

THE MARINE
BIOLOGICAL STATION
OF SAN DIEGO

A SKETCH OF ITS HISTORY AND PURPOSES

— AND —

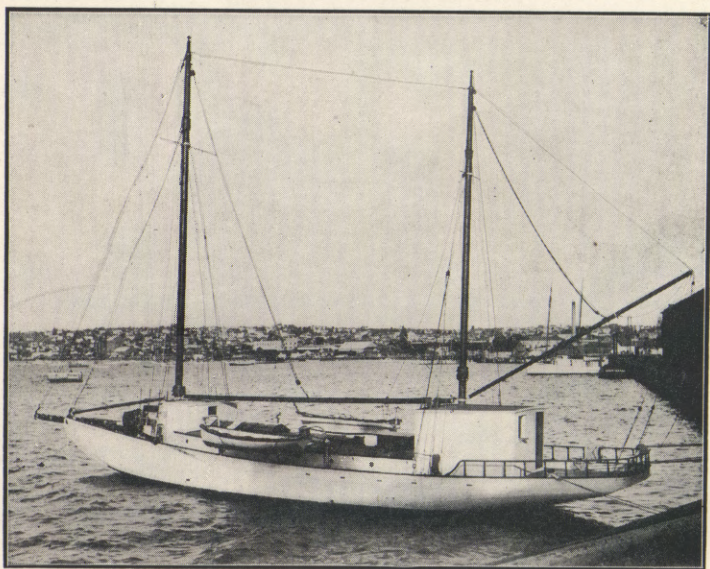
WHAT THE STATION IS, WITH AN EXAMPLE
POPULARLY TOLD, OF THE INVESTI-
GATIONS BEING CARRIED ON

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THE NEW LABORATORY AT LA JOLLA



THE ALEXANDER AGASSIZ

PREFATORY NOTE.

Readers of this pamphlet not residents of San Diego should be informed that the little essays were written primarily for the San Diego community, having been first published in the morning paper, the San Diego Union. "A sketch of its History and purposes" was printed in the New Year's Edition of 1910. "What the station is and an example, popularly told, of the investigations being carried on," was run as a serial in the Sunday papers from October 24 to November 14, 1909.

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CONTENTS

A SKETCH OF ITS HISTORY AND PURPOSES:



THE BATH-HOUSE LABORATORY AT SAN PEDRO



THE LAUNCH, "ELSIE"

A SKETCH OF ITS HISTORY AND PURPOSES

1. **The Various Places at Which the Station Has Lived, First and Last.**

This is the season for looking backward and forward in the things that lie nearest one's heart. True as this is the world over, it is especially true with San Diegans who believe in their city—and who of them does not?

The Marine Biological Station is heartily with the rest of the community in this.

The station (not the association) was born, a puny child, in a tent laboratory at Pacific Grove in summer of 1892, and was kept alive for a number of years only by dint of patient, scientific nursing.

In 1901 it was brought to the wonder-working climate of Southern California. Two years at San Pedro with Los Angeles furnishing the bottle and it progressed from the liquid to the solid food stage.

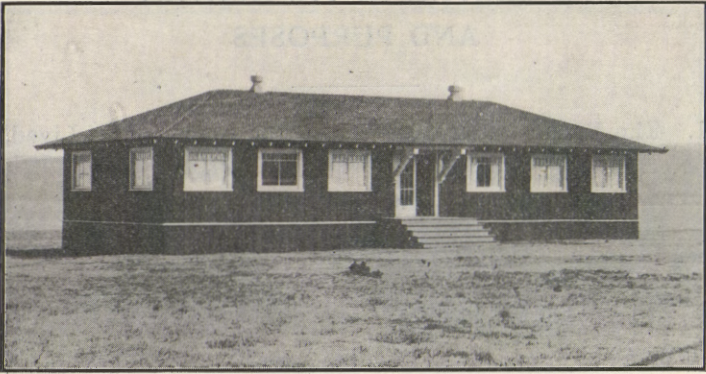
Then, in 1903 and 1904, came the period at Coronado with San Diego as combined nurse and mother, and the infant began to walk at first by pushing a chair, then afterwards alone.

It would not, however, do to give the impression that the removal to Southern California was as late and sudden as this narrative would indicate.

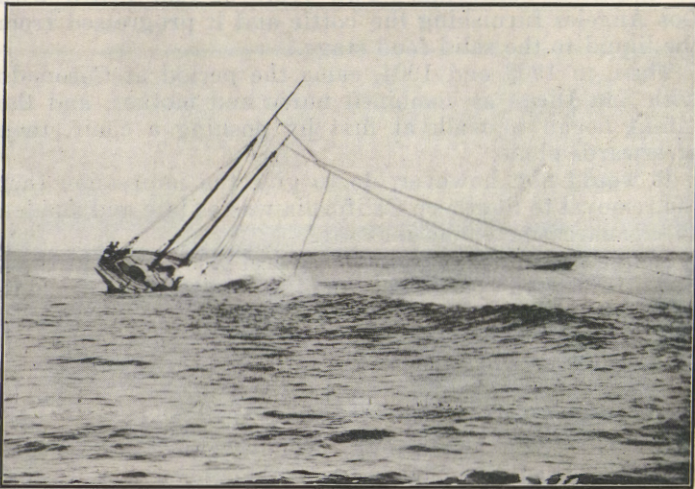
Helpless as the babe was for several years after birth, it nevertheless was brought with its tent to Avalon, where it camped during the summer of 1893. Besides this, it made numerous piecemeal excursions to various points on the coast from Santa Barbara southward during the years between 1893 and its coming to San Pedro in earnest in 1901.

A little old bath house on the government breakwater at San Pedro that somebody had abandoned was washed out and patched up for the child's abode during this period.

At Coronado it was domiciled on the glassed-in porch of the boat house on Glorietta Bight. The ample quarters, wholesome and abundant nourishment and clean air of this



THE ORIGINAL LABORATORY AT LA JOLLA



THE WRECK OF THE "LOMA"

habitat, as compared with that at San Pedro, caused the youngster to grow lustily.

Then in 1904 came the removal to La Jolla and the period of "the little green laboratory behind the bath house." And what a time of luxury and contentment and strengthening of sinews this has been!

Finally, with the broad, brown acres on Long Beach and the stern, spacious reinforced concrete dwelling, all the child's very own, the period of youth, full-visioned, full-strengthened, venturesome, hopeful youth, has arrived.

2. The Various Boats in Which the Station Has Gone to Sea.

But the biological station has lived its short life afloat as well as ashore. It was born to the sea as well as to the land.

Alongside the picture of the San Pedro home is shown the bustling launch "Elsie." Though working for hire, this little boat was able-bodied and true, and the cart-loads of good things she gathered up from the bottom of the sea, where there was not too much water, are to this day a source of delightful albeit serious labor for numbers of naturalists.

After the "Elsie" came Manuel Cabral's fishing boat, the "St. Joseph," which, for her size, probably did more work than any other boat that has yet been in the station's service.

In the wake of the "St. Joseph" came the "Loma," memorable for having been the first boat owned by the station (thanks to Mr. E. W. Scripps) and for having offered up her life in the cause she had espoused on the rocks of the noble headland after which she was named.

Now the pretentious, beautiful "Alexander Agassiz," dedicated to the service from the laying of her keel, has the heavy responsibility of coming after these three humbler craft and justifying her greater costliness and pretensions by performing proportionately greater works. We think she will measure up to her responsibilities, and propose to give her every chance to do so, but she has taken a hard contract.

3. Some Reflections on Bigness and Greatness of Institutions.

But youth, full of visions, is ever impatient of looking backward. It is by nature faced toward the future.

I would like to tell the people of San Diego what, as scientific director of the station, I would like to have the institution do and be. But, of course, it will be understood that this is very far from telling them what it is going to do and be. Having visions is, as everybody knows, one of the cheapest of pastimes, if not indulged in too seriously—so seriously, that is, that no time and energy are left for converting some portion of the vision into reality.

Suppose we begin with a few reflections on the size of such institutions. Somebody has remarked that we Americans are over-fond of bigness. Noting that San Diegans are good Americans, and assuming that they may have some of the weaknesses as well as all the virtues of their countrymen; and assuming that of these few weaknesses love of bigness may be one, I imagine these questions being asked: How big a thing is this station likely to be? How many buildings is it going to have, and how large will they be? How large a working staff will be required, and how much will be **paid** them? How many and how large boats will be necessary to do the work at sea?—and so on. My general reply to such questions would be: If the station does the things I would have it do it will, unfortunately, have to be rather big. My ambition for it—and in this I am sure I speak for its patrons and official friends as well as for myself—is that it should be great rather than big.

