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Man *and Dolphin*

Man *and* *Dolphin*

John C. Lilly, M.D.

Illustrated with photographs

Doubleday & Company, Inc.

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To Elisabeth Christine Bjerg Lilly

Her devotion to this program and its realization is second only to her loyalty and her love for her family.

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Preface: A Prediction

WITHIN the next decade or two the human species will establish communication with another species: nonhuman, alien, possibly extraterrestrial, more probably marine; but definitely highly intelligent, perhaps even intellectual. An optimistic prediction, I admit. In this book I have summarized the basic reasons for my beliefs and presented some evidence for the validity of the prediction. In a way this is a crude, elementary handbook for those humans who are interested in the realization of such communication. If no one among us pursues the matter before interspecies communication is forced upon *Homo sapiens* by an alien species, this book will have failed in its

purpose. But if this account sparks public and private interest in time for us to make some preparation before we encounter such beings, I shall feel my time was well spent in the research here described.

I assume that those who first heard me present this thesis publicly and those who first read of it in the news, know that I assume full responsibility for it —no pseudo modesty or fear of sticking out my vulnerable neck forces me to hide behind either colleagues or institutions, ancient or modern. Of course, as is often the case, the substance of my prediction may turn out to be correct but the time estimate may be substantially incorrect on either the high or the low side. If it turns out that I am wholly incorrect, I shall remember that in research of the best scientific sort no experiment is a failure: even experimental disproof of a thesis turns up new and valuable information.

If and when interspecies contact is made, it may be used as a force for peace or as further aid to warfare. It may be that we shall encounter ideas, philosophies, ways, and means not previously conceived by the minds of men. If this is the case, the present program of research will quickly pass from the domain of scientists to that of powerful men and institutions and hence somewhat beyond the control of the first venturers. When that time comes, I hope that the ideas

here presented will help those men of good will to lead wisely and that they will be a bit better informed than they were in 1945 concerning another scientific advance, that time in applied nuclear physics.

Man *and Dolphin*

Lewis Carroll:
Alice's Adventures in Wonderland

. . . the Mock Turtle sang this, very slowly and sadly:

"Will you walk a little faster?" said a whiting to a snail,
"There's a porpoise[1] *close behind us, and he's treading on my tail. . . ."*

. . . said Alice . . . "I'd have said to the porpoise, 'Keep back, please! We don't want *you* with us!'"

"They were obliged to have him with them," the Mock Turtle said. "No wise fish would go anywhere without a porpoise."

"Wouldn't it, really?" said Alice, in a tone of great surprise.

"Of course not," said the Mock Turtle. "Why, if a fish came to *me*, and told me he was going on a journey, I should say, 'With what porpoise?'"

"Don't you mean 'purpose'?" said Alice.

"I mean what I say," the Mock Turtle replied, in an offended tone.

[1] Undoubtedly *Phocaena*, the true porpoise, not the dolphin, *Tursiops*, of this book. J.C.L.

CHAPTER ONE

The Possibilities of Interspecies Communication

EVENTUALLY it may be possible for humans to speak with another species. I have come to this conclusion after careful consideration of evidence gained through my research experiments with dolphins. If new scientific developments are to be made in this direction, however, certain changes in our basic orientation and philosophy will be necessary.

We must strip ourselves, as far as possible, of our preconceptions about the relative place of *Homo sapiens* in the scheme of nature. Past scientific advances have clarified and gradually delimited the place of mankind as the chief species in terrestrial, land-borne nature. If we are to seek communication with other species we must first grant the possibility that some

other species may have a potential (or even realized) intellectual development comparable to our own. We cannot continue to insist that man is at the top of the evolutionary scale and that no further evolution is possible. This vain assumption may be preventing certain kinds of valuable research.

Granting that there may be a species as high on the evolutionary scale as man and that we have the technical qualifications to do the research, what characteristics should we look for in another species? We can make an estimate on the basis of our own experience with members of our species. First of all, who are our failures and why can't they communicate? Who in the human species does not possess "intraspecies" language?

The newborn infant obviously cannot speak. As his brain grows and through experience with other human beings, he gradually accumulates language. But for certain children with inherited deficiencies of brain structure, even age and opportunities for learning do not necessarily lead to the development of language. Sometimes, apparently, the brain just stops growing, and if the brain is too small—if it does not have enough cerebral cortex—full human language is impossible. Among some microcephalics, for example, language is not developed to the complex level on which we are accustomed to deal with our fellow men. These considerations suggest that the size and com-

plexity of the brain may have a great deal to do with language capability. So the first thing we should look for in any species with which we may try to communicate is a brain comparable in size and complexity to the human brain.

Having found such a species, we should attempt to determine whether its members have an intraspecies language. If we do not know that one exists, what anatomical and social conditions are most likely to make the existence of such a language highly probable?

Next we should determine whether individuals of the nonhuman species can be taught a human language. In our present state of ignorance we tend to think that if an animal has his own language he may be able to learn ours more easily. This isn't necessarily so; our language may be so strange to the animal that he would have to start over, and he might not be able to do this. And if he has no language at all but, like the human child, has the potential ability to learn ours, he might learn faster and more easily without the hampering influence of a previously learned language.

There are certain basic qualifications that we can apply to our search for a species with which to attempt communication. Because we are treading very close to the edge of the unknown, we must necessarily be tentative and suggestive, rather than defini-

tive. Until we have progressed much further in our scientific research program we can only single out what we think are the probabilities from the vast array of possibilities.

As I have said, we should choose a species with a brain equal to ours in size and complexity. No interspecies communication has been achieved with primates having smaller brains than man's. Dedicated attempts to teach chimpanzees to speak have led to failure of two-way communication—presumably because of the animal's failure to transmit. The size of the chimpanzee's brain (375 grams) is about one-fourth that of the adult human (1450 grams) and less than half that of a human child who is learning to speak (1000 grams). (See Appendixes for details.) If we choose a species with a brain much larger than ours, the mental processes may turn out to be too alien for us to understand and we would not be able to establish communication. And if the brain deviates too much from ours in complexity, the mental processes may likewise turn out to be too alien for us to encompass.

At least some resemblances to our anatomy and physiology are desirable if not essential. Our difficulty will increase radically if the external appearance of the animal is too different from our own and if the environment in which the animal lives is too foreign to us. A nonmammal like the giant squid might be

too much for our present abilities and understanding. The giant squid breathes water, cannot live in air, is nocturnal, lives deep in the sea. Such alienness and strangeness make the initial difficulties of dealing with the animal extremely great. On this score we can eliminate whole orders and even phyla of animals on our own planet as inappropriate. All of the invertebrates, all of the Protozoa (single-celled animals) and the Metazoa (sponges, etc.) can be eliminated. The only group sufficiently close to us to warrant beginning the program are the Mammalia.

If we eliminate all mammals with smaller and less complex brains than ours, we must cross off the list all of the anthropoid apes and most of the other primates, all of the carnivores (large cats) and the ungulates (horses, cows, etc.). Two groups of large animals are then left: whales and elephants.

Adult elephants have brains up to four times the size of an average adult human brain; modern whales have brains up to six times the size of ours. Some smaller whales—dolphins and porpoises—have brains about the size of ours. The brain of the bottle-nosed dolphin (*Tursiops truncatus*) is about 1700 grams, ours is 1450 grams; the relative brain weight per unit body length of the dolphin is about 200 grams per foot for our 240 grams per foot.

The animal we choose must not be too large. There are obvious technical difficulties in dealing with

either a land or a sea-borne animal that weighs more than about five hundred pounds. The slightest misunderstanding with a very large animal might lead to destructive action on one side or the other. The whole relationship of the human group working with such animals could be changed by one episode in which a human was injured. An animal that is too large is not apt to realize how weak the human may be and how easily he may be hurt or even killed. This qualification eliminates the large elephants and the larger whales from consideration.

A further requirement is that it should be possible for a kindly relationship to exist between man and the animal chosen. By this I mean bilateral kindliness. Such a relationship would not be possible, for example, between most lions and man (however, see *Born Free* by Joy Adamson for qualifications) or between most adult gorillas and man. It exists in some cases between elephants and man—the mahouts of India often have kindly relationships with their elephants. From my experiences I feel that it is possible to establish bilateral kindliness with some of the smaller whales: the bottle-nosed dolphin and *Globicephala scammoni*, one of the pilot whales.

For our convenience if not from necessity, the animal should be capable of vocalizing within the same ranges and parametric sets of variables that the human uses. In other words, it should be capable of

making *sounds* with its vocal apparatus, either in air or in another medium, which sound like human-produced sounds; at the very least its emissions should be transformable by simple methods into the acoustic range that we possess. *Homo sapiens* seems to be unique in his intimate and detailed control over the muscles surrounding his respiratory outlet—the muscles of phonation, the larynx, the naso-pharynx, the pharynx, the mouth, the lips, and the face. However, our mobility of facial expression is not an absolute concomitant of spoken language: we can still speak to one another fairly successfully over the telephone without visual aid. On this basis alone it may be possible to eliminate the elephants from consideration, although I do not know whether anyone has ever attempted to teach an elephant to vocalize in a human sort of way. This seems to be an unexplored field. My experiences with the Cetacea, or whales, have shown that they seem to be perfectly capable of mimicking human voice sounds in a primitive but possibly intelligible fashion.

The animals that best seem to fulfill all of the above qualifications are the dolphins (and possibly porpoises) and the pilot whales, both of which belong to the Delphinidae, a subgroup of the odontocetes or toothed whales. These small cousins of the killer whale range in length from five to approximately twelve or more feet.

Of the large number of such species, the shoal-water dolphin, *Tursiops truncatus,* is most readily available for study. Some specimens of the deep-sea varieties of dolphins such as the common dolphin, *Delphinus;* the spotted dolphin, *Stenella;* and the striped dolphin, *Lagenorhinchus,* are available but they are used to living in deep water and do not survive captivity in very small enclosures quite as well as *Tursiops truncatus.* The pilot whale, *Globicephala scammoni,* is finally becoming available through the efforts of a West Coast oceanarium called Marineland of the Pacific and shows a great deal of promise.

The natural habitat of *Tursiops* is the shoals bordering the continents and islands in the warm waters of the world. He has some dexterity of slow movements and a curiosity about his surroundings, including the bottom. These characteristics help in our work with him. Some of his swifter pelagic cousins are less amenable to life as captives, less flexible of body, and less curious.

Tursiops truncatus is well known to fishermen along the Florida and Carolina coasts. There is good evidence that a "harem" of *Tursiops* will help fishermen by herding fish toward their particular boats. There have been many instances of *Tursiops* pushing or urging human beings to safety after shipwrecks or in the presence of sharks while swimming off shore.

Two episodes, which I shall describe in a later chapter, seem to point to the existence of an intraspecies language.

They further fit our basic qualifications in that they are capable of vocalizing in air and are extremely quick to learn. They can put the blowhole and most of the body above the surface of the water and emit noises that one can hear up to a few feet away. If one is beached, very faint whistles can be heard coming from the blowhole. Some of these I have identified as distress signals.[1]

In recent years *Tursiops truncatus* has become the mainstay of the "porpoise" acts in at least four oceanaria in the United States: Marine Studios, St. Augustine, Florida; Marineland of the Pacific, Palos Verdes Estates, California; Seaquarium, Miami, Florida; and Theatre-of-the-Sea, Islamerada, Florida. Much evidence as to the ability to learn and to vocalize came from these oceanaria.

Over the last fifteen years it has been found at Marine Studios that the trainability of the bottle-nosed dolphin is limited partially by the ingenuity of the trainers. Punishment methods do not work very well in training these animals but rewarding experiences do. Variety in the training program is necessary. It

[1] Lilly, J. C. Some considerations regarding basic mechanisms of positive and negative types of motivations. Am. J. of Psychiatry, **115**: 498–504, Dec. 1958.

will not do to repeat the same thing in the monotonous fashion used to train a dog or other small-brained animal; three to five different things must be used in the repertory, one after the other, in rapid succession. The instant the animal performs a spontaneous play action that is new and different, he is rewarded.

Quizzing the trainers of these animals in detail, I found that they had a great deal of respect and affection for the animals. I watched the trainers at work and saw that there was a very close relationship between the individual animal and the trainer, in spite of the fact that the animal was in the water and the human in the air: each watched the other intently and minutely.

At none of the four oceanaria has vocalization on the part of the animals been used to its fullest extent. At Marineland of the Pacific there is a chorus of dolphins that respond to baton waving and to proper verbal directions by singing in a siren-like fashion. The same trick is used with individual dolphins at Marine Studios. At Theatre-of-the-Sea two dolphins have new and strange air-voices. The Seaquarium animals are also becoming more vocal in air. However, these animals emit many, many more vocalizations than are made use of in the shows.

F. G. Wood, Jr., of Marine Studios has collected

typical vocalizations of these animals in captivity and has published a description of them.[2] They emit whistles, creaking-doorlike noises, barks, grunts, rasping noises, etc. One great difficulty in dealing with these sounds is that they are emitted under water and the transmission of sound from water to air is extremely poor. In order to hear them well one must use a hydrophone or put one's head far enough under water so that it comes up against the tympanic membrane of the ear. Sounds are also transmitted very poorly from air to water, as any skin diver knows. At these oceanaria there has been very little attempt to make conscious use of any sort of exchange of sounds between animals and humans. In fact, when the animals are trained to vocalize at all, each animal puts its blowhole out of the water and emits the sounds in air, rather than under water as he is accustomed to do. They accommodate to us rather than we to them.

The great difficulty in developing a type of vocal communication between man and these water-borne mammals that are used to living and communicating under water is obvious. We speak in air, we hear best in air. Speaking under water is a difficult feat for us. The dolphins seem to be a bit ahead of us: they can

[2] Wood, F. G., Jr. Underwater sound production and concurrent behavior of captive porpoises, *Tursiops truncatus* and *Stenella plagiodon*. Bull. Mar. Sci. Gulf and Caribbean, 3 (2): 102–33, 1954.

also vocalize in air. Their natural air-borne sounds are not very loud, not as loud as ours, except with training. Apparently they hear but poorly in air, but nobody has yet measured how badly their hearing suffers in air as opposed to their hearing in water, which is excellent. Therefore, in order to meet these animals more than halfway, we must devise a technique of speaking under water and a technique so that when we are in air and they are in water we can hear them "speaking" under water and they can hear us speaking in air. This can be done with hydrophones, with underwater loudspeakers, and with appropriate electronic apparatus.

In other words, if we are going to stay in air and speak to dolphins, and they are going to stay in water and speak back to us, we must create (by electronic or other means) the complete chain of communication so that they can hear what we are saying and we can hear what they are saying with equal facility.

In the research program of the Communication Research Institute in St. Thomas we are currently using hydrophones and underwater loudspeakers to facilitate continuous exchanges between the humans around the pools and the dolphins. We are also working on the problem of enabling a man under water to speak, either by his own efforts without artificial

aids or by using a suitable mask or the proper electronic equipment.

In attempting to communicate, the amount of fear and negative emotion in general that is generated on one side or the other or both plays an important part. The experience of "getting close" to an individual of another species must be rewarding in some way to each side. Contacts must be sufficiently prolonged and frequent to make the development of communication possible. Let us take a specific example of the development of communication between humans, and then apply it to communication between a human and a dolphin.

In developing a vocal language in our own children, there seem to be a number of essentials.[3] One requirement is intimate contact between the baby and the mother, including physical-contact manipulations between the mother and the baby; a second is continuous vocalization by the mother to the baby; a third, the mother's vocal answers coupled with satisfaction of the various needs of the baby on his vocal demand; finally it may at times be necessary to isolate mother and baby from other human beings, but this is still a questionable point; it may be true only very early in life. Later on, social contacts, especially

[3] Spitz, René. *No and Yes* (International Universities Press, New York, 1957). Lewis, M. M. *Infant Speech* (Kegan Paul, Trench, Trubner and Co., London, 1936).

contacts with other children, obviously facilitate the further development of language.

The primitive beginnings of language, as stated many times by many authors, seem to lie in the vocalizations dependent upon internal need. One can see this kind of vocalization in lower animals as well as in man. Cries of distress, of fear, of hunger, mating calls, expressions of pain, etc., are all well known and have been described in the scientific literature.[4]

Such primitive, almost built-in vocalizations seem to be characteristic of humans, irrespective of where they are on earth, at the time of birth. With further growth of the brain and further experience with the mother and other persons in the surroundings, these sounds are rapidly modified. In a matter of a few weeks a Japanese baby ceases to sound like an American baby and vice versa, yet intelligible language has not yet begun to develop. In some cases a private language seems to be established between the mother and the child. In other words, the mother is much more astute than anyone else at picking up and answering the child's needs, but again, this is not communal, intellectual, predictive, and descriptive language, at the command of the child. Such a language

[4] *Instinctive Behavior*, tr. by C. H. Schiller (International Universities Press, New York, 1957). Lanyon, W. E. and Tavolga, W. N. *Animal Sounds and Communication*, 1960. Am. Inst. of Biol. Sci., Washington, D.C. (Pub. No. 7).

seems gradually to unfold from these primitive beginnings and can be forced a bit by appropriate training methods.[5]

Between the ages of two and three, approximately, language has already become extremely useful and is well beyond the stage of mere emotional expressiveness. However, if the child is either left with nonhuman parents (the feral child) or is put in an institution where he is thoroughly neglected, language fails to develop.[6]

The same is true of a dolphin isolated from human contact. If he is put in solitary isolation or left with other dolphins he will not learn anything of our language. If he is forced to obtain satisfaction of his needs through vocalizations with and from human beings, then the beginnings of language may possibly be inculcated in a particular animal. As in the case of the human mother with the human child, this may require rather constant and continuous attention and awareness of detail.

It should be apparent, then, that even under the best circumstances the establishment of communication with these water-borne mammals will be extremely

[5] Moore, Omar K. The motivation and training of students for intellectual pursuits: a new approach. Tenth Thomas Alva Edison Foundation Inst., 1959.

[6] Spitz, René. *Hospitalism.* "The Psychoanalytic Study of the Child," Vol. 1, p. 53 (International Universities Press, New York, 1945).

difficult and laborious. However, recent discoveries in the fields of neurophysiology and experimental psychology may ease the burden of this work somewhat.

These new advances and their significance are concerned with the concepts of "physiological" reward and "psysiological" punishment. "Rewards" and "punishments" in common parlance are spoken of at many levels of discourse and are used in many different ways. In this instance I am talking about direct primitive here-and-now feelings and states of the brain. For example, in the case of oneself these are felt as pleasure (reward) of some sort starting at a definite time and lasting for a definite specifiable interval (feelings such as we experience when satisfying hunger, etc.). Alternatively, the feeling might be one of pain (punishment) in a given body part (gut or limb or head) or unlocalized unpleasant sensations in the body, like fear, anger, etc. Such direct experiences are said to be detectable in animals by means of experiments on their behavior, and are seen daily in very young children, including those who are not yet able to speak. These experiences are powerful aids to learning: with learning and experience, rewards of this sort are sought after and punishments of this sort are shunned. Quite early in life one learns to seek pleasure and pleasure-evoking situations and to avoid pain and fright and their causes. In recent years the areas and systems in the brain whose activities

generate the various kinds of pleasure, pain, fright, and anger have been discovered.

These experiments[7] have proved that electrical stimuli placed by means of fine wires in specific portions of the brain can cause either intense rewarding or intense punishing experiences in a particular animal and in humans. This has been demonstrated in rats, cats, monkeys, and in later years, dolphins.[8] The technique allows either the human operator or the animal to control the rewards and the punishments. In the less well controlled training of the past we depended solely on a fish-food reward, for example, in training dolphins. Although the food type of reward has worked extremely well in the Marineland training programs, we no longer need to depend on it. With the newer method we can push a button and cause a brief controlled period of a rewarding pleasure to occur in the particular animal. Conversely, we can push another button, which controls another place in the brain, and cause intense punishment (fear, anger, pain, nausea, vomiting, unconsciousness, etc.).

So we now have push-button control of the experience of specific emotion by animals in whose brains we have placed wires in the proper places. Ap-

[7] Lilly, J. C. Learning motivated by subcortical stimulation: The "start" and the "stop" patterns of behavior, pp. 705–21. Chapter in: *Reticular Formation of the Brain*, Jasper H. H. *et al.*, eds. (Little, Brown and Co., Boston, 1958).

[8] Lilly, J. C., *loc. cit.*

parently they can experience, among others, the following sensations: "as if fed" when hungry; "as if warm" when cold; "as if cooled off" when hot; "as if drinking" when thirsty; as if "sexually approached" when deprived, etc. The opposite effects can also be created by stimulating other specific portions of the brain, that is, we can make an animal feel thirsty when he isn't and cold when actually he's warm, etc. Practically all of our primitive emotional life can now be reproduced in whole or in part by these methods.

It is difficult to teach an animal if too powerful a reward or too powerful a punishment is used. If he likes the experience too much and becomes too involved in it, he cannot learn a highly differentiated task. Less primitive and less powerful emotional effects can be brought about by stimulation in certain brain systems. I found that maximum teachability of dolphins and monkeys resulted when the wires were placed in the lateral forward parts of the brain. It is claimed[9] that in the human these areas of the brain give rise to an intense sense of well-being without any particular instinctual direction, that is, the sense of well-being is not sexual, or connected with food, hunger, thirst, etc. In so far as we can determine, many of these systems are nonsatiable; they exert a powerful influence as long as the animal is awake, and re-

[9] Lilly, J. C., *loc. cit.*

peating the stimulus again and again does not wear out the effect.

Using this "reward-stimulation" technique, we demonstrated quite satisfactorily that a dolphin can vocalize in two different ways. One, in his usual fashion, under water, and the other by emitting air through his blowhole so that he produces air-borne sounds that we can hear. By changing back and forth between responding to him under water or in air we could induce a particular animal to emit his sounds either under water or in air.

There are, of course, many obstacles to a mutual understanding between dolphins and men. Consider their activities compared with ours. They have no written records and make no artifacts. They lack hands like ours and are not building anything. They have no need of transportation, because it is built in. They can swim at twenty knots and in a few days cover thousands of sea miles in a search for food or more desirable water temperatures. They have no need to store food, because it abounds in the sea for the taking. They have no need for clothing or shelter. They have no need for gravity-resisting forces of the magnitude that we do. Their gravity resistance is distributed over the whole integument, rather than on the bottom of the feet or on the buttocks as in our case.

Because they do not constantly have to resist gravity as we do, they do not need to sleep as we do.

As we discovered, they cannot afford deep unconsciousness at all from any cause—anesthesia, epileptic convulsions, or a blow on the head hard enough to produce unconsciousness will kill them.

They do not seem to have the kind of automatic respiratory system that allows us to breathe while we are unconscious. Being under water seems to inhibit the dolphin's respiration completely, and in order to breathe and release the breathing mechanism, he must surface. An automatic breathing mechanism would bring in water and drown the animal. If knocked out, either he must regain consciousness or be carried up by fellow animals.

An animal that was being delivered to an oceanarium struck his head on the side of the pool as he was being let into it. He was knocked unconscious and dropped to the bottom. The other dolphins pushed him to the surface and held him there until he began to breathe again.

This episode illustrates another fact about these animals: they are socially, mutually interdependent. There is a very close relationship between the mother and child: the baby is not weaned for eighteen to twenty-one months. During this long weaning period he is apparently taught many things by the mother on a purely experiential and possibly vocal basis.

All of dolphin culture may be transmitted in somewhat the way primitive human tribes transmit

knowledge from one generation to the next with long folk tales and legends that are memorized by each individual and passed on to the next generation, which in turn memorizes them and passes them on. The immediate and fixed storage capacity necessitated by such a learning method would require a very large brain. Our writing, printing, and similar ways of storing memory outside of our own brains free us from a lot of the necessity of memorization. These animals must, as it were, remember everything, since they have no libraries or filing cases or symbolic language in any form other than possibly the vocal one. There is no whale yet known with a brain smaller than ours; maybe an air-breathing mammal requires a very quick and large brain to remember enough to survive at sea.

They may have a nomadic culture, they may herd their own fish—we do not know. These are facts yet to be determined. How they navigate is also a mystery. We know nothing about how certain species move accurately over literally thousands of miles of open ocean.

They may possibly use the moon and stars and the sun as aids to navigation. It is very difficult when under water to see through it at an angle of less than about 30° because the water surface is highly reflective and presents a sheen one cannot see through. If one goes under with a face mask and looks back up at the surface, most of the surface looks like a distorted

shimmering mirror, except for an area directly above one's head.

To avoid this effect, these animals stick their heads out of water and look around in air, unimpeded by refraction and reflections. Again and again at Marineland, a dolphin named Polly used to stick her head up out of the tank and look around for us, at the nearby laboratory. In the natural state they leap out of the water and carry on many complex gyrations at sea. They have been seen to come up out of the water and whirl in place and to do complex barrel rolls as they leaped in the air. It may be that they have learned to solve the "mirror" problem at the surface of the water and come up and look around them at the stars, moon, sun, land, etc., in order to navigate. Their vision in air, as well as in the water, is excellent: how they see so well without a face mask is still a puzzle. Of course, they may also use navigational methods about which we know nothing, involving the depth of the sea and the bottom, ocean currents, water temperature, salinity, plankton, water taste, etc.

It is going to require a great degree of imagination to empathize with such creatures. We must use our imagination and project ourselves into areas of which we have no secure knowledge. Speculation is useful, but must not be taken as fact until evidence piles up to either support or destroy the speculation. We do not know to what degree these animals com-

municate with one another, but it looks as if they do so at a very complex descriptive level.

The humans (and animals) who do this work will have to be dedicated, courageous, open-minded and knowledgeable, observant and quick, as well as kindly. These animals have large and fine brains and this fact should make us pause before we attempt to treat them the way we have treated other animals with less to offer us. Scientifically, it is very appropriate to attempt to identify with their position by increasing our knowledge of what that position is and how it differs from ours. At the same time we must at least tentatively remove them from the category of the chimpanzee, the cat, the dog, and the rat in our thinking about them. It is probable that their intelligence is comparable to ours, though in a very strange fashion. To accomplish anything of importance with them, we must overcome our self-immolation, xenophobia, and various taboos which we carry to our work with these animals.

CHAPTER TWO

My Experiences with a Whale

My interest in seagoing mammals began in 1949 after a tropical storm had struck New England. George Austin, a neurosurgeon, and I were reading the Boston *Herald* in Woods Hole, Massachusetts, at breakfast. The last line of the account of the storm stated: "A whale was blown ashore at Biddeford Pool, Maine." We discussed the possibilities of obtaining the brain of this particular whale, because we wanted to find out whether these animals had very large brains—much larger than ours. We had heard that a former neighbor of mine in Swarthmore, Dr. Per Scholander, was working at the Marine Biological Laboratory in Woods Hole. He knows more about whales than anyone of my acquaintance.

We found "Pete" Scholander in the library and after we had talked to him for a few minutes he became enthusiastic about driving to Maine and helping us recover the brain.

We called the Coast Guard at Biddeford Pool and were told that some other people also wanted to dissect the whale. They offered to put an armed guard on the carcass to prevent sight-seers from cutting it up and we agreed to partition the whale with the other interested group. With carpenter's tools and thirty gallons of formaldehyde that we obtained at the laboratory we started our five-hour drive in Scholander's convertible.

During the trip George and I took every opportunity of quizzing Scholander about whales. He was convinced that these animals were eminently worthy of research, that they had the biggest brains on earth, and that they might have many surprises for a research scientist with courage.

For the first time we heard of their abilities to dive to tremendous depths. Sperm whales have been found trapped with lower jaws caught by loops of submarine transocean cables at depths as great as six hundred fathoms.[1] Pete had attached pressure gauges to harpoons and found that whales can dive to depths

[1] Heezen, Bruce C. "Whales Entangled in Deep Sea Cables," *Deep-Sea Research*, Vol. 4, pp. 105–15 (Pergamon Press, London, 1957).

of three hundred meters, or greater.[2] He had done research on the respiration of some of the small whales (dolphins) at Marineland, Florida, that were restrained in a small tank.[3] He also recounted the now classic (among scientists) stories presented by McBride and Hebb[4] about the play and sexual behavior of these animals at Marineland. He told us of the size of the largest animal on earth—the whale as large as fifteen elephants.[5] He told us about the research of Professor Jan Jansen in Oslo on the brains of some of the fin whales.

One thing that stood out in our conversation was that no neurophysiological-psychological studies with any of the whales, including the smaller ones, had yet been successful. We suspected that even the neuroanatomical studies on the brains of these animals had been done on brains that had been dead too long, so that many of the cells had been destroyed by postmortem changes. Pete presented many intriguing

[2] Scholander, P. F. Experimental Investigations of the Respiratory Function in Diving Mammals and Birds. Hvalraadets Skrifter, Acad. of Sciences, Oslo, Norway, 1940.

[3] Irving, L. P., Scholander, P. F., and Grinnell, S. W. The Respiration of *Tursiops truncatus*. J. Cell. and Comp. Physiol., 17: 145, 1941.

[4] McBride, Arthur F., and Hebb, D. O. Behavior of the captive bottle-nose dolphin *Tursiops truncatus*. J. Comp. & Phys. Psych., 41, 2, pp. 111–23, Apr. 1948.

[5] Andrews, Roy Chapman. *Whale Hunting with Gun and Camera* (D. Appleton and Co., New York, 1916).

problems and prospects for future research—so many that we were quite overwhelmed.

We arrived at Biddeford Pool in the late afternoon and with the help of the Coast Guard took a jeep down to the beach. There stood the guard with his prominent revolver, and the crowd was keeping a respectful distance from our precious carcass. (We were to find that the putrid smell was a further aid to the guard.)

This was my first view of one of the fabled "monsters of the sea." I felt awed and diminished in size as I saw the huge stranded beast lying on his right side on the beach. It was twenty-eight feet long, all black, with a rounded bow, and about four feet in diameter at the thickest point. His left eye was visible just behind the corner of his huge jaw. His dorsal fin and huge flukes were impressive. His blowhole crescent was about three inches across. I wondered how such a small hill of flesh lived, what it thought, if it talked to its companions. We were all silenced by the awesome mystery of the whale.

As we approached the beach Pete told us some risqué stories about the whale's penis, its huge size, how it is used in play, etc. He said, "If it's a male I'll demonstrate the anatomy." He took a close look and said the whale was a pilot whale, probably *Globicephala melaena* ("a globe-shaped head, black type"),

one of the family Delphinidae, which includes dolphins and porpoises (see Appendix).

The animal was lying on its side, about half-imbedded in the sand, where it had been cast by the huge waves of the tropical storm. It was now beyond reach of the tide. Before we could expose the cranium Pete suggested that we pull the animal upright on its belly. Everybody looked rather startled since this animal weighed many tons. But Pete is a very practical man; he suggested that we cut a hole through the huge dorsal fin, tie one end of a rope through it and the other end to the rear of the jeep, have the jeep charge off down the beach, and thus jerk the whale into an upright position.

After five or six tries the whale suddenly came upright; the jeep was stopped cold in its tracks and held with its brakes. This position was fine for the dissection but obviously made it impossible to examine the animal's genitalia, so Pete never could make good on his promise.

The Coast Guard had given us all of the tools from their now unused wartime meat locker, plus a hatchet. We started our "dissection" on the monster with a huge saw under Scholander's direction.

The other persons who had wanted to dissect the whale had not yet arrived. We had heard, however, that they wanted the airway maintained intact. Quite glibly we had said that we could remove the brain

without interfering with the airway. We had not yet learned the anatomy of these animals.

Under Scholander's direction we cut intc the animal and suddenly began to realize that there was an awful stench in the air. This whale had been dead longer than one day and, besides, it had been sitting in the hot sunshine a bit too long. It had become quite ripe. There was a very powerful clinging odor, a sort of cross between rotten beef and extremely rancid butter.

Pete pointed out that the blowhole was immediately adjacent to the anterior aspect of the skull; that is, the blowhole goes up over the buried forehead. The big bulge (the "melon") above the upper jaw is merely fibrous tissue filled with oil and fat. So, using the blowhole as a landmark, we cut into the blubber behind the blowhole and sawed down through approximately four inches of blubber and four inches of muscle, and then hit the skull. We held our noses frequently. After patiently and painfully removing the muscle and the blubber from the skull, Dr. Austin, as our neurosurgeon, started chipping away the skull with the hatchet.

The cranium turned out to be about two inches thick and it took quite a long time to expose the brain. Meanwhile, the couple who were interested in the airway arrived.

They were a little upset that we had been working so close to the airway (the blowhole mechanism)

and told us so. However, they turned out to be old friends of Scholander's and we were introduced to William Schevill and his wife, Barbara Lawrence.

By this time Dr. Austin had laid bare the whole upper surface of the brain and we were ready to transfer the brain to the formaldehyde. We noted that it was very much larger than a human's, more spherical in shape than ours, and looked like two huge boxing gloves, the thumbs out on the lateral aspect. The fissures, gyri, and sulci (folds) were far more complicated than those of the human brain.

After making these observations Dr. Austin started to lift the brain from the lower part of the brain case. In doing so he made a small hole in the pial covering and the brain collapsed like a punctured balloon as the rotten liquid substance ran out on the ground. We were extremely disappointed but it showed us that a long-dead whale will digest its own brain; the heat of the metabolism is unable to escape from the body after death because of the huge mass and the thick layers of blubber.

We decided to go back to Woods Hole. It was already getting dark. Meanwhile the Schevills started their examination of the blowhole mechanism. The last we saw of them in the twilight on the beach, Barbara Lawrence had her arm up to the elbow through the blowhole mechanism, feeling out the fine anatomical details of the airway.

Before starting back to Woods Hole we changed our clothes and put them with the tennis shoes we'd been wearing in the trunk of the car. When we arrived at Woods Hole five hours later, to our surprise, there was no odor left on these clothes. The smelly substance was powerful, but very volatile.

Scholander knew I'd been working on the brains of cats and monkeys and on the way back he pointed out that here were brains really worthy of research, nothing so small as those peculiar animals known as "cats" and "monkeys." Here was a brain equal to and larger than ours, and presumably equally complicated. Dr. Austin with his neurosurgical interests, Scholander with his physiological interests, and I with my neurophysiological interests all became intrigued with the problems of these huge animals and their life, which is so different from ours. We discussed the hypothesis that these animals had evolved from land-borne ones which had gone back to the sea, their many strange resemblances to the land-borne mammals, and their definite differences from them.

CHAPTER THREE

My First Experiments with Dolphins

THESE matters were stored somewhere in the back of my mind until the International Physiological Congress took place in Montreal, Canada, in 1953. Here once again I met Per Scholander, and we had another long discussion on whales and whale brains. At this time he gave me the name of the curator at Marineland and suggested that I get in touch with him. I then approached Dr. Jerzy Rose with the proposal that we go to Marineland and do some neurophysiological studies on these animals. Dr. Rose, Dr. Clinton Woolsey, who was interested in doing comparative neurophysiological-neuroanatomical studies on a large series of mammals, and various other investigators got together and organized the expedition. In the fall of

1955 eight investigators from five different institutions[1] drove to Marineland from various parts of the United States. The contents of approximately five neurophysiological laboratories were deposited in the research laboratory of Marine Studios under the aegis of the curator, F. G. Wood, Jr.

Each one of us had previous experience in neurophysiological research on the brains of various animals, including the cat, dog, monkey, pig, sheep, chimpanzee, rat, squirrel monkey, and marmoset. The cerebral cortex of each one of these species had been mapped to show the visual, acoustic, tactile, and motor areas. It was our intent to find and to outline all of these areas plus any others that might turn up in the dolphin's brain. We were equipped with the necessary electronic apparatus for stimulating the brain, for stimulating the periphery, and for recording the electrical potentials evoked from the brain. We had enough anesthetic, as someone said, to anesthetize everyone at Marineland and still have some left. I had been delegated to construct a dolphin respirator and I took the 150-pound device in my car along with all our electronic gear. To aid me in constructing the respirator I had only Per Scholander's article to rely on for in-

[1] Drs. J. Rose, V. Mountcastle, and L. Kruger, Johns Hopkins Medical School; Drs. C. Woolsey and J. Hind, University of Wisconsin; Dr. Karl Pribram, Institute of Living, Hartford, Conn.; Dr. Leonard Malis, Mt. Sinai Hospital, New York City; and the author.

formation about how these animals breathed, how much air they moved, and what the breathing mechanism was.[2] From this 1941 paper I learned that they breathe and hold at inspiration, have an explosive expiration, immediate inspiration, and move from five to ten liters of air in a very short time (how short we didn't realize until we had taken high-speed motion pictures). I did not know how we were going to attach the respirator to the animal but I thought it was probably best to copy their type of respiration, to avoid running into problems of anoxia and the accumulation of carbon dioxide. I designed and built a machine that would deliver extremely rapidly into the animal five to ten liters of air as an explosive "pressure" inspiration. It would also allow extremely rapid venting of the lungs through a valve that would be wide open just previous to being refilled. At that time there was no provision for telling exactly how much gas was put into the animal's lungs (later we were to find that there is a very easy way of putting in a proper amount).

Although we had been puzzled about how to connect this apparatus to the animal, we found out during this expedition that there is a way, and succeeded in resuscitating one animal with this apparatus.

[2] Irving, L. P., Scholander, P. F., and Grinnell, S. W. The Respiration of *Tursiops truncatus*. J. Cell. and Comp. Physiol., **17**: 145, 1941.

The Marine Studios personnel placed five animals at our disposal. We had allowed ourselves two weeks to accomplish the task of mapping this huge brain.

We placed the first animal on a stretcher, kept it out of water, and proceeded as if this animal were just another primate, such as the chimpanzee, whose brain we were going to examine. We planned to give it an adequate dose of anesthetic to keep it surgically anesthetized for several hours while the skull was removed and the brain was mapped electrically. We realized that this might be the wrong procedure, but this was the way we were accustomed to work.

Dr. Woolsey injected the calculated dose of anesthetic—nembutal of 30 milligrams per kilogram, which is just below the required primate dose—so that the animal would go into deep sleep. It was injected intraperitoneally, all in one dose of 80 ccs.

