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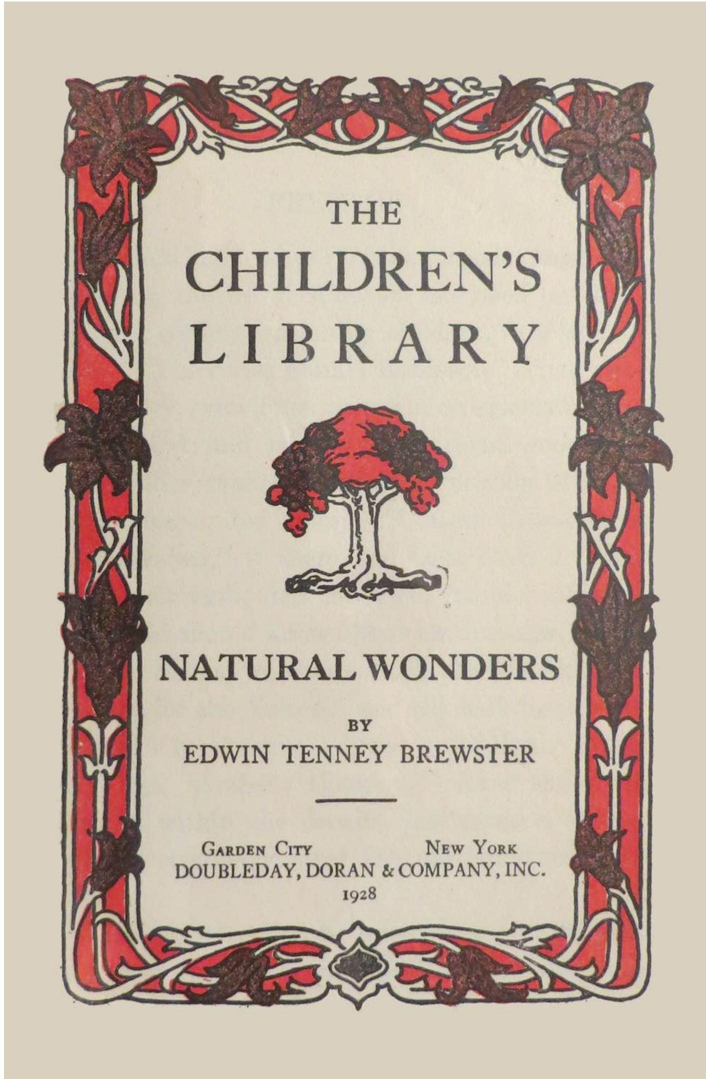
NATURAL WONDERS

The Robin Moth



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BY
EDWIN TENNEY BREWSTER

GARDEN CITY NEW YORK
DOUBLEDAY, DORAN & COMPANY, INC.
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PREFACE

No small part of our fundamental knowledge concerning the world of nature has been put into shape for comprehension by children, time out of mind. “The Swiss Family Robinson” is half natural history, even if not always of an especially convincing kind; and science of all sorts, good and bad together, makes up no small portion of Jules Verne’s uncounted tales. “Cousin Cramchild’s Conversations,” if there had been such a book, would have embodied the Victorian idea of what every child should know about his universe; while of actual books, we elders recall at once Abbott’s “Science for the Young,” and the half dozen contributions to juvenile knowledge of John Trowbridge and “Arabella Buckley.” Even the great Ostwald, within the decade, has made a child’s book on chemistry after the old conversational form.

In school, moreover, between his geography and his nature study, the modern child becomes acquainted with not a little modern science, while in most of our states a detailed acquaintance, by no means always scientific, with his own physiology is required by law of every public school pupil. One thing with another, today’s child of eight or ten is supposed to know a little of physics and of biology, together with a good deal in a general way of earth science and the elements of human physiology.

Naturally, there are excellent texts and reading books in all these fields. So far as I am aware, however, the present work is the first attempt to set before young readers some knowledge of certain loosely related but very modern topics, commonly grouped together under the name, General Physiology. It is, in short, an attempt to lead children of eight or ten, first to ask and then to answer, the question: What have I in common with other living things, and how do I differ from them? Incidentally, in addition, I have attempted to provide a foundation on which a perplexed but serious-minded parent can himself base an answer to several puzzling questions which all children ask—most especially to that most difficult of them all: By what process of becoming did I myself finally appear in this world?

How far I have succeeded with either task, I leave to the mothers who shall read this book aloud.

E. T. B.

Andover, Massachusetts

NATURAL WONDERS

CONTENTS

ILLUSTRATIONS

Frontispiece

Full Page Illustrations

In the Text

I

How the Chicken Gets Inside the Egg

There is no more fascinating sight to be seen anywhere than an incubator full of eggs just as the chickens begin to hatch out. You look through the little glass window in the side and see, at first, only rows of clean white eggs, dozens upon dozens of them, looking as if they were all ready to go into the family ice-chest or to be made into omelets for breakfast.

But they are not. First you begin to hear faint scratchy sounds. Pretty soon, here and there, a hole breaks through the broad end of an egg, and a tiny bill sticks out. The little chick is packed so tightly into the egg that it can move only its head. So it pecks and pecks; and stops to rest; and pecks again; and the hole in the shell gets larger and larger; until by and by, the egg cracks open, and a brand-new chicken draws its first long breath and looks out into the world.

After that, the chick usually takes a long rest, for it is pretty tired. When it feels better, it begins to move its legs and wings, and a half-hour or more after it first began work, it gets clear of the shell and stands up on wabbly legs, wet, bedraggled, weary, as disconsolate looking a little object as can well be imagined. Shortly, however, the feathers, which at first were plastered tight to the skin, dry off and fluff out, the legs get steady, and soon there is running about a rolypoly yellow chick, seemingly at least twice as large as the egg which held him only an hour before. Truly it is a wonderful sight, five hundred eggs turning into little chicks in an incubator, for all the world like the kernels of corn changing to pop-corn in the popper.

But wonderful as it is to see the way a chick comes out of an egg, it is still more wonderful to see the way it gets in. A fresh, new-laid egg has no chick inside. After it has been kept warm three weeks, it has—all ready to come out. The question is how the chicken got there.

Many different men have studied this question. For the most part, they have started a dozen or more eggs at once, and then taken them one by one and two or three hours apart, and cautiously broken them open to see what was inside. Sometimes, however, a student of eggs carefully cuts away the shell on one side, until he has made a hole about the size of a ten-cent piece. Over this he cements a sheet of glass as thin as paper, so that he can look through this tiny window into the egg, and see the chick grow.

This is really easier than it sounds. The yolk, as everyone must have noticed in hard-boiled eggs, does not stay in the middle of the egg, but always floats to the upper side. The chick, too, always forms on the upper side of the yolk; and when the egg gets turned over, the yolk rolls round like a barrel in the water and brings the chick to the upper side. So the chick, until it grows big enough to be a tight fit, always lies crosswise of the egg, on the upper side of the yolk just under the shell.

At first, of course, there is no chick at all, but only a round white fleck hardly larger than the head of a large pin, on the side of the yolk where the chick is by and by going to be. Before the end of the first day after the egg is laid, this little fleck has become somewhat oval in outline and an eighth of an inch across. Through its center runs a whiter line, as thick as heavy basting cotton and a sixteenth of an inch long; about half as large, that is, as an “l” or a figure “1” in the type on this page.

This is the beginning of the chick. Only it has hardly yet begun to be a chick, for it has as yet neither head, tail, wings, legs, eyes, nose, mouth, heart, stomach, brain, nor any other parts. It is in short, only a tiny line of chicken substance, which is now to begin to be made into a chicken.

Early in the second day of incubation, the little white line begins to get thicker on the end where the head is going to be. The brain and spinal cord appear first; later in the day there is the first sign of eyes and ears. At about the same time, the heart begins to form, and the minute blood vessels to grow out into the yolk like the first roots of a tiny plant. Before the end of the second day, the heart has begun to beat, and the blood vessels have begun to absorb the yolk to feed the growing chick. The yolk, in its turn, feeds on the white; for as everybody knows, the yolk and the white of an egg are stored up food, on which the little bird can live and grow until it is old enough to get out of the egg and shift for itself.

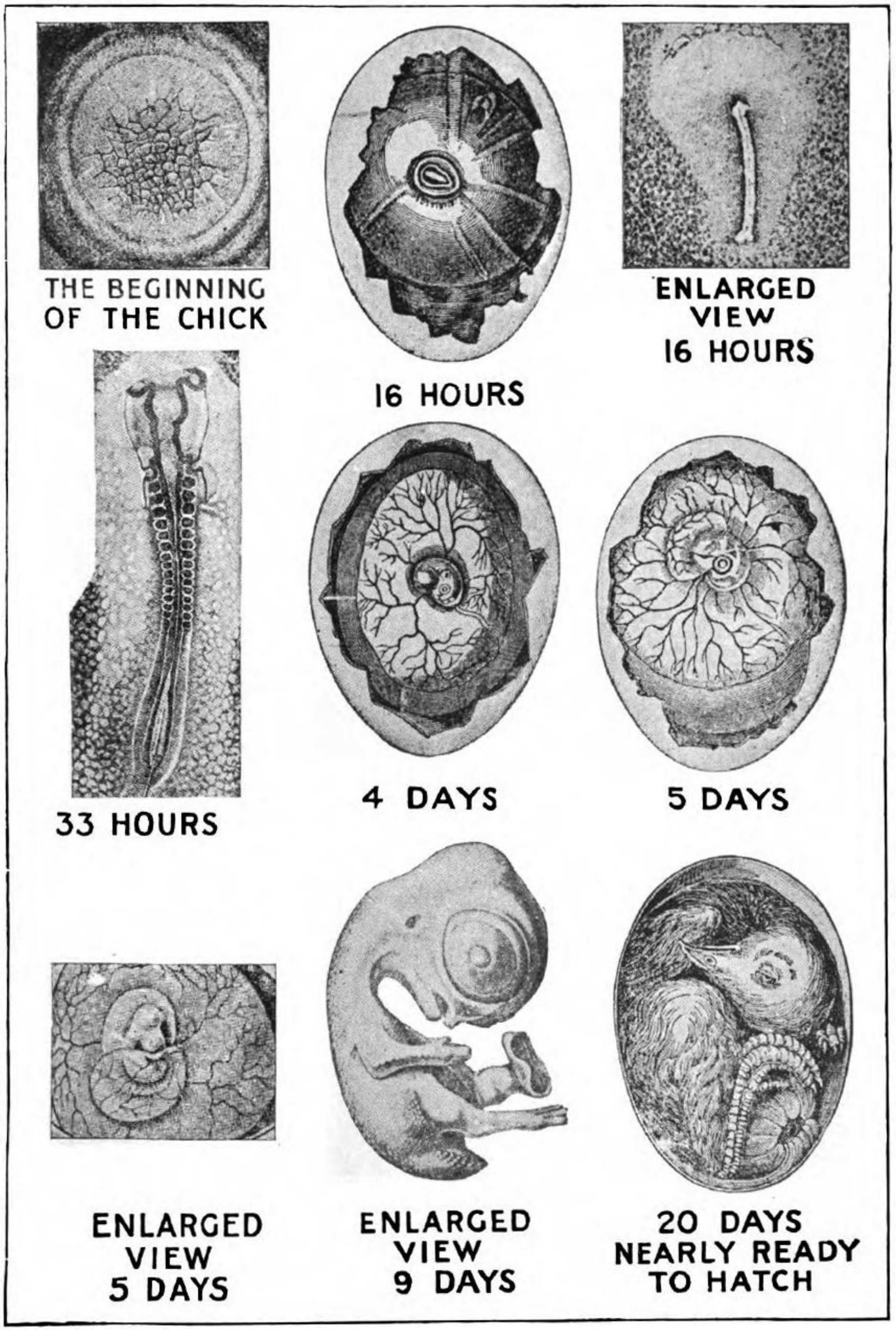
At the beginning of the third day, or a few hours before, the chick, which has been lying on the yolk face down (only it hasn't any face yet), turns over on its left side. It is getting to be a big bird now, a quarter of an inch long and as thick as a good sized pin. Next, the brain grows rapidly; and so do the eyes, though these are not so large as the eyes of the finest needles. Now too, the nerves begin to form; also the lungs, the stomach, liver, and other organs of digestion; and there are beginnings of a tail, though without feathers.

During the fourth day, there are signs of a mouth. Legs and wings, looking just alike, begin to bud out from the body. Another day, and one can tell which is which; while now there appear beginnings of the skull and of the place where the back bone is going to be. Meantime, the little bird has become more than a half-inch long—though it does not yet look the least bit like a bird, but more like a large "?" mark. There is still no front to the body, and the heart, beating merrily away, hangs out in the yolk.

With the second week, the little chicken does begin to look something like a real bird. The bones begin to harden; while on the tip of what has been just an ordinary nose appears a speck of chalk, which will by and by harden into a bill. The claws begin to grow; and there are signs of feathers, each one still enclosed in the little transparent sac in which it forms.

At the end of two weeks, the white of the egg is all used up; and the little bird, which has been lying crosswise of the egg, now turns to bring its head toward the broad end. The yolk, too, is getting small; and on the nineteenth day, the chick pulls the last remnant into its little tummy, and begins to close over the hole. At about the same time also, he pecks through into the large air space which one sees in the broad end of an egg, when he eats it, hard-boiled, at a picnic. For a week or more, he has been breathing by means of a sort of gill, much like that of a fish, only that instead of being on the side of the head like a fish's it grows out from the middle of the stomach on a long stalk and spreads over the inside of the shell. So the chick breathes through the shell, which is full of minute holes almost too small to be seen. But after the last bit of yolk has been taken in, this gill shrivels up and drops off, and the chick breathes with its lungs like the rest of us.

At the end of three weeks, there is nothing left of the egg but the shell and a tea-spoonful of water. The chick, which began life the size of a pin head, now fills the shell jam full, with only just room enough to peck the hole that lets him out. On the twenty-first day of his imprisonment, out he comes.



How the Chicken Gets Inside the Egg

II

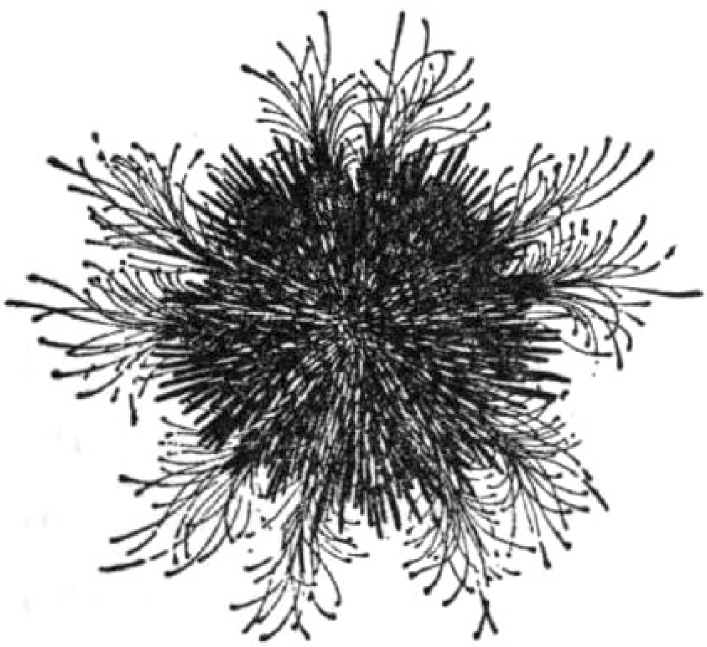
Some Other Sorts of Eggs

All birds lay eggs. Some are brown or white like the hen's egg; some are green, some buff, some blue; many are speckled. Some, like the eggs of the screech owl, are almost as round as marbles; not a few are so pointed at one end as to be fairly pear-shaped. The hummingbird's egg is the size of one's finger tip, the ostrich egg is as large as one's head. But all alike they have shell and yolk and white; and by and by, a little bird inside. Only sometimes, like the chick, the little bird hatches out with feathers grown, and only needs to dry off and get its breath, before it is ready to run about and pick up a living for itself; and sometimes, like the little robin, it has no feathers, cannot stand up on its legs, and has to be fed by its parents, like a human baby.

Snakes and turtles have eggs also, very much like birds' eggs. Like these, they have white and yolk; and the little reptile grows in the egg almost exactly like the little bird. For curiously enough the turtles, snakes, lizards and crocodiles, tho they look so very different from birds, are really very like them. They all have large eggs, with large yolks; and the little animal begins at a point in the side of the yolk, and does not, for a long time, fill the entire egg.

Oddly enough, there does not seem to be much connection between the size of an animal and the size of its egg. Big birds, to be sure, have big eggs; and little birds have little eggs. But a great crocodile, fifteen or twenty feet long and able to bite a man in halves, is hatched from an egg no larger than that of a goose. The little salt water minnow, or killifish, which is only as long as one's finger, has very large eggs, for a fish, almost as large as small blue berries, and quite as large as the eggs of salmon and trout which grow to be a hundred times heavier. But cod fish, which sometimes are almost as large as a man, and the great sturgeons, which are as long as three men and as heavy as a horse, have eggs not much larger than the periods on this page, smaller even than those of a tiny ant. As for the little sea creatures, star-fish, sea-urchins, and the like (which to be sure, are quite as large as a hummingbird or a wren) their eggs are but fine dust, which cloud the water and are too small to be seen at all.

However, the smaller the eggs, the more of them there are, to make up. While some birds lay only two eggs at a time, and few more than a dozen, some fishes lay a hundred or more, the cod a hundred thousand, and the sturgeon two or three million.



A Sea-Urchin

Sometimes, when one is poking about in the brooks in the spring of the year—as every boy and girl should do, for it is great fun—one happens upon masses of transparent jelly half as large as one's head, full of tiny black dots. These black dots, which are just about the size of the o's in this book, are the eggs of frogs. If instead of being in round masses, they are in long strings, a yard sometimes in length, then they are almost always the eggs of toads; but if they occur neither in masses nor in strings, but separately, then they are the eggs of newts.

It seems strange that a frog should be able to lay a mass of eggs and jelly forty or fifty times larger than the frog itself. The real egg, however, is only the dark speck; and this when it is first laid has only a thin coating of jelly, hardly thicker than paper and nearly dry. As soon, however, as it touches the water, this dry jelly begins to swell, and goes on swelling and swelling for three hours until it is a hundred times larger than it was to start with.

These balls of frog's eggs look, then, very much like tiny hens' eggs with black yolks, broken into a bowl ready for cooking. They really are not quite this; because the frog's eggs have no shell and no white, being simply yolk and nothing else. In fact, the only sorts of eggs that do have white are those of birds and reptiles; while few others have shells either. The jelly of frog's eggs is not "white," because it is not meant for the little frog to eat, but to keep other creatures from eating him. Besides this, it helps to keep the little chap warm.

You will recall that the little chick begins as a tiny dot on one side of the yolk, and keeps growing larger and larger until it uses up both yolk and white and fills the entire shell. Not so the little frog. Always, from the very beginning, it is as large as the egg. It is the egg, in fact. You can see that the egg is dark above and light below just as the tadpole will be, and the frog after him. At first, however, the baby tadpole does not have any parts or members. He gets in proper succession, eyes, ears, backbone, brain, skin, tail, and the rest; but he does not grow any larger until he hatches out, wriggles his way thru the jelly, and begins to eat.

At first the tadpoles are very tiny, only a quarter of an inch in length; and they cling in tufts to the under side of the water plants. After that, I suppose, everybody knows what happens.

There is still another curious difference between hens' eggs and frogs'. When a frog lays an egg, that egg is nothing else but just egg—the little frog has not begun at all to form inside it. But when a hen lays an egg, while there is no little creature in that either, still the egg has already begun to get ready to turn into a chick. Some animals go farther than this, so that when their eggs are laid, the little creature is already formed inside, and so has only the last part of his growing left to be done outside. Certain fishes, certain reptiles, and various other animals besides, actually put off laying the eggs until so late that the young is all ready for hatching. Such eggs are laid and hatched at the same time, or even hatched first and laid afterwards.

All the four-footed creatures which have fur and hair, horses, cattle, dogs, cats, monkeys, and the like, manage in this way. And because this kind of egg doesn't get knocked about, it does not need to have either hard shell nor thick jelly to protect it, but only a thin skin. For this reason, and because the egg hatches a few moments before it is laid, people are apt to miss it entirely, and so to get the idea that these animals have no eggs at all. But they have—one egg for each little animal.

We pretend that the bunny rabbits at Easter are hatched from the colored Easter eggs. They really are hatched out of rabbits' eggs. No one notices the remnants of the rabbits' egg, because what little there is soon dries up to almost nothing, or else the old mother rabbit eats it. Besides, one has all one can do to look at the new bunnies. Nevertheless, all little animals come out of eggs, puppies, colts, lambs, calves, kittens, every kind of living creature that is big enough for you to see, and a good many besides that are so small that you have to look for them with a microscope.

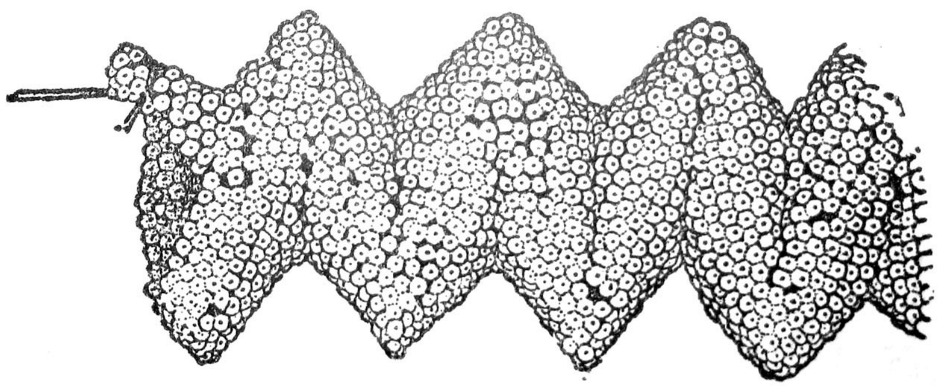
III

Little Fishes In The Brook

Of all eggs, the most interesting, I think, are the fishes'. Nearly all of these are pretty small, little round whitish globules like sugar pills. Some, like the eggs of trout and salmon which one finds in the gravel banks of rapid streams, are as large as fair-sized beads. Many, like the eggs of sea fish which float near the surface of the ocean, would go thru the eye of a darning needle.

The point, however, which makes them especially interesting is that so many of them are like tiny glass marbles. The membrane around them is so clear, and the substance of the egg itself so transparent, that with a magnifying glass, one can look right thru the egg, and see the little white fleck inside grow from nothing at all to a real fish, long enough to reach clear round the egg and lie with its tail almost in its mouth.

Some eggs are much clearer than others. The clearest are, at first, like clear glass, so that they can not be seen at all under water. Soon, however, a tiny vague white spot begins to form on the lower side. Then one can make out that the egg is covered with a rather thick membrane, that within this is a narrow, clear space filled with water, while within this and still smaller, floats the tiny yolk which is the real egg that is going to become the little fish.



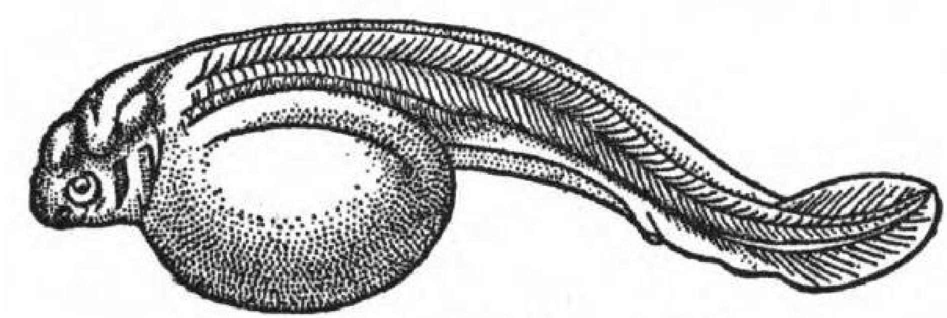
Eggs of Perch after Egg Laying.
(From Bulletin of U. S. Fish Commission.)

The white spot on the yolk is not itself fish, but only fish stuff, which is being made ready to turn into fish by and by. The spot grows larger and thicker, until it looks like a round dab of putty stuck on the side of a marble. When this cap has grown until it is about half as much in diameter as the egg itself, it thins in the middle and thickens at the edges, until it forms a ring. A very strange thing, thereupon, happens to this ring. It begins to grow; and as it grows, it keeps slipping farther and farther round the egg. Soon it has become a band round the middle of the egg. Then as it moves along still farther to the other side of the egg, it has, of course, to grow smaller in order to fit. So it does, and the extra length taken in at one point in the ring, forms the body of the little fish. The head has already begun to form from a thickening at one side of the ring before it passed the middle of the egg. The two sides of the ring form the two halves of the body. But the tail being easier to make, does not grow out until much later.

Now there is a head and a body; but the only difference is that the head is bigger. Neither has any parts. There are no eyes, ears, nose, or mouth in one; nor any fins, backbone, stomach, nor scales in the other. These all appear later, much as in the chick—eyes, ears, brain, and heart early; fins and tail, scales and the whole front of the body not until long afterwards.

Many learned men have spent their entire lives in studying the way in which all these various parts form in the young animal, and a most strange and fascinating study it is, quite worth any man's spending his life on. If I were to tell all that is known about the least part of one fish, the tale would fill up this entire book and leave no room for anything else. I shall, therefore, tell about the eyes only—partly because they are interesting and important organs; but more because they happen to be parts of the body which form in the same manner in all animals that have a backbone, whether they are fishes, frogs, birds, four-footed beasts, or human beings. The eyes with which you, my reader, are reading this page, grew in the way I shall describe, as I have myself seen it in the egg of cod and sea-bass.

In general, the part of the body to form earliest is the brain. Next after that come the eyes. These begin as two buds which grow out one on each side of the brain where the head is going to be. Each is a hollow, bubble-like affair on a short stalk; as much as anything, except for size, like a hollow rubber ball stuck on a pencil stub. One would think that this hollow ball would simply change into an eyeball; but it doesn't, for Nature rarely does things simply. Instead, one side of the eye-bud folds in, as you might push in a hollow rubber ball with your finger, until it forms a cup. This cup is the eyeball. The sides grow out until the hole narrows down to the dark opening in the middle of the eye which we call the pupil. Various kinds of eye-stuff grow over the edge and form the interior parts of the eye; other tissues on the outside thicken the walls and form the transparent cornea in front; and while the pupil is still large, a portion of the substance which is later to become the skin, buds into the eyeball to form the lens of the eye. The reason, then, for this round-about process, this doubling in of the original eye bud to make a cup, which afterwards closes down to the eyeball we finally use, is to get various substances inside the eye, and finally to leave a pupil for the light to enter.



"Salmon With Yolk Sac."

Thus far, like the little chick, the little fish has had no front to its body. It lies on the yolk, curled round it like a child with the stomach ache hugging a pillow. By and by the tail grows out free of the yolk. The head also lifts clear, and the lower jaw has room to form. Last of all, the sides of the body grow completely round the yolk, and put it where it will do the most good.

Now the fish is ready to hatch. For some time it has been giving occasional wiggles inside the egg membrane; finally it breaks thru and floats out. It is a tiny helpless creature, still more than half yolk. It cannot swim, but floats, belly up, and mouth wide open, not yet able so much as to close its jaws.

From this time on, the fish grows rapidly, living on the yolk, which grows smaller and smaller. At first the little creature floating on its back can only give an occasional wiggle. As the yolk becomes more manageable, the fish wiggles more. Soon it turns for a moment on its side, then clear over; and by the time the last of the yolk has disappeared, it is swimming right side up and has begun to eat the still tinier water creatures which are its food. At this stage, if it is a fresh water fish, it begins to be visible in the shallows in schools of minute, but veritable, fishes a quarter inch long and mostly eyes.

IV

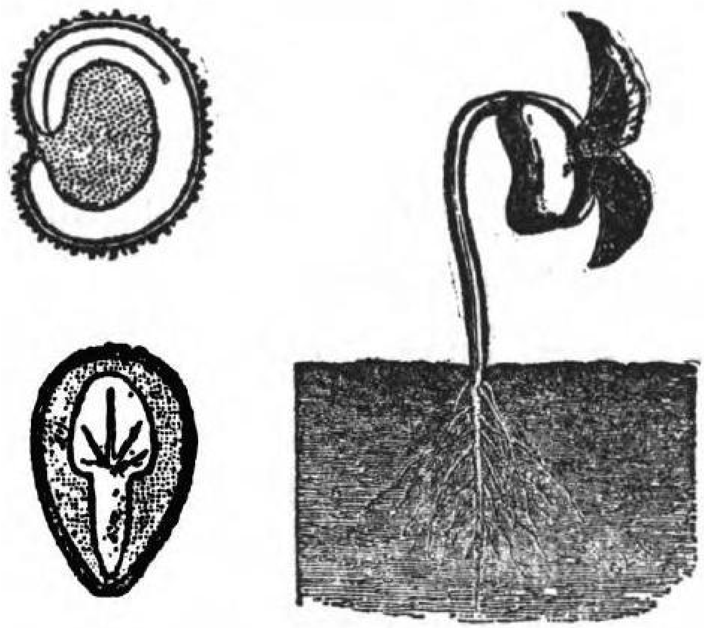
Of Plants' Eggs

The plant's egg is, of course, the seed. We commonly say that the plant grows from the seed. And so it does. Yet this is not exactly true either, because the ripe seed is already a little plant, folded up tight and packed away in a hard case, like a chick inside its shell.

If one takes, for example, an ordinary bean or a peanut, peels off the shell and opens it carefully, it separates into two halves, held together by a little nodule at one end. These two halves, which together form pretty much the entire bean, are really two fat leaves. They are the yolk of the bean egg, on which the new bean plant is going to feed until it has grown leaves and root, so that it can pick up a living for itself out of the earth and air.

The rest of the new plant is the little nodule which lies between these seed-leaves. Curled up against the outside of the seed, like a puppy's tail between its legs, is a short fat root; while hidden away between the seed-leaves is the next pair, tiny leaves almost too small to see, but real leaves nevertheless.

So the bean is an egg. Not a new-laid egg, but an egg with a little plant inside, all ready to hatch out and grow.



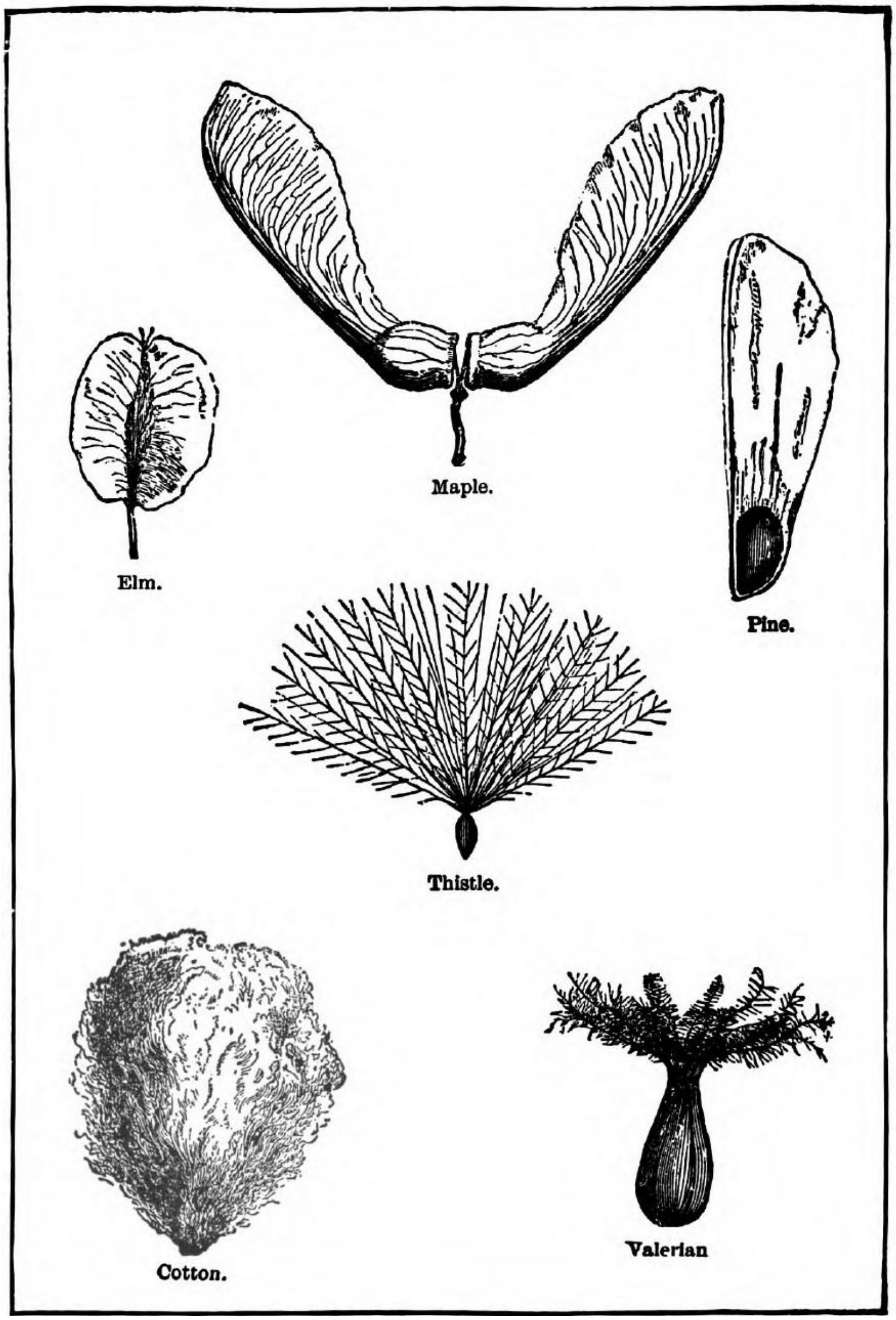
The bean egg changes to a bean plant.

If instead of cooking and eating the bean, we plant it in the ground, or in wet sawdust or blotting paper, it soon hatches out. The shell drops off, the seed-leaves first take in water and swell and then shrink away to nothing as the growing plant eats them up. The little root grows down, the little leaves grow up, the whole plant turns green and begins to climb the bean pole.

All seeds, then, are eggs just ready for hatching. They are like fish eggs, however, rather than like birds' eggs, because the little fish and the little plant both save most of their yolk to use in getting a start in the world after they are hatched out. But the birds, you will recall, because they have large eggs and plenty of room inside, keep on growing till the yolk is all gone, and then hatch.

The little plant, as you might expect, gets inside its seed almost exactly as the little bird or frog or fish gets inside its egg. The "string beans" which we eat in the summer are fat pods stuffed out with bean-stuff to be used in making seeds. There are tiny beans inside, which are new-laid bean eggs, and so have no little plant inside, but only bean-stuff. The little bean plant, starting from nothing, forms one part after another, like chick and fish.

But where does the egg come from in the first place? The bean egg forms in the pod, too small at first to be seen at all, and keeps growing until it is big enough to begin to form the new plant. In exactly the same way, the mother fish, and the mother frog, and the hen, have a sort of pod inside them. First this pod stuffs and fattens itself out with egg-stuff, like a string bean. Then some of it turns into little eggs, too small to be seen. These grow and grow, like the beans in the pod, while the pod shrinks away. Only after they have grown a great deal, do they begin to form little beans, or fish or chicks inside.



Seeds that have Plumes and Wings

First of all, in short, the bean pod begins as a minute speck and grows into a proper pod. Then the bean inside this pod begins as a minute speck, and grows into a proper bean. Then the new bean plant inside this bean begins as a minute speck and grows into a proper bean plant, ready to be hatched out and shift for itself. So part of the mother plant becomes pod, and part of the pod becomes bean, and part of the bean becomes little growing plant. So it is with little fishes and little birds and little rabbits and puppies and kittens and all the rest of the little animals that you know.

V

What Little Boys and Girls are Made Of

“What are little boys made of, made of?
  What are little boys made of?
Snaps and snails and puppy dog’s tails;
  That’s what little boys are made of.
What are little girls made of, made of?
  What are little girls made of?
Sugar and spice and all that’s nice;
  That’s what little girls are made of.”

So says the old nursery rhyme. It has this much truth in it, that little boys and little girls are far from being alike, and it isn’t worth while to try to make either one over into the other. What little boys and girls are really made of, and all other living things as well, is a much longer story.

Oddly enough one can tell this story more simply by telling first about little star-fish and sea-urchins, and what they are made of. Star-fishes’ and sea-urchins’ eggs (for the two creatures are really very much alike, for all they look so different) are much like the eggs of fishes. They are round and transparent, and so minute that they look like fine red dust in the water. Naturally, therefore, few people ever see them at all.

Each of these eggs is a tiny drop of fluid substance with a very thin skin round it. It is in fact, not unlike a toy rubber balloon, filled with thin jelly mixed with oil, and set floating in the water.

This then is the young egg, before there is any sign of a growing creature inside. One would perhaps expect to see the oil and jelly mixture change gradually into a star-fish. Instead of this, however, this little balloon-like affair splits squarely in two, and makes two little balloons just alike, which lie side by side and more or less flattened against one another, like two soap bubbles blown from the same pipe. In about a half hour, each of these balloons or bubbles, “cells” as they have come to be called, has divided again; so that now there are four. The four soon become eight; the eight, sixteen. In the course of a few hours, there are hundreds, all sticking together and all very minute; so that the whole mass looks like the heap of soap bubbles which one blows by putting the pipe under the surface of the soap suds.

So the first single cell of the new laid egg, small as it was, has become several hundred still smaller. These, however, are not yet star-fish, but only star-fish-stuff, arranged in a little pile like a heap of bricks, and all ready to build into a star-fish.

Now if a man is building a house out of bricks, he piles the bricks near where the house is going to be; and then he takes them, a few at a time, and cements them into his wall. Not so the star-fish house. This has to be built right in the living brick pile. It is as if we dumped a heap of bricks in a field, and then each brick of its own accord got up and went to its proper place in the house. The little ball of cells which is the egg, begins to swell, and fold, and move. It pushes out one part here, and doubles in another there. The cells divide rapidly in one place, and form a thick solid bunch; in another they spread to a thin sheet. By and by, there is a little creature; not indeed a star-fish, but something with a stomach and an outside skin, and between the two, certain nondescript cells, which later on are going to make the hard skeleton and the muscles. After this, the cells still keep on dividing, but instead of getting smaller and smaller, they wait each time they divide till they grow to full size again.

Thus the baby star-fish grows. And by growing fast in some places, and slowly in others, and in still others not growing at all, it changes at length into a veritable star, altho no bigger than a grain of sand.

All eggs change into little animals in this same way. The hen's egg yolk is such a cell—a thin skin filled with oil and jelly. The frog's egg is another, with one side colored black. The fish egg is like the others, with an especially clear jelly that one can easily see into. Frog eggs and star-fish eggs and sea-urchin eggs, most sorts of eggs in fact, split fairly in two the first time they split at all, the whole yolk divides and the little animal, from the first moment when there is any at all, is always as large as the egg. But birds' eggs, most fish eggs, and some other sorts too, are so loaded down with fat that the egg does not divide clear thru, but as I have already explained, only at a tiny spot on one side where the jelly is thickest. But whether this pile of minute cells which is the heap of little animal bricks, is a small spot on the side of a large egg or the whole of a small one, it all comes to the same thing in the end. When the proper moment arrives, the living cell bricks move to their appointed stations, and the new creature begins to form.