It is a truism that bigness and greatness are not necessarily the same thing; that either may exist without the other. There is, however, a truth implied here that people frequently miss. It is that, at least as far as institutions of scientific research and learning are concerned, real greatness must necessarily have a dread of mere bigness. If a great institution is big it is so from compulsion and not from choice.

A moment's reflection enables one to see why this must be so. Institutions are always created to do particular things. They are rarely, if ever, for the purpose of just being themselves. Schools are to educate the young; insane asylums are to take care of those whose minds are deranged; prisons are to hold in custody and reform criminals, etc., etc. But all these cost money and time to build and maintain. So it follows that anything put into the institutions themselves over and above what is essential to enable them to perform their specific functions is just so much impairment of their efficiency. All that goes into the machinery itself is just so much taken away from that for which the machinery exists.

It comes out, then, that every institution which aims at the greatest possible efficiency will strive to keep itself as small and mechanically simple as it can and yet do the things it has to do.

The principle is, I suppose, much the same as that which makes what is called over-capitalization in business establishments. The danger is, however, probably greater to institutions of the kind here considered than to those of the business world. This is so because, in the first place, an educational, a philanthropic, or a scientific institution has nothing so definite as are the dividends of a business with which to measure its efficiency; and, in the second place, because of the more public character of the institutions, especially those actually built and supported at public expense.

A careful study of public institutions would, I believe, find that in spite of the fact that their perennial need for more funds is in a way real, they are generally over-capitalized, or at least ill-balanced in their capitalization.

From these considerations it appears that the ambitions and welfare of an institution ought always to be discussed from the functional instead of from the structural standpoint—from the physiological rather than from the morphological side, as we say in biology.

So on this basis I proceed to speak of what, in my opinion, should be the ambitions and aims of the biological station.

4. Visions of Future Greatness.

(a) In Scientific research.

Its functions as a research institution—as an instrument, that is, for adding new knowledge of nature to that already possessed—would always be chronologically the first to receive attention. For the good of this function the working staff of the laboratory should be largely increased. Our investigations on both the life of the sea, and the sea itself, already under way, call urgently for a permanent head chemist and physicist of experience and recognized ability.

At the present time all we can do is to make a partial examination of the water samples being brought to the laboratory by the hundreds, the person in charge of the work, Mr. G. F. McEwen, of Stanford university, being able to spend only a few weeks in La Jolla each summer vacation. The vast field of chemical study of the organisms themselves we have not been able to touch at all yet.

One thoroughly good man, broadly trained in both chemistry and physics, would, with the aid of assistants for the water work on the one hand, and for biological chemistry on the other, strengthen and broaden our researches greatly.

Biology is rapidly becoming as much a mathematical science as are astronomy and physics. Innumerable countings and weighings and measurements are essential parts of the raw data of biology, and they are indeed "raw" until they have passed through the crucible of advanced mathematics.

The day of unbridled deduction as to what might possibly be true, based on one or a half dozen random observations, is, or shortly will be past in biology, as it was long ago in the exacter sciences. So a head mathematical biologist is greatly needed. Such a man would, in addition to prosecuting his own special researches, be chief consultant on questions of method pertaining to the quantitative treatment of biological problems, and would have general direction of the work of collecting such data, and of the subsequent reduction of them. This kind of work is extremely time-consuming and much assistance from younger, less advanced investigators would be indispensable. Mr. Michael and Miss Johnson of the present staff are pegging away at their interminable columns of figures, and are bringing out interesting results, in spite of the fact that they have no full-fledged mathematician to appeal to in times of need.

As I calculate, a permanent laboratory staff of eleven persons would carry forward the investigations now blocked out with a good deal of efficiency.

At present we can run the Agassiz only a few days once a month or something like that. Could we keep her in commission all the time so that she might be at sea half the time, say, and subject to call at a moment's notice when investigations in the laboratory come upon matters that need new material and new observations in the field, the thoroughness of the investigations would be increased out of all proportion to the increased cost, because, for one thing, the part of the boat's crew not needed aboard while she should not be at work, could be occupied in diverse ways about the laboratory, the aquarium and the museum.

Stating the matter approximately, I should say that an increase of 50 per cent. in expenditure here would result in an increase of 100 per cent. in efficiency.

Then there is the important side of the station's nature, namely, the non-resident, or part-time-resident, staff to be thought of. So far nearly all the results published have come from this source; and I am quite sure that in the future, however numerous and eminent may be the naturalists who live and work all the time at the station, much of its strength will lie in the workers who come for short periods. In addition to the many kinds of work the station may do through this means that it could not otherwise do, the organic connection of it which this will maintain with various outside scientific centers must be a perennial source of health and strength.

(b) *In Instructing the Public about Biology and the Pacific Ocean.*

Now I wish to speak, briefly, of an aspect of our enterprise that has heretofore been but little considered, but which should be of especial interest to the local community. I refer to the possibilities open to the station of becoming an educational as well as a research institution. What I have in mind is not, however, an establishment for instructing boys and girls on the ground and organized into classes, but for teaching grown-ups. Here in a few words is the kernel of my views: Biology, taken in the broadest way, contains vast numbers of facts and generalizations that in themselves would be genuinely interesting to most intelligent persons could they but be known to them. But, of vastly greater importance, many of these are of the utmost importance not only to sound views of human life but to conduct as well. How are these facts and generalizations—these fruits of research—to be more widely disseminated among the people than they are? The answer—and in practice almost the only answer—so far given to the question, particularly in our country, has been the school and the college. Education, especially as touching nature, is hardly thought of as being anything else than the formal instruction of children. States and cities and counties and rural districts devote vast sums of money to education, so understood. But having provided liberally for education during the earliest years of life, the thing is dropped almost absolutely, the assumption being that with graduation from the school education is “finished.” How about the soundness of this theory and practice? Who does not recognize that in any ordinary business or profession, the moment one ceases to learn that moment is it time for him to “shut up shop and quit”? Why should it be otherwise

with the business of living? It would not be were there a real business of living. "Business is business," and living consists mainly in eating in order to keep on doing business, and in gratifying a few other of the more insistent desires.

Really, it might almost be said of the business of living, as well as of other kinds of business, that the moment one ceases to learn about it that moment he would better shut up shop and quit. The person who tries to go through life on the wisdom he acquired in school makes about as much of a botch of it as does the physician or lawyer who practices his profession on his college lecture notes and text books.

Saint Paul surely knew what he was saying when he remarked about the difference between a boy and a man. Children think and act as children and they ought to, just as men think and act as men and ought to; and a child's education will not do for a grown person. What a boy wants is not philosophy, but his senses sharpened and his head filled with well selected, well ordered facts.

I would have the San Diego marine station contribute something, so far as biology is concerned, to the rectification of this serious defect in our educational notions and practices. This I would have done by making the station operate on the principle of the modern dairy creamery. A creamery is an establishment the purpose of which is to separate and make available for use the cream that is originally disseminated in minute particles all through the milk as it comes from the cows. The cream is extracted by centrifugal force.

Scientific results as they come from the technical investigations of the laboratory with minute particles of vital truth disseminated all through them, I would have looked upon as milk from which the cream is to be extracted.

The ideal would be for each investigator who spends a year, say, on a particular investigation, to then put in a few days or maybe weeks, in centrifugalizing it to get out the generally utilizable truth it may contain. The butter thus produced could be marketed in two ways. In the first place, for the immediately surrounding community there could be a free market, so to speak, in the form of a combined lecture and demonstration hall in which the investigator could, at times previously announced, display and dispense his goods for such of the public as might be moved to attend.

The other way of marketing, designed more for reaching the larger public, would be a popular journal; a weekly or monthly journal the sole aim of which should be to make scientific subjects intelligible to non-scientific people. There is, I am aware, a supposition widely held both among scientific investigators and those who are guiltless of technical learning that the deeper truths of nature are too obscure, too recondite to be comprehended by the rank and file of human beings even of highly civilized lands.

The fact is, I am convinced that what makes so many of the so-called truths of science seem so hard is the circumstance that they are not true, or at best not more than half true.

A famous French philosopher, Rene Descartes by name, who lived some 300 years ago, made a great point of the clearness of our knowledge and our ideas as a test of their truth. How far this doctrine of Descartes should be credited with the fact I do not know; but it is undoubtedly the case that French men of science have generally a remarkable way of telling what they know so ordinary people can understand it. A Frenchman is quoted as saying that a scientific man who has really discovered something can always make it plain to the first person he meets on the street.

