present to tell in what way practical use will be made of it. So far the disintegration of atoms by artificial means, though certainly effected, seems to offer no hope of practical application, and it may perhaps be in the field of catalysis that our new knowledge will be first applied.

There can be no doubt that those who have a training in, and aptitude for, physics and physical chemistry, and at the same time feel drawn to invention, cannot do better than study practical problems in those industries in which organic chemists only, as a rule, are employed. Such industries are rubber, cellulose, paper, brewing, sugar refining, etc. Already a great deal of physical and physico-chemical study is being carried on in these industries, but they are so vast that there is room for much more. After Schwerin had laboured

almost unrecognised for many years at the applications of electrosmose, it is at last finding its way into practical use, and there cannot be the least doubt that the application of photochemistry, and perhaps of electromagnetic radiation and oscillations, will grow. There are far too few Faradays about nowadays, ready to try new combinations of natural forces and observe the results without preconceptions. Everyone who experiments continually observes inexplicable effects, and I have often thought that some means of publication for these would be of great benefit to science. However, even when they are published, science takes a long time to do something about it. One of the most amazing sights I have ever seen is Mr. Mordey's experiment of a heap of mixed dry quartz and magnetite sand, in a porcelain dish resting on a three-phase alternating magnet. When the current is turned on, the particles of magnetite crawl out of the sand like ants, and make for the end of the dish. No satisfactory physical explanation of this effect is known, but its utility is obvious.

There is, indeed, an immense field for empirical experimenting in chemistry. There is nothing to prevent anyone from entering it, even those without any chemical training at all. An ideal combination is between a non-chemist with an instinct for experimenting, who thinks of experiments which would never occur to any chemist in his senses, and a chemist who explains the results that he gets.

It is very natural that the minor inventions in inorganic chemistry are now coming almost exclusively from the research laboratories of large industrial firms, for there investigations are conducted systematically

under the best possible conditions, and with all the necessary unskilled assistance to enable a very large number of tests to be made with a slight variation in the conditions. But there is still nothing to prevent private individuals working on everyday problems which are obvious to all of us. For example, the whole matter of corrosion by weather, town air, and sea-water, and the discovery of protective methods for all sorts of conditions, has received far too little attention from private workers. It is surprising that in a country like ours, where so many people take up hobbies, there are so few who make a hobby of research work of this kind. Even when they do so, they often go about it in such a helpless and half-hearted manner that nothing of value can result. It is of course necessary to find out what has been done, and what the best known methods are, before attempting to make improvements.

It is needless to say that the best methods known are not the best-known methods—those commonly employed by the ordinary mechanic or builder. It takes a long time before improved paints and other anti-corrosive and protective materials are generally introduced.

We see everywhere the effect of corrosion on iron, steel, brass, aluminium and like alloys, wood, paint, and building materials. It is still impossible to protect the ordinary type of roof permanently from leakage; all methods and materials at present known give way sooner or later to the effects of weather and sun. In exposed positions the ordinary brick wall is pervious to rain, and no means of preventing rain being blown through such walls has been yet devised, excepting

covering them with tar. The stucco used so often in sea-side towns develops fine cracks through which a storm will blow astonishing quantities of water. No efficient means of repairing these cracks is known, and this is only one example of a case where it is open to anyone to experiment with a view to finding a remedy.

Another illustration of the possibilities still remaining to purely empirical experimenting is in the matter of solvents. It is impossible to predict whether a given liquid of known chemical composition will or will not dissolve a known chemical solid. When it comes to solids of less definite nature, the possibilities of production are still vaguer. Quite recently two German chemists have made a discovery of the greatest importance, namely, of a solvent which disintegrates wood by dissolving the ' lignin ', which after cellulose, is the chief constituent of wood and is the material which binds together the cellulose fibres. The new solvent acts upon the wood at a temperature below the boiling point of water, and under ordinary atmospheric pressure ; and the lignin is not chemically altered in any way, but can be separated from the solvent by simple distillation of the latter, which can then be used for opening up more wood.

In order to prepare cellulose from wood, it has hitherto been necessary to attack it with hot strong chemicals (caustic soda, calcium sulphite), and under pressure. The lignin and resin are thus dissolved and partially decomposed, the cellulose remaining pure, but somewhat injured, whereas the new solvent has no action upon it at all. The new solvent is also suitable for disintegrating straw ; and the economic consequences of this discovery, if it should turn out to be as

remarkable as reported, will be very great. It is evident that the converse of this, a binding material enabling cellulose to be reconverted into a material as strong as wood but plastic before finishing, should also be obtainable. This, of course, should be of such a character that the regular fibrous structure of the wood is retained, and not replaced by the irregular structure of paper. It is quite possible that the new solvent we have just spoken of will enable the lignin itself to be utilised, or to be treated in some way so as to make it of value, instead of it being, as at present, a waste product.

We have seen that in chemical invention we range from one extreme where science is able to tell us exactly what we are doing, to the other extreme where the most we can do is to make a wild guess at some of the chemical reactions taking place. The great fields of chemical invention lie between these two extremes. Until recent times there was far too much rule-of-thumb and far too little science in English experimenting, but this state of affairs is now in danger of being reversed. There is a tendency to investigate in the laboratory at very great length complicated substances and products of all kinds, and to accumulate an enormous amount of information about them. This work is often very fascinating to the scientifically trained chemist, but it should be remembered that in a great many cases an exact knowledge of the chemical constitution of such a substance as low-temperature tar will not help us very greatly to decide exactly what it will do under given circumstances.

As soon as a practical problem is set, such as the utilisation of a given by-product, or the production of a given result (cement, artificial resin, protective coat-

ing), out of given materials, the problem at once arises as to how far the study of the existing science of the subject should be carried, and how much of the available time and labour and money should be devoted to scientific work ; such, for instance, as chemical analysis and the study of physical and microscopic properties. In practice we see the widest possible variations ; in some cases the work done is purely empirical, while in others an enormous quantity of analytical information, tables, and curves of all kinds, as well as laboratory samples, are accumulated. In the latter case, as a rule, far more data are collected than can possibly be applied practically, and in most cases the results are completely wasted, since subsequent workers, attacking the problem from an entirely different point of view, have no use for them.

The differences in style are usually due to necessity and not to choice. The rule-of-thumb experimenters are often painfully ignorant of chemistry and physical chemistry ; they are too lazy to acquire the knowledge, and at the most they employ a badly paid and inexperienced chemist to help them. The amount of money wasted annually in useless experimenting by the managers of works and departments of works must be enormous.

Equally, the over-scientific tend to be devoid of initiative and offensive spirit ; it is easier and more comfortable to peg away day by day in the laboratory, and the procedure can be represented as much more thorough and profound than haphazard experimenting. Furthermore, experimenting in this field is often a dirty and uncomfortable business if properly supervised.

The great successes have been obtained by men who

thoroughly digested the science of the subject in a well-trained mind, and then forgot all about theory and attacked the problem empirically, with the greatest industry and alert observation. In this line of experimenting, the sharpest eyes, nose, and even ears are necessary. All the routine in the world—sampling, labelling, recording, analysing, plotting curves, and so on—is no substitute, and will of itself be unlikely to lead anywhere at all.

We have already referred to Goodyear's experiments on rubber in the very early days. It is strange how long it has taken to develop some of the modern processes, which all depend on simple empirical facts which one would have expected to have been discovered long ago. A great deal of modern development depends upon the simple fact that the rubber latex, that is, the unchanged emulsion of rubber which comes from the tree, can be preserved indefinitely by the addition of small quantities of ammonia. Vulcanising compounds are now added to the latex, and all kinds of objects can be coated with latex and the rubber then vulcanised after the coating has been made. The spongy rubber now being introduced for all sorts of purposes is latex containing vulcanising material and beaten up, by means of an apparatus exactly like an egg whisk, into a froth. Towards the end of the beating process a little coagulant is added to the mixture, and it is immediately poured into moulds, whereupon it sets solid, the fine air bubbles which have been whisked into it rendering the mass porous. It is then vulcanised by heating to a low temperature.

When one considers the length of time during which the rubber industry has been of first rate importance, it

is surprising that so simple a process has only just come into practical operation.

In all probability there are numberless other equally simple processes of the kind waiting for their discovery by someone whose mind is not completely occupied by preconceived ideas of what can be done with a given material.

In chemistry, as elsewhere, the work accomplished by the research machines of large corporations is considerable, but it by no means puts the single worker at a hopeless disadvantage. The vast organisations of the German dye firms are often referred to, and thought of their sheer weight of numbers has probably deterred many an English worker from tackling a dye problem. Yet, to take a single instance, a German firm had twelve research chemists working from 1912 to 1918 on a certain dye known as Naphthol AS. Its production remained a German monopoly until 1926, in spite of our own much advertised determination to beat the Germans at organised research. An independent English worker, Dr. E. B. Higgins, then tackled the problem, and in a month had devised a new process. This process he then developed into commercial production in association with friends, none of whom had any connection with the dye industry, and drove the German product out of England. The industry, thus established, was then bought up by an English dyestuff firm.

Perhaps the most important branch of purely empirical chemical work at the present time concerns artificial plastic masses. Although the production of objects by moulding plastic or liquid substances has been known from the earliest time, its possibilities have

only been thrust upon public attention quite recently, through the development of bakelite, erinoid, acetate cellulose, and other masses which can be given all kinds of attractive colours, and moulded into almost any desired form. Some of these substances are also capable of receiving a high polish, are almost perfectly resistent to corrosion, and are not particularly brittle. They are now familiar to everyone in table ware, toilet fittings, fountain pens, and all kinds of fancy objects, some of which have very beautiful and brilliant colours.

It is obvious that moulding an object in this way represents the ultimate ideal of mass production, and it certainly was the first means of mass production known to man. But until modern times only a few varieties of moulding were known—casting metals, casting in plaster, and stamping or pressing clay. Of these, casting in plaster is ideal as a process except for the fact that the mass does not solidify quickly, and consequently puts the mould out of action for too long a time. The ideal substance would flow readily into a mould, no matter how intricate, without requiring the aid of pressure, and would then harden sufficiently to be removed almost immediately. The final product, which might of course be the result of a further hardening process, would in the ideal case be strong and light, capable of being given any colour, and having a hard surface resisting both mechanical and chemical attack.

If the ideal material were discovered, nine-tenths if not more of the objects of everyday life, houses, furniture, utensils of every kind, the body and fittings if not also the engine and chassis, of every motor vehicle, railway train, and so on, would all be turned out in a finished state by the simple operation of forcing the

material into suitable moulds. The only remaining possibility of progress would then be to find the way of getting into the fourth dimension, because if we could do this, we should be able to get an object of any shape out of a mould without taking the latter to pieces, no matter how complicated it might be. This access to the fourth dimension is already an urgent requirement of industry.

The slow but sure advance of invention has been almost entirely a matter of sheer empirical work, and it has taken place along several main roads. Each of these roads has been entered upon by pioneers whose early work received very little attention. Bakelite, for instance, is what is called a synthetic resin. Now every organic chemist since the beginning of science has synthetised resin, but unfortunately this fact has been one of the chief sources of annoyance and bad temper in organic laboratories. For the object of the organic chemist is to obtain as high a yield as possible of a substance of known formula, and in very many cases the difference between a full yield and one of a miserably inadequate description is represented by a mass of insoluble resin, which is extremely difficult to get rid of from the vessels used. It is not surprising that few organic chemists ever realised that there might be the potentiality of a vast industry in making such resin on purpose, and until Baekeland discovered how to control the production of resin so as to enable it to be moulded and finally turned into the hard and chemically indifferent substance known by his name, the industrial production of synthetic resin was very small. The development of other plastics has also been almost accidental, acetate cellulose, at the present

moment of very great importance, really having arisen out of the artificial silk and unbreakable glass industries. These industries gave a large quantity of waste, and it was the attempt to utilise this waste which led to the discovery that it could be made into a plastic material.

It would be interesting to set down all the different possibilities by which a plastic material flowing readily into an intricate mould can harden into a mass solid enough to allow it to be taken out of the mould. We may attempt to make a list of these.

1. Simple freezing of the liquid, as when a metal is cast in a mould.

2. By actual physical removal of the liquid constituent, as when a thin mixture of clay and water is poured into a porous mould, which sucks out the water, leaving the clay solid.

3. By a chemical reaction which results in the liquefying constituent being bound chemically, the products of the reaction crystallising in such a manner as to give a solid mass. This is the case in the simplest form with plaster of paris, where the calcium sulphate combines with the water to form a hydrated crystalline solid. In portland cement the reaction is much more complicated, and the water plays only a subsidiary rôle.[1]

4. By pure molecular rearrangement or polymerisation. This takes place in the last stage of bakelite manufacture, but is difficult to distinguish from

5. Reaction between two liquid constituents in a state of mixture, which occurs in the earlier stages of

[1] It is interesting to note that Leonardo was apparently the first to suggest making cement blocks in moulds for building (*M.S.B.*, p. 79).

bakelite production between formaldehyde and phenol. Here, however, the water produced by the reaction has to be got rid of.

6. By a change in colloid structure, as when liquid gelatine sets to a solid. Acetate cellulose, celluloid, and other plastics of this type probably come into this category, though these all consist of mixtures of some fundamentally gelatinous substance with so-called plasticisers, which probably act by adsorption to modify the colloid structure.

The above list is probably far from being exhaustive, but it will be seen that every item is at present only represented by a few instances, if we except the first. In the case of metals, however, the ordinary casting yields results so rough that they can hardly be considered in the present category. Only die-casting yields finished and accurate pieces, and here strong alloys require enormous pressures and temperatures for casting. If an alloy could be found with the casting properties of type-metal and the strength of duralumin, it would have a revolutionary effect upon industry, for an immense amount of machine work would at once be abolished. The ingenious process of casting clay into porous moulds is being superseded to some extent by the electro-osmotic process, which is also being applied to india-rubber latex. In this process the mould is filled with a thin slurry of the substance, and made one pole of an electric circuit, the other pole being inserted in the liquid as symmetrically as possible. The current then causes the fine particles of clay or rubber to pack up tightly against the surface of the mould, whereupon the liquid can be emptied out, and in some cases the mould can be immediately taken apart. In other cases

the mould is heated and the coagulated material thus caused to solidify further.

This appears to be a general method which holds possibilities for the future, since there is no reason at all why it should be limited to the particular instances in which it is applied at present. It is obvious that a suitable binder could probably be found for almost any kind of powder thrown down in this way, assuming that a binder would be necessary. The chief drawback in principle is the fact that the process is one which would necessarily take time, and since complicated moulds are very costly to make, the smallness of output would be apt to necessitate an excessive expenditure for moulds. It is obvious that this process could be carried out in all kinds of liquids, and that it presents the very great advantage of not requiring pressure. This fact operates to reduce the cost of the necessary moulds.

There is little that can be said about the other processes, since of recent times almost every conceivable variety of plastic organic material has been tried and experimented with.

A very important matter in this connection is the incorporation of solid matter in the plastic mass. Hair, straw, wire, and other fibrous materials have been used to reinforce plaster and earthenware from the earliest times, and wire has also been used to reinforce castings of lead and tin alloy. Reinforced concrete is a modern development, depending upon the fact that iron and portland cement have almost identical coefficients of expansion with heat. If this were not the case, it would be impossible to cast cement around iron, since the two would be separated as a result of changes of tempera-

ture. Another possibility which has been less exploited is that of producing the objects in a very porous form, and strengthening them afterwards by soaking them with a liquid which then solidifies and forms a strong binder. Plaster of paris objects heated in Carnauba wax become very hard and strong, and this is a line of development which might very well lead to valuable results if it were followed persistently.

In spite of all that art has been able to do, Nature is still ahead with the substance wood, which is unique in its properties. The reason for this is twofold, first of all the cellular structure, which gives strength combined with lightness and at the same time renders minor damage to the surface practically innocuous as regards strength. Thus a spar or rod can be made of steel or duralumin to be lighter for the same strength than wood, but a slight injury to it, which would be of practically no effect on the wooden spar or rod, robs the metal of the great part of its strength.

The second reason for the great strength of wood lies in the peculiar molecular structure of the cellulose containing it. This regular structure is such that the chemical bonds between the atoms are so disposed as to confer the maximum of mechanical strength. In all our artificial materials, on the other hand, the structure is completely irregular. It is possible to treat a pure solid metal in such a way as to bring the atoms into completely regular arrangement, but the result here is of no particular advantage, since we are not dealing with the powerful linkages which exist between unlike chemical atoms. If someone could show us the way to arrange molecules of certain chemical compounds in an orderly manner so that their linkages result in

mechanical strength, our whole use of materials would be revolutionised. Working as we do with atoms and molecules arranged in a higgledy-piggledy manner, we instinctively imagine certain classes of substances to be naturally strong, and others to be naturally weak. This is an erroneous impression ; the strength of our strongest materials, such as duralumin, steel, phosphor-bronze, and other metals, is the strength of compounds and not of pure substances, and there is no inherent virtue in the compounds called alloys, as compared with others.

In the meantime, progress is being made in the artificial development of cellular structure, though with materials the molecules of which are not ordered as in the ideal state. The porous rubber preparations of various quality are now very well known to the public, and it is certain that advance in this direction will proceed. Curiously, portland and other cements though they have been produced in porous forms, are still not completely successful, while porous metal is only in the stage of being announced periodically in the newspaper press, but never appearing as a commercial proposition.

Attention may be drawn at this point to the valuable results obtained by sintering powders. This was first done in the case of quartz sand, the result being a porous material very suitable for filtering purposes. The next product of the kind was glass sintered in the same manner, and this material now has a great many uses. There can be no doubt that the research in this direction will be sure to lead to further valuable material. Indeed it may possibly turn out that the final production of cellular material, the cell walls of which have a structure giving maximum strength, will

be arrived at by sintering or otherwise causing to adhere, grains of material first arranged under the influence of some force (possibly magnetic or electrostatic) which will set them all in a desired direction.

Sheer playing around with plastic mixtures which can be moulded without pressure, and set hard sooner or later, is within the reach of everyone, and is by no means the hopeless business that it might appear. An enormous amount of experimental work must be in progress in this field, and yet here again we are constantly finding that the 'mad' inventor meets with success where the more scientific experimenter fails. Indeed, the person without any scientific knowledge but possessed of sufficient industry and a certain instinct for experimenting may triumph over the highly trained chemist whose knowledge might prevent him ever discovering that a mixture of oil and vinegar makes a good salad dressing, since he knows that they will not mix or combine properly.

In this kind of experimenting there is one golden rule: experiment with known quantities of known materials. As regards quantities, the rule can easily be observed; when it is broken it is usually through eagerness and haste. It often seems a silly thing to waste time actually weighing or measuring small amounts of substances which are added to a mass, and often a mass the weight of which is not known. Nevertheless this should be done, and a careful record kept of every experiment and the results obtained from it.

As regards materials, the rule is extremely difficult to observe. No material purchased commercially can really be described as known; the only defined substance is a chemically pure substance, and this as a rule

is unobtainable. But there is a second rule which may serve as a substitute, namely, never to use the whole stock or batch of any substance. A sample should be kept and labelled with its origin.

The most famous case in history is that of Auer von Welsbach's discovery of the incandescent gas mantle. He began by dipping fabrics of various descriptions into solutions of the nitrate of metals which when ignited gave highly refractory oxide. He started from the perfectly correct assumption that the intrinsic temperature of a Bunsen flame was quite sufficient, if communicated by a refractory oxide, to radiate light at high efficiency. He saw that the only possible plan would be to surround a very thin mass of oxide by the flame, and in order to obtain this mass, which we now know as a gas-mantle, he made a suitable shape in cotton or silk, and then dipped it into a solution of the nitrate of one of the earth metals, which on ignition leaves a mass of refractory oxide.