Now we know what little boys and girls are made of. They are built of enormous numbers of these living bricks which we call cells, just as other living creatures are. All of us, men or animals, trees, bushes, or grass, were once, each of us, just one single round cell which divided, and divided, and divided again, until it became a vast number. Out of this vast number the new plant or animal builds itself.

If it is an animal like ourselves, this body stuff, before it becomes a body, is a round ball. A furrow doubles in along the place where the back is to be, and becomes the spinal cord. A rod strings itself along underneath this, and becomes the backbone. The front end of the spinal cord grows faster than the rest, becomes larger, and is the brain. The brain buds out into the eyes. The outer surface of the body, not yet turned into skin, buds inward and makes the ear. Four outgrowths come down from the forehead to make the face. The limbs begin as shapeless knobs, and grow out slowly into arms and legs. Sometimes these make a mistake at their ends, and split into six fingers or toes instead of the customary five. Then if the little creature is a human baby, the Doctor has to cut one of these off; but if it's a kitten we say it has double paws and will be a good mouser—tho really I don't suppose it makes the least difference.

Most of our growing, then, is just the increase in numbers of these little living bricks. There is a spot at the bottom of each finger nail where the nail cells are dividing and pushing out the finger nail. The white spots in the nail do not mean that one has been telling white lies, as some people say. They come because one happens to bruise the soft "root" of the nail where the nail cells are new and easily hurt like the soft flesh of a little child.

When we were very much younger than we are now we had no teeth. As biting-time drew near, the cells of the thin skin which lines the mouth began to multiply so rapidly where the two gums touch one another that they soon formed a thick ridge growing back into the jaw. A little later, and this ridge continued to grow at twenty separate points while it stopped growing everywhere else. Soon these twenty growing points opened up into twenty pockets. From the bottom of each pocket grew up a tooth; while from the side of each there budded out another pocket in which, when the baby is eight years or more old, the second teeth form. But the three back teeth in each side of a man's jaw, tho they come late and are the largest he has, really belong to the first milk set, the rest of which he lost as a child.

Even the hair grows by the division of cells at the inner end of the little bulb which you see on the end of the hair when you pull it out and look at it against white paper. Just between hair and skin is a spot which is neither hair nor skin, where all the growing of the hair is done.

So we are not built like a cement or a wooden house, but like a brick one. We are made of little living bricks. When we grow it is because these living bricks divide into half bricks, and then grow into whole ones again. But how they find out when and where to grow fast, and when and where to grow slowly, and when and where not to grow at all, is precisely what nobody has yet made the smallest beginning at finding out.

VI

More About Living Bricks

The largest of these living bricks is the yolk of an ostrich egg; since this is, of course, like all eggs before they begin to grow, a single cell. The smallest known are certain of the bacteria and germs which float about in the air, and are so minute that they cannot be made out even with the strongest microscopes. All one can see is that there is something there; something which if placed a thousand in a row, would still not reach across a grain of dust.

Few cells, however, are as small as bacteria on the one hand, nor anything like as large as the yolks of birds' eggs on the other. Many are just comfortably visible to the unaided eye. But the great mass of cells which make up our own bodies, the bodies of other animals, and of plants are a little too small to be made out with a common pocket lens, tho an ordinary microscope shows them with ease.

While the egg yolk is dividing to form the first hundred or more living bricks out of which the little animal is to be built, the cells are all about alike, generally round except where they are flattened against one another. As soon, however, as they begin to move about into place to build the new animal, they begin themselves to change. Some remain small; others grow large. Some grow out into long strings, and become muscle fibers or nerve. At one point, many thousands together swell up with oil and become fat. At another, more thousands build themselves about with hard lime phosphate, and become bones and teeth. Those which form within them little brown granules, give the color to hair and skin. The blood is colored red by the coin-shaped cells which float in it. In certain parts of the eye, on the other hand, the cells have to remain perfectly clear and colorless, else the light could not come thru and we should never see truly.

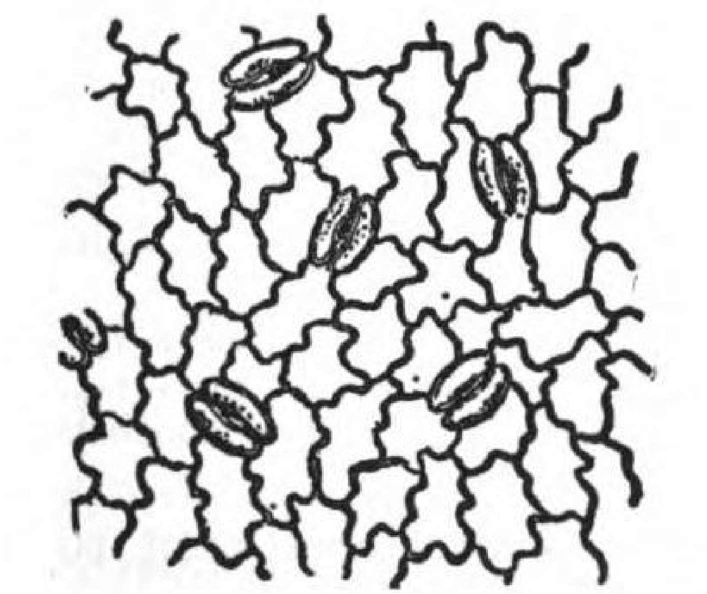
When an animal is very young indeed, long before it is ready to leave the egg, the whole outer surface of its body is covered with a single layer of these cells. They are packed closely together, and flattened against their neighbors so that the sheet of cells is not unlike, on a small scale, the marble floor of a public building or the block pavement of a city street. Like other living cells, these grow, and divide. They cannot grow sidewise, for the space is already filled; nor inward for that way lies the entire body. So they split off a piece of their outer ends. Then they do it again, and yet again; until the outer skin of the body, from being one layer of cells in thickness has become many.

Only the original inner layer, however, grows and divides. The split off ends dry up to a roundish cracker shape, grow hard and homy, and become the thin outer skin of the body, which we run pins and needles under, and pull off or scrape off when we "bark" our shins, without hurting. This part of the skin is dead. It gets rubbed off by our clothes, or soaks off in the bath tub and has to be scrubbed off the sides. But as fast as it is removed on the outer surface, it grows again from the living bottom layer. No matter how old one gets, this lower layer of the skin continues to split off the outer ends of its cells, just as it did before there was any proper skin at all. Most parts of the body grow thruout their mass; but the skin grows only on the inner side.

On the palms of the hands and the soles of the feet the skin grows very rapidly and is especially horny. When one works with his hands more than he is accustomed, the first effect is to wear the skin thin and sore, or to pull it loose from the bottom layer and make blisters. In the end, however, the rubbing only makes the live skin work faster, until it builds great homy callouses that no work can wear thru. But when our boots do not fit and rub in one spot, this also starts up the live skin to working hard. First thing we know, we have a corn. For a corn is only an especially hard and thick callous, where the living skin made a mistake and grew too much in one little spot.

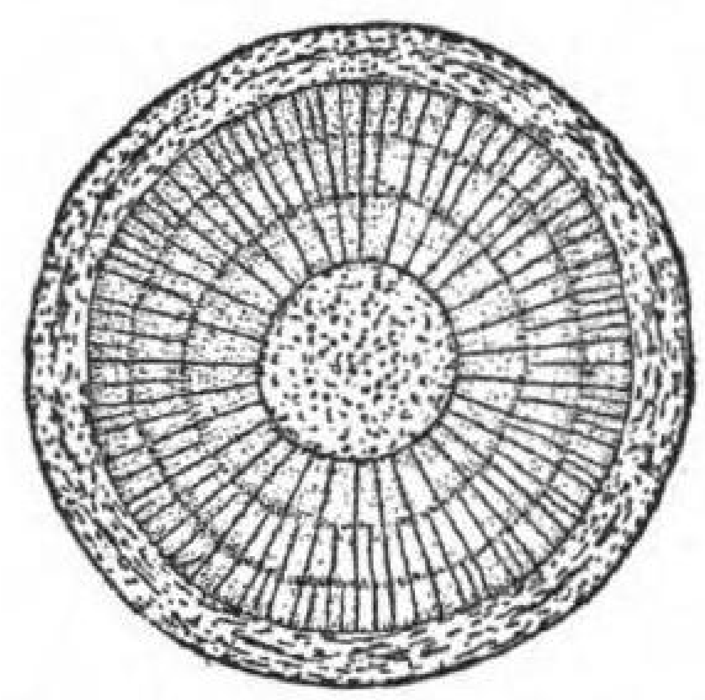
Each finger nail and toe nail is a sort of corn. It grows from a fold of skin, forming from the bottom layer like any skin, but it is especially homy, even more horny than the hardest callous. The hair, also, is a sort of corn. The skin doubles in to form a minute pocket; and at the bottom of this pocket this same living under layer of the skin grows into a narrow shaft of cells, dry and dead and homy like skin and nails.

The horns of animals, too, are only thick hard skin. Sometimes they have a core of bone inside, but the outside is just a special sort of skin. Wherever we go in the body, there we find some special sort of cell. They may be large, small, thick, thin, long, round, soft, hard. They may build this, that, or the other thing around them. They may have this, that, or the other thing inside. But in one way or another the whole body, from head to heels, is built of these cells and their products.

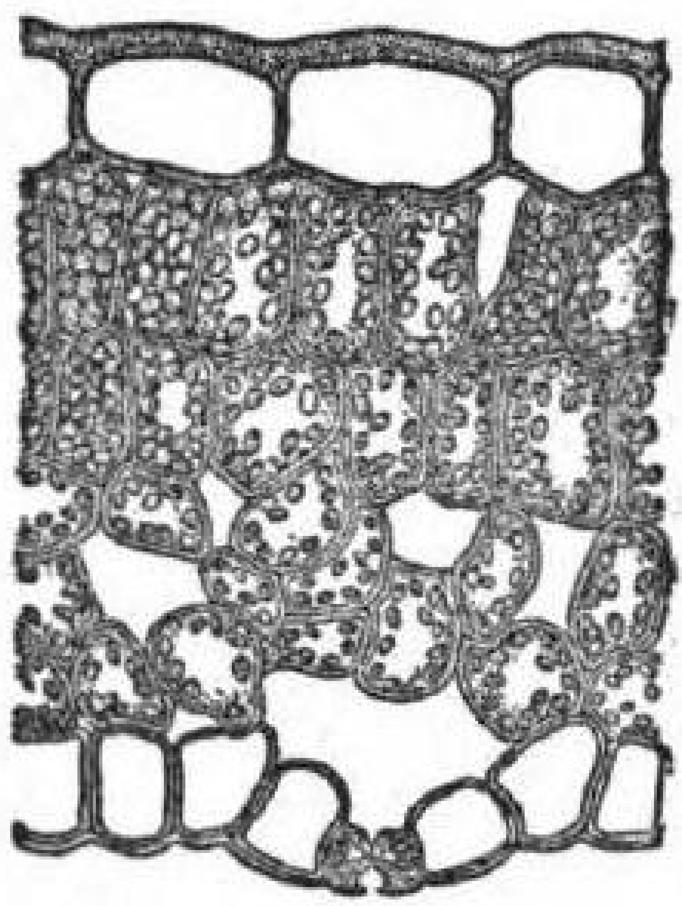


Living bricks which make the skin of a leaf. Five pairs of these are the lips of breathing holes.

It is the same way with the plants. They too are built of these living bricks. Each leaf and blade of tree or grass is covered with a sheet of colorless cells one layer deep, which one can often peel off from the green pulp underneath. The green pulp, in turn, is a rather loose pile a half dozen thick, of roundish brick-shaped cells, each containing scattered grains of green coloring matter. The solid wood of a tree is only the thick walls of long slender cells, overlapping at the ends and packed tightly together. These cells lie lengthwise of the tree; that is why wood splits with the grain so much easier than it cuts across it.



Cells of the inner tree pulp. The rings show that the tree is three years old.



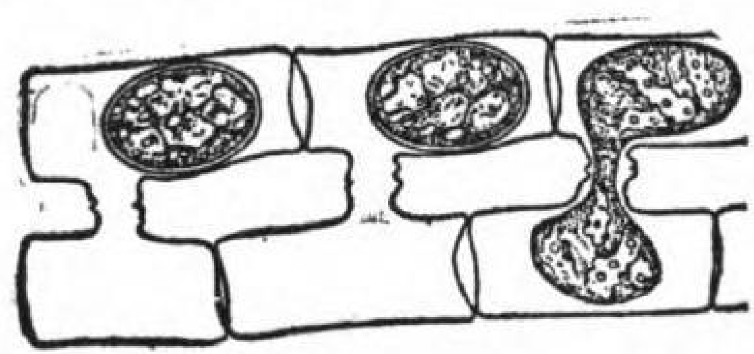
Cells of the outer skin of a leaf. At the bottom is the mouth of a breathing hole.

I have already said that at the time of year when the tree is growing rapidly, these woody cells are large; but when the tree is growing slowly, they are small. So each year there is a change from large cells formed in the spring to smaller ones grown in the fall. The next year, the living substance of the cell moves off to the growing region next the bark, and leaves the old wood cells empty. These, therefore, never change; and because the large cells and the small ones do not look quite alike, we see the annual rings of wood in the tree trunk, as thick as card board, which give us the light and dark lines in our furniture and our hard wood floors. From these one can tell, not only how old the tree is, but also what were its good years when it grew rapidly, and what its poor seasons when it hardly grew at all. If a drought came along any summer, or if insects one year ate off all the leaves, that too shows in the wood. But trees which grow in the tropics, where they keep growing the whole year thru, do not have annual rings.

While some cells of the tree form wood and some green pigment, others in the bark produce cork, as one can see nicely in the thin layers of cork in the bark of an elm. The cells of juicy fruits swell up with water, and form sugar and various flavoring matters and pleasant acids. Where the animal cells swell up with oil and become fat, the plant cells swell up with starch grains and become a potato or the thick seed-leaves of a bean. But other cells form gum, rosin, turpentine, pitch, and the various oils and the like, pleasant or bitter, which we use for food and medicines.

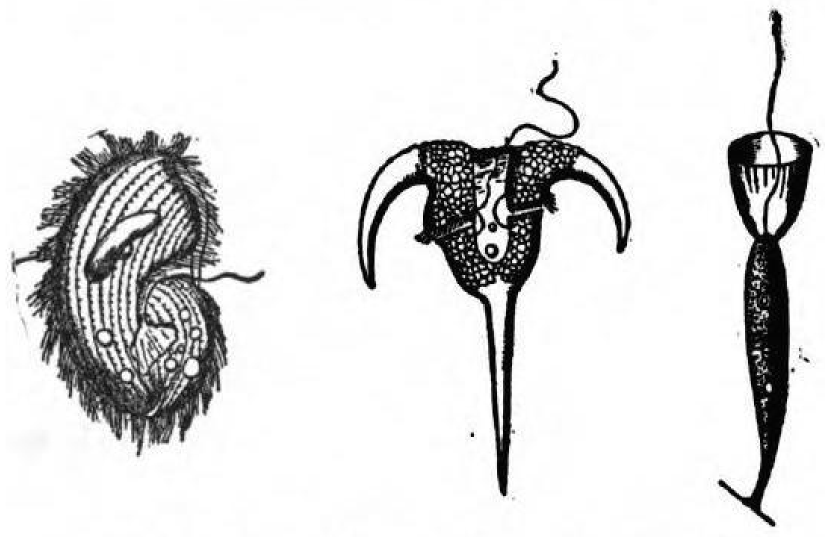
So the plant, like the animal, is just a great mass of different sorts of these living bricks, and of the various substances which they form within and around them.

Naturally it takes millions upon millions of these living bricks to build up the body of a man or an apple tree, still more of a whale or one of the giant redwood trees of California. Many humbler creatures, on the other hand, both animals and plants, contain comparatively few. Our common green pond scums, for example, which tho they are plants, have neither leaves nor stems nor roots, are like single long lines of tiny green barrels set end to end. Our common sea-lettuce is a sheet of cells only one layer thick; while other sea-weeds and water plants are but bundles of a score or more. Often the fewer such bricks there are, the larger they are; even at times, to a half-inch in thickness and an inch or more in length.



Cells of a pond scum much enlarged. The green living substance flowing from one to another unites to form an egg or spore.

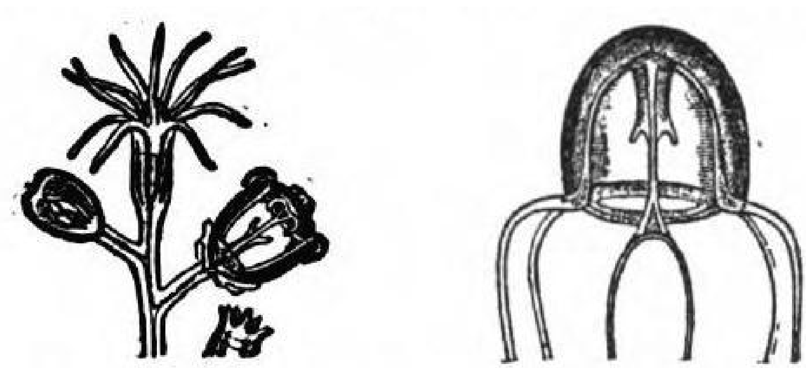
A vast number of plants and animals, moreover, are single cells. Such among plants are the yeasts with which most of us make our bread, and a few of us brew our beer. Such also are the hundreds of different sorts of bacteria, which tho some of them are the germs of various catching diseases, are for the most part useful enough. But of these we shall learn more by and by. The green spots and patches on the bark of old trees and fences, and sometimes even on damp earth, are due to enormous numbers of minute plants, green with the same green pigment as the leaves of the largest tree; while the green tint of the gray lichens on rocks and tree trunks is caused by similar single-celled plants which grow among the white fibers of the lichen proper. Besides these, there are many like plants which float about in fresh water, each a single cell.



Three sorts of infusoria much enlarged.

The diatoms which one finds in the mud at the bottom of ditches and mud-puddles, tho they have shells and move about, are usually counted among plants; but the water of most ditches and puddles swarms with amoebas, infusoria, animalcules of various sorts, most of them large enough to be made out with the unaided eye when seen in a tumbler against the light, and each a single cell.

Many animals, then, and many plants are just one single cell and no more. Many others, like pond scums and sea-lettuces,—which are plants,—and sponges and jelly-fishes,—which are animals,—are composed of many cells, but all pretty much alike. But the animals and plants which we know best, kittens and oak trees and horses and grass, and the creatures we know best of all which are ourselves, are made up of many cells, and many different sorts—skin and bark and wood, flesh and fat and leaves and hair and all the rest, so many that it would take half an hour merely to write them all down.



Some jelly-fish grow on stalks and some swim about in the sea.

These "cells" then, are the living part of every plant and animal. Each of them became by the splitting in halves of an older cell; each of these in turn by the splitting in halves of a still older cell, until we get back to the egg which is the great-great-great-grandfather of them all. But the egg itself arose by the splitting of still another cell, which, of course, was part of the parent's body. This came from yet another, and so on back to the beginning of life on this earth, tho nobody knows how long ago that was.

So the living flesh of us has always been alive. Most of it will die; but some of it will live on in our children and our children's children, until the and of the world.

VII

How Much of Us Is Alive

How much of a tree is alive? Certainly not the outer bark. That falls off in dry scales, or can be scraped off down to the white layers within, and the tree be none the worse. Certainly not the wood. One often comes across old trees that have lost limbs or been carelessly pruned, which are entirely decayed out on the inside, so that nothing is left but a thin shell next the bark. Yet these trees grow as vigorously as ever, and bear leaves and fruit like a solid tree. The bark is dead; and the wood is dead. Between the two is a thin layer, perhaps a quarter inch thru, which is alive. On one side, it is changing into dead wood. On the other side, it is changing into dead bark. The new wood is alive, and the new bark. Between them is something neither wood nor bark, but just living tree-stuff. The green leaves also are alive, and the green twigs, and the blossoms, and the growing buds. But at least half of every living tree is already dead; while the larger and longer lived a tree is, the smaller proportion of it is alive at one time.

How much of a hen's egg is alive? Not the shell, for that is mostly just chalk. Not the white, for that is merely the little chicken's pantry shelf where it keeps the food on which it is to grow. The living part of the egg is the yolk—unless somebody boils the egg and so kills it. Sometimes, too, the egg dies, as any living thing may; then we usually find it out.

Even we ourselves are not all alive. I have already pointed out that our hair and nails are not alive at all, and that our outer skin, the thin skin, that is, which we tear off when we bark our shins, is fully alive only on the inside. Our "bark" in fact, is very like a tree's. Each has a soft, thin, living layer on the inside, which grows, hardens, dies, forms a water-tight layer over the rest of the body, cracks into scales, and drops off. Where one forms cork, the other forms horn. Indeed the cork stoppers of our bottles are made from nothing more than an especially thick corky bark of a certain kind of oak, like the especially thick and homy soles of all bare-footed savages and some bare-footed little boys.

"The blood," we say, "is the life." And yet the blood itself is dead. The watery part is just soup; water and salt and fat and jelly. The minute, coin-like, red blood corpuscles carry the oxygen of the air from the lungs all over the body. But there are similar oxygen-carriers, likewise dead, in bottles in the drug-stores. The corpuscles are dead cells alive once, and like the hard skin cells, a great deal more useful dead than alive.

As for our teeth, the hard white enamel on the outside is just about as much alive as a clam shell. The baby tooth, as I have already explained, is formed in a little pocket in the gum. The inner part of the tooth grows up from the cells at the bottom, very much as a hair grows out from the bottom of the still smaller pocket where it starts. In fact, the tusks of pigs and the long front gnawing teeth of squirrels and rats are still more like hairs, for they keep growing from the root, and wear off at the outer end. The tooth pushes thru the gum; and as it goes by, the cells at the sides of the pocket and on top plaster it with a coating of enamel. Therefore, as most of us find out to our cost, this enamel once destroyed, can never grow again. Once clear of the pocket where it was formed, it has to last us the rest of our lives; and little boys and girls who don't keep their teeth clean when they are young, have to put up with something not nearly so good when they are grown up.

The inside of the tooth is not quite so dead as the outside—one sometimes gets the impression during a visit to the dentist that it isn't dead at all. The tooth, inside the enamel, is mostly bone; and bone is mostly lime, like clam-shells, mortar and chalk, plaster, and the great boulders and ledges of rock in a limestone country. The rest of the bone is living substance, scattered cells far apart from one another with long roots, that look as if they had grown out into the bone like tree roots into the soil. Really, however, it is the other way. Before there were bones, there were bone cells. These build themselves round with the hard bone substance, pushing their neighbors away and leaving only the long root-like strands of living substance. It is thru these root-like living strands that we feel the dentist's auger bore into the solid tooth. But cutting the outer enamel does not hurt at all simply because no part of that is alive.

We are, then, built of living bricks, but of living bricks set in dead mortar. We saw that the great trees, complex and long lived, have more wood and bark and other dead substances in them than the shrubs, herbs, and grass. These in turn are less alive than the lowly water plants and yeasts and molds which have no wood or bark at all. The same is true of animals. The jelly-fishes and infusoria have neither skin, hair, bones, nails, nor blood, and are pretty much all alive. So the more a creature's life is worth, the less of it is alive.

Even the living cells themselves are not wholly alive. The thin living jelly always contains water and salt, which are—just water and salt. Fat cells contain drops of oil, which are simply stored up food material, no more alive than the oil in an oil can. Plants, on their side, store up their food largely as starch, no more alive than that in a package from the grocers. Besides oil and starch, some cells contain gum or rosin or saliva or milk or sweat, which they pour out from time to time. These substances, too, can hardly be considered more alive while they are in the body than when they are outside.

So the living substance is the cell jelly. Everything outside the cell is dead; many cells even are dead, while not a few, even while alive, contain so much dead stuff within them, that there is more oil in a young hen's egg than there is chick, and more starch than corn-plant in a grain of corn.

VIII

How We Grow

By "we" I mean all living things, trees and grass and dogs and cats and boys and girls. For as you, my reader, have I hope already discovered, we who have the breath of life in us are a good deal alike, whether we are oaks or men. We don't look much alike, to be sure. But when we consider the things that are not alive—the stones and stoves and bats and balls and such—and see how very different we are from these, then we get some idea of what being alive is, and understand how being alive makes us blood-brothers with everything else that is alive also.

Now things that are alive usually do more or less growing. We have already learned something of this growing of little creatures in the egg—how the eye buds out as a ball and afterwards folds into a cup, how the limbs sprout out from the body as shapeless lumps which only gradually turn into hands or feet or wings. We have learned something of the way the bones grow, and the skin, and the hair, and the nails. Now we have to learn something more about the way a little child or a little tree grows up to be a big one.

The tree, we already know, grows larger round only between bark and wood. It grows taller only at the tips of its branches. The solid wood, once formed, does not change. If then, you drive two nails into the trunk of a little tree, say a foot apart and one above the other, even if that tree should grow to be a hundred feet high, those two nails would remain just where they were, a foot apart and just the same height from the ground as before. The little tree looks so much like the big one, that one cannot help thinking that it has simply grown thruout, so that the same branch which was once at the height of one's head has now been lifted to the height of the house eaves. But this is not the fact. The lower branches of the little tree have died and dropped off; what are now the lower branches of the large tree, were once the top twigs of the little one, which have always been at the same level where they now are. The top branches of the large tree, as the tree grows still larger, will in their turn become, first the middle branches, then the lower ones, then will drop off entirely.

Now this growing at one end which looks like growing thruout is pretty common in our own bodies. We have seen how the hair grows at the inner end only, and the nails likewise, and the skin. Ignorant people will tell you that cutting off the ends of your hair, or singeing the ends; and that smearing various messes on the outside of your skins will change the quality of either. Don't you believe them. After wood and skin and hair and teeth are once grown, all we can do is to protect them. Really to affect their growth for good or ill, we have to do something to the growing end.

The bones also grow in spots. The child's leg bones and arm bones and finger bones do not simply swell up to become the man's. The head of each bone, the rounding end, that is, where it touches the next, grows on the outside. But the shaft does its growing chiefly at two spots, one at each end where the shaft joins the head.

The bony part of the tooth, on the other hand, starts as a paper-thin sheet, but full sized. The living cells which build the hard bone, lie on the inside of this shell. They keep building on more bone on the inner surface, pushing themselves toward the middle of the tooth, until the tooth wall is so thick that only a narrow space is left in the center. But their long roots which they leave behind, still reach thru to the outer surface of the bone, ready to ache when there is occasion. Meantime, the outside of the tooth pocket, as we have learned, has been plastering on enamel on the outside of the shell, and pushing itself farther and farther away.

A plant's roots, like its branches, grow at the tips; and the nerves in our own bodies grow in somewhat the same way, beginning at the inner end, and somehow finding their way thru and around the other tissues of the body, till they find the place to which they were sent. But the muscles and the fat grow thruout their mass, like dough being raised for bread. Most of the hollow tubes of the body—the blood vessels, for example, and the red lane down which our breakfast goes—grow in this way. But the hollow bones, as they grow, are taken down on the inside to enlarge the hollow, and built up again on the outside with old material and new to enlarge the shaft.

Even the blood grows, the watery portion coming from the food we eat and the water we drink; but the red and white corpuscles which float in the watery part, are made in special factories in the body (some of them in the marrow of the bones) and turned loose in the blood stream.

Growing, you see, tho easy to do, is by no means so simple as it appears.

IX

How We Grow Up

Ten years from now, you who are reading these sentences will be grown up. Once you were little pink and white babies, all soft and sweet and clean. And because you were soft and unresisting, you grew at a tremendous rate. At first you probably doubled your weight in six months. Then it took three years; then six or eight. By the time you are twelve, you probably will be half as heavy as you ever will be. In all the rest of your lives, you will do no more growing than you did in the first 180 days of them.

You will grow, too, as you have grown, by fits and starts. Sometimes you will shoot up like sunflower stalks. Sometimes, again, you will stop growing large, and begin growing hard. You will not seem to be getting bigger; but you will be getting stronger. Then, when you start growing again, you will perhaps find that you really can't do so much as you could when you were a year younger, nor do it so well.

So you will keep on, sometimes growing large and sometimes growing hard, but almost never both at once, until you come to the full stature of men and women, and your soft baby flesh that couldn't lift its head from the pillow has changed to tough muscle and hard bone. That is, of course, supposing that you have taken care of yourselves. If you haven't—why then it may be different.

This growing up is so common an affair, so many of us do it, puppies and calves and kittens and little rabbits and baby birds, that we usually forget how wonderful a matter it is. Wonderful indeed it is; yet hardly less strange is it that after we have grown a while, then we stop. Yet our hair, as we know, doesn't stop, nor the skin, nor the nails. Sometimes parts of the body which have hardly grown at all in youth, start up and grow in middle life. But the parts of the body which count, the parts which if they did grow would make us larger, these somehow know enough to stop.

It is not so with some other living creatures. A tree does not stop growing so long as it lives; nor does a fish. The big oak or the big trout may have grown faster than the little one; most likely it has simply been growing longer. We call any creature adult when it is large enough to have children of its own. But the oak bears acorns and the trout lays eggs, and then keeps on growing till it is ten, twenty, fifty times bigger than it was when it first had little ones. It is as if the cat, when her kittens were growing up, kept on growing along with them; and next year when there were more kittens kept on growing nearly as fast as they; and kept on year after year as long as it lived until it got to be as large as an elephant. And still its kittens would be just kittens, no larger than before.

Many animals manage their growing this way. The star-fish egg, you remember, is for size like a minute grain of dust, and the baby star when he first hatches out is hardly bigger. After that, he eats all he can get and grows as fast as he can, like any other kind of baby.

But suppose the little star-fish, as large say as a pin head, doesn't find enough to eat. Does he then starve? Not a bit. He simply doesn't grow. The eggs hatch out in the late spring within a few weeks of one another, and the little stars which do not happen upon a good boarding place, go practically without food all summer long. They remain perfectly healthy; but they scarcely grow at all, so that at the end of the summer they are still the pin heads that they were six months before.

On the other hand, when a star-fish happens to be born where he can find plenty of barnacles or small clams or mussels, he doesn't do much but eat, and grows to match. It may happen, then, that of two stars, hatched on the same day, the one which has been well fed will be no less than five thousand times larger than the other which has gone hungry. Now a grown man is only about fifteen times as large as a new-born babe. But this is as if two babies, each six months old, should be, one no heavier than at birth, while the other weighed twenty-five tons and was as large as a whale.

So you can't judge by appearances. The star-fish that you pick up at the shore may be a very young animal which has been well fed, or a very old one which has gone on short rations, while a young star, still growing, may be twenty times larger than his own great-grandfather.

X

How We Grow Old

After we grow up, we grow old. People say that we first grow up to men and women; then we continue adults; then we grow old. Really, however, we begin to grow old the day we are born; while we shall never again grow old so fast as we did when we were babes in arms.

For growing old is simply growing hard. We begin life as squashy little babies. Our bones are like green sticks. Our flesh is like dough, only the softest cloth must touch our skins, and Nurse has to hold her hand under our poor backs to keep our heads from dropping off. Children are not squashy, but they are still soft. You can pinch children. Sometimes you do. But you can't pinch a grown man, any more than you can pinch a board. Children are of course, much harder than babies. All the same, if you put your fingers in your mouths, or stand too much on one leg or slouch over your books or shrug your shoulders up beside your ears when you play first base, or sit on one foot when you curl up in the big chair in the library, or do any other of the forty-leven things that somebody has to tell you forty-leven times a day not to do, then you will pull your bones all out of shape as if they were so much India rubber; and when you grow up and your bones and muscles set, then you can't get back into shape again—tho you'll wish you could.

For get hard you will. Then you will be grown up. When you are just hard enough, you will be in the prime of life, able to work as easily as you now play, and liking it, I hope, even better. But still you will keep on getting hard; and when you get too hard, then you are old.

So growing old is growing hard. And since the younger you are, the faster you grow, you never grew old so fast as when you were a tiny baby, and you never again will grow old so fast as you are growing old now.

And the moral is, as the Duchess used to tell Alice, that since we stay young and soft only a very short while, and grown-up and hard most of our days, we'd better, as much as we possibly can, make the short end of our lives help out the long one.

What I mean is this. While we are young, we are soft and plastic and teachable. As we grow older, not only do our bodies harden, but our minds also. We can do a great deal more after we are grown up than we can while we are children; and I think we are, if less light-hearted, on the whole quite as happy. But we shall be a great deal less able to take up anything new. Let us, therefore, practice while we are young those things which will bring us most happiness, after we are too old to change.

For example, suppose a boy is fond of out-door games, as every normal and healthy boy ought to be. He plays baseball all the spring, tennis all summer, football thruout the autumn, and what there is left of the year goes into ice hockey. He plays expertly, has a glorious time; and he grows up manly and strong. This is as it should be—so far.

But suppose the same boy, thru school and college and at work. There is no more football for him, and no more ice hockey. For a few years he may get an occasional game of baseball; if he is very lucky he will get a little tennis. But tell me, boy who is reading this page, how many of your father's friends and associates ever play at all the games at which you spend your spare time?

Now while we are supposing, let us suppose that this boy of ours, instead of spending all his spare time at games, spent only half. The other half he shall devote to sports which are not games. He shall learn to ride a horse, to fish, to handle a sail boat, to swim, row, paddle, to climb mountains, to take care of himself in the woods, and above all to walk thru level country and enjoy the sight of all he sees. By and by, this boy will grow up. In the natural course of things, he will put away bat and ball and hockey stick before he is thirty, but rod and saddle and oar will bring him happiness and health almost to the end of his days.

There is a difference too in games. One plays football thru school and perhaps in college—eight years at the outside. But one world's champion tennis player was well by forty; he must have played thirty years. A golfer gets forty or fifty years of pleasure for the trouble of learning his game. You may think you will learn the boy's game now, and the man's game later. But you won't. You will learn the man's game now along with the boy's, or else you won't learn it at all. You will be too old to learn, and go gameless to your grave.

Or suppose a girl is fond of music, and learns to play, very nicely, the banjo. It will be charming enough, summer evenings on the porch—so long as one is young and has only a girl's soul to express in music. But by and by she will grow up to be a woman, and have little children of her own. Will she get out her banjo Sunday evenings and play for them hymns and solemn songs, or tinkle coon melodies for them when they are sick? Indeed she will not. She will put that banjo on the top shelf of the spare bed room closet, and wish she had spent her effort learning some other instrument more worth while.

So it is with everything else. If, while we are young, we train our ears to enjoy good music, and our eyes to love good pictures and good furniture, cloudy landscapes and great trees, and our minds to care for the important things of life, literature and religion and art and science and politics and history, we shall still possess growing sources of happiness longer after we have ceased to care to read stories or to be able to play ball. A wise child will study the happiest adults whom he knows, and learn to like and to do whatever most helps to make them blessed.

However, I meant to tell about how we grow old, rather than how we can best get ready to be so.

Oddly enough, most living creatures do not grow old. They simply live along till some other creature comes along and eats them up, or till the cold weather comes on and they freeze. A fresh egg is so soft that it hardly holds together; a young chicken is as tender as you please; while an old hen has to be boiled for days in order to be eaten at all. But an old fish isn't tough; neither is an old lobster. Who ever heard a cook asking for little oysters, for the sake of getting them tender and juicy, or a fisherman preferring small fish? We like these the better, the older and larger they are. All animals, before they hatch out of the egg, are very soft. Afterwards they all grow larger and harder. But some stop growing big and continue to grow hard; and some stop growing hard and continue to grow big. The first sort grow old; the second do not.

Now when you come to think of it, about the only animals that grow old are the four-footed beasts, ourselves, and the birds. But the rate at which these various creatures grow old may be very different indeed.

Let us take a new-born human baby, and a new-born puppy, and a new-born mouse. All these are helpless little babies; and all three start immediately growing up and growing old. But while it takes six months for the human baby to grow to be twice as large as it was at birth, the puppy doubles its weight in nine days; while the little mouse, in the first twenty-four hours doubles its weight twice, so that at the end of its first day of life it is already four times as large as at the beginning.

At six months, the human baby, if he is very much up and coming, as you no doubt, my reader, were, can just begin to sit up without a pillow at its floppy back; it cannot walk a step, and it hasn't a tooth in its head. But a six months puppy is a wiggly little beast, who runs away miles when he gets lost, chews up the family overshoes, and is well on the way toward losing his milk teeth. Meanwhile the mouse has grown up to be as large as he ever will be, has children of his own and probably grandchildren.

At five years the mouse is dying of old age. The puppy has become a sedate and middle-aged dog; but the baby is still a little child, just beginning to go to school, and still some years from losing its first tooth. At ten years, the child is young, the dog is old, and the mouse has become ancient history.

You musn't think that the larger animals live longest. A horse is as large as six or eight men, but it is old long before a man first votes, and the birds, which are in general much smaller than the beasts, also in general live three, four, and five times as long. Even the elephant, thought to be longest lived of all beasts, lives no longer than we. But fish and turtles and crocodiles and shell-fish and the like, which are neither beasts nor birds and grow big without growing old, may outlive even parrots, elephants and men.

I dwell upon this at some length because there is no doubt that just as the dog grows old more slowly than the mouse, and the man grows old more slowly than the dog, so some men grow old, more slowly than others. Some people have used up their lives and are old at fifty or sixty; some are still young and hard at work at seventy and eighty. Now it rests partly with ourselves which we shall be. Five is not a large number to multiply by. But five times your present age, my reader, will take you well up to middle life. In no small degree, it is for you to choose whether you will come to five times your present age with the best part of your lives over and done with, or with the best part still to come. What, in general, your fathers and mothers are telling you is right and teaching you to do, will contribute to the one result; what in general they are telling you is unwise and wrong will doom you to the other. That indeed is how we know that some things are right and others things are wrong. People have tried, many times over, and found out, to their profit or to their cost.

XI

Why We Grow At All

Did you ever stop to think how extremely convenient it is to have two parents? Mama stays at home and takes care of the little children, reads and sings to them, tells them stories, puts them to bed, spanks them when they are naughty and kisses them when they are good. Indeed, you couldn’t get on very well without Mama. Neither could you get on very well without Daddy. Daddy doesn’t seem so important as Mama; but if Daddy didn’t go to work every day, and earn money for Mama and their little boys and girls, where would house and food and clothes and birthday parties and music lessons all come from?

Suppose there were no Mamas at all, but only just Daddies. Then of course there would be no aunties, nor nurses nor cooks nor big sisters nor kind ladies in the next house. There would be only just men; and half the men would have to stay home from the office to take care of the little boys of the other half, and then their work wouldn’t get done, and there would be no end of trouble.

It would be almost worse if there were only Mamas and no Daddies. For then all the Mamas would have to go out to work; and even when they could earn enough to hire a nurse, which I am afraid would not be often, the best of nurses isn’t like Mama. So it is really much better as it is, when we have both fathers and mothers, one to work abroad, and the other to work at home and take care of the children.