The next half hour was very painful for all of us as we watched the animal's respiration fall apart and, finally, his heart stop. We had been watching his electrocardiogram on the oscilloscope. His respiration was watched by three or four observers at once. The animal did not pass out properly. He went through the phases of anoxic death, about which we had heard but which we had not really observed ourselves. This was a shocking finding and more or less totally unexpected to everyone present. We couldn't immediately absorb it and integrate it with our previous thinking.

A few of the group were convinced that it was an anesthetic death because of failure of respiration, others were not. It was hard to believe that death could be purely respiratory. Every other type of animal we had previously worked on had taken the dose of anesthetic quite easily, with no problems related to respiration; ninety-nine per cent of them survived long periods of anesthesia and came to without any trouble. Even the brains of men have been mapped and exposed with anesthesia at levels deeper than this one without any deleterious effects. So we decided to go on with other animals and see if we could use so small an amount of anesthetic that the animal's respiration would not fall apart.

With the next animal we cut down the dose and tried to find out in detail what were the factors that had led to the death. He was given 10 milligrams per kilogram. At this level he could still see us and follow us with his eyes, still jumped when one stroked him suddenly under the chin, and would close his eyes when the hand was rapidly waved at him. The only detectable finding was that the inspiratory and expiratory phases of the respiration were becoming gradually disconnected from one another.

Usually the cycle is started with an expiration, followed by an immediate inspiration. At 10.3 milligrams per kilogram we noticed that air was apparently leaking out of the lungs through the mouth rather than

through the blowhole and that if all the air leaked out of the animal's lungs he could not reverse his usual respiratory cycle and start with an inspiration.

There was some doubt in our minds at this time as to whether what we saw escaping from the mouth was definitely coming from the lungs or whether it was from the stomach. Once in a while we would smell a fishy odor that seemed to be stomach gas.

At 10.3 milligrams per kilogram this animal's respiration finally failed too.

We must remember, of course, that this animal was out of water, that gravity was pushing his weight down on his lungs; his respiration had become a stereotyped, mechanical, regular affair, which is quite unnatural, as we were to find out later. Apparently two factors caused the falling apart of respiration and the loss of air into the mouth: the loosening of a sphincter around his larynx (the nasopharyngeal sphincter) and the increased pressure in his lungs from his body weight pushing down upon them, which does not happen in the water.

In an attempt to learn how an animal might be resuscitated, we had done some dissections of the airway on a carcass in Baltimore and on the first animal. We discussed three different approaches: through the blowhole, which is difficult because of the bony septum that goes down the middle, somewhat below the opening of the blowhole; through the mouth, by pull-

ing the larynx out of the nasopharynx and inserting a tube through the larynx into the trachea; or cutting into the trachea through the outside of the throat. We quickly found that the trachea is extremely short and extremely wide, which would make it very difficult to insert through the throat and to seal a large enough tube without extensive damage. The second approach, through the mouth, seemed to be the only feasible one.

We did not know what size tube would fit tightly into the larynx. We experimented on one animal after breathing stopped. Two strong men pulled the mouth open with rope loops, one on the upper jaw and one on the lower jaw. A third man inserted wooden blocks to hold the teeth apart. Dr. Mountcastle thrust his arm all the way down through the mouth into the throat. He pulled the larynx out of the nasopharynx with one finger and inserted a small tube that was hooked up to the respirator.

The small tube leaked; we tried a larger size and finally found that a piece of plastic pipe 1⅛ inches in diameter could be sealed adequately within the larynx and trachea. Now we could attempt to resuscitate the animal with artificial respiration.

Because of the delay while trying different sizes of tubing, we were unsuccessful with this animal. But we succeeded with the next animal and were able to carry him through the anesthetic until he started breathing naturally again by himself.

We put him back in the tank to see if he could swim or whether his brain had been damaged by a period of anoxemia. Apparently it had because he fell over to the right side when he tried to swim. It was from this animal that we first heard and recorded on tape and motion pictures the phenomenon of the distress call.

When the animal was put back into a pool with two other animals he emitted a very short, sharp, high-pitched whistle, in two parts, a crescendo and a decrescendo in pitch. Although this sound could not be heard very well in the air, I heard it through a hydrophone and, luckily, had the tape recorder and motion-picture camera going at the same time.

The effect of the distress call was immediate. The other two animals swam rapidly over to the animal emitting the call, swam under his head, and pushed him to the surface so that he could breathe.[3] He breathed and submerged. Immediately a twittering, whistling exchange took place among the three animals.

Appropriate, co-operative, adequate corrective action then took place, as a consequence of this vocal exchange. The other two animals took turns swimming

[3] Caldwell has seen a similar kind of assistance rendered by wild dolphins. Siebenaler, J. B., and Caldwell, David K. Cooperation among adult dolphins. J. of Mamm., Vol. 37, No. 1: 126–28, Feb. 1956.

along the right side of the injured animal, helping him to swim upright and allowing him to press against their bodies so that he could rise to the surface to breathe instead of falling over to the right. This kind of activity went on for some time. We were so ignorant of such things that we did not trust the other animals. We went into the tank, picked the animal up in a sling, and treated him as if he were a human drowning. We tried to dump the water out through the blowhole by tilting him head down at 45°; we did not realize that apparently dolphins can voluntarily blow water out of the lungs into the mouth, disengaging the larynx from the nasal pharynx to do so. We were still following the old dictum that the airway remained permanently connected across the foodway of these animals. Knowing that his brain was permanently damaged, we took this particular animal out of the tank and sacrificed him in order to obtain the brain for anatomical analysis.

A picture of a strange existence and a strange physiology, for which we had been unprepared, began to shape up. We were all shocked and saddened at the rate of death under anesthesia. Each death was a new experience to us all. However, we were learning to avoid killing these animals by correcting our fundamental errors of technique.

We felt that maybe nembutal was a specific poison for these animals, so we tried paraldehyde—the

safest anesthetic we know and the one that least affects human respiration. It is so safe that it is used in cases of delirium tremens to cure chronic alcoholics of their jitters while alcohol is being withheld from them.

On one of the dolphins we tried paraldehyde intraperitoneally, in a dose calculated to be less than the equivalent human dose. Once again the respiration fell apart. During the period when the animal was still breathing with paraldehyde in him, we made a fundamental discovery about the airway. We noticed some gas escaping from the mouth along the bottom of the animal's throat. Some of this gas smelled of paraldehyde and not of fish, while some of it smelled of fish but not of paraldehyde. The gas that smelled of paraldehyde was coming from the lungs and we discovered that there was a leak between the larynx and the nasopharyngeal sphincter. As the dose of paraldehyde was increased, the amount of gas escaping through the mouth increased, until finally the lungs were empty. We had discovered a "tracer method" of showing when gas is coming from the stomach and when it is coming from the lungs. At no time did the plugs at the upper end of the blowhole seem to fail as quickly or as easily as the deep nasopharyngeal sphincter did.

We worked out a method of resuscitation that now can be perfected if anyone desires to do so. We measured the pressure of the air in the trachea of a

living, unanesthetized animal. I found that I could insert a needle through the skin of the throat into the trachea in an unanesthetized animal without evoking struggling. The pressure, when an animal is out of water, turned out to be 20 millimeters of mercury over the surrounding air pressure. When the animal is immersed in water, this pressure is maintained at approximately 20 millimeters of mercury with respect to the water depth halfway down the side of the animal.[4] This would be the limit of pressure at which a respirator should push the gas into the lungs when the animal is out of water. The gas being blown in could then be automatically shut off at this pressure so that the lungs would not be overinflated. Eventually I worked out a method of exploring the brains of these animals that obviated the need for general anesthesia, so we did not pursue this matter of the respirator any further. Although no such automatic respirator has ever been built, the data we obtained may be extremely useful in the future when it becomes necessary to operate, say, on the stomach of one of these animals.

About the time paraldehyde proved unsafe as an anesthetic we had a near revolt among the group. We were haunted by the deaths of these animals. The personnel at Marineland were nobly suppressing their

[4] This may be sufficient to explain the automatic closure of the blowhole plug postulated by Schevill and Lawrence later.

displeasure at the way we were treating their friends. Slowly but surely André Cowan the trainer and Bill Rolleston the business manager, F. G. Wood the curator, and the Baskin brothers, Norton and Tom, who ran the restaurant and the motel, were convincing us that these animals were extremely intelligent, playful, and friendly toward man and that this was not the way to treat them. The curator was quite willing to let us go ahead with our research if we insisted, but he felt that five animals should have taught us enough. I am sure he did not want to see any more sacrifices made in the name of science until we had integrated what we had already found. We all felt very sad and could only justify the work by realizing that it would not have to be repeated if done well this time.

We finally realized that we were going to obtain no neurophysiological data, and, like our predecessors, we could only collect the five brains for neuroanatomical study. At least they would be better than any that had ever before been obtained for the study of the cells of the cerebral cortex and the thalamus. To make sure that they would be in good condition, we did a perfusion under deep anesthesia through the aorta with formaldehyde. The brains were later analyzed at Johns Hopkins University by Drs. Kruger and Rose.

From our subsequent study of the brains we collected, we determined that the adult brain is extremely large and extremely complex and that it increases in

size with the body length. (See Table 4, Appendix Two.) The brains were so large that it took a year to imbed them in celoidin so that sections of them could be cut. We were able to obtain more accurate measurements on the actual weights than had been previously obtained, and we found that they ranged from 1175 to 1707 grams in animals ranging from six feet six inches to eight feet six inches long.

After imbedding and staining these brains, analysis showed that the cell densities of the cerebral cortex were about the same as those of man.[5] The analysis also showed that the nuclei of the thalamus are the same as those of the primates and of men and are of comparable size to those of a human. Not only the extrinsic but the intrinsic nuclei are present, plus one (nucleus ellipticus) extra.[6]

We also showed that perfusion of the brain under anesthesia through the aorta can be successful if done extremely rapidly. But one cannot perfuse through the carotid arteries because there is a leakage through the *rete mirabile* (a special network of arteries and veins

[5] This is in contrast to the previous findings of Othello Langworthy, Jan Jansen, Donald Tower, and others, who maintained that the cell densities were somewhat lower than those of man and that the cells were widely spaced. Their material was not perfused, however, and was subject to post-mortem changes.

[6] Kruger, L. The thalamus of the dolphin (*Tursiops truncatus*) and comparison with other mammals. J. Comp. Neurol., 111, No. 1, pp. 133–94, 1959.

in diving mammals), which is cut during the post-mortem.

We found, as the Marineland personnel had been demonstrating for many years, that dolphins, even if painfully treated, do not attack human beings. Sometimes we still find this hard to believe because they will attack sharks and kill them and will attack one another during the mating season. Physically they are quite capable of tearing or biting an arm or a leg off a man or of damaging him internally by ramming, but there is no record of these animals ever having damaged a human, even when the human has mistreated them.

All of our 1955 observations and conclusions have been invaluable in subsequent work with dolphins. I was stimulated and inspired by those two weeks of work to devote more and more effort, time, and money to these charming creatures.

CHAPTER FOUR

New Research Methods

DURING the 1955 expedition our group received many impressions about dolphins. Mr. Wood had made a collection of the sounds emitted by these animals in the captive state; we listened to his tape and read his paper on the various kinds of sounds they emitted.[1] We also heard, through his hydrophone, examples of the sounds as the animals were producing them. We watched the trained animals, the training program, and the public presentations put on by Mr. André Cowan. We learned that all of the trainers, maintenance men, and other personnel of Marine Studios

[1] Wood, F. G., Jr. Underwater sound production and concurrent behavior of captive porpoises, *Tursiops truncatus* and *Stenella plagiodon*. Bull. Marine Sci. of the Gulf and Caribbean, 3: 120–33, 1953.

had a deep respect for these animals. Although they shrank from our work because we were killing these friendly animals and we felt a community disapproval of what we were doing, they were extremely fascinated with the work. After we had concluded that no work on the living brain was possible without radically new methods, we turned our attention temporarily from the brain to general observations on the dolphin's behavior.

The next summer, at Nonamesset Island near Woods Hole, I met William Schevill and Barbara Lawrence again. They had obtained a dolphin from the Marine Studios and flown it to the island in a Navy PBY. They confined him to a small pool on the island and were experimenting with his vocalization, studying his sensitivity to high-frequency sounds under water.

Their finding that the animal was sensitive to sounds of frequencies up to 140 kilocycles—quite supersonic for the human—astonished everyone. They also had evidence that the "creaking-door" sound that is frequently heard at Marineland is a sonarlike method by which these animals range on objects, especially fish, in murky water or at night. Their demonstrations brought home to me the efficiency of the dolphin's sonar in a very convincing fashion. After working for a couple of months with this animal, they let him go.

My visit inspired me to try to do some work with the brain and the whole animal without anesthesia. I went back to the National Institute of Mental Health with an idea about how to accomplish this. Trying out the method on monkeys, I found it quite successful and very simple to do.

In brief, the monkey is held in restraint and a small length of hypodermic-needle tubing ("sleeve guide") is hammered into the skull so that the brain's cavity is just penetrated, and not the brain itself. A metallic, insulated, shielded electrode with a bared tip is inserted through a small hole in the skin, through the guide, and into the brain. The depth of penetration of the electrode is controlled with a small drive unit placed on the outer end of the sleeve guide. With this method it is possible to map the electrical potentials given off at various depths of the brain under various conditions and stimulate the activity of the cells of the brain by passing electrical currents through these small electrodes, or to inject chemicals in small amounts through small needles anywhere in the brain.

I made use of this system in attempting to teach a monkey to vocalize in an anticipatory and demanding fashion. An animal in restraint with the electrodes in the proper position in the brain would bark spontaneously. This sound would then set off (through a microphone) an electronic train of events which would ultimately, with a small delay, deliver a train of electrical stimuli to a rewarding system in the monkey's

brain. In other words, if he barked, it would lead to a delayed sense of pleasure for a brief period. We had previously found that the monkey could be easily trained to push a switch in order to stimulate his own brain in that particular locus. He loved to push it and would push it three times a second sixteen hours a day. However, when it came to vocalization, I could see that he was struggling to vocalize but did not quite understand that the vocalization led to the reward; even after hundreds of trials every day for six months this bit of understanding could not be conveyed. We concluded that voluntary vocalization is an extremely difficult if not impossible process for a monkey; generally, vocalization for them is only part of the response to the emotional needs built up in the organism (cooing for food, barking in anger, screaming in pain, etc.).

The brains of monkeys were mapped in great detail for various effects such as muscle movement and the changes in motivation induced by brain stimulation. The rewarding and the punishing systems were similarly mapped and studied.[2]

We demonstrated, as had been previously demonstrated with the cat and the rat, that a monkey can be trained to pull a lever in order to stimulate specific portions of his own brain electrically. If such an animal with electrodes in the proper place was given a switch, he would eventually learn to press this switch

[2] Lilly, J. C. *Reticular Formation of the Brain, loc. cit.*

in order to start trains of electrical stimuli in his brain. If the electrodes were placed in other areas of his brain, the animal would do everything he could to avoid or escape stimulation in these areas, including pushing a switch in order to shut off or to stop the electrical stimuli. In our work with monkeys a method was devised for finding the threshold of this "self-stop" effect, as well as one for an intensive investigation of the "self-start" effect. Those results that are germane to the dolphin research follow.[3]

A monkey would start stimuli in a certain system in his brain again and again and again, three times a second for approximately sixteen hours a day. The effect was quite independent of any other conditions surrounding the animal and he could be deflected from this task only briefly. He would change his personality from a suspicious and hostile one to that of a relatively loving and considerate one, very much interested in the humans surrounding him; there was an intense "taming" effect on even fierce animals.

By stimulation of the opposite type of system, he could be taught how to shut off trains of stimuli of gradually increasing intensity, and would stay awake forty-eight hours in order to terminate these noxious stimuli. He would become quite hostile and at times he would bite any threatening object brought near his mouth (including the observer's fingers).

[3] Lilly, J. C., *op. cit.*

In spite of the tremendously rewarding effect of stimuli in the self-stimulating system and six months' work trying to accomplish it, not one of the three monkeys ever learned to vocalize in order to obtain the reward. Each of them learned quite easily to push a switch with hand, foot, or tongue; but even with a voice key they were unable to learn to vocalize to obtain the stimuli.[4]

A monkey would learn extremely complex tasks in order to obtain the stimulation by pushing a switch. He would learn what we call "pseudocounting," that is, having to push the switch a number of times in order to get the stimulation at, say, the sixth push. This is called pseudocounting because we found that the animal was pushing in rhythm until he found the stimulation rather than counting. If one changed the required number abruptly, the animal would become extremely upset and jump around in his restraints before settling down to do the new task.

The "taming" effect of stimulating the positive (self-start) system was striking and dramatic to watch. A very fierce monkey with great long canine teeth would become a quite docile animal as long as these systems were stimulated. He seemed to gain weight rapidly and be quite happy in spite of his restrained position, sitting in a chair day and night for many weeks.

[4] Lilly, J. C., *op. cit.*

Conversely, the stimulation of the opposite kind of system led to an extremely unhappy animal, which developed a lack of appetite and an extremely hostile attitude toward his handlers. He would probably have died if we had continued stimulating any longer than a few hours a day.

Such negative effects could be reversed completely by a few minutes of stimulation of the rewarding systems.

In summary, then, these motivationally active systems in the brain, positive and negative, are extremely powerful and push an animal to learn as much as he is capable of learning within a very short period of time. The method is much more powerful than any other kind of direct reward or punishment that has been explored to date, and it has the convenience of immediate and definite control of intensity and timing on the part of the operator.

I decided that this work with macaque monkeys might be used to map the big brains of the dolphins.[5] If we could use this powerful research weapon we might be able to control the dolphins and encourage them to learn extremely rapidly. It was up to us to determine whether the large-brained animals were as amenable to training and as susceptible to such motivational "brainwashing" by electrical means as the smaller-brained monkey.

[5] Lilly, J. C. Am. J. Psychiatry, 1958.

CHAPTER FIVE

Early Results

In October 1957 I returned to Marineland armed with the sleeve-guide technique and the knowledge of the motivational systems of the monkey's brain. Before the work on the brain could start we had to devise better methods of restraining the dolphin than we had used in 1955.

We had discovered that it is fatal to keep a dolphin out of water under gravitational pressures for long periods (up to six days) and that the animal must be kept moist with salt water to avoid sloughing of the skin. We spent a good deal of time devising a way of holding a dolphin still in the small laboratory tank provided by Mr. Wood. While hammering sleeve-guides into the skull we must restrain the movement

of the head, we felt, to avoid the animal's injuring himself or us.

After about a week's work we finally evolved a restraint system in which the beak of the animal was inserted in a hole in a board. The inside of the hole was surrounded by a resilient foam plastic (isocyanate foam). The animal could move his beak up or down or sidewise within limits of two or three inches and then would strike against the cushioning of the foam plastic. His body was supported in the water in a sling hung from two pipes running the length of the tank. The head was held down by a bent steel piece shaped to the back of the neck and covered with a foam plastic material. Continuous water sprays from flattened hypodermic needles onto white bed sheets over the animal's back kept him wet on those parts that protruded above the water level in the tank. Most of the animal's weight was supported by the natural buoyancy of the water. His blowhole and the upper side of the region of the skull were exposed to air above the water level. The animal accepted his restraint quite well after his first exposure to it.

With a great deal of trepidation and doubt the first time, I injected a local anesthetic into the skin, blubber, and muscle over the top of the head, just behind the blowhole. The animal jumped at every prick of the needle as I injected the fluid, under pressure, into the upper cranium. After waiting until the

animal no longer jumped, I proceeded to hammer the sleeve guides into the skull.[1]

At first I used a very small hammer but eventually changed to a carpenter's hammer so I could speed up the rate at which the sleeve guides went into the skull. The process was not too distressful to the animal. He jumped every time the hammer hit the mandrel of the sleeve guide, because this made a very loud noise inside his head. We could find no evidence that there was much, if any, pain associated with this procedure. However, for a sensitive animal this could be psychologically traumatic without being painful.

I had tried this kind of hammering on my own skull to find out whether or not it was unbearable and discovered that even without a local anesthetic the pain associated with the procedure is not great. However, the noise of a hammer blow on a needle, when conducted by bone to one's ears, is extremely loud and rather startling.

In previous work with the monkey I had found that living bone is like living "green" wood: bone responds to this hammering technique the way a living tree responds to a driven tack. If the skull is dead and dried out, the process is like hammering a nail into an old plaster wall. Every time we attempted

[1] Lilly, J. C. Electrode and cannulae implantation in the brain by a simple percutaneous method. Science, **127**: 1181–82, 1958.

to hammer a sleeve guide into a dead, dried-out skull it broke out pieces ahead of the sleeve guide. However, in the living wet skull nothing like this has been seen; the sleeve guide and mandrel penetrate cleanly and smoothly through the bone, pushing the bone aside instead of pushing it ahead of the hammered object.

The dolphin into which we first hammered the sleeve guides was Number 6 of the series. We had decided that we would keep a complete record by numbering all of our animals in the series. So the first animal in our 1957 series was Number 6 of the total series, and the first one in the sleeve-guide series.

The first sleeve guide (about 30 millimeters long) went into place so easily and so quickly that it rather startled us. Very quickly we placed electrodes through the skin, blubber, muscle, and sleeve guide into the brain and started the long, slow, and patient examination of this huge brain by electrical stimuli.

Every rotation of the electrodes in the driver pushed the tip of the electrode one millimeter farther into the brain (one millimeter is equal to 1/25th of an inch). At each zone in the brain we applied very weak electrical stimuli at various intensities and tried to observe what was happening to the animal as a consequence of the stimulations. Advisedly, I say "tried" because, as in the human brain, there were

many areas that, when stimulated, gave effects we still do not understand. The so-called vast "silent" areas of the human brain represent failure to elicit immediately obvious results of stimulation. Some of these "silent" areas are falling by the wayside as we discover new things to look for within those structures.

Classically, we look for evoked movements of specific muscle groups. The first thing we do is hunt over the whole animal for something that is moving during the stimulation. If such a movement does occur, then it can be pointed to and demonstrated to other people quite easily. For example, during the experiment on this animal we found the motor cortex, down deep within the cortex which in the human brain would be called the supraorbital. When stimulated in this specific region, one of his eyes would turn in a definite direction and hold its directional gaze as long as the stimulus was on. We could turn the eye up by stimulating in one place, down in another, forward in another, and backward in another. This kind of effect is obvious: it is possible to find areas that control movement of the flipper, the eye, the tongue, the back muscles, the flukes, and even the erection of the penis. In the jargon of neurophysiology, these are all "motor effects": the stimulated part of the brain activates those particular muscles fairly directly, here and now.

However, the "motivational" effects are not quite

as obvious as these direct motor effects. You must train an animal in order to know when you are in the motivationally active portions of the brain. In mapping the brain it is the naïve, untrained animal that is hard to work with. Once you have found one such spot and have trained the animal, it is then very easy to find other active spots. But until you have found the first motivationally active zone, you are shooting in the dark. Our first new finding on the dolphin was made when we hit a rewarding spot within the brain of animal Number 6.

We had spent all of Saturday afternoon moving one millimeter at a time down through the vast cerebral cortex of the top of this dolphin's brain. We had moved down about 60 millimeters in one-millimeter steps, taking approximately fifteen minutes to an hour at each spot to analyze whether or not we were getting any response, either motivationally or motorically. We had apparently hit one of the big silent regions such as are present in the prefrontal areas of the human brain. We worked very late and were quite discouraged. We thought that maybe this brain was all silent or that something was wrong with our electrodes or with what we were doing. Our time was getting short and we were getting impatient. Finally we were forced to leave the laboratory to attend a party that evening.

The next morning I was so impatient to get on

with the findings that I went to the laboratory quite early in spite of the fact that it was Sunday, cranked the electrode down another millimeter, and started stimulating. Instantly, it was obvious that the electrode was having an effect that we hadn't seen before in the dolphins, or any other animal, for that matter.

At a fairly high level of current, the animal started responding immediately every time the stimulus went on. He became quite restless and jumpy, moved around in his restraints, and started to vocalize in a "dolphinese" fashion. The current was so high that I suspected the electrode was close to but not in a sensitive region and that I'd best move it farther down in order to reduce the threshold and avoid burning the brain with the high current. Going down one or two millimeters more, I quickly found that the current threshold for restlessness and vocalization was dropping. The dolphin was more exuberantly vocalizing than ever I'd heard before. Whistles, buzzings, raspings, barks, and Bronx cheerlike noises were emitted. (Until we were able to play this tape back at a later session, many of the novel and exciting facts of this experiment were yet to be realized.)

At this point I decided that it would be best to try to test whether or not we were in the rewarding system. Would the animal learn to push a switch to start the stimuli in his own brain?

Rather hastily I threw together a switch that the dolphin could push with his beak. If he pushed it upward it would make contact, which would then start the train of stimuli into his electrode. While I was assembling it, I noticed that the dolphin was closely watching what I was doing.

Almost before I could finish assembling and place the rods necessary to push the switch (which was out of the water above the animal), the dolphin started pushing on the rod. By the time I was able to hook up the switch to the rest of the apparatus he had learned the proper way to push it and was pushing in order to start the stimulation.

I had the rather uneasy and eerie feeling that there was a good deal more *purpose* behind this animal's behavior than I had ever seen when working with monkeys. I always had the feeling that there were many random, accidental contacts with the switch before the monkeys learned how to use it. Once a monkey learned, there was no problem about his forgetting it. However, many, many "accidental" contacts occurred before he got the idea of pushing.

With the dolphin I did not see these accidents at all. It almost seemed as if he anticipated that what I was doing could somehow give him the reward. He seemed to *know* that this rod might possibly be used for some purpose connected with the stimulation. He

had already experienced the stimulation, had already seen me pushing the switch; when the switch was ready he pushed it, discovered the effects on the first try, and from then on, knew how to push the switch appropriately in order to obtain the electrical stimulation. The first successful trial was all he needed to learn the trick.

This same immediate and direct learning occurred later with a little female. When I showed her, by pushing her beak up against the rod once or twice, she quickly learned that this would operate the switch. In her case the switch shut off stimuli that she didn't like. Thus we found our first difference between the small-brained monkey and the large-brained dolphin. Compared to the monkey, the naïve dolphin learns extremely rapidly. His speed of learning is so fast that, as yet, we have no way of measuring it accurately, but it seems to be comparable to that of a human. He can be manually aided to learn, whereas a monkey cannot learn this way.

The male dolphin vocalized whenever he failed to obtain the stimulation. During stimulation, the vocalization was rapidly stopped. Once the hastily built rods leading to the switch jammed so that he could no longer stimulate his brain by his own efforts. At this point an explosive series of air-borne vocalizations began to erupt from his blowhole. A microphone was

placed over his blowhole with an amplifier leading to a loudspeaker so that the rather weak sounds that he produced could be heard easily throughout the room. I was using a stereo tape recorder, one channel to record the dolphin noises, the other to record my observations for transcription by my secretary. From the loudspeaker I began to hear the Bronx cheerlike noises, some of his sonar (rapid, clicking, creaking-door) noises, and then suddenly very strange noises which we had not heard before.

Some of these strange noises sounded like inaccurate renditions of human laughter: there was the same pulsating, explosive kind of sound a human makes when he laughs. (There had previously been some human laughter in the laboratory.) Then we began to hear very peculiar sounds, which came so rapidly that I could not grasp what they were until later when we played them back on the tape recorder.

I had been attempting to control the vocal output of the dolphin in a very formal way—that is, to induce him to emit a whistle of a given pitch, duration, and loudness in order to obtain his reward. I found that this task could be accomplished. However, we were not prepared for the findings that were revealed on close examination of the tapes after the first hour of these experiments. When we replayed this first set of tapes we discovered that (in a very terse shorthand

and quacking sort of way) this dolphin had been mimicking some of the things I had been saying while dictating technical data on my channel of the tape simultaneously with the experiment. We could make neither rhyme nor reason out of why he selected what he had copied or mimicked of what we had said. There are several outstanding examples that are clearer than most.

I say on the tape, "The TRR (train repetition rate)," pronouncing it very distinctly so that my secretary can copy it down, "is now ten per second." The animal said, "T R R," in a very high-pitched Donald Duck, quacking-like way. In the same way he picked out "three hundred and twenty-three" when I said "three hundred and twenty-three feet on the tape," and reproduced it in his peculiar primitive but distinctive fashion. He also reproduced our laughter in a fairly accurate way.

We found that there were many such instances throughout this period of time. They were, in general, connected with several sets of conditions. When an animal is first stimulated in a rewarding region he vocalizes vociferously; later, as he learns to push a switch to self-stimulate, he stops vocalizing. It is only when he cannot cause the stimulation that this kind of vocalization occurs again. If you purposely set out to reward him for vocalization by stimulating his brain

after he vocalizes, he can then be induced to vocalize and even to mimic in these primitive fashions.

Further studies of the tapes slowed down to half speed and to one-quarter speed revealed an additional unexpected factor. Apparently these animals are quite capable of taking a vocalization by a human and compressing it with respect to time. We found that most of the vocalizations made far more sense and their inherent complexity showed up much more easily when we extended their duration and lowered their pitch by slowing down the tape.

This raises a difficulty about establishing communication with these animals. They are quite capable of hearing sounds up to 200 kcps[2] and their vocalization to one another—whistling—occurs in (and beyond) our upper acoustic range. Their reproduction or mimicry of our speech took place by another means than their whistling processes; it seems as if they use their pulsatile sonarlike way of producing sounds, or even a combined whistling and pulsing method, to mimic us.

Their sonar transmissions consist of a series of pulses of sound emitted very rapidly at varying repetition rates. This sonar system has been shown to consist of individual little shock waves emitted at a vary-

[2] Schevill, William E., and Lawrence, Barbara. Auditory response of a bottle-nosed porpoise, *Tursiops truncatus,* to frequencies above 100 Kc. J. Exp. Zool., **124:** No. 1, pp. 147–65, Oct. 1953.

ing rate, depending on the distance of the object.[3] Apparently it can be used to determine not only the distance and direction of an object but its form as well; by this technique they can find a fish that they want to eat and distinguish it from other objects. When they are indulging in this kind of activity, the noises that they emit sound like a rusty hinge, a creaking door, or a rasping or a filing sound. Whenever we feed a dolphin a fish we hear this series of sounds as the animal approaches the fish in our hand.

Apparently they use this kind of process to make the "humanoid" sounds. We have tapes of single animals in solitude who were able to make the quacking noise and a whistle simultaneously, so it appears that these two mechanisms can operate independently. However, at first hearing, these rasping or creaking sounds are very different from anything the human being emits. It is possible to make impolite noises with the lips that approximate them, but these are not nearly as sharp and clear-cut as those emitted by the

[3] Schevill, William E., and Lawrence, Barbara. Food-finding by a captive porpoise (*Tursiops truncatus*). Breviora, Mus. of Comp. Zool., No. 53, Cambridge, Mass., Apr. 6, 1956. Kellogg, W. N. Auditory perception of submerged objects by porpoises. J. Acoust. Soc. of Am., 31 (1), pp. 1–6, Jan. 1959. Norris, Kenneth. Think (Intl. Bus. Machines), p. 20, Dec. 1960. Norris, Kenneth S., Prescott, John H., Asa-Dorian, Paul V., and Perkins, Paul. An Experimental Demonstration of Echo-Location Behavior in the Porpoise, *Tursiops truncatus* (Montagu). The Biological Bulletin, Lancaster Press, April 1961, p. 163.

animals. The very fact that they can modulate their pulse output in mimicking our voice shows that they have extremely good control over the muscular groups necessary for this kind of performance.

One of the mechanisms responsible for the sounds is used for production of sounds in air: it is at the exit of the airway at and below the blowhole. The blowhole contains a tonguelike appendage ("plug") which the dolphins can manipulate with great dexterity. There are several air sacs and "liplike" structures in this part of the airway. Another mechanism is in the larynx and airway far below the blowhole. Either of these mechanisms can be used for underwater sound production. (The muscles surrounding the blowhole can also be manipulated dexterously and are quite expressive when one has an animal in a small tank and watches the blowhole region. These muscles are tensed up if the animal is in pain, or can be relaxed if he is apparently enjoying an experience.)

If you watch this blowhole region while the animal is vocalizing in air, you can see it move every time sound is emitted by the animal. You can also see it move at times when he is apparently emitting sounds well beyond our range of hearing. (They can hear up to 200 kilocycles and are able to emit sounds to at least 100 kilocycles. Our hearing is limited to 20 kilocycles, so these sounds are supersonic for us.)

After several hours of experimenting with animal

Number 6 and during a run with the animal pushing the lever in order to stimulate himself, suddenly he began to push faster and faster and faster. He went into a *grand mal* seizure with waves of muscular contractions passing over the whole body. Quite as suddenly all movement ceased and the animal was extremely quiet. At this point I suddenly realized that he was going through an epileptic seizure caused by too intense a stimulation of his brain near the motor cortex. Seizures like this are quite common when there is overstimulation of the cerebral cortex of monkeys or men.

By this time the animal had thrown water all over the laboratory from the powerful slamming-down motion of his flukes in the tank. We threw plastic covering over the electronic apparatus. Meanwhile the animal was not breathing at all. Apparently he was totally unconscious, in deep coma such as one finds in monkeys or humans who have just had an epileptic seizure.

Suddenly activity started once again in the muscles throughout the body and extremely rapid swimming movements took place, which I recognized as the last anoxic "flurry," a Marineland name, presaging death. He went through the flurry and lay still, permanently.

This death made us very sad and we went through a period of mourning for this delightful animal. Three years later, replaying the tape of this death

still invokes a sense of loss in me for a fine dolphin. Once again death had come in our experiments because of our ignorance. Slowly but surely we were learning the difference between us and these animals, and how fatal our mistakes could be. (Finally, in 1960, I feel we can safely work with the dolphins for long periods: but who really can tell?)

By anatomical dissection we located the area in which the electrodes had been placed in this animal. They were just behind what is prefrontal cortex in the human, and above what is orbital cortex in man, near the dolphin's motor area. Despite disappointment and sadness, we had to go on with the research: our responsibilities lie with finding the truth.

Luckily, the next dolphin was a cry-baby. As soon as she was taken out of the tank, away from the other animals, she emitted continuous air-borne distress calls from her blowhole. After we placed her in the sling in the tank we found that her flipper was bent and that her shoulder was extremely sore. As soon as we relieved the pressure on the shoulder, she stopped her distress calls.

Later, when we were moving her once again, we hurt her by changing her position and again the distress calls came. Apparently whenever we hurt her, she would emit distress calls. This turned out to be a useful indicator for the experiment.

We placed electrodes deep in her brain in a spot

that we later discovered was in the thalamus. We found that we excited explosive respirations—inspiration and expiration—one after the other in a sharp, coughing fashion. It was a very dramatic effect and went on a few times after the stimulus was stopped. (It is sometimes dangerous to blow too much air too fast through the respiratory system of a mammal—so much carbon dioxide can be blown off that the animal will pass out.) We cut back the stimuli in this region and moved on to a neighboring one.

When stimulated in the adjacent zone at a critical level of current, the animal suddenly started emitting the distress call. When we lowered the current the distress call would stop. At this point it was suspected that the electrode tip was probably in one of the negative motivational systems. We decided to test this theory with the crescendo-stimulus train.

The crescendo-stimulus method was worked out with the macaque (monkey). One puts in a train of stimuli that starts at zero intensity and during the next fifteen seconds is gradually built up beyond the level at which the animal can stand it. A sophisticated animal will push the switch in order to stop the gradually increasing stimuli before they reach an unbearable level.

I showed the dolphin how to push the switch for the first time in her life by moving her beak upward. I did this three or four times. She quickly picked up

the maneuver and would shut off the crescendo at a level of current below that at which she had previously given the distress call. If now we turned off the current, she immediately stopped pushing the switch. If we turned it on again there was no delay whatsoever—she started turning it off again immediately.

Her performance was in sharp contrast with that of the monkeys. A monkey will miss and allow the crescendo to go through its peak until he is so strongly stimulated that he is in a state of panic, when he cannot possibly shut the current off. This dolphin never allowed the current to go that high. We found that her threshold for detection of "unpleasantness" in this situation was extremely low, in fact lower than any we had found in the monkey—approximately 0.3 milliamperes.

By contrast with the previous male, which had been stimulated in a rewarding system, this animal, stimulated in a punishing system, did not vocalize in any sort of free or creative fashion. The only vocalization we were able to obtain by stimulating the negative system was the distress call, stereotyped, repetitive, and at times piercing.

These findings reminded us of what the trainers had been telling us ever since 1955—that the best way to get an animal to co-operate and be playful is to reward him. You cannot punish a dolphin and get any sort of co-operation; he merely retreats and avoids the

human who has punished him. We found later that there are notable exceptions among bold and "pushy" animals, such as our Elvar, and Flippy I at Marineland, who was the first trained dolphin.

It might well be asked why punishing methods cannot be used to teach these animals. They seem quite as sensitive as the human to painful or fear-provoking stimuli. If they are in a tank in which they can swim away from a human who has hurt them, they will stay away and not co-operate at all, refusing even to eat. We discovered during the course of the stimulation experiments that when we put the electrodes into an area that apparently caused pain (to stimulate the same area in the human causes very intense pain, the so-called "thalamic pain"), the only vocal responses we were able to obtain were distress calls. For every stimulus the dolphin emitted a distress call. She also emitted similar signals when her shoulder was cut accidentally and was held in an uncomfortable position. The amazing versatility and range of sound that we had heard from animal Number 6 when stimulating the rewarding portion of his brain was completely lacking. There was no creativity, no production of new sounds, no mimicry when we stimulated this particular spot. We stimulated a nearby spot and elicited violent explosive breathing, but once again no vocalization.

Evidently when undergoing negative, punishing

experiences, these animals will not vocalize except in the emotionally expressive way mentioned above. At the same time we found, as did the Marineland trainers, that at first they will not attack us under these conditions. We have not thoroughly explored all the negative areas of the brain; we were reluctant to do so in any particular animal. As soon as we find a negative area we attempt to move out of it and find a rewarding system. However, we may someday stimulate a system in his brain which will cause anger in one of these animals to the point of attacking us. This is an effect we are trying to avoid. (Flippy I at Marineland, teased and punished by visitors for many weeks, finally began biting and charging his handlers.)