He was rewarded with the discovery of a mantle of what he imagined to be pure thorium oxide, which radiated light with high efficiency. He hastened to patent this discovery, and the invention soon became of the highest commercial value.

However, it was not long before it was shown that pure thorium oxide radiates light very inefficiently, and that Welsbach's results were obtained not with pure thorium oxide, but with such as contained about 5 per cent of cerium. In many countries Welsbach's patent was upset because he had claimed the use of thorium only.

A very much worse case even than this is where a result is obtained and cannot be repeated, because the particular materials used are no longer obtainable, and

the particular impurities to which their virtue was due are not known. It is by no means always possible to recover by analysis of a product the exact original set of ingredients necessary to produce success. This was possible in Welsbach's case, but in more complicated cases might easily be out of the question. I once met a distracted man, almost on the verge of suicide, who had obtained thousands of pounds' worth of contracts for a new floor-covering which he had worked out after years of experiment in the woodshed. This was composed of cement, fillers of various kinds, and silicate of soda. Suddenly he was unable to repeat his result. Apparently this was due to the fact that the silicate of soda hitherto used was no longer obtainable, and what he was now able to purchase was of different composition. He had none left of the original quality, nor was he able to trace it to its source, since he had simply bought it retail, and could not find where his retailer had obtained it. If he had retained a sample he would have been able by an analysis to discover exactly what material he was dealing with.

A still more remarkable case than this came within the experience of a friend. One of the largest firms of British printers was offered by an Italian a composition for casting stereotype moulds of type. It had perfect qualities, and was of almost incredible mechanical strength. The Italian soon found it necessary to prepare a fresh supply in London, and purchased the ingredients, which included slate dust, manganese dioxide, and silicate of soda. The result was a complete failure. Finally, he returned in despair to the oilshops of his native town, where he had obtained his original supplies. The result was again a failure, and

as far as I know, until this day the result has never been repeated. My friend, a consulting chemist, was called in to help, but very wisely declined the commission.

It is a good rule that any good result obtained with a certain mixture should be repeated with the same ingredients but of the highest obtainable chemical purity, and again with ingredients of commercial quality derived from as many different sources as possible. This rule applies to all empirical chemical experimenting, as in paints, adhesives, waterproofing compositions, solvents, and so on. Thus a solvent to be used in leaching a mineral should be first tried out on the pure material mixed with an absolutely indifferent substance such as pure sand. One may then proceed to try as many natural varieties of the substance to be dissolved as possible, and finally the natural mineral, which in many cases will contain substances attacked by the solvent in addition to the one which it is desired to extract. There are hundreds of problems in this field waiting to be solved, perhaps the most important being that of finding a process for extracting platinum corresponding to the cyaniding of gold. If any invention could be guaranteed to make a fortune for its inventor this would be the one. In view of the fact that it would be Soviet Russia which would benefit most, he might have some difficulty in finding support in other countries.

Inorganic chemistry alone embraces an enormous range of industry, and though it might at first sight seem an unpromising field for chemical invention to-day (as opposed, of course, to chemical engineering), there can be little doubt that many important developments

will still take place in this field. The natural sources of chemical elements, that is the minerals and similar materials, are almost infinite in their variety, and as the world demand continues to increase, the more easily won sources will become exhausted, and it will be necessary to exploit those which are not at present worked on account of greater expense and difficulty. The present over-production of raw materials of all kind is temporary, and can hardly last more than a year or two at the most.

The extraction of minerals always presents two alternatives, physical and chemical. The physical methods (to be found in any textbook on ore dressing) are very interesting and important, and are far too little known outside the mining world. They consist in the separation of the constituents of mixed powders (crushed ore) by utilising the difference in some physical property between the various constituents. Specific gravity, magnetic permeability, and surface tension against various liquids, are the properties most widely made use of, but the dielectric constant, the electric conductivity, the coefficient of friction, and one or two others are used to a smaller extent. It is surprising how little all these ingenious and extremely effective methods are known to chemists who are not in touch with mining. For instance, magnetic and dielectric separation may be used on the smallest scale (even under the microscope) in the laboratory, and, between them, often enable a small quantity of a mixed powder to be separated physically into its constituents. An examination of this sort should be regarded as a routine preliminary to the chemical examination of any mixture, since the analysis only gives the elementary constituents

as a rule, but not the nature of the different compounds present.

There can be little doubt that these methods of separation could be applied usefully in chemical manufacturing processes which give solid mixed residues. This is an instance where the application of ideas from one branch of technology to another branch would be productive of advance.

Conversely, developments are to be expected in the application of simple chemical methods to the treatment of mineral ores, though here of course an immense amount of work has been done, and further advance will involve either the discovery of new reactions, or of suitable materials for treatment. The possibilities in this field are illustrated by the cyanide process for the recovery of gold. The tailings from the earliest gold workings in India, where the gold was separated by washing, contain no more gold than the tailings from the most modern type of water concentration machinery. The cyanide process, on the other hand, is capable of removing almost the whole of the gold from these tailings, and has been applied to work over the heaps accumulated in the course of ages, as well as to treating the tailings from modern plants working on freshly crushed material.

Not only the use of liquids, but even that of gases has found successful application, as in the famous Mond nickel process. Anyone who intends to work in either of these directions should thoroughly study the history of the unsuccessful attempts which have been made. In the days when tin was an expensive metal, it was found that it could easily be driven off in the form of chloride from a mineral, either by mixing the

latter with common salt and heating it, or by subjecting it first to reducing gases and then to chlorine. Simple as these two processes seem, the practical difficulties were so great that they were only applied successfully to a very limited extent. The gradual development of the process like that of cyaniding, superficially so simple and straightforward, is a matter of the overcoming of one trouble after another which appears as soon as large-scale working is attempted. Nevertheless, anyone who discovers a method or reaction capable of extracting valuable material would have a reasonable chance of support, provided the demand for the material in question were regarded as sufficiently great to warrant expenditure on development.

Perhaps the most important point to remember in all work of this kind is that natural products are very various and variable. It is necessary, of course, to experiment with artificial mixtures, indeed it is better to simplify conditions at first by doing so. But every promising result with these should be immediately compared with that obtained with the natural product.

Chemical experimenting with a view to finding materials or compositions of everyday use has one attraction : if success is obtained, a small business can be founded without any capital worth mentioning. But let the novice be under no illusions as to the profits to be obtained. It is true that cosmetics, for instance, cost far less than the bottles or packages in which they are contained, but they are nevertheless by no means so profitable as it would appear, for the costs of advertising and selling are enormous. The public is hopelessly and incurably suggestible, and only the poorest will buy what are regarded as cheap and nasty imita-

tions of proprietary articles, but are really the same things exactly, often made by the same manufacturer; for the owners of proprietaries rarely manufacture anything like their whole output, if they manufacture at all. But a composition as good as plastic wood, for instance, but much cheaper, would be readily saleable.

In no field of work is it more needful to study the literature of the subject than in chemistry. Though a great deal of translation has been done, it still remains almost essential for the student to read German works in the original. In spite of the slump, or perhaps on account of the increased and enforced leisure which it affords to technical men, prodigious tomes continue to pour out of the German press, unfortunately at prices which, in view of the depreciation of sterling, make their acquisition by the English technical man, afflicted with leisure to read them, very painful. But they afford a source of detailed and exact information, especially in the more empirical industries, which simply does not exist in English. In many branches of work we are so far behind, that an English translation of a German work costing £2 or £3, and produced by its publishers for profit, could hardly hope to sell a hundred copies.

CHAPTER VIII

ELECTRICAL INVENTION

THIS field of invention is one of the most difficult of all in which to achieve success, while at the same time it is one of the most tempting. It exemplifies most perfectly all the principles and dogmas committed to paper in this book.

First of all it demands natural aptitude to grasp the fundamental electrical principles. Since wireless became popular, many thousands of persons have given proof of a natural aptitude for dealing with very difficult electrical matters, while remaining completely ignorant of formal theory. They seem to have got the hang of the matter instinctively. Conversely, innumerable persons have made electrical work their career, from the early days onwards, without ever really grasping what it is all about. Such minds are to be found even among teachers of electrical engineering, and they are very common indeed among wiremen and wireless men.

The last generation of such persons got along quite well by the use of mechanical and hydrostatic analogies ; everyone used to read Lodge's *Modern Views of Electricity*, in which electrical phenomena were ' explained ' in terms of racks and pinions and all kinds of mechanical contrivances. But although we find this method of

mechanical analogy pursued in many popular books on wireless, we do not find it in the minds of the clever youngsters who build experimental sets and go in for short-wave reception. On the contrary, the modern tendency is to translate difficult mechanical problems into more familiar electrical analogies, as in the case of the mechanical gramophone and the Constantinesco torque-converter.

Electrical theory is, however, many-sided, and few people have an instinctive grasp of it in every direction. Also it is now inextricably mixed up with atomic physics and chemistry, for these matters enter into the theory of dielectrics as well as into all the means by which light is produced electrically. At present, electrochemistry is much more electrical than chemical as regards its main practice. Developments are evidently pending, particularly in the field of photochemistry, which will involve the application of some of the most recondite questions of electrical theory to practical problems.

Since the materials for electrical experimenting are now purchasable at almost every street corner, there must be an enormous amount of experimenting actually in progress. Every now and then one sees, or hears about, the most absurd devices which are being tried at the expenditure of much time and money. Experience shows that really new and valuable inventions, however seemingly simple, continue as before, in this field as in all others, to come almost exclusively from a few experimenters. Take for example Mr. S. G. Brown's microphone pickup, and also his high-tension supply from low-tension batteries. Both these inventions are simple in principle, and have long been attempted by

innumerable experimenters of less ingenuity than Mr. Brown. The early history of electricity is most instructive in this connection. After Volta's discovery, which enabled anyone to experiment with electric currents, at the cost of a few shillings, and created an enormous stir in the intellectual world of the time, a prodigious number of people set about experimenting with them, particularly persons of education, wealth, and leisure—yet the fundamental laws of electro-chemistry, electromagnetism, and electro-optics, were all discovered by a very few people, Faraday first and foremost, and long after Volta's publication.

Nevertheless it is certain that there are many more persons possessed of a naturally electrical mind than there are such properly trained. One is often pained to see how a young wireless fan, with the most astonishing natural aptitude for thinking (or rather feeling) in electrical terms, is far too lazy to study his subject properly and develop his natural gift. Usually mathematics is the bogy; he has been subjected at school to the slavery of learning to 'do examples', and the subject is henceforth so unpalatable that he never succeeds in learning the elements of electrical theory.

The question whether it is worth while for any physicist or technologist to work at mathematics against his own inclination is much debated. It is of course quite true that original work is never (or hardly ever) done mathematically. Gauss and Einstein certainly sensed instinctively the physical reality, and used mathematics only to prove the result. The same is certainly true of most physical investigation, whether in pure science or technical work. On the other hand,

one finds that the non-mathematical are frequently liable to harbour a plausible fallacy for a time. The writer is of this type of mind, and is capable of entertaining a completely fallacious idea for a considerable time, until an uneasy conviction begins to steal over him that all is not well, and he sets to work laboriously to work it out mathematically, when the ' nigger in the woodpile ' soon shows his black face.

On the other hand, one often finds that mathematically-minded people exhibit great reluctance to entertain strange ideas. They seem to feel that there is really no point in imagining things, when there is something so definite as mathematics to serve as a guide. The greatest minds, for example Kelvin or Einstein, are able to use mathematics with more or less ease, as a tool to keep check as they go along with their physical thinking.

The essence of the matter is perhaps as follows. Every mathematical formula is simply a shorthand way of stating a physical reality ; in the present connection, we may take the dielectric constant and the way in which it enters into the formulae for all kinds of electrical phenomena. Merely to twist and turn these formulae about will result in nothing more than we know already ; on the other hand, to think about electrical phenomena without knowing the rôle played by the dielectric constant is sheer waste of time. The formulae state the exact relevance of this constant, but this relevance must be appreciated physically, and not as a matter of symbols upon paper. Not less important than the actual mathematical formulation of such an electric constant is its practical range of values. We have a classic instance in Edison's mistake concerning

diamagnetism. He rightly grasped the fact that a diamagnetic body is less permeable to magnetic lines of force than air, but he did not realise that the difference between the permeability of diamagnetic substances and that of air is negligibly small from a practical point of view, when it is a question of reducing magnetic leakage.

We may say that no student can gain a proper comprehension of electrical theory without some mathematical training, and that this training should be of a fundamental character, as opposed to learning formulae and practical devices which are so helpful in standard technical design, but extremely misleading when it comes to original work, for the reason that they are over-simplified.

In no field of technical invention do we find a greater gap between the knowledge acquired by pure scientific investigation and the degree to which that knowledge is applied in practice. As regards by far the greater part of modern electrical practice, the student might be content to acquire his theoretical knowledge from books thirty years old. All the knowledge acquired in the last thirty years has resulted in little more in the field of invention than the photo-electric cell, the triode valve, and one or two other minor applications. Indeed, the instances that have just been given only demand an elementary knowledge of electron phenomena, which were really known thirty years ago. X-ray spectroscopy, and quite recently electron diffraction, which are fairly recent discoveries, are being applied to the technical examination of materials, but this application hardly involves invention in the ordinary sense, and is merely the use of newly discovered

physical phenomena to guide the technologist in his examination of special materials.

A great deal of modern technical progress in electricity has depended upon empirical work, such as the discovery and utilisation of magnetic alloys and new forms of dielectric. As regards the latter, the cable industry is a supreme example of progress almost entirely of an empirical character. There is still a great deal of room for this kind of work, and the gradual development of suitable materials drawn from all branches of industry will certainly result in surprising developments as time goes on. A great deal of the progress in the production of cheap wireless components has been due to patient experimenting of this kind, but it is a very difficult matter for the independent inventor to produce anything of value in this field, since the use of various materials in mass production depends upon the production of these materials themselves in a form fully satisfactory on a very large scale.

Another example of empirical progress in electrical work is the automatic telephone, which depends for its success not only on a very great deal of ingenuity in the construction of circuits, but still more upon what has been found out by practical experience concerning such simple things as contacts. In theory almost anything can be done by means of electromagnets and suitable contacts, but practical experience of a disastrous description led to such devices being looked upon with the gravest suspicion by all designers. Take for instance the case where it is required to use the indication of a delicate instrument to operate automatic apparatus. One might suppose that so simple a problem, which is at least fifty years old, would either have found the best

possible solution, or at anyrate have been explored so thoroughly that we should now know all about it. So far from this being the case, we find that innumerable types of apparatus of this kind exist, greatly differing in design, while electricity finds a successful competitor in compressed air, whereby all the troubles incidental to make-and-break contacts are avoided. Every practical designer has his own set of recipes, even to-day. One often hears the opinion expressed, or did so until quite recently, that any apparatus involving a few contacts, relays, and similar electrical gadgets is inherently unreliable.

But in the meantime the automatic telephone has started upon a triumphant world career, and it is a perfectly appalling mass of these very devices : but it works. The reason is simple—design. In the past, inventors of such mechanisms have ignored, as a rule, all but the most obvious factors. Rubbing contacts, with as much power behind them as possible, and magnets with as much power as possible consistent with keeping down the operating current ; such was the epitome of design. Questions of the inertia of parts, the time-factor of the magnet, the electrical constants of the circuit, the correct proportioning of condensers to eliminate sparking, were all ignored. Likewise, very often, such elementary matters as insulation, and protection of coils and contacts from dust and moisture.

What can be done in this respect may be seen from an instrument which I recently saw at the Cavendish Laboratory in Cambridge, for relaying an α-ray counter. All the classical work on the disintegration of the atom necessitated the counting of the scintillations produced on a fluorescent screen by α-particles and other charged

atoms in fast movement. This work was extremely laborious and by no means devoid of risk, for the accompanying gamma-radiation might affect the eye. But the new apparatus ticks over a common meter counter every time an alpha-particle enters the chamber of the apparatus. Even the inconceivably minute energies of the so-called ' cosmic radiation ' may be relayed in this way. This device depends for its action on the thyratron tube, in which an arc carrying a considerable current is started by a minute electrical impulse applied to the grid.[1]

At present, wireless and television occupy by far the largest share of public attention. Here, as elsewhere, we are amazed at the relative infertility of the big firms, which have allowed such men as E. K. Cole and J. A. Baird to score heavily by producing workable apparatus which, however ingenious and important, involved no new fundamental principles or discoveries, but demanded the creative personality, working at fever heat, to bring it into being. Plenty of opportunity remains for the individual worker. For instance, where is the wireless set so designed that the layman can detect the common causes of failure by following implicitly a simple routine of tests, and so tell whether he needs a new battery, whether a valve has gone, or what else ? The problem of making gramophone records at home is tantalisingly near solution, but not yet solved. Nor is that of a simple, brilliant, easily modulated lamp for television reception.

There is an enormous field for invention in the application to new purposes of the newest electrical

[1] See Ward, Wynn Williams, and Cave, *Proc. Roy. Soc.* A, **125**, 173 (1929).

devices. The electron tube of all kinds, the photo-electric and selenium cell, the high capacity condenser, all these and numerous other new pieces of apparatus are available for the solution of problems of all kinds. The possibilities inherent in the time-synchronised supply network have certainly not been yet realised. It opens fresh prospects for recording instruments, and when someone turns up possessed of the foresight and energy which have popularised the cash register, a money-saver, recording instruments will be popularised as time-savers. It is quite astonishing that the average employer is content to pay a handsome sum for an instrument to record the times of arrival and departure of his employees, but rarely invests in apparatus which records what they do when they are on his premises, and when they do it. I refer to such matters as starting and stopping machines, opening certain doors, even sitting in certain chairs, and so on.

An example of an extremely neat and most valuable application of modern devices is Mr. Alan Stevenson's method of signalling to ships their distance from a lighthouse or lightship. It is an invention of an encouraging type ; one that shows what can be done by creative thinking, without any experimenting at all. A gramophone record is made with a certain sound, such as the blast of a horn, followed by the words one, two, three, and so on, at intervals equal to the time taken by sound to travel one, two, three, etc., miles in air or water. The record is used to feed a transmitting aerial, the sound of the horn being also fed to a loud-speaker or hydrophone transmitter at the signal station. The ship receives the sound instantly via wireless, and the following numeral words. Later, the sound reaches it

via air or water, and chimes in on the series of numbers coming in by wireless. These tell the listener at once the distance away of the transmitting station. Small corrections for variations in the velocity of sound with temperature can obviously be made by adjusting the speed of the gramophone record.

The coming boom in modern 'functional' architecture and interior decoration will be sufficient to ensure that very great advances are made in the utilisation of electric lighting. In this respect, as in so many others, we are at present some ten to twenty years behind the more civilised countries, but it is quite likely that, once we have grasped the point, we shall still find many outlets for ingenuity left to us. The great diversity of form of electric lighting to-day, its fussy and messy character, tell us that there is room for invention. It is not at all impossible that inventions of first class importance still remain to be made by the simple combination of the laws of reflection, refraction, emission, and so on. We need only recollect some recent successes, such as the use of a mirror to reflect light from the sky through a sign on a van, and the illumination of the edge of a sheet of plate glass, upon which letters and designs are sand-blasted.

One of the most attractive possibilities in this field is the construction of an artificial Riviera. Tentative efforts have already been made, but no one has yet ventured to do the job really well. Yet it is well within the scope of present methods. The sky can be perfectly imitated by the device, common in foreign theatres during the last twenty years, and now actually used in one or two theatres in this country, of a white dome lit by blue light. The illusion when standing

under it is perfect. A powerful arc provides light and heat radiation, with a sufficiency of actinic rays to produce a healthy tan. Modern methods of ventilation would allow of perfect freshness of the air, even if a swimming pool were included. A rich man might defy all the horrors of the London winter in such a dwelling.