In fact, this arrangement is so much better than any other that pretty much all the living world has adopted it. You know the ears of corn which we buy in August and September and eat off the cob. You know too how it comes from the shop, all wrapped up in soft green husks, with the long silk hanging out of the end, that little girls in the country use for dolls’ hair, and ridiculous little boys try to smoke in pipes. The ear is the mother corn, and the kernels wrapped snugly away in the green husk are her children. Or rather they are her eggs, with the little corn plants inside, almost ready to be dried over winter and be planted and start life for themselves. Each kernel of corn has one fibre of silk, which is joined to it at one end and hanging out of the ear at the other.

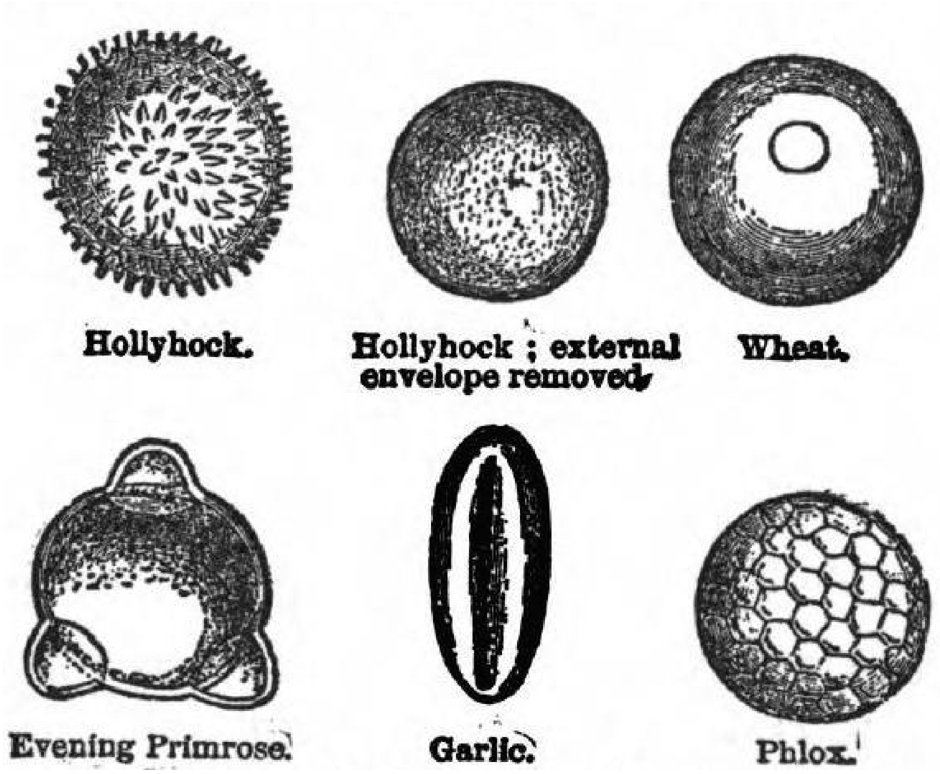
The cob is the mother of the corn. Its father is the tassel.

The ear, then, is the mother of the corn. Its father is the tassel at the top of the stalk. From each branch of the tassel hang many tiny brown bags, each about as large as a grain of rice, and each filled with a very fine brown dust. This dust is called pollen. And unless a grain of this pollen falls on each thread of silk of each ear, then the kernel at the other end of the thread will never grow to full size and never become a seed; but will always remain small like the undersized kernels at the end of the ear. If the tassel is cut off; or the silk pulled out; or the ear tied up in a paper bag, then the ear forms no proper seed.

Sometimes, on an ear of sweet corn, one finds a few kernels, or a single kernel only, that instead of being white like the rest, is yellow. This means that somewhere in the neighborhood, it may be miles away, somebody has planted a field of common yellow corn, which we make into corn meal, but do not eat off the cob because it isn't sweet. A grain or two of pollen from this yellow corn has been carried by the wind and fallen on the silk of an ear of sweet corn. So the father of that particular kernel is yellow and its mother white, and the kernel is colored just as if a white woman had married a Negro or an Indian.

Different plants manage these things differently. The ancient Egyptians, who lived on dates much as we live on corn and wheat, used to plant orchards of date palms as we plant orchards of our fruits. Every year, at the time when the cultivated date trees were in blossom, the Egyptian farmers used to go out into the desert, cut branches from certain wild palms which never bore fruit, and carry them in procession thru their date orchards. They did not know why they did this. They only knew that if they omitted the ceremony for a single year, that year they got no fruit. We know now, of course, that the date-bearing palm is the female tree; and the wild palm which doesn't bear anything is the male. The procession with branches thru the orchards simply brought in the pollen.

Most plants, on the other hand, not to take any chances, have seed and pollen in the same flower. Many too, instead of relying on accident and the wind to carry one to the other, are arranged so that insects and humming-birds, in seeking food, shall make the transfer. Some, few, however, like the willows, have seed and pollen on separate trees.



Pollen Grains much enlarged.

The water plants manage in much the same way. They, for the most part, turn loose in the water what in them corresponds to the pollen, and waves and currents carry it to the young seeds. The simpler water animals, sponges and sea-anemones and shell-fish do much the same. While the female sea-urchin or star-fish produces eggs as small as dust, the male produces a still finer pollen-dust, which we call milt or sperm. If one grain of this happens to float against an egg, the egg at once begins to change to a young animal. Otherwise after a week or so the egg dies and that is the end of it. Of course, under these conditions, the chance of egg and milt getting together is pretty slim, and the waste of eggs is enormous. So the fishes, which can move about, have a much better plan. When the female salmon, for example, swims up the rivers to leave her eggs among the gravels in the swift water, the male goes along with her. After she has laid her eggs and gone away, along comes her mate and scatters milt over them. So the salmon egg is pretty sure to grow; and the salmon can afford to have few eggs and larger, and so give her little ones more yolk to live on and a better start in the world.

The bees have a still better device. The single queen bee, as everybody is supposed to know, lays all the eggs of the hive. When the queen is young and the new swarm is just starting, she annexes enough of this pollen-milt-sperm to last her the rest of her life, and stores it up in a little sack. Then whenever she lays an egg, all she has to do is to give this sack a squeeze, press out a little of the contents, and start the egg growing into a new bee.

Strangely enough, however, altho this practice of having two parents is so very common among both animals and plants, and so universal among human beings, it is not, so far as we can see, at all necessary. Potatoes are thick underground branches, and not seeds at all. Yet we plant them and they answer exactly as well. Many lowly creatures, like the yeasts, the bacteria, the infusorians of stagnant water, and the like, never have anything resembling seeds or eggs. There is a parent. The parent splits in halves. There are two children. And where is the parent?

Among the common green plant-lice which swarm on the leaves in the summer, the males all die early in the season. After that the females go on laying eggs, and these hatch more females which lay more eggs, for ten and twelve generations, before the cold weather comes on and some of the eggs begin to hatch out males once more. They get along exactly as well when each insect has only one parent, as when it has two.

In the case of the queen bee, if while the egg is being laid she squeezes the sack, then the egg hatches out a worker, which has therefore, two parents. But if she does not, then the egg hatches out a drone, which has only one. There are many other strange facts of this sort, which have been known for a long time, but which nobody has yet been able quite to understand.

Some facts still stranger have recently come to light. It has found that in the case of many sea creatures, star-fish, sea-urchins, shell-fish and others, that if the eggs are kept in common sea water, but kept carefully away from any milt, they soon die, and never grow up at all. But if any one of a considerable number of substances is added to the water, sugar, salt, acids, and other things, then the eggs, tho they still have only one parent, proceed to grow into the proper sort of little sea creatures, just as if they had two.

It is really a great mystery; the most that any one can say is that the eggs are there, but something in the water, or the absence of something, stops their growing. Add sugar, salt, acid, or milt and they grow. In the case of the land animals, this something is probably in the blood—for as you know, the blood is salt like the sea, and in many other ways much like it.

At any rate, this is practically a most convenient arrangement. A mother bird, for example, is herself born with all the eggs she is ever going to lay already formed inside her. But something in her blood keeps those eggs from growing bigger than pin heads. They don’t grow into proper eggs, that can hatch into little birds, until the mother bird gets a mate to help her build the nest, and to feed the little birds when they come, and sometimes to feed her too. Then some of them do grow up and hatch; and the two old birds take care of them.

But as I said, it is all a very great mystery, which the wisest men do not yet completely understand, and little boys and girls can hardly expect to understand at all.

XII

Things That Do Not Have To Be Learned

So far in this book, we have been learning about the body. We know something about the wonderful life-jelly of which all living things are made—how it is itself the soft parts of plants and animals, and how it builds for itself the hard shell and bones and wood, which are its supports and its tools. We know, also, something about how each particular animal or plant or human being starts as a minute fleck of this life-jelly, grows to be, first a seed or an egg, and then a full grown animal, a man, or a tree. We know, too, something of the living bricks which build the bodies of living creatures; and something of the difference between young creatures and old ones. More than this, I trust, we have learned that all this curious information is not to be looked at merely as something interesting or amusing; but that like all the teachings of science, it is something that will help us to live wisely. For as we come to know, we ought also to learn to do; and while we are finding out something about living things, we ought also to be finding out something about living.

We have, I say, thus far been learning about our bodies. Now we shall turn to a still more important part of us, and try to learn something about our minds. Our bodies, we found, are very much indeed like the bodies of animals and even of plants. Perhaps we shall find that our minds also are like those of other living things. Perhaps we shall find them to be something very different indeed.

Most of us, I suppose, have seen at least one little baby. I don't mean a small baby merely, one that sits up in its carriage with a pillow behind its back, and smiles up at you when you look in under the hood. I mean a real little baby, a week or two old, that can't turn its head over on the pillow or put its hands anywhere in particular, and instead of being nice and pink, is as red as a little beet—for the little baby's skin is so very thin that it uses it to breath thru, to help out its poor little lungs, just as the frogs and other water creatures which have lungs breath thru the skin also. You know the size of baby I mean; if you haven't had any younger brothers and sisters, there must at least have been something like it in the next house.

Now there are several very strange facts about such little babies, of which by no means the least strange is this: If you take such a very weak and tiny creature, just able to move its arms and legs, and put a finger or a small stick across the palm of its hand, the little one will grip so hard that you will have no small difficulty in getting its fingers loose again. In fact, some babies will actually allow themselves to be lifted in this way; and will hang by their hands a minute or more before they will flop down again into a helpless heap.

So here is one thing that the wee baby can do better than he can when he gets to be older and a good deal stronger, and better sometimes than he will ever be able to do it again. It is something, too, that he did the first time he tried, didn't have to learn, didn't have to practice, didn't have to do anything but just be born knowing how. Pity we can't all get our geography lessons and our piano practice done this easy way!

There are not a few other things which we all did exactly right the first time, without ever being shown how, or practicing, or seeing anyone else. For instance, when we were very young indeed, and very small, about as young and small, in fact, as people ever get, somebody gave us our first drink of water. We were not a day old then; and we didn't even know enough to look at the same point with both eyes at once, but let them straggle off, one eye looking at one thing and the other at another, so that both got generally mixed up and couldn't make out much of anything. But we knew all about drinking. We shut our little mouths tight round the stopper of our bottle, and sucked away like little steam pumps. The water went down the front of our throats, crossed over to the back, and went into our thirsty tummies. Meanwhile, our breath went in at our noses, down into the back of our throats, crossed over to the front, and went down our wind-pipes. But tho wind and water had to go crosswise of the same passage, we never made a mistake, and opened or shut the wrong lid for the wrong fluid, so as to let the air into our stomachs or the water into our lungs. Which really, when you consider how young we were, and how this was the first drink we ever took, was decidedly clever of us.

An act of this sort, which we are born knowing how to do and do right the first time without ever practising or being taught, is called an instinct. Mighty handy, too, they are, these instincts. Think what would happen to a baby that didn't have the sucking instinct, and couldn't take a spoonful of water nor a drop of milk till somebody had explained about drinking and showed him how to swallow without letting it run down the wrong way. I don't believe there would be much chance of that baby's ever growing up. To be sure, the other instinct that makes the little baby grip so hard on one's finger, really, isn't any particular use to him in these days. Long, long ago, nevertheless, when our ancestors were wild men and only half human, the little baby had to cling to its mother when she ran thru the forest with the wild beasts chasing her. Then if the little baby couldn't hang on tight, it was pretty likely to get eaten up. But the babies that clung to their mothers, while their mothers were climbing a tree with both hands, and so couldn't hold on to them, these babies lived to grow up, and the memory of that far away time still lingers in each little baby's grip.

Some things are so important that one really has to know them. Did you ever think why girls like to play with dolls and boys do not? Why, on the other hand, boys can throw stones and girls cannot? Girls like to play with dolls, because when they grow up to be women and have real babies of their own, these babies have got to be dressed and fed and washed and tended and taken care of when they are sick. All this is very hard work indeed, about as hard and trying work as anybody ever has to do; so that if your own particular mama did not have a natural and instinctive love in her heart for all babies, she would not have jumped up at night every time you cried, no matter how cold and sleepy she was. If taking care of little babies were just plain work, to be done no better than other sorts of work are done, it would be pretty unpleasant for the babies. So women are made to love babies so much that even when they are little girls they like to play at taking care of doll babies, in default of real ones. But boys and men, they don't count; so they do not have this taking-care-of-babies-and-dolls instinct.

But the boys and men can throw things, because before the invention of guns (which really was not very long ago) and before men lived in cities and planted crops, about the only way to get anything to eat was to get out and throw something at an animal and kill it. Then, too, when there was a war (and this often used to be most of the time) the fighting had to be done with spears and swords, which had to be thrown, or else used to strike and thrust with, which is pretty much the same thing as throwing. So it happened that for ages upon ages before our ancestors became civilized, while the women stayed at home and took care of the children, the men went out and threw things. And that is why today, girls like to play with dolls, but boys like to hunt and fish; and why boys can throw stones, and girls can't.

Boys, then, are born with the throwing instinct. Throwing is as easy for them to learn as walking. But girls haven't it. For them learning to throw is as hard as learning to walk on the hands. So we see how both with walking and throwing, the inborn instinct makes learning easy, tho it does not altogether take the place of practice.

XIII

Why We Like Certain Things

We have seen that the reason why all proper little girls like to play at taking care of dolls is that their mothers, and their grandmothers, and their great-grandmothers, and their great-great-grandmothers, and all other sizes of grandmothers for a thousand generations, and after that for another thousand, and after that nobody knows how many more, have all been taking care of real babies, until anything that looks like a baby has become about the most interesting and precious thing there is. We have seen also that boys learn to throw things easily, and like to throw things because all the while that their many times great-grandmothers have been taking care of the children, their many times great-grandfathers have been throwing spears and javelins at other people's ancestors, or at things to eat running about on four legs.

Every proper boy likes to hunt and fish and camp out and play Indian because the most of mankind, up to a few centuries ago, have spent their entire time in hunting, fishing, living in huts, and generally playing Indians. Indians themselves, of course, play Indians all the time; and up to the beginning of the Christian era, our own ancestors, living in the wilds of northern Europe, were about as wild as Indians, and did little except play Indians all their lives. Who knows but that, a thousand years from now, after men have been civilized for a long while, and been getting their livings many years standing at benches or sitting at desks, all proper boys will think it great fun to study out of a book indoors? Perhaps they may; but I think it will be a long time first!

Every proper boy, too, when he gets old enough (and that is not so very old) likes to play at games. Now pretty much all these games, when you come to think of it, baseball, cricket, hockey, tennis, golf, I don't know how many more, all involve hitting a ball with a stick. If we like to throw balls with our hands because our wild forebears threw javelins and spears with theirs, can you not guess at once that the reason why we like to strike balls with sticks is that these same wild forebears had for so many ages been striking things with clubs and swords? We like what our ancestors had to do. If we cannot cut and thrust and hack and throw and strike at wild animals in the chase or at other men in battle, at least we can do it with a ball. So bat and ball are the boy's dolls. He plays with them for the same excellent reason that his sister plays with hers.

But why does every proper boy like to climb, and every proper girl too, if she has lived in the country and had a proper chance? About the first thing most of us did, as soon as we learned to creep, was to head for the nearest stairs, and try to climb up. When we get a little older, we cannot so much as set eyes on a fence or a shed roof without wanting to be on top of it; while as for trees, who of us, at a certain age, is satisfied until he has been to the top of every tree in the neighborhood. As for climbing mountains, that is one of the greatest games there is. So there is a climbing instinct in us, as well as a throwing instinct and a hit-something-with-a-bat instinct.

Now our wild ancestors who fished and hunted and played Indians for a living probably did not do much climbing. But long before their day we had certain still more ancient ancestors who were only half human and lived in the trees; and long before these, in turn, were still older ancestors who were not human at all, but regular apes who had hands in place of feet, and could climb like monkeys. These spent their lives in the trees; and in memory of them, each of us in turn, before he is quite old enough to play bat and ball games, is possessed to climb like a monkey, and climbs almost as surely and well.

Some people say, too, that the reason why a drowning person throws up his hands (the very worst thing he possibly could do under the circumstances) is that, being quite crazy with fear, he forgets completely his surroundings, remembers only the dim and far off time when the tree-folk escaped danger by climbing up out of the way, and reaches up for an imaginary branch which hasn't been there these many thousand years. Perhaps this is so; for my part, I believe it is. At any rate, there is the wonderful grip of the new-born babe. Where did he get it if not by climbing trees, or clinging to his mother when she fled with him thru the branches?

Some people say also that the reason why we like to play hide-and-seek is that our ape ancestors, and our half-human ancestors, and our wild ancestors, and our half civilized ancestors, down to considerably after the time when the school histories begin, have spent no small part of their days stealing softly upon their enemies and the wild creatures they were hunting for food, or else hiding all mousey quiet while some enemy or wild beast is hunting after them.

There are a few people even who say that the reason why we like to go in swimming (we do like it, do we not?) is that in some sort of dim way we remember a still more ancient forebear who lived all the time in the water, who in short, was a veritable fish and did nothing else but swim. I don't believe this myself. Not that we did not have such an ancestor—there doesn't seem to be much doubt about that. But it all happened so very, very long ago that it doesn't seem possible that there should be any trace of those days left. Still who can tell?

At any rate, we like to do a vast number of things that our forebears had to do whether they liked them or not; and if you can think of any other reason than this why you like baseball and hide-and-seek and climbing and dolls, I wish you would tell me.

XIV

Animals’ Games

Now that we know why boys play with balls and bats, and girls play with dolls, let us see if we can make out why kittens play with strings and puppies bark after wagons.

Perhaps you have already guessed. The grown up house cat and wild cat get a living all or in part by hunting birds and mice. They crouch close to the ground, creep slowly upon their prey; then seize it with a rush. That is just what the kitten does when you drag some small object slowly across the floor. The kitten doesn’t know why it chases a spool on a string. Really, however, it is playing at hunting small creatures, as its ancestors have hunted them in reality for a million generations.

Puppies are different from kittens. They don’t care much about spools and strings; but they like to run about over the fields and chew up their owner’s shoes. Now the wild dogs, and their cousins the wolves, do not go out alone and hunt small animals as the cats do. They go in packs; and they hunt large animals, wild sheep, wild oxen, deer, which they chase, sometimes, for days at a time. Spools and strings, therefore, are too small potatoes for the puppy; he chases wagons, automobiles and trolley cars, playing he is hunting big game. He doesn’t creep up cautiously on a ball of yarn, not to frighten it. Instead he barks at the top of his voice to call the rest of the pack. He runs away to play with other dogs, because the dogs and wolves are social animals; and when he chews up a rubber boot, he is playing that the pack has killed a moose and he is gnawing the great leg bone.

Of course, the puppy and the kitten do not know that they are playing at hunting when they chase spools and bark at carriages, any more than a boy knows why he likes to climb trees or hit a ball with a bat. But you can see for yourselves that the difference between the play of puppies and the play of kittens is just the difference between the work of a grown cat who hunts small creatures alone, and the work of a grown up dog who hunts large creatures in company.

Not many young creatures, such as we commonly see, do so much playing as puppies and kittens, tho boys and girls do a great deal more. In fact, the wiser any animal is when it grows up, and the more it is able to do then, the more playing it does, and the more interesting games it plays, when it is small. Calves and colts and lambs do not play especially interestingly, because wild cows and horses and sheep do not do much except eat, sleep, and run away from something that threatens to eat them up. But young squirrels, kept in cages, sometimes play at burying nuts in the floor of their cages for their winter supply of food; and young beavers, kept as pets in the house, have been said to play at building dams of chairs, canes, and umbrellas, across the parlor floor. Always, however, no matter how tame the grown animal is, the kitten plays at being a wild cat, and the puppy plays at being a wild dog, and the little boy plays at being a wild Indian; all because cats and dogs and men have been tamed and civilized for only a short while, but ran wild for ages.

There is one game that we all play, children, kittens, puppies, monkeys, and I don’t know how many other young creatures—and that is make-believe fights. We do it with sticks and snow balls and wooden swords; the little animals chase one another back and forth, and pretend to bite and scratch in the fiercest manner, as if they were fighting for their lives. Most animals do have to fight for their lives, many times over; so did most men in earlier times, before we had policemen and jails, and when everybody had to look out for himself.

Did you ever notice that a kitten is ticklish in just the same places that you are? You stroke the kitten's back or head or legs, and it is as pleased as can be. But you touch it along the front of the body, or around the front of the neck, and at once it begins to bite and scratch and protest its best. All creatures that can be tickled at all are ticklish in the same places; and all these places happen to be precisely the spots where the great blood vessels and other important vital organs are close to the surface, and where, therefore, a wound would be most deadly. So when little animals play at fighting and pretend to bite one another, they bite hard enough to tickle. They don't like to be tickled any more than you do. So they learn to protect those ticklish places in their play, and when they get to be grown up and fight in earnest, they have already learned not to get bitten in those spots where the bite would do most damage.

So the young animal's instinct is to play at doing whatever his ancestors have been doing for work; and he has this instinct in order that he may like to do when young what he must do when old; and so have practice in doing it, and learn to do it well. Unfortunately, as men become more and more civilized, they have continually to do more and more new things, while they still persist in liking to do the old ones. That, I suppose, is why some boys and girls do not like to work.

XV

Some Instincts of Chicks and Kittens

It certainly is a most fortunate circumstance that all animals are born with a natural instinct for doing the particular things which they will have to do to make a living in the world. It would certainly be most inconvenient if moles and rats had an instinct to fly, and birds wanted to hide in drains and cellars; if cows thought they must dive into the water to catch fish, and seals tried to come ashore and graze in the pastures. As it is, each creature has the particular set of instincts which make it want to do the things which it can do best.

You remember what I told you in first pages of this book about the little chick inside the egg. It lies quietly and grows, until it is twenty-one days old. On the twenty-first day of its fife, for the first time, the chick feels the instinct to peck. It has no idea why it wants to peck, nor what will happen if it does. He only knows that pecking against the inside of his shell is precisely the one thing that he wants to do. So he pecks away—until, presto! out he comes into a new and very much larger world.

By and by, after the chick has got rested and dried off, he staggers up on his legs, and begins to look around him. His eye catches some small object—peck! he goes again, and catches the bit in his mouth the first time he tries, unerringly. It took you weeks to learn to put your hand where you wanted it; in fact you couldn't so much as put your fingers in your mouth till you had tried many times. But the chick is born with the pecking instinct, and hits at the very first shot.

Yet the chick does not know what to peck at. He simply lets drive at whatever chances to catch his eye—a bit of gravel it may be, or something very nasty, or even a fleck of light on a blade of grass. What is good to eat and worth pecking at, he has to learn by trying just at you do. Neither does he know anything about drinking. In the course of time, as he goes about pecking at all sorts of things, he snaps at a dew drop on the grass or a sparkle of sun light on the water in his drinking vessel. So he gets his first drink; and in the course of time, he learns what water looks like.

Some day, perhaps, the chick will happen to walk into the water, not seeing any reason why one should not walk on water just as well as on land. Then he will think how very wet and unpleasant water is, and out he will scramble as fast as possible. But if the chick were a duck, tho he would not know anything more about water when he saw it than a chick does, yet as soon as he felt the water on his legs, that feeling would start up his swimming instinct, and away he would go, swimming the first time he tried as well as ever he will. Yet a duckling would sit on the edge of a pond till he grew up to be an old duck before ever the sight of the water would make him want to swim in it. The instinct starts up only when the duck gets its legs wet. Either a duckling or a chick would sit down beside a dish of water till they died of thirst, before they would try to drink, if they did not make a start by pecking at something in the water or on the bottom.

So you see the instinct does not tell the animal anything, it merely starts him to doing something, from which he can learn more for himself. It is just the same with us. We have an instinct to creep, and after that to walk; these take us about so that we can see things for ourselves. We have an instinct to climb; but we have to learn for ourselves how much a branch will bear, and the difference between poplar tree wood which will snap off and spill us out on our heads, and apple tree wood which will not.

So you see that what animals know by instinct is always how to do something. It may be how to swim, or how to fly, or how to build a nest, or how to bite some other creature in the neck. Usually it is some very simple act, that will simply give the creature a start in life.

Did you ever see a kitten play with a mouse? The kitten's instinct is to chase any small object which is moving away from it—spool, string, tail, ball, mouse, indifferently. The kitten sees the mouse and runs after it. But the kitten will not hurt the mouse as long as the mouse keeps still. You could put the mouse on the kitten's head and let it go to sleep there, and the kitten would never touch it, so long as the mouse did not try to run away. But the minute the mouse runs, away goes the kitten after it.

We say it is cruel of the kitten to torment the mouse as it does; to let the poor frightened mouse think it has a chance to get away, and when it tries to run, swooping down on it again. But the kitten isn't cruel. The kitten chases the mouse because it runs; plays with it a few moments; then forgets all about it till it starts to run again. But of course, the kitten is so large and rough compared with a mouse, that sooner or later it is pretty certain to scratch the little creature. Then for the first time, the kitten discovers that there is meat inside the mouse, and that what it thought only an amusing plaything is also good to eat. After that, the kitten becomes a mouser.

It is something the same way with a dog. His instinct is to pursue and bite large things that run away. If, therefore, you run from a dog, he will run after you; and having started running, he is pretty likely to bite. But if you pay no attention to the dog, move only slowly, and do nothing to start up his run-after-something-large-and-bite-it-in-the-legs instinct, the dog will bark, but will not touch you.

One might go on at considerable length describing one after another of the curious instincts of the various creatures we know. Many of these, however, you can see for yourselves, just by watching young animals, kittens, puppies, chicks, babies and the rest, and noticing what they do all of their own accord, without ever being taught.

Of all these curious instincts, I know of nothing more curious than the way in which the instincts of our common nesting birds play hide and seek with one another thru the changing seasons of the year. Each in turn comes to the fore, governs the birds' conduct for a few weeks, then dies down to give place to the next; but only to reappear once more in its proper place during the following year.

When our song birds come north in the spring, one of the first things they do is to pick out mates, and get to work building their nests. We may be very sure that no young bird, hatched out the year before and building her nest for the first time, has the remotest idea why she is building it. She finds a spot in thicket, hollow tree, or barn, which somehow looks right to her. Then she finds that bits of string, hair, moss, wood, and the like, which she has never bothered her head about before, suddenly become the most interesting and attractive things in the world, and before she knows it, she is building a nest; the same sort of nest that other birds of her sort are building, tho it may be that she was brought up as a pet in the house and has never seen a nest in her life before. When she is older, and has built a great many nests, she will perhaps build the least little bit better than she did the first time; but it will take a pretty sharp eye to tell the difference. The bird who has never seen a nest will always build the right size and kind at the first trial, and build it almost as well as she ever will.

By and by there are eggs in the nest. I don't suppose the bird knows how they got there, and I am quite sure she doesn't spend any time wondering about it. The thing she cares for now is to sit on those eggs; and the bits of string, hair, moss, and wood which once seemed so valuable interest her no more.

Still she has not the least idea what the eggs are for. She merely feels that her one desire is to settle down on top of them and sit there; just as you, my reader, at night when you are tired and sleepy, just plain want to lie down on something soft. A little later, and instead of wanting to sit quietly on her nest, the mother bird is possessed to rush round the country, picking up things to eat and stuffing them into hungry little mouths. She can not possibly know what it is all for. She just has a sort of hunger for feeding her babies, as at other times she has a hunger for feeding herself. But a few weeks later, she hasn't the slightest interest in these children of hers, doesn't know them by sight, and is just as likely to fight them away if they trouble her as if they were total strangers. The hurry-round-and-find-something-to-feed-the-babies instinct has served its purpose and gone back into cold storage. Another instinct is taking its place, and pretty soon the birds will be off for the south to spend the winter. Next year they will do the same thing right over again. But how much they remember of what happened the year before is just one of those things that I, among others, would give something to find out.

XVI

Certain Stupidities of Animals

It is a good idea for boys and girls to keep pets. Often it is rather hard on the pets; but the boys and girls get much happiness out of their animal companions, and they learn a great deal about the ways of animals besides.

Any of you who keep pets could, I have no doubt, tell me many wonderful tales of the extraordinary intelligence of these horses, dogs, cats, pigeons, cavies, mice, parrots, rabbits, squirrels, and what not, which, according to their nature, share our hearth rugs or our back yards. You who do not, have only to ask the man next door who keeps a horse or a dog, or the woman on the other side who has a cat or a parrot, to learn that animals are only just a little short of human, and if they could only talk, would soon prove, as we say, to "know more than most men."

Now there is no doubt that many animals are extraordinarily clever. I could easily fill this whole book with stories of their sagacity. At the same time, they are often extraordinarily ignorant, and sometimes extraordinarily stupid. And because you will always be hearing abundant stories of their cleverness, I am going to tell you sundry tales of their stupidity. Between the two, perhaps we shall strike a just balance.

Let me begin by telling about my own dog, a white and brown collie, whom I, in common with all owners of dogs, regard as uncommonly intelligent. When I tie the dog up, I use a light chain, one end of which runs on a long trolley wire fastened between the house and a tree. This, by the way, is a good way to tie a dog, for then he can run the length of his trolley wire and the length of his chain besides, and yet not have to drag much weight or tangle up a long chain. Very often, however, my dog, after running out beyond the tree as far as he can go, starts to come back again on the other side of the tree. Of course he can't do it, for the chain is fast about the trunk. Now what would you do, if you were tied up that way, and found that your trolley wouldn't work? I am sure you would look at once to see whether you had not got your chain twisted round the tree; and when you found you had, you would run round the other way and untwist it. Of course you would, and you wouldn't stop to think twice. But my silly dog has never caught the idea. When he first finds himself caught up short, he pulls and struggles. Then he sits down and howls for me. I go out and walk round the tree the other way. The dog follows me; and at once is free. I suppose I have done this in exactly the same way fifty times. Yet the foolish dog never has learned to do it for himself. And yet he is a wise dog—as dogs go. I suppose the reason is that his wild ancestors never were fastened up on trolleys, so there is no chain-untwisting instinct to start him learning.

Or perhaps you think monkeys are especially wise little creatures. Then consider this case: A man had a monkey, and was trying to find out exactly what it did know. So he used to put the monkey's food in a box, lock the door with a key, leave the key in the lock; and after many trials, taught the monkey to turn the key, open the door and get his food. Then he tried taking the key out of the lock and laying it down beside the door, to see whether the monkey would have sense enough to pick it up. But the monkey didn't. No matter how hungry he might be, he would simply stand and wait until the man picked up the key for him and put it in the lock. Then he would unlock the door as usual and get his dinner. Fifty times in succession the man picked up the key and put it in the lock, while the monkey stood two feet away and watched every movement—but the monkey never learned to do this simple act for himself.

Should you like to try for yourself an experiment that will show you how little the wisest animal understands? Then get a wide-mouthed bottle (a milk jar will do nicely), put in it a piece of fresh meat or fish; hold it above the head of a hungry cat so that she will see the food first thru the bottom; then set the bottle upright on the floor, and watch the cat try to get the morsel out. She will probably not go to work at all the way you would; and your way will be decidedly the better.

Cats suggest coons; and coons, like cats, are commonly thought to be especially clever little animals. So they are; but always with an animal's kind of cleverness, not our kind. Somebody who has been studying coons more carefully than they have ever been studied before, reports facts such as these: A coon is taught to open a box to get his food. The door of the box fastens with a bolt, and the coon has learned to pull the bolt and open the door as readily as you or I could do it. The bolt is now changed over to the other side of the door. The change completely baffles the coon, who has to learn his trick all over again, and that with almost as much difficulty as when he learned it the first time. Even coming up to the box from a different direction would throw the beast off, so that he would boggle a long while over a door which he had been unfastening with the greatest ease.

Another coon was given a food-box with a door fastened by a simple latch. The youngest child would have merely looked at the latch, lifted it with his hand, and taken his food. But it was too much for the coon. He scratched and scrambled and hunted all over the box; until in the violence of his efforts he fell off the top of the box and landed on his head. As he stood on his head in front of the box, pawing the air with all four legs at once, one hind foot chanced to catch on the latch, lifted it, and opened the door. So Mr. Coon got his dinner.

Next time he was hungry, what does he do but go and stand on his head in front of the box, and paw the air with his hind legs, till he hit the latch again, and got another dinner. In the course of half-a-dozen trials, the coon learned to put his paw in exactly the right place, and give just the right push to open the door at once. But all the time he continued to stand on his head to do it. It was not until the twenty-eighth attempt and the twenty-eighth dinner, that it occurred to the silly coon that he could lift the latch just as well standing right side up.

Still another student of animals has been testing rats. Now an old rat is proverbial for wisdom; they laugh at cats, and it is pretty nearly impossible to get them to go near a trap, unless they are nearly starved. Let's see, then, some things that a wise rat does not know.

Rats, of course, are used to running thru holes in the walls of houses, drain pipes, and the like, and are clever enough at finding their way in such places. So this man made a set of passages, such as a rat would naturally live in, and put seven rats in it. These soon became at home, and would find their way at once thru the maze of passages to the spot where their food was kept, running at full speed. Then the man took a long straight passage with a sharp turn at the end, and shortened it up by three feet. The next time the rats were put in, they all started pell-mell for their food; but when they came to the shortened passage, tho it was broad day light, every one of the rats ran smash against the end wall; and it actually took as long for them to learn that the length of the passage had been changed, as it took to learn the way round in the first place. But when the passage was made longer than before, the rats ran their customary distance to the place where the side opening used to be; then turned and butted into the side wall. This they did time after time, and even after they had learned to turn at the right point one day, they were just as likely to butt the wall the next. Really, they did not seem able to think about the matter at all.

But I am saving the strangest case for the last. This is about a cow. The cow used to make a great deal of fuss for her owner because she would not stand to be milked unless she were allowed all the while to lick her calf. One day the calf died; then there was much trouble, and no milk at all. But the farmer understood the ways of cows. He took the calf's skin, stuffed it with hay, and gave the mother that to lick at milking time. To be sure, the stuffed calf had neither head nor legs and didn't look the least bit like a calf—but it was all right to lick, and the mother cow licked it contentedly and gave down her milk as before. One day, when the tender parent was caressing her little calf at milking time, she happened to unrip the seam where the skin was sewed up. The hay fell out; and the mother cow, without the slightest surprise or agitation, proceeded to devour the unexpected provender, and never left off until the little hay calf had entirely disappeared down her throat.

I understand that this practice of giving a cow the stuffed skin of its calf is the regular thing in some countries, where the cattle are wilder than with us. I am told also that a like device has to be employed with camels. Each camel refuses to be milked, unless she can have her little one to lick. But the natives are accustomed to kill and eat the little camel, and give the mother its skin. This answers exactly as well; but if they try to palm off another skin on her, she knows the difference at once. Out of a hundred living camel-calves or their stuffed skins, the mother camel will always pick her own, and never be content with any other. Yet she doesn't bother her head over the difference between her live calf, and its dead skin lacking legs and head, with the hay stuffing sticking out of the seams! Truly, animals are as stupid about some matters as they are wise about others.

XVII

How We Differ From The Animals

How do we differ from all other living creatures? Not in having hands; the monkeys have four hands, and if hands were the test of humanity, would be twice as human as we. Not in lacking coats of fur or features; pigs and elephants have skins as bare as ours. Nor is it that we walk on two legs; the birds do that, and the kangaroos. The difference is not even in the fact that we have no tails; for some of the apes also are as tailless as we are. Besides, when you come to think of it, most animals do not have tails—insects do not, nor clams and oysters, nor sea-anemones and star-fish, nor corals and sponges, nor frogs and toads, nor jelly-fish; even the birds, unless you count the feathers as part, do not have tails that one could really wag.

After all, too, we human beings do have tails; or at least a string of tail bones, an inch or more long, tucked away inside our skins. This coccyx bone, as it is called, is the place where it hurts so fearsomely when you sit down too hard on a pebble or a bicycle bar, and it catches you in one little spot just at the end of the back bone. When that happens, you may remember that the difference between you and the animals is not altogether in tail bones. Once in a while, too, men do have veritable tails, as large as a finger, and round and curly like a pig's.

The one essential difference between ourselves and all other creatures on the earth is neither in hands nor skins nor legs nor tails, but in talking. We can talk and the animals cannot.

But you say right off, parrots can talk. Oh, no, they can't! Parrots can speak, in the sense that they can say words; but that is a quite different thing from talking. Dumb people, tho they cannot speak, have no difficulty in learning to talk with their fingers. The parrot can be taught to repeat words, whole sentences, even pieces of poetry—but no parrot ever learns to talk about the things that he is interested in. No parrot, for example, ever tries to tell about the forest where he was born, nor his voyage to this country, nor the animals he met in the store before he was bought. He, says "Polly wants a cracker"; but he doesn't say, "I want to get out of this cage and fly about"; and no two parrots ever yet tried to converse with one another.

How different it is with children. They try to talk long before they can. They pick up words for themselves. They talk with one another; and when they don't know the word for something they want to say, they make one up. Don't you remember various words that you and your playmates invented, that other people do not know the meaning of? In short, we human beings have a talking instinct; just as birds have a nest-building instinct, and squirrels an instinct for hiding nuts in the ground.

So if we should take a lot of robin's eggs, hatch them out in an incubator, feed the little birds by hand and never let them see a grown up bird or a nest, there is no doubt that when the proper time came they would sing, build nests, and take care of their young, much as if they had been brought up by their parents in the usual manner. In the same way, if we should take a lot of tiny babies and bring them up where they never heard a word of speech, there is little doubt that when it became time for them to talk, they would invent for themselves a language to talk with. Indeed, some people think that the reason why there are so many different languages in the world, hundreds and hundreds as there are, is because at various times children have been lost, or all the old people of a tribe have died, and the children having no one to teach them their parents' tongue, have had to make up a new language for themselves.

But no animal could possibly do this. Whether because they lack this strange talking instinct, or because they simply haven't anything in particular that they want to say, no group of animals has ever invented a language, nor has any single animal ever learned to talk our human speech. A parrot can utter words; a dog can understand them. But somehow no creature except ourselves ever puts the two together, and talks.

I don't think we ever half realize what an advantage this being able to talk is to us, nor how utterly helpless we should be without it. Suppose for example you are lost in a strange city. You stop the first passerby, and you say "I want to find such and such a street." "So many blocks up or down," he answers, "so many to the right or left"; and with one or two more simple questions from time to time, there you are right on your doorstep.