For my part when I hear men of science talk about their investigations and discoveries being too hard to be comprehended by ordinary mortals, and too subtle and remote to be of interest or use to such people even if they could be comprehended; and when I hear philosophers and teachers talk of secret, inside doctrines and special illuminations, my suspicions are at once aroused—not as to the competency of those who are to be taught, but as to the mental incompetency if not something more to be dreaded, of those who teach.

But to come back to the original question of the possible future size of the biological station. Perhaps I have said enough to make it clear that should my visions be even approximately realized the institution would become rather big in spite of us. Just how big and just how much money would be required to make it so I do not like to contemplate, though two of the large mechanical items in this bigness may be mentioned. One would be an extensive, carefully planned public aquarium. The other an equally extensive, carefully selected biological library.

The station could be made big at a comparatively small

expense. It can be made great, as it conceives greatness, only at great expense. The public is invited to help us make it great.

WHAT THE STATION IS, AND AN EXAMPLE, POPULARLY TOLD, OF THE INVESTIGATIONS BEING CARRIED ON

Many San Diegans know of a little green building behind the bathhouse at La Jolla in which there are a lot of curios from the sea, some dead, some alive, and they know, too, that a trim looking craft, the Alexander Agassiz, goes a-fishing from time to time, seemingly to get more curios for this little building. They know further that a reinforced concrete building of considerable size is being erected on the barren cliffs beyond La Jolla to make room for more curios. They know finally, in a vague way, that all these together make the "biological," which is a "school" or a "government fish hatchery," or "something."

A less number of San Diegans have given sufficient attention to this "biological" to get a notion that it is something more than a curio shop, and would like to be instructed rather definitely as to what biology and a biological station really are.

Earlier in my career as a scientific man I used to resent somewhat the persistent question of practical folks, "What is it good for?" Today the larger the number of persons who ask the question, the better I am pleased. Especially do I wish the intelligent people of San Diego would insist that this enterprise in their midst need expect no particular encouragement and help from them unless somebody in a position to know tells them clearly what biology, marine biology in particular, is about, and of what use it is.

Suppose we begin by answering some of the easiest, but more frequently asked questions. The Marine Biological Station of San Diego (that is its official name) is not a United States government institution; it is not yet even a State institution. It is strictly local, as its name indicates. However, the articles of incorporation that give it a legal right to exist provide that a little later it shall become a department of the University of California. But while the station has no organic connection with the uni-

versity, it is on intimate terms with that great member of the state's intellectual life.

The station is not a school. Girls and boys do not congregate there to be instructed. It is not a fish hatchery, nor has it to do primarily with any marketable product of the sea, though it is mightily interested indirectly in all sorts of establishments that are concerned with such products.

These negative facts out of the way we may go on to some positive ones. The marine biological station is first and foremost a research institution in pure science.

What does this mean? Here we have the question that probably is aimed at by persons who want to know truly about biology and the "biological." It can be answered in general terms very easily. A research institution in pure science is one that takes hold of some piece of nature, larger or smaller, for the purpose of learning all it possibly can about that piece, regardless of how trivial the facts, each taken by itself, may seem; regardless of how much time and labor and expense may be required to get at these facts, and regardless of whether or not they will have any bread-and-butter value.

1. The Value of Useless Knowledge of Nature.

Does this sort of thing pay?

It would, I believe, be superfluous to show that but for just such seemingly useless work somewhere, sometime, by somebody, there would not be such a thing today as a steamship, a railroad, a telegraph, a telephone, an automobile, a printing press a really comfortable home, a surgeon's knife, an anaesthetic, or any article characteristic of modern civilization, even to a jack-knife, a fruit jar or a soda fountain.

People generally who read and observe know that the starting place of the whole material side of so-called western civilization is rooted in unremunerative studies of nature.

What they do not so well recognize is the extent to which the intellectual, the spiritual side of civilization rests upon the same foundation.

This is the aspect of the matter, speaking for biology and the biological station, I would like to present briefly. It probably will be agreed by everybody that a sane person is better off himself, and better for those around him, than an insane one. Think about it a little and you will see that to a large extent sanity consists exactly in being on

good terms with surrounding nature; and that being on good terms with nature depends largely on knowing nature and rightly estimating its forms and forces. I would not be understood by this to mean that ignorance of nature and insanity are identical. What I do mean is that there is much, very much, in common between them. Change this to the affirmative form of expression and it contains the kernel of the first point I would like to make—the knowledge of nature possessed by a person or a people that has been acquired in essentially such ways as the “biological” is acquiring knowledge, is to a very large extent the measure and substance of the sanity of that person or people.

(a) *The Coming of Halley's Comet.*

Let us be concrete. A famous comet, Halley's, that has been coming toward the earth for the last thirty-five years and more, is now arriving on schedule time. Several of the great observatories being on the lookout for it have already caught sight of it photographically. Some time next February, so the astronomers tell us, we ordinary mortals may begin to see it with our unaided eyes in the constellation of the fish, and that by the middle of May it will be at its nearest point to us, and so at its biggest and brightest. Everybody will be interested in it; men of science for the opportunity afforded them of learning more about it, the character of its light, the material of which it is composed, its speed, the path it follows and so on; and the rest of us for its novelty, its beauty, and its mystery. But—and here is the main point for us now—there will be no dread connected with it except on the part of ignorant people. I have no doubt we shall hear more or less of ominous attribution and prediction about it, even among neighbors of ours here in San Diego, who would resent being called ignorant; and a goodly (badly, rather) lot of charlatans will unquestionably use it in their trade. But we of enlightened lands know perfectly well, or may if we stop to think a moment, that there is no more ground for seeing omens in this comet than for seeing them in the sun or the moon or any of the planets or stars.

How vastly different it has been with the visits of this beautiful object in past ages! Down to its return in 1759 it had frightened great numbers of people of even the most enlightened countries “out of their wits,” as we say. It had been made responsible for all sorts of calamities from disease and from the elements; it had been in-

voked for vengeance upon enemies; it had been used by tyrants and bloodthirsty warriors to help on their degradation and destruction of simple-minded people. "Lord, save us from the devil, the Turk and the comet," is said to have been added to the Ave Maria when this same comet came along in 1456, soon after the taking of Constantinople by the Turks.

(b) *Commonness between Astronomy and Biology in Motive and Method.*

But what has all this to do with biology and a marine biological laboratory? Much, very much.

The motive and general method by which comets have been changed from objects of fear and dread to those of interest and admiration are exactly the motives and the methods of the marine biological station of San Diego, and of every institution of research in pure science. But further—and here is the meat of this instance—there is exactly the same need today for releasing minds and souls from bondage to imaginary hostilities in nature that there has been in all past time.

It is a matter of history that one of the most serious difficulties Columbus had to contend with in working his way across the unknown waters of the Atlantic was the superstition and fear of his men. They were "scared out of their wits"—were to a degree insane, or, if you prefer, not sane. That was four hundred and seventeen years ago. There is every reason for believing that the next four hundred and seventeen years will increase our race's sanity as regards the sea, and its inhabitants as much as have the last four hundred and seventeen. Man's diminution in dread not only of the sea but of all nature will continue indefinitely in the future just as it has in the past. I like the affirmative form of expression better. Man's safety with, his control over, and his love for all nature will go on increasing in the future, for all time, so far as we know, in much the same way and rate that they have increased in the past. I have no doubt many readers will be disposed at first to question this proposition. If, however, they will think about the matter seriously their doubt will, I am convinced, become less and less. They will recognize not only that what I say is probably true, but they will see a long way into the character of the future gain. I fully believe that, for one thing, the time will come when their will be wide spread among people a fondness for most living things, plant and animal alike,

of much the same sort that many persons now have for roses and trees and pet birds and dogs.

What we call enlightenment is not an absolute, it is a relative thing. We are more enlightened today than we were yesterday, and shall be more enlightened still tomorrow.

(c) *Sanity Toward Nature.*

Here is a fundamental point: Nature is an enormous aggregation of things—objects—each having certain metes and bounds, certain qualities and powers, beyond which it cannot go. Now, knowledge of nature, sanity toward nature, consists exactly in not only ever increasing the extent of our inventory of these objects, but of recognizing, without addition or subtraction, that is, accurately and justly, the forms, the qualities, and the forces of these objects—what they are and what they are not; what they can do and what they cannot do.