Electrochemistry, once as much in the news as television is to-day, has almost ceased to progress, either theoretically or practically, until recently, when the development of atomic physics and the quantum theory led to new advances on the purely scientific side. These are worth the attention of practical men. The performances of electrochemistry, vast industries though they be, do not yet equal its promises. Apart from alkali manufacture, copper refining, and aluminium production, it plays only a small part in modern chemical methods. It is a common remark that what can be done elegantly by an electrochemical method, can generally be done more cheaply, if less elegantly, by a purely chemical method. Some promising large-scale processes, such as the fixation of nitrogen and the sterilisation of water by ozone or ultra-violet light, have been worked for a time, but are now dropped. Synthetic gas reactions (fixation of nitrogen, production of organic compounds from CO, CO_2, CH_4, etc.) are being effected by catalysis, though the silent discharge is known to bring about some remarkable effects; only ozone is at present being made, for certain organic oxidations, by electricity.

The great hope of electrochemistry, the finding of a universally useful process to absorb the output of central electricity stations in times of low load, has failed to mature. The primary cell consuming carbon

or water-gas seems farther than ever from practical politics. It is possible that the coming introduction of compressed gases for driving motor vehicles, rendered possible by the production of very light steel vessels, might allow of the use of pure oxygen and hydrogen, generated electrolytically under pressure. The necessary data are not available to me to calculate this suggestion. The complete absence of all noxious fumes (apart from those possibly due to the lubricant) would be an advantage. We shall return to the matter in a later chapter.

There is still room in electrochemistry for an inspired empiricism. The recent discovery of the copper oxide rectifier, and the still more recent discovery of its photoelectric properties, is a reminder of this. Already a tiny electric motor has been driven by sunlight falling on a cell about $\frac{1}{10}$ of a square inch in area. But at this rate, one of 1000 square yards would be needed to deliver a kilowatt. The only practical result so far is a photometer, which is applicable in photography as an exposure meter. The exposure is indicated by the deflection of a moving-coil instrument.

At one time great hopes arose in respect of certain photochemical reactions taking place in aqueous solution. Cells can be constructed which deliver a current the energy of which is derived from a reaction taking place between two constituents of the electrolyte, and this reaction is then reversed in direction by the exposure of the electrolyte to strong sunlight. But the output of energy is small compared with the bulk of the apparatus, and the matter is now regarded as hopeless.

Electrical discovery in pure science is far from

having come to an end; the phenomenon of 'superconductivity', for instance, came as a complete surprise. Before its discovery, any novelist daring to suggest the possibility of a conductor of zero resistance would have been laughed at by serious men of science.

The chief demand made upon the experimenter in electrical work is for a clear grasp of the interplay of complicated, non-material factors. L. B. Turner, in the preface to his new work *Wireless*, puts this matter (as well as the matters dealt with in the body of the work) in a way which can hardly be bettered: "The effects dealt with in electrical engineering—unlike mechanical—are remote from the sense-perceptions of ordinary daily life. The student can acquire the power of visualisation, and that sense of the naturalness of the phenomena he meets which is a prerequisite of engineering efficiency, only by supplementing his theoretical studies with much experimental exercise in the laboratory or elsewhere. Particularly in high-frequency work does a lack of prolonged practical experience make itself apparent. Proficiency with mathematical equations and circuit diagrams is indispensable, but is not sufficient to make the student effective as an engineer. He must manipulate the things whose idealised qualities are portrayed in the circuit diagrams; and often a rather long apprenticeship proves necessary."

To this we may add that here, as elsewhere, intensive imaginative thinking must precede drawing, sketching, and calculating. However complicated an apparatus may be, the constructor should be so familiar with it from the start as never to need to refer to a diagram.

CHAPTER IX

PSYCHOLOGICAL INVENTIONS

THERE is a psychological element in very many successful inventions; indeed such an element is only absent in the case where an invention does no more than fulfil an existing objective need. If a certain type of gear wears out rapidly, or functions in some other respect unsatisfactorily, a new type having better characteristics will sooner or later be adopted, the only psychological element then coming into play being natural conservatism. But in many other cases, the psychological element is predominant in the success of an invention. It may, in itself, be almost devoid of ingenuity, and may even be difficult to prove to exist at all. The whole merit will then lie in the recognition by the inventor of a potential need, one, generally speaking, not consciously felt. Conversely, much inventive ingenuity is wasted owing to complete misconception as to a practical need.

It is amusing to recall that one of Edison's very earliest inventions was a device by which assemblies such as Congress could record a vote without a member moving from his place. Any competent electrician today could fit up a meeting-hall in this manner, at the cost of a few pounds. Each member would have on his desk two buttons, one marked 'aye' (or preferably

'yes'; cabinet ministers would have a large one with 'in the affirmative') and the other 'nay' or 'no'. When a vote was taken each member, if he desired to do so, would express his opinion by holding down one or other of the knobs. His mouth, legs, and one hand would be free for the purposes of emotional expression.

Edison soon discovered, in fact was told by a Congressman in emphatic language, that the object of Congress was not to get through business quickly but to waste time, and that every Congressman would regard him as an enemy of the State, or at any rate of democracy, if he succeeded in introducing such a device. In the same way, if the only use for broadcasting were to broadcast the deliberations of legislative assemblies, it would nowhere in the world be used at all, although the fathers of democratic government would have regarded its invention as heaven-sent, in order to allow the people to take an intimate interest in their chosen representatives.

A typical case in which psychology plays a large part is that of system; systems for dealing with business accounts, cost-keeping, store-keeping in factories, filing, indexing, and so forth. The invention of double-entry book-keeping has been regarded by many authorities as one of the most important ever made in human history, though it would, I should say, be impossible to protect it under any existing patent or copyright laws. The same is true of the card-index, also a major invention.

Invention of this type has recently grown greatly in importance. Life becomes more and more complicated. The object of system is to compel persons to act correctly who would be otherwise too stupid, forgetful,

or inattentive to do so ; and furthermore, to save labour so that the work may be done not only by a less capable type of person, but also by fewer such.

Indeed, modern system will necessarily draw more and more persons into its net, as life becomes more complicated, and even the best memory ceases to suffice for daily needs. For those who are adaptable, system represents an actual economy of energy. On the other hand, it may very easily be abused, and become actually more trouble to carry out than would be doing the work without any system at all. This fact needs emphasising the more, as system is now a subject of high-pressure salesmanship. Not a few small businesses are being choked by it.

The mechanical aids to system have formed a large field for inventive activity in recent times, and there is still a great need for further advance. At present the growth of system is outstripping the progress of invention. For instance, who has not struggled uncomfortably with a telephone directory at an automatic public call-box ? We have made no advance since the invention of paper in our methods of keeping a register of names for ready reference, and yet we turn from this almost prehistoric contrivance, when we have finally found our number, to an automatic telephone which is a miracle of modern invention. The solution of this problem is simply waiting for development ; the pages should be photographed in a minute form upon a strip of film, which would pass in front of a projection system throwing an enlarged image upon a screen. By pressing a suitable button the required section would appear.

Not nearly enough use is made of photography in

modern business and technical work. The photostat should be in every office. The use of a photostat employing cinema film would enable documents to be copied accurately and instantaneously, the copies taking up a minimum of room, and being easily projected when need arose to refer to them.

Generally speaking, every small or great interruption to the smooth and effortless conduct of business or life generally, due to psychological causes such as negligence, forgetfulness, want of interest, fraud, and similar human weaknesses, offers a direct incentive to the inventor. Often the ingenuity required is not in the physical construction. The means already exist. The use, for instance, of transparent containers for household stores, so that lowness or absence of stock is seen at a glance ; the construction of reminder boards with sliding indexes—these and a few similar and very obvious notions, combined into ' kitchen cabinets ', are now bringing in very respectable revenues to quite a few firms to-day. On the other hand, it is in this field that success is most difficult to attain. Ever since kettles have existed, they have boiled over and caused mess and annoyance. I have no doubt that some hundreds of persons, in the course of history, have fitted a whistle to a kettle, in the sure and certain hope of immortality as benefactors of humanity. Yet we find to-day that the demand for kettles fitted with whistles is comparatively small, although their price is negligibly greater than that of ordinary kettles. Anyone with a craving to invent household gadgets could not do better than thoroughly investigate the psychology of this matter. I cannot say that my own efforts in this direction have met with great success ; it would appear, however, that

women dislike the brutal and imperative nature of the kettle's protest.

We cannot afford to neglect the fact, so ably expressed in Butler's *Erewhon*, that machines are coming perilously near to being our masters instead of our slaves; indeed, that they are so for a very large number of persons in subordinate positions to-day. There is certainly on the part of the working class a deep resentment against this fact, and it may well be that the housewife's anger at the shriek of the kettle is fundamentally based on the feeling that it is undignified for a human being to be the slave of a machine. When recording instruments are used in a works, it seems somehow derogatory to human dignity that little boxes all over the place should be patiently and relentlessly spying on everyone's doings and writing down their observations. A bullying and ubiquitous foreman would at least be human.

This psychological objection is naturally present also in the mind of the management, which even in these days when relentlessness is often a *sine qua non* of control, still feels that a display of trust towards employees may actually create a spirit favourable to efficiency.

For this reason perhaps, the eavesdropping microphone and automatic camera, both of which could be used with great effect, are very slow in being adopted. But I feel sure that they will nevertheless make their way into practical life, especially if we move in the direction of communistic government. It is obvious that, to suppress private enterprise, you must suppress privacy.

It is particularly in the field of everyday utilities

that the psychological element is of the greatest importance. There are certain general matters which should be borne in mind in this connection. First of all, the gradual education of the public in the use of mechanical and electrical contrivances is making great headway, but it should not be over-estimated. Also, the multiplication of gadgets, no matter how efficient or simple to operate, is very soon resented. They need to be kept clean, and stored, and if they are only of service for certain operations which do not occur very frequently, their sale will be limited. At any exhibition, we see every year a great variety of admirable devices, which nevertheless only find their way into comparatively few households. For instance, egg-beaters, mincers, and other special cooking devices, which have a limited utility, also have a limited sale, while their manufacture at an attractive price is impossible unless their sale is very large. The inventor is rarely inclined to allow for the enormous cost of explaining to the public a new device, however useful. While in technical life, a really valuable invention will slowly but surely make its own way, in the household market no device has any chance unless it is supported by extensive advertising, or sales-pushing in some form or another.

When our social politicians talk about the way in which production has outstripped consumption, they always neglect this factor of selling cost. Nowadays, in order to sell even a very useful article to the public, the retail price must be four or five times the manufacturing cost, if a moderate return is to be gained. The difference is expended in distributing and selling costs, and it is thus obvious, since most of this cost eventually goes in labour, that the majority of the

population must be engaged in forcing one another to buy what a minority is making from the raw material. The minority of real producers is usually so badly rewarded that its purchasing power is very small.

Actually the great majority of the population, if left to themselves and supplied with food, clothing, and shelter, in return for exertion equal to the actual cost of these necessaries, would simply vegetate. In order to make them use even the few appliances used to-day for the purpose of spending their leisure and making their homes comfortable, a stupendous psychological effort is necessary. An American defined business as the art of making a man buy something he doesn't want at a price that he can't afford, but this really overlooks the fact that advertising creates the want by sheer study of the psychology of buyers. In an actual instance, an exceedingly useful appliance for woman's use was advertised first on a half-page of a home journal. The result was that the profit just covered expenses. Then a quarter page was taken at exactly half the price before paid, with the result that the sale was exactly halved. Since the explanatory matter was identical in the two cases, the difference in effect was not due to the virtue or otherwise of the article, but simply to the fact that the so-called minds of the readers were more impressed by the larger advertisement. When the advertisement was finally reduced to one-eighth of a page the sales were not quite halved, and so a small profit resulted.

Every inventor should study a book from the list given in the bibliography on the art of advertising. The inventor is always liable to over-estimate the logical attitude of the public towards its purchases; he has to learn that selling, while it must have a certain

basis in reality, is almost entirely a matter of sheer hypnotism. The inventor is also in the position of a salesman himself, and must first convince a number of people that they will be able to sell his invention to the public. Convincing these people is itself a psychological art.

A very important point to-day is the question of trouble and attention required for the use of domestic inventions and gadgets. The slow progress of the vacuum-cleaner is largely due to this; while it is of course infinitely less labour and trouble to use than a broom, it requires a certain amount of care in its storage, and a certain attention in starting it up, emptying the dust out, and so on. The inventor, by nature inclined to approach every technical device with interest, and to enjoy its use, and being also of a positive and energetic type of mind, usually underestimates the mental apathy of the general public, which finds even the simplest operation a trouble to perform, unless it has been taught the operation in childhood and so can perform it more or less automatically. It is a good rule, therefore, to bear in mind when there is a choice in the design of a certain gadget, that the manipulations required should be such as are familiar to the public. For instance, it would be much better to use a tumbler switch than any other kind of switch on an electrical device, simply because everybody is familiar with it in this country.

In the field of domestic invention, ingenuity is particularly misplaced, since it leads inevitably to unfamiliar forms. The very quality which makes them so attractive to the technical man makes them repulsive to the public at large.

In this field we must recollect that there are two chief remunerative markets, the very low price and the luxury market. It is a positive disadvantage for an article to have a medium price. The highly priced article must of course be manufactured in such a way as to justify by its durability, finish, and good working the high price charged for it, but often the profit will nevertheless be much greater on a limited sale than if the attempt is made to produce a popular article at a low price, which nevertheless does not leave the margin necessary for advertising. The highly priced article can always be sold by good salesmanship, if it really has any kind of value, and the investment necessary to market it is very much smaller. In such things as vacuum-cleaners, home cinematographs, water-softeners, and refrigerators, the highly priced articles are probably much more profitable than the so-called popular lines. It is needless to say that the psychological element enters greatly into the detail of the design. It would certainly pay, in designing an expensive vacuum-cleaner or refrigerator, to keep in mind the lines of the most luxurious motor-cars.

A field of invention essentially psychological is that of games. It is one in which enormous fortunes have been made, but it is extremely doubtful whether there is more in this than the play of pure chance. Various kinds of puzzles and such things as diabolo have brought fortunes to their inventors, but this has been due to the happy chance of a society craze, and equally ingenious and meritorious ideas have failed completely to attract favour. On the other hand, the so-called craze for Yo-Yo, a very ancient device, has been brought about solely by ingenious and determined adver-

tising. It is instructive to note that the correct method of advertising is to say that everyone already *has* the craze, whereupon fiction becomes truth in a night. It is an amazing revelation of popular mentality to those whose minds retain an element of self-determination.

These remarks do not apply to the design of toys for children, and while the Germans have been most successful in this field, and may seem to have exhausted the possibilities of cheap and attractive manufacture, it might nevertheless be worth while considering whether some of the more recent manufacturing processes do not offer new possibilities. One of these is seen in the production of balls from spongy rubber; and the new moulding processes, now being applied to table ware and ornamental objects generally, might perhaps offer entirely new possibilities in the design of toys. The enormous success of Meccano, which owes its inception almost to an accident, shows us that this field is always open to new ideas. Meccano arose out of the fact that a manufacturer of small stamped parts gave his children the strip from which the parts had been stamped to play with together with some small nuts and bolts.

Mechanical toys are the oldest of all forms of mechanical invention, and were certainly known in the East long before the serious possibilities of mechanism had dawned on the human mind. It is difficult to tell how much is fable and how much is true, in the stories of mechanical birds and so forth which we find in the *Arabian Nights* and other Eastern books. In our own civilisation, elaborate mechanical clocks with striking figures were built in the fourteenth century, and of course have been developed ever since.

This field was enormously expanded by the development of coin-freed mechanism, and now there is plenty of scope for the invention of amusing devices operated by coins. No better instance of a psychological invention could be found than in the absurd and amusing fortune-telling machine recently to be seen all over London. A generous view of all sorts of weird devices (at least, so they appear to the non-technical) is afforded by a window, and when a penny is dropped in the slot a tremendous clatter and flashing of lights occurs. Conspicuous is a fountain pen running to and fro on a guide between a series of electromagnets. This oscillates to and fro at right angles to its movement as if writing vigorously, guided by an unseen hand, but the nib is invisible. In a few moments a card drops out with your ' fortune ' in imitation handwriting. If one of the chief goals of all human endeavour is to produce a sense of pleasure and well-being, the inventor of this entirely futile and absurd contrivance, which produces a state of absorbed and amused enthralment in four or five spectators for about half a minute, at the cost of a penny, is a person at whom no one has the right to point the finger of scorn. In all probability he is socially a more valuable man than his next-door neighbour.

Another very important class of psychological invention is that of musical instruments. Here the sole criterion of success or otherwise is the production of pleasant sound, and at present we have no means of foretelling whether a certain quality of sound will be regarded as pleasant or otherwise. The saxophone,[1]

[1] Of which it was said, " A cow makes as good a noise, and gives milk as well ".

for instance, the sound of which is now regarded by the majority as agreeable, and by a minority as hideous, is a very old invention, dating back to about 1850. The Stroh-violin, which has great power, has never been produced in a quality which has allowed it to rank as a first-class instrument in the orchestra. It is certainly remarkable that no instrument has yet been produced, in which the sound is emitted by strings or wires as in the harp or piano, but having these excited, not by a blow, but by some means which would cause them to emit a pure sound such as that given by the bowed string of a violin. No doubt very many efforts have been made in this direction, but it still seems very likely that some day a successful method of exciting vibration will be found, and that an instrument will be produced combining the qualities of reed instruments such as the accordion, with the superior musical quality given by strings. In this connection it should not be forgotten that the modern methods of amplifying sound are certainly applicable to musical instruments, though to hear the average wireless set one would not suppose this to be the case. Existing first-class equipment is capable of giving results entirely free from all the defects of loud speakers of the ordinary type, and it seems exceedingly likely that effects fully equal to those of the grand organ or grand piano will be obtained with very much smaller and less costly keyed instruments coupled with suitable amplifiers.

A very important class of invention into which the psychological element enters is that concerned with our physical and bodily comfort. In the domain of clothing and furniture, outstanding advances have been made in recent times, such as the various types of

fasteners for clothing (press-button, zipper), and in furniture the various types of arm-chairs, beds, toilet appliances, and so on.

We might class noise-reducing apparatus in this category, but here there is no element of psychological insight required as regards the problem; we are all supposed to be agreed about it. But in this field a very serious difficulty arises. An old story tells of a man who was so annoyed by his neighbour's dog barking that, finding all remonstrance in vain, he bought it, with the intention of having it destroyed. A few days after, its original owner complained bitterly of the noise the dog was making in its new home, while the new owner expressed himself entirely unaware of any disturbance at all.

One of the largest firms of compressed air percussion drill makers has taken up the manufacture of a silencer, which reduces the noise by 85 per cent. But it costs about five pounds, hence the public must continue to endure agonies when streets are repaired, because those who would have to pay for the silencer do not hear the noise. This factor, more than any other, is responsible for the fact that so little advance is made in combating noise in modern life. Perhaps the only way in which something could be done would be by the wide use of a standard noisemeter, by an entirely independent authority. There must be enough highly nervous persons to whom noise is a torture, to allow of a society being formed to measure and certify noise. This society would set up and seal a self-recording noisemeter wherever desired, and would then furnish a certificate showing the results of the test.

There would be a great eagerness on the part of

landlords of good class houses and flats to secure favourable certificates, and they would then find it worth while to spend money in efforts to keep general noise down, and in harrying by every possible means all disturbance of quiet. In opposing the establishment of noise-making institutions in a given neighbourhood, its existing noise figure could be quoted, and the actual financial loss due to increased noise could be estimated on the basis of experience.