But suppose your dog gets lost. He can not stop the next dog or man he sees and say, "I belong to Mr. So-and-so on Such-and-such Street; tell me how to get home." All he can do is to look up into some one's face and whine; and that may mean equally well, "lam lost," or "I am hungry," or "I want a drink," or "The little boy that owns me has gone into that house and I wish he'd hurry up and come out," or "I don't like the place where I am living because there is a horrid cat there that scratches me on the nose, and I wish I could go home and live with you instead," or "I know you have been in a meat market, because I can smell the nice smell of the fresh meat, and I wish I were going to have some for my dinner in place of dog biscuit which I don't like."

All these ideas, and forty others like them, the dog would have to express in precisely the same way, and leave to his hearer to guess which one he might happen to mean this particular time. In fact, about all the ideas that a dog can express are, "I want something that I haven't got," "I am afraid I'm going to get something I don't want," and "If somebody doesn't look out, there's going to be a very dickens of a row here in about a minute." What he may think beyond these simple matters he has pretty much to keep to himself.

And did you ever think how extremely difficult it would be to learn anything, lacking words to learn it with? You can tell the capitals of the United States, or the chief rivers of Asia, or the kings of England, because somebody who knew has told somebody else, and he somebody else, until the information has at length filtered down to you. Whatever you do not know and want to know, you can find out from somebody who does know, either by asking directly or by looking in a book where somebody has written it down. But a dog can find out things only by seeing them for himself, and when he does find them out, he has no way of telling any other dog anything about them.

No wonder that cow I was telling you about a short while ago was not in the least surprised when her calf ripped apart and the hay fell out. Why should she not think that all calves are stuffed with hay, and are expected sooner or later to rip apart and provide hay for their mammas' supper? She has no way of finding out what calves are made of inside. If you wanted to know, you would ask. She couldn't.

I suppose a child going to school and asking questions at home and getting them answered, as every child should, learns at least a hundred times as fast as any animal can possibly learn. I suppose too that a dog or cat, living in one place and doing about the same things every day, learns in a year or two all that there is to be known about his particular world, and so finds out nothing more all the rest of his life. You learn for lessons something new every day, you see new people, and visit new places, you have new things to eat, and new clothes. But the animals always have the same clothes, and the same things to eat. Most of them do not travel; if they do sometimes make new friends, the new friends cannot tell them anything. Think, then, how ignorant must be the rabbit shut up in one pen, the cow confined to one pasture, the parrot always in the same cage. They do the same things day after day; in a week they have learned all there is to be known.

Of course, an animal cannot tell time nor count; for telling time and counting require words. He cannot give names to anything, nor remember anything by name, nor think about anything in words. Indeed, it is pretty difficult, without words, to do any thinking at all. We can learn, think, remember, plan, contrive, teach, ask questions, answer them, because we have words to work with. The animals have no words. Therefore, the wisest of them is like a child of four.

XVIII

Something More About Speech and Thinking

We say commonly that we think with our brains. That is true; but it is by no means the whole story. The brain has two halves, just alike, exactly as the body has. In fact, the two sides of the brain are even more precisely alike than the two hands.

Nevertheless, we do all our thinking with one side only. If we are naturally right-handed persons, we do our thinking on the left side of the head. If we are naturally left-handed, we do our thinking on the right side. But we do not use both sides. Each half of the brain governs the muscles of one side of the body; but the thinking is done with one side only.

This very peculiar state of affairs is in some way or other connected with our power of speech. The animals, who cannot use words, do their thinking, so far as we know, equally on both sides of their heads; and we have every reason to believe that if we did not talk, we too should do our thinking with both sides.

Let us see if we cannot in part make out the reason for this arrangement. Let us suppose you are using your mouth and tongue, not to talk with, but to eat your breakfast. Each half of the brain, as I have said, controls the muscles on one side of the body; and as I dare say you have long ago been taught in school, a set of long nerve fibers, like so many telephone lines, connects each muscle with the proper region of the outer surface of the brain. You are, we are supposing, at breakfast, and you take a bite of bread and butter. At once, the two halves of the tongue telephone by way of the nerves, each to its own side of the brain, "Something good to eat, shall we chew and swallow?" Then each half-brain telephones back, "Message received, stand by to chew, on signal; will call up other side." Then each side of the head rings up the other side and says, "Bread and butter reported in my half the mouth; shall chew at once. Are you ready to start? Go!" And away go the two sides of the face working together.

Now of course I do not mean to say that this is literally what occurs every time you attempt to do anything that requires both sides of the body to act together. Nevertheless, something like this really does happen. You know how a tiny baby cannot even look at the same point with both eyes at once, but sends them straddling off, one looking one way, the other another. It takes some days for the two halves of the baby's brain to learn to consult one another, and to handle their two eyes in co-operation. So with any act that uses two hands, or two feet, or a hand on one side of the body and a foot on the other. The two halves of the brain have to call across to one another, along certain nerve fibers which run back and forth between the two, in order that the actions of the two sides of the body may keep together. You can easily see that if one side of the brain tried to open its side of the mouth, while the other side was trying to shut its, you would probably have to start for school without your breakfast.

Naturally, after the two brain halves have been living together for a few years, growing up together in the same house, they learn to work almost like one. Still this signaling back and forth does take time. So long as we are merely eating, or walking, or shoveling snow, the process goes on fast enough. But talking is a different matter. When you are talking thirteen to the dozen, just as fast as you can chatter, every several letter of every single word you utter demands at least one change of position of tongue or lips or throat, and generally of them all.

What would happen if the two halves of the brain had to stop to call one another up and say, "Now I am on the point of starting to say 't' with my half of the mouth. Are you ready with yours?" "Now I am going to tuck on an 'h.' Are you ready with your side?" "Now go ahead with the 'e.' Start." It wouldn't do at all. It's altogether too slow a way to get talking done. So by way of saving time, one side of the brain has taken entire charge of the talking; for this, one side only of the brain runs both sides of the mouth.

When we eat, then, both sides of the brain are in action. But when we use the very same muscles for speaking, then we use one side of the brain only. When we lift a weight with both hands, we signal to the muscles from both halves of the brain. But when we play the piano with both hands, the same side of the brain takes charge of both. I am, for example, using a type-writer, and writing with both hands. Only one half of my brain, however, has charge of the writing. The other half simply side-tracks itself, stands aside, and doesn't meddle. But the minute I stop writing and start to put my machine in its case, then the other half-brain switches on again, and takes care of its side. If I should hurt my right hand, so that I had to do all my writing with the left, the writing side of my brain would still do all the writing, while the other side that commonly manages my left hand would stand and look on. All these very special, complex, rapid and difficult tasks, like talking, writing, playing the piano, or running the type-writer, are done by one side of the brain. The slow and easy things are done by both.

But the animals, who do not either talk or write or play musical instruments, they use the two sides of their brains alike.

XIX

Why Most Of Us Are Right-Handed

We do our talking with one side of the brain only. But talking is somewhat intimately connected with thinking. We ought to always, we generally do, think before we speak; while much of our thinking, and on the whole the most important part, consists in saying over words to ourselves.

Speech and thinking, then, go so often together, that it becomes a great convenience to get the thinking done also on one side of the head only, and on the same side with the speech. It might have been either side; it did happen to be the left. One cannot say why, any more than why the heart should be on the left side and the liver on the right, or why some snail shells curl one way and some the other. But at any rate it is the left side.

Now I don’t know whether you have yet been taught in your school physiology, if you have not yet you will be shortly, that the nerves which run from the brain to various parts of the body, cross over to the other side from the one on which they start. Thus the right side of the brain controls the left side of the body; while the left side of the brain controls the right side of the body.

But if the thinking is all done on the left side of the head, which hand will act more quickly on the thought? Evidently, the right hand; messages for that hand travel directly along the nerves, crossing sides once. Therefore we are right-handed.

Some people, however, are born with the “speech center,” as it is called, on the right side of the head instead of on the left. For such persons the most direct path is to the left hand. These persons, then, are naturally left-handed. The difference, therefore, between a right-handed and a left-handed person is not so much in the side of the body with which they have learned to act, as in the side of the brain with which they have learned to think. But the animals, who think on both sides alike, also use either forefoot equally well, and are neither right nor left-handed.

This talking on one side of the brain has another curious result. Did you ever stop to think why a right-handed batter stands with his left side to the ball? Or why a driver of a horse sits on the right hand end of the seat? Or why the engineer of a locomotive sits on the right side of the cab, altho this position forces him to use his left hand for the throttle valve? Or why you sight a gun or look thru a spy-glass with the right eye? Or why you draw a bow with the right hand on the string?

It is all on account of this same one-sided speech center. This has made us right-handed; it has also made us right-eyed. We think much in words; but we also think much about how things look. We think most quickly concerning messages which come in on the thinking side of the brain; and those are from the right eye, since the eye nerves, like those from the hand, cross sides on the way. So hand and eye and speech and thought all use the same side of the head; and sight and thought and action follow one another most easily. Being then right-eyed, we stand to bat, or sit to drive, or use gun or bow or telescope, in the way which gives the better sight to the better eye. But of course, naturally left-handed people are also naturally left-eyed.

Some people, however, are as we say, ambidextrous; that is, they use both hands about equally well, just as all animals do. Nobody, however, is ever naturally ambidextrous. Sometimes the ambidexters are people who have hurt the right hand, and had to learn to use the left. More often they are persons naturally left-handed who have been taught to use the right hand more than is natural in an effort to make them right-handed, tho of course they really are just as left-handed at ever, since no use of the other hand will change over the speech center. But some ambidexters, oddly enough, are made so by an injury to the sight of the right eye, if they were right-handed to begin with, or to the left eye if they were left-handed. Hand and eye have so often to work together and work quickly, that one tends to use the hand on the side of the better eye, even when that is the wrong side.

At any rate, tho it is an excellent plan to learn to do all heavy work equally well on either side of the body and with either hand, fine work and quick work and thinking work had better be done with the hand that does it most naturally. This keeps writing, thinking, speaking, memory, and the rest all close together, on one side of the head, handy to one another, instead of scattering them about, some on the wrong side of the body, some on the right.

XX

Where We Do Our Thinking

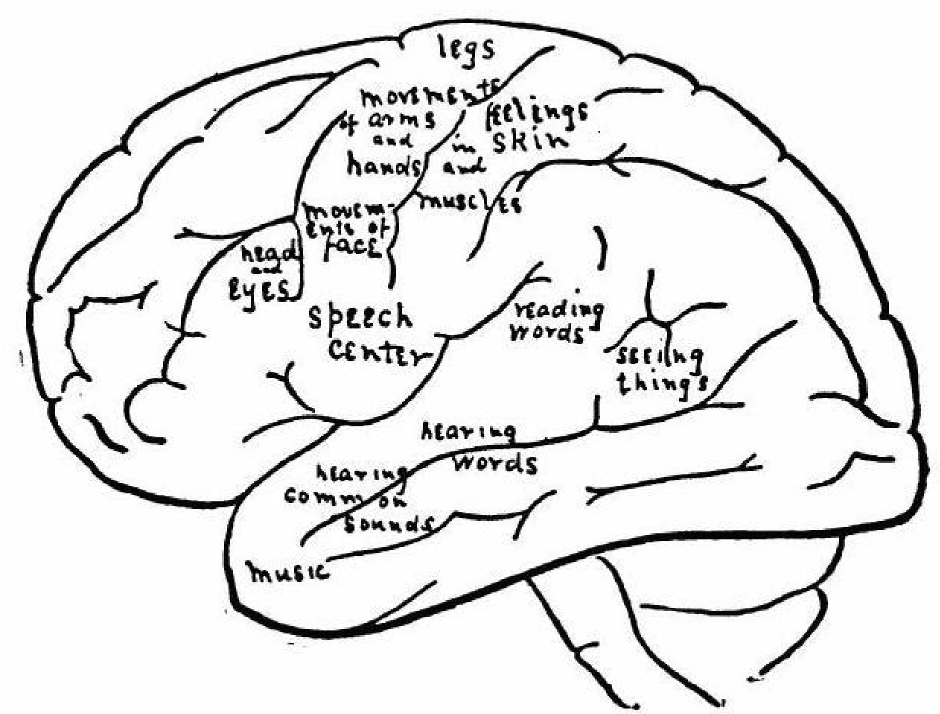
We think only on the left side of our heads—that is easy to say if we are normal right-handed persons. If for any reason we have got to thinking on the right side, that will, as I have explained, usually result in making us left-handed.

Yet we do not use the whole of even one side of the brain. So far as is known, we do not think at all with the front part of the head. All our speaking and most of our thinking are done from a spot hardly larger than a cart-wheel dollar, which lies on the side of the head just above the left ear. At any rate, an injury to this particular part of our brain puts a sudden stop to our ability to think and speak.

When you put your left elbow on the table and lean your head on your hand, your hand just about covers the only portion of the brain with which you ever do any thinking at all; while only with the part that lies directly under the middle of the palm, and is as I have said, about the size of a silver dollar, do you ordinarily think very much or hard. This thinking part of the brain lies on the outside, and is just about as thick thru as the hand is.

But even this small thinking place in the brain is not all alike. Directly over the ear, a place that you can almost cover with your thumb, lies the most important part of all, the place where we remember and handle words. At the bottom of this word spot, we remember how words sound. An inch farther up and toward the back, we remember how words look in print. A little farther up and forward lies the "speech center," from which, when we want to talk, we direct the tongue and lips what to say. Thus we get our word-hearing, our word-seeing, and our word-speaking centers close together, so that when we speak we have close by and handy our memory of what we have heard in words, and of what we have read.

Just below the place where we remember words, and a little forward of it, lies the place where we remember other sounds which are not words, such as the noises of bells and whistles, barking of dogs, mewing of cats, all buzzings and creakings and gratings and crashings, all laughing and crying. Every kind of sound which isn't either words or music is recognized and remembered here. Beyond this spot, still farther forward and down, and just above the rear end of the cheek-bone, is the place where we remember music. If we don’t know anything about music, and can’t tell Yankee Doodle from Old Hundred, then we don’t use this part of our brains at all. But if we do know one tune from another, and know a good many to recognize them when we hear them, here is where we do the knowing.



A right-handed person has all his thinking spots on the left side of his brain.

Back of the word-seeing part of the thinking spot, and reaching pretty well round to the back of the head, lies the place where we remember everything we see, except words written or in print. Above the word-speaking part of the brain, or speech center, from which we control the mouth, throat, lips, and tongue, which we use in speaking, lie the various points from which we manage other parts of the body. As you might expect, next the speech center lies the center for the rest of the face and for the head and eyes. Above that comes the center for the hand and arm. Still higher up, right on the top of the head, comes the center for the legs. So whenever we do anything with any part of the body, we have to signal the proper muscles from the part of the brain that lies between the tip of the ear and the top of the head. Close behind this region is the spot where we feel everything that touches the skin; so that we can make the movement and feel the results most handily.

So as you see, the surface of the brain is a sort of map or chart of the entire body. Every muscle, every point on the skin, the eyes, the ears, the nose, the tongue, every several organ which we possess, has its own special spot on the surface of the brain, somewhere above or behind the ear. Each half of the body is charted on one side of the brain, a spot in one for each spot in the other. But we who have to use these brains to think and remember with, as well as to see and hear and feel with, and to control our muscles, have chosen to do this thinking and remembering with the spot on the left side of the head which corresponds to the muscles of the lips and mouth and tongue, and to the eyes and ears and the right hand. Thus we have everything convenient, all in one small spot on one side of our heads, where we can get at everything with the least trouble. But what the front part of the brain is for, is something that nobody knows much about.

Certain very strange results follow from this practice of ours of using only one side of the brain to think, remember, and speak with; and using different parts of that for thinking and remembering about different sorts of things. Once upon a time there was a workman who was hit hard enough to break his skull, on the left side of his head, pretty well round toward the back, and just over the spot where, as I have explained, are stored up all the memories of things seen. He seemed not seriously hurt; but when his wife came to see him at the hospital, he did not know her. Neither did he know his children nor his friends. In fact, he didn't even know that they were human beings. He had absolutely lost the memory of everything that he had ever seen.

But the minute his wife spoke he knew her at once. Or if he could feel of any familiar thing he knew what it was. All the while, he could see perfectly well. His eyesight remained as good as ever, he simply couldn't remember that he had ever seen things before. The plain seeing, he could do with either side of his head; and the left side being hurt, he did it with the other. But the remembering that he had seen the same thing before, he did with the left side only; and when he could no more do it with that, he could not do it at all. Yet his memory for sounds and the feeling of things was just as good as ever; because the places where he did these sorts of remembering were not under the place where he got hit. And the moment the doctors lifted out the splinter of bone that was pressing on his seeing-things spot, then he remembered wife, children, friends, everything as before.

Here is another case, much like the first, and yet curiously different: An educated woman, somewhat well along in years, went to bed at night in ordinary health. During the night, however, a small blood-vessel burst and formed a tiny blood blister on the left side of her brain, about an inch in front of the spot where, as I have been telling, the workman was hit who couldn't remember his wife when he saw her. She had, in short, a sort of internal black eye, just on the spot that she had been using for sixty years and more to remember written and printed words.

She woke up in the morning, therefore, totally unable to read a single word. She could see as well as ever, understand perfectly every word said to her, speak and write without the least difficulty—but she simply could not read. Give her a printed book, she could count the letters in every word, draw them on paper, tell which were tall, short, round, or square, see them in fact just as well as before—but she no longer knew what they meant. It was exactly as if she had never learned to read at all; and being much too old to learn again, she never read another word as long as she lived.

There is another accident which is so little uncommon that probably every one who reads this book will some time in his life see an example of it. This is a case where a blood vessel bursts on the left side of the brain and wrecks the speech center. The person to whom this happens, immediately forgets how to talk. If the blood clot is small, so it presses upon the speech center and nothing else, the victim of this sort of accident can read and write as before, and understand all that is said to him. Oddly enough, too, he can make any sound that he ever could, and repeat parrot-like any words that he hears. But he cannot remember the meaning of words. He is precisely like a man suddenly transported to a foreign country where they speak a language which he never heard. His own language has become to him like Chinese.

Strange indeed are the freaks of these accidents to the left side of the head above the left ear. One man, a musician, finds that while he can hear music as before, he hears it only as noise, and no longer recognizes it as tunes. He has been hit low down on the side over the spot where he keeps his music memory. Another, hurt a little higher up, can hear noises as before, but cannot tell a factory whistle from a church bell. Not that they sound alike; but he has forgotten which is which. Occasionally, a watch-maker, engraver, or other skilled artisan, will get an injury well up on the side of his head at the place from which he manages his right hand. Then he loses all his special skill of hand. He can still use his right hand for ordinary acts, dressing, eating, shoveling coal; but the power of doing thinking-things is gone. He has become like a day laborer who has never learned a skilled trade.

There is a strange case of a business man who got a blood clot just over his word-thinking spot, but toward the upper side so that while it ruined his speech center and the place where he kept his memory for the look of printed words, his memory for the sound of words escaped. He could neither read nor write, nor speak a word; but he could understand what was said to him. Curiously enough, he could handle figures as well as ever, for the figure-remembering spot and the figure-writing spot had escaped. So for seven years this man kept on with his business. Every letter had to be read to him; and all he could do in answer was to write down figures and point to them. Meanwhile, he took lessons most diligently, trying to learn to write and speak with the other side of his brain. But it was no use.

There was also a learned man, who in addition to his native language, which was English, knew Greek, Latin, and French, and could besides read music. After his accident, he could read his native English only with the greatest difficulty, about like a child of six or eight who can make out easy words, slowly; while writing, he could scarcely read at all. French, he could read much better; as well, say, as a high school graduate. Latin he could handle pretty well; about like a boy just out of college. But Greek and music he could read and write exactly as well as he ever could. The accident, which had pretty well spoiled the place where he remembered his native language, had only damaged the spot where he remembered his French, had hardly touched the place where he remembered his Latin, and had missed entirely the place where he kept his memory of music and Greek.

You understand, of course, that when one of these very same accidents occurs to a left-handed person, no matter how much it damages his head on the left side, it does not destroy his speech or memory. Or if the same thing happens to a right-handed person, on the right side of the head, his speech and memory do not suffer. The hurt has to be on the thinking side in order to affect the thinking.

When little children are hurt in these ways, at first they suffer loss of speech or memory just as men and women do. But little children, as I have already explained, are not hard and set like grown up people. They can start over again, and learn to think, speak, and remember with the other halves of their brains. But as soon as any one gets too old and stiff to learn anything new, then he is too old to learn an old thing over again on the other side.

Do you see now why you have to go to school five hours a day, and sit on a hard seat studying still harder lessons, when you would much rather sneak off and go in swimming? It is so that you may build up these thinking spots in your brains. We are born with brains like the animals, alike on both sides. Only slowly, painfully, with much hard and disagreeable work, that we had a great deal rather not do, do we manufacture a one-sided human brain. We begin young, while the brain is still growing. With years and years of work and study, we slowly form the thinking spots over our left ears, which we are to use the rest of our days. When we are grown up, we can no more form new thinking places on one side of our heads, than we can form new thinking places on the other side, after the old ones have been destroyed. The business man who lost his ability to read, never learned to read again, tho he worked at it six years, harder than any child ever studied. If he had put off learning to read till his old age, he could never have learned at all.

It does seem a long time that we sit on a piano stool doing our daily practicing, and mighty little fun. Let us then remember that all the while, we are making a time, tune, and harmony remembering place just back of the left temple, and tying it up with the spot farther up on the side of head from which we manage our hands and fingers. It is slow work; but when once we get the job done, we shall be able to enjoy and remember music with it for the rest of our lives—forty, fifty, sixty years. Surely, this is cheap enough at the price of a little daily practicing.

It really is a good deal as if we were born like a dog or a horse, with head, body, and legs, but no hands, and had to make our hands for ourselves. How we should work in such a case, building our fingers, shaping our thumbs, and in every way getting the best possible sort of hands to use thereafter. And what should we think of any careless child who left off a finger or two, or was too lazy to put on a proper thumb, and so had to be deformed and crippled all the rest of his life.

But the thing which makes us different from dogs and horses, isn't half so much our hands, as it is the spot of brain substance which we build for ourselves over our left ears.

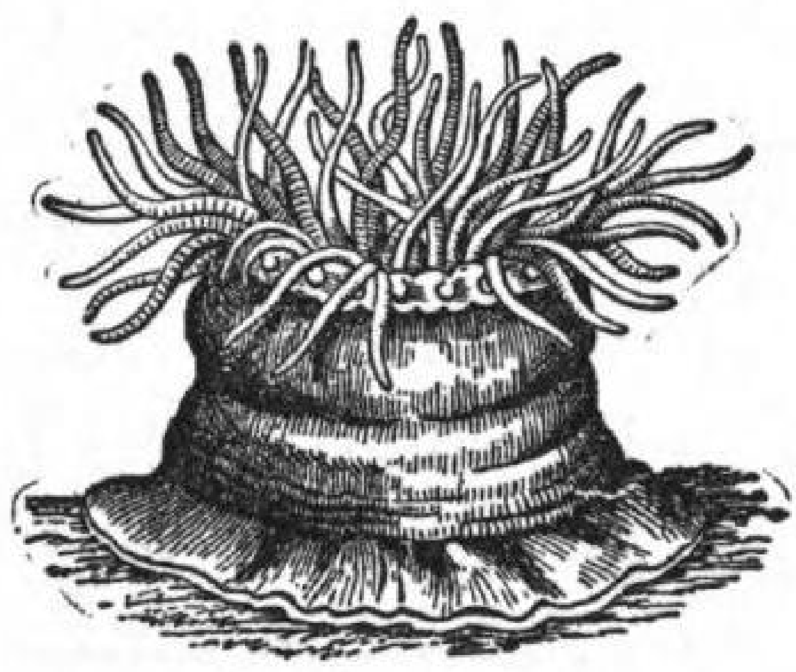
This spot looks like the corresponding spot on the other side. But somehow or other, nobody knows just how, our work and study and trying hard make that particular patch more important for us than anything else in our whole bodies. If we fail to build good thinking spots while we are young, we shall be deformed and crippled for the rest of our lives.

XXI

Where Some Of The Animals Do Their Thinking

It really is a great advantage to us to bring all our thinking into one small spot, where everything is handy to everything else. It is, in fact, almost like the convenient little kitchens they have on railway dining cars, where the cook can reach every dish and pan and kettle, cupboard, stove, refrigerator, coal-bin, pantry, china closet, and all, without shifting his feet or hardly even turning round. If you want to understand how great this advantage is, consider the case of some animals who not only have no words to think with, but in addition, do their remembering and thinking, such little as they do, at several different places or all over their bodies.

There, for example, is the sea-anemone, such as one finds at the sea side, in the salt water pools, after the tide has gone out. Beautiful creatures they are, set solidly on thick muscular bodies, and pushing out their long pink or yellow tentacles, a dozen or twenty of them, sometimes, like the petals of a daisy. Only you must be careful not to alarm this animal flower. If you do, sometimes if you so much as let your shadow fall across him, in an instant he will pull in those pretty tentacle-petals, and turn to a lump of tough jelly, almost as hard, and not much more interesting, than half a rubber ball; and there you will have to sit and wait and wait for something to happen, only it never does, until somebody makes you come in and change your shoes.



A sea-anemone.

However, if you are careful, you can begin to feed this animal flower with bits of meat or fish. Drop a morsel cautiously on one of the tentacles, and he will reach out with the tentacles near by and roll the food slowly over and over, until finally, with much difficulty, he will get it into the center of the disk where his mouth is. Then he will slowly open his mouth and work it in. In short, the tentacles are the sea-anemone's hands and fingers; but he feeds himself clumsily enough, and cannot make any movement quickly or certainly, except shutting up when he is frightened.

If you think you can fool the little animal by feeding him with pieces of shell, or wood, or pebbles, or anything that is not food, you will soon find out that he is wiser than he looks. These things, which he cannot eat, he simply lets fall off his tentacles to the ground. But real food he will eat and eat and eat, till he swells up and up and up, and you think he is going to burst, only he never does; and in time, if you do not get tired feeding him first, he will take the food more and more slowly, and finally will refuse it altogether.

Now if instead of feeding the sea-anemone with pieces of meat, you press the meat against blotting paper so that the paper soaks up the juice, and then feed the creature, sometimes with real meat, sometimes with blotting paper and meat taste, at first he will swallow both with equal avidity, not knowing apparently the difference. After a half dozen trials, however, he will begin to take in the blotting paper somewhat less rapidly than the meat. He will continue to take the paper with more and more hesitation until after some twenty trials or so, while he swallows the meat as before, he will refuse to take the paper at all. He has learned the difference.

All this time, you must have taken pains to offer the real food or the imitation to the same tentacle, so that the same fingers shall have stuffed the morsel into the mouth. If now, after the polyp has thoroly learned the difference between meat and paper, on one side of his mouth, you try feeding him in the same way on the other side, you will discover that the new side knows nothing whatever about what has been happening on the other. The anemone which has learned to take meat and leave paper on one half of his body, still takes them both on the other half, and it will take just as long to teach the difference to the second side as it has already taken to teach it to the first.

The reason for this peculiar behavior is simple. The sea-anemone, instead of doing the remembering for his whole body, all in one spot, as we do, spreads it out over a ring of brain which circles the mouth, between the mouth and the base of the tentacles. He does the remembering for each tentacle close to the base of the tentacle itself. Each therefore remembers something of what has happened to itself, something less of what has happened to its next neighbor, still less of those beyond, and almost nothing at all of what has happened to the tentacles clear over on the other side, a whole inch away.

Even that much remembering, however, the tentacle-brain does not do especially well. After the animal has learned his paper-meat lesson thoroly one day, and can tell the difference straight off every time, the next day he has as thoroly forgotten it. If he learns it once more on the second day, he will as completely have unlearned it again on the third, and will swallow paper and meat with equal zest.

So much then for animals who do their thinking in rings instead of in spots. Now we shall see what happens to a creature who tries to do his thinking all over his body.

I have already mentioned the infusoria which swarm by the thousands in the water of ditches and puddles. They are decidedly small animals, the largest of them no bigger than a pin head; and as I explained before, they are remarkable in that each infusorian is just one single cell. Most of them are free-swimming, that is, they go about as they like thru the water as a fish does; but some grow on stalks like flowers, tho even these can usually let go their anchorage and float away to a new station.

More common infusorians, much enlarged.

Small as they are, they feed on still smaller plants, the bacteria. Nevertheless, they do not know their food either by sight, hearing, taste, or smell. One hungry infusorian, looking about in search of his dinner, will pass right by a mass of bacteria large enough to feed him the rest of his life and not notice it. He will swim so close as almost to graze the feeding ground, yet keep straight along without turning or pausing, as if it were not there. The next instant, he may run against some small particle which isn't good to eat at all, and swallow it down forthwith. In fact, the infusorian simply swallows whatever happens to hit his mouth. If this happens to be good to eat, why so much the better. If it happens to be only a grain of dust or a fleck of shell, down it goes just the same; the infusorian doesn't know the difference.

When the infusorian, swimming straight ahead, runs into some obstacle too large to swallow, it stops, backs off, turns a little to one side, and goes ahead again. But he never takes any pains to turn toward the side which will do the most good, or to notice whether he turns enough to do any good at all. He is just as likely, having run against the extreme end of some object, to turn exactly the wrong way, so that he hits it next time fairly in the middle. Then he backs off once more, turns again, and swims ahead. Perhaps this takes him by; perhaps he butts the obstruction again at the spot where he struck it first. Then he tries again, and yet again, and in the course of time, usually manages to get by.

So the infusorian is a funny little machine, made so that when it hits anything it backs off, turns somewhat, and goes ahead again. If one is very clever with his fingers, as men who study creatures such as these have to be, one can take a slender needle and touch the infusorian on the front end—we cannot call it the head. Thereupon he stops, backs, turns, and goes ahead. Touch him on his side. Again he stops backs, turns, and goes ahead. Prick him from behind. Once more, he stops, backs—right on to the needle which is pricking him—turns, and goes ahead. Try heating the water. As soon as the infusorian feels uncomfortably warm, he stops, backs, turns, goes ahead. Try cooling it. The same process. Add to the water something that the creature notices, acid for example. Still the same old stop, back, turn, go ahead; tho often the next go-ahead sends him straight into the drop of acid and burns him up.

So far as we can see, therefore, everything that the infusorian feels at all, feels to him exactly like everything else. No matter what it is he feels, nor on what part of his body he feels it, he always acts in precisely the same way. It is, moreover, doubtful whether one of these animals ever learns or remembers much of anything, or in any other way ever finds out how to do anything which he could not do about as well the first instant of his life.

XXII

What Plants Know

Of course, the plants do not really *know* anything. Still they usually act wisely; and that is practically just as good as knowing, and often looks very much like it.

For instance, one sees little pine trees growing in a pasture. Each year they send up a "leading shoot" a foot or more long, straight up into the air, to become by and by the main trunk. Each year, also from the point where the trunk ended the year before, there starts out a whorl of little branches, a half dozen or so of them, some of which will by and by become the main limbs. It is the same way with the firs and spruces. If you haven't seen these growing out of doors, you have at least had them for Christmas trees in the house.

When these little trees grow in the pasture, pretty soon a cow comes along and eats off the top so that there is no longer any leading shoot to grow up into a trunk. What does the tree do then, but pick out one of the side branches from the uppermost whorl, and turn that up into a new leading shoot. So the tree gets a trunk in spite of the cow. Somehow or other, nobody understands how, one of those green tufts which was meant to grow into a horizontal branch, changes its mind, turns up, and becomes the vertical trunk.

This may happen five or six times to a single tree—for when it isn't cows, then it's wind, or insects, or something else, that kills the bud that ought to grow up into the main trunk. So one finds often in the woods, trunks of evergreen trees that grow up straight for a few feet; then take a sharp turn to one side, and another straight run of trunk; then another turn. Each of these turns means that something has happened to the leading shoot, and that the tree, like a very wise vegetable, has at once made another leading shoot out of a side branch. But still the curve remains to show where the branch had to change its mind.

It certainly is most clever of the tree. I for one, should like much to know how that side branch finds out that something has happened to the leader, and that it must step into the gap; and how the tree decides which side branch it shall be that is to make the change. Sometimes, indeed, the tree doesn't seem to be able to decide, so that two branches turn up instead of one; and after that, the tree has a double trunk. Sometimes, too, when the leading shoot is weak but still alive, a side branch turns up; and if the leader recovers itself and grows up strongly again, there will be here also a double trunk; but in such a case, one trunk will grow up straight, while the other starts out with a turn. So the tree sometimes makes a mistake, just as we all do. But it almost never makes so bad a mistake as to have three branches turn up into trunks, tho as far as numbers go, it might have six.

Another matter that all plants seem to understand is the difference between up and down. At least they never make the mistake of sending their roots into the air and their stems down. You recall the bean plant that is inside the bean, with its little root and its tiny stem and leaves tucked snugly away between the two big seed-leaves which are most of the bean. You may plant the bean any way you like, right side up or wrong side up, point the stem up and the root down, or the stem down and the root up, put the bean flat on its side, even plant it in one position for a while and then dig it up and turn it over to another. It makes no difference what you do; that little stem will twist round and grow up, and the little root will twist round the other way and grow down, tho each has to travel half way round the bean to do it. Somehow every seedling does tell which from t'other.

Now the question is, does the plant grow up because up is up, or because up is toward the light? The matter is easily settled. If we plant a seed in a pot, pack the earth in solidly, put a screen over the surface to keep the earth from falling out, and then tip the pot upside down then if the stem wants to grow up it will have to grow away from the light, and if it wants to grow toward the light it will have to grow down. Thus we shall find out whether the plant goes by light-and-darkness or by up-and-downness.

As a matter of fact, while nearly all plants are influenced by both, for young seedlings just getting their start in the world, the question of up and down is much the more important. So a seed planted in an upside down pot, will grow its stem up into the dirt, and its roots downward into the air.

So a plant knows in a way, up from down, as indeed it must, else a tree would not be able to send a tall trunk straight up into the air. Besides, when a tree happens to get uprooted, and yet lives, the new part of the trunk which grows after the accident, does not continue the direction of the old fallen portion, but turns and grows straight up. You can see this sort of thing almost anywhere in the woods.

The plant also, in a way, knows which way the light is falling on it. Commonly, as everybody is supposed to know, the plant grows toward the light. Yet the curious thing about it is that some parts of some plants always grow away from the light. The leafless runners of the strawberry geranium grow away from the light; but when they begin to form leaves on their ends, then they change and grow toward the light like other plants. The tendrils of many vines also, always grow away from the light, while the leaves and, stems are growing toward it. The reason is that by turning away from the light, they turn back toward the rock or tree trunk or wall or trellis which gives them support.

Thus the plant, that seems to know two things, is twice as well off as the infusorian that knows only one.

XXIII

What Plants Can Do

As trees and vines and shrubs and bushes are wiser than they look, so they can do more than we commonly suppose. We think of all plants as merely sitting still and growing; but they really do much more. Most ponds and ditches, the water squeezed out of bog moss, even damp spots on rocks or the ground, often swarm with minute green plants, that swim about quite as freely as if they were animals. Some of these, single-celled, pear-shaped affairs, have two long tails at the smaller end, with which they lash the water and so get about as freely as do the equally small animals which live with them. In fact, some of these little plants are so much like some of the infusoria, which I have already told you about, that about the only way to tell them apart is by the green color of the vegetable—tho to be sure the plant is apt to have two tails, while the animal has only one.

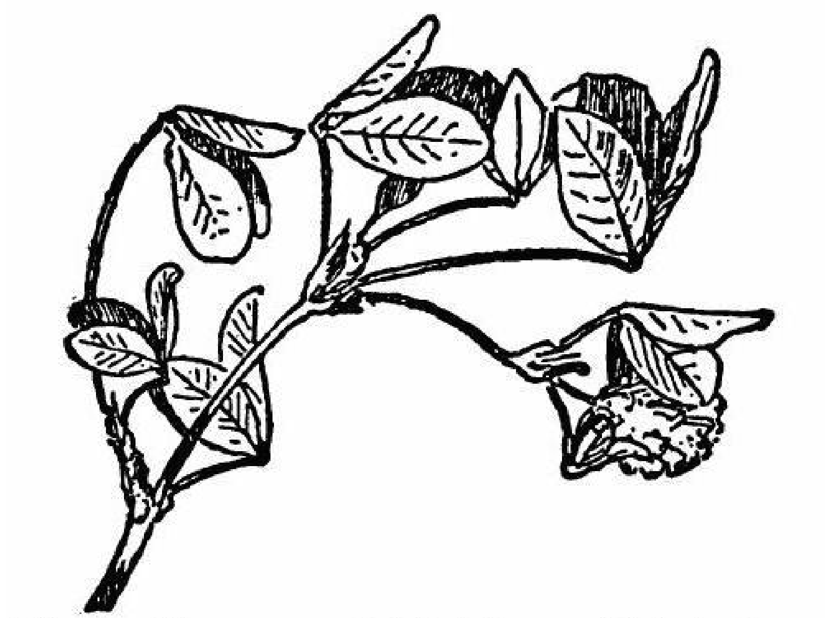
Then there are the so-called “diatoms” which live, absolutely millions upon millions, in the slippery coating which covers the sand and stones at the bottom of streams and ponds. These are commonly counted among plants; but they have two shells like an oyster and swim about freely—as an oyster does not, for all it is an animal. Then too, there are the “slime moulds,” which at some times of the year look like common puff-balls, and at other times change into a soft jelly, and crawl away to find a new place to change back into a puff-ball again.

In short, there is simply no end to the animal-like actions of the simpler plants, for after all, plants and animals are a good deal alike. To be sure, you don’t have any difficulty in telling a cow from an apple tree, but that is because a cow is a very complex sort of animal, and an apple tree is a very complex sort of plant. But the simpler plants, which have neither stem nor twigs nor leaves nor roots nor branches, and the simpler animals, which have neither heads nor legs nor bones nor muscles nor skins, are naturally not nearly so different from one another as apple trees and cows. And when you come to the very smallest and simplest creatures, the distinction between the two seems hardly worth counting. Some animals grow on stalks, and some plants swim about or crawl. Many plants are not even green; a few animals are. Once in a while, you find the very same creature described as an animal in one book, and as a plant in another.

However, I began to tell you about the animal-like actions of the plants which we see more commonly, the ordinary trees and shrubs and bushes, grass and house plants and the like.

We say that plants grow toward the light. They really do much more than that. When a houseplant has stood for some time at a window, in the same position, every leaf, as you know, is set to face the light, so that as much sunshine as possible falls on the upper surface of each. But if you turn the pot round, so that the leaves face away from the light, within a day or two, every several leaf will have skewed itself round toward the window again. So the plant can move its leaves about as much as an animal can move its head; only it moves very much more slowly. But the sunflower, grown out of doors, can wag its head fast enough to keep up with the sun. Indeed, it is called the sunflower, not so much because its blossom looks like the sun, as because, in the morning at sunrise, it bends its tip over toward the east so that the rising sun shall strike the upper sides of its leaves, follows the sun around thru the sky all day, and in the evening finds itself with all its upper leaves facing west. Then in the night it nods back again ready for the next sunrise.