Is there anything worse than mild folly in the belief in the “sea serpent?” That depends. If the belief involves the notion “monster,” then yes, decidedly, for the belief is of the self-same kind that has prevented men from being sane, that has filled them with dread, in all ages. It is a question not of nature, but of state of mind. The person whose mental attitude is such that he easily and unwittingly puts into the sea from his own consciousness a creature that does not exist in the sea, and holds it to be as real as those that do exist there, is also in a state of mind to attribute to all sorts of innocent creatures and persons qualities and powers they do not have and hold these powers to be as real as the ones they actually do possess.

The so-called “devil fish”, the octopus, common along our shores, grows to a large size, particularly in far northern waters; but in twenty years of beating up and down the coast from San Diego to western Alaska, I have never met a specimen that a sturdy 15-year-old boy could not handle, if he was not “scared out of his wits” to begin with. The animals have a great number of efficient sucking discs on their arms, which work as any wide-mouthed, flexible cup does when you invert it on a smooth surface, press its rim into close contact with the surface, then lift on the middle portion of the cup. The thing sticks under these conditions from the weight of air or water, as the case may be, outside with none to offset it inside.

The suckers of the octopus have no “stings” or piercers

of any sort, and the animal can no more suck blood with them than a treetoad can suck blood with its toes.

The creature has a good pair of jaws, and can bite, or rather crush, once it gets a thing well into its mouth. But the mouth, judged by our common criteria of this member, is in as awkward a position as can well be imagined.

A person wading in the water among rocks where there are devil fishes, is about as likely to be attacked and bitten by one of the animals as he is to be injured by the explosion of a watermelon, when walking through a melon patch. Both things are possible.

The octopus secretes a great quantity of black fluid and makes use of this by squirting it into the water to envelope itself in "pitch darkness" against the approach of enemies. But the fluid is not poisonous, nor the leastwise injurious to anybody or any creature, so far as we know.

In short, the animal is not a "horrid thing," as it is painted in story and in many a dimly lighted imagination. There is nothing devilish about it.

And here is the moral of the "devil fish": If there is a corner of your mind that wants to attribute to the octopus malevolent qualities and powers that it does not possess, and is content to overlook or deny to it qualities and powers of interest and beauty that it does possess, mark my word, the same corner of your mind will tend to treat such at least of your fellowmen as you do not know well, in the same way. This unfortunate corner of your mind will, like all other corners, be true to itself—to its own qualities. It is the old impossibility of blowing hot and blowing cold at the same time.

This glance at the octopus and the moral we read in it, brings us to where we may give one answer to the question, What is biology?

Biology is that department of natural knowledge that is insatiably curious about every living thing that inhabits the depths of the sea, the expanse of the land, and the heights of the air; that affirms nothing and denies nothing dogmatically, about these living things, but gets all the information it possibly can concerning their qualities, observed and imagined, to the end that: It may fear no living being except on the basis of proved powers for ill; and that:

It may trust and love all living beings according to the strict measure of their deserts.

With these general considerations about biology to go

on, we will now speak of some of the special things the San Diego station is trying to do.

Everyone among us here on the shores of the Pacific who is possessed of unimpaired faculties is interested to some extent in the sea and the creatures that dwell therein—just as he is interested in all nature with which he comes in contact. I do not believe there is any real exception to this. Even a group of persons who would shut themselves up in a seaside cottage of a pleasant, sunny morning and play bridge, would almost certainly stop for a few minutes to look and exclaim at a big whale, were one to come plowing and blowing close in-shore. But such momentary notice of merely the biggest, most uncommon, most striking things is not really interest; it is mere curiosity, someone may say. Well, so be it. I shall not seriously object to the distinction if you think it ought to be made. But whatever you call it—and here is the point—it is the starting-place of all knowledge of nature, ordinary and scientific alike. It is where rationality, where real sanity, begins. Furthermore, not only does knowledge begin here, but so long as it remains rational it never for one instant wholly departs from such interest, or curiosity.

(d) *Curiosity and Science.*

It is frequently said that science is common sense refined and extended. That is one way and a very good way of putting it. Another way, rather more useful for our purpose now, is to say that scientific knowledge differs from ordinary knowledge in the extent of its curiosity, and the extent and way it follows this up. The word curiosity is done considerable injustice by our everyday English speech. Look it up in any good dictionary, and you will see that in its ancestry it runs back to the same starting place from which our word care comes. The curiosity of science is the kind that cares, and cares mightily. It cares without limit. Not only does it care about big whales—it cares about little whales, too; it cares about all whales that live now or ever have lived. And it cares about them through and through, about their bones and intestines and skin and blood, and the worms that live on them and inside of them, and all the rest.

Some eccentric person whose name I cannot recall is said to have reached a point, after long and earnest reflection, where he could deliberately say, "I accept the universe." It is exactly that sort of eccentricity that

characterizes science. By accepting the universe, science means that it holds the universe to contain nothing whatever too small or too big, too simple or too complex, too ugly or too beautiful, too common or too uncommon, or too anything else, to be interesting—to be worth knowing. But more than that. It does not hold the universe in this way merely theoretically. Its faith is alive and motor. It not only holds the dust on its shoes to be worth knowing, it is sure there is an endless amount about it that can be known, and proceeds even to spend money, to say nothing about time and talent, to investigate that dust. Literally this is what I mean. It is not the language of a school girl's valedictory that I am using. No one has even touched the garment's hem of real science who can turn from the minutest, commonest fragment of nature with "useless" and "uninteresting" on his lips. To the man of science the universe says: "Inasmuch as ye have done it unto one of the least of these ye have done it unto me." And so among other innumerable places where he goes and asks and tries to answer, he goes down to the sea, and the questions there about big things and little pour in upon his mind in a resistless flood. So he hurries away to find somebody to help him with money and laboratories and boats and microscopes and thermometers and nets and balances and measuring sticks and books and chemicals and all sorts of things in order that he may do his best to cope with his flood of questions.

Take any familiar animal that happens to drop into your mind and begin to ask questions about it—reasonable questions, I mean; questions, that is, that might be answered at least partly by such studies as we know to be practicable—and see what a list you soon have, and what an undertaking you would have on your hands if you were actually to set about answering them!

Take any of our common fishes, for example the barracuda. For what portion of its lifetime does a particular barracuda grow? How long does it live? What are its chances of dying of old age as compared with those of being gobbled up by some other creature or creatures? How many enemies has it and what are they? How far does it travel in its more or less regular journeys up and down our coast? Does the same fish follow much the same course each year, or is it quite haphazard in its wanderings? How fast can it swim at its best? How many and what kinds of animals does it eat upon occasion? What

about the mating of the males and females? How many eggs does a female lay at a single laying, and how many layings would be due from her in an average lifetime? What sort of a thing is the little barracuda when it first hatches? What are its enemies? What does it eat at first? Do the old fish take care at all of the young ones? What is the temperature of a barracuda's blood and is it always the same, like that of man's, or does it change like a frog's with the temperature of the water in which the creature happens to be?

And so you might run on endlessly as it seems for no other reason than that you keep on being curious—keep on caring. You have decided to accept the universe and the barracuda is part of it.

Or suppose the insignificant, all but invisible little organism that makes most of the rusty water and phosphorescence during the summer months, drops into your mind and you ask questions about it—for it, too, is part of the universe we have accepted. Do you think your list will be shorter than that about the barracuda?

But I started to give a typical instance of scientific investigation and I must be about it or my instance will turn out to be merely an introduction to an instance.

Perhaps I shall be pardoned if I am egotistical in presenting this case to the extent that one cannot avoid being if he talk about things he happens to know first hand. One of the reasons, I imagine, why so many of the facts of nature we try to teach to others, in school and out, seem so dull and dubious, is that we ourselves know them only through somebody else's mind. Emerson has remarked somewhere about a man's having an "original relation with the universe." Under the spell of the doctrine of evolution we are wont to think of an original relation as one dependent upon origin. But to Emerson's phrase we can attach a quite different and very important meaning. By original relation Emerson probably meant an intellectual relation in which no second person is inserted between the student and the universe.

2. A Few Things That May Be Learned by Studying One Kind of Animals (Salpa) Long Enough.

(a) An Incomplete Description of the Creature.

All fishermen of this port and probably many other persons have seen from time to time a form of life floating in the sea that reminded them of a cartridge belt filled with cartridges. Sometimes these belts are almost or

quite long enough to reach around a man and the cartridges are as large as those for an ordinary shotgun.

A portion of one of these belts is shown in figure 1.