Another important category of psychological invention is that of safety devices. At the present time there is a great deal of discussion concerning the enormous number of accidents occurring on the public highways. This problem is very largely psychological, and it is not improbable that it will be dealt with finally by means as yet uninvented, which will be based upon a careful consideration of the psychological causes of street accidents. It is obvious, for instance, that the motor horn is quite inadequate as a warning in crowded streets. Here one of the commonest causes of accident is sheer absence of mind or distraction of attention. A person, perhaps parting from another in an emotional mood, turns suddenly and plunges into the road. Or, a person walking along the pavement, deep in thought, suddenly looks up to see the bus he wants on the other side of the road, and dives across after it. Short of fencing the curb, how are such accidents to be prevented ?

Accidents in factories also need to be considered from the psychological point of view, whereas the factory inspector is apt to consider only physical preventatives. Directly these inconvenience the work in any way, they are liable to be abolished on the sly.

Another field of invention into which psychology

enters is that of all matters concerning personal appearance. In so far as real and obvious improvement in good looks is produced, the psychological factor may otherwise be entirely disregarded, though of course people will suffer anything to improve their personal appearance. If a hair-dye or a complexion improver produced decidedly better results than those existing, it would be rapidly adopted, no matter what discomfort attended its use ; indeed, the permanent waving of hair which is making small fortunes for a considerable number of people, is a very uncomfortable proceeding for the victim. Anyone who invented a cure for baldness would have within his grasp an enormous fortune, even if the cure involved agonies in its application.

In this field of commerce, at present, the procedure for successful money-making is simple. The actual cosmetics can be obtained wholesale at a trifling cost, perhaps one-twentieth of their retail price. A good and striking design for all packing and advertising matter is worth money, and will not be secured without it. The whole available money to be risked and the whole available ingenuity must be put into selling. It is useless to attempt to compete with others by underselling ; lowering the price does not increase the sale. As in the case of the anthracite briquettes referred to in an earlier chapter, the public believe that the cheaper article is inferior to the dearer.

Advertising offers a large field for invention, though much of it lies outside the beneficent shield of the Patent and Copyright law. It offers peculiar scope for the ingenious, quick, and adaptable technician. It is obvious that every advertising device is the more effective, the newer it is ; its effect wears off steadily as it becomes

more familiar. We must assume that electric sky signs still earn their keep, but they have of course cheapened greatly as their manufacture has developed.

At the moment, moving devices for shop-windows are on the increase ; at present they are of extreme crudity in design, and hardly seem to be improving. They attract only one type of person, who cannot see anything mechanical without stopping to stare at it. I feel that much more could be done by means of motion to produce aesthetically pleasing effects which would cause a majority to linger, and so inevitably see the displayed goods.

The use of films for advertising is making little headway. This is due to the fact that ordinary projector mechanism wears films out very rapidly. We have already referred to the fact that projectors with a steady motion of the film increase the life by about ten times. This, coupled with simple gear for endless repetition, will sooner or later make film advertising especially on daylight screens, of very great importance. As I write, the Thorne Baker colour film, a very great advance, has been demonstrated ; if more firms existed in this country with the courage and enterprise of Messrs. Spicer, who are responsible for financing this invention, the industrial outlook for England would be brighter.

The police do not regard film-showing in shop windows very favourably at present, but on the other hand, the modern notion of shop construction is to have inside window space directly accessible from the pavement. The endless repetition of a good colour film would be a means of advertising far exceeding in effectiveness anything at present in existence.

Since this book is concerned only with technical invention, this chapter is one of comparatively minor importance. But it is impossible to leave the subject without pointing out that invention of a psychological character has played, and is playing, a most important part in the history of humanity. It is hardly possible for us to realise what an immense change has been brought about by the invention of methods of governing the masses and influencing their minds in a desired manner. The whole technique of modern bureaucracy has been built up upon the invention of printing on the one hand and, on the other, upon the addition of persuasion to compulsion. There are many people who think that this technique is overreaching itself, and producing a complication which is leading to the process known as a vicious circle. We see this particularly in taxation, where the very facility with which schedules and classes and forms can be multiplied leads to a counter-offensive of the same type on the part of the taxed. To the technologist, the whole machinery of modern government has the characteristic Heath Robinson look, the stamp of mild lunacy. A construction designed with quite other objects in view—those of the mediaeval monarchy—has been made to function in the modern industrial era by the continual addition of gadgets and dodges, each designed only to deal with some particular trouble, and not to improve the function of the whole. This is a fair description of modern social legislation for the last hundred years or so. We are suffering to-day from the appalling results of trying to make a jumble of unrelated devices perform work for which a well-designed and far simpler machine is necessary. Probably the whole affair is now beyond

the possibility of reform, and the next stage will be that well known to the engineer in such cases, in which the entirely unsatisfactory functioning of the machine disheartens everyone connected with it, and so leads to it being worked with less and less efficiency—if that word ever had any application in this connection.

Chapter X

INVENTION AND THE TRANSFORMATION OF ENERGY

It is a commonplace familiar to every newspaper reader, that modern industrial civilisation has been founded upon inventions which have enabled man to make use of sources of energy which, for the most part, have lain unused until recent times. These sources of energy are at present two in number: firstly, carbon and hydrocarbon, stored in the earth as the remains of living organisms which utilised in their formation the sun's energy—coal and oil, namely; and secondly, water-power, which is derived from the contemporary action of the sun in raising, by its heat, water above the level of the sea.

The latter form of energy, water-power, has been used from very early times, but until the time of Leonardo, when the possibilities of mechanism were realised, mankind was entirely ignorant of the potentialities contained in it. Even so, the development of the steam engine is largely due to the fact that water-power, as obtained from water-wheels of traditional construction, was quite inadequate to fully realise the possibilities embodied in early textile machinery, and was liable to disturbance by drought and frost. The horse-power even of the largest water-wheels rarely amounts to more than about 10 to 20, whereas we may place

the limit of horse-power of the reciprocating engine at about 8000, and that of the steam turbine at about 70,000, for single units. Modern water-turbines, of course, are also made in very large units, up to 90,000 H.P.

Not only the size of the units, but also the efficiency with which natural sources of power are utilised has been the subject of very great advance. That of the best piston engines to-day is about 17·5 per cent and that of steam turbines about 20 per cent. Internal combustion engines give much higher efficiencies than these; suction gas being about 25 per cent, engines working on blast-furnace gases about 27·5 per cent, while the Diesel engine has a maximum overall efficiency of 35 per cent, and it is claimed that the mercury-steam turbine will equal or exceed this.

To anyone ignorant of physics, the above figures at once suggest that a very large margin for invention and improvement exists in the case of these so-called prime movers. This is not the case, the efficiency being limited by the peculiar conditions under which a transformation of heat energy into mechanical work takes place. It is not within the scope of this book to discuss the problem; but the reader is strongly recommended, if he takes an interest in the matter at all, to turn to one of the works mentioned in the bibliography. It may, however, be said that the laws relating to the transformation of heat into work, the laws of thermodynamics as they are called, apply quite generally and quite independently of the means by which the transformation is accomplished. For instance, they apply to the generation of an electric current by thermo-electricity. An innumerable throng of inventors has

tried to evade them, and thermo-electricity has always offered great fascination, but it is exceedingly unlikely that this is anything but a blind alley.

The transformation of other forms of energy is not, of course, bound by these laws, and it is most unfortunate that we should as yet be unable to convert the chemical energy of coal and oil directly into electrical or mechanical energy, since no theoretical limitation to the efficiency of such conversion exists. As it is, we are obliged first to produce heat, which we can only utilise very inefficiently.

The development of heat engines of all kinds has been slow. The first reaction turbine was proposed by James Sadler in 1791, and the first impulse turbine by Bailey Jack of U.S.A. in 1792. A forerunner of the Curtis turbine was patented by John and Ezra Harthan in England in 1858. Parson's original patents ran out before his turbine was adopted on any extensive scale.

The reason for this slow progress is the fact that improvement in this field depends not only upon ingenious practical ideas and theoretical knowledge, but also upon the possibility of carrying them into effect by the use of contemporary tools and materials. Watt himself was bankrupted, together with his first financial supporter, for this reason; only when he moved to Birmingham and was able to obtain the necessary tools and materials to carry out his plans, did he succeed in producing practical engines. A modern steam turbine is the result of long, and often disastrous, experience, which has cost very dear to obtain, both as regards its materials and its execution.

In this field, therefore, there are many promising lines of development which are still awaiting such

advance in materials and methods of construction. The most obvious of these is the gas turbine or, more generally, the turbine operated directly by the products of combustion of the fuel. Turbines burning oil and gas have been successfully built, and it may be said that their only drawback is the fact that materials cannot be found of sufficient durability for use with them.

A very recent development illustrates the type of invention that is making for progress along such lines. Messrs. Brown-Boveri have taken up a suggestion put forward long ago by Prof. J. T. Nicholson, and have built a plant in which fuel and air are burnt under high pressure in a combustion chamber. The mixture is, as we have said, much too hot to be led direct to a turbine, so it is first cooled by being passed through a steam boiler, where it generates steam which operates a turbine. But this boiler is a very special kind of boiler, for the hot gases are rushing through it at a much higher velocity and pressure than in ordinary boilers. Now, another Englishman, Osborne Reynolds (we still have the creative thinkers, but there seems to be a falling-off in financial courage), long ago showed that the heat transfer from hot gases to water in a given boiler flue is proportional to the *weight* of gas of a given temperature passing through it per second. Hence the Brown-Boveri boiler generates steam at a much greater rate for its size than an ordinary boiler, since the gas is much denser and faster moving ; indeed, by using it you could tuck away the boilers for an existing plant along with the condensing plant.

Obviously you can reduce the temperature of the gases to any extent, and so take more or less power

from the gases. As a matter of fact, the gas turbine is fed with practically cold gases, and used to drive the air-compressor. The boiler can be delivered, for 10,000 KW., all ready erected for installation; it is more like a machine, in fact, than our ordinary notion of a boiler. The makers call it the 'Velox' boiler.

This plant exemplifies a general principle which should always be borne in mind. What is a disadvantage in the gas turbine, the high speed of the hot gases, is an advantage in the boiler. Combine the two, and you make the best of both worlds.

This is not the only example of such combinations. The Still engine, for instance, utilises the waste heat from the Diesel engine to generate steam, and a maximum overall efficiency of 45 per cent has been obtained. It is, however, necessary to run the Diesel engine at a higher temperature than is desirable, and this introduces great difficulties with lubrication. Lubrication is, in fact, as every motor-car user knows, one of the worst troubles in the modern internal combustion engine. Here again there can be little doubt that a gradual advance will take place.

The Le Roy Emmet mercury steam turbine system is an assured practical success; it is a development due to the General Electric Company of America. A 10,000 KW. plant has been in use for some years at Hartford, Conn., and two larger plants are now in course of construction. The principle is to use mercury instead of water in a boiler fired in the ordinary way by coal or oil; the vapour operates a turbine and is condensed. Result: a plant as efficient as an ordinary steam turbine plant. But given away with this pound of tea is a handsome present; the mercury in con-

densing at over 400° C. raises steam at high pressure, and this yields almost as much power again. The overall efficiency is about 35 per cent, as against 17-18 per cent for steam turbine plants alone.

Another revolutionary notion actually put into full practice is the Löffler boiler. The idea is to use the furnace to heat steam, not water ; in fact, the ' boiler ' is all superheater, as it were. The superheated steam is partly passed to the plant, and partly passed back to an evaporator, where it generates saturated steam, which is forced by a pump into the superheater. The apparatus stops working if the pump breaks down, which causes some adverse comment ; also, it is not self-starting. But against this we have release from the infinite care necessary to protect modern high-pressure boilers from impure water, and also certain excellent self-regulating characteristics which we cannot further go into here.

It is obvious that the inventions we have been discussing could all have been thought out and calculated on paper ; in this field there is endless scope for cogitation of this kind. Unexpected troubles will always develop in practice, but these can usually be overcome, and can often be tested for by special tests at little cost, before heavy expense is incurred. Charles Parsons was an expert at such tests ; the famous *Turbinia* was designed on a little model driven by twisted elastic.

What most daunts the investigator in this field is the difficulty of foreseeing the lines along which the final utilisation of coal and oil power are likely to go. Are these (especially coal) to be used raw, or first transformed to gases, liquid fuels, cokes, hydrogenation products, etc., with recovery of valuable by-products ? Is

the internal combustion engine or the vapour engine the prime mover of the future ? Reciprocating engine or turbine ? Is there any chance for the fuel-fed electric battery ?

Ordinary motor-cars have actually been run with coal-dust as fuel, though here again the difficulty of lubrication is very great. Coal-dust mixed with air is a powerful explosive, and if the coal could be freed entirely from gritty particles there would be very little difficulty in adapting engines to make use of it. Diesel actually began his researches with this end in view. It is not at all improbable that entirely new methods might be devised for obtaining from coal a fuel free from disadvantages, when used in internal combustion engines, without the difficulties and expense attached to carbonisation or hydrogenation. Fascinating as the latter process is, it seems a very roundabout way to go to work to obtain mechanical power from coal, and only the belief that valuable by-products will pay this cost leads people to experiment with it. But it should always be remembered, as we have already remarked in connection with chemical inventions, that the present market-price of a by-product offers no sure ground for the calculation of a process involving its production on a large scale. Particularly the by-products of coal treatment have in recent times fluctuated very widely both as regards supply and demand. If a very small quantity of a valuable by-product could be obtained, matters would be different ; thus the noble metals obtained in the refining of nickel, copper, and other metals are of great help to the cost of the process, but they do not seriously affect their own market-price.

Meanwhile progress is going on in all directions,

excepting perhaps that of obtaining electricity direct from coal, which seems to have been abandoned as hopeless, after so much hope had been set upon it. New internal combustion designs must be under test by the hundred ; an interesting one is the Michel, worked out in Berlin, in which three cylinders radiate star-wise from a common combustion chamber, and the two-stroke cycle is used. Inventors will not leave the two-stroke engine alone, although the Ford designers seem to be convinced that, for cars at any rate, present-day practice has a certain finality.

A really astonishing engine is the Malone, which works by the expansion of *water*, on the fundamental principle of the old hot-air engine. It is claimed that a 500 I.H.P. engine has made 30,000,000 revs. without breakdown, that the thermal efficiency is 25 per cent, and that there is a considerable saving in weight and bulk as against existing power plant.

The Fuel Research Board in Britain, as well as numerous other organisations here and elsewhere, are spending hundreds of thousands in research. A really authoritative critical study of the whole problem is badly needed, but only a person with the insight of genius, the widest possible knowledge of engineering and chemistry, and great industry, could produce it. It should be noted that the problem of transmitting energy over long distances is intimately bound up with the subject, and that this problem has social and political aspects. We are now committed to the electrical ' grid ', a very vulnerable device. The popular notion that transmission by radiation is possible is almost certainly fallacious.

One of the most promising fields for invention in

connection with sources of energy undoubtedly lies in the utilisation of plant material. We have already referred to this in connection with chemical invention, but the whole question needs consideration from the widest possible point of view. In tropical countries, where water is plentiful, an enormous growth of vegetation takes place, and there can be no doubt whatever that means could be found for obtaining power from this. Plants use about 3 per cent only of the sun's radiant energy, but this represents fifteen times our total coal consumption. At present very little is done, though in some parts fuel alcohol is being made from suitable juices, but the main source of fuel should be the cellulose, and if a new and easy method of breaking down cellulose to sugar, or even alcohol, could be found, extraordinary developments would be possible. The present known methods of obtaining these substances from cellulose are extremely crude and involve the use of chemicals which are very costly in tropical countries. While an enormous amount of work has already been done in this field, and it is unlikely that any development of the present methods will bring sufficient reward, the discovery of some entirely new method is by no means impossible.

If we now turn to water-power, we find that the modern turbine utilises this so efficiently as to leave little room for improvement. The efficiency of some turbines is well over 95 per cent, and the question of the utilisation of water-power has become entirely one of the payment of interest on capital expenditure. Present conditions have led to a situation so ridiculous from a scientific and technical point of view, that we must regard it as purely temporary. In the Black

Forest, for instance, water-power with a very high fall is readily obtainable at moderate expense by damming high valleys. Nevertheless it is found actually cheaper, according to present methods of calculation, to generate power from coal, although the latter has to be brought a long way by rail. At the present time, the utilisation of water-power, excepting in countries such as Italy and Switzerland, depends in its economics upon the possibility of combining with the water-power station some other useful end, such as the regulation of the river, the provision of a reservoir, or the insurance of the supply of energy in a coalless district against dislocation of the coal supply. Against this, we have the drawback that the water supply is liable to interruption by freezing of the sources. It is possible that in some cases it might pay to adopt methods of preventing this. Where the supply is derived from country liable to heavy accumulation of snow, the use of means to prevent freezing of the reservoir would allow of at least that water produced by the earth's heat reaching the reservoir being utilised.

In the field of water-power we again find a number of possibilities which are fascinatingly on the verge of realisation. The chief of these is the utilisation of the tides, or, more promising still, the utilisation of the power of a great river flowing into a tidal sea. One such scheme, the Shannon, is now completed, at a cost of £6,000,000 ; the maximum yield of power is said to be 72,000 KW. Another, the Severn barrage scheme, has been defeated, after much discussion, by the timidity towards all new enterprise which seems to characterise this country in the twentieth century, as compared with others.

There can be no doubt whatever of the technical possibility and sure technical success of these schemes, and the sole problem is whether, according to our methods of calculation, they would pay financially. Since millions of horse-power, which could be utilised for the production of wealth, are being annually wasted, it appears to the writer that the State might regard the furtherance of such a scheme as one of its first duties, and devote to it the taxes at present devoted to very much less useful ends. In the available data regarding the Severn scheme, for example, the interest on capital (to be guaranteed by the State) is calculated at 5 per cent. A reduction to present rates of interest would make all the difference. The scheme was originally calculated to cost £28,000,000, and yield 500,000 H.P. ten hours per day.

The utilisation of the rise and fall of the tide alone, and of the force of waves, is in quite another category. The reader will probably be aware of the fact that energy in any form is measured by a product of two factors : a quantity factor and an intensity factor. In the case of water, for example, the quantity factor is the volume ; the intensity factor, the height through which it can be made to fall in doing useful work. In the corresponding case of a fuel, the intensity factor may be taken as the temperature attainable in a furnace fed by the fuel. In the case of electricity the intensity factor is the voltage. Now it is a law of Nature that the utilisation of energy of low intensity will generally require larger, and hence more costly, apparatus for the same output than if the energy is of high intensity. This is the case with the tides, since the maximum height of rise is very small. But a further factor must

be taken into consideration, namely, the fact that the tide is only at its highest over a very short period twice in twenty-four hours. This being so, the means for utilising the energy of the tides has either to be adapted to work at a much lower duty than the tides' maximum intensity, or else the means of storage of the water must be capable of collecting a great deal of water over a very short period.

The above facts have hitherto prevented the energy of the tides being utilised excepting in very rare cases and on a very small scale. The total horse-power of the tides in the British Isles is estimated by Davey as about two and a half millions. It would appear that here there is room for some fundamental idea of an entirely new character. We may refer in this connection to a very ancient device known as the water-hammer, which enables the power of water flowing under a very small head to be used in an entirely automatic and very simple and cheap device to raise a part of the water to a much greater head. I am not aware of any instance in which this device has been used for the generation of power; in all probability it would turn out to be too high in capital cost excepting in special instances. But it gives us a hint that ways may be found around what seems a complete obstacle to further advance. It does not seem impossible that the power of the tides might be used to first raise a smaller quantity of water to a higher level, this then being employed to work a turbine. A recent device of great simplicity, the Savonius rotor, might perhaps be of use in this connection. As will be seen from the illustration, this, when placed in a fluid, rotates in the same direction whatever the direction in which the fluid flows past it.

It is proposed to use this both as a tidemill and a windmill; also, it may be used on a ship for propulsion. One of the troubles is, that the maintenance and attention required by such a device would be considerable as compared with its power output. Nearly all natural waters are liable to carry mud, weed, sand, and other solids, which might clog or even damage the installation.