Many leaves, if you notice them closely, have a soft bunch or cushion, either where the blade of the leaf joins the stem or where the stem of the leaf joins the branch or sometimes at both places. This is the joint on which the leaf does its turning. The clover, which is an especially active little plant has one of these joints for each of its three leaflets.

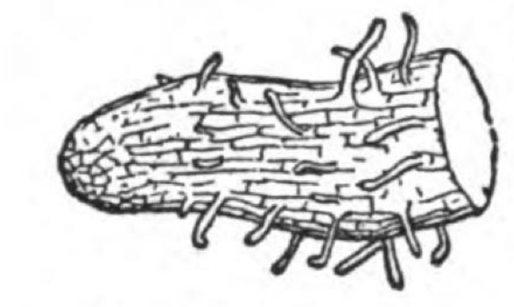


The leaf has a special joint on which to turn.

Not only the leaves of a plant, but the tendrils also, and the soft green parts of the stem, and the slender tips of the roots, turn and twist slowly, moving like the limbs of a very sluggish animal. Did you ever wonder how the climbing vines, the beans, peas, morning glories, woodbines, and the like, manage to find the poles and trellises on which they grow? The seedling comes out of the ground six inches or a foot away from the nearest support. Next thing you know, it has grown straight for the support and begun to climb.

This is the way it manages to find its way. When the young shoot first comes out of the ground it grows up straight like any plant. Pretty soon, however, being but a slender vine, it begins to bend over. Thereupon, it begins to sweep its tip slowly round in a circle—hop and honeysuckle toward the left, bean and morning-glory toward the right. As the stem grows longer, the circle gets bigger, the tip reaches out farther and farther after a support. When at length it does swing round against pole or trellis, it still keeps on winding, and so continuing to grow, winds itself up toward the top. If one pole is not high enough, when it reaches the top, it again sweeps its long growing end round till it catches something else and winds up that. Thus the vine finds its support in the first place, having reached the top of that jumps across to another, almost as if it could see where it was going.

The coiled tendrils of grape vines manage in the same way. They, too, sweep round in a circle till they catch a support. Sometimes, too, the tendril, instead of merely growing round an object, actually closes down and grips it like a shutting hand.



A root much enlarged, shows cells and hairs.

Or perhaps you have wondered how the roots of a plant manage to find their way thru the soil, always picking out the cracks and openings and never butting up against a pebble and having to stop. This is the way it manages. Instead of growing straight forward, steadily, the tip of the root grows out by perhaps the thickness of a sheet of tissue paper. Then it pulls back again not quite so far. Then, perhaps half a minute later, it grows out a little farther, and again draws back. Meantime, the root tip is writhing and twisting like an earth worm, only much more slowly. Whenever the moving tip touches a pebble or a grain of sand, the growing region, which is just back of the tip, grows a little faster on the side where the touch came, and so throws the tip of the root away from the obstacle. In this way, sooner or later, the root hits the open space and grows thru. You see, it is almost exactly like the way in which the infusorian gets by obstacles with its touch, back, turn, and go ahead; except that where the plant grows the animal swims.

Not only the root-tips but all the soft, green, growing parts of a plant are continually pushing out and drawing back, twisting, turning and bending; only the movement is generally so very slow that one can hardly make it out at all. Yet there are certain "sensitive plants" which when touched, pricked, heated or cooled, roughly handled, jarred, or in almost any other way made to sit up and take notice, fold up their leaves or drop them.

All plants, however, give some sort of slow jump or twitch or bend when anything is done to them. They are made sluggish with cold, put to sleep with ether and chloroform, revived by water when they are thirsty, even made uncertain of movement when beer is poured over their roots; all of course, just about like an animal under the same circumstances. Both alike move more feebly when they are tired; both alike stop moving when they are dead.

The plant, in short, is a very sluggish animal, shut up tight in a wooden box, so that only the ends of its roots and shoots stick out where we can see them move. We know, however, that all the living jelly of the plant does move, tho we cannot see it inside the wood. To be sure, the plant moves only very slowly. A leaf will turn when a lighted match is held near it; but if somebody held the same lighted match equally near your nose, your jump would be something like four thousand times quicker. Nevertheless, some of the slowest animals are not a bit more rapid of movement than the quickest plants. The fig tree and the fresh water clam, for example, are equally slow to move when they are touched, but move they both do.

But we must not forget the turning of the plants' leaves toward the light, for that is, after all, the one movement of plants which we have all seen for ourselves.

The curious thing about it is that the leaf turns, not because the light falls on the leaf itself, but because the light falls on the stem. If we cover the blade of the leaf, but let the light fall on the stem, then the leaf will turn; but if we shade the stem and leave the blade uncovered, then the leaf will not turn. Or in case there is a joint in the stem where the turning takes place, as in the clover leaf, then there is where the plant does its seeing. Allow the light to strike the leaf, cover that spot only, and the leaf is blind, but cover everything else, and the leaf turns as before.

Nor is it only sunlight toward which the plant turns its leaves. The great Darwin, who was one of the first to study this matter carefully, had a plant that after being kept a long while in the dark, screwed round its leaves to face a small lamp twelve feet away. Some of the so-called "sensitive plants," will start turning toward a candle ten seconds after they first catch sight of it.

Oddly enough, however, the leaf will move in exactly the same way, if instead of letting light strike the stem, one rubs salt on it, or brings a hot wire near by. In fact, leaves, tendrils, and other soft green parts will turn toward a red hot wire till they touch it and are burned to death. So the plant is after all much like the infusorian. It can do one thing, which is generally right; but it does that one thing just the same, even when that is the worst thing it possibly could do.

XXIV

Some Plant-Like Doings Of Animals

The plants, then, know enough to do two things—to grow up or down with stem or root, and to turn toward the light or away from it. This really, if you can call this knowing, is about all they do know. Now I am going to tell you about some common animals which are not much better off than the plants; which know up and down, and know the direction of the sunlight, and know mighty little else.

Happy is the community which does not know the brown-tail moth. Wherever it appears, it spreads like a pestilence, eating every green leaf off a tree, and leaving it in mid-summer as forlorn and bare as at Christmas time. A great tree that has taken a hundred years to grow, the progeny of one moth will kill in three.

The brown-tail moths, their cousins the golden-tail moths, and several other sorts of moths, lay their eggs in the late summer and early fall. The little caterpillars hatch out that same season, grow to be something like a quarter inch long, and spend the winter in a cocoon-like nest which they spin for themselves much as does a silk-worm or a spider. In the spring, having eaten nothing all winter, they leave the nest, crawl to the ends of the branches, and proceed to devour the new leaves.

But how does a little worm, no bigger round than a slender pin, finding itself in the midst of a great tree, with nothing near it but tough bark which it cannot eat, know in the first place that there are fresh green buds anywhere, and how in the second place, does it find its way to the tips of the twigs where the buds are? The answer is, that it doesn't. The little caterpillar knows no more about buds and food and the way to them than the tree itself does. It is simply built like a tree, so that when it first leaves its nest, it always turns its head up, and when it has a choice between light and darkness, turns toward the light.

So the caterpillar simply turns up and toward the light, just as a plant would, and with no more intelligence than a plant has, and no more idea what it is about. But of course, crawling up and toward the light, sooner or later brings it to the outer ends of the branches where its food is.

You can easily prove this by putting the young caterpillars in a bottle, or a wide-mouthed jar. If you lay the jar down on the table with the closed end toward the window, every caterpillar will crawl to the closed end, and never a one will crawl back away from the light to the open end and escape. You don't need any cover; the light holds them fast prisoners. But turn the jar round, open end toward the window, and soon there will not be a caterpillar left in it.

Suppose now, when your caterpillars are at the closed end of the jar toward the window, you take some fresh leaves, from the tree on which you found the insects (since these are presumably the sort they eat) and put them in the open end of the jar away from the window. The little caterpillars will stay where they are till they all starve to death, before one of them will turn round and crawl away from the light toward its dinner. They are even more helpless than a plant, which can at least send its roots toward water, no matter how the light comes.

Also, as I have explained, the caterpillars must crawl up. So they cannot escape from an open jar placed mouth down. Neither can they escape from an open jar placed mouth up; because when they come to the lip of the jar, in order to go farther, they must turn head down to crawl down the outside. But they cannot crawl head down so there they must stay. Moreover, if you put food in the bottom of the jar while they are at the top, they can never crawl down to get it. They cannot turn head down, and they do not have sense enough to crawl backwards.

There is, nevertheless, this difference between caterpillars and plants. If the plant grows up and turns toward the sun at all, it does so always; but the caterpillar changes its nature, and after it has reached the buds and once fed, then the impulse to move upwards and lightward, is no longer useful, and so in a large measure disappears.

Still many sorts of caterpillars keep these willy-nilly turnings, until they are full grown. Our common—our much too common—tent-caterpillar, is accustomed to leave its tent during the warm part of the day, crawl to the tips of the branches where its food is, eat until the cool of the evening begins, and then return to its tent. In no sense, however, does it go after its food, knowing what it wants. During the warm part of the day, it simply becomes like a plant stem, head up, and crawls. It has to head up, and it has to crawl. So in the end it reaches its food, but it doesn't know anything about how it gets there.

I have often on an early summer afternoon, when the caterpillars are getting restless and just ready to start out, taken the tent, inhabitants and all, and put it on top of a post or a smooth rock. The caterpillars being disturbed, at once start to crawl away. They start in all directions. In a moment, of course, they find themselves crawling head down. That being against the rules, they turn and crawl up again. In no possible way can a single caterpillar get off the top of that rock or post, until the regular time for them to knock off eating and go back to the tent. Then they have to crawl down; and cannot crawl up if they try. So the chief difference between tent-caterpillars and plants, is that while the plant always turns its root down and its stem up, the animal turns its whole body down at certain times of day, and turns its whole body up at certain others. One can hardly say that either has any more sense, or intelligence, or knowledge, than the other.

All caterpillars, while they remain caterpillars, have to crawl toward the light. All caterpillars, also, after they have changed into butterflies and moths, when they fly, have to fly toward the light also. That is why the swarms of moths collect around the arc lights on the streets, fly into lighted rooms thru unscreened windows in the evening, circle about the reading lamp, or if the light chances to be a candle with an uncovered flame, fly into it and are burned.

People will tell you that the moth is curious, wants to see what the light is. But he isn't; any more than the leaf is curious to look out of the window to see what is going on in the street. Both alike simply turn toward the brightest light. The moth, having turned toward the light, when he flies, flies toward it. If the leaf could fly, it also would fly into the flame and be burned.

The reason why moths only fly into the lamp is that they are about the only insects that fly at all while the lamps are lighted; most other winged insects, also, head toward the brightest light. So do vast numbers of other small animals, snails and crabs and various water bugs, earth worms, leeches, infusoria, and even minute fishes just hatched out of their eggs. But older fishes and all the larger animals with fur and feathers, have more sense. They go where they please and turn any way they like just as we do.

Many small animals, on the other hand, are like plant roots. They have to head according to the light, but they head away from it, and so move toward the darker places. In fact, it is rather the rule for the young insect, before it gets its wings, to burrow like a root and turn away from the light, but to turn toward it later after it gets its wings.

Perhaps the strangest fact of all is that some water animals which ordinarily head away from the light, turn round and head toward it, as soon as a little acid is added to the water. Alcohol, even common soda water or ordinary salt, has the same effect. But some salt water animals which normally head lightward, if put into slightly fresher water, promptly turn tail to the light. All of which shows that the creature himself hasn't much choice in the matter, and probably doesn't know much about it anyway, any more than if it were a plant.

These turnings of plant or animal, toward the light or away from it, up or down, the heading up-stream of many fishes, and the necessity for crowding into cracks and corners of many insects and other small creatures, all these are called "tropisms." Tropism is merely the Greek word for turning. I tell you the name, because we human beings who have speech, if we want to think about a matter, have to have a name for it to act as a handle for our minds to take hold of.

We see, then, that the various sorts of living creatures which we have met thus far in this book, tho they are all made of much the same sort of living jelly, have really quite different sorts of minds. We ourselves, as you know, have reason, speech, intelligence, feeling, and instinct. The animals most like ourselves, dogs and cats and horses and the like, have also intelligence, feeling and instinct. Animals very different from ourselves such as fishes, insects, and the various strange sea creatures, have some intelligence, some feeling, a few strong instincts; and besides these, certain tropisms. But the simplest animals of all, and the plants, have neither intelligence nor instinct, but only feelings and tropisms.

All living things, then, plants and animals alike, have feeling. I have already explained something about instincts and tropisms; and told you, if not much about intelligence or reason, at least something about speech. Now I shall tell you something about the one thing which all living things have in common, and that is feeling.

XXV

The Five Senses and The Other Five

Traditionally, of course, we have five senses—sight, hearing, touch, taste and smell. Yet we sometimes say that we are "frightened out of our seven senses," as if there were seven and not five. Really, the number of our different ways of feeling is neither five nor seven, as we shall now see by counting them up for ourselves.

Five at least we are sure of, the traditional five. There is no need for anyone to tell us what our eyes, ears, and noses are for; nor that we taste with our mouths as well as talk and eat, nor that we feel touches anywhere over our skins. As to this last, however, I don't think we always realize how completely the sense of touch is confined to the skin. Headaches, for example, we feel on the outside of the head; the brain itself can be pinched, cut, burned, and generally maltreated, and we not feel it so much as we feel a pinprick on a finger tip.

Do you remember how, a few years ago, when you had not so many things to do as you have now, you used to amuse yourself by whirling rapidly round in one direction, till you were dizzy and could hardly stand up. For a few moments, or till you whirled around in the other direction, you lost your sense of right-side-up-ness; you didn't know sky from ground; and if you had been whirling especially fast or long, you probably fell down flat, and couldn't get up again. When you dance, too, without reversing, by and by you get giddy, the floor begins to curl up at the edges, and you become uncertain as to which way is down.

The trouble is not with the eyes, because we get dizzy with our eyes shut. We really have a sense of up and down, which is neither sight, hearing, touch, taste nor smell; but a sixth sense. Its organ is a portion of the inner ear, the so-called labyrinth; and it tells us, not how things look or sound or taste or smell or feel, but whether we ourselves are right side up. Too much whirling upsets this sense of equilibrium, just as too bright a light dazzles the eyes, or too loud a sound stuns the ears. A shark will swim with his head cut off; but his ears being gone, he is as likely as not to swim upside down.

There, then, are six senses. Let us see if we can find number seven. While you are sound asleep at night, you do more or less turning over in bed, so that in the morning, you are lying in quite a different position from that in which you went to sleep. Yet altho you remember nothing of what you did in the night, when you awake in the morning, and before you open your eyes, you can tell exactly the position of every arm, leg, or finger. You know just how much each joint is bent. You have, in short, a sense of where the several parts of your body are, which is none of the six senses which we have recognized heretofore.

So, too, if you shut your eyes, and let some other person move any member into another position, you feel it move, and know all the while just where it is. Or suppose you are playing short-stop, and fielding a hot grounder. Your eye is on the ball, and your mind on the game; but your hands drop, and your back bends, and your knees sink, all to precisely the right degree to bring your hands where the ball is. You have a most accurate sense of where these hands are, tho you neither see nor hear nor touch nor taste nor smell them. A piano player relies on this same muscular sense, when without looking at the keyboard he skips unerringly from one note to another, never going too far nor stopping too short. In fact, this muscular sense is really one of the most accurate of all our senses. We can see a speck of dust much too small to feel; but a person used to using a microscope or doing other nice work, can make a movement with his fingers as small as the twentieth part of the width of a hair—and that is a good deal smaller than any unaided human eye can possibly see.

As you might guess from its name, this muscular sense is located partly in the muscles. Still more, however, do we depend on the joints. We do not feel one bone slip over the other, that would be plain touch; but we know with extraordinary accuracy just how far the joint has moved and just where it is at any moment.

Here then are seven senses; now for number eight. Take something not too sharp, a tooth-pick will do, or the point of a lead pencil, and touch the skin lightly on the back of the hand or on the forehead or near the elbow. You feel, of course, the touch. Now move the point ever so little, by the thickness say of a small pin, and touch again. You probably feel the same touch as before. Continue this touching, and before you have tried twenty times, you ought to discover a spot where the point feels suddenly cold. In short, some points on the skin feel pressure, which is the ordinary sense of touch. But other points feel cold, which is a different sense, an eighth sense, and not touch at all.

There is also a ninth sense, the sense of heat. If you are very careful indeed, and notice very closely, you can find heat spots, just as you found the cold spots. Only these are much harder to locate, so that you will probably not be able to make them out.

One more sense is located in the skin besides these three. That is the sense of pain. Tho to be sure other parts of the body feel pain also—the muscles and joints when we have rheumatism, and the teeth when we have the tooth ache. Pain is not touch. In the first place it feels very different, and in the second place, it is quite possible to lose one sense and keep the other. In certain diseases of the nerves, the ordinary sense of touch remains as before, but the sense of pain completely disappears. One can be pinched, cut, burned, in the most violent manner, feel the touch of fingers or knife or hot wire, and yet not feel the slightest pain. And the same thing is true, after one has taken the right amount of ether or chloroform; one isn't asleep, and one can feel touches but one does not feel pain—and a wonderful blessing it is sometimes.

I wonder whether many of you have ever heard of cocain, or had it used on you when you got something in your eye, or had to have something done to the inside of nose or mouth. (Only you musn't call it "co-cane," in two syllables, as many people do and as it looks in print, but "co-ca-in," in three syllables; for it is extracted from coca leaves, and the name is "coca," with the "in" added on, like strychnin, atropin, protein, and the names of so many drugs and medicines). Cocain, then, looks a good deal like common salt, but fit grain or two in a drop of water, placed anywhere where the skin is thin, soaks thru to the ends of the nerves, and for ten minutes or so, puts an end to all feeling there. If now we apply cocain to the tongue in just the right strength, it takes away for the moment all sense of pain, while it leaves the sense of taste as before, and the sense of touch. One can bite his tongue and feel the bite, yet it does not hurt. One can drop hot syrup on it, taste the sweet, and yet not feel the burn. But if we make the cocain a little stronger, then when the pain goes, the taste goes with it. One can feel something in his mouth, but cannot tell sugar from salt; while a drop of strong acid, tho it burned a hole in the tongue, would neither taste sour nor hurt. A still stronger dose of the drug suspends all feeling—pain, taste, and touch alike.

So pain is a different sense from touch, just as much as taste is. Besides, if you take a sharp pin and make a line of pricks close together, much as you did when hunting for cold spots, taking pains to prick equally hard each time, you will be pretty sure to discover certain points where the prick hurts much more than it hurts the thickness of the pin away. This, of course, is a pain spot. Between these you hardly feel the pain at all.

There are, then, in the skin, cold spots, hot spots, touch spots, and pain spots, from two to three times as many of each as there are fine hairs on the skin. Under each of these spots, is the end of a nerve, either branching like a little bush or ending in a sort of oval knob, much the shape of a foot ball. And just as the eye sees, but doesn't hear, and the ear hears, but doesn't see, so each of these nerve endings feels either pain, or cold, or heat, or pressure, but only one of them.

How many senses have we then? At least ten, which is twice the traditional five. Besides these there are thirst and hunger, which are certainly feelings, tho neither sight, hearing, touch nor any of the rest. Then there is that peculiarly unpleasant feeling which comes to us after we have dined less wisely than well, or have been rocked too fondly in the cradle of the deep, the sensation, I mean, which we call "sickness" or nausea. This makes thirteen senses. There are several more in addition to these, more or less vague affairs, which for the most part tell us only what is going on inside our own bodies.

If therefore, you ask how many senses we really have, I shall have to say that we had better call it ten. At least we have ten well defined sorts of feelings, which tell us what is going on outside our bodies—and after all, that is what senses are for. These, then, will be sight, hearing, touch, taste, smell, heat, cold, pain, equilibrium, and the muscular sense. Each of these has its own special place, in eye, ear, joint between two bones, or little spot in the skin. If we lacked any one of these (as indeed many creatures do) there would be something which it is important for us to know, but which would be forever impossible for us to find out.

XXVI

Eyes

I am not going to tell you about the wonderful structure of the eye, nor about how it works. That, if you have not learned something about it already in your school physiology, you will get sooner or later, certainly before you get thru the high school. This book is mostly about things that you do not learn in school.

I have, however, told you something about how the eye grows, how it buds out from the side of the brain, and then doubles in to form a cup; and how this cup becomes at length the nervous portion of the eye, the retina, which therefore, tho it lines the eyeball, is really part of the brain; and how this retina somehow or other, in a way that nobody understands, picks up the image of the things we see, and sends it along the optic nerves to the part of the brain which lies above the ear and round toward the back of the head. I think you know also how these optic nerves cross over, just as most of the other nerves do, so that the left eye reports to the right side of the brain, and the right eye reports to the left side. You know also how, in the end, both these reports get turned over to the left side of the brain, and remembered there; so that while we see with both sides of the brain, we remember what we have seen with one side only.

Aside from these matters, there are various little points about the eye which one can make out pretty well for himself. One of these is the reflections from the front of the eye. You know, if you look into a window in the day time, or try to look out of a window after dark, or look into a glass tumbler, or at the face of a watch, or in general, look at a glassy surface or at water, when it is lighter on your side than it is on the other, instead of seeing thru quite clearly, you see reflections from your side.

It is, naturally, the same with the glassy front of the eye. Look into another person's eye, or into your own with a mirror, and you see reflections of windows, lamps, your own head, or any bright objects. You ought to be able to find three reflections of each bright spot. The largest, which is always right side up, is the reflection from the clear glassy front of the eye which covers the entire colored part from which we call our eyes blue or brown or gray or what not. If you look carefully, a little sideways, you will be able to get a still smaller picture, coming from the front surface of the lens of the eye, which lies just behind the round black hole in the center of the colored curtain. This also is always right side up. But there is still another, always up side down, which is the reflection from the back side of this same eye lens. These last two, you can get also by looking at a common spectacle lens, or by looking into the front of a camera.

For of course, the eye is really a little living camera. It takes a little picture like that in a camera, always upside down, at the back where the plate holder or the spool of films goes in a kodac. We can actually see this picture at the back of an animal's eye; and what is more, people have sometimes taken out the lense of an ox's eye, and taken a photograph with it as if it were a lens of glass. Indeed it is possible, tho the process is decidedly difficult, to take an ox's eye from the butcher's shop, keep it in the dark, let it look quickly at something bright, and then by treating it with the proper chemicals, actually to fix on the retina, as on a camera plate or film, the last object which the eye saw. There is a dark pigment in the retina, called the visual purple, which changes color in the light, and so forms the image.

But how this image or picture gets to the mind is another question; a question, I am sorry to say, which nobody can altogether answer. We do know, however, that there are nerve endings in the retina, something like hot spots, cold spots, touch spots, and pain spots in the skin, only of course very much nearer together. Probably there are three kinds of these—red spots, green spots, and blue spots. Each spot sees one color; and by combining these colors in all sorts of ways, we build up the complicated pictures which we see. Still it is by no means impossible that there may be, not three, but six elements in our eye-pictures—white, black, red, yellow, green, and blue. Nobody really knows; and it all shows how little, after all, we have succeeded in finding out about ourselves, in spite of whole lifetimes of study of many hundreds of scientific men. Who knows but that some of you who read these pages may be the ones to discover some of these things which all the world thus far has not been able to learn.

There are still other curious facts about our sight which anybody can make out for himself. If you take any colored object, this book for example, put it behind your head; and then slowly bring it round in front, while you keep your eyes looking out steadily straight forward, you will notice certain very peculiar facts. In the first place, you will discover that you can see surprisingly far toward the back of your head. A horse can see all the way round, and if he did not wear blinders, could watch the people in the carriage behind and the road which stretches out in front, along with everything in between, all at once and about equally well. Many animals, in short, can see clear round their heads. We can't; we can see only about half way round.

Then you will notice that you can see that something is there and moving, while it is still so far round to the side that you cannot at all make out either its shape or its color. Furthermore, you can see the color perfectly well, long before you can make out the exact shape. Indeed, you can make out the shape of ordinary letters well enough to read them only when you hold them exactly in front of the eye. The least little movement out of that one small spot mixes a whole page to a gray blur; curiously too, you can make out blue and green decidedly farther round toward the corner of the eye than you can tell red.

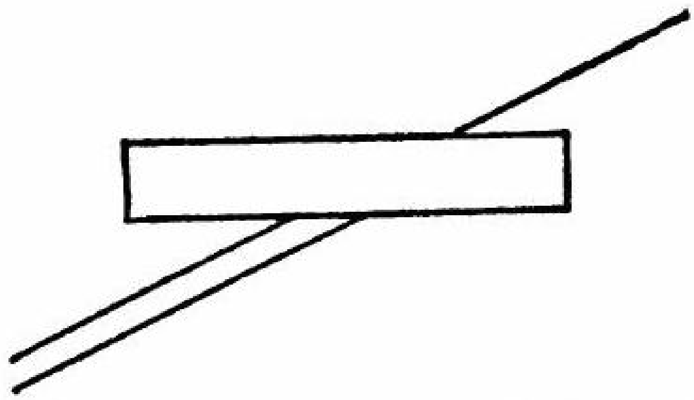
In short, then, we can see movement considerably farther round toward the backs of our heads than we can see color. We can see blue farther round than we can see green and green farther round than we can see red. But we cannot see shapes accurately, except right in front of our noses.

Now curiously enough, all animals that can see at all, can see something moving; tho they cannot see colors at all perfectly, nor make out the shape of anything. Many lowly sea creatures have eyes of this sort. A better kind of eye, like those of many insects, can see colors, but not make out much about shapes; while certain ants can see blue and green but are blind to red. Few indeed are the creatures that can see anything like as clearly as we see, looking hard at an object straight in front. Even a dog cannot do it, nor a horse.

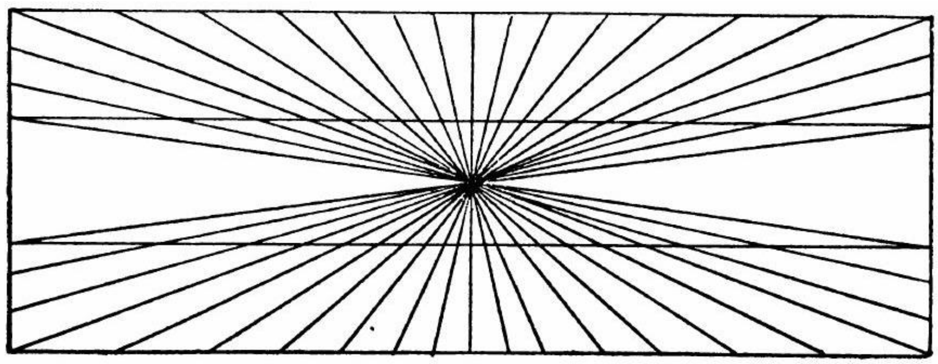
XXVII

Seeing and Believing

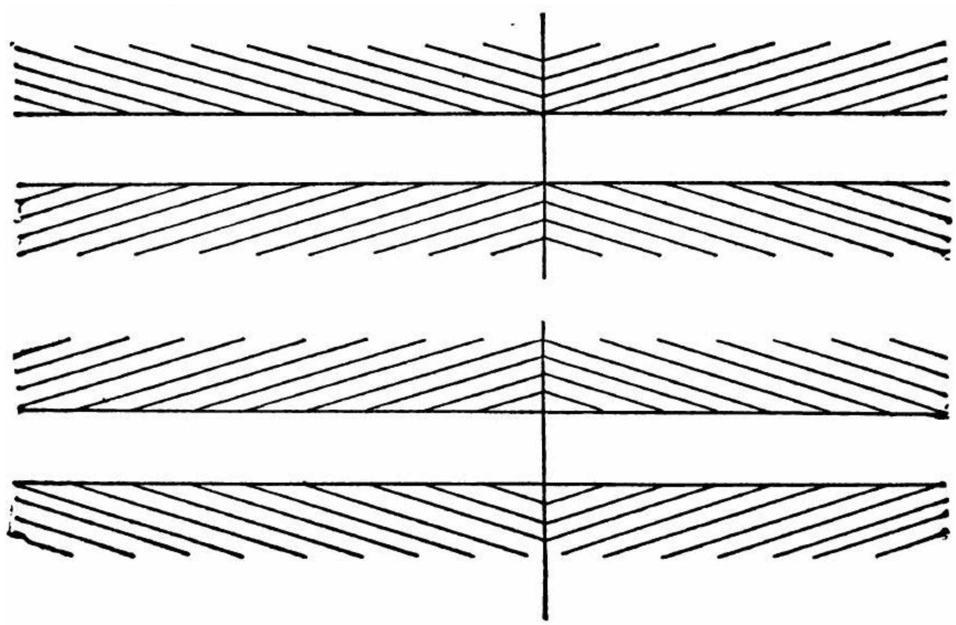
Even we ourselves, we human beings, by no means always see so truly as we think we do. Take a look at this figure and say which of the two lines in the south-west corner continues the single line in the north-east corner. Then lay on a ruler or a strip of paper, and see which line really does run clear across the figure.



Or look at the figure below, and say which way the curved lines bend. Then take a straight-edge and test them.

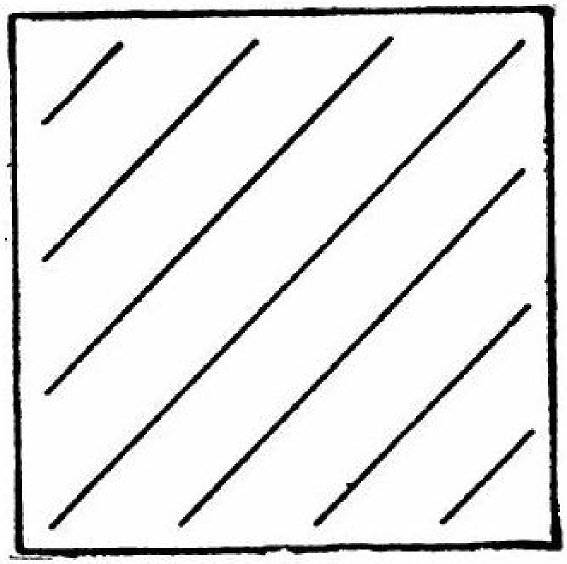


Where, in this next figure, are the white bands widest, in the middle or at the ends?

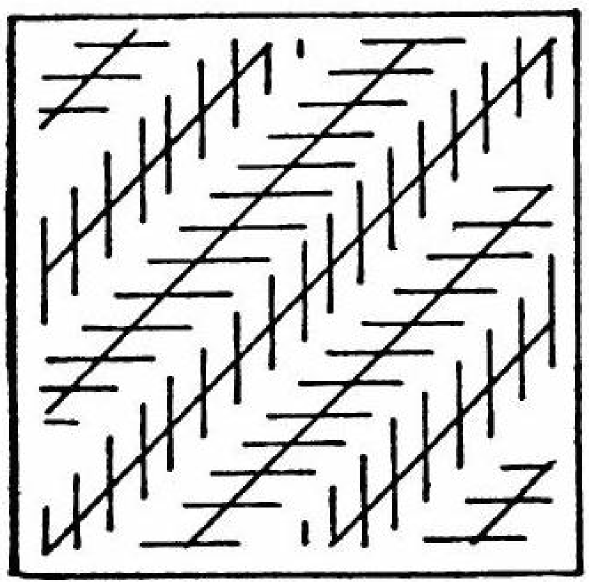


Lay two strips of paper along the sides of a white band, one on each side, so as to cover up the slanting lines. Where now is the band widest?

Here is a square with some lines drawn across it. Are the lines straight? Are they the same distance apart everywhere?



Now I will add certain other lines to the same figure. Are the original lines still straight and the same distance apart everywhere?



Or look at the B’s, H’s, S’s, 3’s, and 8’s on this page, that look about the same size at top and bottom.

B, H, S, 3, 8.

Then turn them up side down and see what they really are.

Or to take one more curious illusion, the lines of the figure on the next page are really flat on the paper, where the printer put them. But there is a point near the bottom of the page, about as far from the line nearest the bottom as that is from the ones nearest the top, where if you cover one eye and look at the lines with the other, each line will appear to stand straight up from the paper like a little post.

Or possibly you think your eyes always report correctly concerning colors? Then try looking at a landscape, with your head up side down, so that the view appears under your arm or between your knees. Are the colors the same as before. If not which is right?

Or try this experiment, take some brightly colored object—paper, cloth, or almost anything—in size anywhere between one and four inches across, lay it on a sheet of white paper, put the two in a strong light, and getting arm's length or more away, stare steadily at the colored object for a half minute or so, until the eyes begin to tire. Then whisk away the colored object, continue looking at the same place, and notice what you see on the white paper, where nothing is. Or you can do what is really much the same thing, by looking at a window up against the bright sky, and after a moment turning away and shutting your eyes.

In all such experiments, one sees the outline of something that isn't there, but in a contrasting color. We have, as you will recall, at least three sorts of color spots in the retina, red spots, blue spots, and green spots. By looking at a bright red we tire the red-seeing spots, so that everything looks blue-green. If we look hard at bright green, we tire the green-seeing nerves, and things look red-blue, which is purple. An eye tired of blue, sees yellow.

The curious thing about this is that about one man in thirty and one woman in three hundred is "born tired" to red. Such persons are said to be red blind. Otherwise they can see as well as anybody; but red things do not look colored at all. None of us can see red far round to the side out of the corner of the eye, as well as we can see green and blue. Color-blind persons have the corner of the eye all the way across, and cannot see red anywhere. They can see red things; but they cannot see them red. Railway train men and masters and pilots of vessels have to depend on red and green lights for signals. Such persons, now-a-days, are carefully tested for color-blindness; and all who cannot see red as the rest of us see it have to find some other occupation.

Why do we have two eyes? We can see outlines exactly as well with one; in fact, all the more difficult sorts of seeing, sighting a gun, using a microscope or telescope are done entirely with one eye. We can see colors exactly as well with one eye as with two. The only thing that we can't see well with one eye is distance.

Try with both eyes open to put your finger rapidly on various spots arm's length or so away. You can hit the mark every time. Now cover one eye—always when you want to use one eye, don't shut the other; cover it, but keep it open. Also, by the way, if you are to use a microscope or a gun, don't shut either eye; learn to keep both open, but to look with only one. With one eye only, then, try to put your finger rapidly on various points which you did not look at until after you had shut off the sight of the other eye. You can do it, but much less quickly and certainly than with both eyes. The nearer anything is, the more do the two eyes have to turn in, when both look at it at once. After eight or ten years of practice, as most of us have had, we learn to judge distances pretty accurately, just by the feel of this turning in.

All these peculiarities of our eyes, the judgment of distance, the different portions of the retina which see most clearly and which see colors, the various ways in which the eye is deceived, and the like, all these you can make out pretty easily for yourselves. There remains, however, one especially curious matter which you will hardly be able to discover, unless you take some little pains and follow directions pretty closely.

This is the so-called blind spot. We have, as you have seen, in each eye, a small spot in the center of the field of vision where the sight is especially sharp. This is, in fact, the only part of the eye that we can see to read with. Near this, between it and the nose, is another spot, about the same size, with which we cannot see at all.

We can prove this from the figure below.

Hold the page about a foot in front of the face, as if you were reading. Cover the right eye and look at the cross on the right, or cover the left eye and look at the dot on the left. Keep looking steadily but without too much effort, while you move the book back and forth, bringing it nearer to the face, or trying it farther away.

You should be able to find a distance at which the other mark, the one at which you are not looking, entirely disappears. You can see all round it, but the place itself is on the blind spot and is gone.

With some practice, one can make anything, not too large, disappear in the blind spot. Boys in college, when they are studying about the eye, sometimes amuse themselves in church by getting the clergyman on the blind spot, and so blotting him out. It really is queer enough. You cover one eye, and look with the other at the wall behind the preacher a little toward the side on which your own nose is. When you get just the right point to look at, the man simply disappears. You see the wall and the pulpit and the chairs or what not, on both sides. You hear the preacher's voice. But the preacher is gone. You don't even see a black spot where he was. Or if you are clever, you can cut off his head and leave his body; or cut off his body and leave his head hanging in the air.

All this, however, requires more control over the body and more steadiness of attention than boys and girls usually possess. I should not have told you anything about the wicked students if I were not sure that you will have forgotten all about the matter long before you get old enough to try it.

Meanwhile, don't forget that as there is a blind spot in each of your eyes with which you simply cannot see what you know is there all the while, so there are many other things in heaven and earth which you cannot see, though they are there. Then don't be too certain, when you happen to be blind to what other people see, that the people who do see are mistaken.

XXVIII

Some Other Senses

We really know far less about hearing than about sight. The eye is where we can get at it, to look inside, and to see how it works. But the ear, the inner ear that is, where the hearing is done, is set deep inside the head, in the midst of a solid bone, the hardest piece of bone in the whole body except the teeth. Nobody, therefore, really understands how we hear.

We do know, however, that the ear is two different things. One part of it is the organ of hearing—I am speaking always of the inner ear—while another part, as I have already explained, is the organ of the sense of equilibrium, the feeling of direction and right-side-up-ness. But just how much of the ear goes for hearing, and how much for right-side-up-ness, and exactly how either part works, and especially just how we tell one sound from another, are things that are still left for somebody to find out.

Nor do we know much more about smell. We know that the smelling is done in the upper part of the nose, that the nerves of smell do not cross over and report to opposite sides of the brain, as so many other nerves do. But how we tell one odor from another, nobody understands; and we are even farther away from understanding than we are in the case of the eye.

We do, however, understand taste. At least we understand as much about it as we do about sight; for the two senses are much alike. There are four kinds of taste spots, scattered over the tongue and the inside of the mouth, mostly on the tongue. Each of these gets one kind of taste—salt, bitter, sour, or sweet. Oddly enough, different people have these four sorts bunched in different parts of the tongue, so that not all people taste the same thing in quite the same place.

But you will say at once, we taste many things that are neither sweet, sour, salt, nor bitter; there must be many more than four tastes. There are not. What we commonly call tastes are really smells. We smell things that are in the mouth, and think we taste them.

If you don't believe this, simply hold your nose. It is an old trick to get somebody to close his nose tightly, and then while all sense of smell is thus cut off, to bring into the room a piece of raw onion, put it in the victim's mouth, and ask him to guess what it is. If the onion is not brought into the room until after his nose is shut off, he cannot tell what it is that he is eating. For the onion has almost no taste. But the moment one lets go his nose—then he knows! There is no doubt that the onion has smell—enough and to spare!

Almost any of the senses can be fooled. Put your finger on you forehead; then move your head slowly from side to side so that the finger, held motionless, slides over the skin. Your muscular sense and your sense of equilibrium both testify that the head is moving and the finger is still. Yet you can't make yourself believe it. It insists on feeling as if the head were still, and the finger moving.

Or try the senses of heat and cold. Take three dishes, one of hot water, one of cold, and one of a mixture of the two that shall feel neither warm nor cold but tepid. Put the fingers of one hand in the hot water, and the fingers of the other hand in the cold water. Keep them there a minute; then put them both in the tepid water. The tepid water will feel hot to one hand and cold to the other. Really it isn't either. Perhaps, too, you have noticed, when you go in bathing, that as you wade in, you feel the cold only at the surface of the water where the skin was last wet. Hence the wisdom of going in all over at once with a header.