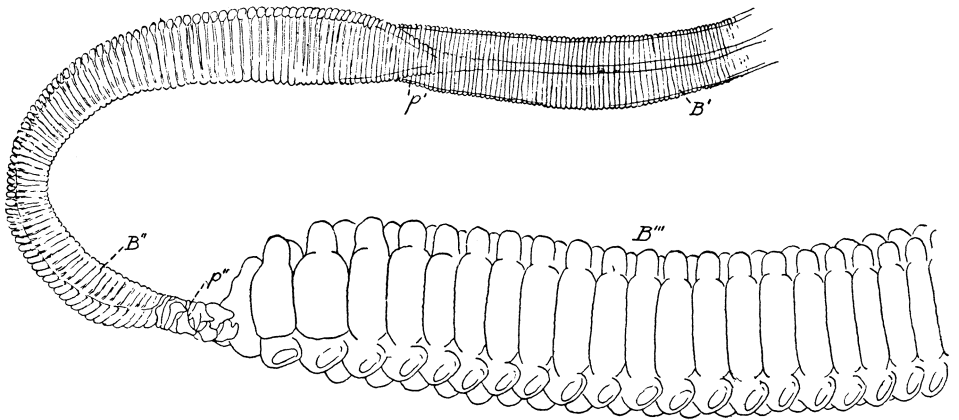


Figure 1.

Another creature that is not infrequently thrown ashore by the waves resembles somewhat (not much) what one can imagine an X-ray photograph, side view, of a sperm whale would be should the ribs happen to be the only part of the skeleton that showed. A fairly successful drawing of this animal is given in figure 2, pg. 23. Most of the creature's body is almost as transparent as a clear glass bottle. What looks like ribs are muscles. What seems to be the head end is really such, though we cannot, zoologically speaking, quite bring ourselves to allow that the creature has a full-fledged head. For one thing it comes too near being brainless to be accounted as having gone beyond the first stage of cephalization (that means headization, though linguistic proprieties do not permit us to say so). The star-shaped dot on top in the figure, just over the irregular U-shaped organ, is the brain, considerably exaggerated in size by the artist. The only thing in the way of sense organs the animal has is a single, rather simple structure, called an eye, so small and so closely associated with the brain that it can hardly be shown in a figure like this, even by a skillful exaggerator with the pencil.

What looks like a mouth is a mouth; there is no deception here other than that in reality the hole is larger and more mouth-like than the figure indicates. Here, as almost everywhere in the animal kingdom, the mouth is

one of the most prominent and trustworthy (in the zoological sense) of the animal's characteristics. The rule is general—that if we can't tell by off-hand inspection where an animal's head is, we hunt for the mouth, and wherever that is found we say the head is. Generally, though not invariably, the brain, or what passes for a brain, will be found not far from the mouth. These simple considerations might be of some practical use in other domains than that of technical zoology.

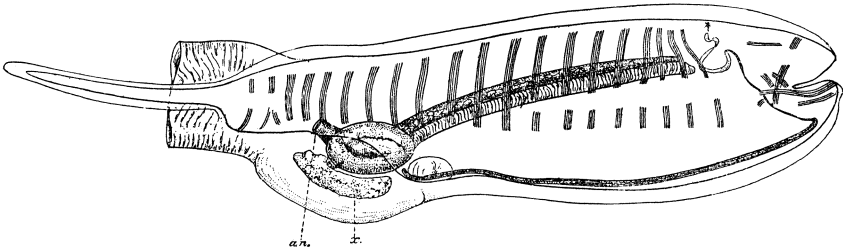


Figure 2

If the animal be looked at from above or below instead of from the side, it will be seen to have two tails instead of one. Just what use it makes of two tails we do not know, perhaps because we do not know what use it would make of one had it one instead of two. It surely does not use the tails to swim with, and since there are no flies in the sea, and since there seems to be no mechanism whatever for moving the tails, they are probably not used for driving away flies. The tails usually, always it seems, in older individuals are of a rather pretty green color, and to be prettily green may be the reason for the existence of the tails, since except for a small patch on the body the animal has no other green color. But because, as above mentioned, the creature is without eyes that can see, it is not quite clear what good being pretty can do it.

So far as can be made out, the utility of the tails is about the same as that of the quirl on a pig's tail. The use of the quirl on a pig's tail is to make a quirl-tailed pig, so it would seem. If the reader is disposed to smile at this argument I ask him to put a grain of seriousness into the smile, for the logic of it is practically the same as that which has passed muster with a whole generation of serious biologists bent on explaining once and for all the existence of every feature an animal or a plant has by natural selection. Natural selection explains the origin

of things, you know, by supposing them to be useful in the struggle for existence.

But zoology and not evolution is our topic now.

(b) *How it Swims and What it Accomplishes by Swimming.*

I said a moment ago that the creature does not use its tails in swimming. How, then, does it swim, for it does, it having nothing of the nature of fins? Imagine a beer keg with both heads knocked out, the hoops covered into muscles and the thing suspended in water and made alive. If the muscular hoops contracted strongly one after another in quick succession from one end of the body toward the other, the narrowing of the keg would drive the water out in the direction of the end that narrowed last, would it not? And this would send the keg along in the opposite direction. This is essentially the method by which the creature does its traveling, the repeated contraction waves going in the same direction sending it through the water by a succession of jumps.

How much does such swimming accomplish? That is, can an animal traveling by so awkward a method really go anywhere? Would it be possible, for instance, for one to swim during its lifetime from Point Loma to San Clemente? If the sea were to be wholly without waves or currents and the animal were to beat along persistently in one direction, it might possibly make such a journey. As a matter of fact, though, such conditions are never realized.

The truth is a great host of sea animals of about the grade of organization of this one swim in a strict sense nearly all their lives, yet never go anywhere in the sense that a higher animal like a tuna, for instance, does in its annual migration.

They do, however, accomplish two things of great importance to them, by all this work. In the first place they keep themselves from sinking to the bottom of the ocean. Almost all animals, marine ones with the rest, are slightly heavier than sea water, so would sink slowly had they no means of overcoming their weight. The other thing accomplished by swimming is the more or less regular up and down migrations practiced by them.

With the remark that the long, narrow structure seen in the figure extending diagonally through the body is the animal's gill; that the nearly spherical mass below and

behind is its intestine; and that the creature's name is Salpa, we drop the subject of its anatomy and turn to a consideration of how it performs two of its most basic functions, namely, those of taking food and perpetuating its kind.

(c) *How it Feeds.*

We compared the salpa, it may be recalled, to a beer keg with both heads knocked out. The whole interior is, then, filled with water all the time. Now, the sea water swarms with microscopic organisms, so the water inside the keg as well as that outside is full of these, and all the salpa has to do to get a meal is to pick them out of the stream of water that flows through it every time it jumps ahead in the swimming operations described above.

Imagine a man with his lungs transformed into a single great sac which opens to the outside freely far down on his back. Then imagine such a man immersed and swimming, mouth wide open, in a tank filled with vegetable soup, so that a current of the fluid containing its fragments of potato, meat, carrots, cabbage, etc., would flow constantly through him, as he should move forward.

Imagine further that this queer man's stomach communicates with the sac, the orifice of communication having a contrivance by which the food fragments could be picked out of the fluid as they should pass along. There you have a picture that illustrates fairly well the food-getting arrangements of salpa. The propagation question we take up now, and will dwell on it more at length.

3. Its Propagation Studied Somewhat More Fully Than Its Other Functions.

(a) *An Egg that does not Develop into an Animal like the One that Produced It.*

We have been accustomed so long to see chickens hatch from hens' eggs that it would be quite a shock to us were we to set a batch of such eggs and get from them a brood of owls instead of chickens. The creature that develops from the egg of salpa is no more like its parent than an owl is like a hen. The two figures, 2 and 3, are of parent and child, the one with no tail and few muscle bands being parent, the other with the tail and a larger number of bands being child. There is little or no exaggeration, the reader will, I think, allow, in the statement that these are no more alike than a hen and an owl.

But it would be entirely wrong to suppose there is anything so freakish in the salpa's way of propagation as the coming of an owl from a hen's egg would be. The point is that every individual salpa (of this species) with no tail and few muscles, produces eggs that give rise to tailed, many-muscled salpas, and that every egg of every such salpa comes out that way.