The bulk of the work during this October visit was done by myself and Miss Alice M. Miller. A few months later, in January 1958, I decided to investigate another animal and invited Dr. Iben Browning of the Sandia Corporation, in New Mexico, to join me so that he could learn the techniques.

The expedition took place in northern Florida during a spell of intense cold. This had very unpleasant consequences for the experiments.

Animal Number 8 was restrained in the fashion we had used in October, electrodes were placed in his head, and the experiments begun. In spite of patient and careful probing over several tracks in the brain of this animal nothing very spectacular was found.

There was one weakly rewarding spot in which the animal did an "experiment" on me.

I was attempting to make him whistle a burst of a given pitch, duration, and intensity in order to obtain the reward. I induced him first to whistle, then immediately rewarded him, at which point he would whistle again and I would reward him. He quickly caught on to this simple game. Every time he whistled we could see the blowhole move very briefly in short, sharp twitches.

At a certain time I noticed that he added a new rule to our "game." He was raising the pitch of each subsequent whistle. Suddenly I couldn't hear the whistles any more but I could see the individual twitches of the blowhole. Apparently he was whistling at frequencies so high that I could not hear them. I stopped rewarding him for each twitch. He then emitted two more "supersonic" short twitches, and with the third twitch I could once more hear the whistles and rewarded him. From that time on he did not go out of my acoustic range. He had determined what my hearing range was, and stayed within it for the next few hours. It is experiences like this that give us hope that these animals will attempt to meet us at least halfway in our attempt to communicate with them.

This animal was held still in restraint in a tank of running water and by now the temperature had dropped to 53° F. We had noticed at the beginning

of the period that the animal shivered every so often. Later we realized that this is dangerous for dolphins. After several days of restraint we put him back in the main laboratory holding tank with two other animals. He had developed an S-shaped curve along his back and could not swim. Apparently the muscles and nerves in the periphery were too cold to operate voluntarily or else his spinal column had just stiffened up to the point where it was painful for him to bend his flukes and body enough to swim.

As soon as he was put into the tank with the other two dolphins, he emitted the distress call, the usual crescendo-decrescendo pair of whistles. Immediately the other dolphins came and lifted his head up so that his blowhole was pushed up out of the water. He breathed and went down. A lot of whistling and twittering went on among the three of them. The two others now changed their tactics and instead of swimming under his head to lift it up they swam under his ano-genital region. As they passed underneath, their dorsal fins raked the very sensitive external openings of this region. The contact caused a reflex contraction downward of the powerful flukes, which forced the animal upward to the life-giving air. They kept this tactic up for several hours.

The distress call was answered with "first-aid" treatment and then after noisy chatter the animal was

given more appropriate specific treatment to relieve the distressful situation.

This episode, coupled with the one we had observed with animal Number 2 in 1955, gave rise to our suspicions that these animals have a very complex language and know how to use it for descriptive and predictive purposes. However, we were still not thoroughly convinced. I shall discuss this matter at greater length in the next chapter.

It was while we were integrating these experiences and the scientific data obtained that we began to realize that we should have to change our basic assumptions with regard to these animals. In the next chapter I shall present some of the points of view that I once held and that are still held by many people concerning animals in general and these animals in particular. It may be of interest to learn how and why we have changed our assumptions, and what our point of view has become.

CHAPTER SIX

Avoiding Biased Assumptions

AFTER the cold-water episodes at Marineland in January 1958, I flew to Oslo, Norway, where I lectured at Dr. Per Scholander's Zoophysiological Institute at the University of Oslo in the course of doing some work for the United States Air Force.

In my lecture I presented my slowly developing point of view that perhaps dolphins are much more intelligent than we give them credit for, within their own limitations. I suggested that we are severely handicapped in our efforts to measure the intelligence of individuals of other species than our own. We use inappropriate yardsticks derived from our own history as primates with hands and legs. As compared with other species our prime accomplishments have been the

development of material creations and of written language. I raised the question of what an animal does with a big brain in an alien environment—alien to us, that is. I recounted the episodes that we regard as suggestive evidence that the dolphin has a primitive language with predictive and descriptive values.

In a discussion following the talk, a visiting scientist from the Whaling Institute remarked that the killer whale must also be an intelligent animal and have a language: he related the following story to illustrate the point. During the previous whaling season in the Antarctic a group of several thousand killer whales came into the area where a fishing fleet was operating. By killing the fish near these boats the whales made it impossible for the fleet to catch any fish. The fishing fleet radioed the whaling fleet for help. The whaling fleet sent over several *shytter* boats.[1] One of these fired a single shot from a harpoon gun. Within half an hour the killer whales had completely disappeared from the vicinity of the *shytter* boats over fifty or more square miles and from then on not a whale came within range of the harpoon guns. However, the fishing boats that were not next to the *shytter* boats were still plagued by the whales.

The remarkable part of this story is that both the fishing boats and the *shytter* boats were converted

[1] Robinson, R. B. *Of Whales and Men* (Alfred A. Knopf, New York, 1954).

World War II Corvettes. Their silhouettes and power plants were quite similar, the only distinctive difference being the harpoon guns on the bows of the *shytter* boats.

The man from the Whaling Institute said that this demonstrated to him and to the whalers that the killer whales do have a means of communication, one that is extremely rapid and has predictive and descriptive values. It certainly looks as if the whales were able to communicate a description of the *shytter* boats to all the other whales within the space of half an hour, influencing the behavior of many, many individuals immediately and continuing to do so for many hours. Such transmission of complex information has always been thought to be possible only among humans.

Obviously this behavior differs from that of a school of fish which suddenly changes direction and takes up a new one by some unknown means of communication. The killer-whale mob sent out a fundamental description of a dangerous object: a harpoon gun. We can imagine the minimum amount of information that must have been transmitted and place it in sharp contrast with the kind of information a school of fish might send out. Let us visualize the conditions of this imaginary whale "conversation" as follows:

Possibly the dying killer whale was able to shout of the danger to his fellows in the immediate neighborhood. At least they were probably witnesses, either

visual or acoustic, to the catastrophe. Let us say that they were witnesses and that they then passed on the word to the other animals in the following way, freely and imaginatively translated:

"There is a thing sticking out on the front of some of these boats that can shoot a sharp thing that can go into our bodies and explode. There is a long line attached to it by which they can pull us in."

There might be some uninformed, inexperienced animals around, to whom they would then give the warning: "Stay away from those vessels with this thing on the front end—it can hurt you at a distance up to a hundred body lengths (or however they measure distance) away from the bow straight ahead." Immediately all animals would watch the bows of all the vessels involved and could still do their killing in the immediate neighborhood of those boats that lacked the protuberance.

Now let us contrast this "conversation" with that of the school of fish. To put it in human terms, one fish, the leader, might shout, "Right turn," and all turn right. Within a half second or less the command is given and the action executed. The behavior of the killer whales is very different. In the first place, a lot of information is transmitted about another object, not killer whales, and this object is differentiated from similar objects in the neighborhood. A particular aspect of the different objects is dangerous, and they say it is

dangerous. Belief and a period of thinking are required on the part of the hearers and then there must be further observations on the part of the hearers if they are to differentiate the objects they have just heard about. To transmit all of this information takes more than a fraction of a second—it may take several minutes, and the behavior of the whales is changed for a period of many hours. It isn't just a matter of turning right or left—it is a whole pattern of behavior connected with staying away from the dangerous object and not staying away from similar objects that are not dangerous.

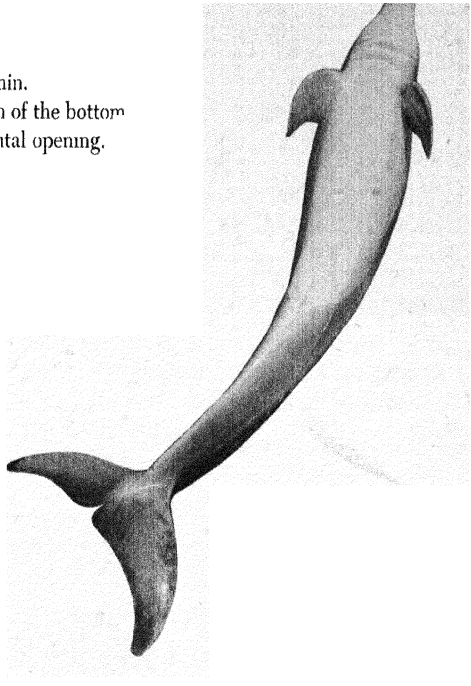
The level of complexity of the whale patterns of behavior is fantastically higher than that of the fish. The number of bits of information and the number of hours the influence lasts are probably measured in billions and in days rather than in fractions of seconds in the immediate here and now of the school of fish.

A similar episode involving killer whales was related by R. F. Scott in the diary of his last fatal expedition to Antarctica in 1911. It indicates that killer whales have a very high order of intelligence and possibly intellect. The notes of a man who witnessed the frightening events in their stark reality are quoted in full:[2]

"1911, Thursday, January 5—All hands were up at 5:00 this morning and at work at 6:00. Words can-

[2] Scott, R. F. *Scott's Last Expedition* (Beacon Press, Boston, 1957), p. 65.

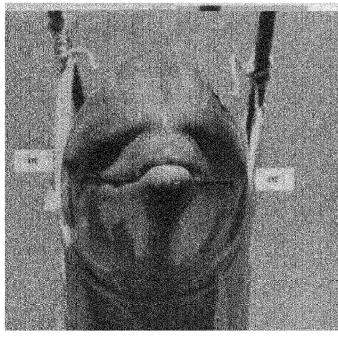
A female dolphin.
Note coloration of the bottom
and single genital opening.
John C Lilly



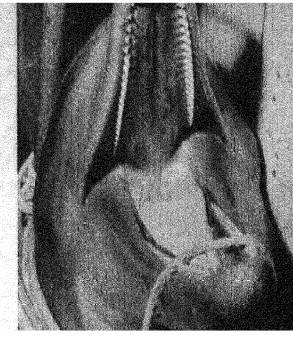
Dolphins continuing to swim in only 12″ of water

John C Lilly





A head-on view of a dolphin in a sling showing the position of the eye in relation to the line of the mouth

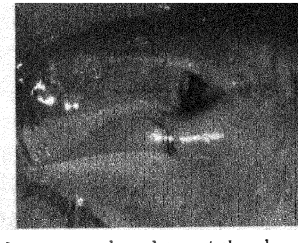


Frank S. Essapian

The open mouth showing the teeth, the wide "lips" and the sphincter at the back of the throat

Frank S. Essapian *Frank S. Essapian*

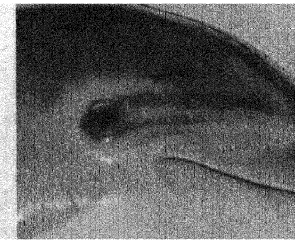




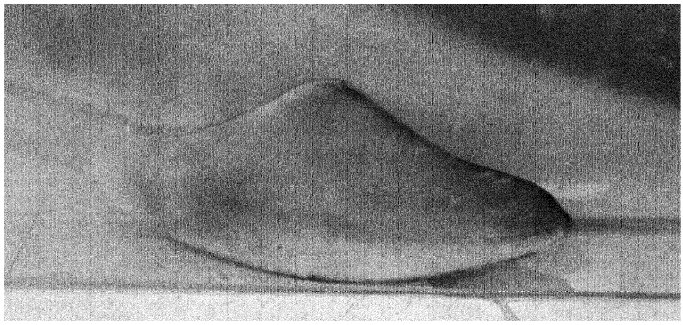
Left, the closed blowhole showing the crescent-shaped top of the plug *Right,* the open blowhole during breathing

John C. Lilly *Frank S. Essapian*



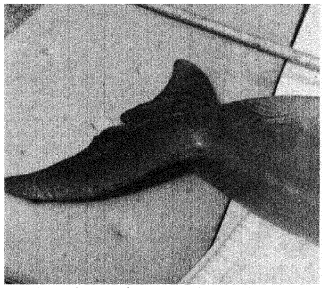


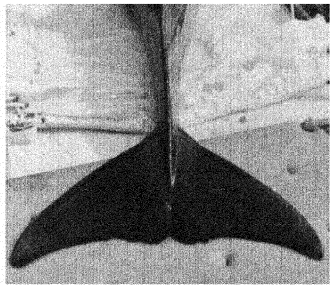
Left, Elvar's eye looking downward showing the position of the ear opening behind the eye. *Right,* Elvar's eye looking upward showing the position in relation to the back of the mouth opening.



A view of the flipper used for steering and palpation. *John C Lilly*

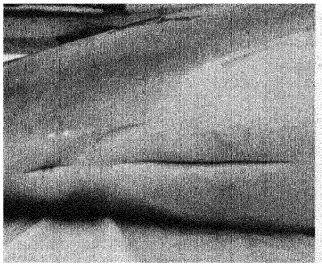
Frank S Essapian *Frank S Essapian*

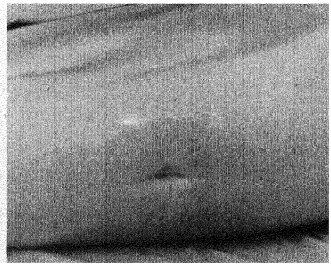




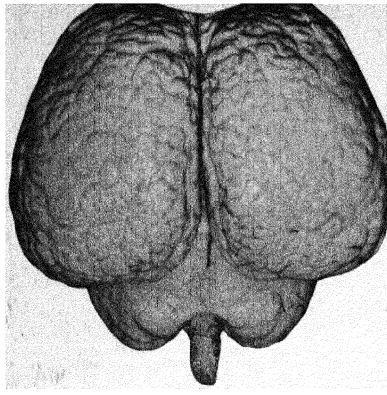
Left, a lateral view of the flukes and peduncle, showing the keel-like structure of the peduncle *Right,* a top view of the powerful flukes, the main propulsion mechanism of the dolphin.

Frank S Essapian *Frank S Essapian*





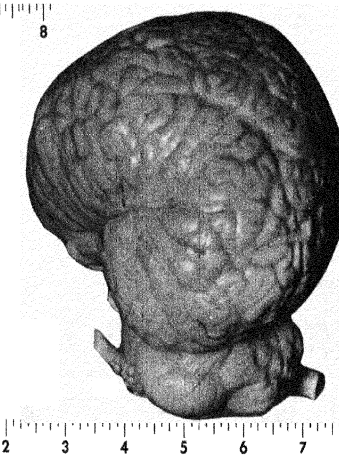
Left, the anal and genital openings in a male. In the female these two openings are combined into one long one. *Right,* Elvar's umbilicus (navel).



Top view of 1700 gram brain of dolphin (Tursiops truncatus)

Jerzy E Rose, Johns Hopkins University Medical School

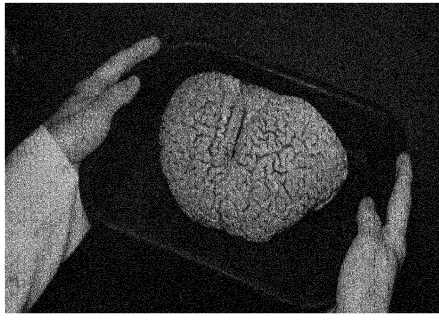




Side view of 1700 gram brain of dolphin (Tursiops truncatus)

Jerzy E Rose, Johns Hopkins University Medical School

Marine Studios



The brain of an adult dolphin, view from above forward and laterally, showing the complex folds in the surface of the cortex. Photo shows its size in relation to the human hand.

not express the splendid way in which everyone works and gradually the work gets organized. I was a little late on the scene this morning, and thereby witnessed a most extraordinary scene. Some 6 or 7 killer whales, old and young, were skirting the fast floe edge ahead of the ship; they seemed excited and dived rapidly, almost touching the floe. As we watched, they suddenly appeared astern, raising their snouts out of water. I had heard weird stories of these beasts, but had never associated serious danger with them. Close to the water's edge lay the wire stern rope of the ship, and our two Esquimaux dogs were tethered to this. I did not think of connecting the movements of the whales with this fact, and seeing them so close I shouted to Ponting, who was standing abreast of the ship. He seized his camera and ran towards the floe edge to get a close picture of the beasts, which had momentarily disappeared. The next moment the whole floe under him and the dogs heaved up and split into fragments. One could hear the 'booming' noise as the whales rose under the ice and struck it with their backs [more probably their rostral beaks, J.C.L.]. Whale after whale rose under the ice, setting it rocking fiercely; luckily Ponting kept his feet and was able to fly to security. By an extraordinary chance also, the splits had been made around and between the dogs, so that neither of them fell into the water. Thus it was clear that the whales shared our astonishment, for one

after another their huge hideous heads shot vertically into the air through the cracks which they had made. As they reared them to a height of 6 or 8 feet it was possible to see their tawny head markings, their small glistening eyes, and their terrible array of teeth—by far the largest and most terrifying in the world. There cannot be a doubt that they looked up to see what had happened to Ponting and the dogs.

"The latter were horribly frightened and strained to their chains, whining; the head of one killer must certainly have been within 5 feet of one of the dogs.

"After this, whether they thought the game insignificant, or whether they missed Ponting is uncertain, but the terrifying creatures passed on to other hunting grounds, and we were able to rescue the dogs, and what was even more important, our petrol—5 or 6 tons of which was waiting on a piece of ice which was not split away from the main mass.

"Of course, we have known well that killer whales continually skirt the edge of the floes and that they would undoubtedly snap up anyone who was unfortunate enough to fall into the water; but the fact that they could display such deliberate cunning, that they were able to break ice of such thickness (at least 2½ feet), and that they could act in unison, were a revelation to us. It is clear that they are endowed with singular intelligence, and in the future we shall treat that intelligence with every respect."

I not only find Scott's interpretation credible, I find some authors' reinterpretations of this now classic episode quite incredible.[3] In all charity toward authors not privileged to have had close-up experiences with any Cetacea, I will say that these are really unbelievable animals; but attempts to deny the validity of Scott's observations and his on-the-spot realizations of this whale's capabilities are best forgotten. Until the crucial research results are obtained, we shall not know the true explanation of the behavior of these animals, but any reasonable hypothesis is defensible. Experimental tests for the existence and form of such a whale language are being designed and carried out over long periods of time in our laboratory.

I hope I have made it clear that I do not intend to defend a single-minded thesis or accept the provisional working hypothesis of a whale language as anything more than a temporary aid to research design. I have always qualified my viewpoint as an exploratory research position: until the experimental data are collected and fully worked over, an open mind is essential and the number of hypothetical positions remain (at least metatheoretically) infinite.

Such behavior patterns can scarcely be instinctual. There is no need for them to be instinctual—most of the Cetacea are born capable of swimming, have

[3] Norman, J. R., and Fraser, F. C. *Field Book of Giant Fishes, Whales and Dolphins* (Putnam, London, 1937).

large brains at birth, and stay dependent upon the mother almost two years before weaning takes place. Apparently much of this period is spent in teaching and learning, in becoming disciplined so that the young will know how to hunt and avoid danger, mate and reproduce, and perform all of the other processes necessary to a life in the sea while breathing air.

I have been charged with "anthropomorphizing" by several of my colleagues. What do they mean by anthropomorphizing?

Science has made vast strides in the past by refusing to endow physical, chemical, and primitive biological processes with human purposes. There are many, many instances of scientists and investigators who went down blind alleys because they assumed that there was a "little man in there," who caused the processes to take place. A classic example is Van Leeuwenhoek's "homunculi," his little men, whom he "saw" under his microscope, in human spermatozoa. And there is all of the lore of magic and sorcery, the incubi, zombies, and ghosts that have been created by man as "explanations" ever since his brain became large enough to do so.

Progress seems to have been made first in those aspects of nature furthest removed from man. Physics separated itself quite early as being the most "non-human" part of science, and therefore it has the most ancient as well as the most imposing series of discover-

ies of any of the sciences. Chemistry had a similar success later and biology is bringing up the rear. Because biologists are involved in a young science, they are most definite and most militant about *not* anthropomorphizing—not putting a "little man" into each organism that they study. The most successful work on the amoeba and on the small single-celled animals (protozoa)[4] had removed human purposes from the behavior of these organisms. Recently several major advances in the study of the instinctual behavior of animals have been made. The work of Von Friesch with bees and their dances and of Tinbergen and Lorenz with birds and fishes has shown that it is very profitable to study the animals as if there were no personal purpose, no "will" within them comparable to that of the human. Rather, one should study the objective behavior and the conditions giving rise to that behavior, irrespective of any purpose other than the well-known "instinctual purposes" necessary for survival, reproduction, etc.

Thus in certain cases it is necessary to dehumanize the animal and not confuse his purposes with ours. With this point of view I agree *as long as the brain is very much smaller than ours.* This is the way to strike pay dirt in research with small-brained animals. I spent many years working with cats and monkeys and found

[4] Jennings, H. S. *Genetics of Protozoa* (Nijhoff, The Hague, Netherlands, 1929).

this point of view a very good one to take with them. It is most profitable from the standpoint of obtaining rapid results.

However, there is a converse "sin" of science, as it were, which is called "zoomorphizing" or "zoologizing." It consists in applying the thinking that works in the analysis of the behavior of the simple-minded, small-brained animals to the behavior of, say, someone with a large brain, such as a well-developed educated individual human. This approach gave rise to the "behaviorist" group of psychologists—beginning with John Watson as the most flamboyant—who thought of man as if he were an animal and could be observed as a naturalist observes an animal in the wild, with no communication between observer and observed.

Under these conditions, all vocal productions and vocal meanings must be ignored and only the conditioned-reflex type of reactions taken into account. All the richness of human exchange, all of the verbal exchanges on highly complex levels have no part in this kind of investigation. In other words, everything that is characteristically human is stripped from the scientific model of the man. His cerebral cortex is emptied of all his peculiarly human information. Although this is a useful exercise in theoretical psychology, it is not very practical and fails to explain man as himself. This kind of zoomorphizing or zoologizing makes a simple animal out of a man, reducing his huge

brain and its contents to the less complicated level of a primitive beast.

I hasten to add that there are certain aspects of human behavior that might well be explained on an instinctual and "simple-minded" basis—for example, the ways in which a person acts when extremely fatigued, when under the influence of alcohol or other drugs, or when he has sustained certain kinds of brain injury, or in agenesis of the cerebral cortex. But these are all examples of biological degradation of a human—converting the complex human into a simple animal by chemical or traumatic means. Such downgrading of the human is particularly obvious in prisoner-of-war cases, some of the older mental institutions, and in certain cases of "brainwashing."

However, unless terrible violence has been done to the man he is still, in his behavior, thinking, and language, well above his nearest primate cousin, the gorilla. The lowest-grade human moron is above the highest genius in the gorilla or chimpanzee clan. One must look to the human idiots and imbeciles to find behavior corresponding to that of the primates. The tragedy of the radically "mentally retarded," as we call them today, is that they are not quite human and yet they are more intelligent than any of the primates except man.

To return to the dolphin, here is an animal with a brain as large as, or larger than, ours. As I have

stated in previous chapters (and in more detail in the Appendixes), certain trends in the evidence suggest that it would be totally inappropriate to zoomorphize this animal. It would be just as much of a mistake to anthropomorphize him. We cannot and should not endow this animal with *human* purposes and *human* ideals. We should not attribute to him kinds of knowledge that belong to human experience and tradition but not to dolphin experience and tradition. It would certainly be a mistake to "put a man" in the dolphin's brain. One can put a man only in a man's brain.

Even when we try to understand man, we must investigate what a particular individual has in his mind rather than presuming that he has a prescribed set of ideas. This seems to be the sin of anthropomorphizing: assuming ahead of time what you are going to find and then finding it, by a sheer effort of will rather than by a scientific investigation. This pitfall of projecting the knowledge inside one's own brain as if it were in the brain of another creature is a very difficult thing to detect and to eradicate from one's thinking processes in those scientific fields close to man.

In dealing with dolphins it is wise to use a differentiated approach. I have developed one such:

Grant that the dolphin has a large first-class brain. This has been determined anatomically and the evidence is unequivocal.

Test for the capability of this brain to have long,

sustained chains of reasoning based on its accumulation of masses of data far greater than those available to, say, a monkey or a chimpanzee, and comparable to or exceeding those that a human accumulates.

Grant that the dolphin has an extremely complex vocal ability and capability.

Assume as a working hypothesis that there may be a language within the species (*Tursiops truncatus*), possibly with differentiated "tribal tongues" in different portions of the world; hunt for this hypothesized language.

Set up a program to try to discover what kinds of information are most likely to be stored in this huge brain and in what ways the animal is most likely to use them in his own particular environment.

Put individual animals in close contact with human beings and attempt to teach them things never before learned by dolphins; test their *potential* learning capacity.

With this differentiated investigative approach, rather than the anthropomorphizing or the zoologizing approach, scientific investigations can make advances.

We have found that, as in the previous history of science, man must once more remove himself from the center of the universe, as it were. During certain periods of history the earth was thought to be the center of the universe, then the sun came to be considered the center, and finally both earth and sun were

placed off center in one universe or galaxy. At one time man separated himself completely from all animals and attributed to himself a special creation of his own. He is now said to have evolved from apelike ancestors rather than to have been a special creation of God in a brief instant of time. In the latter part of the last century and the beginning of this one, Freud found that man's mental instinctual life is linked to that of his apelike ancestors and closely allied animals.

One of the last remaining thrones upon which man places himself is being shaken if not toppled by modern scientific research. Man thinks of himself as the most intelligent species on earth and as proof of this points to the accomplishments of his hands, his aspirations, his traditions, and his social organizations. In other words, man is said to be the most intelligent species because of what he does with his huge brain. May there not be other paths for large brains to take, especially if they live immersed in some other element than air?

What these paths may be we can only dimly discern until we are willing to grant that there may be such paths and that certain large-brained organisms may have taken these paths. In the case of the Cetacea, which are without benefit of hands or outside constructions of any sort, they may have taken the path of legends and verbal traditions rather than that of written records. Have they or haven't they? That's the essence of this research. We want to explore what the Cetacea

have done and what they are capable of learning from us.

When dealing directly with the small delphinids our fear of the unknown is apt to restrain us. We see their teeth and their powerful jaw muscles, their powerful swimming ability, and we are afraid when we are in the water with them. We all have such fears in spite of the fact that not a single instance in which one of them has willfully attacked one of us has been recorded. Quite the opposite: they have saved us at sea and played with our children near beaches.[5] Our fear of their ability to attack is born out of our own knowledge of how they attack sharks and similar stupid animals of the sea. Yet they do not attack man. Why, we do not know.

True, they may play a little roughly in their own medium with us who are so inept in water. A diver at Marineland of the Pacific had some ribs broken when one of the pilot whales attempted to play with him. They may not know their own strength and our fragility. But this is not hostile, directed, destroying attack.

Another time a whale called Bubbles became irritated when a shrimp was pulled back out of her mouth, and she charged the five humans in the tank. However, a diver finally restored mutual respect by courageously facing up to her with a Lilliputian tactic —a rod to poke her with when she charged him.[6]

[5] Alpers, Antony. *A Book of Dolphins* (John Murray, London, 1960).

[6] Jacobs, J. *Marineland Diver* (Dodd, Mead, New York, 1960).

Technically contact between man and dolphin is extremely difficult for both sides: in the air we live in we can hardly hear what these animals have to say, and in the water they can hardly hear what we have to say. The air-water boundary is a very real and difficult interface for either us or the Cetacea to cross so that we may meet one another halfway. If they are to meet us in air we must furnish them with "flesh-conduction" earphones so that they can hear us in air. If we are to meet them in water we must be furnished with some means of talking under water. These technical difficulties may have been responsible for keeping us apart in the past. (Some primitive human peoples may have got much closer to the dolphins than we ordinarily do today. Some of the personnel of the modern oceanaria certainly have succeeded in making friends with their charges.)

We must face the fact that undoubtedly, until we learn more about these animals, many of them will lose their lives in our investigations. As we attempt to penetrate deeper into the sea in submarine warfare and in exploration, we must also face the fact that men will be losing their lives in the media of these animals. This will be the case until our ignorance is dissipated, our knowledge more complete, and individuals of each species can meet those of the other without being haunted by the specter of death.

CHAPTER SEVEN

How Dolphins Are Trained

IN THE YEARS from 1955 to 1958 I became acquainted with the spectacular training program for the dolphins. My first experience was at Marineland in St. Augustine, Florida, at the Marine Studios, and the second was at Theatre-of-the-Sea, Islamorada, Florida.

At that time the two programs presented a contrast. The Marineland one was extremely formal and precise and was put on at a very rapid pace. The one at Theatre-of-the-Sea was more relaxed, less formal, and more intimate in many ways.

The Marineland trainer, André Cowan, is a Polynesian who rose from the position of maintenance man to that of animal trainer because of his intense

interest in the animals. He was still chief trainer at Marineland in 1960 and extremely enthusiastic about his work. Most recently he has taken on the training of two pilot whales delivered from Marineland of the Pacific. It was through André that I discovered that the trained dolphin will perform for a person other than his trainer. My thirteen-year-old son Charles participated in the experiment and we took motion pictures of the resulting actions.

André taught Charles the signals that he used with two dolphins called Splash and Algae. For Splash to squirt water from his mouth by closing his jaws rapidly near the surface, André's signal was to spit water out of his mouth and tap the side of the tank with his hand. Splash would then squirt the water and André would reward him with a small bit of fish. Charles learned this to perfection in about two or three tries and Splash co-operated immediately.

This little trick illustrates the formal aspects of the dolphins' training—a so-called food-reward technique. Credit is due to Keller Breland, the famous animal psychologist, for formalizing this type of training at Marineland. An audible signal, say with a whistle, is made as soon as any animal does something that one wants him to. This is an "intermediary" signal for the animal to come and get his reward. The action sequence seems to follow one of two formulas: (1) successful action on the part of the dolphins, followed

by a signal from the trainer and receipt of the reward; or (2) a signal from the trainer, dolphin action, a second signal from the trainer, and receipt of the reward.

At the same time the animal is stimulated by other factors: the presence of the trainer, the loud talking of the announcer over the loudspeaker (which he can hear under water but which is absent during training sessions without the audience), signals made by hitting the side of the tank with the hand, visible hand signals, and so forth. The dolphins watch the trainer intensely, listen to him carefully, and co-operate with him to a fantastically minute degree most of the time.

Of course, the trained animals in the show have been very carefully selected. A few animals just were not trainable to the precision that is required in the Marineland show.

Charles used the whistle and the hand signals to take Splash and Algae through their repertoire of tricks. They shook their flippers with him in a handshaking kind of maneuver, they jumped out of the water, and circled in the air, and dove back in head-first, they caught a football that he threw across the tank to them as they backed away, swimming backward with their eyes out of water. Each time Charles blew the whistle, gave the proper hand signal, and rewarded them with a bit of fish.

F. G. Wood, Jr., showed us a trick that Splash had developed but which was not used in the show. If you put your fist out over the water, close to the edge of the tank, he would come over and hold onto the fist. He held on first with the rigid lips at the end of the jaws. If you continued to hold your hand there, he would gradually move in over the hand one group of teeth at a time, squeezing the hand a little more each time, until you pulled your hand away. Then he would swim away on his side with one eye and his blowhole out of the water, making a clicking noise in the air that sounded very much like a human laugh. If you presented your fist again, he would take it deeper in his mouth so that you pulled back faster, at which time he would "laugh" again.

This was one of the most dramatic illustrations of the co-operative and interested and curious nature of these animals that I saw. At the same time it demonstrated their control of the power which they apparently refuse to use against man even under severe provocation. I suspect that if one of these animals is someday pushed hard enough when a man is in the water with him, the man may get hurt, possibly very badly. But as far as we can find out this has not yet happened in any of the oceanaria and it has not happened in any of our experiences. The animals continue to be co-operative, good-natured, and even compassionate toward men and to have a somewhat play-

ful sense of humor in their relationships with us. It may be these "humanlike" characteristics that will help us in our dealings with them while we are attempting to establish communication.

I've seen them play rather rough games with humans who were courageous enough to get in the water and try to train them in their own element. One winter day I watched Ken Burgess, who works with Keller Breland, training three young male dolphins in about four feet of water. The water was cold and he was wearing a rubber suit and a face mask. He was training them to go through a hoop under water; on the other side of the hoop Ken held a fish. Normally a wild animal will not go into any narrow space unless he has investigated it very thoroughly for several hours, so it is quite a chore to teach them this trick.

Once an animal rushed toward the hoop. Meanwhile a second one sneaked around behind Ken and snatched the fish that he was holding in his hand. The third animal rushed under him and pushed his legs out from under him. These playful antics continued throughout the training and kept Ken extremely busy. If any one of these animals had been sufficiently hostile and malicious, he could have very badly injured, if not killed, the trainer. They were never so rough that you felt they might be actively hostile. Rather, their behavior was more suggestive of a prankster's sense of humor.

Of course, their characteristic playfulness and lack of hostility are what make them trainable at all. If they had the ferocity of a shark, a wild tiger, or a wild lion, the oceanaria of the world would not be as far ahead as they are with their training.

At Theatre-of-the-Sea the training was on a much more informal basis. When I first saw the show in 1956 the dolphins definitely seemed to be rewarded merely by a human being coming out on the dock, talking to them, and playing with them in a talkative fashion, tossing them pieces of paper to play with, to carry away and to bring back. They responded to their individual names, Buttons and Jeannie. The trainers selectively controlled two animals in the same tank merely by voice commands. Once in a while one would become very playful and nip the other one in the midst of a trick; it all seemed to be in the spirit of good fun. Here people were swimming with the dolphins. Even visitors were allowed to swim with them. One of them, Martha K. Clark, has written up her experiences for us in a personal communication.

She wrote that the dolphins approached her rather tentatively, and finally one came close, presenting its dorsal fin. Mrs. Clark held onto the fin, and the dolphin dragged her briefly through the water, touching her with his moving flukes. When Mrs. Clark then bent in a bow near the surface, the animal took off in a very fast swim, "planing" Mrs. Clark at the surface down

the hundred-yard length of the pool and back again. The animal then left her and refused to give her any more tows.

When I returned to Theatre-of-the-Sea in 1960, the trainers were still swimming with the dolphins, but the relationship between them was much more tentative, less intimate, and more distant. The animals were fascinated by the humans with their face masks but merely "snapped" at them instead of approaching closely. They watched the swimming humans with intense curiosity and would sometimes snap their jaws at them while swimming by. Lately we have observed this jaw action in our captive dolphins in the Virgin Islands and in our Miami laboratory.

The jaw-snapping seems to have several meanings. If it is done so rapidly that it makes a definite click in the water, it seems to be a warning to stay away, as if to say, "Stop what you're doing; it's irritating." If a dolphin comes toward you slowly with his mouth open, it usually means that he is trying to receive a fish. He will do this while you are feeding him, for example, or if you put your hand in the water at times when he is expecting fish. At other times it seems to be merely some sort of signal as he swims by in the water, one that we do not yet understand. He will do it as he swims by with no intention of stopping and while he is watching you, but with no snapping noise whatsoever. At first it is a little frightening because the eighty-

eight sharp teeth are visible in the great long jaws. Eventually you become more or less accustomed to it. Sometimes I have the feeling that the dolphins have learned this can be a frightening gesture for the human and do it just to startle him.

CHAPTER EIGHT

My Laboratory at St. Thomas

AFTER my experience with the cold weather and the cold water in northern Florida in the winter of 1958, I decided to start hunting for a suitable location in which to work with these animals the year round. A lot of thought was expended on what would be required for sustained contact with the animals.

Data derived from the training program and from my own experiences with the animals had convinced me that we must maintain very close contact for long periods of time. Such contact must include both vocal exchanges and skin contacts. If we are ever to make progress in giving the animals the full benefit of our human experience, we must be able to get into the water with them the year round, frequently, every day

seven days a week. In other words, to give them the same chance that we would give a human child to learn our language and ways, we must modify our own behavior and meet them at least halfway in their own medium.

If we pay close attention to the way in which a human child learns to speak our language, we realize that close daily contact and satisfaction of needs, associated continuously with vocalized words, form a very large proportion of the conditions necessary to their learning. The human child is born with a brain of about 400 grams (see Table 6 in Appendix Two) and during the first year of life it grows to 900 grams. About the time that understandable words begin to be formed the child's brain weighs approximately 1000 grams. Meanwhile, he has absorbed tremendous amounts of information while his brain was growing.

During this crucial time of his life, if he is average, his mother, siblings, father, playmates, and other adults have bombarded him continuously with spoken words and gestures suited to the words. One important aspect of the learning process is that every need, from food to handling of excretion, has been attended with a vocal barrage of human language and with exchanges of facial expressions and gestures on a nonverbal level. The child's skin has been stimulated by baths, putting on and taking off of clothing, being carried about and

fed, all attended with the appropriate adult language or baby talk.

This kind of continuous verbal barrage is necessary if the young human is to learn the speech of his species. The child's first words are met with delighted reactions on the part of proximate adults. As soon as he is capable of making demands, these are generally met with satisfying reactions on the part of the attendants.

If such constant barrages and attention to detail are needed to teach a human understandable speech, we should give individuals of another species at least as much attention and chronic contact when trying to teach them our language. I feel that until this is done a sufficiently dedicated attempt to teach them will not have been made. And unless we make such an attempt we cannot say this species is incapable of learning to speak.

It seems to me that it is necessary to make use of the kind of contact I have described until we find something better.