Even the sense of touch, in general the most reliable of the senses, can be deceived. When you are fishing and get a bite, where do you feel it? Most fisherman feel the bite at the end of the line, as if their nerves actually ran the length of the rod and down the string to the hook! And when a ball player cracks out a long hit, I leave it to all boys, if he doesn't feel the place in the bat where it hits the ball. Or to take a commoner example, when you touch your hair, where do you feel the touch? In the hair itself where there is no feeling at all, or in the scalp where it really is? Or once more, if you hold the point of your nose between two fingers you feel one nose; but if you cross the fingers, and then touch your nose between the crossed parts, then you feel two noses.

Still on the whole, our senses are pretty reliable. The eleven different sorts of feeling spots in eye, tongue, and skin, that tell us about red, green, blue, heat, pressure, cold, pain, sweet, sour, bitter, or salt, and the ears and nose which we don't know so much about, all these tell us, on the whole, the truth. Yet we never can be quite sure; so that wise people, and especially wise boys and girls, will beware of contradicting other people who chance to see, hear, taste, smell, feel or believe, a little differently from themselves.

XXIX

The Sight and Hearing Of Ants

So much then for our own senses, our sight, hearing, taste, pain, and the rest of the ten, or as many more as one thinks it worth while to count. The animals also have their senses, never apparently, more than ours, oftentimes fewer, sometimes very few indeed. So far as they have senses, these are like our own. But since some animals haven't any eyes, yet can see—a little; and some haven't any noses, yet can smell; and most of them haven't any skins, yet can feel; one may easily guess that their seeing and smelling and feeling is not done quite in the same way that ours is.

I begin, then, with an animal that has eyes and can see, has no nose and can smell, and does its hearing with its legs. This animal is the ant. Of course, there are a great many different kinds of ants, as there are a great many different kinds of human beings, and these are by no means all alike. Some are black, some white, some yellow. Some are, for size, like the smallest letters on this page; some are more than an inch in length—and you can imagine their bite! Naturally also, sight and hearing, taste and smell, are not quite the same in them all.

Time would fail me to tell one half the strange ways of these interesting creatures, the most interesting creatures, probably, in all the world of little animals. Just as soon as you can, you must get hold of the books of Fabre, M'Cook, Sir John Lubbock, or Professor Wheeler, and read these strange things for yourselves—how the ants live in cities underground, have workmen and soldiers, carry on wars against their neighbors, raid their enemies' nests and make slaves of the captives, have plant-lice for cows, and milk them of their sweet juice, and in return for this, feed and care for the plant-lice and their young, pasturing them on the roots of plants, and making no end of trouble for the farmers whose plants they are.

All this, I say, and many times more, no less fascinating, you can read for yourselves in the proper books, not only about ants, but about their cousins the wasps and bees as well. Just now, however, we are concerned with how much the ant knows, and how he manages to find it out.

Ants, in general, you must remember, live for the most part in total darkness under ground. The workers, to be sure, leave the nest in search of food, but the industries of the ant city, the storage of food, the care of eggs and young, and the building of the city itself, go on as if at the bottom of a mine. The queen ants, which lay all the eggs for the colony, and the male ants, who like the drone bees are gentlemen of leisure and don't do much but loaf, are for most of their lives like the vine tendrils which I have already told you about. Whenever the light falls on them, they turn their heads down stream to the ray; and so if they move at all, they have to go toward the dark.

This, of course, holds them prisoners in the nest. But when at certain times of the year, a new brood of males and females appears, these ants, which, unlike the workers, have wings, suddenly become like the leaves and stems of plants; they have to head toward the light, and when they crawl or fly, they have to fly toward it. So when the rays of the sun happen to strike the nest, and light up the interior, out comes the swarm of winged males and females, leaving the wingless workers behind. Away they fly toward the sunlight; and those who are fortunate enough to find a suitable spot unhook their wings, settle down to found a new colony and a new nest. Thereupon, for the remainder of their lives, they turn their backs on the light like a tree root. The rest, however, die, after they have lost their wings, so that one sometimes finds great quantities of these scattered about after the swarming.

The workers, on the other hand, who have to be in and out of the nest about their business, do not have this tropism. They can take the light sidewise, or end on, or any other way, just as we can. The object of the tropism is to keep the males and females in the nest until swarming time, and then to get them out. Really, could there be invented a simpler or more effective way?

The worker ants can see. What is more, they can see colors. Nevertheless, they do not usually see quite the same colors that we see. For the most part they are red-blind, just as one man in thirty is. But unlike the color-blind human being, many ants make up for this red-blindness by seeing one or two other colors to which we are blind.

Of course, you know the colors of the rainbow, beginning with red at the bottom and running up thru orange, yellow, and green to blue at the end. You see the same colors also in a dew drop, or in the light which has come thru the corner of a square ink-well or the beveled corner of a mirror. These are the so-called primary colors, by mixing which all other colors can be made.

Now we, ourselves, do not all see the same rainbow colors. The great Sir Isaac Newton, who made a special study of rainbow colors and gave them their names, claimed to see seven—red, orange, yellow, green, blue, indigo, and violet. I myself can see only six; that is to say, I see only two colors beyond the green. More persons, apparently, see six than seven. Try it for yourselves and see how many you see.

The curious thing about the ants is that certain sorts, at least, see the rainbow colors as many of us do—green, blue, indigo, violet; and after that keep on still farther beyond this point, and see one or two more colors, which we never see, and for which, naturally, we have no names. Then, as I have said, to make it up, they are totally blind to red, and nearly blind to yellow. Some ants go even farther than this. They are totally blind not only to red and yellow, but to all the colors which we see. They do all their seeing by means of those two or more colors, farther out in the rainbow than the violet, to which we human beings are totally blind.

There is a considerable practical convenience in this. The worker ants, while they themselves run freely in and out of the nest, from darkness to light, usually try to keep their eggs and young in the dark. So when you turn over a stone and open into an ants' nest, the most that you get is a glimpse of piles of white eggs or larvae, and a throng of workers skurrying about to drag them out of sight into the ground. You really can't see anything at all of the regular daily life of the underground city.

But people who study ants simply carry them into a dark room, and look at them by red light. Since the ants cannot see red, they think they are still in total darkness, and so keep right on undisturbed with their work as usual.

Doubtless, it has already occurred to you, that in this particular the ant's eye is very like a photographic camera. You who have cameras, open your plates and films by red light, because the sensitive chemicals are blind to red, and so treat red light as if it were darkness. You probably do not know, however, that it has now become the practice to take especially sharp pictures of small objects thru a microscope by means of some of these colors which the ants see and we do not. These colors do not come thru glass, and the instruments have to be made of quartz; but they take beautiful pictures in what seems to us total darkness, and what to an ant would seem some familiar color, about which we know nothing.

On the whole, then, certain ants at least rather have the advantage of us in seeing colors. We, on the other hand, more than make it up when it comes to hearing sounds.

We ourselves, however, differ in this a good deal from one another. Practically everybody who can hear at all, can hear all the notes of a piano, from the big growly end up to the little squeeky end. You young people can hear much shriller sounds than any on a piano; but we old codgers, whose ears are getting stiff, do not hear shrill sounds, even when we hear perfectly well those of lower pitch. The squeek of a mouse is about the limit for most people. Some can hear it, some can not. But cats can hear easily a mouse's squeek, and much higher sounds besides, such as no human being can hear at all.

But the ants are still more inferior to us than we are to the cats. Some sorts which have been tested, can hear only two, and sometimes only one, octave above "middle C" on the piano, tho this is only half way up to the squeaky end of the key board. They hear well enough up to that point, and then are deaf to all sounds beyond.

Ants, moreover, do their hearing thru their legs. We ourselves, do something like this, when we grip one end of a stick in our teeth and scratch the other end with a pin. Even a lead pencil will do for the experiment; the sound is twice as loud when we shut our teeth on the wood and hear the scratching thru the bones of the jaw, as it is when we listen with our ears alone. Miss Helen Keller, completely blind and deaf, managed nevertheless to enjoy music by holding a music box in her hand, and feeling the jar; and she conversed in a telegraphic alphabet by tapping with her foot on the floor, taking the reply in the same way, by the jar, when anyone answers her.

The ants manage in much the same way. Stand an ant on cotton wool, and he is totally deaf to all sound. No sound, high pitched or low, can reach him thru the air. But put him on a hard surface, on his legs, and he hears thru his legs, taking the jar much as Miss Keller does. In fact, all sound is jar, either of air or of something else; a fact which you can easily prove for yourselves by striking a bell, and then touching a finger nail to the vibrating edge. Naturally we hear best with ears; but lacking these, any part of the body will make shift that can feel jars.

XXX

Ants' Noses

Ants see, then, and hear. But their hearing is not at all good; while they do most of their work in pitch darkness underground, where they can not possibly see anything anyway. So they depend on touch, and still more on smell. Smell, therefore, is their chief sense, as sight is ours. So much thinking as they do, they do largely with their "smell center."

We in a strange country, find our way back home by remembering what we saw on the way out. An ant gets home by following the smell of its outward trail. We recognize our friends by sight, and know them by the way they look. An ant recognizes its friends by touching them with its feelers, as no doubt you have often seen ants do, and so getting the familiar odor, smelling out each other's claims to acquaintance.

For the feelers or antennae are the ant's nose. It feels with them, and it also smells. As you can discover by looking at any ant, the antenna is like some whips which have a stiff handle and a long flexible lash fastened to its end. The handle sticks out sidewise, and the lash is jointed so that it can be moved about freely.

Our common brown ant has eleven joints in its whip-lash. With the joint at the tip it smells its nest. With the tenth joint it gets the general odor of the colony to which it belongs. With the ninth, it follows the scent of its own track. With the eighth and seventh, it recognizes the helpless young which are its care. By means of the sixth and fifth, it knows its enemies, the inhabitants of other ant cities with which it is at war. What the remaining four joints next the handle are for, is by no means clear.

An ant, therefore, which has had the outermost joint of its feelers cut off, or has lost them in battle, does not know its own nest. One that has lost the two outermost, does not recognize its fellows when it meets them away from home. One that has lost the outermost three joints, can not smell its own track and so can no longer find its way home. If the seventh and eighth joints are gone, the ant no longer has the slightest interest in the eggs and the helpless young, which before the mutilation it would have fought to the death to defend. Apparently, it no longer knows what they are; like the men who wake up some morning with a little blood clot on the surface of their brains over their left ears, who can see words but not read them, and don't know what their wives and children are. On the other hand, ants from different nests, which have lost the whole of their antennae down to the fourth joint, live together in perfect peace and harmony. But ants from different nests, deprived of their antennae only as far as the sixth joint, straightway start to fighting like cats and dogs; and never leave off till they are all killed or disabled.

Apparently then, the ant has enemy-smelling spots, and egg-smelling spots, and track-smelling spots, and friend-smelling spots, and nest-smelling spots, strung along in order on the lash-like part of its feelers; so that when one of these sets of spots goes, that particular sort of smell goes with it.

The ant, I say, depends greatly on smell. Probably it never knows any of its fellows, or any of its young, separately as individuals. It only knows that they have a certain familiar smell. At any rate, ants taken from a nest, soaked in water with ants from another nest, till they have taken on the foreign odor, and then returned to their own nest, are promptly set upon and killed as if they were invaders. But ants soaked in water with members of the colony, so that they have the proper colonial smell, are received as brothers.

Each sort of ant has its own peculiar odor, so different from that of other sorts that even the blunt human nose can tell them apart. Each nest of ants, too, has a slightly different smell from that of other nests of the same sort, so that each ant knows its own, tho the differences are too small for us to detect. All the ants of a colony are the children of the single queen, who lays all the eggs for the entire ant city. All the ants of a hill, therefore, instead of looking like their mother, smell like her. Each ant, then, recognizes its own brothers and sisters, its mother, its mother's sisters, and the children of its mother's sisters, who are its cousins. All these have the familiar smell, and the ant treats them as friends.

Ants from a related nest whose smell is nearly right, but not quite, are received with suspicion, and not allowed to take any part in the care of the young. Those whose odor is still less familiar are dragged about and roughly handled, but allowed to live. But those whose odor is entirely strange are promptly lynched, and their bodies dragged away to the waste heap.

The odor of the queen ant remains the same thruout life. Consequently, any ant will always recognize its own mother. But the odor of the worker ants changes with age. An ant, brought up in a nest, learns the queen odor, and the general nest odor, and the odor of workers of its own age, and of all younger than itself, and of all older than itself to which it is accustomed. But a young ant taken away from its nest, and kept away for two months, will find that its older sisters have meanwhile taken on a new smell. It treats them therefore as enemies. Yet an ant, once familiar with the odor belonging to any age, will remember it for at least two years.

There are some other peculiar results of the ant's reliance on its smell. Occasionally, in the fields and woods, one finds what are called mixed nests of ants. Two different sorts of ants, which ordinarily are mortal enemies, springing upon one another and fighting to the death on sight, are found living together in harmony, caring for each other's young, and in all respects behaving as if they were all of the same sort.

The way these arise is this: Two young queens, of different kinds, starting their new colonies, happen to settle so near together that the young workers mix with one another as soon as they are hatched out. From their infancy, therefore, each sort knows the smell of the other; and being used to it, thinks it quite the right and proper thing. So the ants grow up together, while the odors change so slowly with age that they never seem strange. Indeed, such nests have been made in this way by students of the ways of ants, with as many as ten different sorts in them, all living peacefully together.

When, however, such a nest is separated, and the two sorts of ants kept apart for a few months, the mixed nest cannot be reformed. Each sort of worker ant will recognize and care for the queen of the other sort, and all young of the other sort of all ages up to the time when the nest was split up. These the ant remembers. But all workers older than this have, of course, taken on an unfamiliar smell. The old friends have become enemies, to be slain on sight. So each sort of ant befriends the young of the other, whose smell it recalls, tho it has never known the individuals; while it fights to the death its former friends of its own age, with whom it has been working side by side, but whose odor has become strange.

Evidently then, an ant has no instinctive liking for any particular smell. It simply has to learn a set of smells, and what they mean, just as we have to learn our lessons. I think you will agree that for ants living under ground, smell is on the whole the best sense to tie to and do one's thinking with. But for us, living upstairs in the sunlight, sight is, I am sure, very much the most useful of all the senses.

XXXI

Some Other Eyes and Ears

The rest of the insects are, in general, much like the ants. They have their feelers or antennae, growing out in front of the head, with which they both feel and smell. Most of them seem to taste their food in their mouths. Nearly all have eyes.

As for ears, a good many insects, apparently, hear as the ants do, without any regular ears, and just by feeling the shake of what they happen to stand on. At least, nothing is known about their having any regular ears; though it is quite possible that some of them hear through their wings. Certainly, a tight hard wing, like a house fly's, when one wasn't using it for flying, ought to make a very decent sort of ear, one would think.

Grasshoppers and the like have proper ears. Though instead of being where we have ours, on the sides of our heads, Grasshopper Gray carries his ears on his hind legs, on the side of his great jumping thighs; while the ear itself, instead of looking like a human ear, is like a tiny drum—a tight thin head with a hollow underneath. Some other insects have their ears on the side of their bodies, about the middle. You can see these things for yourselves; they are not hard to find.

[Ear of a mole cricket on the front leg.]

Some of the jelly-fishes have ears, not at all good ones, but still ears. Some also have eyes, not so good even as the ears, and not good for much anyway. But the same kind of jelly-fish doesn't have both ears and eyes; whichever he gets, he goes without the other, having apparently not sense enough to manage both. As for the sea-cucumbers, they sometimes have more than fifty ears apiece, none of them good for much.

Most all of these simpler sorts of ear are much like tiny rattles. There is a hollow ball lined with nerves. Inside the ball is a small hard ear-stone, or a number of smaller grains of ear-sand. When a sound comes along, (for a sound is nothing but jar), it shakes the rattle, so that the little stone inside bangs against the nerves. Then the animal hears. In the cod fish these ear-stones are unusually large, as large as the end of one's thumb; children sometimes call them lucky-bones, and use them for playings. We also have these little rattles, two in each ear, with ear-sand. But these, which are all there is to the ears of lowly creatures, are only a small part of our hearing machinery.

[Back of the frog's eyes are the ear drums.]

You will find the ears of lobsters and crayfish, which are little fresh water lobsters, just at the point where the smaller feelers, which are double at the end, join the body. These, too, are merely ordinary ear-rattles; you can make out the opening on the upper side of the feeler. Of course, you know the ears of the frog—the big spots on the side of the head, back of the eyes. These spots are the drums of the ears; the real ear, much like our own, is inside. We have such a drum, only it is at the inner end of the hole into the ear, where it is much safer than it would be outside.

[A newt.]

The fish's ear you cannot find. That is inside; and the fish hears through the bones of his head, just as we do when we hold a stick in our teeth and tap the end, while we keep our ears stopped with our fingers. But the long dark stripe which you see on many sorts of fish, running from the place where the neck would be if fishes had one, the whole length of the body to the tail, and also forward across the head and around the eye, only you can't make it out so well there, this also is a sort of ear. In fact, the ear itself is really a part of this "lateral line" very much improved—so much improved that we human beings and the four-footed beasts and the birds haven't found it worth while to keep the lateral line at all. But the newts and salamanders still have it.

As for eyes, of these also there are all sorts. The star-fish has five, one at the end of each of its five arms, a tiny black dot. The jelly-fishes, some of the commoner sorts at least, have their eyes, such as they are, where the long tentacles join the center of the bell underneath. Some of the worms have several hundred eyes; some have a pair of eyes on each of the dozen or twenty joints of the body. The leeches, the common blood-suckers which get on our legs when we go swimming, have ten pairs of eyes, all on the front end.

Oysters, clams, and other "bivalves" have their eyes along the edge of the shell. Many of the snails have them on stalks, which they can pull back into the head or push out. The snail in Mother Goose, that

".,,put out her horns
Like a little Kylo cow"

and frightened the four-and-twenty tailors, was really only putting out her eyes to see these valiant heroes. Some of the shell-less snails, or slugs, besides the eyes on the ends of their horns, have a lot more, occasionally nearly a hundred, sprinkled over the back.

Such eyes, however, are really not good for much. They serve to tell light from darkness. They let the creature know when a shadow falls on him—which is usually the shadow of something on the point of eating him up, so he gets warning and bolts. We ourselves can do as much with our eyes shut tight; and that's about all most eyes will do wide open. There are not many really good eyes, till you get the single pair of the animals with back bones.

The Star-fish Has Eyes on His Arms; The Slug Also Has Eyes on His Horns; The Snail Has Eyes on His Two Longer Horns

Still there is one very fair sort of eye, though not nearly so good as ours, and that is the strange compound eye of the insects.

In general, the insects have either one, two, or three little eyes, at the front of their heads, which they use, probably, for seeing things close to them. Besides these, they have their two great compound eyes, often many times larger than all the rest of the head. The two together usually make almost a ball, and with them the bee or wasp or moth or dragon-fly sees clear round the horizon, above him and below him, all at once, and all equally well.

You know if you take a roll of paper, and look through it as if it were a telescope, you see a small bright spot at the end. If you had two such rolls, and could look through them both at once, you would see two such spots. If you had a thousand or more such paper tubes, and could look through all these at once, you would have something very like the compound eye of an insect.

Our eyes, as you know, are cameras. They form real pictures at the back, on the retina. But these compound eyes are not cameras, and they do not form any pictures anywhere. Instead, the insect looks out through one eye tube, and sees one spot of color; and through another, and sees another spot; and through a third, and sees another. Looking through some hundreds all at once, he sees a corresponding number of hundreds of spots.

But even ten thousand such spots would make no such sharp picture as we see in the small center of our field of vision where we see most clearly. Flies and ants and bugs and grasshoppers see only as we see things far round at the sides of our heads. They can see much farther round than we can; but they can't see nearly so well anywhere.

So a fly never could see to read, even if he could ever learn. The page of letters and the white paper would simply mix to a gray blur. A fly cannot get through a netting with a half inch mesh, unless there is a light behind it. Altho the holes are many times larger than his body, he cannot tell hole from string well enough to fly through. If you try to put your whole hand on a fly, or hit him with one finger, you cannot do it. He sees something dark coming, and stands from under. But you can often get him by bringing down the whole hand slowly; and then, just as he is about to take flight, dropping one finger on his back. He can see the whole hand against the wall of the room; but he cannot see clearly one finger against the others.

So on the whole, the fly does not really see much with his little eye; in fact, taking, one thing with another, we boys and girls and men and women probably see more distinctly, and make more use of our eyesight, than any other creature that breathes.

XXXII

Having Senses and Using Them

All animals feel. So, too, do all plants. At least, all animals and plants sometimes move when they are touched. So they must feel. Whether they know that they feel or not, is another matter. Most likely, all plants and all the lowest animals, feel as we feel in our sleep, when we get tired of one position and turn over, or feel cold and pull up the bed clothes, without knowing at all what we are about. Somebody has said that the mind "sleeps in plants, dreams in animals, and wakes in man," and that is really just about the state of affairs.

All animals except the very lowest also taste and smell. At least they choose their food, as they couldn't very well do if they did not smell or taste it. Tho when you come to think of it, for an animal living in the water, taste and smell are all the same thing. The food is in the water, the creature's mouth is full of water, and its nose (if it happens to have one, as most water creatures do not) is full of water also. So it doesn't make much difference whether you say that the creature tastes the water or smells it.

Most animals have eyes and can see. Not a few also, which have not eyes, can still tell light from darkness. The earthworm, for example, has no eyes at all, yet it always avoids bright light, and keeps in its burrow when the sun is out. Neither has it ears, yet when it is part way out of its hole, it will at once pull back again when certain notes are sounded near it on a piano.

We might almost say that every bit of the life-jelly of which all living things are made has itself all the five senses. All of it seems to feel, and all in some faint way to see and hear, taste and smell, move and remember. Besides this, the life-jelly makes itself all sorts of eyes and ears, all sorts of mouths and noses, all sorts of muscles and brains, in order that it may see and hear, smell and taste, feel and move and remember better than it could do without them.

But all this time that we have been thinking about ants, and star-fish, and earthworms, we have been neglecting the creatures which we really care most about, and certainly know best, the cats and dogs and horses and rabbits and various pets of all sorts which we know by name, and which in return we believe are fond of us. These animals, the four-footed creatures with fur, and the birds, are of all living things most like ourselves. They are most like us in body, they are like us also in mind; and they have the same senses that we have—five, seven, ten, a dozen or more, according as we choose to count them.

They have, I say, the same senses that we have; but they use them differently. Nothing, I think, is more striking about dogs, for example, than the small use they make of their eyes. Often, indeed, they seem half blind; they fail to recognize their own masters ten yards away; get separated from them, and run round frantically, smelling of everything in range; while all the while, the master can see the dog perfectly well, and pick him out at a glance from a dozen others. One would think that the dog would simply look round, see his master, and join him.

I don't think that they really are half blind. They probably can see nearly as well as we. They simply don't use their eyes, and depend instead on their noses. Sight is the most important sense for us, as it seems to be for the birds. But the beasts seem to depend most on smell.

The tales we read about the scent of dogs, and especially of bloodhounds, are often almost beyond belief. The bloodhounds, I understand, are so-called, not because they are especially fierce, in fact they seem to be on the whole a rather gentle sort of dog, as dogs go, but because they are supposed to smell one's blood, and to be able to follow the smell almost anywhere. I suppose they really do smell the perspiration; but they do it thru the sole of a heavy boot, when one has simply walked along over the ground; and they follow that inconceivably faint odor, hours after, and pick it out from all other smells, even those of other people cutting across the track.

Yet I sometimes think we make out the dog's sense of smell to be more wonderful than it is. The same dog that tracks footprints so marvelously will nose round in all sorts of dirt as if he had no sense of smell at all, and eat things that we would not have in the house.

We also can do a little smelling. Anybody can smell the vapor of bromin in the air when there is one part in two hundred thousand. Hydrogen sulphid, which is the gas that makes the smell of rotten eggs, will scent up 1,700,000 times its bulk of air. The least little grain of musk will scent a room; as little as the fifty thousand millionth of an ounce can be smelled by a good nose. Tea and wine tasters (who of course are really tea and wine smellers) can pick out the place where grapes or leaves grew, and the season of the year. Wine tasters can tell one year's vintage from another, and distinguish between the top and the bottom of a single bottle.

No dog, probably, can smell anything like such small quantities of these substances, or detect such minute differences. We smell musk and wine and tea; he smells footprints. One can't say that either has a better nose than the other. Really, a good deal of the difference between us and the animals is that we depend on sight and hearing, because we can use these two senses to handle words. We can see words, and we can hear words; we cannot taste or smell them. So we get to relying on eyes and ears. But the animals, which don't use words anyway, they think more about smells.

There is still another way in which we are apt, I think, to overestimate the senses of animals. We know, for example, that a horse will find his way home on a dark night, when everything is pitch black, and the driver cannot see his hand before his face. We say that the horse must have wonderful sight to make out his way under such conditions.

The real fact is, however, that the horse goes straight home thru darkness and storm, not because his eyesight is good, but because it is poor. He is at home in the night, because he does not see especially well by day. Those of you who have read *The Last Days of Pompeii* (as everybody should, for it is a famous old story) will remember that when, during the eruption of Vesuvius, the city was darkened under the shower of ashes, so that the inhabitants wandered about in the streets completely lost and quite unable to find their way out, the blind girl was able to lead her friends straight to safety. She had always lived in the dark, and could find her way as well one time as another.

So it is with horses and other animals. They seem to see in the dark, when they really hear and smell. A horse especially depends for finding his way, on his muscular sense. While his driver is noticing houses and trees and sign-boards, the horse is noticing so long a pull up one hill, so much holding back down another, so much level stretch between. The man is lost when he cannot see his houses and sign-boards; but the horse's hills and levels are still there.

You remember the rats that, when the passage in their maze was shortened, kept running full tilt against the end wall; and then when the passage was lengthened, kept turning too soon and butting into the side wall. The rats were depending on their muscular sense. They remembered their way as so long a straight run, then a turn. They could run as fast by night as by day, because they didn't do much seeing either time.

We also depend on our muscular sense far more than we commonly realize. Doubtless we all know how to button our coats. But how do we know? We certainly do not know how it tastes, smells or sounds. I don't think we often remember how it looks. What we do remember is the feeling of the buttons and the movements we make. But if we try buttoning with the other hand, or put on a coat that buttons on the other side, we feel as awkward as can be. We can see as well as before; the touch has not changed; there never was any taste, hearing, or smell. The difference is in the movements. The muscular sense is learning something new.

How hard it is to bat on the other side, to use any tool the other way round, or make any change which is strange to the muscular sense. That shows how much we all rely on it. If we play the piano, and remember pieces without the notes, it is by this muscular sense that we do it. Our fingers seem to know the tune; and in a sense, they really do. Surely, if a musician can find his way back and forth over the keyboard thru a long piece of music, by means of his muscular sense, it is not so remarkable that a horse should find its way home over the road, or a rat scamper thru its holes, guided by the same means. They don’t really see in the dark, they simply turn on another sense. We have it also; but mostly we trust to our eyes, instead.

There is another sense, too, on which animals are more given to depending than we are, and that is the sense of equilibrium and direction, which, as I have explained, has its seat in a part of the inner ear. You know the game where you are blindfolded, turn around three times, and then try to blow out a candle. If your direction-sense is at fault, as it generally is, you turn too far or not far enough, blow where the candle isn’t, and make everybody laugh. Men who have to find their way about over a wild country, explorers and the like, sometimes have this direction sense trained to a wonderful degree. They simply cannot get lost anywhere. The rest of us, who depend on street numbers and the sign-boards on the lamp posts, don’t have much use for this sense, and so never really learn to use it. Many animals depend on it a good deal. They find their way home in truly marvelous ways; and we say it is “instinct.” It really isn’t instinct, but just plain sight, hearing, smell, and direction sense. Men who have practiced their direction sense can find their way quite as well.

So in general, the animals haven’t different senses from ours, nor on the whole better ones. But they use them differently; and cultivate some senses which we let go to waste. For the most part, the animals depend on smell far more than we. Smell is apt to be their principal sense, as sight is ours. Because they don’t use their eyes as much as we do, they notice and remember more of what they learn thru their sense of direction and their muscular sense. But a man who tries hard can usually beat any animal at his own game.

The fact is, I suppose, that we, men and beasts and birds alike, have all the senses there are, all that any sort of creature could have anyway. Then each, according to his nature and habits, uses one more than the rest, to think and remember with.

XXXIII

Seeing In The Mind’s Eye

Not all us human beings use our eyes, ears, and noses in the same way, as a simple experiment will show.

Shut your eyes and think of the name of some familiar thing, like

BREAKFAST TABLE.

What did you see in your mind’s eye? Some people see that breakfast table just as clearly as if they were in the dining room with the table itself before them. They see the cloth and the plates and the food, the people at their places, the walls of the room, the furniture, all just as sharp and bright and natural as if they were looking at the things themselves. Others, more commonly, see the room and table dimly. They do indeed have an inner picture, but it is more like the picture one gets of things far round at the side of the head, out of the corner of the eye. They have a general impression, right as far as it goes; but they can't see the patterns on the plates, nor the position of each fork and spoon. Still other persons, though there are not many of these, and children are almost never this way, cannot see any mental picture at all. They have no mind's eye. They cannot see anything unless it is actually there.

People who can make such inner pictures are said to be eye-minded. Children are especially this way. Sometimes, indeed, they have difficulty in telling the difference between what they actually see, and what they dream or imagine. Then sometimes, they get punished for telling fibs.

Some people have this gift for making mental pictures to an extraordinary degree. If they have a lesson to learn, they see the page of the book before their inner eyes, and simply read off what it says. I knew of a type-setter in a printing office, who was a crack speller. He could spell anything. Give him a hard word, and he simply saw in his mind's eye his composing stick with the word set up in type in it, upside down and backwards, as type is set by hand. Then he simply read off the letters, and always got it right.

Some musicians, as I have explained, remember their pieces as if in their fingers; but some see the inner picture of the notes, and read them off as if from a real score. There is a story of a public speaker, who in the midst of his speech stopped, hesitated, went back and said something different. He explained afterwards, that while he never read his speeches from a real manuscript, he did always read them from an imaginary one which he saw before his mind's eye. This time, the manuscript that wasn't there had some words written in between the lines, so that he could not read them easily.

Possibly you have heard of the truly wonderful performances of some champion chess players. Chess is played on a board like checkers, only it is a vastly more complicated game, with six different sorts of "men" all moved in different ways. Nevertheless, many players can play about as well when they do not see the board at all, as when they do. They make a mental picture of the board, sit blindfolded, and as the game goes on, they keep track of every move, as they are told what it is, by altering their inner picture. Some of the best chess players have played ten, fifteen, and even twenty different games, all at the same time, blindfolded, and won them all against as many separate players, each playing one game and looking at the board. Such a champion player has to carry in his head the picture of ten, fifteen, or twenty different boards, each with sixteen men, scattered about over sixty-four squares, and all continually changing. Yet they do this without ever making a mistake; just by these inner pictures in the mind's eye.

Some eye-minded people can see a picture on a blank sheet of paper so clearly that they can mark over it with a pencil, and in this way make most accurate and effective drawings. Some can picture to themselves all four sides of a room at once, and imagine what is behind them as easily as what is in front. Some do not even hear directly what is said to them; but as each word is uttered, see the same word printed before their mind's eye, and then read it off. There are those who say that they cannot wake up in the night and think of the bright sun, without having their eyes dazzled!

Now it is a great advantage to be eye-minded. There is no easier way of learning one's lessons than by seeing books and maps and charts and diagrams, whenever you want them, right in front of your eyes, so that all you have to do is to look and see. The difference between boys and girls who get their lessons almost without effort, and those who get them only with the greatest labor, and then promptly forget them again, is often in just this power of making mental pictures. Some people can remember a page so clearly that they can actually read off the first or last words of each line, or read the printing backwards. Naturally, lessons come pretty easy to such lucky people.

Then too, to be eye-minded is a great source of happiness. One sees in the course of his lifetime, all sorts of beautiful and interesting things. If he can, whenever he wishes, recall these as mental pictures, almost as vivid as the reality, it is like seeing the reality all over again. He always has with him a collection of pictures, which though he cannot show to another, he can at any time enjoy for himself.

The eye-minded person, moreover, has still another string to his bow. Not only can he recall what he has seen; he can also imagine things which he has not seen, and so tell in advance how they are going to look. The engineer about to build a bridge, the architect planning a house, the housekeeper deciding how she shall arrange a room or set a table, the girl considering a new dress, the boy laying out a ball field, all can work to vastly better advantage if they can see exactly how everything is going to look, before they do anything. It is a great deal easier to change things in one's mind, than after they get into wood and iron and cloth. No one can possibly succeed as engineer, architect, designer, dress-maker, milliner, and the like, unless he can make these pictures in his mind's eye, and see how things are going to be, before he wastes time and material on the reality, Fortunately, this eye-mindedness is easily cultivated. One has only to attend to his mental pictures, and try to see all there is in them, to have them grow sharper and more complete. In fact, children usually have so much of this faculty that if they only kept what they have, instead of letting it waste away from lack of use, they would be far better off when they grew up than most grown-ups are. As we get older, we get to thinking more in words, and we lose the knack of making pictures. All is, we simply mustn't.

XXXIV

Ear Minds and Others

Some persons are ear-minded. If you say to them

BREAKFAST TABLE.

they don't see any breakfast table at all. Instead they hear in their mind's ear the sound of dishes, the murmur of conversation, and the clatter of knives and forks. When they have learned their lessons, and stand up to recite, they hear an inner voice telling them what to say. They cannot easily remember how places look on the map; but they remember the songs of birds, the different whistles and bells of their neighborhood, they like lectures and readings, and when they have heard a tune once, they know it again. Such people may find it hard to learn to read a foreign language, but they make it up by learning easily to understand it when spoken.

Musicians are apt to be ear-minded. Mozart, for example, could listen to a long piece of music, then go home and hear it over again as many times as he liked in his mind's ear, and so write it down at his leisure. Beethoven, after he became stone deaf, used still to write his magnificent symphonies, that took hours to perform, making them up in his head and hearing them in his soul's ear—violins, and trumpets and cymbals and drums, each in its proper place, long after his bodily ears had ceased to hear any noise.

Not many people are ear-minded; not nearly so many are as eye-minded. Those that are, can always hear sweet music and pleasant sounds, whenever they will, and recall the words and voices of their friends. Surely there is much happiness in being ear-minded. Whatever ear-mindedness one has, is well worth hanging on to and improving.

More people are muscle-minded. Think of a

BALL.

Do you see the ball in your mind's eye? or do you hear the word ball in your mind's ear? or do you feel the ball in your fingers, and the pull of your muscles as you throw? If the last, you are muscle, or motor-minded, and you probably found yourself saying to yourself the word ball.

Motor-mindedness, too, is a great convenience. It helps to make games come easy, and dancing, and all sorts of gymnastics; it makes it easy to carry oneself properly, to use tools, to be skillful with one's fingers, to play musical instruments. Motor-minded people are apt to talk easily, and to learn readily to speak foreign languages. Anything, in short, comes easy to them which involves doing something.

Nearly all blind people are motor-minded. If they are also deaf, then of course, they have to be so. I have seen a blind man get off a street car, turn into his street, walk down the street as far as his own gate, and there turn in without the least pause or hesitation, any more than as if he could see. He couldn't see. He simply felt that he had walked just far enough. And he had.

Do you want to know which of the three possible sorts of minds your mind happens to be? Then think of the street number of your house, or the year in which Columbus discovered America. Did you look for the figures, or listen for them, of try to say them to yourself? Did you see 1492 printed out somewhere, or did you hear something say it; or did you feel yourself saying it in your throat? In the first case you are eye-minded; in the second, ear-minded; in the third, motor-minded.

Most persons are mixed-minded. They have one principal sense, with which they do most of their thinking; but where that is not convenient to use, they employ another. Occasionally even, they use the third. I am myself motor-minded. To learn anything, I say the words over to myself. If anybody tells me anything, I cannot remember it, unless I first say it over; and whenever I think of anything, I say words about it to myself. I can Recognize tunes when I hear them, but I cannot recall a tune, unless I fit it to some words or sounds and think of myself as singing it. But I can think of how things look, or imagine how things will look, much more easily than I can think about how they sound; and I can, with some effort, think how things look without starting to say anything about them to myself in words. So I am also somewhat eye-minded.

Most of you will probably find yourselves, first eye-minded, then motor-minded. That is, on the Whole, the most useful arrangement. But the best sort of mind is one that can handle all three kinds of ideas; and think about seeing, hearing, and doing all about equally well. So you had better notice which you can't do, and set about learning to do it.

XXXV

Living Automobiles

If you will think back over what you have already learned in this book, you will see that we began by finding out something about how we men, the animals, and the plants come to have any such things as bodies at all. We learned how the little chick forms inside the egg, and the little plant inside the seed. We learned, too, about the wonderful life-jelly or protoplasm of which all living things are made; how it shapes itself into cells; how it builds these cells into our various members, eyes and bones and hair and muscles; and how the body changes, as we grow from youth to maturity, and from maturity to old age.

Then, after we had learned something about this body of ours, we turned to consider how we use it. We found about something of what animals cannot do, and what they can do, and how they do it. We learned how animals of various sorts, and plants as well, see and feel and act; and we learned also something about how we ourselves do our thinking, which is so very different, and so very much better done, than that of any animal or plant.

Now we turn to a different matter. We have taken up being, and doing, and thinking. Now we shall consider living. We shall learn about how the body of the plant or animal feeds itself and keeps alive, and how the different parts of it, the bones and skin and leaves and bark, manage to get on with one another, and work together like a well-made machine.

For, of course, the body is a machine. It is a vastly complex machine, many, many times more complicated than any machine ever made by hands; but still after all a machine. It has been likened to a steam engine. But that was before we knew as much about the way it works as we know now. It really is a gas engine; like the engine of an automobile, a motorboat, or an airplane.

I don't suppose that any boy, at least, needs to be told the difference between a gas engine and a steam engine. In the one, we build a fire under the boiler, and turn water to steam. Then the steam goes thru a pipe to the cylinder, where it pushes the piston back and forth, first on one side, then on the other, and so turns the wheels.

In the gas engine, on the other hand, there is no boiler, no steam, and no fire. A mixture of air and gasolene vapor flows into the cylinder, cold. There it explodes, set off by an electric spark, and the push of that explosion moves the piston and makes the wheels go round.

We, I say, are not steam engines. We have neither boiler nor steam nor fire. But each little working cell is like a little cylinder, which takes up from the blood air and food, mixes them together inside itself, waits with everything ready to go off, gets the proper signal thru a nerve, then explodes and does something.

That's the way a muscle does its work. It is a many-thousand-cylindered engine. Each little fiber of the muscle is a cylinder; and each time you lift your hand or move your foot there is a perfect battery of minute explosions. You cannot hear them, for there is no pop—the muffling is vastly better than any engine-builder ever devised. But you do feel the heat; and if you move fast and hard enough, you have to stop to cool off and get a drink.

The plants also are many-cylindered gas engines. They do not do so much work as animals do, not so much running round and moving things. But they do move, and certainly grow and lift themselves high in the air. This much work they do by exploding their cells, just as animals or automobiles do theirs. The growing plants take their food out of the air thru their leaves; and they take also the air itself in the same way. They mix these together inside their cells; and when there is work to be done, growing, moving, or any other sort, they explode a little of the mixture and do it.