One of nature's very greatest merits is her dependability. The biologist perhaps above all students of nature learns to expect the unexpected, so to speak, in this marvelous world of ours. Queer, even sensational things are his daily bread. The reason why he "keeps his head," is

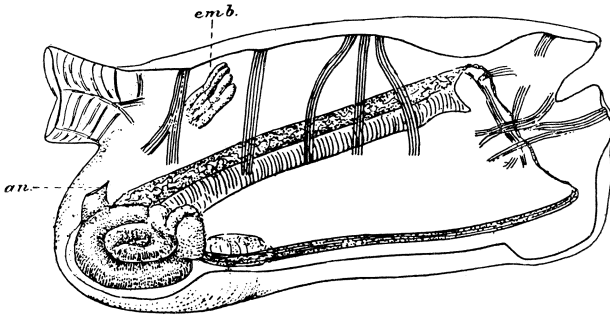


Figure 3.

not bewildered or unduly excited over the marvelousness of things, is the fact that however queer and marvelous a given phenomenon may seem when he first comes upon it, if he studies it closely enough he finds that after all there is some sort of orderliness and law behind it; that at least some of the causes operating to produce it can be made out. Whatever in nature is done once, under the same circumstances will be done again, and again, and again—and again. That is the thing. In this sense nature has never yet been proved freakish or queer, in spite of the vast scrutiny that has been bestowed upon her.

The eggs of this tailless salpa give rise to tailed salpas. From the standpoint of the way chickens and humans propagate, such a proceeding seems queer indeed; but you can depend upon it, in this particular kind of salpa the eggs of tailless individuals will hatch into tailed individuals every time. At least nobody has seen anything to the contrary.

Well, then, the question at once arises, where do the tailless individuals come from? Instead of answering, suppose I say I will not tell, but that we will have a prize guessing contest on the puzzle, free to all.

On what basis will the guesses be made? Surely on none other than what the contestants know about propagation in other kinds of animals and perhaps plants, although only the boldest, most imaginative, most facile guessers would be likely to go to the plant world for suggestions that might help.

One of the most familiar experiences, that, namely, of the chicken yard, would probably be appealed to first, and the guess made that the tailed salpas produce eggs which being in some way different from the eggs of the tailless ones develop in their turn into tailless individuals.

No, that is not right.

Then the guesser may bethink himself of the frog with its tadpole; the silk worm with its larva and moth, and other similar cases, and so guess that the tailless salpa turns into the tailed one after a while.

No, wrong again.

And so the guessing might go on, but the chances are that the right guess would never be made. It almost certainly would never be except by someone who knew quite a good deal about the propagation of organisms generally.

Just here let me remind the reader of an exceedingly important matter touching the way not only a naturalist but everybody else increases his knowledge of nature, if he does this at all first hand; that is, if he ever learns anything for himself instead of through being told by someone else. Think a bit and you will agree with me, I believe, that he does it always by being to some extent a guesser. The man of science calls his guesses hypotheses; but little matter what he calls them. The essential thing is that the most far-reaching hypotheses any man of science ever has or ever can make is at heart a guess, and that guessing is a thing that everybody in the least observant and thoughtful does almost all the time. The only thing that makes a scientific hypothesis different from an everyday guess is the fact that the hypothesis is more carefully thought out and expressed than the ordinary guess. I must carry this side reflection one short step farther. Guessing is a vastly important operation. But at the same time a guess is without merit except as it sets up something for observation to aim at; something that is to be proved or disproved by observation. This being so, what happens when one makes a guess rather carelessly and of such a character that he can get no observational proof or disproof as to its correctness? This is what happens or is altogether too likely to happen: The one who makes such a guess is likely (just because it is his) to assume the guess

to be right. He is, you see, fairly safe in doing so if no one is able to prove it wrong. And so such a person becomes a dogmatist in the worst sense.

A dogmatist is in essence one who holds guesses to be proved when they have not been proved; and the particular point I wish to bring home is that every one of us, be he scientific or otherwise, is prone every hour of the day and every day of his life to become a dogmatist.

If we found tailed and tailless salpas always mixed together, and could observe the tailed ones produced from eggs of the tailless ones, how very easy it would be, falling back on the familiar case of the tadpole and the frog, to guess that the tailed ones turn into the tailless after a time! And how insignificant seems the question of whether this or some other is the true relation between the two salpas! So why spend time and money to test the correctness of the guess? Insignificant truly is the question compared with that as to whose guess is right about, let us say, what Socialism would do for mankind were it to be fully established.

But here is the point: If you are willing to make a guess as to how the tailless and tailed salpas are related, then hold that guess to be right without getting observational proof that it is right, you are in imminent danger of being willing to guess on any vital question whatever, and hold your guess to be right without proving it to be so.

Having come upon such a probable fact as that the tailed and tailless salpas are related to each other in some way, there are three courses open to you, by any one of which you can escape being a dogmatist: First, you may pass it by as too insignificant to be worthy of even a guess. But if you adopt this course you have not "accepted the universe." You have accepted only certain parts of it, the vast majority of it being held by you as too insignificant for your acceptance. The second alternative is to make a guess, but decide that you must leave it as such so far as your own efforts are concerned. This would mean that you have indeed accepted the universe, for even though you cannot prove it all by yourself alone, you hold nothing about it as too insignificant to be worthy of at least a guess as to its meaning. The third alternative is to not only make a guess on the question, but to forthwith fall to work to find whether or not the guess is right. This means the study of salpa with your hands and eyes and such other organs and senses as

may be called upon, as well as with your guessing faculty.

The "Biological" accepts this third course, with all this implies. Hence do full-grown men and women of its scientific staff unblushingly spend not only their time, but also such money as may be given the institution in proving the correctness or incorrectness of such guesses as this.

And so we come around again to the cartridge belt that has something to do with the tailed salpa.

(b) *Animal Propagation on the Principle of the Strawberry Runner.*

This peculiar affair is made up of tailless salpas, scores of them, hung together in regular fashion. The belt grows on the body of the tailed salpa something as a bunch of bananas grows on the banana plant. Indeed, as intimated some paragraphs back, it is to the plant rather than to the animal kingdom that zoologists are wont to go for an analogy to the mode of propagation here exemplified. The cartridge belt has a small nearly smooth end, as the picture shows. This smooth piece is called a stolon, another name, as everybody knows, for the "runner" of a strawberry plant. It is this stolon that grows out of the body of the tailed salpa.

But it is seen at once that the similarity between the two is general rather than particular. In the first place the strawberry plants on the runner are scattered along it at considerable intervals, while the salpas of the cartridge belt are close together. The strawberry plants are on the runner, the runner remaining after the plants have reached a large size. There is, on the other hand, nothing left of the salpa runner or stolon, in the part of the belt where the salpas are nearly full grown. The salpas use up all of the stolon.

Again, the strawberry runner increases in length by growth at the tip. The salpa stolon, on the contrary, increases by growth at the point where it is attached to the tailed salpa. In other words, while the youngest plants on a given runner are always at the far end from where the runner started, the youngest salpas in a string are at the near end.

But perhaps the most important difference is the fact that while the plants on the strawberry runner are the same as the plant that produces the runner, the salpas produced by the stolon are, as we have seen, quite different from the salpa that produces the stolon.

Propagation like this where different kinds of animals

alternate regularly with one another is spoken of by zoologists as "alternation of generations." A fact that should not escape notice is that while one of the forms of this salpa—the tailless—has sex like ordinary animals; the other—the tailed—may be said to be sexless. This one has no generative organs in the usual sense.

Very fittingly, it was a poet-naturalist, Adelbert de Chamisso, who discovered this almost dramatic mode of generation, and, a circumstance that may well give the case an especial interest to us on the shores of the Pacific, is that although the discovery was made nearly a hundred years ago, it was on a species that occurs abundantly in our waters, though actually taken by Chamisso about the Hawaiian islands.

A pleasing touch of the discoverer's imagination is found in his way of expressing the facts he observed. He says that any individual salpa is not like its parent and child, but like its grandparent and grandchild. May I, without seeming pedantic, quote his words, written in Latin? "Species salparum sub duplici conspicuiuter forma, prole per totum vitae cursum parenti dissimili, stirpem autem huic similem generante, ita ut quaelibet Salpa matri aequae filiabus dispar, aviae, neptibus et sororibus par sit."

(c) *Seven Thousand Measurements of Small Salpas.*

The aspect of this sexless, cartridge belt mode of generation which I wish to consider somewhat more fully is that in which the process exemplifies the wide-spread phenomenon of rhythm in the course of nature's operations.

To bring this out we must show the necessity of invoking measurement and calculation in such studies. In passing I would remind the reader of the remark made some ways back concerning the common ground of motive and method on which Astronomy and Biology stand.

During the last year and a half, Miss Myrtle Johnson, now of the scientific staff of the laboratory has made something more than 7,000 measurements, mostly under the microscope, of salpas contained in the cartridge belts. To many persons such a performance would, no doubt, make Miss Johnson seem the most curious of all the "curios" contained in our collections. But perhaps a still more remarkable thing about this case is the fact that the University of California gave the young woman the degree of Master of Science last spring, largely for having done this curious piece of work! What can sensible, practical people think

of their fellow beings who do such things and of great public institutions that encourage them in it?