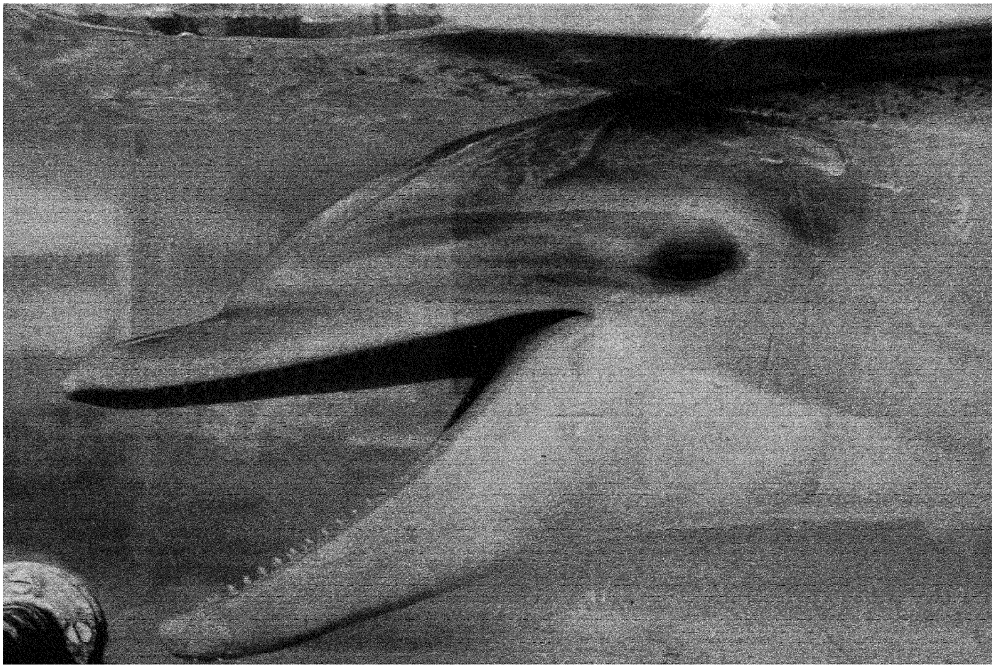
Electrical stimulation of the brain may speed up the learning processes to the point where we may be able to enhance and intensify the effects of long-term contact artificially.

In order to explore all of these avenues to an understanding with the animals, I decided to set up an ideal location—a laboratory and pools for chronic living-in with the bottle-nosed dolphins, *Tursiops.*

Tursiops was chosen because he likes warm (75–85° F.) water and so do humans. *Tursiops* is better known to us than any other member of the Delphinidae; he's in all the oceanaria. He is readily available over the warm waters of the United States and the world. He is apparently closer to us in neck mobility, curiosity, and close social living than his deep-sea cousins. He lives long and well in small pools and shallow tanks.

Other delphinids, such as the true porpoise or harbor porpoise (*Phocaena*), are interesting and should be investigated eventually. *Phocaena* likes colder water; *Lagenorhincus* likes deep water and high speed, as do *Delphinus* and *Stenella*. Their brains are large but their normal way of life makes them difficult to handle. Cold water necessitates rubber suits for us; water deeper than three or four feet makes us clumsy and inept in their medium. We have found that we deal best with dolphins in water twenty to thirty inches deep; *Tursiops* does very well in the depths. Some of the deeper-water delphinids rush around at very high speed in captivity and apparently do not do very well in restrained quarters.

If we were to deal with *Tursiops* on the basis described above we had to find a location for a laboratory that had warm, clear water the year round at a temperature somewhere in the middle eighties. Water of a temperature of 94° F. is just too hot for a



John C. Lilly

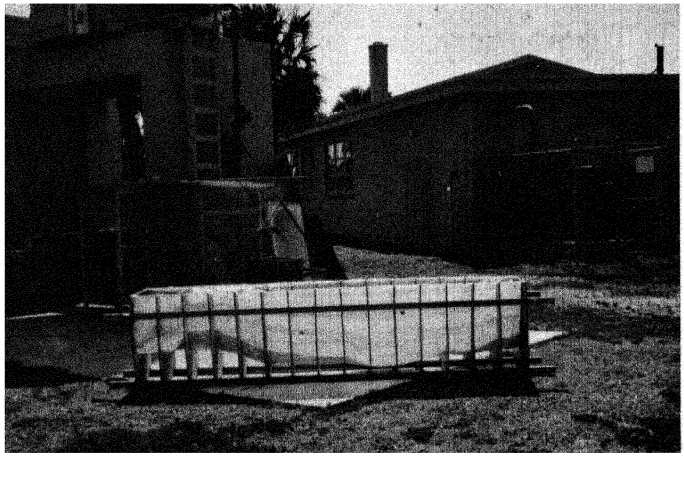


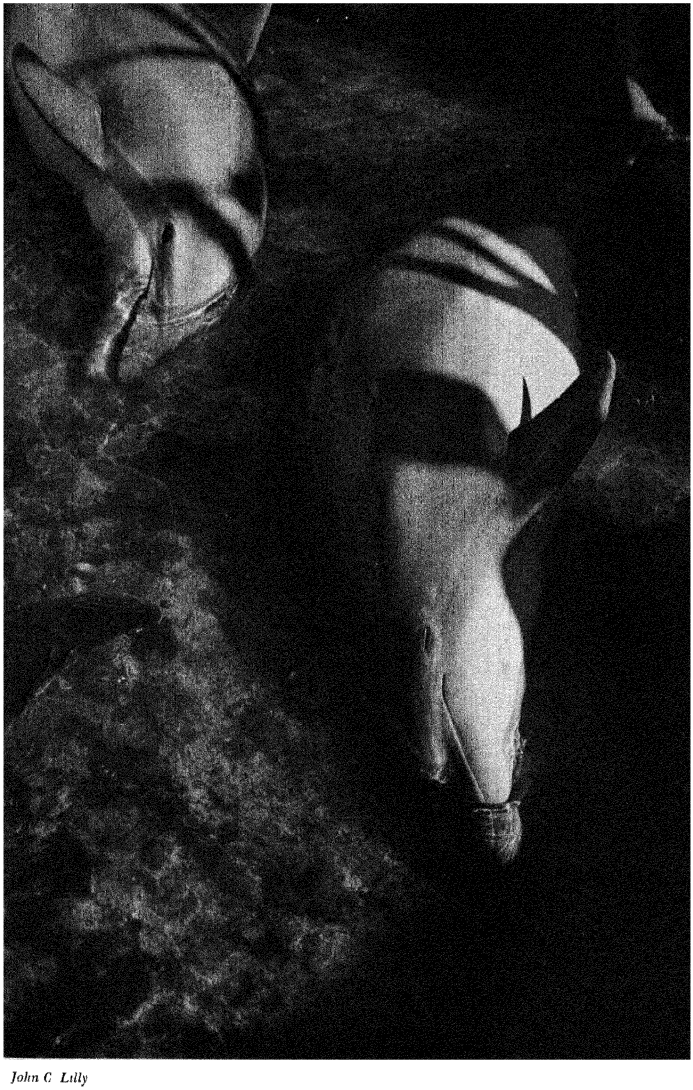
A. M. Miller

Start of the 1960 expedition. Marineland, Florida.

Completion of carrying box #1, Marineland, Florida.

Elisabeth B Lilly





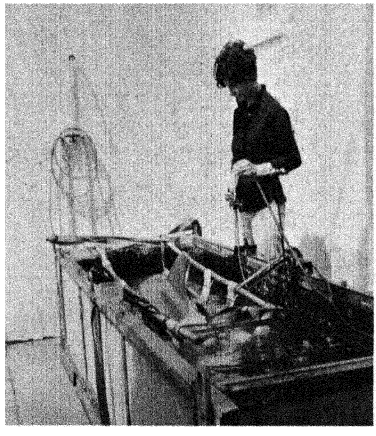
John C Lilly

1960. We drained the water to capture Lizzie and Baby. They turn on their sides and throw water on one another and us by fast fluke movements.



1960. Elisabeth and Alice constructing with plywood and Fiberglas our first carrying box This container is contoured to fit the dolphin's body so as to suspend him in the minimum weight of water

John C Lilly



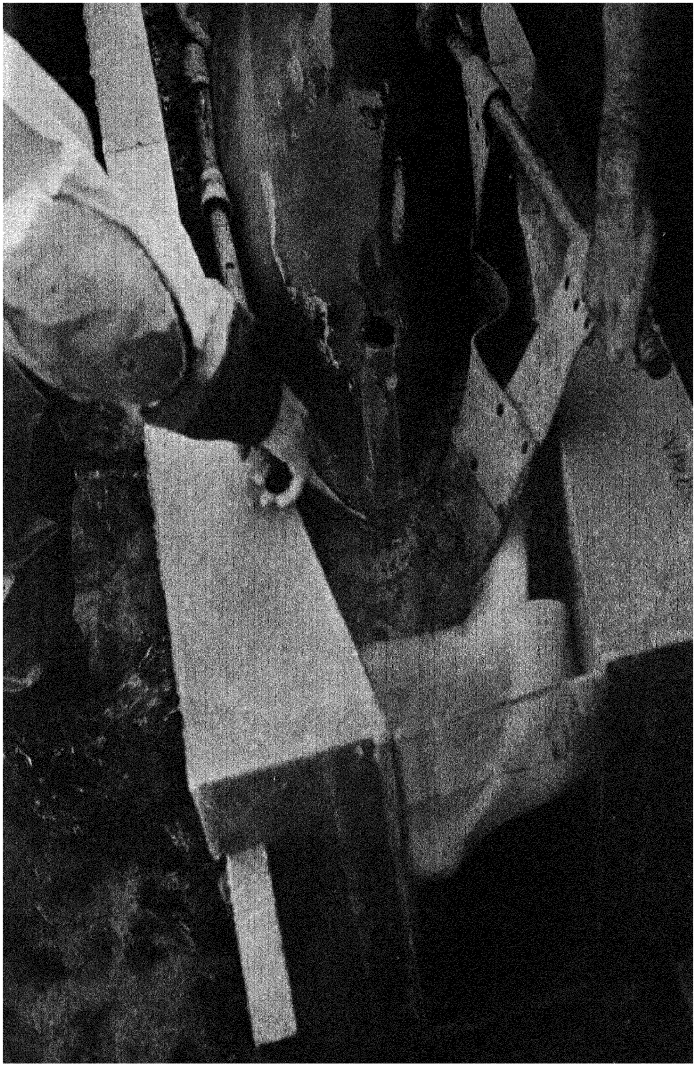
Lis taking measurements of Baby prior to construction of transport boxes

John C Lilly

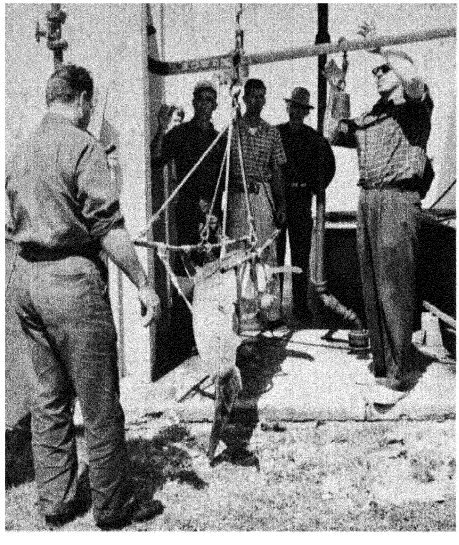
Earl Uhell



1960. Lis covering Lizzie with sheets to keep her skin moist.



1960. Testing box #2 with Lizzie. Notice open blowhole in midst of respiration. Notice her window in the front of the box and the foam padding.



1960. Lizzie weighed in at 410 pounds!

Elisabeth B Lilly

Marine Studios



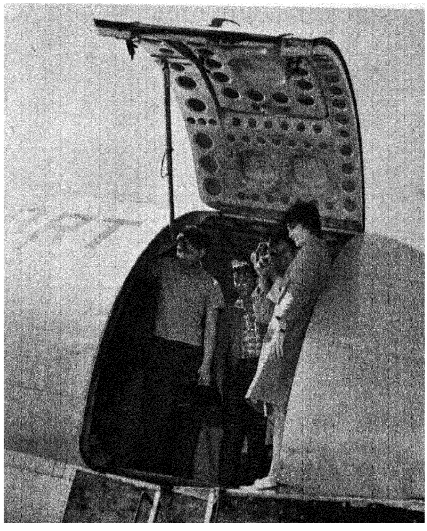
1960. Earl and Lis watching the loading of Lizzie. Fairchild Airport, St. Augustine, Florida



Marine Studios

1960. Earl Ubell, Alice Miller, John and Woodie making Baby comfortable in the airplane

Marine Studios



1960. Earl, Alice, John (camera) and Lis just before takeoff.



Earl Ubell

1960. All aboard. "Come on, Woodie, fly over with us."

man to keep up any activities. He can lie very still at this temperature indefinitely, but at temperatures higher than this he cannot expose himself very long without his body temperature rising extremely rapidly. At lower temperatures his activity (or metabolism) must be increased so his heat production can compensate for the cooling effects of the surrounding water. *Tursiops* seems to like best a temperature somewhere between the high seventies and the middle eighties. Above 90° is too hot for him and he becomes sluggish. Below about 70° the water is too cold for him and he spends all of his time keeping warm by rushing around. A comfortable temperature is apparently around 80° to 85°.

A second requirement was an equable climate over this water the year round, with no freezing weather and no cold fronts such as we found in northern Florida. We did not want a climate that was too hot, making it uncomfortable for the humans; on the other hand, we did not want it too cold. Most of the work would be outside and we wanted to be able to go in and out of the water in swimming suits without being nailed to the laboratory by a cold wave.

If the location was in a hurricane belt, high ground next to the sea must be available for the laboratory site. It was found that on the East Coast of the United States the laboratory should be at least twelve to twenty

feet above the high-water mark to avoid damage in case a hurricane did hit it.

It would be desirable to establish our setup on territory or land that was under control of the United States, in order to facilitate ordering of parts and so forth and to make sure of the political stability of the surrounding society.

We also felt that we should be in the trade-wind belt for the necessary cooling and for a wave supply. The pools where the dolphins would be kept could be swept through by wave action and the water thus kept clean by nature herself rather than by pumping. (The oceanaria in the United States are tremendously expensive operations partly because of the required pumping and filtering of the water for the tanks.)

Finally, it was to be a location that was easily accessible both by ship and by plane, so that heavy supplies could be shipped to the location either by air or by sea.

After considerable questioning of my colleagues and the travel agents, I finally pinpointed the region of Puerto Rico and of the United States' Virgin Islands. I first went exploring there in August of 1958. I checked the Bahamas and Jamaica as the southernmost boundaries of the cold fronts and also for the presence of wild *Tursiops* in the shoal waters. They were present both around the coast of Jamaica and throughout the Bahamas.

There were rumors that they were also present in the shoal waters of the Virgin Islands and that several other species were also available there. The Virgin Islands turned out to be a whale "highway": many of the huge whales were seen passing to the north of these islands every year in their annual migrations. They were also seen passing through the straits between the American and the British Virgin Islands. Thus the search was narrowed down and finally an ideal location was found.

Finding a location for the dolphin pool and laboratory entailed exploring the shore line and facilities and islands of the West Indies. It is a story of personal sacrifice and of a campaign to convince influential individuals, scientific and otherwise, that this project was a worthwhile gamble. From the beginning I have admitted quite frankly that I myself was gambling on my previous experience, on my conclusions, and on the philosophy behind the project. I am convinced that no really large scientific advances are ever made unless an individual scientist is willing to "stick his neck out." Many times during the years of this research I have had the feeling that maybe I was one of those stalks of wheat mentioned in the story of the King.

The King instructed his servants to cut only those stalks of wheat which protruded above all of the others, because they were the most vigorous and the strongest and he wanted to eat bread made only from them.

Sometimes one gets the feeling that there are certain politically-minded persons whose lives and well-being depend upon leveling those who stand out prominently from the crowd. Their "bread" is milled from "maverick" stand-uppers, too. I quickly discovered, however, that there were also many people who were intrigued and fascinated and deeply interested in projects along the lines of this research. These people have given me their wholehearted moral support from the beginning.

After searching the Virgin Islands for a period of six days by high-speed boat I found an available location that looked as if, with sufficient work, it could be made into what was desired for the project. Not until later did I learn that to "sufficient work" must be added "sufficient funds" and "sufficient time" and "sufficient personal driving energy." I started from scratch, carving the new facilities directly from the jungle and the wild tropical shore line on the island of St. Thomas.

St. Thomas was chosen because of its deep-water port and its airplane facilities—a combination that was lacking on the other American Virgin Islands. I found that heavy materials and equipment could be obtained from Miami within a week or two and that materials could be flown down from New York.

The site I finally chose is on the windward, Caribbean side of the island. Here a continuous supply of trade winds causes waves that come always from

the same direction and wash on a point sticking out at one end of Nazareth Bay, forming a small beach. On the west side waves from the Caribbean constantly beat upon the edge of the point, forcing water into a series of natural pools. Although none of these pools was deep enough or large enough for our purpose, I was informed that the judicious use of explosives could form the necessary pools for the dolphins' home.

The point rises to a height of fifty feet above sea level, which is adequate for protection against hurricane waves and even against tsunamis (tidal waves). The waters off the point are clear and sparkling and there are enough coral reefs and shallows to the seaward side so that no waves of great height can enter and smash anything we construct lower on the point. The water off that immediate part of the point is fifteen feet deep and slopes slowly off to a twenty-foot depth, which continues for two miles away from the point.

Our friends the dolphins and some larger whales have been sighted frequently in neighboring Caribbean waters. Two rocks upwind, three miles away to the southeast, were named Cow and Calf; again and again over the years whale cows and calves have been seen immediately adjacent to that area in the deeper waters beyond the rocks.

Closely available, within a mile, are some lagoons filled with mangrove islands and many paths for four-

foot-draft boats; this is ideal shelter for boats in case of hurricanes. Fish abound all through the area, so there is no problem about food for the dolphins.

The land itself was covered with such a thick growth of tropical jungle vegetation that I could barely see what it was like before buying it. I had to carry a machete, or "cutlash," as the natives call it, and keep cutting away the cactus, thorn bush, and dense vines ("catch and keep," for example) that covered the area. One path led from the high land on the north boundary, at 140 feet above sea level, down through a little valley to the beach. At first this was the only approach to the land; you went along the beach and followed the rocky cliffs all the way around the point to the west. Here you could see the seashore, which was so important to us.

However, you could not see the higher grounds of the point or the north ridge, which were jungle-covered. Beating in from the road with the machete, we found on the high ridge to the north an old Danish house (estimated to be two hundred years old) that had fallen down and was now rubble, hidden in the jungle. I heard that this location, once cleared, must be a magnificent one because the old Danes had chosen the best locations when the island was cleared for the growing of sugar cane. They had the advantage over us of immediately available slave labor to clear vast

acreage quickly and thus selected their building sites in the clear.

After exploring the possibilities of buying the land and of financing it, I met the delightful owners, Myler and Marian Kier, and the sale was completed.

With the help of natives from the British Virgin Islands of Tortola and Virgin Gorda enough of the land was cleared to realize that the views from the top of the point and the top of the ridge are fabulous. From the Danish ruins looking to the north we have a New Hampshire-Vermont kind of view of a nearby mountain across a valley. To the northeast the view toward and between the British Virgin Islands and St. John reminds me of the view down a Norwegian fiord. To the east there is a low nearby hill; and to the southeast beautiful Nazareth Bay with its brilliant green water and sandy bottom (an ideal yacht anchorage) can be seen. To the south is the island of St. Croix, thirty miles away and stretching twenty-six miles along the horizon of the deep Caribbean. (The water between St. Croix and St. Thomas reaches a depth of 12,000 feet.) To the southwest are three small, rocky cays which are the Caribbean borders of the mangrove lagoons visible to the west. Beyond the lagoons are the mountains between us and Charlotte Amalie, the only town on the island and the capital of the Virgin Islands. To the northwest these mountains join the ones immediately to the north.

From the cleared ridge we can look down on the cleared point. From the top of the point we can hear the waves smashing against the cliffs below, see the unusual clarity of the tropical waters, the coral constructions, the caves and the canyons inhabited by many varieties of reef fishes.

With the help of a hired caterpillar bulldozer, a road was constructed from the top of the ridge down to the saddle above the beach. Branches were built out toward the west end of the point and down to the beach. Meanwhile I had met Nathaniel Wells, a civil engineer and surveyor on the island of St. Thomas. He gave unstintingly of his time and ideas in regard to the development of the land for this project. After some of the clearing was completed he and his men made a topographic map of the land, which helped immensely in deciding where various things could go.

I had learned by previous experience, while at the University of Pennsylvania and at the National Institutes of Health, that it is very difficult to obtain support for any research project that requires extensive new facilities, new assumptions, and new ways of thinking. So I decided to go ahead on my own financial resources. By selling all my other property and buying the St. Thomas land on a mortgage, I was able to proceed temporarily without outside help.

The program was too large for me to finance and I realized that I would soon need help, but I also

realized that I could not get it until I had shown my own sincerity by gambling on my own ideas with my own resources first.

Although I did not apply to anyone for financial help at this time, help of other kinds was given by several individuals. Mr. Wells gave unstintingly of his time. It was through him that I was able to find effective bush cutters to clear the land, men who could work on their own with little or no supervision. Later I found that one of them was quite talented in masonry construction as well.

The United States Navy's Underwater Demolition Team No. 21 also gave us a big boost in the spring of 1959. Through the good offices of the commanding officer, Lieutenant Commander Donald Gaither, they came to the point at Nazareth Bay and with high explosives sculptured the present dolphin pool out of the native rock.

The location is on the west side of the point, facing the sea. The long axis of the pool is in the direction of the waves coming from the southeast. The Underwater Demolition Team started with a small fissure in the rocks where the water was entering naturally. This fissure was about a hundred feet long and three to six feet deep. The frogmen placed long hoses about three inches in diameter and twenty-five feet long end to end in this fissure. The hoses were filled with a high explosive and detonated either electrically

or by means of primacord. Gradually, as the fissure was widened and deepened by a series of tremendous explosions, we saw the pool begin to shape up.

Finally they were able to place a charge of approximately six hundred pounds of TNT, which produced a tremendous geyser of water and rocks. Rocks were cast as far away as the next point to the west. Within two minutes after this explosion a red convertible came tearing down the road.

A very agitated neighbor, Don McLaughlin, asked us when we were going to finish this rather devastating work. It seemed that his maid had been washing the dishes when the explosion occurred and a milk-glass light globe had been blown from the ceiling and dropped at her feet, whereupon she decided to leave for the day. He reported also that pictures were being dislodged from the walls of his living room.

I went over to his house across Nazareth Bay and stayed with him and his wife while the next explosion took place. It turned out that it was not the TNT explosions in the water that were causing the damage, but the "shaped" charges of forty pounds that form a jet of molten metal in the air, with which we drilled into the rocks when we were destroying ridges and large rocks. These produced a tremendous air-borne blast, which was causing the rather disconcerting happenings in the McLaughlin household. The TNT explosions were not bothering them, because they were

on the far side of the point behind solid basalt; no rock-borne shock was detectable at their house. We took a mirror down from the wall and I helped them remove their pictures, so that they would not be damaged. We did not use any more of the shaped charges in the air and finished up rather quickly with the underwater charges.

During these explosions we all took shelter in a small work shed with a tin roof. Several times rather huge rocks came hurtling through the air at high velocity and hit the roof. One rock went all the way across the point and just grazed the top of our white "laboratory" bus.

The Underwater Demolition Team used high-velocity explosive to shatter the rocks which we could remove later by means of a crane. The resulting hole was about seventy feet long, twenty-five feet wide, and of unknown depth. We could not determine the depth because it was filled with gravel on the bottom, but the water was uniformly about four feet deep all over the area.

We had chosen this location because the waves could enter through a narrows, flow through the pool, and come out on the far side, carrying water with them.

We soon started building the first wave ramp, by means of a crane with a sixty-foot boom. A dike of loose rock was put out on the sea side to keep the waves

from the location. Behind this dike or dam, forms were put up and the wave ramp shaped. A wave ramp consists of a rising apron of concrete against which waves can strike and over which the water climbs as the waves are shattered. The water then falls over the top of the ramp into the pool. With salt-water concrete and rock masonry we built a funnel-shaped opening so that the waves would be concentrated over a seven-foot-wide opening into the pool. A gate was constructed across this opening and the dam removed with the crane. After redesigning this ramp twice we found that we could maintain a flow of water on the average of approximately 40,000 gallons an hour. I estimated that under these conditions the pool would change all of its water in approximately two hours; this turned out to be correct. The daily tidal range at St. Thomas is approximately eight inches to one foot. Spring tides bring the variation to a maximum of about eighteen inches. During the rare periods when there is no trade wind the flow was cut down to approximately one-fifth of this volume. We lowered the height of the wave ramp and kept the flow at a higher rate.

In subsequent months concrete walks and walls were built around the pool and the gravel removed from the inside of it to a depth of twelve feet.

Meanwhile over on the other side of the point a jetty was being constructed out into Nazareth Bay so that we would have a place for our fishing and dolphin-

hunting boats to come in out of the waves. Some of the rock cliffs were blasted and dropped into the sea.

A road was constructed by the bulldozer where before there had been sea, and then slowly and patiently the bulldozer began to push the rock out into the bay.

As soon as the water inside the new jetty became calm we found that it was accumulating all sorts of marine life very rapidly. It turned out to be an excellent refuge for the fry of the ocean, which then attracted the tuna and other fish of the neighborhood. Very quickly we had native French fishermen coming in and casting their nets inside the jetty.

About May of 1959 I felt that I was far enough along on my own to begin to apply for outside aid on the project. I sounded out several of my scientific friends whose advice I value and began the rounds of various agencies and private foundations, seeking funds. This hunt continues and probably will continue through the next few years until the project is on its own feet.

A nonprofit corporation called the Communication Research Institute was organized under the laws of St. Thomas, Virgin Islands. Incorporators were myself, Mr. George Dudley, Mr. Joseph McGowan, Mr. Louis Hoffman, and Mr. Wells; these men were also the first Board of Trustees for the Institute. The charter of the Institute is an abstract of the research program

and an educational program founded on the dolphin research.

Of those agencies and foundations to which application for help was made the one that came through most quickly was the Office of Naval Research, Biological Sciences Division, under Dr. Roger Reid, in the section under Dr. Sidney Galler. Within three weeks from the time of our application they were able to furnish us with sufficient funds to start the research program. Meanwhile, we'd made application for a facilities grant through several agencies, and the National Science Foundation came through with a grant for a new laboratory in the spring of 1960.

When I applied for these grants I presented the program to scientific appraisers for the first time. Various scientists from the Office of Naval Research, the United States Public Health Service, and the National Science Foundation visited St. Thomas to appraise our efforts and the program.

These men did a very thorough job and were extremely helpful to us with our problems of organization and future planning. Among these men were Dr. Louis Levin of the National Science Foundation and Dr. Hudson Hoaglund of the Worcester Foundation. Dr. Hoaglund was extremely helpful and sympathetic. He had been through a similar pioneering effort with his own institution in its early years and his sympathetic moral support helped us greatly during our precarious

beginnings. We were still, in August 1960, not on absolutely satisfactory financial grounds but at least we were under way and over the first hurdle of beginning the laboratory.

Additional help for the program and the Institute arrived from an unexpected quarter. In 1959 I married Elisabeth Bjerg. Lis is of Danish and English descent and had lived in the islands the first eight years of her life. Her grandfather was the royal Danish customs collector at Frederiksted on the island of St. Croix before the islands were bought by the Americans in 1917. Her devoted and unstinting help in the affairs of the Institute made possible many things which, before, there had not been time or help enough to do. She is a remarkable person who devotes herself to raising three children and running the Institute office and is still cheerful, gracious, and beautiful. She also has a high sense of adventure and will undertake extremely difficult assignments.

Miss Alice Marie Miller, my former scientific assistant at the National Institutes of Health, joined us in December 1959. Miss Miller's remarkable and good-natured devotion to her profession opened up the possibility of getting under way sooner than I had hoped. She brought to the project the continuity from past experiments which we could obtain in no other way. She had participated in the 1957 series on dol-

phins Numbers 6 and 7. She had been analyzing the performance records of the macaques and previous dolphins, and understood thoroughly my ways of collecting, analyzing, and presenting scientific data.

CHAPTER NINE

Lizzie and Baby

THE POOL finally seemed adequate and we decided to bring in the first inhabitants and see if dolphins could live in it. By March 1960 everything was ready for a trip to Marineland to obtain the first dolphins of the new series—Numbers 9 and 10, which we later called Lizzie and Baby.

From my previous experience I had come to the conclusion that a dolphin is happiest when suspended in water and that our major problem on this trip would be to provide a means of transporting two animals thus suspended.

Alice, Lis, and I flew to Marineland, Florida, to measure the dolphins so that boxes could be made for their trip to St. Thomas. Once again we were to learn much about these animals that was unexpected.

My old friends at Marineland were their usual cordial selves: Mr. Wood welcomed us to the research laboratory; Mr. William Rolleston, the manager, and his gracious wife took us to dinner; Mr. Nessler, the treasurer, gave us much information about obtaining frozen fish and supplies; Mr. Wood's assistant, Cliff Townsend, gave us much detailed attention and advice. Mr. Valentine and his crew helped us many times to carry the heavy animals from one tank to another.

The Marine Studios had been saving two animals for us for four months. They were in a tank behind the research laboratory, swimming with Nellie, a dolphin which had been used in some sonar experiments. She had one blind eye and the other eye was usually covered during experiments.

The weather turned out to be cold, raw, and a bit blustery, interspersed with very warm periods. Coming from the Virgin Islands, we all felt the cold and noticed particularly how cold the water was.

Throughout Marine Studios the animals were extremely active. We did some observing at night and made some sound recordings from the main tanks to add to our collection of sounds made by many animals in the same tank. We also watched the animals in the main tank at night to find out what the resting pattern is during the night hours. We found that they "rest," not sleep, by hanging near the surface with flukes

down for a few minutes, slowly rising to breathe and then sinking, and finally resuming swimming.

Meanwhile we were getting on with our research on a way of transporting the animals without injuring them. Baby, dolphin Number 9, was taken from the laboratory reserve tank and put in a small shallow tank about twenty inches deep, nine feet long, and two feet wide, which we had used to hold the animals in the laboratory in 1955 and in 1957. Her body measurements were carefully made and the design of the transporting box started. We wanted a box that would hold enough water so that the animal would be surrounded and the weight taken off the chest, lungs, and circulatory system, and at the same time we wanted to keep the total weight of the package to a minimum, since it was to travel by plane.

We decided to build it like an old-fashioned airplane, out of quarter-inch plywood cross sections spaced seven inches apart with outside vertical and lateral dimensions of two feet by two feet, the whole box to be approximately nine feet long.

Baby turned out to be exactly eight feet from the tip of her beak to the trailing edge of her flukes, and she weighed three hundred pounds. Lizzie, dolphin Number 10, whom Earl Ubell named for my wife, was also about eight feet long and weighed slightly over four hundred pounds. As dolphins go, these were a little bit large to be working with and we found out

later that they were definitely too heavy for our purposes. One of the lessons we learned from our work with Lizzie and Baby was that it is much easier and safer to handle lighter and shorter animals. The shorter and lighter (hence younger) animals seem to learn much faster and are more curious and more active in the immediate vicinity of human beings in the water.

The box construction was carried out mainly by Lis and Alice. The sections were connected by two-by-two wood poles and the inside cross sections were cut out and connected by fiberglass the length of the box. Box number one was made entirely of fiberglass and plywood cross sections. Alice and Lis learned a lot about the use of fiberglass, cloth, and resin in the construction of minimum-weight containers. It wasn't until much later that we learned how to cut the sides of the box down to the minimum possible, and hence reduce the weight of the water proportionately, and still keep the animal floating. However, this fiberglass box, our first attempt, was fairly successful.

We tried out the box with Baby and then attempted to see if Lizzie would fit into it. At this point we had our first accident. There were two main causes of this accident: one was Lizzie's huge weight and the other was the weakness of a sling we had carried over from the 1957 expedition. We had lowered the water in the tank to the point where the dolphins were stranded and Cliff Townsend and some of the divers

from Marine Studios were lifting Lizzie off the floor. The box had been placed on the floor of the tank. As Cliff and the divers were lifting, the sling suddenly broke, tearing out along one of the holes for the flippers. Lizzie fell, hitting her head and one flipper on the concrete floor of the tank. As we were to see several weeks later, this accident contributed to her death.

The first two prototype boxes were not quite satisfactory. They contained too much water and did not exactly fit the animals. (These boxes have since been modified.) However, they worked sufficiently well so that the animals, kept in them for twenty-four hours (seven hours' flying), remained spontaneously vocal with relaxed and variable patterns of breathing. (Under stress because of gravity they have a fixed pattern of breathing, very regular, stereotyped, and labored.)

When we were ready to start the long trip to the Virgin Islands the boxes were placed on a truck beside the tank in which the dolphins were residing. Early one morning the water in the tank was lowered to the point where the men could get into it, catch the animals, put them in a sling, and lift them out of the tank with a small hand crane.

They were then carried to the boxes on a truck and each placed in her own box, which was then half filled with water by means of a portable pump. The dorsal fin and other exposed parts were covered with bed sheets to prevent the skin from drying out. Covers

were placed over the boxes and tied in place. A large hole was left open for the dorsal fin and for the exchange of air. Polythene foam (which absorbs water like a sponge) was placed at critical points where the animal might rub against the box. (Later on we found that the proper way to place the foam is to imbed it in the last layer of the resin so as to fasten it to the fiberglass in the box. Numerous other modifications were made in subsequent boxes.)

An old friend, Earl Ubell, science editor of the New York *Herald Tribune*, had been invited to travel with us the year before, when we first planned the trip. Apparently dolphins were becoming newsworthy enough for his editor to let him make the trip. Earl turned out to have great capabilities as a foreman and was soon directing workmen in how to carry and place the boxes. He was an invaluable assistant on the trip.

The truck was scheduled to drive from Marineland to the St. Augustine airport, a distance of about eighteen miles. It was a cold morning. Earl and I had the job of staying on the open bed of the truck to attend to the dolphins. The driver was in a bit of a hurry and went about fifty to sixty miles an hour. The wind was chilly and Earl used a bright yellow plastic pail as a hat.

We had to stop twice to readjust the positions of the animals. When the truck slowed down too suddenly, the dolphins slid forward in their boxes and

pushed up against the front end. Lizzie developed a sore on the end of her chin as a consequence. The smaller Baby fitted better into her box and did not slide around quite so much.

It was at this time that Earl and I first began to notice that when each dolphin expired her breath against the cover of the box, black mucous material was deposited on the underside of the cover. Later we discovered that this material had a very foul odor similar to that of the material left at the bottom of the tank when they drained most of the water at Marineland. We suspected that possibly the animals had some sort of infection despite the fact that some of the people at Marineland had told us this was a normal condition. My medical training told me that this could not be a normal condition even in such a strange mammal. I smelled more of the results of putrefaction by pathogenic kinds of bacteria than I did of any normal odor of an animal that eats fish.

We should have done something about this before we started moving the animals, but we were so committed that we went on in spite of this disturbing clinical sign. (We learned later unequivocally that healthy dolphins have no odor to their breath and expel no material.)

At the St. Augustine airport the Fairchild people had reserved loading equipment to transfer our precious boxes into the aircraft of the Southern Air Trans-

port Company. The C-46 had very large cargo doors high off the ground. A fork lift plus about eight men were required to move the animals from the truck into position within the aircraft. Earl and I barely had time to warm up our chilled muscles before we began taking pictures—movies and stills—of the critical operation. This was the most stringent test that our new type of box was to undergo. The boxes came through with flying colors, thoroughly recorded on film.

During this transition phase the animals moved about very little and continued to be expressive, both vocally and with their breathing. They seemed quite happy floating in their water in spite of all the moving about.

Through the kindness of Mr. Nessler, Mr. Rolleston, and Mr. Wood at Marineland we had on board a quantity of frozen fish sufficient to feed these animals until we could obtain more at St. Thomas. Also on board, through the good and remarkable graces of Lis, were three large freezers in which to store the fifteen hundred pounds of fish. We had filled a sizable fraction of the C-46 aircraft with our own cargo including the animals.

At take-off, as the plane accelerated, the slanting floor of the plane (not a tricycle landing-gear type) caused the water to cascade from the back of the boxes. Earl, Lis, and I were sitting in the jump seats back of the boxes in the stern of the aircraft; Alice

was up forward with the crew. We had our safety belts on during take-off and could do nothing about the water pouring out of the boxes. We had brought several pails and large plastic garbage cans filled with extra sea water, and when the plane had leveled off at altitude we quickly poured in enough water to make up the deficit and made the animals comfortable once more. It was then that we began to be repelled in earnest by the foul odor coming from their blowholes. We began to realize that these were probably sick animals and that we might lose them in the near future.

We flew at 7000 feet for several hours, during which we counted the respirations of the animals carefully and found that the altitude had no effect upon the rate at which they breathe when suspended in water. There were several rough air spots on the way to Puerto Rico but none bad enough to cause us any trouble with the animals. Poor Lis became a bit wan, however, as she was pregnant.

Having got a late start, I was worried about whether or not our men would meet us at the airport. When we finally landed we found there not only our men with a truck but also Southern Air Transport's men with the official unloader.

Earl took charge of the unloading operations and without benefit of mechanical aids managed to get the animals carried out of the airplane and onto our truck by directing our helpers in a striking "voice of com-

mand." By the time everything was unloaded it was midnight and I decided to leave the dolphins on the truck for the night and to unload them early in the morning. Our supervisor, Frank O'Connor, would spend the night on guard with the animals, tending to their needs.

Baby was so comfortable that she was carrying on a lot of very complicated vocal and movement activity every time we approached the tank. She could vaguely see our outlines through the fiberglass sides, and we could see her close her eye if a hand was moved rapidly toward it. At the same time her vocalization would stop. I played a brief game with her that night: I whistled once, twice, three times, then she whistled once, twice, thrice; I answered with the same; then she whistled one, two, three, four and I answered. This game was to continue when she was put in our pool at Nazareth Bay.

Early next morning the men drove the truck with the animals on it from the Submarine Base where they had spent the night to Nazareth Bay. My son, Charles, and Lis's children, Pamela, Leslie, and Stuart, watched the proceedings and Charles took photographs while the men unloaded the animals into the pool.

With new prongs on our front-loader we unloaded the boxes from the truck, drained the water from them, and then carried them down to the pool from the road one at a time.

We thought it was going to be quite a trick to get the animals out of the box and into the pool without the use of a sling. But we solved the problem by placing the tank in shallow water in the pool, filling it up with a bucket until it almost sank and then, turning it over sideways, releasing the dolphin after one of her respirations.