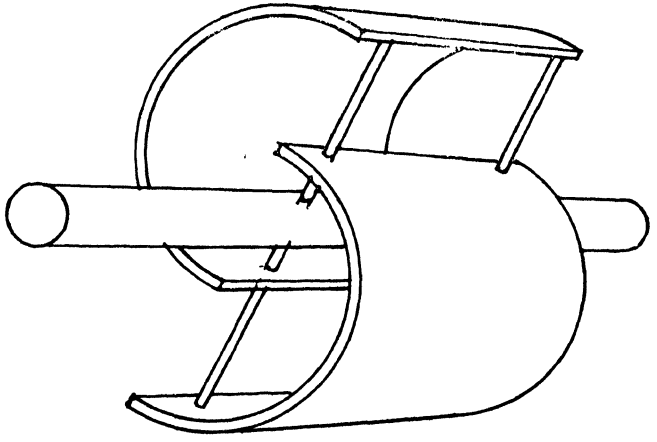


FIG. 2.

Since the reader can be referred to a number of excellent discussions of the present position of steam and water-power, it is not necessary here to discuss these any further. A thorough study, not too wide and not too narrow, of any aspect of the problem might lead an original mind, especially one not prejudiced by being too deeply entangled in some particular form of practice, to see some entirely new and far-reaching possibility. The whole subject is full of pitfalls for the shallow thinker, and some of the most important

matters of present-day practice appear quite paradoxical. For instance, the economy of pre-heating water before introducing it into the boiler by means of live steam, appears completely mysterious ; it looks as if steam, after having been generated at the high pressure of modern boilers, were being entirely wasted on work which could only be economical if performed by waste heat. Another important matter, similarly mysterious to the uninitiated, is the question of storage of energy over periods of low demand. It is obvious that the plant of an electricity generating station has to have a very much larger capacity to meet the peak of the load in winter, than is necessary during most periods of the day and year. Storage of electricity in accumulator batteries is hopeless on account of the capital cost, and the same is true of storage of energy by pumping water to a height, though this fact is already rather remarkable. That energy should be stored in practice in the form of steam under pressure in containers heat-insulated as well as possible, seems about the last thing that anyone would think of doing. There can be no doubt that yet further apparent absurdities of this kind remain to be worked out, and these are less a matter of experiment than one of thought by a mind free from preconception. The data in existence to-day concerning the properties of steam, water, fuel, and solid constructional material, are so full that almost any proposal can be subjected to fairly exact calculation.

We may now turn to some of the sources of power which have been the despair of inventors ever since the importance of power came to be recognised. First and foremost of these is wind-power. The power of the

wind is certainly variable. Nevertheless there are surprisingly few days in the year in which a moderate supply of power is not available. In Denmark the utilisation of wind-power by small plants, in which electricity is generated and stored in accumulators, is widespread, and it might be interesting to know why this system has not spread to other countries. In Denmark both light and power used on the farms are obtained in this way, yet in this country, even in very windy districts, such installations are very rare or non-existent.

The utilisation of wind-power on a large scale is impeded by the difficulty of storage of the energy produced. Even if we could make sure of a store or accessory source of energy during the period of complete absence of wind, we should still be confronted with the fact that the windmill must be built to withstand the strongest tempests, and that these are at least five times as powerful as the average working wind. This puts up the capital cost enormously, and the more so in the case of large plants.

This is the best connection in which to discuss the problem, one of the main problems in connection with energy, of the storage of energy generated in excess of immediate requirements. No general economic solution of this problem exists at the present time. In the case of steam generating stations, we have the storage of live steam as a way out. Only in situations of an exceptionally favourable description is the pumping of water to a high level economical. It is obvious that the erection of water-towers would be far too costly a means for carrying out this system. Compressed air is, I believe, used in certain cases ; but the capital cost is here also serious, and if the compression is to be

economical and the utilisation equally so, the machinery is costly in proportion to its output. Compressed air is a trap for the scientific ignoramus. There is no energy stored in it ; in expanding and doing work, it derives its energy from its own heat and that of the surroundings. In practice, heat has to be supplied.

At one time the greatest hopes were centred on electro-chemistry. It appeared reasonable to suppose that an electro-chemical process might be discovered which could be carried out on some cheap and easily available raw material, and result either in a product of utility in itself, or else one capable of being used to generate electricity when required. Such processes are, however, very few in number. At one time the production of electrolytic soda and bleach might easily have fulfilled this function, but unfortunately it would be impossible to-day for an electricity generating station making soda on any considerable scale to market its product, since the great chemical combines have everywhere closed this possibility to all but the very smallest producers. The electrolysis of zinc chloride in a molten form has been proposed, and also of the same salt in aqueous solution. This yields zinc and chlorine gas, and these can be stored, and caused to re-combine with generation of electricity. The writer believes that this plan is one which might still be carried out economically, but he is well aware that such electro-chemical processes, when carried out on a large scale, usually require skilled supervision. Also, the storage of the gaseous chlorine would present considerable difficulties. Nevertheless the writer has actually constructed cells consuming zinc and chlorine of such remarkably good qualities from a load characteristic

point of view that, if the regeneration of the zinc chloride could be accomplished successfully, he thinks the process might be a practical success.

Another possibility is presented by the electrolytic production of metallic sodium. This, brought in contact with water, generates great heat which could be used to vaporise the water and so provide steam ; and hydrogen is also produced, which could be burnt in an internal combustion engine. The product, caustic soda, would then be re-electrolysed. Here again we have a question of skilled supervision of the plant.

The utilisation of the sun's radiant energy is another field in which electro-chemistry may possibly play a part. However, the first and most obvious plan to consider is that which has already been often practically realised, namely, the use of mirrors to throw an image of the sun upon a boiler. It is obvious that this source of energy is intermittent, but it is available over the whole of practically every working day in many parts of the world.

The desert of Sahara receives as energy from the sun 1800 times that produced by the total coal burnt in the world. It is estimated that the plants of the world utilise only 3 per cent of the sun's radiant energy, and that this represents fifteen times our consumption of coal. It is obvious that these figures place the energy received from the sun in the first rank as regards possible utilisation by humanity. It is rather strange that so little has been heard of machines for making use of it, for they have been successfully built and operated. At an ostrich farm in Pasadena, California, a conical mirror made up of a large number of small mirrors was built with a diameter of 32 feet, a steam boiler being

placed in the focus. In one hour a steam pressure of 150 to 225 lb. was obtained, and this was used to drive a pump delivering 2000 gallons a minute, and a dynamo. Several other installations of this kind have been built, and it may be that the advent of stainless steel mirrors, or better chromium plating, will enable more practical construction to be devised. The question of keeping the mirror directed towards the sun should not give rise to much difficulty, since we now have means of regulating the speed of electric motors which would give amply sufficient accuracy for the purpose.

It is rather difficult to understand why more progress has not been made along these lines. No doubt the capital cost compares unfavourably with modern internal combustion engines, and the compactness of the latter, as compared with the unwieldy and widespread form of a sun-power plant, has a great deal also to do with the neglect of the latter. Also, where the sun's heat is strongest, water is often uncertain, and cooling water for condensation still more so.

As an illustration of what simple consideration of existing possibilities in a new combination may lead to, we may refer to the Claude-Boucherot system for utilising the heat of the surface of the sea in the tropics. We are taught in elementary science that the efficiency of a heat engine depends upon the difference between the temperature of the boiler and the temperature of the condenser; and this leads to the almost universal assumption that any engine working between very narrow limits of temperature, being necessarily very inefficient, must also be uncommercial. These two words have been taken as synonymous, whereas it is obvious that if the source of heat costs nothing and is

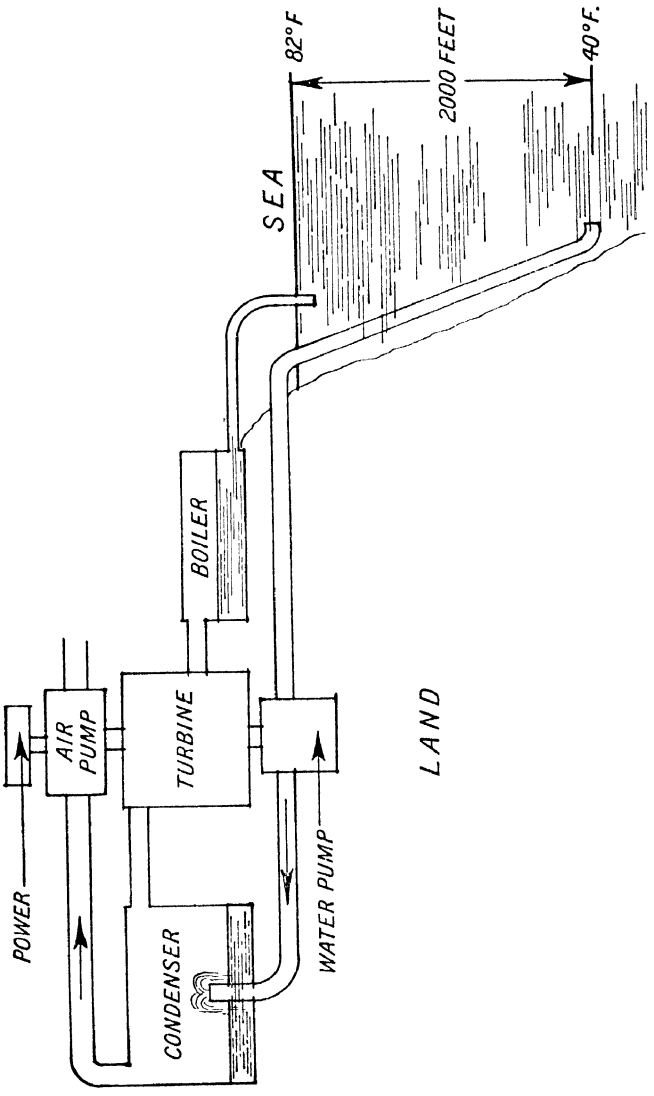

82°F
2000 FEET
40°F.
SEA
BOILER
AIR PUMP
TURBINE
POWER
CONDENSER
WATER PUMP
LAND

FIG. 3.

almost unlimited in capacity, inefficiency does not matter in the least, unless of course the capital cost of the engine and appurtenances is excessive. Claude and Boucherot have made out so good a case for their system, illustrated diagrammatically in the figure, that it is actually in course of construction. The ' boiler ' is here at a temperature of 82° F., that of the surface of the sea under tropical sun. This water is sucked into a vessel connected to a turbine, and beyond that to an air-pump ; the water evaporates and the steam passes through the turbine into a condenser. This condenser is cooled by pumping up sea water from a depth of two thousand feet, where the temperature is 40°. It is obvious that the mechanical work required to raise this water is only that due to the pipe-line friction plus the small difference of level between the condenser and the sea. In demonstrations given in Europe, a 100 H.P. turbine was shown working with a temperature difference of 18° F. It is obvious that the whole of this proposition is susceptible of approximate calculation from a cost point of view, and if such a calculation in any case of the kind can be shown to exhibit a credit balance, serious attention will be paid to it.

A rival to the utilisation of the sun's radiant heat is the utilisation of the photochemically active rays. There are several methods known for obtaining an electric current by the direct action of light upon chemical substances. A mixture of mercuric chloride and ferrous chloride is transformed by light partially into mercurous chloride and ferric chloride, and these two solutions have an electro-chemical difference of potential of 0·17 volt. It is thus possible to make a

battery in which the second pair of chemicals are changed into the first pair as a result of the delivery of current, and are then transformed back by exposure to the sun's light. It is obvious that this apparatus would be very bulky for the amount of current delivered, and this is the reason why no serious attempt has been made to carry out the scheme on a large scale. There are other methods by which light can be indirectly transformed into electrical energy, but these do not appear more promising than the one we have mentioned. This field of invention is one in which much work could be done on paper, by calculation alone. There is very little room for experiment on a small scale, since possibilities of this kind belong rather to chemistry than to engineering. There is always room for investigation of means for obtaining alcohol for power purposes from waste products and from tropical vegetation, but this work belongs more properly under the heading of chemistry.

It appears worthy of consideration that a very small but very useful source of energy might be given by a device utilising the heat of the sun on a thermopile of low tension arranged to charge accumulators. Everywhere in the world, as soon as civilisation is left behind, a small source of electric power is now required for wireless, and this might be furnished by such a device.

Some very eminent men of science have interested themselves in the utilisation of the internal heat of the earth, and a reference to a recent paper on this subject is to be found at the end of this book. There can be little doubt that, sooner or later, some attempt of this kind will be made, though the calculation shows that it would hardly be profitable at present. But there are

parts of the world where very great heat is available fairly close to the surface. In Italy, at Laderello, 7500 kilowatts are being generated from steam obtained from bore-holes, and these are only from 200 to 700 feet deep. Near San Francisco a similar plant is at work. It is obvious that possibilities of this kind will be exploited only very slowly, since so little experience exists upon which to base the spending of large sums of money which are necessary for experiments on a sufficiently large scale.

Few people realise the fact that road transport is now by far the greatest consumer of mechanical energy. The combined horse-power of all the installations producing power from coal, water, and natural gas in the United States is only one-third of that of all road vehicles. This is the result of the internal combustion engine, and it is obvious that development is only beginning. At present fuel for these engines is very dear ; exclusive of tax, 1 therm of petrol costs 6d., as against ½d. for coal. But the time is certainly coming when much cheaper liquid fuel will be available.

The internal combustion engine has been developed in recent years by firms of a very much more progressive character than the older engineering firms, spurred on moreover by acute competition. We are now witnessing the gradual convergence of practice, as is evidenced by the recent new Ford car, which, so far from bringing any surprising developments, is designed in an almost conservative manner. In this field of work, independent inventors have done far less, apart from accessory matters, than might have been expected. A very large number of engines have, in the course of the development of the present-day standard

type, been built to try out devices which have shown great ingenuity, but have not succeeded in finding acceptance.

It is probable that the independent inventor had now better turn his attention either to devices of a subsidiary character, or else to striking out in new directions. Particularly the field of variable gearing has been so thoroughly explored that it is unlikely that any revolutionary advance will be made.

A word should be said concerning perpetual motion, which is one of the oldest fields in which inventors have given the whole profession a bad name. A few very interesting little books have been written on this subject, and it is interesting to learn from them that the principal offenders have been of English nationality. These were by no means all of them persons of inferior ability ; for instance, Sir William Congreve, a member of parliament and the inventor of systems of printing, and of the rocket known by his name, was responsible for one of the most ingenious proposals of the kind. Nor is the supply of such inventions exhausted ; or rather, the hoariest fallacies are being continually revived, and still find to-day financial support of a substantial character. The writer encountered quite recently such a case in a London suburb, where but a few years ago £5000 had been extracted from local residents for experiments on lines at least two centuries old.

Not only in the field of perpetual motion, but also in many other matters relating to the generation and distribution of energy, we find fallacious proposals of all kinds, some fairly obvious, and others not quite so transparent. The study of these fallacies is by no means time wasted ; everyone who attempts to do

original thinking in technical matters must have himself repeatedly been guilty of conceiving an unsound scheme. The more critically trained we are, the more quickly are we able to see through our own errors, unless we are too optimistic to be capable of self-criticism at all.

Within the writer's recollection there have been several outstanding examples of ideas which have formed the basis for quite large expenditure, and yet were of a character so obviously foolish that every competent technician at once ridiculed them. Some readers will remember a steam engine with a fly-wheel many times larger than usual, and provided with a device by which the steam could be cut off periodically, the machinery being then driven for a time by the energy stored in the fly-wheel. Such an engine of very considerable power was actually built and exhibited publicly. Another absurdity was a railway built entirely upon girders supported upon piers at intervals. At each pier there was a hydraulic or other engine which raised the track slightly when required, so as to produce a down gradient between it and the adjacent piers. The train was to move by running perpetually downhill, it being raised, together with the track, as it passed each pier. This idiotic proposal was shown in the form of a large and elaborate working model, which, of course, worked most satisfactorily. Many absurd electric railways have been devised in which the train was moved along the track by the action of magnets placed at intervals, and here again elaborate models have been the means of drawing many thousands of pounds from the pockets of unwary investors. We shall have something to say in the last chapters concerning the fact that all these follies have yet failed to lead to

the establishment of some system for testing the technical soundness of ideas for which it is attempted to raise money.

Of recent years, the transformation of mechanical and electrical energy into sound has acquired great industrial importance. There is no field of experimenting more completely open to the independent worker, but it is to be feared that he has failed to justify his existence so far. E. M. Ginn, it is true, has performed the typical lone inventor feat of producing the perfect mechanical gramophone, while the big manufacturers have produced every conceivable kind of device except the right one; but in the field of electrical sound generation we have yet to hear anything tolerable to a sensitive ear, except at powers and prices impossible to the ordinary man. Unfortunately, the ear of the public is now so debased, that large and important theatres and halls fit reproducing equipment which is simply beneath criticism, although they could afford, and indeed probably obtain for the same money, equipment which would give all but perfect results, at any rate from gramophone records.

The difficulty at the present time is that the conversion of electrical into sound energy is very inefficient, especially at the lower frequencies; or rather, efficient conversion involves the use of very large horns, which are quite impossible in domestic installations. The moving-coil speaker needs to have a cone at least 18″ in diameter to reproduce the lower frequencies, and to be mounted in an efficient baffle-board. Such a speaker requires a great deal of power to drive it. In spite of the enormous attention which inventors have devoted to this subject, it is in a most unsatisfactory

state, and there is no obstacle in principle to a great advance being made at any time by an ingenious person.

One of the greatest developments of modern times has taken place in organ-building. Here, as in so many instances, the inventive genius has been British, but the enterprise has been foreign. It would be interesting to know how much has been paid to the United States on this account alone, for the modern cinema organ, which originated in the work of an Englishman, Hope-Jones, was developed in its initial stages in America, because Hope-Jones went there in 1903, after battling with all kinds of prejudice, and even *sabotage*, in this country.

The problem of building a key instrument which supplies current to a loud speaker has occupied inventors ever since the discovery of the telephone, but it still remains unsolved. There can be no doubt, however, that its solution will come very shortly. One can easily imagine a hollow cylinder carrying on its circumference all the notes of the scale in sound-track, of any desired instrumental quality. This cylinder, revolving at a constant speed with a source of light outside and a photo-electric receiver inside, would supply any desired note at will by the touch of a key. But there are plenty of other schemes which might work. One ought to be able to produce speech-current of any desired form by induction, but no one has yet shown us how to do it.

To this chapter on energy belongs the subject of explosives; these are regarded by the laity as being supreme manifestations of energy. Here there is much misapprehension; petrol produces, volume for volume,

four times as much energy as nitro-glycerine. But explosives are able to generate much higher pressures, for most of them are equivalent to combustion in solid or liquid oxygen. If, in fact, we mix an easily combustible substance, such as cotton-wool, with liquid oxygen, we get a fairly efficient explosive ; one that is actually used in practice.

Great as has been the value of explosives to man's peaceful pursuits, it is his warlike instincts that have caused their development. At the present moment, when it is impossible to get any useful invention introduced, and difficult even to exploit a frivolous one, there is still a welcome everywhere for the man with a new and deadly means of destruction. I may be excused, I think, from attempting to discuss here the cheerful possibilities of modern warfare. They have received sufficient attention of late. Their main feature as a field for invention is, that expense is no object. It would be really interesting if someone were to find a means of using the metal gold for lethal purposes. The economic consequences in case of war would be amusing to those who survived.

Much attention has recently been given to rockets, for they form practically our only hope of ever being able to escape from this planet ; and it may not be long before means of escape will be in great demand. But the notion of sending mails by rocket through the stratosphere is by no means chimerical, though it must not be forgotten that modern methods of communication by wire and wireless, such as telephotography and teletypewriting, afford sure and certain means of transmitting all documentary material, in facsimile if necessary.