Before we can speak intelligently about what this wholesale measuring amounts to we must know more definitely than we yet do what we are measuring.

Heretofore I have only intimated that there is more than one kind, or species, of salpa. The reader will understand that the two sorts of salpas—the tailed and the tailless—of which we have spoken are not two species. They are only two kinds of individuals of one and the same species.

By dint of dragging various kinds and sizes of nets through the water all about here at different seasons during the last seven years we have found that at least nine species of salpa occur in this quarter of the Pacific. Of course we are likely to find others if we keep on dragging for another seven years—which we expect to do. It is not probable, though, that we shall find many more, or any more that occur abundantly. If we get others they will probably be mere stragglers that belong properly to some other portion of the world and are brought here by unusual conditions of some kind.

Now each of these species has its own peculiar kind of chain of salpas; so, however much we may refine and elaborate our measuring and other sorts of examination of the chain of any one species we shall not dare to conclude that the chains of other species are like it in every respect. The chains of different species will almost certainly be found to be like it in a general way only. A wonderful thing is this matter of likeness and difference among living beings. It seems as though for every new similarity we find between any two organisms, by looking closely enough there is sure to turn up a new dissimilarity to balance it. We often remark, more or less carelessly, that "human nature is alike the world over." What we really mean is that human beings all have something—a good deal, in fact—in common. But who does not well know if he thinks a minute, that human beings are also different the world over? Who has ever seen two human beings, even twin sisters, exactly alike? Undoubtedly twins look so nearly alike sometimes that you cannot distinguish them until you become thoroughly acquainted with them. And this is just one of the most interesting points in these cases. The recognition of differences depends on close acquaintance. Carry your acquaintance to the extent of comparing the greatest number of features and characteristics

possible and resorting to measurings and weighings, and the differences come out more and more sharply. Question: To what extent is that elusive something we call personality dependent upon just the fact of difference between people?

But enough of this side talk—at least for now. We are to see what comes from measuring salpas.

The picture of the cartridge belt shows a long piece attached to one end that is marked off into a great number of very small regular sections. The extreme end of this many-sectioned portion we called the stolon and compared it to the strawberry runner. The fact we want to get at as directly as possible is that the numerous very small cross sections of the narrow portion are the beginnings of another lot of salpas. Pushing the cartridge belt simile farther, we may say that what we have is at least two belts grown together endwise, one, that farthest from the parent, containing larger cartridges, large enough relatively for a 12-bore shotgun, say; the other belt, nearer the parent, containing much smaller cartridges. The smallest made, those, for instance, used in a No. 22 revolver, would not be small enough relatively to represent the salpas of the smaller belt.

Now, if the statement previously made be recalled, that the oldest salpas of a chain are always at the far end, new ones being produced only at the near end, it will be easily understood that those farthest out on the chain would be larger than those nearer the parent. You would expect them to be larger, because they have had a longer time to grow, and have, presumably, made good use of their opportunity. But why should they not grade down evenly in size from the largest far-end ones to the smallest near-end ones? Why, in other words, do they occur as they do; i. e., a bunch of large ones all of nearly the same size, then a bunch of much smaller ones again all of nearly the same size, and so on?

We might make various guesses why, but before a guess could be made that would be entitled to be called a scientific hypothesis we should have to more than glance at the facts. We should have to get as many facts as we could and think them over carefully. A hypothesis we have defined in substance as a guess founded on observed facts well thought about. Reflecting on what we see here we naturally question thus: "Since the salpas do not grow in the way we should expect, i. e., since they grade down from large to small in bunches instead of one by one, what

is the size relation of the individuals within the bunches? Are those at the far end of any given bunch larger than those at the near end, or are they all of the same size?' The animus of the question is, you see, that since the facts of growth are not what we should expect them to be, then what are they?

Well, in the first place by merely carefully looking at a bunch that is undoubtedly whole (the bunches break to pieces easily, so have to be handled gently), it is seen that while in the main the salpas of the same bunch seem to be of the same size, there are a few not only at the near end, but also at the far end of the bunch that are distinctly smaller than the majority.

Now anyone who has curiosity enough to find out this much can hardly stop without wondering just how far the size gradations at the two ends of a bunch extend. And when his wonderment has gone this far he sees that he is questioning about differences in size too small to be recognized by the unaided eye. So if he is really bent upon following up his curiosity he is driven to measuring. In other words, he has come to the point that all truly scientific study reaches sooner or later, namely, that of not only asking, How much? but of undertaking to find out. Surely nothing is more characteristic of science than this question. And another very important thing to be noted is that in no other respect is the close kinship between scientific knowledge and the commonest, everyday knowledge more clearly seen. How much does a thing cost? How much will a given piece of land produce? How much water is there in the city reservoir or the kitchen teakettle? How much can the horse pull and the man lift or endure? How much is the annual rainfall? And so on.

There seems to be nothing in this world that does not exist not only in quantity, but in limited quantity, and we appear to be compelled to measure these quantities in one way or another to get on with any success and comfort. Even our affections do not escape. It is all right to love pleasure and money so long as we do not love them too much—more, that is, than we love various other things.

But we must stick to salpa now.

Before stating the outcome of Miss Johnson's measurement of salpas that occur in chains of the cartridge belt style, it will be better to see what she gets from measuring those of a species in which the chain takes the form

of a series of wheels attached one to another at opposite points in their circumferences.

Every fisherman, and for that matter every boatman of our coast, must have been this species of salpa, for the strings of wheels, each wheel (a cylinder, really) about the size of a large apple, are conspicuous objects with their bright yellow intestines as they hang suspended, of a quiet day, in the clear blue water somewhat below the surface.

The diagrammatic (if anyone thinks it easy to draw an exact figure of one of these objects let him try it) illustration, figure 4, was made by Miss Johnson to help the reader to the facts about these chains that chiefly concern us in this study. It shows that the wheels are not present at the small end of the chain; that is, at the end by which the chain is attached to the parent, but that they are formed abruptly, as it seems, at a considerable distance from this end, the salpas having there grown to quite a size, relatively.

Another fact that the illustration brings out is that before the wheels are formed the little salpas are in two rows. In this respect this portion of the chain of this particular species is like the cartridge belt style of chain.

It will, of course, be understood that a diagram like this represents merely a part of a chain at some particular state of growth. In life there would be one or two

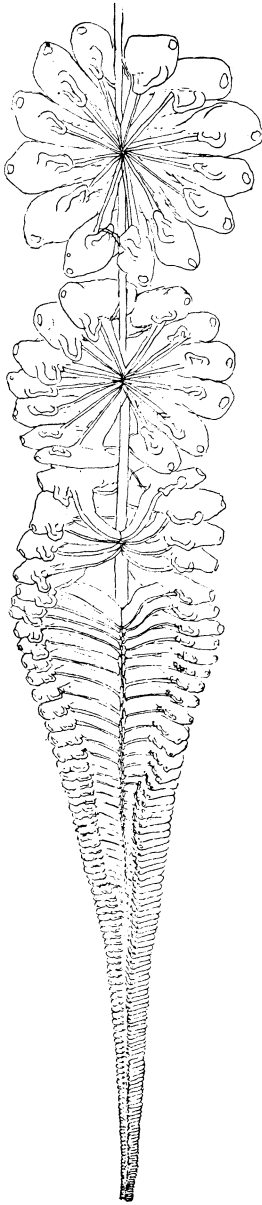


Figure 4

dozen of the wheels, and since the whole thing is growing regularly, minute new salpas, and new wheels are being constantly formed, and the wheels already existing are becoming larger all the time.

Now, the same curiosity that led us to ask why bunches of salpas are formed in the cartridge belt type of chain leads us to ask why wheels are formed in this chain. Or, putting the query in another way, Do the wheels in the one species subserve the same purpose as the bunches in the other species, and are the two sorts due to somewhat the same causes or principles of growth?

This question or guess (a question always changes into a guess with the greatest ease) calls for more facts than we have. Among the additional facts that, from long experience, we presume would contribute to the answer are, as before, those of the size relations among all the salpas of the same wheel. So measuring must be resorted to again.

First, a few words about making measurements. Any lot of repeated things like these salpas in a chain that are so very nearly alike must be measured, if the measurements are to be of any great value, in regular order. That is, the measurements must begin at some definite point, must go along regularly, not skipping any members, and must stop at a definite point; in other words, the measurements must be serial. This, you see, individualizes the members of the series. Number five or number seventeen, for example, in a given series, is so-and-so, as compared with any other member in another series.