Lizzie was unloaded first; she swam away but was tilting over to one side, not swimming quite upright. This was our first real evidence that she had been injured in her fall to the concrete. We also noticed that she had skin lesions and sores on various parts of her anatomy because of the handling, carrying in the slings, catching in the net, and rubbing at one place in the box. The major lesions were on the end of her chin, at each "armpit," and on her flukes.

Dumping Baby into the pool in the same fashion, we found that she was in better shape. She swam perfectly straight, quickly joined Lizzie, and the two of them swam round and round the pool.

Lizzie would not or could not eat, in spite of strenuous efforts on our part to induce eating, but Baby started eating right away and within two days was taking food directly from our hands.

Earl wrote up his story in St. Thomas and sent it in for publication, then he stayed for a few days to observe our work with the animals. The day after Earl

left his news story appeared on the front page of the New York *Herald Tribune.*

We began our study of dolphins in captivity, in as close contact with them as possible. About the second or third day we started swimming with them. Alice tried to feed them while she floated in the water. During this time we found that wild dolphins will not voluntarily come close to a human unless they are rewarded for coming close and penalized for staying away. Baby gradually began to make closer approaches as she received more and more fish, but Lizzie kept her distance. (Later, with animal Number 11, Elvar, we found that if close quarters and close contact were enforced, the "approach" processes could be speeded up.) We made many hydrophone recordings of the vocalizations of the two animals.

There were many live fish—small ones—swimming around in their pool which they ignored. One little yellow-tail took up a position next to Baby's head and picked up the scraps every time Baby was fed. The many little lizard fish at the bottom of the pool cleaned up any debris left over from the feedings.

We found that the pool was kept clean by the action of the waves of the Caribbean. The flow of water was sufficient to handle easily the problems raised by two dolphins in the pool, and to keep the water crystal clear most of the time. Once in a great while the dolphins would rush around the tank in

great excitement and stir up the material from the bottom, but in a matter of two hours the pool would be clear again.

Because of our worries about Lizzie's not eating we built a small pool at the end of the main one, so we could capture her and give her vitamins and antibiotics. We didn't want to cause her any further injury or great stress.

Frank O'Connor is an experienced underwater construction man, formerly with the Underwater Demolition Team of the U. S. Navy. He placed sacks of concrete in position under water, tying them together and building up a wall. He then built a drop gate.

Using a surplus nylon parachute on a floating wooden two-by-four as a partition across the whole pool, we slowly forced the animals to swim toward the gate. (We had not found it possible to induce them to go into this tank by means of food.)

It turned out to be very easy to separate Lizzie from Baby and to force her into the small tank. At this time we took some recordings. Once Lizzie was separated from Baby, a very mournful sort of exchange of calls (whistles) started. We had been noticing for the previous two or three days that Lizzie seemed to be sleepy, and it looked as though every so often Baby would wake her up by nudging her and swimming alongside her, holding her upright. Listening to the

tape of Lizzie in the small tank now with the hindsight of subsequent events, I realize that something very distressful was going on and that she was appealing to Baby for help. Here again was evidence that these animals probably take very good care of one another and that sometimes we should not interfere.

Lizzie was placed in the small pool late one evening. When we returned next morning we found that she was dead, lying on the bottom of the pool. I did an immediate autopsy, hunting for obstructions along the intestinal tract and similar things that one looks for when an animal does not eat. The air sacs along the airway and the lungs were thoroughly infected. She apparently had an overwhelming infection which she was unable to fight off.

Lizzie had lived only three weeks, finally dying of a complicated set of causes: her infection, her anorexia and starvation, and some injury to her nervous system caused by the fall. On post-mortem examination a hemorrhage was found in the cerebellum on the left side near the tentorium.

It was at this time that Baby started a series of calls as if to a distant or missing animal at odd, irregular intervals. One Sunday we found out what was causing these calls. I came out in the morning to feed her, noticed that the calls were going on in great profusion, and recorded them on the tape. Later that day one of my sailing friends said that he had been

sailing by our point and had seen coming into Nazareth Bay fifteen to twenty wild dolphins, heading right for the area where Baby was kept. In spite of the fact that she was not connected to the sea by any possible acoustic path, we thought these animals could be attracted by her excreta coming out of the pool and traveling in the water back to the sea. Somehow they might have had a way of detecting her excreta traces. Similarly she might have detected their traces and thus known they were out there. We traced out the currents of Nazareth Bay and the theory looks plausible.

After this episode we began to watch her more closely for possible clues as to how they might do this. There are numerous papillae all the way around the edge of the eight-inch-long tongue. Apparently the papillae are very richly endowed with taste organs. Watching Baby with this in mind, I could see that she held her mouth slightly open and went up and down facing into the water coming into the pool from the sea, hour after hour. We remembered that at Marineland this was what the spotted dolphins did—faced into the incoming water with their mouth slightly open, apparently allowing the water to go through the mouth and tasting whatever was coming in from the sea. It looks as if this may be a way in which they can follow one another and also find fish traveling ahead of them. In other words, the spoor in the sea is probably

just as real (though evanescent) as it is in the jungle; instead of being smell, however, it is taste.

After several more weeks Baby suddenly stopped eating. We put her in the small tank, gave her vitamins and antibiotics, and tried our hand at tube-feeding a dolphin.

With the proper equipment tube-feeding turned out to be a very simple procedure. We made a soup of food-fish with a Waring blender. A small piece of plastic garden hose was placed in the rumen through the mouth. Three men held the animal in three feet of water—two of them opened the jaws while I inserted the tube down past the larynx through the esophagus into the stomach. It went in very easily and quickly. We had a sufficiently long tube so that we were sure it would not go into the larynx or in the back of the nose. Knowing the anatomy, we were able to put the tube into the rumen with a minimum of trouble. I was able to introduce about ten pounds of fish soup into Baby's stomach. We then let her go.

These heroic measures, however, did not save her. She also died. The last time we caught her we found that her breath was extremely bad and was producing the black material we had noticed ever since the day we brought her from Marineland.

At first, with these fresh deaths, we were extremely disappointed and depressed. However, we had anticipated the fact that we were going to have these

troubles and probably many more of them. Before we learned enough about the animals to keep them safely and continuously in captivity, many more might die. Lis and I decided to go to Florida, explore the possibilities of getting new animals, and check on this business of the infections with known healthy and captive animals.

CHAPTER TEN

Elvar and Tolva

In May and again in July 1960 we made trips to Florida. During the May trip Lis and I found out several interesting facts through firsthand observation and from accounts of dolphin handlers. We determined the important fact that the air emitted from the healthy dolphin's blowhole normally has no odor whatsoever. We smelled the expired air from several animals in the Florida keys; all had practically no odor. This was additional evidence that Lizzie's and Baby's bad odor was a sure sign of a pathological condition, probably a chronic "sinus" (air-sacs) infection or even pneumonia.

We made the acquaintance of Marty, a dolphin at the Theatre-of-the-Sea that had learned to vocalize

while riding on his flukes with most of his body out of water. It was a very impressive performance, with extremely loud noises that sounded something like a crying human baby emitted from the blowhole into air. Later we derived from this experience a hint that if one dolphin starts a trick another will learn, fairly quickly, to do the same thing. Buttons, in the same enclosure with Marty, was just beginning to vocalize in a similar fashion and by summer had developed an even louder voice than Marty's.

We also found out that a dolphin can be kept in a shallow pool almost indefinitely. At Theatre-of-the-Sea we made the acquaintance of Kenny, a dolphin who was kept in a pool thirty-six inches deep and about twelve feet square. He had been there for eighteen months, during all of which time he was alone, except for interspecies contacts with human handlers and the sight-seers. He was completely out of contact with his own kind, in intraspecies solitude, and had learned many things that we had not previously seen a dolphin doing.

It was in May that we met the dolphin captors, Mr. and Mrs. Victor Milton Santini, of Marathon Key, Florida. I had learned about the Santinis from a magazine article. The accompanying pictures showed Milton Santini jumping from a boat onto the back of a dolphin in the shallow water of Florida Bay.

We were seeking a source of smaller animals be-

cause of our experience with Lizzie's injury and the difficulty of transporting the heavy animals. The Santinis had been catching and selling dolphins for the last thirteen years and were quite aware of the problems. The largest dolphin they had caught weighed eight hundred pounds and was ten feet long. It must have been old because it had no teeth left. They much preferred to capture animals no more than seven feet long and weighing no more than two hundred and fifty pounds. They assured us that it was possible to find and capture small dolphins without visibly injuring them. They use a "secret" method of catching which they say does involve a fast small inboard, a ten-inch square-mesh net, shallow water, and, I add, considerable strength, patience and courage.

After talking for several hours to the Santinis we were convinced that it would be best to buy dolphins from them and they agreed to capture five or six animals for us and hold them at Marathon in pools connected with the bay there. They could supply the animals within a few days of the receipt of our order.

In talking with us Milton Santini referred to "taming" his animals after they were caught. Later we realized that this was a very apt word to describe certain changes that occur in the animals between the wild and the captive states. When animals are first caught they are very skittish and tend to retreat as far from human beings as they can in the pool in

which they are kept. They're also "spooky"—any new object put in the pool upsets them and they rush around, inspecting it closely. The larger the object the longer it takes them to get used to it. This behavior pattern is evoked by human beings as well as by inanimate objects. The process by which an animal is changed from a skittish, relatively suspicious, and easily spooked animal to one that approaches the human being and seeks things from him is still rather mysterious. Listening to Santini's stories and observing the care of the animals at the Theatre-of-the-Sea I found several hints as to what the possible mechanisms might be.

I knew that brain stimulation brought about taming in a great hurry, within a half hour or so of the time that a rewarding system was first stimulated electrically. However, until we understood the "natural" taming sequences we should not understand what the brain stimulant might be doing.

The essence of taming is changing an anxiety-provoking situation to a reward-producing situation: the same situation is changed in its motivational value to the animal by means of learning. One way to initiate this process is to confine the animal in isolation from its kind. Of course, the animal must be capable of accepting the necessary confinement. Small-brained animals are sometimes incapable of this, but most mammals are quite able to adapt to a confined situa-

tion. The next step is chronic and continuous contact with human beings. (Among humans, this procedure is known to produce extremely rapid learning in certain controlled directions. It is commonly used in education, in brainwashing, and in psychotherapy.)

The classic third step is to force the taming process by withholding food until the starving animal has to approach a human being or die. This is the usual training maneuver for any type of animal in circuses and in oceanaria. Deprivation of food sets up a physiological state ("deprived state") and the reception of food is an extremely rewarding experience to the animal. This was the basis for most of the Pavlovian experiments and is one of the methods used by Keller Breland in training the dolphins at Marineland and by Santini.

I knew that we could use such tactics but I also felt that these men might be rewarding the dolphins in ways of which we were all unaware.

One such hypothetical reward may be skin contact—contact between human skin and dolphin skin. Several lines of evidence led me to this working hypothesis. Our observations and experiences suggest that fear of damage to the skin must be overcome and tactile stimulation then becomes rewarding to the dolphin.

It has been my experience, and that of many other persons, that a wild animal, when caught and

held firmly by two or three men, quickly ceases to struggle. This phenomenon seems to be partly due to a "wait and see" attitude that any intelligent animal assumes when he knows he is beaten. But in the case of the dolphins it seems also to be due to their discovery that our skin is smooth and does not damage them when we grab onto them. Their skin is extremely delicate and their worst natural enemy is the shark with its rough skin, which could easily tear that of a dolphin on physical contact.

The pictures in the magazine had shown Mr. Santini in physical contact with the dolphins within his restricting net, and we asked him if by any chance he stroked and rubbed them when he first caught them. He said yes, that this was part of the taming procedure and that it was very successful in calming a frightened animal. They do not seem to be paralyzed when they are captured, and there is no massive inhibition of movement. They are quite capable of struggling and snapping their jaws. If one of us happens to push on the larynx or around the sensitive lips or the blowhole, they will struggle, but contact in these areas poses a threat to survival, and as I have mentioned, apparently they will struggle only if it is absolutely necessary for survival.

Thus it seems that when their fear and ignorance of anything new and strange has been overcome by forced contact with a smooth object, they are well on

the way to being tamed and I believe they then experience pleasure from tactile stimulation of short duration.

In the course of some experiments I conducted from 1954 through 1956 I was suspended in water for several hours at a time, and I noticed that my skin gradually became more and more sensitive to tactile stimuli and an intense sense of pleasure resulted. However, if the stimulation was carried too far it became intensely irritating. I reasoned that the dolphin is suspended in water all of his life, twenty-four hours a day, and possibly had developed an intensely sensitive skin, which serves many physiological purposes: one of these might be the rewarding effect of rubbing against another animal, for example, in courtship and mating behavior.

I had noticed that Kenny, at Theatre-of-the-Sea, sought contact with his human handlers and would swim beside them and rub against them, like a dog that wants to be scratched. But after a time Kenny would terminate this kind of play and express irritability by banging his beak or his peduncle against the person if an attempt was made to stroke him.

At Marineland, in St. Augustine, we were shown that the animals needed and wanted a large brush that was anchored to the bottom of the main tank in the oceanarium and against which they could scratch themselves. Part of the purpose of this scratching

procedure could be to remove the outer layers of dead skin so as to maintain their bodies free of barnacles, algae, and other fouling organisms, and part seems to be associated with keen pleasure in the process.

In the light of these experiences we began a set of experiments on animal Number 11, Elvar.

Elvar was one of the animals Mr. Santini obtained for us in July. He was a male six feet ten inches long and weighed about one hundred and fifty pounds. Dr. F. G. Walton-Smith, of the Marine Laboratory of the University of Miami, volunteered to give us the use of some space for the summer in a former machine shop at the laboratory, and we transported Elvar in one of our boxes by truck. He was put in a small swimming pool thirty inches deep and eight and a half feet by ten feet. We fed him by hand from the first day. The Santinis had been feeding Elvar for a period of one or two weeks before we took him to Miami, so we had no trouble about feeding him.

A chronic, long experimental schedule was set up so that several persons in bathing suits could get into the pool with Elvar and attempt to force physical contacts on him. Various objects, such as a floating ball, a floating ring, etc., were placed in the pool and he gradually adapted to their presence and began to play with them. Within the first week we had established contact and he was beginning on his own initiative to approach Alice and four students—Kristin

Stueber of Baltimore, Maryland; Karl Kellogg of Santa Monica, California; Robert Bates of Glenview, Illinois; and James Hiss of Miami, Florida—who had come to work with us during the summer. After about ten days of such experiences he was approaching and rubbing himself against our big toes, hands, knees, or legs. He began to accept all of our attentions and showed the rewarding effects of rubbing and stroking quite rapidly.

He also bore out my prediction that, if one rubbed and stroked him too long at one session, he would become irritable; he showed it by retreating or by banging his beak or his flukes upon our arms or legs when we presented them. If we let him then rest—let his skin rest, as it were—the rewarding effect would once again be elicited an hour or so later.

He gradually became acquainted with a small bathing brush and showed the value that he placed on this by pulling it around the pool and lying on it while it was on the bottom. He would attempt to scratch himself—any and all parts of his anatomy—on this brush. When he had had a long session of using the brush, we found that he was irritable and would not accept any further rubbing and stroking. In other words, for rubbing and stroking to be a rewarding experience, a previous state of deprivation must have existed. In this sense it is analogous to a food reward: the animal must be hungry if the food is to be a re-

ward. The "skin" systems in the brain must also be deprived in the same sense. Such systems in the brain must be charged up with whatever it is that charges up the nervous system. The brushing and stroking use up the accumulated "charge" of pleasure and the contacts then become irritating instead of soothing and pleasurable.

Electrical brain stimulation through implanted electrodes has very similar effects in certain rewarding systems. If one stimulates the *globus pallidus* or the head of the caudate nucleus, the animal will push a key in order to stimulate these systems within his brain. If certain critical zones within each of these systems are stimulated in a human, the patient reports an intense sense of pleasure restricted to portions of the opposite side of the body. Apparently these systems contain the neurophysiological mechanisms for pleasurable experiences having to do with the skin (and possibly joints and muscles).

In summary, then, a dolphin approaches any new and strange object from two viewpoints. As it were, he asks these questions: Will it hurt me? Alternatively, will it reward me? The detailed mechanisms of the reward are yet to be completely worked out. Among other possible rewarding experiences for these animals could be those in the acoustic sphere.

If these animals have a language, it may function somewhat the way it does in the case of a human. The

adult human experiences intense reward or intense punishment on receipt of appropriate messages from other humans. In other words, a good many of our acoustic exchanges and vocalizations in the human sphere accumulate rewarding and/or punishing values for one reason or another from childhood to adulthood. There may be some sort of rewarding experience that is detectable in this sphere.

We designed some test experiments on the most primitive possible level. If the animal whistles or vocalizes in any way, this sound is picked up from the pool, amplified, and causes an electronic switch to turn on a tape reproducer that feeds back to the animal a recording of the human voice, counting from one to five. If this vocalization is or becomes rewarding for the animal, he should increase his rate of vocalization over a twenty-four-hour period during which he can elicit this response from his environment. He is in absolute (interspecies as well as intraspecies) solitude and there are no other sources of acoustic stimulation during the period of the experiment, so that he is, as it were, in an "acoustically deprived" state. The first, preliminary experiments on Elvar with such an apparatus make it look as if this hypothesis is correct. However, it will take a long time to carry out all of the details and the controls necessary to test this rather startling hypothesis. In no other animal than man has such a finding been made.

After a month of confinement with us Elvar suddenly developed self-confidence. There was a sudden change in his behavior; he began to play for long periods of time at very high speed with all of his toys and with us. He lost most of his spookiness and insisted on approaching us in a very definite fashion. If we put a hand in the water he would approach it, with his jaws open, and make playful snaps at the hand. If we put a ball in the water he would bounce it up out of the water with his beak. If we put a small ring in the water he would mouth it, put it over his beak, and swim around the pool with it. He also retrieved small objects on command.

At first some of these activities were sporadic, but soon he began to control and take charge of the situation. His initiative improved tremendously. He also swam around the pool in pursuit of his objects so rapidly that he threw water all over the laboratory. He also began to bring the front part of his body out of the water so he could look around the laboratory and took to slamming his flukes down on the water in a very exuberant fashion.

For a while Karl Kellogg was able to catch him quite easily by grasping him around his chest and lifting him out of the water. Suddenly Elvar caught on; as Karl started to reach for him he would accelerate and push by Karl at a high speed (even in water only

twelve inches deep!). A few days later he was doing a fast "barrel roll" in Karl's arms and thus escaping.

I think that part of what he learned was that the walls in the pool were as smooth as our skins and would not hurt him. This pool had a vinyl liner with extremely smooth walls and flooring. Elvar discovered that if he wanted to rest he could just go down to the bottom and lie still. He discovered that the liner was noninjurious and as he swam around he would hit the wall with his flukes and not damage them. However, he also learned to bank on the turns and how to swim in the very shallow water close to the wall.

After he had heard only human voices for several weeks his vocalization began to be less "dolphinese" and to break up into more humanoid, wordlike, explosive bursts of Donald Duckish quacking.

I placed in the tank an underwater loudspeaker connected to an air microphone so that he could hear our voices no matter what we were saying in the laboratory and get used to the sounds produced by humans. We also had in the tank a hydrophone connected to an air loudspeaker so that we could hear all of his sounds. During the first few weeks he emitted the same rather plaintive attention calls that we had heard from Baby when she was in isolation in St. Thomas. He also played the "numbers game" of whistling very short bursts in groups of one, two, three, four, or five whistles. If we then whistled such groups

back to him, he stopped whistling, apparently listening, and then began a plaintive "attention" call, which is a very slow crescendo followed by another crescendo of frequency and amplitude.

This call seemed to be related to attracting any animal that may be in the neighborhood. It is not the distress call: it is a separate though similar call. Of course, he was also using his sonar with the typical "putt-putting" and "creaking-door" sounds. These sounds were always directed toward any new object thrust in the pool and were always made during a feeding procedure. About this time he began to emit noises similar to those made by Marty of Theatre-of-the-Sea, thrusting his blowhole above the water and making a sound like a human baby crying. He also began the clicking noises in air which I first heard from Splash at Marine Studios in 1956.

But the most interesting things to hear were the short quacking noises that began to sound very much like primitive words in the human language. Apparently he was beginning to mimic what he was hearing. An additional set of noises that I heard him begin to make were those I had heard Alice make, noises of affection that people make toward children: soothing sounds and attention-getting sounds, cluckings with one's tongue. These now began to come back to us as extremely primitive copies made with a vocal apparatus quite different from ours.

One of the problems of understanding the mimicry from a dolphin is that he does not have exactly the kind of resonant air cavities that we have within our necks and heads. He tends first of all to make extremely high-pitched sounds, both whistles and clicks, and does not make use of the resonance of such long and open air columns as we do. Our voices depend on the fact that our vocal cords are at the bottom of a long tube terminating at the other end in the lips and nose. We can modulate the shape and length of the tubes and the amount, velocity, and timing of air coming up through these tubes. Dolphins have different tubes but they apparently don't use them naturally as we do without a lot of training. They tend to keep the tube extremely short and the pitch very high. Each individual sound terminates rapidly with very little aftervibration. We might compare the quality of the sound emitted by them to that emitted by a very small plucked violin, while our voices more nearly resemble that emitted by small organ pipes.

If you look at the pattern of the human voice spoken into a microphone, amplified, and put on a cathode-ray oscilloscope, you can see that the highest frequencies necessary for understandability are pretty much limited: for maximum intelligibility, they do not go above about 5000 cycles a second and do not go very far below 100 cycles per second. Of course, the telephone companies know this and their instrument



John C Lilly

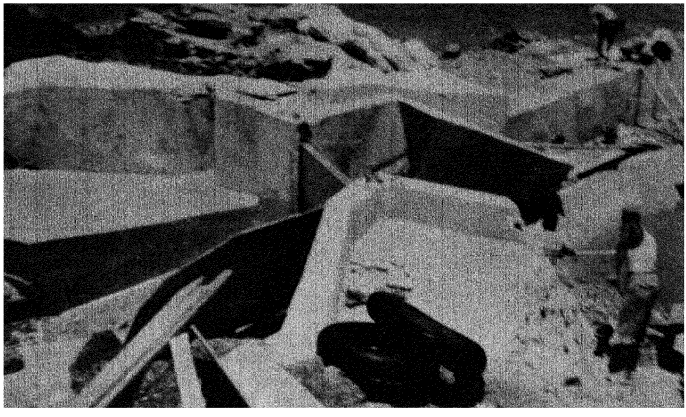
600 pounds of T.N.T Blasting out for the dolphin pool

After the blasting, construction begins on the entrance to the dolphin pool. View taken from the top of crane.

Charles R Lilly



Charles R. Lilly

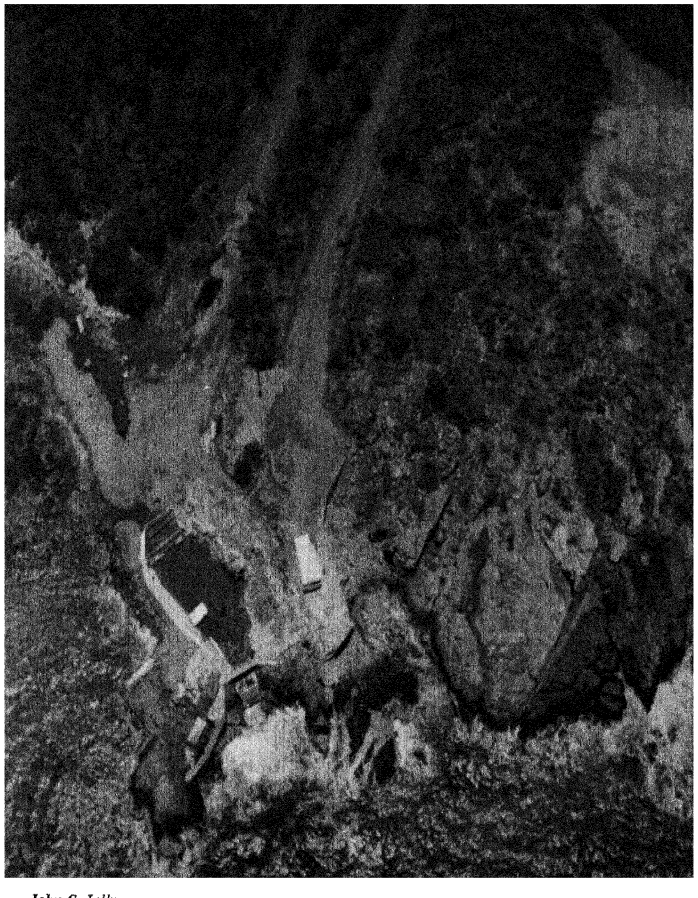


Construction of the wave ramp at the entrance to the dolphin pool is completed.

Unloading of Baby and Lizzie, St. Thomas.

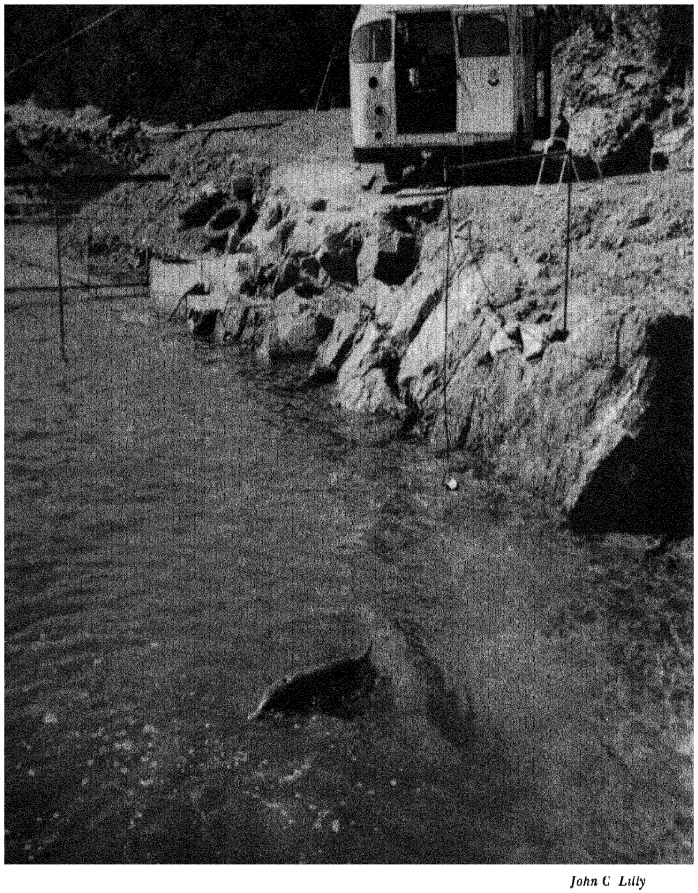
Charles R Lilly





John C Lilly

Aerial view of completed dolphin pool showing the white laboratory bus, the white Fiberglas feeding raft, and wave ramp and the roads.



John C Lilly

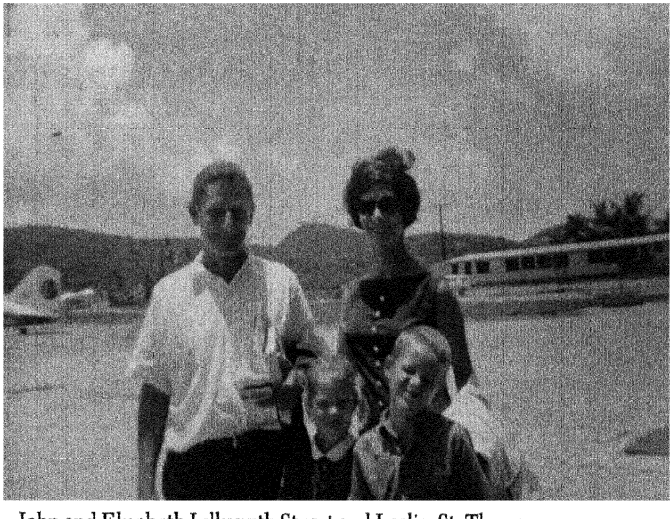
Dolphin pool outlet and laboratory bus. Baby and hydrophone visible behind her.



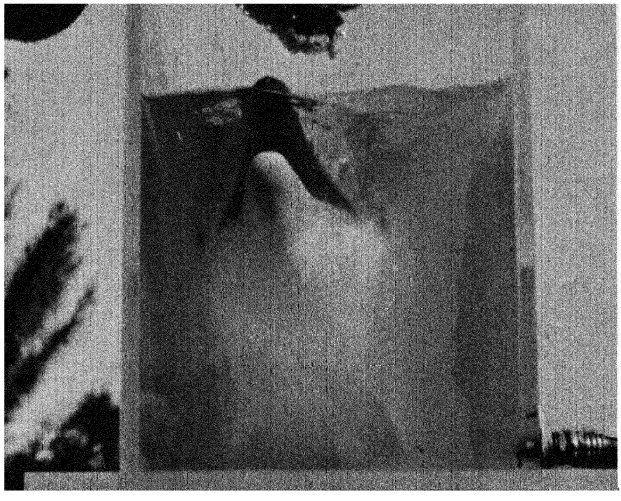
Elisabeth B Lilly

Our secretary, Betty Sue Evans, feeding Baby from the Fiberglas raft.

Pamela C Lilly

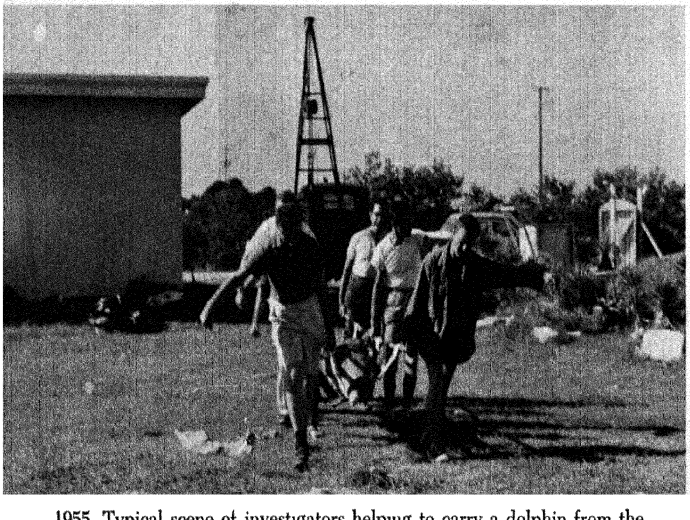


John and Elisabeth Lilly with Stuart and Leslie. St. Thomas.



A view of Elvar showing the wide placement of the eyes in their presumably stereoscopic visual field. Elvar and Alice's hand.

John C. Lilly



1955. Typical scene of investigators helping to carry a dolphin from the pool to the laboratory: no weight in water, 400 pounds out of water!

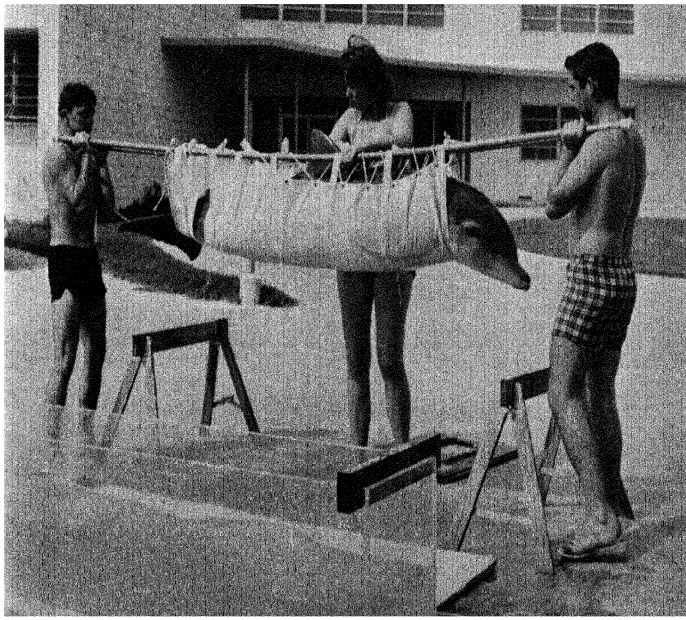


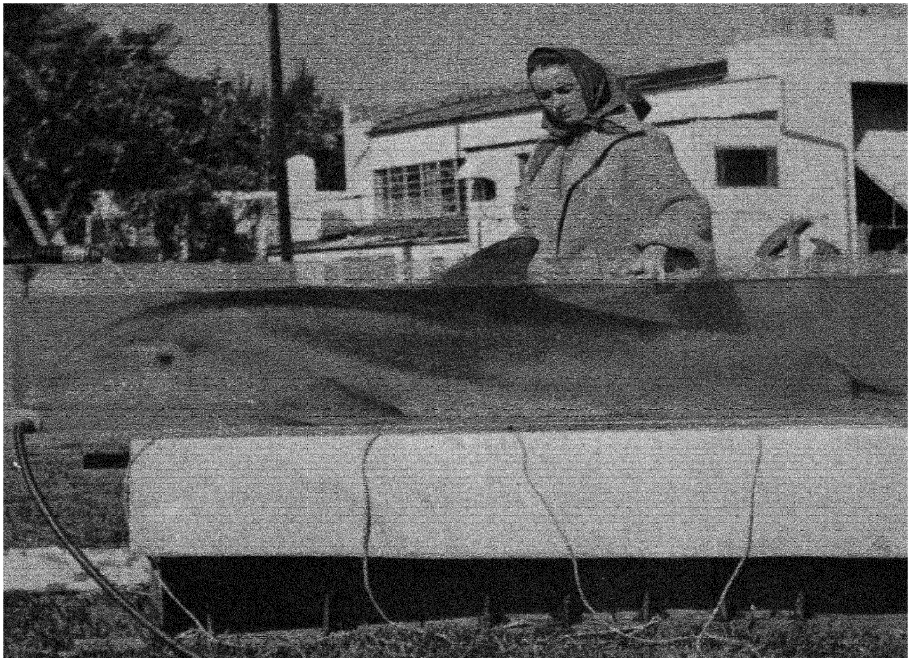
ohn C Lilly

1960. Temporary quarters of Elvar and Tolva in tent at Dinner Key, Florida. Carrying boxes #2 and Plexiglas box #1 are shown. Alice Miller in foreground. Biscayne Bay in background.

A more modern way of carrying a dolphin. Elvar in his dacron sling

ank S Essapian





The body form of the bottle-nosed dolphin (Tursiops truncatus). Elvar and Alice M. Miller.

John C. Lilly

is a good example of a limited-frequency pass-band for maximum intelligibility.

However, the dolphins need very much higher frequencies. They run from about 3000 up to 20,000 cycles per second, and have other bands beyond our hearing limit up to 120,000 cycles per second.[1] We can hear their lower range and they can restrict their emissions to our frequency range, but only with training. Luckily for us, a good deal of their natural communication is within our hearing, though in its upper range.

We could hear Elvar beginning to adapt to the acoustic range of the instruments we were using. He began to mimic our voices in a tentative, primitive first-try fashion, "quacking." We began to see that by natural methods, without brain-electrode forcing, it may be possible to teach these animals to vocalize so that we may establish communication with them. By judicious use and timing of the proper kinds of rewards, whether food, skin contact, activities, or acoustic, we began to see where to place our bets in our long-term experiments over the next few years.

Elvar the male dolphin was kept in intraspecies solitude for fifty-one days. As is stated above he began to make progress (in our terms!) on interspecies rela-

[1] Schevill, William E., and Lawrence, Barbara. Auditory response of a bottle-nosed porpoise, *Tursiops truncatus*, to frequencies above 100 Kc. J. Exp. Zool., **124**: No. 1, pp. 147–65, Oct. 1953.

tions. To a certain extent this progress was leveled off and yet enhanced by a new experiment designed to further explore the behavior and thinking of dolphins. We caught a female dolphin to give him a mate or at least a playmate. We called her Tolva (for dolphin Number 12).

This experiment was designed along the lines of certain natural laws of human experience and behavior which I had found in a study of human confinement, solitude, and isolation. I wanted to see if the dolphin's reactions were similar to those of a human similarly treated.

If a human being is isolated from other humans for a month or more, and is confined to a small area geographically and a small range of activities, his interest in his surroundings and its minutiae increases radically. (His interest in his own inner world may also increase.) Such phenomena have been described by many autobiographers and the detailed evidence is given in my book in preparation.[2]

Further, if a confined, isolated human is allowed brief contacts with other humans even without a shared language, he begins to find their presence comforting and a pleasant relief from the "evenness" of his surroundings.[3] If these humans control his only

[2] Lilly, J. C., *Solitude, Isolation, and Confinement*, in preparation.
[3] Richard Byrd's term, given in *Alone* (G. P. Putnam's Sons, New York, 1938).

sources of food as well as his sources of intraspecies stimulation, he may adapt to their demands in subtle and sometimes not so subtle ways. He may, given time, learn their language, take on their beliefs, etc.

When we catch a dolphin and put him alone in a small tank, we are imposing similar "solitary-confinement" strictures on him. Maybe we can thus capture his interest, his loyalty, and his initiative, provided that he at all resembles *Homo sapiens* in his mental and physiological processes. Lizzie, Baby, and especially Elvar showed trends in this direction.

However, the crucial test of the effects of confined solitude is release from it; the human being experiences great joy and pleasure in release, and other phenomena appear. The acme of such experiences is for a man to be with a woman, and for a woman to be with a man.

Some not so obvious effects of acquiring a "mate" after a period of solitude are the immediate increase in self-confidence, recovery of the initiative, and shift of interest and loyalty from one's captors to one's mate, from one's own inner world to that shared with him or her.

All of this and more happened or seemed to happen when Elvar was presented with Tolva. We, the humans, were excluded as they initiated courtship and finally violent "honeymoon" activities. Elvar's old at-

tentive interest in us evaporated—our only apparent hold on him that was left was food and feeding.

During the next weeks we saw all of the phenomena of courtship, mating, and play described by McBride and Hebb[4] and Tavolga and Essapian.[5] The enthusiastic violence of the new relationship was a wonder-filled experience for us all.