The leaves take in air through breathing holes.

Don't think then that animals and plants and human beings are merely like automobiles. They are automobiles. Their fuel is their food. They mix it with air. They explode the mixture, and move. Anything that does that is an automobile, and runs with a gas engine.

XXXVI

Air and Fuel

We are, then, gas engines. So we have to have air to mix with our gasoline. The simpler water animals, such as sponges, which are mostly holes, and all minute creatures, both animals and plants, simply take it in directly into their cells where they are going to use it. There is plenty of air in water—you can see it fizzle out from the water in a drinking glass when you draw water from a faucet in cold weather. The water creatures breathe this out of the water, and die of suffocation if you put them in boiled water from which the boiling has driven out the air.

Most animals which have blood, use this to carry the air to their cells. For blood, whatever else it is, is nine-tenths water, and will dissolve air like any other water. The insects, however, though they have blood, do not use it to carry air. Instead, they have a system of branching pipes running all over their bodies, and opening at various points on the surface. You can often make these out easily, a pair of openings for each joint, on the sides of caterpillar's body. These pipes carry the air everywhere over the insect's body, even to the feet, so that wherever there is a working muscle, there also is the air for it to work with. Thus the insect has no need of lungs, and has none; and therefore, I suppose never gets out of breath, no matter how hard it works.

In place of lungs, insects have breathing holes like a leaf.

We human beings, and our four-footed cousins, all backboned animals in fact, do not manage in any of these ways. We breathe the air into our lungs. There, instead of dissolving it in the watery part of the blood, we turn it over to the red corpuscles, which are especially made to do this very thing and do it particularly well. These minute, coin-like corpuscles carry the air all over the body, and deliver it over to the cells as they need it. But of course, as you must have already learned in school, the body handles only the part of the air that it can use, the oxygen. The rest it lets go and doesn't bother with. That is where we have the advantage over other automobiles, which can't pick out the part they want but have to take the air as it comes. Still it all comes to the same thing in the end. With all animals the oxygen gets mixed with the fuel and explodes.

Our fuel, moreover, is a good deal like gasoline. Gasoline, as you know, is related to kerosene, benzine, paraffine, and the rest, which are all products of rock oil. They are, then, themselves oils; and gasoline is an oil.

We, too, eat oils; not, to be sure, mineral oils, but animal and vegetable oils, olive oil and butter and cream and all sorts of fats; for fats are merely oils that freeze at common living temperatures and melt only after we get them stowed away.

We, then, burn many sorts of oil. We also burn bread and potatoes and the like, starch and sugar and gums, which though not oils, are much like them; really in a way, oils that are already about half burned. These we finish up in our engines. On the whole, it's much more convenient than depending on one sort of fuel, and exploding only gasoline.

I am not going to stop now to tell you the long story of how the bread and potatoes and the rest of our food finally gets changed over into a sort of sugar; and is as sugar, packed away in the cells of our muscles and other tissues, mixed with the oxygen of the air, and made ready to explode when the signal through the nerve touches it off. The food is taken apart and put together again, combined and separated, stored up when it isn't needed, and used sometimes in one way and sometimes in another. Different animals treat their food differently after they get it swallowed; even different human beings, eating the same food, do not always handle it quite the same way.

Most of us take our food into our stomachs, but the earthworm crawls through the earth, and at the same time lets a stream of earth crawl through him, digesting what is food and leaving the rest behind as he moves along. Amoebas sometimes flow round little water plants many times longer than themselves, crawl along the stem, with the stem sticking out front and back, and digest the juices as they go along. The star-fish, which lives on oysters larger than himself, turns his stomach inside out, sticks it into the oyster's shell; and after he has digested the oyster, pulls his stomach back again. A dog will digest bones; and a cow will digest wood; while a fish will swallow another fish nearly as long as himself, keep the tail, still unswallowed, in his mouth while he digests off the head, and than moves his meal up another notch.

There are all sorts of queer freaks, but the main point is that, in the end, all our food gets built into the cells of our bodies; much of it in the form of sugar, and that this sugar explodes as if it were the gasoline vapor in a gas engine that some man has made. With the force of these explosions, the body does its work; it keeps itself warm with the waste heat.

XXXVII

Men In Glass Boxes

One curious thing about these explosion engines of ours is that, when all goes well with our little insides, we get just exactly the same amount of work out of each mouthful of our food, that we should get, if we should dry the food, grind it to fine dust, and explode the dust mixed with air in the cylinder of an automobile—as it would be quite possible to do, if one wanted to take the trouble.

In fact, the United States Government, for several years, set people to trying just this very thing, by way of finding out how much work can be got out of various sorts of food, and out of which sorts a man can get most for his money. They have a big glass box, as large as a state-room on a steamer, with a bed in it and a table and chairs, and also a stationary bicycle, on which one can ride without moving, and so get his exercise. They put a man in this box, and keep him there for a week. They weight carefully everything that he eats and drinks; and each time he takes a meal they find out, by drying some of the food and burning it and measuring the heat they get from the burning, just how much that food is worth as fuel. Thus they know how much exploding he ought to be able to do in his tiny cylinders.

Then in addition, they keep track of all the air that goes into the glass box, and find out just how much oxygen he uses up to explode the food. They see also how much he heats up the air which comes out of the box by the warmth of his breath, the heat of his body, and the friction of the stationary bicycle when he exercises.

It always turns out that the man makes just as much heat out of the food he eats as the same food would yield if dried and burned; and that it takes just as much air to explode it in his body as it would take to burn it in a stove. So the body is really an engine. It uses up fuel like any engine; and gets the same amount of heat or work out of its fuel as any other well-made engine would.

As a result of these experiments, and others like them, the United States Department of Agriculture has issued a pamphlet, called Bulletin Number 28, which tells, among other things, how much work one ought to be able to do on one pound of almost any sort of food that any civilized human being would ever think of eating. I trust that every girl who reads this book, before she grows up, and goes to keeping house, and has to feed a family, will get this little pamphlet, or something else like it, and study carefully what different foods are really good for. According to the United States Government, a child can do more hard playing, and a man more hard work, on one pound of bread, spread with four ounces of butter, than eight pounds of broiled spring chicken; while ordinary dry crackers and cookies are twice as nutritious as lean meat, and six times more nutritious than oysters, lobster, and most sorts of fish.

Still, there is this most important difference between our living engines and the engines which we build of brass and steel. When a part wears out or breaks in an automobile, if it cannot be mended, it has to be thrown away. But in the body, when a part of the life-jelly wears out, as it is continually doing, we not only make some new to take its place, but we use up the old stuff as fuel to drive the engine.

In short then, some automobiles are built of steel and leather and brass and rubber, and burn gasoline. And some are built of life-jelly and burn sugar. The first sort, when it wears out, we mend with more steel and leather and brass and rubber. The second sort, when it wears out, we mend with more life-jelly, which we get from the portion of our food that is neither sugar nor starch nor oil, but the once living jelly of other plants and animals, which I am sorry to say, we have to kill to get stuff for our own repairs. The plants can make their life-jelly out of the air that they take in thru their leaves and the water that comes in through their roots. But we animals, from the least to the greatest, can get it only by taking it away from something else. For my part, I feel easier in my mind when I take away this life-stuff from some plant like wheat or corn, than when I rob some breathing animal like myself.

XXXVIII

Of Sugar and Other Poisons

Our bodies, therefore, and the bodies of all other animals, are gas engines, which burn sugar by exploding it mixed with air. Most of our food, to be sure, isn’t sugar, but bread and potatoes and cookies and all sorts of nice things made of butter and flour, milk and the like. But as I have already pointed out, the most important portion of this food is either made over into our own life-jelly, or else it is changed into sugar and exploded in our muscles.

Sometimes when the automobile goes by, one of the things you notice is a very bad smell. This is largely the unburned and half burned gasoline. Gasoline, when it burns clean, changes to water and to the odorless and slightly tangy gas which we get in soda water, carbon dioxid as it is called. When you burn gasoline, then, you get the same products as if you boiled plain soda water.

Most things that burn, likewise, burn to carbon dioxid and water. Wood does it, and coal, all kinds of oil that we burn in lamps, and the gas that we burn for light and heat. So, too, do all sorts of candles—paraffin, for example, or wax; and so, too, do the old fashioned tallow candles which our great-grandmothers used to make. Tallow, however, is a fat, except for its taste, like the fat we eat. Practically, we eat nothing that we cannot also burn, when dry—tho we do burn a good deal that we cannot eat.

Most of these burnable foods explode in the body, a good deal as they burn outside. They form carbon dioxid and water—when you “see your breath” on a cold day, you merely see the water in it that came from your exploding muscles. If you eat largely only plain wholesome foods, bread and butter, fresh vegetables, fruit, candy and cookies and crackers, and all the various other foods that burn clean, they will burn clear in your bodies, and you will yourselves be clean and sweet as children ought to be. But if you have a taste for things you ought not to have, and get them, then instead of good clean water and carbon dioxid, you will explode to a lot of unwholesome, poisonous, and smelly things, that are not at all nice outside the body, and are still worse inside.

Unfortunately, we cannot live altogether on these clean-burning fats and starches and sugars, which explode to carbon dioxid and water, and leave nothing more behind than a wax candle when it burns. We can’t make our life-jelly out of these foods. So we have to eat also, eggs and milk and cheese and beans and peas and meat and fish, some parts of which we can build to our life-jelly. But only about a tenth part of our food needs to be of any of these life-jelly-making sorts. The other nine-tenths should be the clean-burning things with which we do most of our work and play.

But whatever the fuel with which we run our bodily engines, sooner or later it gets used up and the waste products have to be blown off into the air. Insects and automobiles, which take the air pretty directly into their cells, blow off their waste gases directly into the air again. The lowly creatures which breath the air in the water, send their carbon dioxid back into the water again. But we who have blood, use that to carry off our exploded sugar and other things.

The water of the burned up food is simply added to the watery part of the blood. The carbon dioxid becomes in the blood ordinary cooking soda; the blood carries the soda to the lungs, and there it changes to carbon dioxid again, exactly as it does when, as cooking soda, or baking powder, you add it to flour and use it to raise cake. Finally it comes out of the lungs with the breath, and that is the end of it so far as we are concerned.

Still, we are not through with it yet; because the plants take in thru their leaves the carbon dioxid that we animals breath out thru our lungs, take it apart again, mix it up with water and other things which they get thru their roots, and finally make it over into wood, and into starch and sugar and the like which we animals eat up once more. So if we eat the plants, the plants also eat us; and the same stuff keeps getting used over and over again. And a mighty convenient arrangement it is, too, since there is precious little stuff to make living things out of in the world at best. Most of the earth is just rocks.

However, I started to tell you something about the burnt up food and exploded muscle-sugar, While it is still in the body, before blood and lungs and skin and kidneys have combined to carry it away.

Did you ever stop to think why you are sleepy when night comes? You play hard all day, running about until your legs are tired enough to drop off. By and by, you begin to be sleepy, an hour or two it may be before your proper bed time. You are tired in your legs. But you are sleepy in your eyes. Your legs are not sleepy in the least; and your eyes are not tired. How did the eyes find out that the legs had been running hard and needed sleep?

It is these same waste matters in the blood. We run our legs off by day; and by night time a hundred thousand little explosions in our muscles have used up so much sugar and the rest, that the blood is filled with the waste material, and the lungs cannot carry it off.

So it stays in the blood and poisons us—not badly, but just about as much as if we had taken a small dose of laudanum or alcohol or any of the large number of sleepy poisons, which kill one by putting him to sleep so hard that he cannot wake up. Our "fatigue toxins" as we call them (which is simply Latin for poisons that we make by getting tired) poison us just enough to make us sleep. While we sleep we don't do much; less of these toxins are formed; the lungs and kidneys have time to catch up with their work; pretty soon the blood is clear again, and we wake up in the morning ready to do it all over once more. We are made to stand a certain amount of poisoning, and get over it. The trouble comes when we poison ourselves With things that we put into our blood, that we might have kept out.

Did you ever think why, after you have been running hard for a long time, your legs ache? Or why they stop aching when you sit down to rest, but don't stop at once? It is these same fatigue toxins. You explode your muscle cells faster than the blood can wash away the products of the explosions. So these accumulate. By and by, they begin to poison the muscle, and you begin to feel the pain. If you keep on working, as people have to sometimes in spite of weariness, the ache and the poisoning gets worse and worse, till the muscle simply refuses to work any longer.

If you stop to rest, the ache of weariness still continues. But after a little, the blood stream washes the muscle clean. Then the ache is gone, and you can get up and run again. Nevertheless, a whole day's play or work will so load up the blood with toxins that it can no longer wash the muscle clean. Then you must take a longer rest, go to sleep, and give time for the blood itself to clean up.

Perhaps you have noticed (if you haven't, try it—only don't lie on the damp ground) that when your legs are tired, they rest and stop aching much more quickly if you put your feet up higher than your head. This is, of course, because the blood current coming from the tired muscles, can run down hill, and so most easily drain off the toxins which make the ache. So too, you can keep fresh much longer, whether you are working or playing with the muscles, or sitting still and working your brains over your lessons, if you stand up properly and don’t slouch. When you slouch, you cramp your lungs. The cramped lungs fail to clear the blood. The dirty blood fails to wash brain or muscles clean, and you get tired sooner than you ought. For the same reason, you tire more quickly in bad air. But if you give blood and lungs a fair chance, they will do a lot of resting for you while you are still at work.

But long before we get in the least tired, we get out of breath. Poisons as before, only this time it is largely the carbon dioxid that does the business. The muscle-sugar explodes, and forms the carbon dioxid. The carbon dioxid leaks out into the blood; and the blood, circulating thru the body, carries it to a certain nerve center high up in the back of the neck. This in a sense tastes the carbon dioxid, something as the tongue tastes it in a glass of soda water.

When the nerve center in the neck tastes a little carbon dioxid, it doesn’t say anything. But the moment the taste begins to get strong (which is in less than a quarter minute after one starts running hard) it telephones over the nerves to the lungs: “Here, here, here! What is the matter with you fellows. Get busy. Breathe hard. This blood is fairly sizzling with burnt up sugar!”

Thereupon the lungs get down to work. They breathe as hard and as deep as they can; while the heart, which has also been telephoned of the situation, beats harder and harder, to give the lungs all the blood they can clean, and the working muscles all the blood they can dirty.

If heart and lungs hold their own, nothing in particular happens. But if we keep running on too hard, so that muscles poison the blood faster than the lungs can un-poison it, then the nerve center which is in the back of the neck interferes once more. When it cannot make heart and lungs work faster, it calls off the muscle. Suddenly it gives us such a feeling of loss of breath and suffocation, that we simply cannot run another step. We have to stop. Then heart and lungs catch up on their work.

Curiously enough, getting one’s “second wind” as we say, when the lungs after pumping violently, settle down to working steadily once more tho we still keep on running, and “getting in training” so that we can do all sorts of exercises without getting winded, both these highly desirable conditions depend in part on teaching this “respiratory center” in the neck not to raise so much of a row when it smells a little carbon dioxid in the blood. We train our muscles to do their work; and we also train this nerve center not to get rattled and turn on that feeling of suffocation until it absolutely has to. We get it used to burnt muscle-sugar so that it doesn’t mind the taste as it did.

So, as I say, we live only by just escaping being mildly poisoned. But the curious thing about it is that among these various poisons which would certainly kill us forthwith, if we did not promptly get them out of our bodies, stands, of all things, sugar.

We eat a good deal of sugar in our food. We make a good deal more out of other sorts of food. If we did not make sugar, and have it always on hand in our blood, we could neither work nor live. And yet thousands of persons, every year, die of nothing in the world but sugar poisoning.

Sugar is so very poisonous that we have a special arrangement in our livers for keeping down the amount that at any one time gets into the blood. But for this, a box of candy, or a meal of bread and potatoes would inevitably kill us within three hours. The blood of a full grown man always contains about a quarter ounce of sugar, that is to say, two ordinary lumps. If he has less than two lumps, he begins to starve. If he has more than three or four lumps, his head feels heavy and he cannot keep awake. He begins, in short, to be poisoned. But any one who should get his blood half as sweet as he takes a cup of tea or coffee, would promptly drop into a sleep from which he would never wake up at all.

One thing then that the liver is for is to catch the sugar as it goes by, after a meal, and store it up where it will do no harm. Then it slowly feeds it out again, as the muscles use it up, always keeping the amount in the blood at two lumps. But if we eat or make more sugar than the liver can pack away, then the rest is changed into fat and stowed under the skin and around the muscles. So we store our food as fat, and use it as sugar—fat, luckily, being one of the few things we make in our bodies that are not poisons.

XXXIX

Snake Venoms and Others

The life of any creature, man, animal or plant, is one long fight against being poisoned. The poisons get us in all sorts of ways. Some, like strong acids and caustics, actually destroy the flesh, just as they would eat a hole thru the top of a stove, and we are crippled or die for lack of a lining to our stomachs. A great many poisons, like alcohol, ether, chloroform, the various alkaloids, such as strychnin and atropin and cocain, which we use as medicines, and nicotin, which is the alkaloid of tobacco, the poisons of many toadstools, caffein (don't call it caf-een, but caf-fe-in, like co-ca-in) which we get in tea and coffee (and therefore ought not to drink either till we are quite grown up) and half a thousand others, mostly with names ending with "in" and the ptomains (again it's three syllables, to-ma-in) which form in fish and ice-cream that have been kept too long, and poison whole families at once, all these do not do any special harm in the stomach. But when they get into the blood stream, they go straight for the nerves and upset them. Ether, chloroform, and cocain, as we all know, begin by paralysing the pain nerves. The pain sense is cut off from the brain, so that no matter how much damage is being done, we don't know anything about it. And a mighty good thing it often is that we don't!

Other poisons attack the blood. The fumes from burning charcoal and some sorts of gas that we use for lighting and cooking, lock the oxygen of the air so tightly to the red blood corpuscles that are carrying it to the cells, that the cells cannot get it away from them. So the tissues die from lack of air, tho there is plenty and to spare in the lungs and the blood—only the blood hangs onto it, and the rest of the body cannot pry it loose. Snake poisons, also, kill by attacking the blood, thus cutting off the supply of air. These dissolve the blood corpuscles that carry the oxygen, and literally "turn the blood to water." Then the blood, having no corpuscles, cannot carry oxygen to the cells of the body, and the body dies of suffocation, tho the lungs take as much air as before. Snake venom, therefore, does not do the least harm in the mouth or stomach. One can suck the poison from the wound made by the snake's teeth, and spit out the poisoned blood, or even swallow some of it, without the least danger. One could wash himself in rattlesnake poison, and take no harm, so long as he kept a whole skin so that nothing got into his blood.

Perhaps you know that pigs are the great enemies of rattlesnakes, killing them and eating them up as if the serpents were so many apple parings. The rattlesnakes bite the pigs. But the pig's skin is thick, and under it is a great layer of fat, in which there is almost no blood. So when the pig gets a dose of poison under his skin, enough to kill two or three men, he does not mind it at all. The venom, shut up in the fat, works out into the blood so slowly that the pig can make new blood corpuscles almost as fast as the poison destroys the old ones. So at the worst, the pig feels only a little discomfort. But the rattlesnake is safely tucked away in the pig's inside, where it will never do any more biting.

What I want you to remember, then, is this: All living things are poisonous. We, ourselves, are continually manufacturing in our bodies carbon dioxid, sugar, ammonia, and a score of other things, any of which would soon put an end to us if we did not have a special machinery for getting rid of them before they get a chance. A great many plants produce also certain special poisons, strychnin, nicotin, and the like, which would kill them if they made too much. A few animals, too, like the snakes and some fishes and various insects, manufacture poisons, which also would kill them. In general, the blood of any animal is a poison to an animal of any other sort, and always a poison of the same sort as snake venom which does no harm in the stomach, but is fatal when enough is taken into the blood. In general, then, each creature has some means of getting rid of its own poisons, but the poisons of any different sort of creature will kill it.

XL

Of Measles and Rusty Nails

Little boys sometimes get careless on Fourth of July. Perhaps they let a cracker go off in their fingers. Perhaps they pull off a toy pistol without noticing where it is aimed. Boys have been known to do both these things.

When this happens someone is pretty likely to get a hole blown in his skin. That of itself is not especially serious; the hole will soon close again. But we are pretty certain to be dirty on the Glorious Fourth, especially if we have been round the streets, in the dust that people’s feet are stirring up. So when we blow holes in our skin, we are pretty likely to blow dirt in also.

City dirt has a great many different things in it. Among them, almost always, certain very small plants, far too small to be seen except with a pretty strong microscope. These are, in fact, a particular kind of bacteria. So we blow thru our skins, hole, dust, and bacteria. The hole heals over, but the bacteria stay inside.

Being living plants, they grow in the blood—like mold in bread or yeast in dough. Being living things, as they live, they make poisons. It happens that this particular plant makes an especially deadly poison, which goes straight for the nerves. Then the victim has convulsions, and almost always dies within a few days.

This is, in fact, the dreaded tetanus or “lockjaw,” which used to kill scores of boys and girls every Fourth of July. Sometimes, too, one catches it by stepping on a rusty nail, not because the rust on the nail does any special harm, but because a rusty nail is likely to be a dirty nail also, with the tiny living plants mixed in the dirt. We rarely get lockjaw from an ordinary cut with a sharp knife, because such a wound bleeds freely and washes itself out. The dangerous wounds are small deep holes and ragged tears, that give the little living plants a chance to hide and grow.

All catching diseases are like Fourth of July lockjaw. Measles, whooping cough, chicken pox, ordinary colds, grip, and many most dreadful sicknesses of which people die, all such are caused by some living thing which gets into our bodies, grows there, and living and growing, poisons us with its waste products. Some of these plants grow in the lungs, like that which causes consumption. In some, like diphtheria, the growth is in the throat. In summer complaint, which sickens the babies in the hot weather, the trouble is in the bowels. Even some sorts of baldness are due to growing things at the roots of the hair. Mostly, however, the plants grow in the blood. In any case, the poisons they make get into the blood; and there they poison the nerves, like the various alkaloids I told you about, or else they attack the blood itself, as the snake venoms do.

The minute animal which causes the “sleeping sickness.”

Some of these disease-making things, too, are not plants but animals. Such, for example, is the minute creature that causes malaria; and another that makes the dreadful “sleeping sickness” that every year is killing thousands of wretched negroes in Africa, in spite of all that can be done to prevent it.

They get into our bodies in all sorts of ways. Some come in the dust, when we breathe dirty air. Some come in dirty water. Some, a great many, come in dirty food, on lettuce and celery that have been carelessly washed, and especially in dirty milk. Some of the worst of all among them, the germs of typhoid fever, are carried on the feet of the common house fly, and planted all over the things that we are going to eat. Rats and mice also carry diseases—in their fur, on their feet, or even in their blood. So, too, do certain stinging, biting, and sucking insects; and when they bite or sting or suck the blood of some larger creature, they plant the seed of some disease in his body, where it grows and flourishes until the animal sickens and perhaps dies. No one, for example, ever catches yellow fever or malaria unless he has been stung by a mosquito which has already bitten somebody else with the disease. The mosquito picks up some of these living germs in the blood of one person, and sows them in the blood of the next; just as one might take seed from one field or garden plot and sow it in another.

All the catching diseases, then, from ordinary colds to pneumonia, and from measles and chicken pox to typhoid and scarlet fevers, are nothing in the world but living plants or animals growing in our bodies and poisoning us. We say that we catch the disease. Really the disease catches us. The disease is a living thing, that in very real sense, hunts for us, and catches us as a lion or a bear might do, or a poisonous snake. If we could kill these lions, bears, poisonous serpents, bacteria, and the rest, why then they wouldn’t get a chance to kill us. Then we should all live to old age—unless we poisoned ourselves, as I am sure some persons are quite foolish enough to do, or met with some accident that we could not help. But of course there are a few other diseases, like rheumatism and heart disease and indigestion, where the trouble may be with ourselves and not with any other living creature that gets after us.

Just to show you how one of these living, catching diseases manages to get on, and when one victim dies, changes over to another, I am going to tell you about something that I am sure you have already heard of either in your history, or else in stories that you have read about the Middle Ages, when the knights wore armor and the yeoman fought with spears and bows.

In those good old times, every little while, whole cities would be smitten with a terrible disease called the plague. Perhaps you already know about the Great Plague of London in 1665, when seventy thousand people perished, and the dead lay in the streets because the living were too few to bury them. The same man who wrote the story of Robinson Crusoe, wrote also a story of this great plague, not a pleasant story, naturally, but one that you will want to read later when you are older.

The trouble was nothing in the world but dirt and rats. The rats lived in the dirt; and the minute, living plant that makes the plague, lived in the blood of the rats. From them it got into the blood of human beings. But so long as a city kept clean and free from rats, it never had the plague. But when it let itself get dirty, as ancient cities usually did, then it might lose a fifth of its inhabitants in a few months.

As people, therefore, began to be more decent, the plague began to disappear; and after about the time of our Revolutionary War, most of Europe had become so clean and civilized that they had no more plague there. But still it lingers in other parts of the world, where there is more dirt, and where people, instead of putting their waste tidily away in the bucket or burning it up, throw it out the back door for rats to eat. Always, even now, the plague threatens Asia. During the first ten years of this very civilized twentieth century five million persons died of it in India alone.

And all because of dirt and rats and fleas. The rat lives in the dirt. The fleas live on the rat, and when they bite the rat, get a stomachful of blood, and with it some five thousand or so of the little plants that cause the plague. Then the flea jumps off the rat, on to a man, and bites him. Then a few of these five thousand germs get into the man’s blood. By the next day, these few have become millions. Within a week, often within two days, the man is dead—simply poisoned. But if the man had kept his house clear of rats and his skin clear of fleas, by keeping them both clean, he would not have been poisoned at all.

I am sorry to say that since the year 1900, and even as late as 1909, there have been cases of the plague in one or two especially dirty cities in the United States. So the National Government had to interfere, to make them clean up and get rid of their rats. Otherwise we might have had a terrible time; while as it was, some three hundred people died—which is more human beings than most of us know by name.

But you can't have the plague without rats, and you can't have rats without dirt. So, therefore, every civilized government in the world keeps men at work in its seaports, killing the rats that come in the ships, lest they bring the plague from China or India, where they don't mind a little dirt.

There is another animal, dirtier even than the rat, and on the whole rather more dangerous—and that is the fly. Wherever there is dirt, there are pretty sure to be the germs of various diseases. If there is anything the fly likes, it is dirt. He eats it; he wallows in it. The dirt sticks to his feet, and the disease germs stick to the dirt; for a fly is not nearly so much smaller than an elephant as a disease germ is smaller than a fly.

Then the fly tracks over our food or falls into our milk. He may carry a million germs on his body, and every time he puts down one of his six feet he plants at least one. In forty-eight hours this single one may have grown to sixteen thousand. Then some boy or girl eats the food and is sick; or some baby drinks the milk and dies.

XLI

The Great War

The hardest battle we have to fight is with these living diseases. They kill more people in each year than have perished at the hands of the enemy in all the wars we have ever fought. During our war with Spain, the flies alone killed in camp four times as many of our soldiers as the Spaniards killed in battle. Every day of our lives in war and in peace, we are fighting for our lives against these unseen foes of pestilence and disease.

This is how we carry on the campaign. Our first line of defense is keeping clean. Every city now-a-days has men who watch its water supply. The surroundings of its ponds and reservoirs are carefully guarded. If necessary, the water is filtered before it goes into the street pipes. Always, if the city is half civilized, it filters all its sewage before turning it into the rivers. Thus, if there are any living animals or plants in the water, they get strained out. In many houses, where the people are especially careful, they strain or filter the water once more, or boil it till they kill every living creature therein.

Then every city has other men to look after its milk. Because milk, being good food for us, is good food also for other living creatures; so that if one single germ gets into a bottle, it will shortly grow to many millions, and play sad havoc with the family that uses it. Careful people, too, do not depend on the city to keep their milk clean, but see for themselves where it comes from; especially if there are children, for children not only drink much milk, but are peculiarly liable to catch the diseases which come in it.

Careful people, in addition, look out that all their food is clean. They see that none has been kept out where dust may fall in it, where rats or mice may brush against it, or where flies may track over it. In all these ways, the seeds of diseases may get sown in our food. One ought to make sure that there are no rats, mice, or flies in the house at all; and one ought to make sure also that all raw foods, like lettuce and celery are thoroly washed, for these often carry the eggs of certain animals, living eggs which will hatch out inside anybody who swallows them, and not be at all to his advantage.

That, then, is our first line of defense—keeping our food clean, lest the enemy enter through our mouths. Our second defense is to keep the air we breathe, clean and fresh and dust free, lest the enemy attack us by way of our lungs, and we die of pneumonia or consumption, or sicken of common colds and the grip. In all this, we are like a country with a powerful navy which can prevent the enemy from making a landing on its coast. So long as we keep these minute foes out of our houses, and still more so long as we keep them out of our cities, they cannot get near enough to us to do us any harm.

But when the enemy has broken through our first line of defense, and begun to lay siege to our bodies, we still have a second line of fortifications to protect us. One thing our skins are for is to stop germs. So long as we keep a whole skin, it is pretty hard for many sorts of germs to gain an entrance. And where the skin is thin, as it is inside the mouth and nose, there is always a somewhat thick and sticky mucous to catch the germs; while the eye has tears to wash them out. We are like fortified cities; and we must not let the enemy make a breach in the wall.

So we must be careful not to neglect even small cuts, sores, scratches, and the like, thru which the foe can enter. People sometimes get most loathsome and dreadful diseases by drinking from dirty cups when the skin of their lips is cracked in cold weather; while the little plant that causes blood poisoning, often gets in by way of a cut so small as to be hardly noticed. No child would ever die of lockjaw, if he did not first cut or blow a hole in his skin.

Strangely enough, a great many of the lesser catching diseases of children, measles and colds and the like, make their way into the blood because of holes in the teeth. A hollow in a tooth gets filled with food. A germ or two finds its way into this food, and grows there till it becomes many millions. So naturally, an assault by an army is more likely to be successful than an assault by a mere handful. Merely by keeping the teeth and mouth clean, and by having a dentist stop the holes in the teeth, one can cut down to less than half, the number of days' sickness in a year. Some people go beyond this, and always after they have been in dust or bad air, wash out their noses with some fluid that will dispose of any of the enemy who have lodged there. In fact, people who have suffered almost continually from colds and grin are sometimes cured at once and completely, by merely a slight operation on the nose, which opens up to the fresh air some hollow in which the besieging hosts were wont to lurk.

Our second line of defense, then, is keeping skin and teeth and nose clean and whole, that the enemy may have no place wherein to hide, and no breach through which to enter. If this gives way, then we must engage the enemy hand to hand.

Then it gets to be a pretty even thing between us. The invaders try to poison us, and we try to poison them. We form an acid in our stomachs—the same acid, by the way, that tin-men use to solder with; one can buy it anywhere. Regularly, we use this to digest meat with; but if any living things get into our stomachs, we give them a dose of this acid, and usually bowl them over.

If they get by this, we poison them with bile. The bile is made in that most useful organ, the liver, and is partly waste matter, more or less hurtful to the body, which we are getting rid of. So since we don't want it to poison us, we use it to poison other living creatures inside us.

That, then, is our third line of defense. If the enemy gets by that, then the war has to be fought out in the blood. Even if we win, we shall suffer damage, and very likely take to our beds and have to call on the doctor for reinforcements.

The blood itself, good healthy blood, that is, will poison the germs; for the blood of any sort of creature, as I have explained, will poison any other sort. Besides that, we manufacture special poisons with which to combat each special creature that makes a special poison to assault us. So each side poisons the other, and the battle becomes a question of which can kill the other first. In one case, we are sick and recover; in the other case, we are sick and die.

When the doctor takes a hand in the battle, he begins by giving us food and medicine, to make us strong for the war. Sometimes, besides these, he gives us something which, while it harms us a little, harms the enemy a great deal more. In a few cases now-a-days, he pumps into our bodies some of the blood of another animal, generally a horse, which has been fighting the same disease, and so has its hand in and can manufacture many times as much stuff to kill the germs as we can. Many, many people have been saved by this means, who otherwise would certainly have died.

In a few cases, too, small-pox especially, by means of vaccination, long before the enemy attacks us, we can be loaded up with ammunition to repel the invader when it does come. The vaccination gives a mild form of the disease (not so very mild perhaps you think, when your vaccinated arm gets nice and red); we defeat this triumphantly, but we manufacture so much "anti-toxin" to do it with, that for years afterwards we are all ready for the first germ that shows its face in our blood, and slay him before he gets a chance at us. The "anti-toxin," as you know, is the substance which we make with which to get back at the germs that are trying to poison us with the "toxin" which they make.

But even the battle in the blood is not fought quite in the open. We have, so to say, breastworks and rifle pits, where we can still make a stand, even after the invaders have gained a footing in our bodies.

Perhaps you have sometimes felt small roundish hard bunches as big as a pea or a marble, under the skin at the side of the neck, under the arm pit, or in the groin. Sometimes these swell up and get sore. These nodules are the lymph glands. They surround the passages through the flesh along which the invading germs are likely to come, after they have burst through the skin. They are then like the fortifications along a road over which the enemy is likely to march. We can feel them only in certain places; but they are all over the body, under the skin, and beneath the membranes of the lungs and the digestive organs, wherever the body is most open to attack.

The garrison of these little forts are a peculiar sort of naked cells, which having no walls or covering to hold them in, can change their shape, reach out, and draw back again, as if they were sea-anemones or polyps or some other sort of water creature, and not part of our bodies at all. These cells are twenty or more times larger than the bacteria. And when the bacteria or other germs come along through the passages of the body on their way to the blood vessels, these guardian cells of ours reach out and grab them, drag them in, and devour them, like ogres that devour travelers who go by their castles, over the high road. Only in this case, our sympathy must be entirely on the side of the ogres.

But these lymph cells do not always stay in the lymph glands. When they like, they let go their anchorage, and go floating off through the blood, or through the lymph; for the lymph is only the watery part of the blood without the red corpuscles, which doesn't stay in the blood vessels but soaks everywhere through the body, feeding and moistening the cells. These lymph cells, or white blood corpuscles, can go everywhere over the body, pushing and squeezing and elbowing their way among the other cells or traveling in the open spaces between them.

When the enemy enters the body, and begins to poison the blood, the white corpuscles smell them, and at once begin to crawl toward the smell, to reinforce their brothers in the particular lymph glands which happen to be at the point of attack. You get a sliver in your finger. The sliver opens a hole in your defense, and carries in some hostile germs. If, therefore, your lymph cells did not come to the rescue, you would inevitably die of blood poisoning. But they do come to the rescue. The white "matter" or "pus," which in a few days comes out of the wound, is in large part the dead bodies of the fallen enemy and of the defenders who have perished in the fight. So in general, the invasion is stopped at the first lymph gland. A few thousand white corpuscles fall in the war. The enemy is massacred to the last man. And the body is saved.

Or else the foe get the upper hand; increase faster than the defenders can kill them off; break through the defense; enter the blood stream; invade the whole body; overrun the country; and put the inhabitants to the sword.

Lymph Cells or White Blood Corpuscles

All our lives long, every day of our lives, we keep up this fight against disease. When measles does not threaten us, then it is colds. The game, therefore, is to strengthen our outer defenses, by keeping our food and houses clean, and our skins and teeth, and the air we breathe. And while we are doing that, we ought also to keep our bodies strong and resistant, with proper food and exercise and sleep, ready to put up a good fight if the enemy should break in. We know so much now about the causes of disease, that being sick or keeping well is a good deal under our own control.

XLII

More About The Great War

We are not the only creatures who have to fight for our lives, every day of them, against an ever-present but unseen enemy. All other animals have to do the same, if they are big enough for any thing else to live inside them. There are parts of this earth where no cattle or horses can live, and where all the heavy work has to be by machinery or by hand, because there are flies there which bite all the larger animals, both wild and tame, and plant germs in their blood. After that the tamed creatures, at least, almost invariably die.

Animals, therefore, have their catching diseases just as we have. Sometimes they are the same as ours; more often they are different—things that dogs or cats or horses catch, and we do not. Once, I remember, it must have been more than sixty years ago, all the horses over entire states suddenly fell sick. One hardly saw a horse on the street or anywhere; and because that was long before the days of automobiles or trolley cars, people had to walk or to drive oxen, and sometimes even to harness up cows. But after a few months, the horses all either died or got well again. Those that got well had their white blood corpuscles trained to fight that particular germ; so there was no more serious trouble. But it would make you laugh to see a span of cows haul a milk wagon.

There is a distemper that kills puppies. There is a chicken cholera which wipes out whole flocks of hens. The monkeys in the menageries succumb to colds and consumption, which they catch from the people who come to look at them. When the plague enters a city, the cattle and the various small animals of the house begin to die first before the human beings, and thus often give them warning, and time to flee. In all cases, some particular living and growing thing breaks through into the blood, or gets a foothold somewhere in the body, and begins to poison it. Then the invaders and the blood cells fight it out—and the best man wins.

There is a disease called anthrax which attacks various animals, ourselves and the birds among the number. A hen, for example, fighting anthrax, will almost always win, if it is kept warm. The lymph cells fight better when the blood is hot. But if the hen’s feet are kept in cold water, then the anthrax wins. The cool blood gives it the advantage.

That is how we and all other creatures catch cold. Mere cold would never give us chills or grip or colds. But our being chilled, or getting our feet wet, or sitting in a draught, just cools down some part of the body enough so that the blood cells can’t fight quite so well. Perhaps it is only for a moment; but in that moment the enemy gets its footing. Some people say that the reason why a dog’s nose gets hot when he is sick, and why human beings and animals have fever when they have anything catching, is so that their bodies may be well warmed up, and their lymph cells may do their fighting in hot blood.

Nor is it only for human beings and animals that all these catching things lie in wait. Plants have their troubles as well. Perhaps you have noticed on wild cherry trees growing by the roadside, or on plumb trees, that sometimes almost every tree in a clump, and even every branch on a tree, will have a hard black lump, as large as your fist, growing out of the bark. The tree is sick; sick with a patching disease of trees called the black knot.

The disease itself is something like a mold. It breaks through at the growing tip of the branch where the bark is new and thin. Thence it grows down the branch sucking up the living substance of the plant and killing everything as it goes. The “black knots” are the fruiting of the invading plant, where it has broken through the bark and is growing fine dust-like “spores,” which are its seeds and will spread the trouble to neighboring trees. When a tree comes down with this trouble, the only thing to do is to cut off every diseased branch a foot or more below the lowest knot, and burn it up. Possibly then, we may get ahead of the enemy, and so save the rest of the tree.

Almost every cultivated plant has its diseases. The brown spots on leaves and fruit of a pear tree are the plant’s measles. The hard lumps in an apple are its mumps. There is a sort of black scarlet fever of wheat, rust it is called, which destroys a million dollars’ worth of grain each year. Some plants look wilted because they need water; some, because they are sick and need medicine.

And they get medicine, too. Sometimes the plant-doctor gives it by soaking the seeds in the remedy; sometimes by spraying it on the leaves with a pump and a hose. In any case, the medicine is some sort of poison that kills the living creature that makes the disease, but does no special harm to the cultivated plant.