Again, it hardly need be said that the measurements must be made with the greatest possible accuracy. An instructive essay might be written on the mechanical devices employed, even in this one laboratory, for measuring. I cannot, though, speak of them here. The only point I will touch under this head of accuracy is the care the measurer has to take to avoid the vitiating effects of mental bias and habit. Every scientific investigator who measures and weighs and counts things (and those who do not work by these methods stop with their investigations not more than half done at best) knows perfectly well that he cannot escape this source of error by merely purposing not to be biased. He must resort to mechanical or progressive devices of some sort to counteract the set of his mind, so to call it, in a particular direction.

Here are the averages of the lengths in millimeters of the

salpas, taken serially, of six wheels, each containing seven individuals in a half wheel:

1st	2d	3d	4th	5th	6th	7th
25	26.4	26.3	26.4	25.9	25.1	23.2

From these figures we can see what we could not see by merely looking at the salpas themselves; namely, that the first (the one toward the small end of the chain in the half wheel) is smaller than any in the series except the seventh; that the second and fourth are the largest of all; and that beginning with the fifth there is a gradual diminution in size through to the seventh. Attention may be called to the circumstance that the third is slightly smaller than either of those each side of it. We are quite sure that this is an irregularity and would disappear were we to take the average of a sufficiently large number of wheels.

(d) *The Mathematician's Way of Discovering Facts about Organisms that Cannot be Seen by Direct Examination of the Organisms.*

Mathematicians have a way of making a picture of series of numbers such as this that frequently enables the eye to recognize facts about the objects measured that cannot be seen by looking on the bare numbers.

Curve for Length of Salpas in a Single Bunch
Bunch Style of Chain

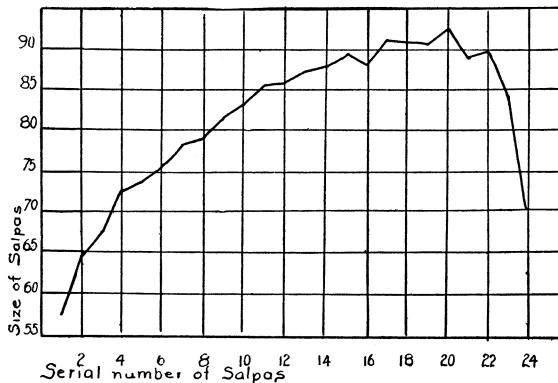


Figure 5

I give two such pictures, figures 5 and 6. One, as the label shows, is for the salpas in a wheel; the other for those of a single bunch from the bunch style of chain.

Curve for Length of Salpas in a Single Wheel,
Wheel Style of Chain

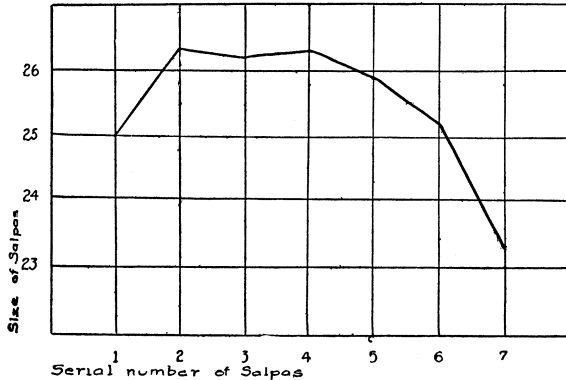


Figure 6

The curve for the wheel is made from the set of numbers given above. The method of making these curves (really portions of the circumferences of polygons) is simple enough. Two sets of parallel lines crossing each other at right angles, and equally spaced, are first drawn. Then, taking the special case in hand, there are laid off at equal intervals on the horizontal lines the serial numbers of the salpas, and on the appropriate vertical lines the lengths of the salpas are marked. An examination of figure 5, taken in conjunction with the numbers given above, will make the principle involved quite clear. By connecting the points marked on the several vertical lines the curved or, more exactly, broken line is obtained, which exhibits to the eye at once the length relations of the salpas that we do not recognize at all by examining the animals themselves.

So by making such pictures we are enabled to see that, as regards length at least, the individual salpas fall into a definite scheme, which is of the same general kind for both wheels and bunches. Expressed broadly, the scheme is that the largest salpas are somewhere in the mid-region of the series or group, rather than at either end of it, in both wheels and bunches, and that there is a more or less regular gradation both ways from largest to smallest.

This, then, is strong confirmation of the guess that in spite of the fact that there is no such difference in size of the salpas of two adjacent wheels in a chain of the wheel type as there is in the size of the salpas of two adjacent

bunches in this type of chain, the wheels and bunches do subservise the same purpose, whatever that may be, in the propagative economy of the two species.

But do these size schemes have any significance beyond that of enabling us to recognize correspondences between two species of salpa that we could not recognize by merely looking at the animals themselves?

Well, for one thing it means the recognition of so much more law and order in the universe that we have accepted, does it not? This of itself is considerable to lovers of orderliness.

But it is not all by any means.

(e) *Rhythm and Law in the Propagation of Salpa.*

What we have here appears to be only another instance of that remarkably wide-reaching and fundamental phenomenon of rhythm in the growth and other processes of living beings.

To tackle this subject seriously here would be to extend this pamphlet to a volume or two.

I will only direct attention to two points in connection with it. In the first place, I suggest that you look around you among plants and animals and see how many instances you can find of series produced by the repetition of nearly the same part or organ in which there are recognizable graded schemes of one sort and another, of sizes.

Look, for example, at the leaflets in many compound leaves; at the leaves themselves of many plants, especially on growths-of-the-year in the branches of many trees; at many flower and seed clusters; at the branches of many trees and annual plants. Look at your own fingers and toes; at the vertebrae of your vertebral column (if you can get an X-ray picture of yourself); at the scales of many fishes and snakes, and at innumerable other things, if you take the trouble to hunt for them.

Now, I trust no one will infer that I am meaning here that the members of all series whatever in organisms fall into schemes of graded sizes; that, in other words, the members of such series are never all of the same size, at least so far as any constant difference is concerned.

No, I am not implying any such thing. I am merely calling attention to the fact that such series are of exceedingly wide prevalence in nature. And I venture to express the hope that such a study as this of salpa may serve to cause a few readers at least to stop and think a second time before they either affirm or deny too broadly

and vehemently on the basis of a few observations with the unaided senses.

On the strength of the many, many easily made observations, and of a considerable number of studies as critical as this of salpa, one might be justified in guessing that all repetitional series in the development of organisms do fall into size schemes of some sort. But—and the point is fundamental—such an affirmation would be only a guess, an hypothesis really. And to the man of science, as we have already insisted, a guess is of value only as a summons to work. Guess about nature as broadly and as often as you like, the student of nature says, only, out with your measuring stick, your scales, your microscope, and your test tubes and “get busy” to find whether you have guessed right or wrong.

The other point about these size schemes that I touch upon is this: Notice that in any one of the wheels and bunches of salpas you cannot interchange at will the members within the same series. For instance, number one in the wheel, for which the sizes are given above, cannot be exchanged with number five or number seven, or any other one. Each one has a place of its own in the scheme. Each one is indeed a salpa in itself, but as surely and as essentially does it have a fixed place in the wheel—in the scheme. Now, supposing we were to go on and measure all the different organs of each salpa in a wheel, and all the functional capabilities of each of these organs, and find that they, too, fall into a scheme of sizes and values. There are many facts that justify the guess that such would be found to be the case. Do not considerations of this sort open up vistas of reflection on the nature and meaning of individuals and their relation to one another in the groups in which they occur that go far toward justifying the belief which some of us have that it is worth while to spend money and time on such undertakings as the “biological” is engaged in?

One more brief remark and we shall have done with salpa and the biological station for now.

“But,” someone will almost surely ask, “what is the final meaning and explanation of these facts and guessed-at facts? Why is there rhythm in the development of the salpa chain? What is the sufficient cause of such size relations among the salpas of the wheels and bunches?”

Somebody has remarked that “a fool can ask questions that a wise man cannot answer.” I have a proposition supplemental to this: A wise man can ask questions that

only a fool, or at any rate a very foolish person, will try to answer.

My final word is: Think carefully on just what you do when you guess about things in nature, and as carefully about not only the uselessness but the actual harmfulness of guesses, unless, as previously said, these are something for sensory observation to work toward. Science is seemingly being driven by its own efforts to recognize that nature is truly infinite through and through, so that guesses that presume to answer once and for all, and completely, questions about her, are answers of the kind made only by those who rush in where angels tread with humility and reverence.