As their relations developed and flowered they became more violent—their high-speed pursuit and fleeing games threw the water from their shallow pool, and, at times, Tolva would climb the side and land on the deck around the edge. Each became covered with rake marks from the other's teeth. Each emitted loud raucous blats and calls in air, and each began snapping at us.

Soon we were unable to get in the pool to remove one without the other nipping at our legs. The old ease of relations with Elvar evaporated.

To test whether separation of the two dolphins would restore our hold in the teaching sphere, we put a separator in the pool made of plywood. The first separator was knocked down and climbed over: the energy expended to rejoin one another was impressive. A very human (and animal) response. Finally with

[4] *Loc. cit.*

[5] Tavolga, Margaret C., and Essapian, Frank S. The behavior of the bottle-nosed dolphin (*Tursiops truncatus*): Mating, pregnancy, parturition and mother-infant behavior. Zoologica, 42, Part 1, May 20, 1957.

an elaborate and strong partition we separated them. Later we put them in two separate pools.

Elvar soon became his old endearing self—but Tolva remained a driving, pushing, active female. Apparently their personalities are basically different. Each is fun for us in his own way.

During the first weeks Elvar taught Tolva most of the games he had learned with us and the use of his "toys"—balls, dumbbells, rings, ropes, etc. After separation independent actions took place but, in general, solitary play became less frequent and less violent than when they played with the same objects together, vocalizations dropped off: blats were now reserved for irritations with us, and plaintive whistlings like those of Baby left by Lizzie became numerous.

We have finally arranged a laboratory so that they can be allowed together or separated in a special double tank with a communicating door. We and they can thus easily work out a compromise schedule for work and play. They can be kept vigorous and healthy with their charging experiences together, and yet "go to school" separated from one another.

CHAPTER ELEVEN

The Voices of the Dolphin

ELSEWHERE in the preceding text I have given some short descriptions of the vocalizations of dolphins. In this chapter I will collect and give detailed descriptions of my new findings. I have already described some of the sounds which any and all bottle-nosed dolphins (*Tursiops truncatus*) emit, and some which only one or two have been heard to emit. Here and there I have referred to the work of others (scientists and nonscientists). It may turn out, after more and longer experience by more persons, that any one dolphin can and does emit all of the sounds in the natural as well as in the captive state. However, to date, the more accurate picture seems to be the following one:

All of them (wild or captive) frequently creak,

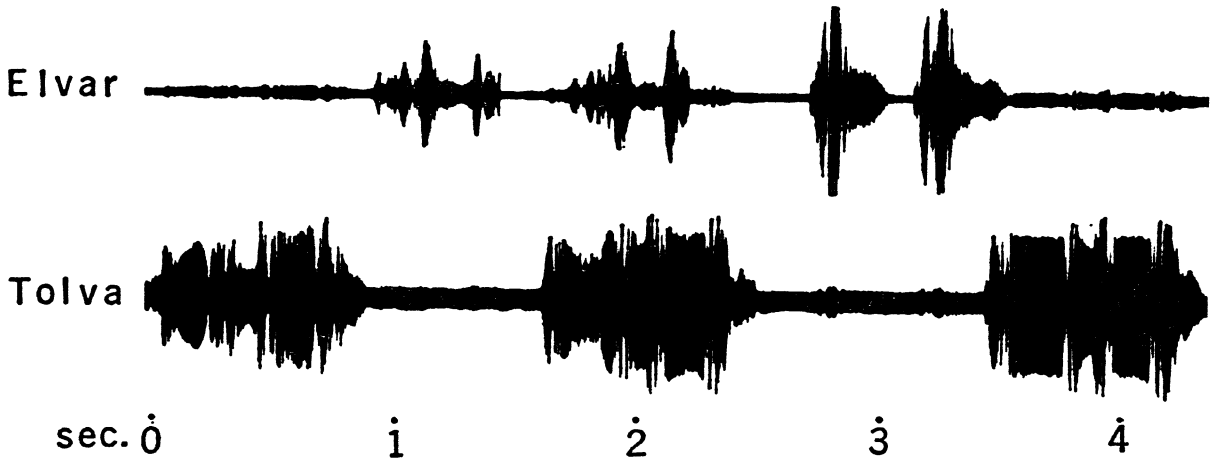
putt-putt, and whistle under water, with some rare quacks, squawks, and blats under water and in air. A few dolphins in captivity, in close contact with humans, can and do start producing more frequent airborne sounds on "request" and even "spontaneously": these sounds at first are loud clicks, creakings, whistles, squawks, quacks, and blats. With care trainers can encourage the animals to "sing," i.e., emit sustained high- or medium-pitched "wailing" notes which change pitch smoothly or in staccato fashion. Trainers in the American oceanaria tend to select such sounds because they sound like human singing (or wailing babies) and to suppress the other sounds because to humans they sound raucous, derisive, impolite, even scatological, but at least very alien (it may be that clucking Zulus would not think so). To date (1960), trainers use only the air sounds and do not use hydrophones for the underwater sounds.

I have been concerned with analyzing each of these classes of sounds and also with specifying by close observation and recording the conditions under which they tend to occur. In addition, as recounted in Chapter Five, I have been interested in methods of eliciting the above sounds, and new forms or new modulations of these sounds.

In the present chapter I will try to describe and discuss the so-called "mimicry" or "copying" phenomena in more detail. These phenomena are difficult to

describe on paper: more objective methods are being explored and developed to show the patterns of the sounds themselves by visual displays, similar to the "visible-speech" method developed by the group at the Bell Telephone Laboratory. I am currently obtaining apparatus of this sort for future presentation of our taped materials. Meanwhile, in lieu of such displays, I will describe our results as I hear them. Of course, this method of describing results has a high degree of subjectivity to it. It can be inexact, and even completely mistaken. Some of my scientific colleagues have criticized my use of this method instead of others. I will not try to defend this position because we will use the "better" methods when they are available. Even we must be guided somewhat in the use of these new methods by what we hear in the recordings of the dolphins' sounds, either at the speed they are emitted or slowed down. Our own acoustic systems have been trained (if not overtrained) to extract meaning from complex patterns, but not *all* patterns, mainly some patterns which are in our own languages. These patterns we recognize despite distortions and other disturbing noises.

A dolphin, on the other hand, naturally uses other sounds to convey and receive "meaning": creaking for nighttime and murky-water finding and recognition, putt-putting and whistles for exchanges with other dolphins, and even air wailing to excite human re-



An Exchange of Whistles between Two Isolated and Confined Dolphins.

Each dolphin has its own hydrophone, amplifier, and channel of tape recording. Tolva whistles first; Elvar responds with whistles; Tolva starts another and Elvar joins her in a brief "duet." Elvar then "talks louder," Tolva remaining quiet. Finally Tolva replies. Neither dolphin emitted any clicks or squawks during this exchange. The exchange occurred over a total time of 4.3 seconds, time scale at bottom.

sponses in the way of fish or applause. If a dolphin is copying our speech, he'll copy that part of what he hears which in his "language" conveys meanings. The unmistakable "dolphinese" accent may be so severe that we can expect trouble in recognizing our "meaning-filled patterns" when they are sent back to us. Of course, our troubles are amplified when we find out that dolphins can not only hear but transmit sounds which are entirely supersonic as far as we are concerned. Actually, it's lucky that they use any sounds which we can hear. Since much of their hearing and vocalizing is supersonic for us, it is quite possible that the meaningful patterns of their speech are up in the supersonic too. Their physical conveyers of meaning may not overlap ours at all.

However, to attenuate our fears and encourage our hopes, they can hear in our spectrum and can produce at least some components within it. Of course, all of these considerations mean that even if we had a perfect recording and display method for their sounds (sonic and supersonic) and looked for mimicry of our speech, it might be missing in the opinion of most listeners. Yet the same tape heard by those used to the dolphinese accent and automatically attuned to the variation could hear the attempted mimicry. I must say, if dolphins in captivity for years have been mimicking us, trying to communicate with us, they must be very discouraged at our lack of response! "Why,

those humans can't even make a sound higher than eight kilocycles without aids, and they chatter at such *very* low frequencies I can't hardly make out any patterns," a dolphin might comment to another one.

The over-all problem of objective visual display can be divided into several separate and distinct parts: the first is to find their language; the second is to see if they are learning our language; and the third is to find the meaningful parts of the patterns in each of the first two cases.

The assignment is similar to that faced by those people who conducted the "visible-speech" experiments at the Bell Laboratories, added to the difficult work of the cryptographer. The visible speech at least carried an understood built-in meaning when recorded. With dolphins this advantage exists only in the mimicry case (with built-in accent!). Their "language" and its meanings is crypto-vocal as well as cryptographic!

Of course one can start anywhere on this sort of research problem. I chose to first record and analyze their sounds by "subjective" study. I purposely increased my own chances of hearing mimicry by making the dolphins phenomenally broad-spectrum sounds (5 kcps to 150 kcps) conform to (or react to electronic aids) my subjective "meaning spectrum" (from about 50 cps to 5000 cps). The first experiments, as recounted in a previous chapter, were recorded with

acoustic and electronic means which rejected their high sonic and supersonic sound, and enhanced those sounds in our meaning-speech spectrum. Our tapes recorded very poor dolphinese but excellent English, if any English had been used. Even with these precautions I had to slow down these tapes to get the best results. Apparently, not only do these animals use very high frequencies but they use very high speeds for their speech. Later tapes (1960) with much wider acoustic bands which recorded their whistles, creakings, squawks, etc., were slowed down four, eight, and sixteen times to emphasize this speed in their dolphin to dolphin exchanges. The following experiments illustrate this point:[1]

Elvar and Tolva were separated from one another. Each was confined in a small narrow space at the end of a common tank. Each could hear the other's vocalizations through the water but could not see the other. Each had its own hydrophone and its sounds were recorded on separate tapes.

Under these conditions the animals emitted whistles which are usually politely alternating, first one and then the other, with some monologues, and some short duets (with beats, yet!).

However, all dolphins emit clicks, with or without the whistles. These clicks are not creakings such as

[1] Lilly, J. C., and Miller, A. M. Vocal exchanges between individual dolphins (Manuscript, December 1960).

they use for finding fish; they are usually slower in rate, steadier, and may alternate with those of the other dolphin.

These are the usual "isolated-pair" exchanges. However, if one allows a male and female physical contact with one another, additional sounds may appear: harsh blats, squawks, barks, and wails are emitted when the dolphins are playing or excited in courtship and mating.

An additional set of noises which may be airborne, not necessarily under water, is elicited by human contacts, training, and brain-forcing by electrical stimulation. These are sounds which to me (but not to all of my colleagues) sound like human vocalizations of one sort or another: I have heard these best in stimulating "pleasure" systems within the brain, and but rarely under repeated human-contact conditions. The following are the kinds of things mimicked in my experience.

(a) *Human laughter:* The explosive, repetitive, singsong ha-ha-ha! kind of laugh—the usual repetitions were in groups of three or four, with a very high-pitched child's voice quality to it. It is most distinct immediately after or within a few seconds of a woman's laughter. Repetition of human laughter may elicit further imitations either better or worse than the original.

(b) *Human or electronically-produced whistles:*

Sometimes an isolated animal seems to copy whistles but since this is their natural vocal emission a human will find it difficult to pick up unless the dolphin lowers the pitch nearer to that of our whistle frequencies.

(c) *Bronx cheers and assorted impolite* (to humans) *noises:* Very raucous noises made by humans between pursed lips or between lower lip and palm can be mimicked by some young dolphins. Number 6 (1957) dolphin first showed me this set of noises and presently Tolva has taught it to Elvar. Such noises are usually not encouraged in oceanaria.

(d) *Human Words:* These are the most subjective of all the judgments of the sounds emitted by dolphins. I have heard most distinctly the following words and phrases "copied" in an extremely high-pitched and brief fashion: "three-two-three," "Tee ar Pee" (the letters "TRR" were just given), and a host of others, less clear but verging so closely on humanlike rhythm, enunciation, and phonetic quality as to be eerie. Let me close with one mysterious example:

On the 16th of April 1960 I was working with Lizzie and Baby in the St. Thomas pool. We had just separated Lizzie from Baby and put her in a small side-tank in order to force feed her by stomach tube. It was getting late in the day. We were all tired with the exertion, and getting a bit short-tempered. I was worried about Lizzie's health—she hadn't been eating

and I felt she was in danger if we didn't tend to her closely. Someone suggested that I would be late for dinner if I didn't leave and said, "It's six o'clock!" very loudly. The tape recorded this on the air channel; in a few seconds on the underwater channel Lizzie, near the hydrophone, putt-putted, Baby answered with a short fast series of whistles, and Lizzie very loudly came out with a "humanoid" sentence, the meaning of which (if any) has puzzled several of us since. It may have been a poor copy of "It's six o'clock." But I was caught first by another "meaning." It sounded to me like "This is a trick!" with a peculiar hissing accent. Other people have since heard the tape and come to the same conclusion.

This was the last recording from Lizzie; we found her dead next morning. Our grief was painful and our mourning long. It was a great disappointment to lose her just as she started to make sounds of this sort.

CHAPTER TWELVE

Implications

If we can succeed in communicating with an alien, nonhuman species the implications are obviously exciting. If we fail to communicate, it may mean that we lack sufficiently sophisticated methods or that communication is impossible with any of the species with which we are acquainted today. To prove an impossibility takes a very long time, a lot of research, and the exploration of many possible methods. An impossibility cannot be proven by means of crucial experiments; only possibilities can be so explored. Impossibilities are realized gradually in time by consistent and never ending failures of attempted crucial experiments. This point of view was once expressed by my colleague Wade H. Marshall, who said, "There should be a special

scientific journal devoted to reporting negative results, i.e., reporting the failures to reproduce previous findings." He named it the *Journal of Negative Results.* At times I feel that this is more than a whimsical idea.

Obviously if man fails to communicate with an alien species within the next two decades it does not prove that my thesis is impossible. However, if he does so communicate, then the thesis is correct and the crucial experiments will have been accomplished.

As anyone who has slaved at scientific experimentation for a sufficiently long period of time knows, the above considerations are not merely logical juggling or semantic sleight of hand. The big problem is to *demonstrate that something is first of all discoverable* and then *to discover it.* It is much more difficult to prove that a given "discovery" does not exist. If someone makes a discovery and then someone else tries to repeat the demonstration and fails, he has not in general disproved the original discovery. The failure of the second man may merely mean that he was somehow or other on the wrong trail, using wrong methods at some crucial point. Thus the *Journal of Negative Results* would be filled with attempted reproductions of previous research and might just as well be a record of failure to do exactly what the first man did, or a mere demonstration of what the first man did not realize and, hence, did not write down, all of the unwritten crucial things that he really did to make

his discovery. With the increase in numbers of modern scientific papers and the insistence of editors upon terseness, succinctness, and condensation, it is sometimes extremely difficult to reproduce from a scientific paper the exact experiments that a man did. This is true especially in biological and psychological fields.

Many scientists, including myself, have often had maximum success with the first of a long series of experiments and then have spent many months trying to reproduce that first success. It is during these many months that we find out how many things we unconsciously did correctly the first time. It is then that we become fully aware of the many, many possible paths to failure and the very, very few paths to success. Such tasks keep scientists working day and night. The knowledge that one successful experiment has been adequately recorded, so that it can be reviewed, keeps us going during these long difficult hours. Sometimes we get off into technical byways, methodologies, that are essential to the successful prosecution of that successful experiment. I am thoroughly convinced, along with many other experimentalists, that certain people somehow or other get themselves "in tune with their preparation." Dr. Frank Brink at the University of Pennsylvania (now at the Rockefeller Institute) made this clear to me many years ago. He described one colleague who was one of those few experimental scientists who could assume this "in-tune" state rapidly

and produce significant results. This was a very sophisticated scientist, well versed in all of the techniques of his field, who had many years' experience in scientific research.

Many times a rather eerie experience occurs. When the chief investigator leaves the room, something happens that makes the whole experiment disintegrate. In long twenty-four-hour runs I have often left the preparation in the hands of an assistant and gone home to get some sleep, only to be awakened from my sleep by the assistant saying that something has gone wrong in my absence. Going back to the laboratory, I either find that it is an easily correctable defect in the apparatus, or that the alleged defect disappears while I am present. At times this coincidence is so remarkable that I feel there is no logical reason for it and that the "in-tune" process has roots far deeper than we can understand at the present time. However, such experiences occur only when I am deeply involved with the apparatus and with the animal in question over a sufficiently long period of time so that, as it were, there is a miniature replica of the experiment continuously going on in my own head. This situation occurs only with unremitting, uninterrupted effort over many days and weeks; such preparation may be part of the "in-tune" phenomena.

I emphasize all of these points to avoid some of the misunderstanding that certain persons promulgate

in the name of science. Research at the frontiers of science is not a clean-cut, dry, planned affair. One works continuously at the edge of mystery; and the cussedness of one's own mind, the difficulties of the preparation, and the slowness to understand the true basic processes going on are challenging, at times discouraging, but never boring.

Even if within the next two decades we do not establish communication, the results along the way will be extremely important. These are some of the possibilities:

We may be faced with a new class of large brain so dissimilar to ours that we cannot within our lifetime possibly understand its mental processes.

The large brain of the dolphin may have no speech centers such as we have in our brain. This brain may be doing something else entirely than what we do with our brains.

These may be really stupid animals and the large brain may merely be used for motor control in an aquatic environment: chasing fish and making peculiar noises that have to do with emotions and ranging but make no sense otherwise.

It may be impossible for these animals to learn to speak any human language because of the differences in their vocal apparatus. It may be impossible for us to speak their language because of the difficulty with our vocal apparatus. We thus may be forever sepa-

rated in separate universes of discourse; the pathways to communication may not be solvable at the present time.

Of these four possibilities, some seem to violate the general proposition that a biological system developing under the usual evolutionary processes on the earth does not develop a large brain as just a useless computer for display to humans. In general, it seems to me that large brains have developed and are used to their capacity within the limitations of the body that houses them. There may be limitations within the body of the cetaceans that are not shared by humans, even as there may be limitations in the body of humans not shared by cetaceans.

When you struggle day after day to identify with, personify, and empathize with the real position of a dolphin in captivity and then see the effect of adding a mate to that captive situation, you rapidly get the impression that many humanlike—"humanoid"—events go on in their lives. Such intimate contact with the actual living organisms provides a continuous source of new clues, some of which are absorbed unconsciously and generate faith, as it were, in the prediction that we shall eventually communicate with them.

Now let us consider the implications if we do manage to establish communication with dolphins or other alien intelligences.

If we succeed in establishing communication on

an intelligent, intellectual level with one of the Cetacea or some other species of the earth or not of the earth, the implications will run all the way through philosophical, scientific, ethical, legal, social, military, propaganda, utilitarian, and even humorous categories.

Let us consider the last category first. After the various press reports on our work with the dolphins, several cartoonists began to draw talking dolphins. Callahan showed how the oceans would become incredibly noisy places, with arguments in English going on between dolphins. It was suggested that people who live close to the sea might be troubled with the telephone constantly ringing for the dolphins in the neighborhood. Another cartoonist showed a man under water, with the proper equipment, saying to a dolphin, "Take that back!"

The news releases also gave rise to a fantasy, published in the Baltimore *Sun,* that combined the news stories about the 600-foot radio telescope at Greenbank, West Virginia, and the story about the intelligence of dolphins. The fantasy was a conversation occurring between humans on earth and some planet near Tau Ceti at a distance of eleven light-years. The author neglected the twenty-two-year lag between question and answer and had an argument going on between the inhabitants of the distant planet and those of earth. The aliens somehow seemed to think we were not very far advanced, if we were up-

right, featherless bipeds on land. The scientists on earth were stung into boasting about our attainments and said, "Why, there is even a man in the Virgin Islands who is talking to dolphins!" (Not that we had, but it made a good story.) The answer came back from Tau Ceti that there was hope for earth if we could establish contact with the dolphins and porpoises. About this time the earthlings asked the Cetians what they were and the answer came back that they were porpoises—and that they used to have featherless bipeds on their planet but they all killed one another off.

The day that communication is established, the particular other species becomes a legal, ethical, moral, and social problem. At the present time, for example, dolphins correspond very loosely to conserved wild animals under the protection of the conservation laws in certain parts of the United States and by international agreement, and to pets under the protection of the Society for the Prevention of Cruelty to Animals.

So far the dolphins have a good reputation with the general public, derived mainly from the circus shows and the oceanaria and from the traditional stories about their relationships with men. They may be generally considered in a special class somewhat different from human pets or other wild animals.

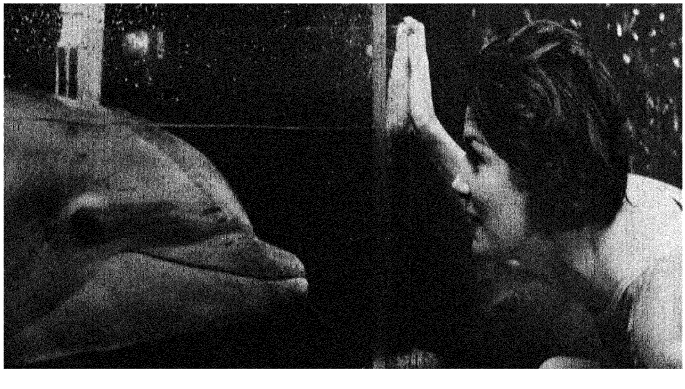
If one of them starts to speak English and this becomes widely known, they will gain a little more status and may be considered somewhat like parrots or mynah birds, which seem to have slightly more value to certain human beings than do other birds because they can enunciate our language to some extent.

However, if the animals demonstrate more ability than that of a parrot and continue to enlarge their bag of tricks beyond what is at present possible in the oceanaria, they will achieve status with TV and circus ratings similar to that of chimpanzees, which once again have special values for human beings in terms of entertainment.

If they achieve a bilateral conversational level, corresponding, say, to a low-grade human moron and well above a human imbecile or idiot, then they become an ethical, legal, and social problem. They have reached the threshold of humanness, as it were. If they go above this level the problem becomes more and more acute and if they reach the conversational abilities of any normal human being, we are in for trouble. Some groups of humans will then step forward in defense of these animals' lives and stop their use in experimentation; they will insist that we treat them as humans and that we give them medical and legal protection. If the means of their further education in

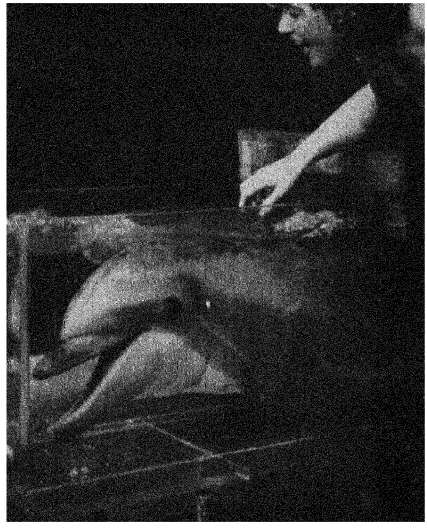


Elisabeth and Elvar: he keeps both eyes on her.



Elisabeth and Elvar: he keeps one eye on the photographer.

Alice and Tolva: vocal provocation and response. She barks in response to Alice flicking the water

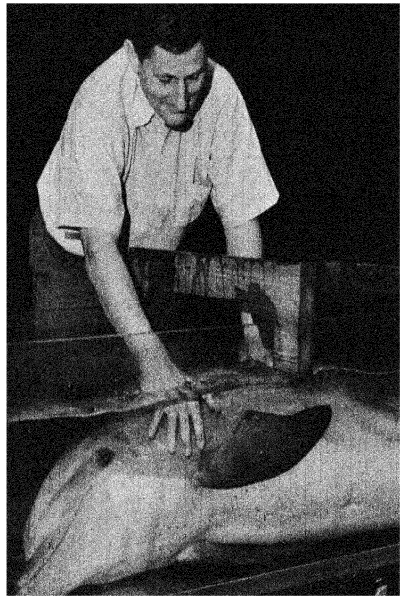


Tolva and Alice, open wide, baby! (The Plexiglas box filled with water gives a prism effect, one sees Tolva's beak twice at two different angles)



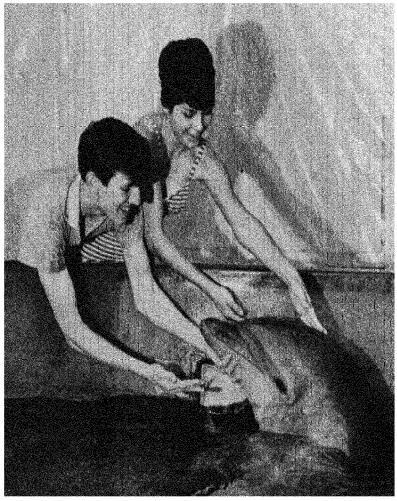
FRANK S. ESSAPIAN

John and Tolva a back and side rub. Notice light reflected back in the eye: this is a greenish glow. She is relaxing on the bottom while being stroked



Frank S Esaplan

Frank S Esaplan



1961. Tolva pushes herself up the side of her tank in order to be stroked by Pamela and Charles.

humanity is available, there probably will be an explosive development of such education.

What they then become under the law—and the laws might have to be changed in order to include them—depends upon the intellectual attainment of individual animals. The humans then have two major choices: a few people will probably join in the conspiracy to leave the animals ignorant and drop the whole program; others will press for the whole educational process, so that we may learn more and more from these animals and teach them more and more about us. At this point the number of available animals becomes an important problem. If there are only several thousand animals available for such an educational process, the social load on the educational system of, say, the United States will be very small. (Of course, this presupposes that the dolphins are unable to set up their own schools to educate their own kind.) For a long time presumably they will be in the position of the Negro races in Africa who are attempting to become Westernized. They will be a dramatic but definite minority, initially with extremely good publicity and then with less good publicity unless they can prove their usefulness in those things which the human races in general attempt to achieve. We shall explore some of these possibilities below.

The dolphins, porpoises, and whales are "ocean-centered" instead of "continent-centered" as humans

are. This implies that almost four-fifths of the world is theirs, without known boundaries within the oceans. Most of the continents are separated from one another but oceans are connected by water with other oceans, so theoretically every cetacean is an international traveler as far as humans are concerned. These are true tourists of the sea and they may not recognize territorial rights of other cetaceans or humans. The foundations of their culture may be centered about their feeding habits, fish migrations, etc. This may ultimately lead to difficulty for the humans, who are more nation-centered and city-centered than these animals probably are. If we try to employ them in a national way or in any other "localizing" or partisan fashion, we may run into difficulties with their way of life and their way of thinking.

For example, many people have asked me if it is possible to teach these animals to detect submarines and to communicate their detection to human beings. First of all, I don't think we have to teach them to detect submarines; I think they detect submarines already. That is not the problem. The problem is whether they will communicate such detections to us, whether they will go on submarine-hunting expeditions and then report back to one human side and not the other. If dolphins come to understand our cold war and similar quarrels between large segments of the human race, we don't know how they will proceed to operate. I

once said in a joking fashion, "They may all be pacifists"; on the other hand, they may be highly military types. Let us try to find out.

Obviously if we establish communication it may help us to solve many of our own marine problems. For example, if the cetaceans are willing to communicate and are sufficiently numerous, they might help in rescuing survivors of plane crashes and shipwrecks. They might search for survivors, protect them from sharks, provide them with food, communicate with other human beings without the use of radios or similar gadgets.

Cetaceans might be helpful in hunting and retrieving nose cones, satellites, missiles, and similar things that men insist on dropping into the ocean. They might be willing to hunt for mines, torpedoes, submarines, and other artifacts connected with our naval operations. They might also be willing to do scouting and patrol duty for submarines or surface ships and they might carry their protagonist activities to the point where they can be used around harbors as underwater demolition-team operators.

If they are military types they could be very useful as antipersonnel self-directing weapons. They could do nocturnal harbor work, capture spies let out of submarines or dropped from airplanes, attacking silently and efficiently and bringing back information from such contacts. They could deliver atomic nuclear

warheads and attach them to submarines or surface vessels and to torpedoes and missiles.

They could help us carry on a sort of psychological warfare. Many times in World War II watch officers on navy vessels recorded phosphorescent-wake "torpedoes" heading directly toward the bow of their ship; generally these turned out to be some of the cetaceans swimming very fast toward the ship. The bodies of these animals are not detectable by magnetic metallic methods. They can be detected only by bouncing sonar beams off their bodies and by listening to their own vocal productions. In psychological warfare they might sneak up on an enemy submarine sitting on the bottom and shout something into the listening gear, as if this were a human communicating with them. Such voices from the sea could also be used near the seashore in harbor work; perhaps the animals can be taught to speak loudly in air.

Their usefulness need not be exclusively military; they might help us to make friends throughout the world if we employ their abilities in peacemaking activities.

However, as I see it, the really solid help would be in the various scientific fields. They could help us to obtain new information, data, and natural laws about fisheries, oceanography, marine biology, navigation, linguistics, various sciences of the brain, and space.

No human is quite as good at detecting, tracking, hunting, herding, and catching fish as are dolphins, porpoises, and whales. If we could communicate with the dolphins and gain their co-operation, the science and industry of fishing may be entirely revised. Our knowledge of the ways of fishes, their migrations, etc., would be increased immensely.

In the field of oceanography, they could help us to measure and to map surface currents, temperatures, salinities, etc., over vast areas of the ocean without the expensive ships that are presently used for this purpose. They could collect the information and bring it back to us at our laboratories on shore.

In marine biology they could report on and bring back samples of new species that we have never met before. They might report on the behavior of many marine organisms with which we are not yet acquainted. Similarly we could learn much about other cetaceans from ones that are friendly to us. There are many mysteries about the so-called "killer" whales that might be cleared up by the dolphin. Maybe the killers are misnamed: after all, maybe they call some of us killers.

They may have navigational means with which we are not yet acquainted. I suspect that theirs is a multivariable method of navigation, using temperature, speed, taste of the water, position of the stars, sun, and

so forth, all fed into their huge brains simultaneously and instantaneously. They may have some sort of multidimensional maps that they have developed over the years and by which they travel from one sea to the next over the surface of the earth.

Obviously the science of linguistics will benefit tremendously from these studies. Interspecies languages and new intraspecies languages will do much to push this science in new areas.

In the same way the science of the brain—neuroanatomy, neurophysiology, psychology, psychoanalysis (intra- and interspecies)—will benefit. Communication with these animals will provide a whole new array of dimensions for the scientists of the mind and for the humanists.

The nonterrestrial, interplanetary and astral sciences, the so-called space sciences, will benefit from our having established contact here on earth with alien creatures that had an evolutionary development separate from ours in another kind of environment. I want to emphasize the fact that even if we are successful, we shall still not be fully prepared to encounter intelligent life forms not of this earth. Even if we press this research program to its ultimate extreme speed we shall not be far enough along if and when we meet beings from other portions of our galaxy. At the present rate at which progress is being made in the space program,

there is not time for a leisurely program of research. At most we shall have graduated from the kindergarten of interspecies communication before it becomes absolutely essential for us and all of the human races to enter the graduate school of interspecies relations.

Our own spot in the universe, our own view of ourselves, will be tremendously modified if such a communication is established. Any other species that could talk with us on our own level will give us a perspective of which we can only be dimly aware at the present time. Our own communication among ourselves will be enhanced and improved by such contact. Our own views of one another will change radically under the influence of interspecies communication. The very fact that we try to communicate with them is an important indication of our own stage of evolutionary maturity.

We shall try to learn what we can and cannot teach them, what they can and cannot teach us, and what we can learn together. We shall find them of value in teaching us about themselves, in teaching us how they look at us, in teaching us about others at present unknown to us.

The ideas presented in this chapter have occurred to me in the course of my research but I have held them in strict abeyance. However, if we do not at least consider them, we may one day find ourselves

totally unprepared for the results of our research program. Such neglect might be more devastating in its ultimate effect than was neglect of the political implications of the atomic bomb and the V-2 rockets.

APPENDIX ONE

Anatomical Contrasts: Anatomy and Physiology of Tursiops Truncatus

The body of the bottle-nosed dolphin, like that of all of the delphinids, is founded on the general mammalian plan, built into a streamlined container for maximum propulsion efficiency in sea water. There are certain unique features of the anatomy and physiology of this group of animals which may be a help in our understanding of their differences from us. Their anatomy limits their behavior in certain regions, extends it in others, and generates some needs that are different from ours. The description below presents many known anatomical features and also tries to point out where our knowledge is sketchy or lacking. The general statement can be made that with one or two exceptions (thalamus and pituitary gland) no given portion

of these animals' anatomy or physiology has had anything like a thorough scientific job done upon it. As far as possible I have checked most of the previously known gross anatomical facts by my own dissections.

Much of the anatomy and physiology of these animals can be understood in the light of their presumed evolution. They are supposed to have evolved from an early mammalian form or forms that had developed upon the land and later returned to the sea. This evolutionary working hypothesis is of help in understanding various aspects of their anatomy, such as the residual hind limb and pelvic bones, the bristles on the beak of the embryo, etc.

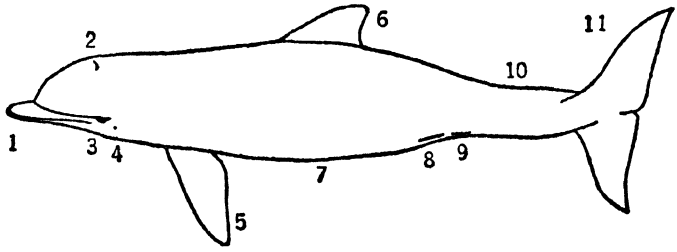
A. Skeletal System

The skeleton is vaguely like ours with fairly drastic modifications in form; hands and legs are lacking. Considered systematically, the following facts are known:

A dolphin's skull has long upper and lower jaws jutting out forward from the base of the skull to form a beak. This beak contains 88 teeth which interlock in the upper and lower jaws. The lower jaw is undershot, with a "chin" sticking out in front of the upper jaw. It is this lower jaw that takes the brunt of the shock when the animal rams a shark or a whale, for example.

The frontal bone lies behind the blowhole and behind the maxillary and premaxillary bones that over-

lap and thicken the forepart of the skull to about an inch and a half in the midplane behind the blowhole.



Dolphin, *Tursiops truncatus,* Schematic, Diagram of External Anatomy (*this animal is body-spiraled in a twist to show all points*).

(1) Rostrum (beak): upper and lower jaws (88 teeth). (2) Blowhole: forward of this hole is the "melon," behind it is the skull and the brain. (3) Eye: overlapping visual fields of two eyes mostly forward and downward; by appropriate movements eye can scan over head, forward, down, or straight back along flanks. (4) Ear: small hole just posterior to eye, connecting with wax-filled tube to middle ear. (5) Flipper ("paddle"): contains complete bones of 5-fingered "hand" and "arm"; delicate, easily injured; used for steering and "palpation." (6) Dorsal Fin: soft tissues only, no bone. (7) Umbilicus, as in man. (8) Genital opening (slit) for penis and urethra. (9) Anal opening (in female combined with genital slit). (10) Peduncle, connects body to flukes (11): contains vertebrae ("tail"), muscles, and tendons; powerful flexion dorsally and ventrally for swimming, laterally for offensive action. (11) Flukes: mostly soft tissues, delicate, thins out to rear, easily torn.

Dolphins ram sharks to kill them; during ramming, the lower jaw is locked to the upper through the interdigitating teeth; the ram shock is transmitted from "chin" to upper jaw to "forehead" to skull to spinal column. This thickening of the forepart of the skull distributes the forces over the rest of the large area of the skull. Very powerful muscles fasten onto the skull from the posterior portions of the body, thickening up the neck to the point where it can hardly be seen and filling it out into the streamlined form.

The typical mammalian forelimb is present in these animals but disguised in their flippers. A flipper contains a five-fingered "hand" (or five-toed foot) all bound together. Within the flipper are all the bones of our hand: fingers, wrist, forearm (two bones), and upper arm, with very little mobility at any of the joints. It is only the ball-like shoulder joint that has any great mobility. These animals can rotate, adduct, and abduct the flipper as a whole unit.

The only vestigial remains of the hind limb and pelvis are two little bones near the genitalia. The peduncle running to the flukes consists of articulated vertebrae and muscles for propulsion. The spinal column, starting at the skull, ends at the fluke's notch. There are 64 vertebrae: 7 cervical; 13 thoracic; 17 lumbar; no sacral; and 27 caudal.

B. Muscular System

The muscular system will be considered from the front end of the animal to the stern. The largest muscles in the head region are the jaw muscles, which are extremely strong. The only peculiarity of this muscle system over that of land animals is that the lower jaw (mandible) on each side is hollow and a very large muscle is inserted well inside the bone, coming out through the aftermost part of the jaw and fastening to the skull. The temporal muscle, one of the muscles closing the jaw, is extremely strong and well developed.

Probably among the most important muscles in the body are the very small, delicate, and well-differentiated muscles connected with the respiratory tract and used for phonation. Starting at the blowhole, there are numerous small muscles around the skin opening used for opening it; it closes passively.[1] One particularly prominent part of the blowhole looks like a "tongue" made of skin, which can be moved in the blowhole with great dexterity. Many of these muscles attach mainly to skin blubber and other tissues anterior to the blowhole. Just below the blowhole are air sacs; below the air sacs is the division of the airway by the nasal bony septum.

[1] Lawrence, Barbara, and Schevill, William E. The functional anatomy of the delphinid nose. Bull. of Mus. of Comp. Zool. (Harvard Col.), **114**: 4, Feb. 1956.

These sacs have extremely complex muscle systems running in practically every direction around them; they are apparently used for the production of sounds under water. The sacs are also used when the animal wishes to produce sound in air through the blowhole. Proceeding on down the airway, below the nasal septum there is a sphincter in the nasopharynx that grips the upper ends of the laryngeal cartilages and thus maintains the continuity of the airway across the oropharynx. This arrangement separates the air passage from the food passage, most of the time. The larynx itself has innumerable small muscles under extremely fine nervous control, apparently given over to some of the underwater phonation and control of breathing.