In conclusion, we may say that scientific engineers are apt to attach too great importance, at present, to efficiency in energy transformations. Many years ago, Ostwald set up the commandment ' Waste not energy ! ' as the true religion of science. Energy is cheap enough to-day ; what is needed are improvements in the means for utilising it conveniently. Nothing could be less efficient than electric heating ; it is very many times more costly than heating by coal. Nevertheless it is now being adopted in large buildings on account of the convenience in construction, and, above all, the certainty that no subsequent damage will occur by leaks, cracking, and similar troubles.

Chapter XI

BIOLOGICAL INVENTION

In his famous essay *Daedalus, or Science and the Future*, J. B. S. Haldane, in discussing the future of technical invention, maintains that the era of physico-chemical invention is drawing to a close, and that the future belongs to biological invention.

Some of the most important prehistoric inventions were biological : the domestication and selective breeding of plants and animals, the preparation and preservation of food and drink, the castration of animals and, in certain cases, man, hygienic measures and tabus (such as we find in Leviticus), and surgery. In modern times, however, our biological invention has been confined almost entirely to the alleviation of disease. It is wrong, I think, to speak of contraception as a modern invention, though Haldane does so ; it has been known and practised in various forms from the earliest times.

Haldane makes a very acute observation. He points out that human hatred of innovation expresses itself differently in respect of physico-chemical and of biological invention. The first is felt as an insult to God, as blasphemy ; the second as an insult to man's dignity. The first attitude of mind is exemplified in the Prometheus legend, and in the persecution of early discoverers and inventors by the Church, and to-day, by the atti-

tude of those who hate industrial civilisation as an offence against the beauty of Nature. For the second, we have enough warrant in the opponents of vivisection, vaccination, birth control, and so on, to say nothing of the horror which the speculations of Mr. Haldane concerning ectogenesis (the production of babies in the laboratory) and the future of sexual relationships, excite in many minds.

While the innate horror of mechanical and chemical invention hardly troubles us to-day, on account of the immense success which it has had in improving our comfort and safety, that of biological invention is still a very real force. It is only kept in check by the boon to mankind of modern medical and surgical science, and this is nevertheless subjected to the severest legislative control. It is practically certain that certain developments in biological invention, which we shall consider presently, will arouse passions and conflicts not unlike those which occurred when the first inventions of modern times began to affect the lives of the mass of people.

Let us first remind the reader of the discussion on aptitudes of mind in the first and second chapters. Among persons with a bent towards natural science, we can trace distinctly an antithesis between the lovers of machines, of matter, and the lovers of life. So strong is this antithesis, that normally I believe, there is not merely attraction to one of these poles, but repulsion from the other. The physicist finds the living world slightly horrible, uncanny, unclean ; the biologist feels a corresponding slight aversion to the cold, inhuman, mathematical laws of matter. The late Professor Geitel is the only case I have personally come across of a

physical scientist with a biological hobby—he collected mimicry insects. Few biologists have any aptitude for physics ; they are mainly recruited from the naturalists —the bug-hunting, not the tool-using, schoolboys. Nevertheless, the logic of modern development is leading to the rise of a race of discoverers and inventors who are masters both of physical chemistry and biology. Both physics and chemistry now owe a considerable debt to men who are primarily biologists ; Einthoven invented the string galvanometer as an instrument of biological research, and biologists are responsible for many advances in physical and organic chemistry, such as electrical oxidation and reduction potentials, rate of reaction, and, of course, the pure chemistry of biological substances such as proteins.

With some reluctance I propose to omit medicine and surgery from this survey. In this field alone of human endeavour, the problem of invention is solved from its social aspect. Admission to the profession involves long and arduous training ; but to the initiate who is willing to devote himself to research, every encouragement is given. Indeed, success as a physician involves as an essential the continual exercise of creative insight. Research, invention, and the application of tested expedients are inextricably interwoven. Patents are barred, excepting as regards purely mechanical appliances. The *Lancet* is sad reading to those who dwell in the outer darkness of manufacturing technology, dominated by the need for dividend-earning, and fundamentally hostile to all creative innovation, for fear of the risk involved. It is the eternal honour and glory of the medical profession that it fights implacably the very source of its livelihood. Imagine film producers in-

spired by a desire to train humanity to find happiness in self-directed effort, and not in mechanical amusement !

The science of genetics, based upon the fundamental discoveries of Mendel, is advancing very rapidly. So far, however, practical application has been made only of the originally discovered principles, and not of the marvellous later developments. Nevertheless, the results are imposing. Rapid improvement is being made in breeding plants and animals of all kinds. The work demands qualities of a high order, and is intensely interesting.

But what has been done is merely a beginning. Mendel discovered the existence of fixed and definite heredity factors ; in place of Darwin's assumption that the offspring is generally similar to the parents, but individually slightly different, we now know that it is made up of factors derived identically from its ancestors. These factors are carried by the chromosomes, minute bodies found in the nucleus of the cell. Each is a collection of factors, arranged literally like beads on a string. With a mixed ancestry (and all races in Nature are a mixture of varieties) the individual, formed by the union of two germ cells, gets a chance mixture of factors. Hence the children of an average couple are nearly always a mixed lot ; one has his father's eyes, his mother's hair, and his grandfather's physique ; and every now and then you have an extraordinary ' throwback ' in which the characteristics of a remote ancestor reappear. This is the basis of the ' colour bar ' tragedy : if one of the partners to a marriage of apparently perfectly white people has a ' touch of the tar-brush ', a child may be born with strongly marked negro characteristics.

But this law is modified by the fact of mutation, upon which we touched in the first chapter ; a totally new factor suddenly appears in a single individual's germ-cells—perhaps only in one of them. A ' sport ' is born. An important point of modern plant and animal breeding consists in a keen eye for these sports, just as a Faraday or a Ramsay needs a keen eye for the experimental happening which reveals an unsuspected fact.

Obviously the next step is to produce artificial mutations. I often wonder how many people in the world are trying persistently and systematically to do so. Probably fewer than one would expect, considering the first-rate importance of the problem : human inertia is much greater than we ever make allowance for. Some little success has been attained with X-rays, though only in producing mutations already known. We must picture the heredity factor as a definite constellation of chemical atoms at a certain point in the chromosome. The facts of hormone chemistry prove that incredibly minute amounts of chemical substances powerfully affect the behaviour and growth of living cells. Adrenalin, the hormone secreted by the suprarenal glands of the kidney, is present in the body only to the extent of about one milligram, or 1½ hundredths of a grain. Hence we have no difficulty in imagining the development of the individual as decided in some respect by the chemical nature of the heredity factor.

Nature takes infinite care that nothing happening to the individual shall affect the germ-cells, and she is supremely successful. While a large section of the lay public believes that the life and experiences of the parents affect the character of the offspring, science is

quite sure that this is not the case. If Erasmus Darwin's son Charles had never been taught to read or write, but had lived the life of a starved and beaten slave, his capacity for begetting (upon the same woman, of course) his brilliant posterity would not have been affected in the slightest.

We can always beat Nature in the end. We shall find out how to produce mutations. Obviously the first successes will be of a hit-or-miss character. It will be a long time before we can decide that our daughter shall be born with a beautiful furry coat, with consequent saving in expense, or breed persons who combine an aptitude for politics with intelligence and moral courage. But when we remember that a single individual mutant may be the parent of a whole race, a single valuable hit will compensate us for the labour expended upon very many misses. For instance, Haldane suggests the possibility of producing low forms of life, such as algae, capable of deriving nourishment entirely from inorganic materials, and particularly of fixing the nitrogen of the air, as certain organisms already do. These organisms would then serve as food for higher forms of life, such as fish, whereby the food supply of the earth would be enormously multiplied.

This is only one of innumerable possibilities. The use of the malaria parasite in the cure of tertiary syphilis suggests that a form of it, or some similar organism such as the syphilis microbe itself, or the trypanosome of sleeping sickness, might be deprived of its injurious qualities, and domesticated in our own blood stream, charged with the task of demolishing dangerous intruders. This business is at present attended to by our own phagocytes, but just as, in our

households, we manage to get the watch-dog to live amicably with the mouser, so in our blood-stream a similar pleasant relationship might be established. The domestication of bacteria in the intestine is necessary to all cellulose-eating animals such as cattle, and very probably to ourselves.

Another, still more remarkable, possibility lies in the improvement of the intelligence of the higher animals. This is no doubt possible within certain limits, and will be attempted, by selective breeding; but our own intelligence must be the outcome of a mutation or series of mutations, and there is no reason why, if we can cause mutations to happen, and watch for them carefully, we should not eventually be able to staff our factories by suitably bred apes; while as regards political and administrative work—but let us curb imagination while there is yet time.

An important field of biological invention to-day is that designated by the misshapen word 'pestology'. Animal and insect pests are responsible for material damage to the extent of hundreds of millions of pounds annually. In addition, many of these pests are active agents in spreading disease among ourselves and our domesticated animals. In Great Britain the chief of these is the rat; and at the moment serious alarm is being caused by the fact that the brown rat, a voracious but otherwise harmless creature, is being beaten off the scene by his old enemy the black rat, whose flea is the carrier of bubonic plague; the Black Death of dreadful memory. In Australia we have the rabbit plague; indeed, no part of the earth is free from some scourge of this kind, imported comparatively recently owing to the greatly increased facilities afforded by modern

transport. Some of these pests, and not the least devastating, are minute creatures, such as the various insects which infest forest trees and cotton and other plantations.

In this context we may refer to the tragic fate of the common flea, the one tiny parasite of man not altogether vile, but redeemed by its supreme acrobatic powers and almost presentable appearance under the microscope, so merciless in its revelation of the more loathsome man-eating fauna. The flea is apparently being exterminated, possibly by some new and mysterious disease, which seems to have developed about four or five years ago, and is creeping Eastwards across Europe. Not only human, but also animal fleas are vanishing; the dog may cease to be blessed by the creature which has hitherto kept him from brooding over the fact that he is but a dog. If the plague-carrying flea of the black rat also succumbs (apparently this has not yet happened), the gain to humanity will be considerable. But one can hardly repress a shiver at the reflection that, say, influenza or cerebrospinal meningitis, neither of which is amenable to our medical science, might very well acquire an equal degree of virulence, and put an end to our own lively and industrious excursions around and in and over this old globe, which has seen not a few of its parasites disappear in past ages.

In the battle with insect pests, all obvious methods are useless, such as traps, poison, etc. In America and elsewhere, attempts have been made to deal with insects of nocturnal habits by setting up great arc-lamps accompanied by huge air-suction machines, which engulf the insects attracted by the lamps. Thousands upon thousands of *tons* of moths have been collected in

this way, without making any appreciable impression upon their prevalence.

The modern method is to cultivate living enemies of the pest. For rats and mice we have the well-known Liverpool virus, but this is in the nature of a poison, and nothing is more certain than that any race of living creatures will quickly get wise to snares of this kind. In addition, extermination will rarely if ever be accomplished by a microbe; the mortality will at first be great, but a greater or less degree of immunity will be acquired. Probably the flea will not suffer extinction. The enemy must be definitely aggressive, and operate by means that simple adaptation cannot cope with. At present our only resource is the discovery and cultivation of the natural enemies of the pest; in some cases this procedure is remarkably successful, as at the moment with the prickly pear in Australia, introduced in 1840, and now being exterminated by the moth *Cactoblastis cactorum*, upon the breeding of which £20,000 yearly is being spent. Still simpler is Dr. Campbell's method of exterminating mosquitos by building comfortable homes for bats. It is said to succeed admirably.

But still more effective would be the development of relentless blood-lust towards pests in the breasts of suitable higher animals. Man, presumably normal and sane, kills for pleasure; the popping of innumerable guns on August 12 of each year bears witness to the fact. But animals only do so in individual cases; dogs, for instance, become sheep-killers; and, aware of their wickedness, are extremely difficult to detect. It is obvious that blood-lust could be developed by selective breeding, perhaps even to the intensity it has in man,

but what would be needed, in most cases, would be a development of greater intelligence. Cynical observers of mankind have been known to maintain that this is not commonly associated with a passion for field sports.

But speaking quite seriously, we can surely imagine a breed of dogs rejoicing in the slaying of rabbits or rats, and intelligent enough to co-operate with one another without human supervision. The study of animal psychology is now being pursued with great energy, and is revealing the fact that individual animals of the same breed differ greatly in intelligence. It is an obvious step to breed for this quality.

These notions are somewhat speculative. Much less so are the developments we may expect from the most recent advances in biochemical research. Astonishing as is the resistance of living cells to all kinds of external chemical influences, excepting those powerful enough actually to destroy their tissue, we are finding that almost incredibly minute amounts of certain substances are able to influence their growth and behaviour in a decisive manner. In our own bodies, the hormones (mostly derived from the ductless glands) play a supremely important part ; upon their presence in correct proportion depends the functioning of all our organs, including the brain. Then we have the vitamins, substances present in minute quantity in our food, and just as essential as the main bulk of the food to healthy life. A deficiency of any of them leads to disease and even death. These substances, unlike the proteins which form the basis of living tissue, are by no means very complicated ; the only difficulty is to get enough of them to find out, by ordinary laboratory methods, their chemical constitution.

A most important property of the hormones is their mental effect. Hitherto we have known and used only a few substances, such as alcohol, caffeine, and morphine (in opium), which act powerfully upon our mental state. In spite of the abuses to which they have been subjected, there cannot be the least doubt that their discovery and utilisation has been of the greatest value to human progress. Man is naturally a solitary, suspicious, quarrelsome animal ; his association in herds for the purpose of common enterprise is a source of endless misery to him. But this association is necessary to civilisation, and alcohol and other drugs have been of great assistance in relieving the nervous strain.

But the time is rapidly approaching when our moods, our very characters even, will be under complete chemical control. We shall certainly find means of experiencing the good cheer excited by alcohol without either its immediately deleterious effects upon our mental powers and sensual faculties, or its (possibly) injurious effect upon health generally. As regards the latter, modern physicians are learning that more ill-health is caused by unhappiness than unhappiness by ill-health ; needless to say, the usual state of affairs is a vicious cycle. Sexual maladjustment, financial worry, injured self-esteem, disappointed ambition—all these are now recognised as the co-operating causes of such perfectly definite diseases as colitis, influenza, furunculosis, and dyspepsia. So that alcohol, by, temporarily at least, abolishing unhappiness, has no doubt contributed far more to human health and happiness by its psychical effect, than it has detracted therefrom by the graver or milder troubles that are laid at its door. But when we thoroughly understand hormones,

and are able to prepare them, we shall be able to feel grave or gay, amorous or coldly intellectual, pugnacious or benign, at will.

At the moment, the sex hormones occupy the centre of attention. They have been prepared in a pure state from urine, and all sorts of other sources for them are now being found, down to coal; for there seems to be a substance responsible for the growth of plants, which is identical with the human female hormone, oestrin. The present process of extraction from urine is somewhat long and troublesome, but it is in itself a proof of the chemical stability of the substance. The empirical composition of the male sex hormone has been determined, but not its constitution. But this may be found out any day now.

It is not difficult to imagine the remarks of some of the Borough Councillors when the first enterprising individual seeks a concession to divert from the sewers the valuable material now being wasted in public conveniences, and to set up a suitable plant for extracting, for human consumption, the various chemical bodies therein. But this is a possibility of the immediate future, as anyone who studies biological literature can see at a glance. Ten thousand Berlin policemen supplied the material for the isolation of the male sex hormone.

Any wise young chemist would do well to consider, not merely the methods for extracting the hormones, but also for the most efficient utilisation of the by-products.

Electroculture, which had so great a vogue some years ago, seems to have disappeared from the news, but a great deal of practical experimenting is going on

regarding the influence upon the growth of plants of light of various wave-lengths, and of radio-active substances and radiations. But in view of recent work on plant hormones it seems as if man will reach his practical ends much more rapidly along purely chemical lines. The electrical influences operate by producing chemical changes, just as they do in the cure of tuberculosis in the human subject.

It is of course impossible within the limits of this survey even to allude to all the possibilities which biochemistry may hold for us. Perhaps the most striking fact is its revelation of the extremely specific action of chemical substances upon living organisms. Ehrlich's guiding notion of the substance toxic only to some particular enemy micro-organism, and harmless to ourselves, is immensely difficult to realise by the method of trial and error, but there can be no question that it is a possible one. The hopes aroused when antiseptics were first discovered were succeeded by extreme pessimism with regard to them, as soon as it was realised that substances such as carbolic acid, chlorine, iodine, and the like were just as lethal to human body-cells as to the germs which preyed upon them. But we know now that this need not be, and the time will certainly arrive when we shall be able to destroy any invader. Those who have had all their teeth extracted as a cure for rheumatism, on account of infection at the roots, will be able to appreciate the joys of the world to come.

But a still more startling development is suggested by the results of the new science of ' developmental mechanics '. Even if we do not succeed in producing a desired mutation in a given organism, we may still hope to influence its growth, for the heredity factors

themselves are, almost beyond a doubt, nothing more than peculiar chemical substances which we may hope to synthesise. Let us carefully note that, in spite of the close connection between the female parent and the child, the former's body appears to have absolutely no influence whatever upon the child's development, all popular ideas to the contrary notwithstanding. Even if the ovary itself be transplanted into a body of other characteristics, as one breed of dog into another, and an ovum or ova be fertilised there, the offspring will receive absolutely no trace of the foster-parent, but will entirely correspond to the animal who supplied the ovary.

Nevertheless the development of each part and organ of the body is undoubtedly due to a (presumably) chemical influence exerted upon the appropriate cells from outside. As most of my readers will be aware, the fertilised ovum grows rapidly by simple cell-division, and soon forms a hollow sphere of cells, as yet undifferentiated and identical in their qualities. This hollow ball then collapses on itself, forming a cup, which soon becomes shaped like a spherical bottle. The further growth of animal or man now consists in the specialisation of different sets of cells for different purposes, so that they grow into arms, legs, brain, and so on.

Experiment proves that, up to a certain point of time, the cells at any given part of the bottle are undetermined, their destiny is unsettled. What decides it? Unless we imagine a mystical little soul slipping into the leather bottle from the fourth dimension, and directing a tailoring process by which the cell-stuff becomes a natural garment complete in all its parts down to the

last frill, we shall have to find some physical or chemical explanation. Now, it has been settled by experiment that the cells of the neck of the bottle are the first to be determined ; obviously they are uniquely situated, and this may give them the predominance. For from them there spreads, quite slowly, some influence which determines the rest. Since the spread of this influence is slow, it can hardly be anything but chemical ; it is no doubt hormone-like in character, and originates in the heredity factors of the neck-cells. But if that is so, then we can step in and play tricks. These facts have been found out by cutting out bits of the developing embryo and transplanting them. If they are taken from inside the line spreading out from the neck of the bottle, they do not take on the nature of their new surrounding, but carry on with the job to which they have been assigned—becoming a leg or an arm, or what not, no matter how inconvenient the situation may be.

With this we must conclude these few remarks concerning biological invention. Whether Haldane is right or not, those who possess the necessary mental capacity to absorb a training covering chemistry, physics, and biology, will not want for opportunities to make use of their acquirements.

Chapter XII

PATENT LAW AS IT IS AND AS IT SHOULD BE

It is impossible to give, within the limits of a single chapter, anything more than an outline of patent law. Patent law was an English invention, and in its present form it is the work rather of judges than of legislators. Perhaps the earliest beginnings date from 1331, when letters of protection were granted to a Fleming by the name of John Kemp, together with his servants, apprentices, and " other men of the weaver mystery, or fullers or dyers ", who might desire to come to England. The object was, of course, to introduce new industries into this country, by granting a monopoly to persons prepared to take the risk of starting them. The situation was thus very much akin to that existing at the present time, when the cost of imports is regarded as a drain on the treasure of the kingdom.