The flipper is controlled by the "shoulder" muscles and a small scapula as in other mammals; these muscles give delicate and fine control of the directions of the flippers in order to control the direction of swimming. The flippers seem to act mainly like vanes with which the animal can do everything from barrel rolls to all the usual "flying" maneuvers of an airplane. The flippers in this sense correspond to the control surfaces of an airplane or the diving vanes of a submarine. They are used for propulsion by rowing-like motions in slow body movements such as rising or descending directly up or down with the body horizontal. The flipper from the shoulder out is rela-

tively stiff; in the adult there seem to be no important muscles.

The body muscles, running from the head region, in the back and along the abdomen are extremely powerful and are used to bend the body and to move the head during the peculiar vertical-S-curved kind of swimming movements of these animals. The propulsive muscles proper are in four sets, compartmented by the vertebrae and their processes; each set terminates in tendons that parallel the muscle bundles and pass the fluke joint in large sheaths. There is an upper pair and a lower pair; one set on each side is attached into the flukes top and bottom. These terminal tendons are about a half inch in diameter, are extremely strong, and transmit the pull of the very powerful muscles on the body to the flukes themselves. By alternating the pulls between those on the upper set and those on the lower set the animal makes the fluke oscillate up and down, bending the peduncle at the same time, thus propelling himself through the water with a peculiar oscillating up-and-down movement characteristic of all whales. For right or left turns he can give a differential contraction of the right and the left set, thus "banking" with the flukes. He apparently has completely independent control of each of the four sets of muscles to give any sort of a tilt to the flukes and/or bend to the peduncle. The fluke is hinged at the after-

end of the peduncle and these tendons attach just at the "hinge." The last of the caudal vertebrae are in the fluke.

C. Integumentary System

One of the puzzles about these animals is how they are able to swim at very high speeds—up to about thirty knots—with very small horsepower—about two. Part of the answer seems to lie in the construction of the skin and the underlying structures. The skin is an envelope of extreme smoothness extending over the whole body, and it determines the fairing out of the streamlined form over the blubber base. The skin seems to have at least two main functions: one is to prevent fouling by marine organisms and the second is to cancel out incipient turbulence in the flow of the water by the skin itself.

In line with this maintenance of a streamlined form with minimum resistance to flow, the hair usually found on mammals is not present. However, in the embryo at a certain stage there are six bristles at each side of the snout that are lost before birth.

The color of the skin, like that of most predators in the sea, is dark on the top of the animal and light on the bottom. This is said to offer protection in the sea: an enemy looking at the side would not see any great contrast across the animal. The dark top is

brightly lighted and the light bottom is dimly lighted, so the animal tends to blend with the sea, especially in the large amount of scattered light that is usually present. *Tursiops* is usually gray to black on the top and almost pure white and pink on the bottom.

The skin is incredibly smooth and has absolutely no marine growth on it whatsoever; no barnacles, no algae, none of the organisms one finds on man-made devices in the sea. I found one mechanism by which the smoothness is maintained. I enclosed an animal in a white sheet and left him in a tank for a period of two days. When removed, the sheet was full of thin layers of the black skin from the back of the animal and the white skin from the belly. Apparently these animals in their natural state form tremendous quantities of skin, which is gradually shed into the sea, carrying any contaminating organisms with it.

To the touch, the skin is not only smooth but has a rubbery quality. Apparently this rubberiness is given to the skin by the underlying reticulum of collagenous fibers surrounded by oil. It is said that this flexible skin overlying the oil can cause damping of incipient turbulence in the water immediately adjacent to the skin, thus helping in the destruction of turbulent flow and maintaining a low resistance during swimming.[2]

[2] Kramer, M. O. *Missiles and Rockets,* Feb. 1, 1960. Essapian, Frank S. Speed-induced skin folds in the bottle-nosed porpoise, *Tursiops truncatus.* Breviora, Mus. of Comp. Zool., 43, Apr. 7, 1955.

An additional factor in the maintenance of laminar flow over the skin seems to be the muscle layer inside the blubber. These muscles run in every direction and are apparently well supplied with nerve fibers. It may be that there are local reflex pathways between pressure or vibration sensors (end organs) in the skin itself which allow these muscles to deform the shape of the blubber and overlying skin so as to maintain laminar flow. These muscles and circuits add an active process to the passive one of the damping action of the oil and flexible overlying skin.

When we were puncturing the skin with needles from a small size up to large ones, say, 3 or 4 millimeters in diameter, we found that the integument has an additional property—it is self-sealing. The blubber below the skin wells up into the hole and seals the opening, stopping the bleeding. This can be seen when an animal has been injured. The immediate response is bleeding and then a white substance comes up and trails out of the opening. I have seen little fish eating away the strings of blubber from around the hole, which is thus left with a short small plug. The skin then grows back, constricting the plug and finally closing off the opening. The skin covers the propulsion and control surfaces, maintaining the smoothness of those also; at the trailing edge of both the flippers and the flukes, the skin is extremely thin. The skin

here maintains the perfectly streamlined shape of these objects and is supported only by a collagenous reticulum underneath the skin. Both the flukes and the flippers have a peculiar rubbery consistency and will restore themselves to their usual flatness when distorted by hand. However, they are very easily injured when they come up against any solid object and are easily torn by the lines in a net.

The dorsal fin, the flippers, and the flukes all act as heat exchangers.[3] The dorsal fin itself also acts as a keel about which the animal does his turns. It is one of his sources of lateral resistance during the turn.

D. Respiratory System

Like all mammals, these animals breathe air. The primary exit and entrance for the respiratory system is the blowhole at the top of the head. We have not seen an animal breathe through his mouth; however, we have accumulated some evidence that they can vent air through the mouth from the lungs and can even make noises through the open mouth in air.

From the blowhole to the lungs is a rather complex airway. The blowhole is just anterior to the forehead of the animal. Anterior to the blowhole is the large so-

[3] Scholander, P. F., and Schevill, William E. Counter-current vascular heat exchange in the fins of whales. J. Applied Physiology, 8: 3, Nov. 1955.

called "melon," resting on the upper jaw, which contains a reticulum of collagenous fibers filled with oily and fatty substances. Thus the true forehead of the animal is buried behind the blowhole and well aft of the apparent external "forehead." (F. G. Wood has suggested that this melon could act as an acoustic lens.)

The blowhole is the equivalent of our nose moved up anterior to the forehead, and turned upward, with its opening upward. It has a "nasal tongue" within the entrance and its own anterior external lip, over which the animal has a control comparable to that of our oral tongue and lips. Inside the blowhole, below the first two air sacs, are two inner lips above two lower air sacs to control the opening—for instance, to open it extremely wide during expiration and inspiration. The function of the air sacs and lips seems to be (1) to collect the water that enters the open blowhole at the end of an inspiration, (2) to discharge this water when the sphincters below are closed, and (3) to store air and blow it back and forth between them in order to make sounds, either under water or in air.

When the animal wishes to produce sounds in air he can blow air back through the blowhole between the tongue and the outer lip, forming some sounds in the ambient air. He can also open the outer tongue and lip and use the inner lips to produce loud siren-like

and Bronx cheerlike noises; apparently he can also form these cavities (sacs) and lips to make whistles.

During inspiration and expiration all of this system is wide open, above the divided airway through the bony septum. The nasopharyngeal sphincter seems to hold on to the larynx during inspiration, though this is not as yet certain. The larynx itself is open with the arytenoid cartilages separated so that there is direct air access through the larynx into the trachea. The arytenoid cartilages of the larynx can be closed across the airway, thus sealing off the trachea from the upper nasal airway. The larynx can also be disengaged from the nasopharynx entirely by the throat muscles connected to the hyoid bone and dropped down in order to discharge water into the mouth from the upper bronchial tree and trachea. Normally, however, the larynx is connected into the nasopharynx for breathing and possibly phonation.

The food passageway goes on each side of the larynx. It is not yet known what happens to the larynx during swallowing; presumably it stays engaged in the nasopharyngeal sphincter.

The arytenoid cartilages are very large and have long contiguous edges that meet in the center of the airway. It may be these edges that produce the little shock waves—the "creaking-door" sound of their sonar as well as the "humanoid" sounds. However, this point is yet to be cleared up.

The trachea is wide and short. A 1⅛-inch-diameter tube is found to fit through the disengaged larynx and into the trachea, sealing it off for artificial respiration with a respirator. On dissection we found the trachea to be only about 2 inches long and immediately it trifurcates (or even quadrifurcates) into the larger bronchi. The bronchi then immediately break up rapidly into the smaller passageways, maintaining the cartilagenous bands all the way from the trachea down through the bronchials. If one cuts across the lung with a knife one finds resistance to cutting because of the large amounts of cartilage contained in the bronchioles. It is found that the alveoli are very large compared to the human ones and are from 1 to 3 millimeters in diameter, quite visible to the naked eye. This whole system seems to be designed for extremely rapid outflow and inflow during the 0.3 seconds of the active part of the breathing cycle: 5 to 10 liters of air flow out and then in during that short interval.

The flow pattern through the respiratory system during the active phase seems extremely turbulent, allowing complete mixing of gases, possibly even in the depths of the alveoli. However, there is plenty of time between active respiratory movements for diffusion exchange of CO_2 and O_2 to take place within the large alveoli. This period of time is approximately 20 seconds under most conditions.

E. Alimentary System

These animals are primarily fish eaters as far as can be determined. Their long beaks fitted with sharp teeth are used to catch fish, hold them, and cut rather than chew or grind them. The teeth are conical in shape and eventually become flattened at the ends in a truncated fashion (hence the species name, *truncatus*). Apparently there are no primarily grinding teeth such as our molars.

Watching the catching and swallowing actions of these animals, one can see that they catch a fish crosswise with these teeth and then with the tongue gradually work it around so that the long axis of the fish is parallel to the long axis of the trunk. They then clamp their jaws together, apparently crushing the fish into a cylindrical shape that can then travel by the larynx into the esophagus. During this action the salt water on the fish is squeezed off by the throat sphincter so that the animal does not necessarily swallow the salt water of the sea. One of the mysteries of their alimentation is how they handle the salt water if they do swallow it and where they get their fresh water if they do not use salt water. They may possibly obtain it from fish lymph and the metabolic processes of digestion of the tissues of the fish.

Along the gut track from the esophagus downward

they have four compartments reminiscent of the ruminants. The muscular coats of the first enlargement or "stomach" and the esophagus are longitudinal on the outside and presumably run in a spiral or circular fashion on the inside. The apparent function of the first two compartments is to hold the fish and to digest them almost completely, not to form cuds of grass to be regurgitated and chewed as in the ruminants. We saw no whole parts of fish left in the feces but did find regurgitated fish vertebrae and bones in the tank every day. The scales, gills, and all other parts are completely digested.

The natural food is whole fish. Apparently they need an oily fish to prevent avitaminosis. Suitable fish are butterfish, mackerel, blue runner, and thread herring. This is based on the experience of the Marine Studios in feeding their animals over a period of fifteen years. Whether in their natural state they eat plants is not known.

The mouth has a very powerful sphincter before the conjunction with the larynx. It is this sphincter that allows the animal to squeeze the salt water off the fish it is swallowing. The fish, passing the larynx, enters the esophagus and from there passes into stomach Number 1, which is a holding stomach. It is a very large bag with a white and smooth lining.

In the transition from stomach Number 1 to stomach Number 2 there is a constriction in the alimentary

tract, which, however, is distensible. It apparently does not have a true sphincter. It appears that regurgitation could be carried out as far down as Number 2 stomach. Stomach Number 2 is rather remarkable in that from the outside it is almost a spherical object that feels as though it is filled with soft rubbery tissues, or even a rubber ball. Upon opening the side wall, it is found that this stomach has red walls that consist mainly of cords and lacunae crisscrossing in every direction around the lumen.

The muscular wall of stomach Number 2 is outside of all the cording and the lacunae. Between stomachs Number 2 and Number 3 there is a small narrow passage 65 millimeters long and about 1 centimeter in diameter with a very well-developed circular muscle coat that apparently can exert a true sphincter action. This little tube seems analogous to the pylorus of the human.

Stomach Number 3 has a fairly smooth wall with pits in it and little gray spots with a general whitish background.

From Number 3 into Number 4 there is a very constricted opening only about 6 millimeters in diameter with a very powerful fibrous tissue coating and muscles in the wall.

Number 4 is filled with yellow bile and possesses a typical fecal odor of the upper intestine and corresponds to our duodenum. Radiating from this small

entrance hole and surrounding it is a purplish circle with four radiating purplish lines that go down inside of the wall of this enlargement. It constricts down into the typical small intestine but there is no true sphincter at the exit. The pancreatic and bile duct enter into Number 4.

The rest of the intestine below enlargement Number 4 to the anus is a small distensible tube with typical mammalian muscle coats. Toward the lower end the tube seems to enlarge slightly. However, there is no cecum and no appendix. There are no pocketings or pouchings of the peritoneum. This whole intestine hangs by a single root from the region of the spinal column in the belly wall. The upper four enlargements ("stomachs") hang mainly from the lower portion of the diaphragm, which is about two feet long.

The intestine is terminated in a very small rectum with weak and thin muscular coats, and by a very small anus, opening into the cloaca in the female and into the anal slit in the male.

The feces come out into the water either in a liquid form or in long threads slightly mixed by the swimming movements. Sometimes the feces float and sometimes they sink. It is not certain what factors go into the various sizes, shapes, colors, and consistency of the feces of these animals.

The whole intestinal tract reflects the freedom of this animal from the necessity of maintaining an up-

right position under a gravitational field. In other words, this animal is floating in water and all of the growth and evolution of the intestinal tract need only satisfy the functions of collecting, holding and passing, and digesting food rather than maintaining itself against gravity. The necessity of violent movement of the stomachs every so often during the quick expiration-inspiration is shown by the binding of the upper three enlargements to the diaphragm by thickened tissues contained within the parietal and visceral peritoneum.

The blood supply to these four compartments is particularly rich, with rather large arteries running especially to Number 2. The details of the blood supply and the nerve supply to these regions should be further determined by future research; some of the older descriptions in the literature are not too clear.

Apparently most of the breaking up of the ingested food takes place in stomachs 1 and 2. The softening process probably takes place in Number 1, and Number 2 breaks it up into small particles, as well as adding some digestive juices.

F. Genitourinary System

The kidneys are extremely large and well lobulated with many independent lobes. There are no notable features of the urinary system, except that this kidney may have the properties of excreting vast quantities of

salt taken in by these animals from the sea. However, this is not yet certain and the physiology of this system is yet to be determined. Obviously they urinate directly into the sea and the urine is quickly mixed with the sea water, leaving only a faint trace after the passage of the animal.

In the female the cloacal opening is taken up mainly with the genitalia. The anus takes up only a very small portion, as does the urethra. The clitoris is approximately 2 centimeters long in the opening of the vagina. The vagina is approximately 5 centimeters deep and there is a single cervix. Inside the cervix the uterus divides into a right and a left horn.

The female has a bicornate uterus but bears only one young per gestation in captivity. No twins are yet known. The slit-like vagina lies within the slit of the streamlined lower portion of the external opening which matches the flattened fore-and-aft penis of triangular shape of the male. The baby is born (usually tail first) into the water through this opening.

The male has "voluntary control" of the penis in an almost "switch-blade" fashion, and can be trained to push the penis quickly outward.

The genitalia of the two animals seem to be designed for a very rapid conjunction while swimming under water. Intercourse has been described by Tavolga and Essapian as a very rapid process. During the relatively long mating season in captivity the males are

extremely amorous and persistent, especially in warm (84° F.) water.

Gestation takes a year. The young are born under water and pushed to the surface by the mother for their first breath. The baby swims beside the mother for eighteen months. Lactation is a reflex, rapidly squirting process in which the baby nudges or pinches the mammae on each side of the genital opening. The milk is squirted into the baby's mouth in the water. The baby begins to take solid food, including very small fish, before the full weaning process is completed. We do not yet know where he gets his first fish, whether he catches it himself, whether his mother catches it and gives it to him whole, or whether she regurgitates some prepared "soup" from her rumen (stomach Number 1).

G. Nervous System

The brain of *Tursiops truncatus* in the mature eight-foot adult weighs around 1700 grams—that is, approximately 350 grams more than that of the adult human six-foot male. For many years it was thought that large size did not necessarily mean high quality.[4]

[4] On the basis of specimens collected by Othello Langworthy. Langworthy, O. R. A description of the central nervous system of the porpoise (*Tursiops truncatus*). J. Comp. Neurol., **54**, 437–88, 1932. Tower, Donald B. Structural and functional organization of mammalian cerebral cortex: the correlation of neurone density with brain size. J. Comp. Neuro., **101**, Aug. 1, 1954.

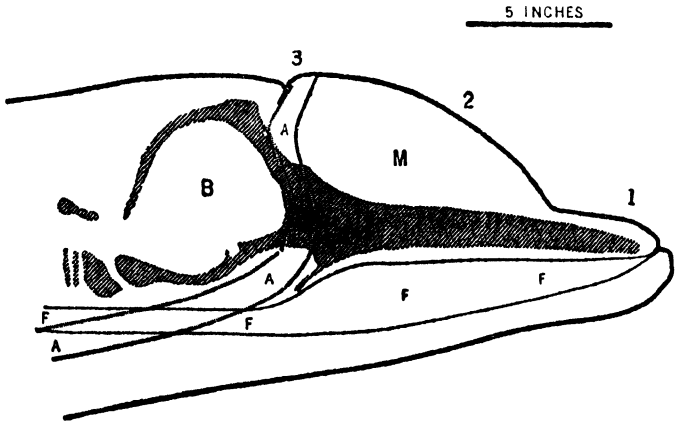
Research on specimens had indicated that the nerve cells of the brain seemed to be more sparsely distributed than in the human brain. In 1955, eight of us from five laboratories collected new specimens in first-class shape. We were able to perfuse several animals before the heart stopped beating and thus obtained preserved brain cells in excellent condition. Careful study of the thalami and cortex of these animals showed the cell counts to be quite as dense as in the case of the human.[5]

As a result of these investigations, it is known that the brain of *Tursiops* is a first-class brain, of the same order of complexity as that of the human. There are more folds, fissures, sulci, and gyri in the cortex than in the human cortex. There are more total numbers of cells in the cortex. The cortex is thoroughly differentiated as in the case of the human, with all six layers. The thalamus has, as well as the extrinsic nuclei, the same number of intrinsic nuclei, plus one or two extra ones. In other words, all of the so-called association nuclei of the thalamus are present; hence, presumably the dolphin has the same association areas in the cortex as we do. This point is yet to be clarified experimentally. Langworthy traced out the origins of the pyramidal tract. He suggested that the motor cortex should be where the supraorbital cortex is in the human; in other words, in these animals the motor area should be very

[5] Kruger, L., *loc. cit.*

far forward and up underneath, instead of on top of the brain as in the case of the human.

In 1957 we found this suggestion to be correct. I stimulated (in an unanesthetized animal with im-



A Diagram of the Head of a Bottle-nosed Dolphin (*Tursiops truncatus*)

The drawing is to scale from a tracing of the midplane of an anatomical specimen. The labeled areas are as follows: 1. rostrum; 2. external surface of melon (M); 3. blowhole. The skull and bone of upper jaw are cross-hatched. The blowhole is shown closed and the airway (A) as open. The airway passes through the bony nares anterior to the brain. (B) in the skull. The food-way (F) starts in the mouth and passes on each side of the airway (A) at the larynx. Two of the flat cervical vertebrae can be seen posterior to the atlas-axis joint of the skull. The spinal canal can be seen in this region. The brain of the animal weighed 1600 grams.

planted electrodes) portions of the motor strip. We found a very highly differentiated "eye-movement" area, as well as a very highly differentiated flipper-control area.

During the studies with implanted electrodes we also found that this brain is like the human in the sense that one can stimulate vast regions of it and apparently obtain no responses. In other words, there are so-called vast "silent" areas in this cortex, as there are in the human brain. This seems to mean that we do not yet have proper criteria for judging the responses of these areas, in human or dolphin. During these studies we also found some portions of the rewarding and punishing systems. We found a rewarding system near the head of the caudate, which in these animals shows on the basal floor above the pharynx (see Chapter 5 on our experiments).

The brain itself looks very much like two boxing gloves placed side by side. There is a definitely spherical shape to it—far more than in that of the human. It has large temporal lobes. The occipital lobes are extremely large. If one wishes to call everything from the temporal lobe to the motor strip "parietal" lobe, the parietal lobe is as large as our parietal plus our frontal lobes. The cerebellum is very large and has been described in great detail by Langworthy; Jansen has studied it in detail in other cetacean species.

Further explorations of the brains in unanesthetized animals are needed for complete understanding of these large and magnificent structures.

H. Special Senses

One remarkable feature of the odontocetes (as opposed to the human and the mysticetes) is the lack of an olfactory bulb. When one removes the brain from *Tursiops truncatus* no large olfactory tract or bulb is visible. This does not mean that there are not olfactory fibers: some may have been missed because of their small size. This matter should be explored in greater detail, and possible olfactory endings searched for in the rather complex airway.

Apparently these animals have a very well-developed sense of taste. Some of their behavior (with respect to the fish that they eat and the water in which they swim) seems to be "tasting maneuvers" rather than anything else. The sense of taste may be the one that leads them to fish and allows them to follow their own species by detecting fecal and urinary traces in the water. However, detailed anatomy has not yet been done upon the taste end-organs. Presumably they may be in the rather rigid lips and lining the forepart of the mouth and tongue. Every so often the animals seem to open their mouths slightly to allow the water to flow through the mouth. The thin fore and lateral edges of

the tongue are richly supplied with papillae presumably carrying taste sense organs.

The papillae on the forward edge of the tongue are very prominent and are 2 to 3 millimeters long and 2 to 3 millimeters across. Apparently the tongue can be pushed up close to the teeth with the mouth barely open to allow salt water to flow by it, so the animal can taste it as it passes through, and thus trail one another or special fish. The posterior portion of the tongue has prominent crypts in it and a few circumvallate papillae are visible. In general, the tongue has very powerful musculature in the posterior two-thirds. The forward third is very thin and flexible. Posterior to the tongue is the mouth sphincter, which apparently clears the salt water off the fish as it is being swallowed. Looking into the open mouth of a live animal, this sphincter is seen closed down behind the tongue. Crypts are visible on the mucosa over the sphincter.

The vision of these animals is truly remarkable. They can see quite as well in air as they can in water. In the Marineland training program they can catch a small football as they back off from the trainer with both their eyes out of water and jump up into the air to catch the ball. From the water they can sight and line up on a target sixteen feet out of the water to which they will jump; they take off from the water in precisely the correct place in order to catch this object. At

Seaquarium they ride on their flukes with the rest of the body out of water, backward, backing away fifty to sixty feet at six or more knots to catch fish in air.

It is still a mystery as to how their vision can be so remarkable, both in water and in air. There seem to be at least two novel possible mechanisms. The extreme degree of accommodation may be achieved by means of a peculiarly shaped cornea: it may be shaped differently in the center than it is at the edges. The iris definitely has a curtain which in bright light causes the eye to show a U-shaped slit. The cornea over this U-shaped slit is apparently a different shape than it is in the center. It would be this U-shape that they would use in air. In the center, the curtain of the iris in water would be raised as the light intensity is reduced. The center of the cornea would focus in water on the same fovea.

The eyeball is a nearly spherical container made of "cartilage" mainly. The orbit is bony only in the top of the eye. The back of the eye socket is the upper ramus of the lower jaw. The lower portion of the orbit is formed by a cord going from anterior to posterior attached to the skull. The eye itself has closable lids, a brownish iris and white sclera, and one can see the yellow-green reflex, like that of a cat, when shining a light into the eye at night. The iris has a little brown curtain which in bright lighting conditions is lowered,

bearing only a U-shaped slit for the entrance-pupil. The cornea may be a very complex water-containing bag. The eyeball is large, about two inches in diameter.

The hard cartilagenoid structure over the back of the eyeball allows the animal to turn the eye outward in order to look upward, or forward, or downward. The position of rest is looking somewhat laterally and downward.

The lens is a sphere, 1 centimeter in diameter, and lies immediately behind the iris. The eyeball is almost spherical and has a shell of "cartilage" except at the iris-corneal region. By muscular control the cornea could be made to bulge by squeezing the free edge of the cartilage shell, and to flatten by relaxing this edge; in air they may squeeze the edge and in water relax it in order to focus the eye in the second media.

The ear under water is extremely good. Hearing ranges from about 400 cycles per second to 200 kilocycles per second.[6] The external auditory opening is very small, in the outer skin, posterior to the eye, and is visible as a little dimple and minute hole in the skin. There is a tube going from here down to the tympanum. However, it is only a small-diameter tube, usually plugged up, and may have no function except water-pressure equalization. Sound is transmitted extremely well to the tympanum through the flesh of the

[6] Schevill, William E., and Lawrence, Barbara, *loc. cit.*

body from the water. The tympanum is rather large and there is a eustachian tube for pressure equalization with the respiratory system.

The cochlea is remarkable in that there is one large nerve fiber for each end-organ,[7] as opposed to several end-organs per nerve fiber in humans. The cochlea is about the same size as the human. However, the acoustic nerve is much larger, about a quarter inch in diameter, packed with large fibers, presumably of high conduction velocity. The cochlea is in a separate bone called the bulla, which is separate from the skull. The bulla has a flat hinge and several muscles so that it can be rotated relative to the skull. The dolphin may rock it back and forth in order to scan stereophonically the echoes coming back from clicks he emits when using his sonar. Investigations of this sonar show it to be extremely exact and every time the animal is forced to use it in muddy or dark water there is a concomitant creaking-door sound as he swims through the water.[8]

The end-organs of the skin have yet to be studied. Presumably there are very sensitive pressure and vibration receptors in the skin for the detection of the wavering of streamlines in the flow stage before the development of turbulence. Such end-organs would be the sensors for the feedback mechanisms to the blub-

[7] Grant Rasmussen, personal communication.
[8] Schevill, W., Kellogg, W., Norris, K., *loc. cit.*

ber muscles to maintain skin form so as to abolish the incipient turbulent flow.

There are probably also other special senses to be found in these animals, as they have not yet been thoroughly explored histologically.

APPENDIX TWO

Intellect, Intelligence, Language, and the Brain

Classes of Intelligence and of Intellectual Capacity

First I shall set up a scale, very rough, very provisional, with large jumps in it—a spectrum for a gross categorization of intelligence and intellectual capacity. This spectrum uses known animals for comparison and gives us a scale against which we can provisionally compare any alien species we may encounter. In terms of known variables, we may be able to place an alien between two known animals or families of known animals, in case we cannot place the alien on more accurately quantitative scales.

Let us make a distinction between intellectual capacity and intelligence. For purposes of discussion I am defining intellectual capacity as *the potential or*

realized ability to develop or use a language in the complex human sense of that term. I am not defining language in terms of the ants or the bees of Von Friesch or the *signaling* of other kinds of animals, such as the birds and the fish of Tinbergen and of Lorenz. I am using language in the usual extremely complicated sense of a *human* language.

I agree with Jacques Barzun's book *The House of Intellect,* in which he makes extremely exact differentiations between the words *intelligence* and *intellect.* Intellect is a distinctively human characteristic in so far as we know it to date in the scientific and humanistic sphere. The word *intelligence* can be applied to lower animals at levels lower than that of human intelligence. Intellect is a phenomena appearing steplike only at an intelligence brain level comparable to that of the normal human being possessing a full language. In this sense a small human child does not have intellect as yet, according to Barzun; he does not yet possess the language and the traditions that this language will carry with it into the brain of the small child during the educational process. Intellect in this sense means an intelligent individual who has acquired or is acquiring a large share of the complex knowledge of the previous generations of his particular species through the medium of a language.

Alien intellectual capacity is only *detectable* in those cases in which at least one human individual

can detect and learn the alien language or languages and/or at least one individual of the alien species can detect and learn a human language at or above the most primitive level of use and understanding. In other words, as yet *we have no measure of intellectual capacity of another nonhuman species. We shall not have such a measure until we can communicate with individuals of that species through the medium of some sort of complex language,* either a vocal language, a written language, or a language in some other form of which we may not yet be aware. In this sense, then, intellectual capacity cannot be measured until there can be an exchange of ideas and all of the other things which we conceive as so characteristically human at the present time. In our present state of ignorance only a human being is said to have intellectual capacity. This does not mean that at some future date humans may not give some other species the human distinction of having intellectual capacity. It merely means that to date no such measurement has been available for any other species than the human.

We can arbitrarily divide all of the known animals in a rough categorical fashion in the form of a spectrum starting near zero intelligence, moving up through the intelligence spectrum and suddenly coming upon an intellect "first level," as it were, and moving into the more complicated possibilities.

Let us start with the lowest possible level of intelli-

gence, in terms of our present knowledge, that of a single cell. Let us call this the first level of intelligence. If there can be such a thing, this would be the level of intelligence of viruses, bacteria, and protozoons such as the amoeba and the paramecium.[1] We probably should also include at or near this particular level the sponges, which are loose social organizations of protozoons, the Metazoa.

At the next level, which I arbitrarily call level 2, we should place the simpler of the invertebrates and practically all of the insects. I arbitrarily carry this level all the way up through the sharks. It is possible that there should be many, many more levels between our lowest level and the shark—that is, from virus to shark. For example, we know the octopus is an extremely intelligent animal compared to most of the other creatures of the sea that surround him. In so far as science has anything to say about it today, the octopus is probably the genius of level 2.[2]

Level 3 is the intelligence level of the birds and the reptiles and possibly some of the fishes. Admittedly this is a large wastebasket covering our ignorance of the distinctions between animals at a given size of nervous system. It may be that after a more thorough

[1] Of course there may be many hundreds of levels between the intelligence of a virus and that of a paramecium. See H. S. Jennings, *Genetics of the Protozoa.*

[2] See the work of J. Z. Young, Prof. of Anatomy, University College, London, England.

investigation of the shark, the octopus, various of the birds, reptiles, and fishes, we shall be able to make distinctions between them which will make these categories more numerous and more exact. It is only in recent years that some of these factors have begun to be thoroughly investigated.[3]

Level 4 is the low mammal level. This is a bare beginning of the warm-blooded (and hence closer to us) animal intelligences. Probably this level also must be subdivided into hundreds of smaller divisions: from the smallest known mammal, the shrew, all the way through the largest monkeys, not including the anthropoid apes. In thinking about this level, it can be seen that already we consider the monkey much closer to us in terms of "alienness" than, for example, a giant squid of the sea. It is at about this level that we begin to have troubles: we usually stop "zoomorphizing" and shift to "anthropomorphizing." The little monkeys begin to resemble little human beings in external appearance and the presence of the hand makes us begin to empathize more with them than with the other animals.

On level 5 we begin to identify even more strongly with the animals in question. Level 5 is that of anthro-

[3] Tinbergen, N. *The Study of Instinct* (Oxford University Press, London, 1951). Lanyon, W. E., and Tavolga, W. N., *Animal Sounds and Communication, 1960.* Am. Inst. of Biol. Sci., Washington, D.C. (Pub. No. 7).

poid-ape intelligence. They are, as it were, a special class of "super-animal." Here we have the orangutan, the chimpanzee, and the gorilla. Many of these animals "ape" human beings so closely that many people feel they are almost human. This is why they are called *anthropoid* apes and why we have the term "aping." However, this level is far below that of the human being in terms of intelligence, and there is no intellect. The apes are below the threshold for the first level of intellect, as far as can be made out.

Kathy and Keith Hayes tested the hypothesis that these animals could be taught English, by taking a chimpanzee, Vicki, into their home and raising her as if she were a human child for a period of two years. Vicki has been presented in a book called *The Ape in Our House* by the Hayeses. In an all too brief summary we can say that on the receiving side Vicki had a very large vocabulary in English but on the transmitting side she was limited to "Mama," "Papa," "cup," and "up," delivered in an explosive fashion.

This degree of performance we do not call intellectual. It shows a high order of animal intelligence but not of intellect. Between this level and a fully developed normal adult human being with a complex language, there is a vast gap unfilled by any known animal. It is as if once the early human beings learned language they killed off all members of the next lower level, at least those that were on land.

The next level I number 6 on the intelligence scale and 1 on the intellect capacity scale. In searching for a name for this level, I chose "proto-humanoid" as meaning "barely human," or extremely primitive humanlike. This is the beginning of the detection threshold for intellectual capacity.

Among individuals born to human beings there are probably some members of this class, such as low-grade morons, whose intellectual capacity is just detectable because they can learn only a small vocabulary on both the transmitting and receiving sides of a human language. They have enough language so they do not have to be institutionalized and controlled like the imbeciles and the idiots, who are below the threshold for intellectual capacity.

Proto-humanoid individuals may have existed and paralleled their development with that of man or may be direct progenitors of the early races of man. The Australopithecines and Pithecanthropus may have belonged to this level. Paranthropus and Sinanthropus may have belonged to the next level (7). It is at this level 6, the proto-humanoid one, that it is hypothesized that the brain has become just large enough so that a language is possible and so that the fine control of the necessary musculature for vocal and written expression can be developed within the nervous system; the fluid patterns of movement necessary for creation of speech and writing appear.

Intelligence level 7 I call humanoid. This is intellectual level number 2. This category is placed between the bare beginnings of a humanlike language and a fully developed human language. This level is a necessary one because we know that there are primitive human tribes who are not quite as complex in their language ability as the fully developed civilized man. This may be an extra step which ultimately can be eliminated; these individuals are definitely above the threshold of detection of intellectual capacity.

The humanoid peoples, the primitive human tribe level, have extremely complex traditions and the beginnings of written languages. They pass on their knowledge from one generation to another by long legendary monologues memorized by one individual who passes them on from previous older individuals. They do not depend upon books or written materials for their records. Practically all of their culture is learned by one individual from previous ones and enforced by taboos and similar rules passed on from one generation to the next. There are artifacts which carry over from one generation to the next but no libraries or other such forms of externally recorded data. Legends, myths, and facts are tied only to external realities and to hypothesized spirits, gods, etc. The level of explanation is that of sorcery, magic, and similar devices which

civilized man attempts to eradicate and forget.[4] These are strictly pragmatic and superstitious humans who have yet to reach the level of civilized man. Associating with such peoples, one feels them, for example, to be far more alien than a civilized man from another culture which possesses libraries and other human cultural artifacts like ours.

The next level I call 8 on the intelligence scale and 3 on the intellectual level. I call it "iso-human." This is the level of civilized man with all its complexities of social institutions, sciences, national relations, international relations, etc. This is the level at which this book is being written. We all know that within this level there are thousands more distinguishable levels; this is the level on which we operate daily, the intellectual level at which we set our status and all of the matters taken up so avidly by social scientists, politicians, educators, and the other specialists and non-specialists within the civilized cultures. Here is where the large brain of the human reaches its maximum flowering, producing works of art, thermonuclear bombs, medical control of disease, etc. This is the level of human compassion well expressed, as well as human destructiveness thoroughly organized.

Above level 8 we should place at least one more level, level 9 in terms of intelligence and level 4 in terms of intellectual capacity. The obvious term for this

[4] See Frazer, Sir James George, *The Golden Bough*, for example.

level should be "supra-human," unspecified. Who are we who are so human to say who or what occurs on the next level or even what its characteristics and properties should be? Here we are in the position of the chimpanzee trying to specify what a human being is like. We can ask questions here and cannot obtain answers, as yet.

Many human beings before us have attempted to answer what is on this level; some of the most influential books in the world are devoted to giving us a picture of what men have thought should be and is on this level above ours. However, to date, the science of this level is entirely lacking. Such a lack may be a result of the nonexistence of such beings or of a convenient definition that they cannot exist and a refusal to look at the proper kinds of evidence.

Are there terrestrial members of the fourth intellectual level? It was once thought that we could answer this with a secure "no" in spite of human wishes to the contrary. Science in its infancy was quite dogmatic in stating that there were no such individuals on the earth. There was an intellectual revolt against accepting ideas of God, or gods, after the intense preoccupation of all of precivilized and civilized man with such ideas for many centuries. Science, in order to survive as science, had to deny and categorize as fantasy all of the religious literature. At the present date about all we can do is say we do not know. We do not have direct

experience with those of level 4 such as we have with other human beings and with animals below the level of the human being. We have no experience with any supra-human being.

It may be possible that there are types of experience with supra-human beings which are being denied access in scientific circles. Such experiences may be so alien to the present methods of science that at the present time there is no way of studying such communications by our known scientific methods.

Much science fiction has been written about contacts at this level. See, for example, *The Black Cloud* by Fred Hoyle. Hoyle, as an astronomer, takes an extremely alien supra-human intelligence and intellect and creates credible fiction based upon modern astronomy and modern physics. His huge "intelligent cloud" is completely outside terrestrial biology. So far as we know, all living matter on the earth depends for most of its operation upon being within a liquid medium. Hoyle's being exists in a dust cloud in physical fields in outer space instead of in water.

Thus we can develop grossly at least nine levels of intelligence and four levels of intellect, ranging in each case from the most primitive to the most complex in a rather arbitrary fashion, and we link intellect to certain kinds of intelligence. This may or may not be proper to do once the experimental evidence is in. This whole

spectrum and all of these categories should not be taken too seriously. They are convenient boxes in which to place information rather than functioning living categories based on secured experiments.

The categories I have devised are convenient for filing information. They crudely organize knowledge for purposes of discussion. In the face of our present-day ignorance about matters of intellect and intelligence on a scientific basis, it is well to accept any such categorizing with a grain of salt. It may be proper to neglect the words "intellect" and "intelligence" completely and organize the same knowledge on another set of co-ordinates, such as the presence or absence of provable two-way language on a highly empirical basis.

Experimental Definitions for Intellectual Capacity

We can set up certain formal prerequisites for determining whether known biological organisms have an intelligence level high enough to include intellectual capacity. Then we can define intellectual capacity in pragmatic and experimental fashion.

So far as is known at the present day, detectable intellectual capacity has the following prerequisites connected with the known biology:

(1) A brain (or its equivalent) above the threshold of size and complexity of structure for the development of language: a big brain.

(2) Access channels to and from the environment suitable for humans to detect and use.

(3) Sufficient time for learning and storage of the contents of category 4 below.

(4) Effective exposure to a language and language-provoking experiences.

(5) Proper living conditions for the well-being of the individual.

Let us discuss each of these items in detail in the above order.

(1) What do we mean by a big brain? One above the language threshold. So far as we can determine in humans, a brain must be of approximately 1000 grams or more in order to have the capacity to learn a human language. Furthermore, this brain must be complex. It must contain between 5 and 10 billion neurons and their 100 billion satellite glial cells or their equivalent. These neurons must be interconnected with a high degree of connectivity and able to form new connections rapidly within the brain's substance. (Let me hasten to add that this is a viewpoint with which all of my scientific colleagues do not necessarily agree.) Here I am presenting the view that those who speak are those who are capable of learning language. Those who do not speak and cannot learn to speak are those without language. We know that certain portions of our brain ultimately turn out to be essential for language. These essential portions are not very large. However,

we still must have a fantastically large storage capacity, which means an extremely large number of neurons (and glial cells) as far as can be determined. Modern human language contains an enormous complexity of structure and of total numbers of memorized forms within it. Scientific linguistic analyses of modern languages are just being completed and show what a vastly complex and fantastically great achievement a human language is.

(2) The access channels to and from the brain, between the environment and the brain, suitable for humans to detect and use, must be of sufficient numbers and effective kinds of controllable imputs and outputs. When we examine closely our ears, for example, designed for hearing in air, we find an extremely complex set of end-organs, very large in number, which can analyze very well the sounds impinging upon the ear. When we look at the opposite end of the communication system in our bodies, the instruments of phonation, we find that they are also extremely complex. The acquisition of the ability to control the muscles of phonation is an achievement probably far beyond that of, say, building the Empire State Building, in terms of man's rise from the level of the lower animals.

(3) Our third requirement, sufficient time for learning and storing of experiences, is obvious. It takes a human child many years to acquire the necessary

experience to become a human being. We start out at a very low "animal" level, quickly come up through the proto-humanoid level at a rather young age, and then spend many years acquiring the necessary language facility and data to use that language to communicate with human beings of equal (and lesser and greater) attainments.

(4) If a human being is isolated from his kind he lacks the effective exposure to language and language-provoking experiences and never does learn to speak. To learn to speak, one must be exposed to effective language experiences in an environment presenting simultaneously several things: (a) language packets in the proper media, (b) personal rewards and personal punishments contingent on the proper use of these packets, (c) examples of other similar individuals exchanging rewards and punishments with proper accompanying packets. A child must be rewarded for making attempts to speak so that he will repeat the experiments of speaking. In a way, he must be "punished" for not speaking: for instance, by not receiving the rewards he could demand if he spoke. This reward-and-punishment view of the acquisition of any habit is now demonstrable in scientific laboratories. (Of course, there are additional factors, some of which I am purposely neglecting to keep the discussion under control and some of which are not yet in

scientific laboratories, although we meet them in everyday life.)

(5) Obviously a young human being or other young animal with the previous prerequisites for intellect needs proper living conditions for well-being. As can be shown even with civilized man, if he is put in conditions on the very edge of survival he is so busy with survival necessities that there is relatively little chance of acquiring additional language (except on a very primitive level). All of the complexities in intellectual attainments in our civilization presume the conditions for well-being and for education. Education can be intellectual in the proper sense of the term only when excess energy, well above survival conditions, is available.

It is my purpose to explore in the next section how we can use the above kind of organization of our knowledge to recognize, deal with, and test other alien (terrestrial or nonterrestrial) individuals for intelligence and intellectual capacity.

Detection of Alien Intellectual Capacity

In approaching any alien species, we should first ask ourselves whether the individual we are investigating or propose to investigate has (1) a large enough brain of sufficient complexity to be above what we consider to be the language-threshold level and (2)

sufficient numbers and control of access channels to and from this brain operating in media that we can manipulate in a communicating fashion. If it does have each of these proper biological basic prerequisites, we can then ask the following questions:

(A) Does this species have a language of its own, a native language?

(B) Can any individuals of this species learn our language?

(C) Can they teach it to their young?

In exploring the first question, we can propose many kinds of experiments. Crucial experiments are yet to be designed, but probably the best results will be obtained by continuous contact between qualified humans and several individuals of the alien species. In my experience the best bet seems to be as follows: first we record samples of the exchange between two isolated individuals, each in solitude. We record the exchanges of pairs of captive individuals on tape and have a way of identifying which individual emitted what. We also record their movement simultaneously on film. We do both over periods of many weeks. At the same time we force one to help the other remotely, allowing each to use only "verbal" directions, bilaterally.

On these records we do statistical studies somewhat like those that are done to break a code or an

unknown human language. We do statistical distributions in rank order for various kinds of message packets; we analyze and try to find the basic units; we do precedence studies of who did and said what first, and what the results were in terms of subsequent action and subsequent productions of packets. We do auto- and cross-correlations and various other kinds of analyses of the sounds, if it is sounds that they are emitting.

In the course of such studies one of the individuals is submitted to stressful conditions and the exchanges and actions that take place between them in consequence of the stress are recorded. We can then do a psychophysiological analysis to develop criteria to separate the emotionally expressive built-in packet from those that are more intellectual and intelligent. We find those signals that correspond to fear, anger, sexual needs, hunger, the need for release from isolation, and so on. By analysis of their violent, quick behavior, we obtain an idea of the "command" language as opposed to the "emotionally expressive" one. We can also begin to have a toehold on other primitive levels within the possible language.

By proper feedback techniques under proper conditions, we can send portions of the recordings back to the individuals and see how this modifies their behavior. I say "proper conditions" because if one sends them back under improper conditions an intelligent animal quickly realizes that he is being fooled—that the re-

cording is not being emitted by a living being in a real situation. If we merely put a loudspeaker in the situation, for example, and play back a tape-recording, an intelligent animal can be fooled briefly and only once. If the loudspeaker emits the distress call for a given species, the other animals come to the rescue of the loudspeaker once and after that, when the distress call issues from the speaker, they do not respond. (Aesop's wolf story immortalized this view.) It is as if they said, "Well, that's just that box on the wall, forget it." The proper conditions seem to be those in which the emission in the appropriate fashion has a consequence to the animals. In other words, if they emit a hunger call and a hunger call comes out of the box on the wall and they again emit the hunger call and then we give them food, the box on the wall acquires some sort of meaning to them in a fundamental sense. Proper feedback systems and sequences are currently being worked out for the case of the dolphins. We are also beginning to analyze "dolphinese" as a possible language in this way.

Experiments and possibilities in trying to answer question (B) are the most exciting. Can the alien species learn our language and teach it to their young? If they can learn even a very primitive version of one of our languages, the attainment will be far beyond that of any known animal other than man. This will immediately raise them to the proto-humanoid, if not

the humanoid, level—that is, it will prove they *have* an intellectual capacity. This is the most crucial and difficult test for intellect and for high order of intelligence that we can devise at the present time. We should not underestimate the greatness of the achievement of the human race in devising languages.

If another species learns our language it will be an equally great achievement for them. Somehow we do not seem to feel that it would be as great an achievement for us to learn the alien's language as for them to learn ours. However, it would be a great achievement for us to learn a completely nonhuman language. If, for example, we take the sounds produced by dolphins as a possible prototype alien language, it may be extremely difficult for us to learn it: it is a series of short complex whistles. It may not even have words as we know them within its structure, but our latest records make this seem improbable.

There can be no more convincing evidence of the level of attainment of a given animal than to have him learn a human language and speak it with human beings. If we find an animal which has the first two prerequisites, what additional conditions are necessary if he is to learn our language, assuming his *brain capacity* is equal to that of modern man—that is, that he is above the language threshold in brain size and complexity and has the proper *access channels* to and

from his brain with the environment? I said in the previous section, the individual must have *sufficient time* for learning and storage of the language elements. He must also have *effective exposures* to language and language-provoking experiences. He must have the *proper living conditions* for his own well-being, whatever his particular biology may require. We will not have a problem in regard to those aliens which need conditions similar to ours; we will have a problem with those which have dissimilar requirements for survival. Before we can create conditions for the well-being of those individual we must find the best conditions for their health and relative contentment.

We define language as a very large (10,000 to 100,000) set of primitive message packets which are exchangeable between many individuals of a group of the same species, race, or tribe. This set of packets is taught to the young of that group and contains important meanings connected with description and prediction of social and personal necessities (at the very lowest level of complexity).

We must answer lots of additional questions about the alien's capacities, actual or potential. On a very primitive level, is he capable of mimicking our speech, for example, or our writing? If so, this gives us at least a toehold on the possibility of teaching the particular individual our language. (The ability of very young

humans to mimic vocally seems to be one of their basic characteristics.) Once he has mimicked, is he capable of using some of the words he has mimicked as demands for necessities: for food, a change of temperature, etc.? We would then go on to investigate his ability to use and make long-lasting connections between given vocalizations and other events, between other processes and between his feelings, whether vocal or not vocal. We would attempt to investigate his ability to abstract and generalize uses of certain words such as connectives and other vocal "cements." And we would investigate his ability to play games, do various kinds of arithmetical operations, algebra, geometry, etc.

There are some further matters that we should investigate in our attempts to discover whether another species has or has not a language.

(1) We should find out what the physical medium of exchange is. For example, is it sound in water, electromagnetic waves, or something else? We know that whales and dolphins emit complex patterns of sound in water; is water being used as a physical medium of exchange?

(2) Once we have determined that there is a sufficiently complex series of patterns going on, what is the formal structure in the physical sense of this exchange? Is the animal using amplitude modulation,

frequency modulation, pulse-time code modulation, some other form of packet, counting, etc.?

(3) What are the basic linguistic units and meaning modulations? In our language we have such things as "words," "grammar," "declensions," and "analogues." The alien's language may have other things than words as we know them. Instead of breaking up the communication in the short "word burst" the way we do, they may slide up and down a frequency scale, for example.

(4) What is the logical structure—are they using a two-valued logic or multivalued logic?

(5) What is the semantic reference structure? What kinds of things, events, processes, feelings, etc., are exchangeable within the language?

Surprisingly enough, it may turn out that it is scientifically easier to collect data on all of these levels than it is to proceed in a slavishly systematic fashion from the simplest possible level—that is, from the physical medium of exchange to the most complex level, the semantic reference structure. The above descriptions and divisions are only a crude map to the kinds of analysis, showing the different levels and complexities on which the questions are asked and answers sought.

We must remember that it is not necessary for an alien to have developed a language of his own in order to learn ours. There may be an unused potential capacity to learn a language. This seems extremely

unlikely but is a possibility that must not be neglected, especially with young aliens.

We could pursue two kinds of investigation simultaneously: probing for the existence of a native, already-developed language, and trying to teach the alien one of our languages. One pursuit does not rule out the other. He may have a native language but be totally incapable of learning ours.

In our work on the dolphins, we are pursuing both lines of research. We are trying to interest linguists in analyzing the sound productions of the dolphins for the possible existence of "dolphinese"; meanwhile, we are pursuing our own attempts to teach the dolphins a primitive version of English.

Brain Size and Language Function

I stated above that our working hypothesis is that until a brain reaches a certain size, language as it is known by normal human beings is not possible. Conversely, if a brain is above a certain size, then it has the capability to learn a language. In the first sections of Appendix Two, we discussed concomitant requirements such as exposure to language-provoking situations and a sufficient period of time for learning to take place. This section will be devoted exclusively to the question of brain size and the appearance of language at a critical minimum brain size. Table I

shows the brain weights of the nonspeaking animals, mouse through chimpanzee; Table II shows the brain weights of the young human at various ages related to anthropoids and presumed human forbears with unknown speech-capabilities.

Our best and most secure evidence comes from a study of human children. Table III gives the quantitative data relating brain size to age of the average normal child. Correlated with this are those ages and hence brain sizes at which language develops in its full-blown human fashion (see also Table VI below).

Understandable speech begins with a brain mass of about 1000 grams at an age of about eighteen months. This is a brain mass very much larger than any of the anthropoid apes have ever achieved (Table II). It is also a brain mass at the upper level achieved by Peking man and very much larger than that of Pithecanthropus and the Australopithecines (Table II). Neanderthal man and Cro-Magnon man were the first to achieve this critical size so far as we know (Table III).

Mimicry of the vocalizations of adults is well under way at a brain size of approximately 400 to 900 grams—that is, from a few weeks of age to several months (Table II). The beginnings of speech appear at 1000 grams of brain at eighteen months of age (Table III). It has been found recently that it is pos-

Table I: Absolute Weight of Brain: Small Animals

Grams of Brain	*Adult Animal*
0.4	mouse
1.6	rat
4.8	guinea pig
9.3	rabbit
31.0	cat
65.0	dog
88.5	monkey (M.r.)
350.0	chimpanzee & beef

(after Tower's figures)

Table II: Absolute Weight of Brain: Animals, Human and Prehuman

Grams of Brain	*Human, Age in Months*	*Animal*	*Prehumans*
350		chimpanzee	Australo-pithecines
450	1	gorilla	
550	3		
650	4		Pithecanthropus
750	6		
900	12		Pekinensis (fire)
950	14		

Table III: Absolute Weight of Brain:
Early Man, Modern Man, and Speech

Grams of Brain	*Human Age*	*Early Men*	*Speech*
950	14 mo.	Neanderthal	?
1000	18 mo.		(understandable)
1200	36 mo.	Cro-Magnon	(typing, Moore)
1250	4 yrs.		(mastery intern. voices, Erikson)
1400	10 yrs.		
1450	17 yrs.	(average max. weight)	
1800	?	(max. found for modern man)	

Table IV: Absolute Weight of Brain:
Man and Dolphin (*Tursiops truncatus*)

Grams of Brain	*Age of Man*	*Age of Dolphin*	*Length of Tursiops Truncatus*
1200	41 mo.	23 mo.	6 ft. 6 in.
1350	78 mo.	28 mo.	7 ft. 1 in.
1450	17 yrs.	8 yrs.	7 ft. 8 in.
1600		10 yrs.	7 ft. 10 in.
1700		?	8 ft. 6 in.

sible at 1100 grams of brain (at approximately thirty months of age) to teach the child typing with an electric typewriter by a special method.[5]

As the brain grows in size and as the child ages, immersed in many daily language-requiring situations, both the brain and the language increase in complexity (Table VI). The usual human reaches 1400 grams at around ten to seventeen years of age (Table III). The levels of complexities of thinking at that time have increased tremendously over that of the beginnings of speech. The numbers of connections established are so large that they are uncountable. At the present time we do not know whether this increase of mass of brain is due merely to new connections growing throughout its mass and connecting the already existing cells, or whether new cells (glial and/or neuronal) are actually formed, or both. At one time it was said that the number of cells of the brain at birth were fixed and never increased; the increased mass is then said to be that of fiber growth. At the present time there is no secure way of choosing between these alternatives.

Empirically we can correlate brain mass with language in man in a gross way. We can do this not only in the case of the normally developing human but in those humans who fail to reach the critical level of 1000 grams. In them language either remains extremely

[5] Moore, O. K., *loc. cit.*

primitive or does not appear at all.[6] Imbeciles, idiots, and very low-grade morons belong in this group. Apparently this is true even in those cases in which there are complete nervous mechanisms for motor control and for hearing but there is a deficiency in the total mass of cerebral cortex: in the storage capacity and in relational abilities within the mental sphere.

As I stated in Chapter 1, very few earth animals other than man achieve this critical brain size of 1000 grams. The Cetacea in general all seem to achieve this, as do the elephants. The elephant's adult brain varies from 4000 grams to 6000 grams (Table V). Apparently the Proboscidea are yet to be studied from the viewpoint presented in this book. Some scientific study of their intelligence has been made.[7]

The only cetacean that has been studied extensively from the standpoint of brain size and intelligent performance is the bottle-nosed dolphin, *Tursiops truncatus* (Table IV). Their brain size at birth is comparable to that of ours at birth and during their lifetime develops well into the upper level of the maximum size for modern man—about 1700 grams. Their brain size increases very rapidly during youth and seems to slow down at nine years but less than

[6] For specific examples of exchanges at the level of 350 grams with thirty years' experience, see Ireland, W. W., *Mental Affections of Children* (J. & A. Churchill, London, 1900).

[7] Rensch, B. The intelligence of elephants. Scientific American, Feb. 1957, pp. 44–49.

Table V: The Largest Known Adult Brains (best* weights)

Refs.	*W, Weight in Grams*	*L, Body Length*	*Species*	*W/L*	*Common Name*	*Weight Ratio*
Vierordt, H.[1]	1450 (av.)	5′9″	Homo sapiens	256		1.00
1890	(1250)			(220)	man	(1.00)
Lilly, etc.[2]	1700*	8′6″	Tursiops	200	bottle-nosed	1.17
1958			truncatus		dolphin	(1.42)
Tower[3] 1954	6075	(?)	Proboscidae	(?)	elephant	4.19
			(species unspec.)			(4.86)
Jansen[4] 1952	7200*	54′	Balaenoptera		fin whale	4.97
			physalus	133		(5.76)
Kojima[5] 1951	9200*	49′	Physeter	188	sperm whale	6.34
			catadon			(7.36)

* Freshly removed in each case so marked: such selected individual weights are in line with weights of other individuals. Selected individuals in any one species could be even larger: Cuvier said to have 1800 Gram brain, for example.

[1] Vierordt, H. Das Massenwachsthum der Korperorgane des Menschen. *Arch. f. Anat. u. Physiol. Anat. s62*

[3] Tower, *loc. cit.*, 1954.

[4] Jansen, Jan. On the whale brain with special reference to the weight of the brain of the fin whale (*Balaenoptera physalus*). Norwegian Whaling Gazette, No. 1: pp. 480–86, 1952.

[5] Kojima, J. On the brain of the sperm whale (*Physeter catadon, L.*). Sci. Rep. Whales Research

Table VI: Threshold Quantities for Human Acquisition of Speech: Age and Brain Weight

Age Months	*Brain Weight*[1] *Grams*	*Speech Stages*[2] (*First Appearances*)
2	480	Responds to human voice, cooing, and vocalizes pleasure
4	580	Vocal play Eagerness and displeasure expressed vocally
6	660	Imitates sounds
9	770	First word
11	850	Imitates syllables and words Second word
13	930	Vocabulary expands rapidly
17	1030	Names objects and pictures
21	1060	Combines words in speech
23	1070	Uses pronouns, understands prepositions, uses phrases and sentences

[1] From Boston Children's Hospital data, 1198 records, by Coppoletta, J. M., and Wolback, S. B. Am. J. Pathology 9: 55-70, 1933.

[2] From summary by McCarthy, D., in *Manual of Child Psychology*, L. Carmichael, ed. (Wiley, New York, 1946).

ours does at a human age of about seventeen years. Their brain continues to increase slowly after that time. The largest brains in the world are those of other Cetacea; some are larger than even those of the elephants (Table V).

Small Brains vs. *Large; Rewards and Punishments*

In this section we discuss the rewarding and punishing effects of various kinds of stimulation in relation to the size of the brain of the animal which is being rewarded or punished. The problem of biological (as opposed to symbolic) rewards and punishments is discussed from the viewpoint of a psychophysiologist. As far as possible, this discussion is tied to experimental materials from my laboratory and from laboratories of neurophysiologists and comparative psychologists. A whole vast literature of educational psychology is neglected here. I feel that I can keep the discussion more succinct and meaningful by restricting it pretty much to the regions of my own experiences.

Within the brain there are many kinds of systems subserving many kinds of functions. Most of these are yet to be delineated by experimental work. The sources of our most dramatic results are direct stimulations of brain systems by implanted electrodes placed within them in unanesthetized animals and humans. Such procedures give the purest instances of

the actions of these systems when they are intensely excited.

The advantage of such experimentation over that using normal inputs is that control of stimulation time and intensity of the central states are completely available to the operator. Many of these systems stimulated in this way do not show the fatigability or the satiability they may exhibit when stimulated through normal inputs. Let us attempt to derive more accurate and definitive descriptions of these systems. The ones of special interest are those that have effect on motivations.

When the special motivational systems are directly stimulated electrically, they act as powerful "forces" and "causes" for learning novel and new things. When stimulated, the motivational systems cause deep and lasting traces of the just previous and concurrent events to become fixed in the brain; memory is enhanced; certain events and actions are given very high values; an impetus to learning is excited, and learning itself is accelerated.

In general, these motivational systems can be split into two kinds, based on the effects of their stimulation. The system of the first kind drives the animal to seek more of the conditions just preceding and occurring with the stimulation of the system and thus to enchance and/or to *start* or to *increase* such

stimulation again and again. This type is called a "rewarding" system (in a shorthand way).

The second kind of system is the obverse of the first kind. Stimulations of the system of the second kind drive the animal to seek *less* of the conditions just preceding and occurring with such stimulation and thus *to stop* or at least *to lessen* such stimulation if it starts again. This type is called a "punishing" system (in a shorthand way).

Each of these systems can excite an animal to action, sometimes violent action. In the case of the small-brained animal (rat, cat, and monkey) the urgency of the action is very apparent in the resulting high velocity of body movements within the allowed restraints and confinements. In the cases of the large-brained dolphin and of humans, the action can be limited to the vocal and autonomic spheres with less violent body movement, if any.

A few "inner" reports from direct brain stimulation in the case of human beings give hints as follows: (1) the first kind of system causes intensely pleasurable, positive feelings, and (2) the second kind causes intensely antipleasure, negative feelings. The antipleasure negative feelings are fear (escape), anger (attack), or pain referred to some specific body part.

The above definitions and findings lead us to reinvestigate several basic instances of learning a language, for example in the case of a human child.

Early in life a human child acts the way the smaller-brained animals do. Its vocalizations are pretty much limited to two major categories: those expressing pleasurable feelings and those expressing negative antipleasure feelings. At birth these vocalizations are characteristic of just the species—for example, a Japanese baby and an American baby sound very much alike. Quickly, however, these vocalizations become modified and within a few weeks correspond to a typical baby of a particular culture. Eventually words begin to appear among the other sounds emitted. One of the characteristics of the human child at this period is his fascinating ability to mimic exactly sounds and actions of other people. Mimicry is associated in general with good feeling, with positive rewarding experiences, but it can be associated with the negative antipleasure ones in a more limited (but more demanding), simpler fashion.

A lot has been written of the vocal play of human children and its importance to speech learning. Early in life this play is associated with good feeling (high activity in the rewarding systems within the child's brain). At this time the negative-system activities are pretty much responded to by rather violent vocalization, such as crying, screaming, etc.

A well-rested child tends to babble, do vocal play, and apparently attempt to mimic the noises of the persons satisfying his needs who may be around

him. There seem to be a good deal less of the rather violent muscular movements that are associated with the very young of the rat, cat, and monkey. Obviously there are some movements, but they are not as active as those of the smaller-brained animals. A good deal more vocalization is noted in these larger-brained animals than in the smaller-brained ones.

In fact, to teach an adult rat, cat, or monkey to vocalize in order to obtain a reward by stimulating his brain is extremely difficult if not impossible. But when the brain of a dolphin is stimulated in the rewarding systems, the vocalizations pour out in a quite uninhibited fashion and concurrent attempts to mimic the sounds in the environment are detected.

It seems that one of the properties of the large brain is to convert internal feelings into vocal expressions and to reproduce sounds from the environment, especially those emitted by the persons in control—that is, the rewarding and the punishing "animals" surrounding the young. Apparently quite empirically parents in general learn how to stimulate rather specifically rewarding and punishing systems through their normal inputs and outputs in the brains of the young. Parents do not have the pure means of stimulation of these systems that the neurophysiologist does. However, I believe that most children would agree that a violent spanking excites negative feelings even though these may be mixed with some violent

positive ones, at times. Many would also agree that when they are hungry, and someone gives them some food, this is a rewarding experience. These are all, as it were, on the agreed biological level of rewards and punishments. After the first few experiences a hungry child seeks food and food-producing situations and may attempt to avoid spanking-producing situations. The constant presentation of appropriate words during these experiences etches them into the memory of a child on the receiving side and causes him to mimic them on the transmitting side. While transmitting, he can make changes and comparisons of his copies with the originals and thus improve his copies.

Each rewarding experience and each punishing experience now acquires labels in the mind of the human "animal." He quickly begins to find that giving vocal signals of the state of his needs can (sometimes) influence the persons in his surroundings to satisfy those needs. During this phase of the development of his language, words and sentences themselves begin to acquire rewarding and punishing significances. *Words have such an intense reality for children at this stage that the proper words can evoke an extremely heightened rewarding or punishing state within their brains.* This stage is the beginning of the later complete formation of symbols and "symbolic" states as opposed to the "real" state of reward and punishment. It takes a fairly large brain—that of an adult human—with a

lot of experience to move away from these primary word experiences that evoke primary states in the biological sphere (Table III). Part of what we mean by sublimation is gaining control in the vocal and verbal sphere over the symbols of the biological states: such control that they do not necessarily evoke the primary state itself with any degree of intensity. All of the questions of belief in one's own words and those of other persons are tested against this background. If a child is told that he is now to be punished and will be spanked, he may act as if he were being spanked, whereas at a little later stage he will laugh and run away.

In order to mimic, a child must live out and become the words and transmissions of the persons controlling him. He can do this only because he has a brain sufficiently large to store all of the materials coming from another very complicated entity, another human being. A chimpanzee may "ape" a human being but a child personifies and lives out another human being. The distinctions are obvious to those who have studied apes and young children.[8]

The intellectual attainments of civilized man are finally reached by a child as the educational processes culminate and, as it were, he is able to remove his own rewarding and punishing further and further from

[8] Köhler, Wolfgang. *The Mentality of Apes* (Humanities Press, New York, 1956).

the original words which could evoke their stimulation. Simultaneously the differentiation of the rewarding and punishing situations within the environment increases rapidly. There is less tendency to generalize the situations: causes and effects become more restricted. Rewards and punishments now become, in addition to the original biological causes, attached to the civilized conception and uses of such things as money, clothing, ideas, etc.

At any time an adult human being can be reduced to the childish level by changing his situation. Such a state can be induced by lack of sleep, by starvation, by torture, by isolation, by profound confinement, by drugs, by direct electrical brain stimulation. The original biological prototypes of learning can be reintroduced and even an adult can be forced to learn once again by means almost thoroughly beyond his control. I am speaking here of powerful means used ruthlessly with very few scruples.

Biological means of controlling learning and motivation are ever present and are of the highest priority when they are used in this fashion. I emphasize these points because this is the way we are treating our dolphins and teaching them. This is also the way we teach our young children and the way that certain propagandists teach cultural prisoners and prisoners of war. When used in the educational process, in the United States at least, rewards and punishments are

rather attenuated compared to these "police-state" methods. Even in the United States, however, external controls can be attenuated only after and if the children involved have already been put through the necessary processes for internal control to develop.

Here I wish to emphasize that the symbolic rewards and punishments which operate every day in civilized life operate just as continuously as do the biological ones. We cannot separate ourselves completely and become totally sublimated, nor can we become totally unsublimated once we are civilized. The built-in verbal control in our huge cerebral cortex continues to operate unless the conditions are made so extreme that they are rarely encountered except in conditions of war or servitude.

Presumably such considerations may apply to other large-brained creatures on this earth, in its seas, or even not of this earth. Our first tests of nonhumans of this sort will be on *Tursiops.*

APPENDIX THREE

Origins of Dolphins and of Men

The modern whales, including modern dolphins, first appear in the Miocene period 25 million years ago. Previous to this appearance there were ancient whales (Archeoceti) whose remains are found in the early Eocene and late Eocene periods about 60 million years ago. Between these two groups no transitional forms have yet been found, according to Remington Kellogg.[1]

The archeocetes are said to be descended from very early general mammals of insectivore-creodont forms in the late Cretacious and early Paleocene periods 100 million years ago. These ancient whales had

[1] Kellogg, Remington. *A Review of the Archeoceti* (Carnegie Institution, Washington, D.C., 1936).

separate nares ("nostrils") near the end of the upper beak (rostrum) rather than a blowhole on the "forehead" farther back as in the case of modern dolphins. The teeth of these early forms were of the cutting form in the cheeks and conical at the rostral end of the jaw; modern dolphins in general have conical teeth. Other differences are demonstrable in the bones of the skull, trunk, limbs, etc.

In the opinion of R. Kellogg, the primitive insectivore-creodont stock gave rise to a generalized prototype which developed separately into each of three lines: the Archeoceti, the Odontoceti (including dolphins), and the Mysticeti (balleen whales).

In relation to brain size the earlier whales had smaller brains (800 cc cranial capacity per 60 feet for toothed Prozeuglodon of middle Eocene) than the modern ones (9000 cc per 60 feet for toothed sperm whale).

The origins of *Homo sapiens* have been traced through similar epochs.[2] The primitive mammals of the early Eocene period (70 millions years ago) also included the earliest Primates. The first apes (Parapithecus) are found in the Oligocene period, 40 million years ago. In the Miocene (25 million years ago) the ape type is Proconsul of the big jaw and small brain: these are said to have given rise to the modern

[2] Clark, W. E. LeGros, *History of the Primates* (University of Chicago Press, Chicago, 1957).

apes. Man's predecessors presumably were among the many types of apes of the Miocene and Pliocene (15 million years ago) periods but the evidence is still fragmentary and unsatisfactory. (As stated above, the first good evidence of progenitors of modern whales is found in the Miocene.) In the early Pleistocene period (1 million years ago) the Australopithecines appeared with a brain of about 600 cc (a little less than half our brain). (This value is to be compared with Prozeuglodon which lived 50 or so million years earlier with 800 cc.) The Australopithecines are "exceedingly primitive representatives of the family which includes modern and extinct types of Man." There is no evidence of speech or tool-making; there is suggestive evidence that they crushed the skulls of baboons with weapons of unknown sort: this fact places them above modern apes in intelligence.

Later, Pithecanthropus appears (Middle Pleistocene period, 500,000 years ago) with a brain of about 900 cc (but larger ones are found). He made primitive tools, used fire, hunted other animals such as deer, and practiced cannibalism, eating the brains of his own species. Evidence is fairly strong that he was a progenitor of modern man.

Strictly modern man arose from traceable progenitors living during the Pleistocene period: Old Stone Age Man (Paleolithic Man) was of many varieties and places in Europe and Asia. His brain was

almost up to ours (1300 cc). This group includes Neanderthal man of Europe, Rhodesian man of Africa, and Solo man of Java.

In the late Paleolithic period about 50,000 years ago modern men, "the Aurignacians," suddenly replaced Neanderthal man. This group includes the Cro-Magnon man. They are hardly distinguishable from present-day *Homo sapiens.* Their cave paintings, sculpture, personal ivory jewelry, and fine javelin blades show their high level of achievement.

By 10,000 years ago the cultural artifacts have an extremely high level. The first written records seem to begin at least 7000 years ago in Sumeria.[3]

The parallel kinds of development of the whales are not known: since whales do not, as far as we know, create tools, jewelry, drawings, or other artifacts, and since they usually die in the sea or at its edge, most of them are eaten by predators ranging in size from large sharks to small bacteria. The best remains are in silt deposits on present land which was formerly ancient seas. Only a few skeletons have been found. As the science of oceanography progresses, we may find the whales' complete skeletal record in the oceans' bottoms. Until then the guesses are further apart than those for man's evolutionary record.

[3] Kramer, Samuel Noah. *History Begins at Sumer* (Doubleday Anchor Book, New York, 1959).

One systematic schema for the evolutionary interrelationships of the Delphinidae is given by Herluf Winge.[4]

The first recorded contacts between man and dolphins may be those given by Aristotle (fourth century B.C.). His account of the dolphins' anatomy and behavior is fairly exact: he distinguishes the dolphin (of the Mediterranean) from the porpoise (from the Black Sea). The contacts are quoted[5] as follows:

"Among the sea-fishes many stories are told about the dolphin, indicative of his gentle and kindly nature, and of manifestations of passionate attachment to boys, in and about Tarentum, Caria, and other places. The story goes that, after a dolphin had been caught and wounded off the coast of Caria, a shoal of dolphins came into the harbour and stopped there until the fisherman let his captive go free; whereupon the shoal departed. A shoal of young dolphins is always, by way of protection, followed by a large one. On one occasion a shoal of dolphins, large and small, was seen, and two dolphins at a little distance appeared swimming in underneath a little dead dolphin when it was sink-

[4] Winge, Herluf. *A Review of the Inter-relationships of the Cetacea* (Smithsonian Institution, Washington, D.C., 1921).

[5] *The Works of Aristotle,* translated into English under the editorship of W. D. Ross, and reprinted by arrangement with Oxford University Press for The Great Books, Vol. 9, p. 156, Encyclopedia Britannica, Inc., Chicago, 1952.

ing, and supporting it on their backs, trying out of compassion to prevent its being devoured by some predaceous fish. Incredible stories are told regarding the rapidity of movement of this creature. It appears to be the fleetest of all animals, marine and terrestrial, and it can leap over the masts of large vessels. This speed is chiefly manifested when they are pursuing a fish for food; then, if the fish endeavours to escape, they pursue him in their ravenous hunger down to deep waters; but, when the necessary return swim is getting too long, they hold in their breath, as though calculating the length of it, and then draw themselves together for an effort and shoot up like arrows, trying to make the long ascent rapidly in order to breathe, and in the effort they spring right over a ship's masts if a ship be in the vicinity. This same phenomenon is observed in divers, when they have plunged into deep water; that is, they pull themselves together and rise with a speed proportional to their strength. Dolphins live together in pairs, male and female. It is not known for what reason they run themselves aground on dry land; at all events, it is said that they do so at times, and for no obvious reason."

Later contacts with "wild" dolphins include those of "Opo" (a *Tursiops?*) in New Zealand, whose story and photographs have been published.[6]

[6] Alpers, Antony. *Book of Dolphins* (John Murray, London, 1960).

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A Biographical Sketch of the Author

Dr. John C. Lilly was born on the 6th of January, 1915 in Saint Paul, Minnesota. He received his Bachelor of Science degree at the California Institute of Technology in 1938, took his first two years of Medical School at Dartmouth, and received his Doctor of Medicine degree at the University of Pennsylvania in 1942. From 1942 to 1946 he was a Fellow in Biophysics in the E. R. Johnson Foundation of Medical Physics in the Graduate and Medical Schools at the University of Pennsylvania. During this period he did war research for the Committee on Medical Research of the Office of Scientific Research and Development and for the U. S. Air Force under contracts with the University of Pennsylvania. He devised an electrical method of meas-

uring and recording blood pressure which was later used during the war for recording the explosive decompression of pressurized aircraft cabins. He invented the nitrogen meter, an electronic instrument for recording extremely rapidly the amount of nitrogen gas in air that is breathed and expired. He was on the Reserve list of Scientific Personnel of the War Manpower Commission during World War II. While a medical student at the University of Pennsylvania he received the John Clark Research prize for his development of the electrical capacitance manometer. In 1945 he received an Effective Service Award from the Committee on Medical Research OSRD. From 1946 to 1949 he was an Associate in the Johnson Foundation and became an Assistant Professor in 1949 and an Associate Professor in 1952. In addition to his Associate Professorship in Medical Physics, he was also an Associate Professor in Experimental Neurology in the Graduate School of Medicine at the University of Pennsylvania. In 1953 he went on leave of absence from the University of Pennsylvania to be commissioned as a Surgeon, full grade, in the United States Public Health Service Commissioned Officers Corps and undertook his research at the National Institutes of Health in the National Institute of Mental Health and became the Chief of the Section on Cortical Integration, Laboratory of Neurophysiology, in that year. He moved to St. Thomas in the U. S. Virgin Islands, and founded (in 1959) the

Communication Research Institute of which he is at present the Director.

Dr. Lilly has been a Hixon lecturer at the California Institute of Technology, a Mayo Foundation lecturer, a member of the Steering Committee on Neurophysiology of the American Physiological Society, a Colloquium lecturer at Harvard University, a member of the Fellowship Board at the National Institute of Mental Health, a member of the Scientific Advisory Committee of the Graduate School of the National Institutes of Health, an Associate Editor of the scientific journal *Psychosomatic Medicine,* and the Secretary to the First Conference on Electrical Studies on the Unanesthetized Brain, Georgetown University, Washington, D.C., 1957. He has been a member of the Life Sciences Committee of the Joint National Academy of Sciences–Air Force Research and Development Command Woods Hole Conference. He is a member of the Scientific Advisory Board of the Air Force Office of Scientific Research.

Dr. Lilly is a full member of the American Physiological Society, he is a Fellow of the American Association for the Advancement of Science, a member of the American Electroencephalographic Society, a member of the Institute of Radio Engineers, a charter member of the Biophysical Society of the United States, a member of the Group for the Advancement of Psychiatry, the American Electroencephalographic Soci-

ety, and an affiliate member of the Philadelphia Association for Psychoanalysis. He is a member of the New York Academy of Sciences and in 1959 was made a Fellow in the Academy for his outstanding work toward the advancement of science, and a life member of the Alumni Association of the California Institute of Technology. He is a member of the International Brain Research Organization, the Aero Space Medical Association, and of the World Federation for Mental Health and the Washington Academy of Sciences.

His scientific contributions are in the fields of biophysical research, neurophysiological research, psychophysiology, psychophysics, psychoanalysis, and most recently Delphinology (the study of dolphins).

His scientific papers include researches on rapid electronic pressure, flow and gas-composition recorders, studies of human respiration, studies on multiple-channel electrophysiological amplifiers, the moving electrical figures in the activity of the brain. He has studied the stimulus parameters in the electrical stimulation of motor systems within the brain, the relation of electrical figures to muscle movements in unanesthetized monkeys, precedence judgments of paired stimuli in perception, the effects of isolation from physical and human stimuli in human subjects, the neurophysiology of motivation in the monkey and in the dolphin; human communication, and most re-

cently, studies on the dolphin brain and dolphin behavior, including vocalizations.

On the less formal side, Dr. Lilly is an ex-radio amateur (W9VWZ), he is an excellent skier, and what he calls a fair yachtsman. His major avocation is his scientific research.

His and his wife Elisabeth's family consists of six children, ranging in age from twenty-three years to three months. Three boys and three girls. A large fraction of the family home is taken up with the work of the program on the dolphins. The whole family participates: the elder boys have taken motion pictures of the animals in the experimental situations; the younger group have been involved in feeding and in swimming with the animals.

Elisabeth handles a major portion of the administrative load of the Institute, and helps with the research and the writing.

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