The industrialisation of the Continent was ahead of that of England in Elizabeth's time, and in the years between about 1560 and 1624 the Crown granted many patents. Unfortunately, as we were taught at school in our history lesson, the Crown proceeded to abuse grossly this privilege of granting monopolies, in order to obtain a source of revenue independent of Parliament. This culminated in the Statute of Monopolies in 1624, which forbade the Crown to grant monopolies other than

to " the true and first inventor and inventors of such manufactures which others at the time of making such letters patent and grants shall not use ", for the purpose of encouraging new industries in this country. The interpretation of the words " true and first inventor " by the Courts has led to the law as it stands to-day. There can be no doubt that Parliament had in mind, in using the term " inventor ", nothing more than the person who is the first to establish an industry. This sense of the word, indeed, still holds to-day ; a patent may be granted for the introduction of a manufacture of any kind, so long as it has not been made known in this country in any way. The person to whom the grant is made does not need to be the inventor in the modern common sense of the word ; and instances exist where a traveller has found among natives in some distant part of the world an apparatus or process unknown elsewhere, and capable of being introduced into our civilised life with advantage.

However, the law now requires that the applicant for a patent should be the inventor in the modern sense of the word, excepting in the above instance. It does not, however, take the words " true and first " in their literal sense ; and anyone who has actually invented and made something for which a subsequent applicant claims a patent, has no right of intervention unless he has published his results to the world. The case has frequently occurred where a process has been kept secret, only to be invented and patented by someone else, who has been able to obtain a valid patent. In other words, the original intention of the Statute has been completely altered.

The fundamental judge-made basis of our patent

system is not that of encouraging the establishment of new industries, so much as of encouraging inventors to make known their results to the world for the general benefit of industry. This the inventor does in his specification, and it is a cardinal point of patent law that the specification should contain full and sufficient directions to enable any person skilled in the art to carry the invention into effect successfully. English law, however, has a peculiar provision which has not been copied by other countries. It allows the inventor to file what is called a ' provisional specification ', which sets forth the nature of the invention, but does not need to describe how it is to be carried into effect. The fee for this is only £1, and every inventor should learn how to draw up such specifications himself.

While the English law requires in a provisional specification only a description of the nature of the invention and not of the means by which it is to be carried into effect, it is necessary to take into account, in drafting the provisional specification, the existence of the International Convention. The International Convention has been concluded between the great majority of countries possessing patent laws, and binds each of the contracting countries to recognise the priority of an applicant in any one country, who applies for a foreign patent in a Convention country within one year of his first application in any single country. These foreign countries, however, naturally require that the " certified copy " of the English provisional specification which they receive should contain all essential points claimed by this person applying to them for a patent, and claiming the priority of his English patent application. The patentee may take advantage of the English law in

drafting his Complete Specification, and include in the latter what are called " fair developments " of the invention foreshadowed in his provisional specification. But these " fair developments " will not be allowed to form the basis of claims for foreign patents, to be dated with the priority of the English provisional. On the other hand, the foreign patent offices are by no means ungenerous, and will allow the English inventor to describe and claim in detail things only referred to in words in the English provisional, which is rarely accompanied by drawings.

There is a point which is often forgotten, and may usefully be remembered in special instances. Application in any Convention country gives priority in all countries, whether the inventor is a native of, or resident in, the country in question or not. And since the German and American offices conduct a fairly thorough search, an applicant may often consider the advisability of making his first application in either of these countries.

One feature in the practice of the American Patent Office with regard to the Convention has led to a considerable amount of recrimination, but it cannot be discussed in detail here. If anyone can (or will) swear that he conceived the idea of a certain invention while within U.S.A. territory before the date of application in the U.S.A. or *abroad* by another inventor of the same idea, he is entitled to a patent. In practice, a two years' limit is set to this remarkable private provisional protection. Publication or sale of the invention during this period does not in any way invalidate the patent. It is a good thing for the foreign inventor with a trustworthy friend in the U.S.A. to send over immediately a full description of his ideas, to be filed for reference.

The inventor will find references at the end of this chapter to a number of books which will give him full particulars as to how he is to proceed. He should remember that he cannot put too much into his provisional specification, at least in the way of facts, ideas, and proposals for future development. He may also conveniently ignore the law, which insists that only one single invention must be the subject of a single patent. He will feel the full severity of this provision when he comes to complete his patent, but the payment of £1 will secure for him priority as regards fairly diverse inventions, even if they are included in a single application, and this applies, of course, to all 'Convention' countries as well. Of course, subsequent division of these applications will cost him a little extra in fees.

He need have no hesitation in putting into his provisional specification matter which he may feel doubtful about publishing, even at a later date when the final application is completed. He can always apply to amend his provisional specification, and the matter thus struck out will not be published at all.

A very good rule is to be lavish with provisional specifications. In these exceedingly difficult times for inventors, it repeatedly happens that the money cannot be found for foreign protection within the Convention year. This is true even of an invention which has only taken a few weeks or months to bring into a marketable form ; and in the case of any more difficult invention, it is almost certain that practical success will not be attained within the period. Since foreign protection costs from £20 to £25 per country on the average, the expense is very considerable if anything like adequate world rights are to be obtained. If, however, the in-

ventor continues to file provisional specifications at short intervals, each fully recapitulating the matter from the beginning, of course with the addition of all further developments, both mental and physical, he is able, provided he has not disclosed his invention too freely, to risk allowing the earlier provisionals to lapse. When success is obtained and money is available he may then base the Convention applications upon the oldest provisional still in force.

Good advice for drafting provisionals will be found in some of the books cited, but it is well to remember to avoid theory, unless it is hoped to obtain a master patent embodying a new principle, in which case, of course, the principle should be fully stated and the theory given. Another point to be remembered is that it is rarely to the advantage of an inventor, and very frequently indeed greatly to his disadvantage, that his specification should be read and understood by his competitors and rivals. A specification which is a model of easy reading, clear description, and good draughtsmanship generally, is therefore only a drawback ; at the most, it might prejudice a judge slightly in his favour, in the event of a patent action. But the latter event is unlikely, and becomes more unlikely year by year, as the law becomes costlier and more uncertain, whereas specifications are read by an ever-increasing number of clever people, who are quick to seize upon the information given in them, and rarely ask the inventor's permission to make use of it. Fortunately, these clever people are also human, and hence when confronted by an exceedingly unpalatable mass of words, which they are supposed to read in their spare time, they usually only glance at the claims and draw-

ings. It very frequently happens that neither of these need convey much information, and hence the really essential points from a technical point of view may be overlooked. The inventor may entirely dismiss from his mind the hope that some powerful person or firm, reading his specification and realising how clever he is, will hasten to communicate with him.

The foregoing remarks apply also to the complete specification. This costs a further £4 stamp, and the task of drawing it up and making the necessary drawings is one well within the capabilities of anyone intelligent enough to understand the purpose which it serves. The reader is advised to study the patent specifications drawn up by good agents, as well as the guides to inventors given at the conclusion of this chapter. A point to remember is that the complete specification must be filed within one year of the date of application, but that the Office will accept sketch drawings as a temporary measure.

It is also possible for the inventor to apply in foreign countries on his own account, though not to complete his patent there. Hence the convention date may be saved in these, provided the necessary papers are filed, at the cost of comparatively low fees. The applications must of course be in the language of the country in question. The U.S.A. application requires a fee of $30.00, and the applicant must also personally attend at a U.S. consulate and there swear an oath as required by law. Hence the papers for the U.S.A. must be in due form as required by regulations, but directions will be found in some of the guides cited. The German application requires a fee of M. 25, and can be filed (of course in the German language) by registered post with-

out further formality. In many Convention applications copies of the applicant's provisional specification, certified by the British Patent Office, will be required, but these need not be filed with the application. But the applicant must claim in his application, with exact date and particulars, the priority due to him under the Convention, and if he fails to do so, he will not obtain his priority ; nor, in the case of U.S.A., will he obtain a patent at all, even if he has not published his invention.

In a great many countries, application is possible so long as the invention has not been published in print.

It is almost needless to say that the services of a really capable agent are quite invaluable, provided that the inventor does not shirk the work of co-operating with him properly. The patent specification is primarily a legal document, and it is the business of the agent, who has a legal training, to view it from this angle. But the inventor must see that it actually covers the fundamental facts, and fulfils the technical requirement of the law, that of containing sufficient instructions to enable the invention to be carried into effect by anyone ' skilled in the art '.

The inventor should clearly distinguish in his mind between pure patent protection, which involves filing a description of the invention which exhibits its originality, and claims what the inventor has done in advance of his predecessors, and the use of patent, design, and trade mark law to ' keep people off the grass '. Under existing laws, in most countries at least, genuine protection is unobtainable, because a patent granted after a careful search by the Office may nevertheless be disputed as regards its validity, from any point of view,

In certain countries, such as Germany, patents which have remained intact for a certain length of time, become automatically unquestionable. The period for this in Germany is five years ; at the end of this period it is no longer possible to bring an action for declaration of nullity, and the Courts will entertain no defence in an action for infringement which pleads any objection to the original patent, either in form or substance. But in this country and most others, the chief value of a patent to a person of moderate means is to prevent other similar persons from entering into competition with him. If they do so, he is able to threaten them with an action for infringement, and they will usually prefer to give way rather than be attacked at law. Hence the inventor should bear in mind that he can obtain a patent for anything almost that he likes to claim. If the Patent Office considers that what he claims has previously been disclosed in a British specification during the last fifty years, it will insert a reference in the specification, and this reference practically invalidates the patent to anyone who knows anything of patent law. But the patent is nevertheless granted, and the inventor may duly mark all his articles with the word ' patent ', and may threaten infringers with whatever audacity he can muster. These, if they take advice, will be told that the patent has little chance of being upheld in the Courts, but that the patentee may still cause the infringer more expense than the profits he is deriving from his infringement.

The moral of all this is that it may be better tactics to patent the obvious features of the invention most likely to be copied, even if the resulting patent is by no means strong in law, rather than the more original

feature, which may often be capable of an alternative. The real value of many a manufactured article or process often consists rather in some non-patentable neatness of design or adaptation, than in the principle.

The various committees and commissions which sit from time to time to consider English patent law, only to recommend changes in some of its less objectionable features, while carefully avoiding the main issue, are fond of advocating the establishment in England of the German *Gebrauchsmuster*. This is less than a patent and more than a design in the English sense. The registration of a design in England is not of the slightest value from a technical, but only from an artistic, point of view. The Courts will decide against anyone who produces a design obviously calculated to be very similar in appearance to a registered design, but they will not protect an original design in the engineering sense of the word. An engineering design, if copied, is not copied with a view to deceiving the purchaser, or to producing the same effect on his eye, as may be the case with, say, wall-paper. A good engineering designer brings together a number of known devices in a way which may be quite new, but which nevertheless does not constitute an invention. As the reader will learn if he studies the books referred to at the end of this chapter, invention is only held to exist in a combination of known devices when the result of the combination is more, or other, than the sum of the results of the individual parts. On the other hand, valuable ingenuity may be displayed in design, and some protection should certainly be afforded to designers, though of course they hardly merit the same protection as is afforded to an invention in the true sense. The reader

will readily think of examples of design in daily life; thus in furniture, clothing, kitchen utensils, heating and cooking devices, it is quite customary to combine several functions in one article. In England, of course, designers quite regularly apply for and obtain patents for these articles, but the validity of such patents is more than doubtful. As matters stand, however, such patents are generally worth the money, for they do actually serve to deter others from copying the design.

The inventor should never forget that a registered trade mark may be of the greatest value, especially if it is skilfully chosen. If an article becomes very popular, the public soon begin to use a registered name as an equivalent to the article, especially if the latter is of a novel description, and has no easy and natural colloquial designation. Famous cases are the words 'tabloid' and 'kodak', which have become so familiar as almost to cause embarrassment to their owners; for these are now obliged to lodge a formal protest whenever the words are used as the equivalent of 'small drug tablets' and 'hand camera' respectively.

The Trade Marks Branch has a curiously humane practice of intimating to applicants, free of all charge, whether a name proposed as trade mark is likely to be accepted. The reader is advised to make full use of this provision, for the art of devising a trade mark consists in making it as nearly descriptive as possible, while the law lays down that descriptive trade marks are not registrable. It has been found impossible to carry out this provision very strictly, as the reader will gather from the many well-known trade marks which are descriptive at least to the educated. Thus Dean Inge coined the word 'bungaloid' as descriptive, and it has

now passed into the language, but the word ' tabloid ' was admitted to registration.

If some of the above remarks may have seemed to reflect unfavourably upon the patent law, let us say that no reflection is intended upon the Patent Office. The inventor will find the treatment he receives from the Patent Office Examiners helpful and considerate in the highest degree. Both in this country and abroad they are readily accessible for personal interviews, and very often no more useful step can be taken than to seek such an interview, and explain the matter thoroughly to the Examiner. This should of course be done in the company of the agent, if one is employed, but if the inventor is prosecuting his application alone, he will receive invaluable advice, especially if he himself behaves in a reasonable and considerate manner. Inventors, unfortunately, are not as a class over-endowed with either of these qualities, and the writer has often had to blush for inventors who have expressed their firm belief in the venality, stupidity, and even senseless hostility of an Examiner. In past chapters emphasis has been laid upon the fact that the inventor should exert himself to the utmost to acquire the power of explaining to others what he is doing, and what he is aiming at. This is very often extremely difficult for a person accustomed to thinking rather than explaining, but he should remember that it is ultimately necessary for him to explain his invention not only to a Patent Office Examiner, but to the world at large, and that the Examiner may therefore be a useful object to practise on at the start.

The preparation of patent drawings is sometimes a matter of great difficulty and labour, to an unpractised

person, and it may be well to mention that in the neighbourhood of the Patent Office are several firms which specialise in making drawings on lithographic stone, of which they will then supply, at a very reasonable rate, as many copies as are required. Their draftsmen are of course fully aware of all the regulations to be observed, and the drawings are prepared in such a way as to be suitable for foreign as well as British applications. Copies of these drawings on ordinary paper often prove very useful in all sorts of ways. With simple devices these drawings may be of the nature of perspective representations, and may then be employed at the start in connection with directions for use of the invention and so on. Since this chapter is not intended to serve as a substitute for the books referred to at the end of this chapter, we will leave the subject of advice to inventors, and turn to that of advice to legislators, with which we will conclude this book.

Patent law is only one branch of the law relating to the protection of what is called in German *geistige Eigentum*, which is imperfectly translated in English by 'intellectual property'. If anyone makes a concrete object, whether from bought raw material or from material obtained from Nature without cost, the object belongs to him absolutely. The law of intellectual property is a late development of civilisation, and is based on the principle that an intellectual product (and, in this, artistic product is also included) should also be the property of its maker. It might thus be supposed that with a recognition of this principle, the law would proceed to apply its ancient methods, perfected in dealing with physical property, to the protection of intellectual property; but this has never been

done in any country. Whereas an appeal to the nearest policeman is possible if a thief takes away a physical object belonging to anyone, and even the theft of electrical energy, although not material in nature, is punishable as a crime, the criminal law does not apply to the theft of intellectual property. For instance, a word-for-word reprint of a copyright book only lays its maker open to a civil action from the owners of the copyright, and if the pirate has made heavy profits out of his piracy, he nevertheless cannot be punished in any way if he succeeds in spending or otherwise disposing of these profits before judgment is given against him, unless he has other assets which can be impounded. In the case of firms, judgments exceeding their available resources are regularly evaded by liquidation, their assets being taken over, often very advantageously, by a new firm formed by the same shareholders, while their liabilities are wiped off.

Thus, whatever the value of the intellectual property, it is in no way protected unless its owner is sufficiently well endowed with means to take action in the High Court, for no lower Court entertains such actions. As regards patents, the state of the law is still less favourable. There is no difficulty in producing *prima facie* evidence in the case of infringement of copyright of books and pictures, and hence an injunction can be obtained at no very great cost. It might be supposed that the same would be true in the case of patents. The inventor receives from his Sovereign a statement that he is given the sole right to " make, use, and vend " his invention, as described in a certain specification. Nevertheless, if he goes to the Courts with this document, and asks for immediate remedy against an

infringer, his chances of obtaining it are very small indeed. The Courts know full well that the chances of the patent being valid in law are equally small, and hence the preposterous state of affairs has come about that the King's Courts may refuse to recognise the King's fiat. The applicant for an injunction is required to furnish a *prima facie* case for his patent being valid.

The Courts themselves are historically responsible for this state of affairs. The intention of the original Statute of Monopolies was that a person benefiting the community by starting a new industry should be encouraged by the grant of a limited monopoly. But about the same time, the entirely different matter of the protection of intellectual property began to acquire actuality for the legal mind. Most unfortunately, the *inventor* was assumed to be protected by the Statute of Monopolies, and hence was left out of account in the development of the law of copyright. The Courts proceeded to interpret the wording of the Statute of Monopolies in an entirely different sense from its original sense, thereby leaving the enterprising *manufacturer* entirely unprotected.

A contributing cause to this was no doubt the way in which the Crown dealt with the powers conferred upon it by the Statute of Monopolies. If such a Statute were passed to-day for the first time as a constructive Act, and not for the removal of abuses, there can be little doubt that it would be carried out by an office set up for that purpose, and with as much strictness as is observed to-day in granting the Royal Warrant to a tradesman. The Royal Warrant conveys no monopoly; it is merely a recognition of excellence. But it is never granted to any firm not of first-rate standing,

nor is it transferable, even to " successors and assigns ". It cannot be doubted that similar conditions would attach to a grant of monopoly, if such were a new thing to-day. Any less degree of scrupulousness would rightly be regarded as liable to bring the Crown into contempt. Only custom allows us to tolerate the present state of affairs, in which certainly the majority of patents would not stand the scrutiny of a court of law, and are effective, when at all, only because no one dares to challenge them.

The result of this fact is far from favourable to the inventor. In order to develop and market his invention he requires finance, and it is usually a very easy matter for those who provide him with this to acquire either absolute property in, or monopolistic rights over, the patent. It is a notorious fact that the original patentees of most successful inventions derive little or no benefit from their success. This success is, of course, by no means due solely to the inventor. A very large part of it is due to the overcoming of all the difficulties inherent in successful manufacture and marketing, and for this reason the business man, never at any time liable to give for a thing more than he is able to get it for, feels entirely justified in taking every advantage that he can obtain for himself. It is foolish in considering this subject to ignore average human nature. It is certainly a fact that if an inventor succeeds in making a good royalty agreement, and then meets with unexpected success, the large sums which he draws are frequently regarded by the business management of the firm as an entirely unjustifiable tax on their business imposed by a private individual, a tax which may therefore be evaded with even greater moral justifica-

tion than the income tax, by every means which a good solicitor can suggest.

Since it has been said by high and serious legal authorities that a patent in itself is little better than a lottery ticket, the above point of view receives a further justification, for the position of a financially successful inventor in the world as it is to-day, is almost exactly equivalent to that of the winner of a sweepstake. Since the majority of inventors get nothing at all, a fair reward obtained by the lucky exception appears monstrously in excess of that suited to his social status. Not only the inventor, but everyone else connected with patents, really suffers from this absurd state of affairs. First of all, anyone who lends financial support to an inventor in return for a share in the proceeds is liable to suffer together with the inventor. He is thus indulging in a very highly speculative use of his money, and would be much better advised to use it at Monte Carlo, or in some similar form of speculation. This fact excludes almost entirely even persons who are willing to use their money in a sound but highly speculative proposition. For this type of person relies upon his judgment, and hence avoids speculation in which the element of judgment can play but a minor part : sheer lotteries and games of chance, in other words.

The field is thus left open to the thoroughly unsound promoter, who is able to take advantage quite unscrupulously of all the features of the situation.

We have already tried in this book to put the inventor on his guard against this type of promoter, but as matters are to-day it is very doubtful whether the best advice is not simply to take this advantage of

getting some return at least for the labour spent. However, there is no great actuality in this advice, for the unscrupulous promoter prefers for his purposes unsound inventions, which must be of such a character as to appeal to the ignorant public by their extravagant claims, and at the same time so vague that serious technical criticism of them is not possible.

We may now turn to another aspect of the patent law which makes its working under modern conditions very unsatisfactory. Master patents, that is to say patents in which a new principle is justifiably claimed, naturally become rarer as time goes on. It is perhaps not too much to say that the essence of a modern inventor's work is rather the perception and correct formulation of a problem and of the commercial characteristics necessary for a successful solution, the solution being hypothetical for the moment. If work is begun on this basis by a man of sufficient technical acquirements and capable of inventive thinking, the result will normally be a number of alternative solutions of the problem, each embodying sufficient invention to constitute a valid patent, and yet not all of them capable of being drawn together under one single principle as a master patent. It will probably be impossible to state beforehand, and even after quite a great deal of practical experience, which solution is most likely to be finally adopted. The final adoption will depend upon very many factors, of which technical efficiency and cost of production will be only two. It is naturally desirable and fair that such an inventor or combination of inventors should be protected, not only as regards the methods which they actually adopt, but also as regards those which they have discovered and

are holding in reserve ; but if they are to obtain this protection all over the world they have to multiply their costs many times, and this is usually prohibitive.

For apart from everything that we have said, the business of invention would be a very speculative undertaking even if the inventor were sure of an adequate reward in every case where his invention became practically adopted. If we take any practical problem of importance, such for instance as metering electricity, we find that there are a number of fundamental possibilities of solution ; and in the particular case taken an enormous amount of work has been done in the past fifty years or so, on at least a dozen lines entirely different in principle. The electricity meter is only now becoming a standardised article, and a large number of types which at one time were in use are now no longer represented in any way.

What has been said of the inventor and his insecurity, applies also to the manufacturer who has become the licensee or proprietor of a patent and has founded upon it a flourishing business. The original intention of the Statute of Monopolies was to encourage such a person by giving him real security so that he could look ahead and not be afraid of investing money in enlarging his business. As things are, that business is now, as far as patent protection is concerned, subject to all the uncertainties attaching to patents. Quite commonly, he may have built it up from small beginnings, and be selling in a field in which he is in competition with a single large monopolist concern, and with nobody else of consequence. As long as he is struggling, the monopolist concern does not need to notice him. When he is successful, it does not need

to acquire his business in order to do what he is doing, as it might do if other large rivals were present. It may safely infringe his patent, and if it is fought and finally beaten, it will have suffered no other disadvantage than paying a part of the inventor's law costs.

It appears to the writer that there is no remedy for the present state of affairs other than a drastic change of policy. The policy proposed is that the inventor, and those who back him financially, should be called upon to record faithfully their experimental work and expenditure from stage to stage, and that in the event of new technical development demonstrably based on their work being financially, or even technically, profitable, in the hands of any person or company whatsoever, they should have an easy and cheap means of putting forward a claim to a moderate royalty. This claim would probably be made from several sides, and in this case the royalty would of course be divided as equitably as possible. These rights would be inalienable ; they would, in fact, not exist in a tangible form, until actual practical success were obtained by someone.

We have of course an excellent illustration of what has been said in the development of the film, the wireless, and their joint product, the talking picture. The fundamental development of the modern talking picture has been due to a number of inventors, chief of whom are the Englishman Lauste, and the Germans Vogt, Engel, and Massolle. None of these persons, nor numerous others who have made contributions of importance, have at present any financial interest, other than a salary at the best, in the vast and world-wide success of talking pictures, while huge concerns have acquired patents of fundamental importance filed by

them and others, and have either fought or made peace with a view to sharing the enormous profits derived from this industry. It may be said that this is the fortune of war, and that such things have always happened. The man who financed James Watt in his first experiments with the steam-engine was bankrupted as a result, and I am not aware that he ever received any reward.

The second proposition is that a grant of monopoly should be made to any manufacturer who definitely sets out with adequate means to found a new industry. This monopoly should be hedged round with very strict safeguards, and should protect him as regards a certain manufacture or process, and all closer equivalents, but not as regards alternatives based upon different principles. Such a monopoly should not be granted to anyone not of the standing of a tradesman receiving the Royal Warrant, nor to anyone not possessed of the necessary means for supplying the public demand. It should be for a very short term, say three years, but renewable up to sixteen or so. The result would be to encourage the investment of money in new industries to an enormous extent, for the grant of monopoly would carry with it a guarantee to an investor that he was dealing with serious and respectable persons, and not with such types as ruined the market for all new inventions in 1928 to 1929, by unscrupulously floating companies based upon entirely unsound schemes. It would be carefully emphasised that the grant of monopoly carried with it no promise of financial success, but only a guarantee that the invention or process actually existed in a marketable and workable form, and that means were available for prosecuting the

business. It has been objected to these suggestions that a change in the English law is not possible without agreement with foreign countries. The writer does not believe this to be the case. It is obvious that the rights attaching to an inventor's priority may be made inalienable, as has indeed been done in Austria; while the compulsory working and compulsory licence provisions which exist in this country as well as many others, would make it possible for any persons desiring the grant of a monopoly involving the use of the patent to obtain the use of the same.

On the other hand, before the grant of monopoly was made, the Patent Office would examine the applicant's specification of what he was proposing to do in much the same way as it now examines any specification, and would then notify him that it had found certain prior specifications which seemed to indicate invention leading up to the result about to be worked by the applicants for monopoly. These patentees would be notified by the office receiving the application for monopoly, and at the same time this application would be advertised, so that other persons claiming to have contributed to the result would be able to notify their intention of making a claim. All these claims would then be put forward to a referee, of the highest technical capacity, in the form of statements of the actual work done, result attained, and money expended, together with the source of the latter. Meanwhile the monopolist would receive his grant, with instructions to reserve, say, a 10 per cent royalty for division among claimants, and as soon as might be the referee would give his decision, stating in what proportion he considered it fair to divide the 10 per cent royalty among the applicants.

It is impossible in the compass of this book to consider all the objections which are likely to be raised against this scheme. As regards the expense, we should not be dealing with the grant of an ordinary patent, but with a really valuable grant, for which a fee many times greater than a patent fee might well be demanded by the Crown. The more serious objection is the difficulty of drawing up instructions to the referee as to what he is to take into consideration. In the first place, it would be necessary to exclude from reward all but living persons. Then a claimant for a share would certainly have to show that he was working with an aim fairly close at least to the object attained by the monopolist. This would exclude entirely the reward of inventions and discoveries which had been made with an eye to entirely different objects, while it would enormously encourage all workers to think and test out the utility of their results in fields other than those in which they obtain them. We have stressed earlier in this book that modern technical advance very much depends upon this application of discoveries in fields apparently in no way related.

I think it would be reasonable also to consider to some extent the fortunes of the claimants. For instance, if a monopoly for sound-on-film talking pictures had been applied for in England, it is very possible that Edison as well as Lauste might have had some justification in putting forward a claim to reward. The same might also be said of large firms such as Siemens-Schuckert, and some American concerns, which had been responsible for the development of valves in circuits used in the final results. But if it could be shown that their work in these directions had already met

with financial reward, whereas that of Lauste and the German 'Triergon' trio had been practically unrewarded, these would clearly have the greater claim.

It should be noted that we have had some experience of reward of invention by committees in respect of inventors whose work was made use of during the war. There has been a good deal of grumbling about the awards, but much of it refers to matters which would not arise in the case I am considering here.

The greatest objection of all is that those who could afford first-class legal assistance would fare a great deal better than those whose funds did not permit of it. It is a deplorable fact that the majority of people are so badly educated, that they are quite unable to state a set of facts clearly and simply. As long as we are willing to tolerate this, we shall find ourselves maintaining a very highly paid set of men (and women) whose business it is to state them for us, and who make the matter all the more difficult by clothing it in formality. In the case we are considering, the award is to be based upon published matter, and no other, and the decision would of course be given by a man trained in the technical field of the subject at issue. All he would have to do would be to say whether any given person's published work represented a definite contribution or not.

We may conclude our survey by a consideration of the question whether anything can be done by the State to encourage invention, beyond arranging matters so that it has a considerably better chance of securing fair reward. The answer, the writer believes, is in the negative. If legislation were passed which secured to inventors and their backers a due share in the event of financial success, private enterprise would do the rest.

More, and above all more interesting, papers would be read; invention would approach pure science in the freedom of publication of ideas and results. Healthy and well-informed criticism would be plentiful. At present such a state of affairs obtains only inside a few (and the most successful) large research laboratories of big concerns; and such institutions need an Abbé, a Whitney, or a Mees at their head to maintain a high level of interest and enthusiasm. But outside, the corresponding stimulus would be supplied by rivalry in reputation. Mr. Wells has often laid stress upon the fact that capitalist competition (as he supposes) deprives the technical research worker of free interchange of discussion and criticism, and thus acts against progress. The suggestions I have put forward would remove this drawback; at the same time, the incentive of profit would remain for the enterprising capitalist. Technical progress depends, after all, largely upon the survival of the fittest among various alternative methods of accomplishing technical ends, and a system of free economic competition is the most effective basis for determining fitness.

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INDEX

ABBE, 130, 254
' Actors ' and ' reactors,' 24
Adrenalin, 219
Advertisement, effect of, 175
  Inventions connected with, 183 ff.
  Use of film for, 184
Agreements, rules for making, 91
Airplane, 45
Alcohol from waste, 207
  Mental effect of, 225
Algae, 220
Alloys, 111
Alpha-ray counter, 162
Alternative methods, 247
American patent practice, 233, 236
Ampère, 58
Animals and man, intelligence of, 1 ff
Animals, breeding of, for intelligence, 221
  Breeding of, for blood-lust, 223
  Learning of habits by, 10
Anthracite briquettes, 67
Antiseptics, 227
Arkwright, 103
Art, creation in, 3
Aston, 36
Atom, disintegration of, 133
Automatic camera, 173
Automatic control of apparatus, 162

BAEKELAND, 45, 48
Baird, 163
Bakelite, 45, 142
Bergius' hydrogenation of coal, 45
Berblinger, 104
Bessemer, 100
Biologists and physicists, 216
Biology and invention, 7 ff., 216 ff
Black Death, 221
Blood-lust, 223
Bohr, 36
Broadcasting, 170
de Broglie, 16, 36
Brown-Boveri (Velox boiler), 190
Brown pickup, 157
Bunsen, 35
Business, essential principles for success in, 90
Business man and inventor, 77 ff.
Butler's *Life and Habit*, 13
  Erewhon, 173

Cactoblastis cactorum, 223
Calcium carbide, 45
Campbell's homes for bats, 223
Carborundum, 45
Case-hardening, 45
Castings, 122
Cave, 163
Chanute, 104
Charlatans, ' inventions ' by, 106
Chemical engineering and mechanics, 102
Chemical invention, 131 ff.
Chromosomes, 218
Cinema projector, 63, 109, 184
Cinematography, invention of, 105
City and invention flotations, 108
Civilisations, rise and development of, 11
Clark, 35

Claude-Boucherot sun-heat plant, 204
Clerk, Sir Dugald, 34
Clothing, inventions relating to, 180
Coal-dust engines, 193
Coin-freed mechanism, 179
Cole, 163
Colour films, 183
Complete specification, 233
Conditioned reflex, 10
Conquest of Thought by Invention, 30, 55
Constantinesco torque-converter, 64 ff.
Coolidge tube, 45
Copley medal and inventors, 34
Copper oxide rectifier, 167
Copyright law, 243
Corporation research, 37, 44 ff.
Corrosion, 135
Courts of law and invention, 4 ff.
Cosmetic inventions, 154, 183
Creative ability, 3
Crookes, 36
'Cross-fertilisation' in invention, 100
Cyanide process for gold extraction, 153

Daedalus, or Science and the Future, 215
Darwin and origin of species, 8, 9, 216
Davy, 26, 34
Designs, registration of, 239
Developmental mechanics, 227
Dewar, 35 f.
Dial telephones, 45
Diamagnetism, 160
Die casting, 128, 144
Dielectric separation, 152
Diesel engine, 45, 188, 191
Dirt, protection of mechanism from, 121
Doctor's Dilemma, The, 30
Domestic 'gadgets,' 176
Double-entry book-keeping, 170
Drafting specifications, 235
Dunne's *Experiment with Time*, 20

Earth, internal heat of, 209
Ectogenesis, 216
Edison, 25, 31, 48, 60, 169
Educational films, 109
Efficiency of engines, 188
Ehrlich, 227
Einstein, 36, 47, 158
Einthoven, 217
Electric car starters, 45
  Invention, 156 ff
  Power station, creation of, 12
  Train control, 45
Electro-chemistry, 166, 202
Electroculture, 226
Electron diffraction, 160
Electrosmose, 133, 144
Encouragement of invention, lack of, 51
Energy, storage of, 200 f
  Transformation of, 187 ff
  Transmission of, 194
Eskimo and mechanism, 14
Explosives, 212

Factors of heredity, 218
Fallacious inventions, 210
Faraday, 26, 35, 103, 158
Fast-moving mechanism, 122
Ferranti, 105
Film, invention of talking, 249
  Use in education, 109
  Use in advertising, 184
Financing inventions, 77 ff.
Firms, attitude towards invention of large, 82
Flea, disappearance of, 222
Flotation process, 45
Foreign patents, 234
Form groups, 13
Franklin, 34
Free, 7
Freudian 'censor' and invention, 19, 72
Friese-Greene, 105
Fuel Research Board, 194

GALILEO, 15
Games, 177
Gandhi, 56
Gas reactions, 166
Gas turbine, 190
Gaslight papers, 45
Gaumont, 105
Gauss, 34, 58, 158
Gebrauchsmuster, 239
Geistige Eigentum, 242
Geitel, 216
Genius in pure science, 36
Genetics, 218
German patents, 236, 238
German technical books, 155
Ginn, 211
Goodyear, career of, 38 ff.
Government, modern methods of, 185
Gramme, 103
Gramophone, 211
Grid system, electrical, 194
Grosvenor, 45
Gyro-compass, 45

HABER'S SYNTHESIS OF AMMONIA, 45
Haldane's *Daedalus*, 215
Half-watt lamp, 45
Hayward, 40
Heat engines, 188
Heath Robinson methods, 185
Heisenberg, 36
Higgins' Naphthol AS process, 140
High and low price markets, 177
Hope-Jones organ, 212
Hormones, 219, 224 ff.

INDIVIDUAL INVENTION, success of, 45
Industrial civilisation, defence of, 52 f
Infringement actions, 238
Initiative of inventors, 25
Insight and invention, 59
Institute of Patentees, 94
Intellectual property, protection of, 242 f.
Intelligence, improvement by breeding, 221
International Patent Convention, 232
Invention, legal view of, 4
By living creatures, 7 ff

KELVIN, 25, 33 ff., 35, 48
Kettle, whistling, 172

Lancet, 217
Leonardo da Vinci, 32
Le Roy Emmet Mercury Turbine, 191
Lister, 34
Loffler boiler, 192
Loud speakers, 211
Lubrication, elimination of, 126

MACKINTOSH, 38
Magnetic separation, 152
Malaria parasite, 220
Malone engine, 194
Manteucci, 35
Marconi, 105
Mass spectrograph, 36
Master patents, 247
Mathematics, 158 ff.
Meccano, 178
Mechanism, 114 ff.
Medical invention, 217
Mees, 254
Mendel, 216
Mercury vapour turbine, 191
Metering electricity, 248
Michel engine, 194
Microphone, 173
Mond nickel process, 153
Monomaniac pioneers, 36
Monopolies for manufacturing, 250 f
Statute of, 4, 230
Monotype, 45
Mordey's magnetic experiment, 134
Morse, 103
Mosquito, extermination of, 223
Motor-car, 36
Moulding articles, 141 ff.

Moving pictures, 45
Mutation, 9, 219

Newton, 58
Nicholson, 190
Noise, reduction of, 181
Nollet, 35
Nuts and screws, 128

Ore-dressing, 152 f
Organ, electric, 212
Originality, early signs of, 58
Origin of species and invention, 8 ff
Osborne Reynolds, 190
Ozone, 166

Packing machines, 72
Papin, 50
Parsons, 192
Partner, inventor's business, 109
Pasadena sun-ray boiler, 203
Patents, law of, 4 ff., 230 ff
Pathé, 105
Patterns for casting, experimental, 122
Pencil sharpener, 68
Perpetual motion, 209
Pestology, 221
Petrol, purification of, 87
Phagocytes, 221
Photochemical energy generators, 206
  Reactions, 167
Photoelectric musical instruments, 212
  Photometer, 167
Photography, uses of, 172
Photogravure, 45
Pioneer invention, 37, 105 ff
Pixii, 35
Planck, 36
Plastics, 143 ff.
Pneumatic tire, 105
Pressings, 122
Prickly pear, 223
Provisional specification, 75 f, 232 ff.
Psychological inventions, 169 ff.
Publication, 95
Publicity and progress, 113
Pure scientific research, 36

Rabbit plague, 221
Recording instruments, 111
Remedies for inequity of patent law, 249 ff.
Research Associations, 95
  Laboratories, 46
Reward of inventors by commission, 252 f
Rockets, 213
Rosse, 34
Royal Society and invention, 34 f.
Royal Warrant, 244
Rubber, Goodyear's work on, 40 f.
  Use of latex, 139
Rumford, 34
Rutherford, 36, 47

Safety devices, 182
Safety razor, 45
Sahara, sun's energy received by, 203
Savonius rotor, 198
Saxophone, 179
Schrodinger, 36
Sea, utilisation of heat of, 203
Selling cost, 174
Severn barrage, 196
Sewing machine, 36
Sex hormones, 226
Shannon scheme, 196
Shaw, 30
Siemens, 25, 35, 103
Sintering powders, 147
Sleeping sickness, 220
Small mechanisms, 124 ff.
Smeaton, 34
Sodium, storage of energy by, 203
Solvents, 136
Specific chemical germ-killers, 227
Spengler, 113

State encouragement of invention, 253
Steam engines, 188
Stevenson's ship signalling apparatus, 164
Still engine, 191
Stringed instruments, 180
String galvanometer, 36
Structure, molecular, of materials, 146
Styles of technical invention, 101
Submarines, 45
Sugar 'purifying' machine, bogus, 107
Sun's energy, utilisation of, 203
Superconductivity, 168
Sykes, 105
Syphilis, 220
System, inventions dealing with, 170

TALKING FILM, 249
Technical progress, limit to, 112
Telephone, 36, 129
  Automatic, 161
Television, 45
Textile machinery, 119
Thermodynamics, laws of, 188
Thermopile worked by sun, 207
Thermostat, 105
Thomson's pneumatic tire, 105
Toys, 178
Trade marks, registration of, 240
Triode valve, 45
'True and first inventor,' 231 ff
Turbines, 188 ff.
Turbinia, 192
Turner's *Wireless*, 168
Two-stroke engine, 194

UNCONSCIOUS AND INVENTION, 10
Universities and invention, 56 ff
Urine, extraction of hormones from, 226
U S A. patents, 233, 236

VACUUM CLEANER, 176
  Flask, 36
Van Malderen, 35
Varley, 35
Velox boiler, 190
Vitalism and invention, 22
Volta, 34
Vote recorder, 176

WAGNER, 3
Ward, 163
War inventions, 213
Water-power, 187
Water softening, 119
Watt, 188, 250
Wear in mechanism, 117
Weather, protection from, 135
Welsbach mantle, 149
Wheatstone, 35
Whitman, 53
Williams, 163
Wilson gear, 65
Wind-power, 200 ff.
Wireless, 45, 110
Working out inventions, 71

X-RAYS AND MUTATIONS, 219
X-ray tube, 36

ZEISS, 130
Zinc chloride, storage of energy by electrolysis of, 202

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