We even speak now of diseases of soils. Because there are minute animals that get into soil and lessen its fertility so that no plant will do well in it. Green-house keepers often bake their earth before setting out plants in it, in order to cure it of any disease that it may have caught while the last crop was growing; while a healthy soil will catch a disease from a sick one, exactly as a healthy animal or plant will do.

The fact that most diseases of men, animals, plants, timber, and soils are living things is something that has not been known many years. Indeed, it is only since the twentieth century came in, that we have really made much of a start at finding out just what plant or animal is responsible for the sickness of any other. It is only a question of time, probably a few centuries at the outside, before we shall have killed off all the common diseases. Then nobody can possibly catch anything any more—measles, mumps, chicken pox, colds, grip, diphtheria, scarlet fever, or anything else. There will not be anything left to catch; and nobody will be sick any more, unless he eats more than is good for him, or does something else that he might just as well not have done.

XLIII

Living Apothecary Shops

Not only are the bodies of all except the very smallest animals and plants at the same time gas engines and battlegrounds; they are also living apothecary shops. Indeed, it is a pretty well stocked drug store that has more different chemicals in it than a man and his horse, and his dog, and the garden that he works in, all together, manufacture every day of their lives.

Think to begin with, of all the different perfumes of all the different flowers, and all the various tastes of all the different vegetables which we eat, and of all the various spices and herbs which we use for flavorings in our food. Think of all the different coloring matters in flowers and leaves. Think of the tar, rosin, pitch, maple syrup, turpentine, gum, varnish, shelac, india rubber, tan bark, and the rest, that we get from a few trees alone. The chemicals made by even the ordinary plants could fit out the shelves of a fair-sized drug store.

We animals have vastly more different things inside us than any plant. Every time we move a muscle, we manufacture soda water. Every time we think, we turn a half dozen different chemicals into the blood. We take a mouthful of cracker, which is mostly starch; and straightway a ferment, or "enzyme," in the mouth begins to turn the starch into sugar. That is why a cracker or a potato tastes sweeter and sweeter the longer one chews it. When the sugar gets into the blood, another enzyme (the "y" is like "i," and the word sounds like en-zime) in the liver turns it back to starch again, so that it stays there in the liver, and can't get out. Then as you know, this liver-starch slowly turns back to sugar again, and leaks out into the blood to feed the muscles. In the muscles, still another enzyme helps it to explode into carbon dioxid and water, only sometimes it forms lactic acid instead, which is the acid of sour milk. Because of these enzymes in the muscles, the gas engines which they are, can run when only moderately warm, instead of needing to be too hot to touch, like other engines when they are at work.

But if instead of making flour into crackers, or having the baker do it, and then eating them, we had made the flour into bread with yeast: then the yeast, which is a living and growing plant, would have formed another enzyme, which in turn would have turned the sugar in the bread into carbon dioxid and alcohol, and the carbon dioxid would have puffed up the bread and made it light. That is what yeast is for. The yeast of beer also, turns the sugar of the grain into carbon dioxid and alcohol. The first of these gives us the fizz, the second we use to poison ourselves with.

Even the color of our hair and eyes depends on an enzyme which manufactures the coloring matter. People who have the enzyme, have dark hair and brown eyes. People who haven't it, have light hair and blue eyes.

In fact, almost anything that any living part of the body has to do, whether to take its food out of the blood stream and build it into its own substance, or to do its work, or merely to grow, it generally has to employ one or more of these enzymes to do it with. These are, in fact, the tools of the living jelly, or protoplasm, which makes our bodies and does our living for us. Without them we could not live a single hour.

I suppose there must be hundreds, or perhaps even thousands, of different chemicals and drugs and medicines and poisons and antitoxins and enzymes forming all the time in different parts of the body. The various organs put them to all sorts of various uses. Among others, they employ certain of them as messengers, to carry signals from one part of the body to another.

I have already explained that the head is one of the first organs in the body to be formed. It gets a start, therefore, over the rest, and a little baby's head is something like four times as big as it need be to fit its body. But the baby's legs and arms, which started late, are not nearly large enough to fit the rest of him. So the limbs have to grow fast, and the head to grow slowly, in order to come out right in the end. How do they know enough?

How fast little girls' feet sometimes grow! At twelve they can wear their mamma's shoes. Then the feet stop growing and the rest of the body catches up. Or when it is time for a boy's voice to change, all of a sudden, his Adam's apple, where the voice comes from, starts growing. In a few months it has increased from boy's size to man's, and the voice has dropped to a deep, if uncertain, growl. Everywhere throughout the body, the different parts start growing, and stop, and keep along together, or get ahead of each other in the most complicated fashion, but always right.

How they manage it, we do not altogether know. We do, however, know that the different parts of the body do signal to one another by means of these substances which they form within their cells, and turn loose in the blood stream. In this way, each organ of the body is able to send messages to the rest—"Start growing," "Steady now," "Slow down," "Stop"—as the case may be. You already know how a working muscle signals to the heart and lungs, and how the blood cells get wind of an invasion, by the altered smell or taste of the blood, and rush to the point where the enemy has broken through the defense, and the fight is on.

So in general, when a message has to go quickly from one part of the body to another, it goes by way of the nerves. But when there is no special hurry, or when the signal must go to some tissue or organ which, like the blood corpuscles, has no nerve connection, then the message has to go by way of the blood.

If then, our legs want to say: "We're sitting on something hard and sharp, please may we move," they call us up over the nerves. If they want to say: "We have been growing too fast, and it's high time we stopped and gave something else a chance," they do it by turning something into the blood. But if they want to say: "We're so dead tired that we simply can't walk another step," then as you know, they use both methods—fatigue toxins and very dreadful aches.

XLIV

What Becomes Of The Tadpole's Tail

The lymph cells, blood cells, white blood corpuscles, as they are variously called, are a sort of standing army, always on duty to repel invasion by any living germs of disease. In times of peace, however, when there is no enemy to be set upon and devoured, they have to work. All soldiers have to work when there is no fighting to be done; and sailors on a battle ship have to keep it clean and in order, row the captain about in his boat, and take turns paring potatoes for the cook. So the cells in our blood are in this like other fighting men.

Their particular work is to keep the body cleaned up, especially the blood. Besides this, they take down and cart away any tissue or organ or part of the body that is no longer any use.

There, for example, is the polywog's tail, after he becomes a frog—also his gills. The polywog, of course, is pretty nearly a fish, with gills and tail, who breathes water. But Brer Frog is pretty nearly a land animal. He breathes with lungs, tho not to be sure especially good ones, so that he has to breathe thru his skin also to help out. At any rate, he has lost his fishy gills, and no longer has any tail.

Where has the tail gone? The white blood corpuscles have eaten it up; and with it, a lot of other things, gills among the number, which the tadpole has to have, but the frog has no use for.

The tadpole, as you know, has no legs. When they start growing (you can see them under the skin, almost the first sign of the coming change) these growing legs turn something into the blood which is a signal to the blood cells to get to work eating up the tail. So the blood cells do get to work. They devour the flesh, cutting into it much as certain insects gnaw into wood, or a woodchuck digs a hole in the ground. Then as fast as the blood cells take down the flesh that is no longer useful, it is used again to build up the new legs. So really the tadpole's tail is used over to make the frog's legs.

Much the same thing happens when a caterpillar turns to a butterfly. The caterpillar, as you have no doubt often seen, shuts himself up in a hard shell. Inside this coffin, or chrysalis, the body of the caterpillar is taken to pieces, and changed over into a sort of thick milk. Then out of this thick milk, the butterfly is formed.

The caterpillar changes into a moth.

So the caterpillar does not become a butterfly simply by growing wings. It is really almost a new creature, built up out of the material of the old, as one might rip up an old coat and have it woven into a rug; and we may be very sure that no butterfly ever has the slightest recollection of the time when it crawled on a dozen legs, and chewed leaves for its food.

We, too, grow and change like frog and butterfly. When we were, say, four or five years old, we had twenty strong little white teeth, each set firmly in the jaw bone on a stout root. By and by, these teeth, one at a time, in pretty much the order in which they first appeared, began to get loose. First we could wiggle the tooth a little; then a good deal. By and by, it hung only by the thin skin of the mouth, so that one good yank, or perhaps only the push of the tongue against it, tore it out. Or possibly we bit into an apple, and left the tooth behind.

Anyhow, the tooth hadn't any root. The hard bone had gone, and with it the soft nerve and blood vessel that used to be inside. There was only the hollow cup that once was the crown of the tooth. The rest had been eaten up, bone, nerve and all, by our blood corpuscles. We needed larger teeth. Teeth, as I told you, once formed, cannot grow any more. So the blood corpuscles chewed up the tooth, as much as they could get at, and used the old stuff to build the new one. No doubt they would consume the entire tooth, crown and all, and not leave a shred behind, if only there were some way of holding the last bit in place while they finished it off. That on the whole would be pleasanter than having to tie a string round the tooth and yank it out.

They do act that way with growing bones. The bones, as I have already explained, grow much as a tree does, by adding on new stuff to the outside. Meantime, since all bones are hollow, the hollow also has to grow. The hollow grows by the taking down of the bone on the inside, just as a tree might decay out at the heart, about as fast as it grew under the bark. This, also, is the work of the white blood corpuscles.

Then, too, the soft gristle of little children changes into the solid bone of grown men. But the gristle never turns to bone. As before, the gristle is taken out, eaten into, devoured, by these living cells of the blood and lymph; and as fast as the gristle disappears, the bone grows into its room.

Or sometimes it happens that two little boys find themselves not in entire harmony, with the result that one little boy goes home with one eye shut up; and the next day, and all the next week, that particular eye is a most remarkable study in black and blue. That is because, during the lack of harmony, something happened to hit one little boy in the eye, and smashed up some of the little blood vessels around it, so that the blood leaked out into the flesh.

Then the white blood corpuscles, which are themselves always leaking out of the lymph spaces and blood vessels, and wandering round thru the tissues, have to set to work to clean up that spilled blood. So they actually eat up the flecks of blood; until by and by, the flesh is all clean and white again, and the black eye is black and blue no more. In general, whenever we meet with an injury or a wound of any sort, these white blood corpuscles take a hand in the healing process, eating away the damaged tissue, and allowing chance for fresh growth.

The white blood corpuscles, then, live to eat. Like certain other creatures who are always hungry, they sometimes eat things that they had better have left alone. Sometimes, people's hair turns white suddenly—corpuscles have actually eaten up the color. Some people even go so far as to say that the reason why we grow old (since, as I have already told you, growing old is mostly growing hard) is because these white blood corpuscles have gone crazy and eaten up the softer parts of us, and left us only the hard ones to grow old with. I don't know whether this last is so or not. But at any rate, these white blood corpuscles, which let go their hold on the places where they grow, and go wandering off all over the body eating everything in sight, would be likely to make this sort of trouble if anything would; and the man who especially says it is so, probably knows more about these matters than anybody in the world.

XLV

Nature’s Repair Shop

Of course, we get hurt in all sorts of ways—cuts, bruises, barked shins, black eyes, once in a while a bad sprain or a broken bone. Then the white corpuscles that are in our blood, and the growing life-stuff or protoplasm which is in our flesh and bones, and all this wonderful and mysterious life that is in us, take us in hand to mend us up. The same power that made us, and that keeps us alive, heals also our hurts. By and by, if we take care of ourselves, we are once more as good as new.

The small and weak and lowly creatures, which cannot take care of themselves as we can, and so are all the time getting into all sorts of trouble, are able to repair damages even better than we. The world is full of timid animals, which have neither teeth and claws to fight with, nor armor for their defence, nor speed of foot or cunning of brain with which to escape their enemies. But to make up in part for this lack, many of these simple beings seem not to mind at all such injuries as would cripple us for life; while they recover completely, and that within a few days, from accidents which would mean instant death to us.

A tiny lizard, for example, may at any moment have to scamper for his life in search of an equally tiny crack in the rock, where it may take refuge from some larger animal which wants it for breakfast. Naturally, oftentimes, the lizard so hardly escapes being “it,” that just as he whisks into safety, his pursuer snaps off his entire tail.

A loss like this would kill most larger animals, but not the lizard. He simply waits round for a week or two while a new tail grows, just as good as the old one, so that he is as well off as before. The same lizard has been known to lose his tail a dozen or twenty times, and each time to grow a new one. Since, therefore, a lizard’s tail is longer than his body, and nearly as large round, the animal must have grown enough new flesh to make at least five or six whole new lizards. Curiously however, the new tails, tho they look exactly like the old one, always have a rod of gristle or cartilage inside, in place of the regular backbone.

So too, with legs. A lizard that has had a leg bitten off, straightway grows a new one. He will even grow a whole new eye, when something happens to the one with which he happened to be born.

Yet oddly enough, the lizard, when he grows new legs and tails is continually liable to make the strangest mistakes. He will grow a new tail, when he hasn’t lost the old one, but only had a bite taken out of it. Then he has two tails. Sometimes he makes even a worse break than this, and grows out two new tails to replace the single one which after all he didn’t quite lose. Then he has three tails, which is at least one more than any proper lizard ought to possess.

It is the same, too, with legs. The lizard seems to get an idea that his leg has been bitten off, when it has only had a piece taken out of it. So he goes ahead to grow a new leg, and as a result, has five. In fact, it is quite possible, to manufacture a lizard, perfectly healthy and apparently happy, with eight legs and three or four tails.

Perhaps you have heard that “the early bird catches the worm.” If so, did you ever consider the transaction from the side of the worm? If the worm happens to be retiring into his hole just as the hungry robin catches sight of him, there is likely to be a tug of war between the eater and the breakfast. The worm swells out the front end of his body, and gets a grip on the sides of its hole, while the bird digs its claws into the ground. Sometimes the worm lets go, and gets eaten up. Sometimes he gets pulled in halves, and only the rear end goes down the robin’s red lane.

The worm minds being pulled in halves just about as much as a train of cars minds getting uncoupled. The front end calmly crawls away into its hole, goes on eating dirt as usual, and pretty soon grows itself a new tail as before.

But what becomes of the severed tail end, if by any chance the robin fails to eat it up? That perhaps is the queerest thing of all. If the front part that crawled away is short, say a third of the animal or less, so that two-thirds of the worm at least is left in the tail piece, then this severed tail grows a new head. So the one worm becomes two. But if the tail piece is shorter, no more say than a half the whole animal, then that tail, instead of growing a head, grows another tail. In that case, the final result is one entire worm, old head end and new tail; and two tails, one old, one new, growing end to end. But of course, two tail ends, and nothing else cannot very well make a living, and, the worm soon dies of starvation.

There is, however, a smaller creature, the fresh water hydra, which quite outdoes the earthworm, when it comes to growing on new parts. The hydra is a very small sea-anemone, about as long as a pin is thick, with a long slender stalk and a circle of long fingers or tentacles round their mouths. One finds them growing on sticks and water plants almost anywhere in ponds.

Cut off one of these fingers, and it grows again. Cut the entire animal in halves as one chops thru the trunk of a growing tree, and the root end grows a new head, and the head end grows a new; root, and there are two new hydras in place of the one old one. Cut the animal into three pieces, head end, root end, and a small bit out of the middle of the stalk. The head end forms an entire new creature. The root end forms an entire new creature. The middle piece, which is neither head end nor root end, but just a little drum-shaped snipped out of the stalk between the two, even that grows a new root end and a new head end, and becomes an entire new creature, which in time grows to be as large as the one out of which it was made.

It is, in short, as if when one ripped off the sleeve of a coat, the coat grew a new sleeve; or when one pulled off the tail of the coat, the coat grew a new tail; while the severed sleeve and tail each grew new coats—pockets, buttons, collars, tails, sleeves, and all.

Our common star-fish, that we find in the salt water pools at the sea shore after the tide goes out, also isn’t at all bad at mending itself up after an accident. The five rays which grow out from its center are continually getting broken off. So one finds often in the water, star-fish with only four rays, or with four large ones, and one smaller one just growing out to take the place of one which has been lost.

But the lost ray, if something doesn’t eat it up, will grow a new star-fish. From the broken end, four more little arms bud out like those of a tiny star just getting its start in the world. The single arm or ray, not only grows out the other five, but in addition forms a new center for them to grow to, a new mouth, a new stomach, a new nerve ring round the mouth which is the creature’s brain; and so one thing with another forms a whole new star-fish with all its parts complete. And all the while, of course, the severed arm cannot eat anything, because it hasn’t any stomach. So it has to make the new parts out of the old, as the tadpole builds its new legs out of its old tail.

Still, I don’t know why any of these things are any more remarkable than that the lizard and hydra and earthworm and star-fish should have formed in the egg in the first place. That after all, is about the most remarkable thing there is in this world.

Not a few animals, moreover, in addition to having this power of mending themselves up after they have been injured, have also an arrangement for getting themselves hurt in a convenient place. The ray of a star-fish, for example, almost never breaks in halves. Whenever the ray gets caught so that it has to come off, it breaks close to the center, so that the whole arm comes off at once.

The crabs, such as one finds at the sea shore in salt water, have a special place in each leg, close up to the body, where the leg is meant to break off. The hard outer shell is turned back into the flesh and makes a round plate of shell with a hole in the middle, cutting right across the leg. Thru the hole run the nerves and blood vessels, but the muscles come to the plate on each side and there stop.

So when a hungry fish "catches a crab" by one leg, the crab digs his claws into sand or sea weed and pulls. The fish backs water with his fins and he pulls. Off comes the leg. Away goes the crab in safety. The leg has pulled off at this plate of shell. No muscle has been torn. The end of the stump is nicely protected; and all the injury that has been done is to the small thread of tissue no larger than a pin, which ran thru the hole in the center of the plate.

More than this, the stump is all ready to grow out again; and actually grows out quicker, after the leg has been taken off at this "breaking joint," than if only a small piece had been taken off lower down. Such breaking joints, where the wound is all healed over before it is made, are somewhat common among animals, especially among those which have a jointed shell on their outside.

Even here, however, there are some queer doings. Sometimes, after a five jointed leg has been pulled off, the one which grows in its place, tho just as large and just as long, has only four joints. Some crabs, and the like, which have the big claws unlike on the two sides, if they lose either one, instead of growing one like it in its place, make a new claw like the one that belongs on the other side. Also, if they lose an eye, they grow a new one; but if they lose both the eye and the eye stalk on which the eye is set, then instead of an eye, they grow a small feeler. Really, one does not know which most to marvel at—their strange power of growing new parts, or their crazy way of growing them wrong.

But of all living repair shops the most uncanny are certain little flat worms, called planarians. These are a half inch or less in length, and fairly common in some places at the sea side, tho they are likely to be mistaken for snails which they much resemble.

Cut off the head of one of these creatures, and inside a week he will grow another—eyes, brain, mouth, and all as good as before. Cut off both head and tail, and still the creature will straightway fit himself out with new ones. Split him fairly in two lengthwise of the body, and each half will grow out a new half; and there will be two planarians, each complete, where only one was before.

Or if one splits the body in halves from the neck down, then each half body grows a new half, and there is a single head with two bodies. Or on the other hand, if one splits the head in two and leaves the body, each half head will become a whole one. Then we shall get a double headed planarian, a sort of Y-shaped creature.

Sometimes, after the planarian has been split in two from the neck backwards, and formed a Y upside down with two bodies and one head, another head, or occasionally two new heads, eyes, brain and all complete, grow out facing backwards in the fork of the Y. Indeed the animal seems to have a sort of mania for growing new heads and tails in all sorts of unbecoming places. If he gets a wound or cut almost anywhere in the body, and the wound happens to open on the whole backward, out of that wound or cut will grow a new tail in addition to the one he already has. But out of such wounds as face forward, there grow out complete new heads. As many as seven different heads have thus been made to grow on a single planarian—some on the middle of the back, some underneath the body, some even on the sides of the tail, and all, no doubt, greatly to the embarrassment of their owner.

As for cut off heads and tails, one might expect them to grow new bodies and become whole animals again. They do not, however, unless the pieces are pretty large. A head, cut off close behind the eyes, grows out, not a body, but another head. So all there is to the creature is two heads, joined neck to neck and looking in opposite directions.

All the time these things are going on, while the worms are making new heads, or bodies, or the two halves of one body are filling out again, the creatures can get nothing to eat. How then do they manage to grow? They live on their own flesh. The old fragment is taken down and used to build the new. An entire worm, made from a half worm, is no larger than the half from which it came. The animal, instead of growing large, grows small.

Whether it also grows young again, is by no means clear. Apparently it does. At least, a planarian that does not get enough to eat, proceeds at once to ungrow, becoming gradually smaller and smaller, till after a few months, it is no more than a fifteenth part of its former size. Whether it really becomes a baby worm again or not, it certainly looks like one, for it is a pretty small human baby that is not more than one fifteenth as large as a grown man.

XLVI

Little Monsters

One usually thinks of monsters as large. They are always, I believe, large and horrible in the fairy stories—giants and ogres and dragons and winged horses and chimeras and three-headed dogs and I don't know what else, all most extraordinary to imagine as well as nice and creepy to read about. Really, however, there is no reason whatever why a monster should be large. It must be horrid, or unusual, or misshapen, or quite out of the ordinary. Then it is a true and proper monster, no matter how small it is. And as a matter of fact, some monsters, as strange as any maker of fairy stories ever invented, are too small to be seen at all, unless one looks for them with a microscope.

The planarian worms that I have just been telling about are monsters. If a two-headed calf is a monster, that people who go to the circus will pay to see, then surely a planarian is a still greater monster, with one extra head in the small of its back, another on the side of its tail, and four or five more hanging on at various places anywhere over its body; and this to say nothing of as many superfluous tails stuck on anywhere between. You know already that these monstrous planarians are formed because the worm, instead of healing up a cut as he should, seems possessed to grow a new head or tail out of it. I am going to tell you now how certain other strange monsters come to be.

You remember that earlier in this book, almost in fact, at the very first, I told you about how the eggs of all animals are, to begin with, single cells; and how afterwards, when they begin to grow, they split, first into two cells, then into four, then into eight, and so on, until finally, the single cell of the egg has become the hundreds and thousands which build the young animal.

Some of these eggs, especially those of certain of the small sea creatures such as star-fish and sea-urchins and the like, are extraordinarily tough. Indeed they have to be, else few of them would ever live to grow up at all. It is quite possible to take these eggs when the single cell has divided into two, and shake these two apart into two separate half eggs. You might think that each half egg would form a half animal. Instead, much like the planarian cut in halves, it forms a whole animal, half size.

Or we can wait till there are four cells, and shake these apart. Then we get four complete creatures, each quarter size. Or we can in the same way make eight. Beyond that we cannot go. Eight animals out of what was intended for one is all that egg can manage.

On the other hand, it is possible to take a half dozen eggs, which ought properly to have made as many separate creatures, and make them stick together into one gigantic egg, from which will hatch out a single gigantic animal, as large as the six or eight together which ought to have come from six or eight eggs.

Other strange things happen when the eggs, instead of growing in ordinary sea water, are put into water which has just a little bit more or less of something in it. For common sea water contains some half dozen different kinds of salt besides the one kind that people get out and use on the table and for cooking; and more or less of any one of these makes a salt water which is not quite the same as the salt water of the ocean. In fact, you must have noticed that salt water made with ordinary table salt does not taste by any means the same as ocean water.

Accidents to growing fish eggs result in all sorts of double monsters.

A different kind of salt water (not very different either, I doubt if anybody could tell them apart by the taste,) sometimes makes a lot of difference with the creatures that grow in it. A little more of one thing, for example, makes little star-fish with their stomachs hanging out of their mouths, instead of inside their bodies where all proper stomachs belong. A little more of another, makes the sea minnows which live in it have only one eye, and that right in the middle of their foreheads like the single eye of the giant cyclops that I trust you have all read about long ago in the story of Ulysses. If you haven't you certainly had better right away, for it is one of the great stories of the world, and has been told to children, and to grown men and women as well, for at least three thousand years, and nobody knows how much more.

Then again, by making things a little different in another way, the baby fishes grow like other proper fishes except that they do not have any hearts. Naturally, however, these particular monsters do not live to grow up. People make all sorts of strange creatures now-a-days by doing something to the young eggs when the new animal is forming.

Curiously too, all this sort of thing may happen to almost any egg by accident. If the two halves of the young egg get separated entirely, then the egg brings forth twin creatures so nearly alike that it is almost impossible to tell them apart at all. But if the two halves get only partly separated, the result is some sort of double monster.

So there are two-headed chickens, and two-headed snakes, and two-headed turtles, and two-headed calves. Sometimes only the tip of the nose is double. Sometimes it is the whole head. Sometimes there are two heads, four front legs, two hind legs, and one tail. Occasionally there is one body with eight legs, because the legs doubled and the body did not.

Just about as often, the doubling begins on the other end. Then there are two tails; or four hind legs and two front ones. Occasionally, two complete bodies are joined at one small region only They just missed being a pair of common twins It all depends on how well separated the first two cells of the egg happened to get.

A two-headed turtle, a crab with an eye on one side and a feeler on the other, and a child with two great toes on each foot.

The famous "Siamese Twins" were about like any other twins, except that they were fastened together side by side by a band of flesh under the arm. They lived to grow up, married, and travelled about the country exhibiting themselves for years. Finally one died; thereupon the other died almost immediately after. But as for that, any twins, if they are markedly alike, are likely to die at about the same time.

Often, too, only the buds which are forming the limbs get divided. Then there are extra fingers or toes or claws or thumbs. Cats, for some unknown reason, are especially apt to have double paws or extra toes. Oddly enough, tho nobody knows why, this happens more commonly on the front paws than on the hind ones.

So you see, the strange power which a few creatures have of making new parts, or extra parts, like the tails of lizards or the heads of planarians, belongs also to all creatures when they are very young. Most of them lose the power as they grow old. But in some animals, like crabs and earth worms and planarians, it lasts up to old age.

XLVII

How The Animals Keep Their Tools Sharp

One can not do much of anything without tools, so of course the animals have to have them. But because they haven’t sense enough to make tools as we do, or even sense enough to use such tools as they find ready made—pointed sticks and sharp stones and shells and bits of bone and the like—as our very savage and very stupid ancestors used to do, the tools of the animals have to grow on them.

The horse’s front teeth are his mowing machine, with which he cuts down the grass. His great flat-topped grinding teeth that lie in a long straight row along each side of his jaw behind the place where the bit goes, are his millstones with which he grinds his oats and corn into meal. But the cheek-teeth of dogs and cats, which also lie along the sides of their jaws, are not millstones, but knives; and their front teeth, like their claws, are traps to seize their prey and long daggers to stab them with. For the cats and dogs do not grind corn; they kill things. They are butchers, not millers.

In fact, when you come to think of it, nearly all the larger animals are either millers or butchers. Either they grind up plants for food, as horses and cows and sheep and goats do; or else they hunt and kill other living animals and devour them, as do the cats and dogs and wolves and foxes and hyenas and such like. Naturally, these two sorts of creatures have quite different sorts of tools—claws and sharp teeth for one, hoofs and grinding teeth for the other. Tho for some reason or other, pretty much all the animals that are strong enough to do any work, are miller animals. All the horses, oxen, ponies, donkeys, buffalos, elephants, camels, goats, llamas, and I don’t know how many more, that any body can get any work out of, all have hoofs and eat plants. The Eskimo dog, so far as I know, is the only butcher animal that earns a living. The rest just lie round and growl.

So the miller animals have to grind their food. Now millstones have to be kept rough; and as fast as they wear smooth, the miller has to “pick” out the grooves to make them rough again. In like manner, the horses and cows and sheep would soon wear their teeth too smooth to be of any use, if they did not have a way of making them once more rough. In these grinding, millstone teeth, the hard enamel, instead of being on the outside of the tooth as with us, is doubled into folds and plates, and mixed in with the bone of the tooth like the streak of fat and streak of lean in bacon, or like the two colors in marble cake. So the bone wears down faster than the enamel, and leaves the enamel standing up in sharp ridges. Thus the top of the tooth is always rough and ready to do its grinding; and because these teeth are pretty long, an inch or more, they last a long time before they are worn out.

But the dogs and cats, which have teeth like ours, with the enamel all on the outside, soon wear down their teeth so that they will no longer cut. That’s why dogs and cats and the wild creatures like them, are so short lived. They are built to grow up quickly and die young, because there is no use in having them made to live longer than their teeth will hold out. At least that’s one reason Why they don’t live longer.

The elephants have a curious way of taking care of their teeth. They have to take care of them, because the elephants live to be very old—a hundred years—a hundred and fifty—some people say even two hundred. Now a hundred years is a pretty long time for a tooth to keep on grinding leaves and twigs and roots, so the elephant has to save his teeth and make them last.

To begin with, he saves his front teeth by not having any. His two great tusks are two upper front teeth grown out till they are not teeth at all, but crowbars that the elephant uses to grub up roots with. They have no enamel and no root. So they can keep growing at the inner end as fast as they wear off at the outer. Being especially hard bone, they last as long as the elephant does, and get larger and larger as long as their owner lives. After that, they get turned into piano keys and billiard balls.

As the elephant spares his front teeth by not having any, he spares his back teeth by not having many at a time. These are very large, not quite as large as a leg of ham, but quite as large, often times, as a loaf of bread.

The young elephant gets four of these big grinders, one on each side of each jaw, and grinds away on them. After he has used these for a few years and begun to wear them down, four new ones grow just behind the first four. By and by, the first set gets worn out; then the white blood corpuscles take down the roots, the crowns—what there is left of them—fall off, and that is the end of that set. By the time the elephant begins to get old, the second set of four teeth has worn out, and a third set has come in. So a really old elephant has only six teeth—the two tusks, if you call them teeth, and four grinders.

The pigs do something the same. They hold back four very large grinding teeth at the last end of the row, and don't let them appear till after the front grinders have been pretty well used up. So too do we in a way. We don't cut our "wisdom teeth" till we are past twenty. Moreover, the wisdom teeth, which are last in the row, and the eight grinders in front of them, two in each half of each jaw, really belong to the milk set which we began to have when we were babies. We don't need them then. So we hold them back till we do, though that isn't for twenty years.

The rats, mice, squirrels, beavers, and other creatures that use their front teeth as drills and chisels, have a pretty clever way of keeping them sharp. You can easily see that a squirrel who puts his teeth through the hard shells of nuts every time he gets a meal, or a beaver who cuts through trees six inches across with his, or a mouse or a rat, would use up any ordinary set of teeth in a few weeks, and have to get on as best he could for the rest of his life without any.

The grinding teeth of these creatures are like other grinders, that last till they are worn down—and that's all. But their four front teeth, two in the upper jaw, two in the lower, are like the elephant's tusks. They have no roots, and they keep growing out from the inner end as fast as they wear off at the outer. But in order to have them held firmly in the jaw, having no roots, these front teeth start way in at the back of the jaw close to the roots of the last grinders. They grow out along the whole length of the jaw bone, past all the other teeth, and come out at the front of the mouth. So the front cutting teeth of mouse or rat or squirrel are about as long as his legs, and start back almost to his neck. Besides this, they have the hard enamel all in one plate at the front of the tooth, instead of over the entire outside as we do. Then as the tooth wears down, the bone wears fastest and leaves the enamel as a cutting edge, always sharp.

The wild pigs do much the same thing with their four tusks. They start them clear round at the back of the jaw, curve them past the rest and bring them out at the sides of the mouth. Then they put two together to make a tusk, and each grinds on the other and keeps it sharp. But I don't think that any animal ever does this sort of thing with more than four teeth. He can make four grow all the time, or two as the elephants do, or none. But the rest have to have ordinary roots, and when they wear out, why that's the end of them.

The fangs of a rattlesnake.

But the sharks grow several rows of teeth at once, starting them inside the mouth and letting them slide over the jaw in the skin. These are not real teeth set in the bone, but only a sort of skin teeth; and the shark grows them by the dozen, new ones as fast as the old drop out. The snakes do much the same thing with their poison fangs, and keep always at least one new pair folded down behind the old ones, ready when these get pulled out. But snakes and sharks don't chew with their teeth, they only bite with them.

Now let’s see if you can’t find out for yourselves how it is that pussy cat keeps her claws as sharp as needles. You can clip off the points, but it will not be many days before she will make new ones, just as sharp as the old. If you study the claw you will see how she does it. The dog has the same device, only his nails are not so sharp.

XLVIII

Why The Blood Is Salt

The blood is really salt. So is the sweat, as you can easily prove by putting your tongue anywhere on your skin, after you have been hot and sticky for a long time. And of course the tears are salt, as no doubt you found out long ago, sometime when everybody was especially horrid and they ran down into your mouth. In fact, pretty much everything about the body is salty, for the reason that it is all made of blood, which is itself pretty salt.

Now the blood is salt because the sea is. I much suspect that if the ocean had always been fresh water, like the ponds and lakes, then our blood, and the blood of all other animals, and all sweat and tears and the like, would have been fresh also. For the sea and the blood are salt with the same kinds of saltness. Their salt is mostly the sodium chlorid which we use for table salt, and besides these, there are calcium which makes limestone and lime and mortar and plaster, potassium which makes potash and soft soap, and various other metals including even gold. Altogether, sea water and blood are extraordinarily alike, especially when you consider that there are vast numbers of little animals in the sea that one can’t so easily tell from the white corpuscles of the blood.

The reason for all this is that the simpler creatures of the ocean do actually use the sea water for blood. Instead of having their bodies shut up tight as we land animals have ours, so that nothing gets into them unless we breathe or swallow, the inside of their bodies is open to the sea water, and the sea water flows in and out freely.

The sponges are like this. They take the water in through their smaller holes, and let it out through the large ones. They breathe the air that is in the water, and they turn their waste matter back into the water again, just as if the water were their blood. Many other creatures manage in this way, getting along without any private blood of their own, and using the great common ocean instead.

The rest of us have simply shut up our bodies and caught a little bit of the ocean inside. We call this bit of ocean, blood; and we have added various things to it. But still it is sea water, the same old sea water that is the blood of the earth and of all the lowly sea creatures that have no private blood of their own.

There are a great many other things also that we big land creatures have and do for no other reason than that some small sea creature began that way, and there has happened to be no special reason why anybody should change.

For example, all fishes, as you know, breathe by taking water in through their mouths and letting out again through a set of slits, usually five in number, at the side of what would be the neck if the fish had one. When the little fish is forming in the egg, at first it does not have any of these “gill slits” and so has to breathe through its skin. By and by, however, after the lower jaw has formed and there is a mouth, these slits punch through and become the convenient openings that we put a forked stick through when we go fishing and so bring home our fish, instead of putting them in our pockets, which is really a practice not at all to be commended.

So the little fish, while still in the egg, has these gill slits in the side of his head because later, when he gets hatched out and swims round, he is going to use them to breathe with.

But the little chick in the egg, after his lower jaw has begun to grow, also has these same gill slits in the side of his neck, although when he hatches out, he is going to breathe with lungs, and is never going to have the least use for gills. So, too, do little puppies and kittens and colts and calves and all the land animals that breathe with lungs and haven't the slightest use for any such holes.

Sometimes the hole doesn't even break clear through. It starts from the inside and comes out, and from the outside and goes in, but the two tunnels never quite meet, and the hole never gets really open. But whether the holes open through or not, they soon close up again, and leave no sign that they have ever been there at all.

All except the first hole on each side, the one nearest the mouth. That never closes again, but remains open and becomes the hole into the ear. There is a hole in from the outside, as you know, the one you used to put beans and pencils in, only you oughtn't. And there is another hole from the inside, beginning high up in the throat just where you can't see it, and running in till it almost joins the other hole. Between the two is just a thin skin, which is the "drum" of the ear, and if you get a hole in it you may never be able to hear again. Because this drum never grew. It is the place that remained after one tunnel came in from outside, and another from inside, and the two didn't quite meet.

So it comes about that all of us land creatures with backbones, who breathe with lungs, start making gill slits which we can't possibly use. Then, because we have them on hand, we use the one farthest in front for the hole of the ear, and close the rest up again. And we take all that trouble—though it doesn't trouble us much at the time—just because various other backboned creatures, which live in the water and don't have lungs, had to make gill slits to breathe with.

There are a lot of things of this sort—parts and organs and members which one creature, while it is in the egg, makes and doesn't use, just because some other creature, when it grew up, had to have them. You know what a short tail a hen or a turkey or a pigeon has—just a stub of a tail, only just big enough to stick its tail feathers in. But a little hen or turkey or pigeon, while it is still in the egg, has a tail like other animals, long enough to wag.

There is a kind of salamander, which is unlike most salamanders, efts, newts, and the like—these are all pretty much the same thing, and you find them almost anywhere in the brooks and the ponds and the damp woods. All of these that you are ever likely to see breathe with gills like a fish, and can live in the water. Only instead of having their gills covered over with a bony plate like the fish, these creatures often have them outside, like a sort of lace collar that hangs down at the side of their necks. Tom, the chimney sweep, in Charles Kingsley's famous tale, after he turned into a water baby, had just such tufted gills so that he could swim under water like any newt or eft, and if you haven't read "The Water Babies," it's certainly high time you did.

What I started to say is that this particular kind of salamander lives on the land. So he doesn't need gills and doesn't have them. But the little salamander, while he is still in the egg, has gills like any salamander, though for all the use he can ever put them to, he might just as well have been furnished with a pair of skates; for by the time he hatches out of the egg, the gills have been taken to pieces by his white corpuscles and the stuff used to make some other part of the body.

All the same, if you break open the egg, take the little creature out, and put him in the water while he still has gills, he will swim away, and live under water as well as any water creature. But if you wait till he hatches out of himself and has lost his gills, then if you put him in the water, he will drown just as you would. So the little salamander, that is going to spend his life on dry land, still has gills while he is in the egg and has no use for them, all just because other salamanders that live some of the time in the water need gills to breathe with.

Then there are the snakes, which have lungs and breathe air like any land animal. Only a snake is so very slender that there isn't room in him for two lungs side by side. So he has only one proper lung, very long and thin, that runs from his neck pretty well down to his tail. Nevertheless, the snakes still keep the other lung, small and quite useless, tucked away beside the front end of the one they do use. Other reptiles have two lungs, so the snakes have to have two lungs also, though they can't possibly use them both, and the other which they don't use, merely takes up room.

We human beings are just as bad as the rest. Every little while, somebody comes down with appendicitis and has to be taken to the hospital to have his "vermiform appendix" taken out. The appendix isn't the slightest use to anybody, we are better off without it, but in cows and dogs and rabbits and kangaroos, and various other animals, especially those that eat grass and leaves, it is a good deal of use for helping to digest food. So we have to have it, to be like the rest—and then pay the doctor to cut it off.

We don't move our ears as horses and dogs and rabbits do. But still the muscles are there; and people say that anybody who wanted to take the trouble could learn to wag his ears like a baboon. Anyhow, the muscles are there, though we don't use them and other creatures do.

We are said to have no fewer than one hundred and eighty such useless things about us—all sorts of little things that are no use to us at all and no use to half the animals that have them. But they are useful to the other half, and we all have to be in the fashion. Among these is a strange sort of single eye, set in the middle of the head, so that we really have three eyes instead of two. Our third eye is no bigger than a pea, and it lies tucked away between the two sides of the brain, well inside the skull, where it cannot possibly see anything. All the four-footed creatures have it. But in none of them is it the slightest use, except in certain lizards, especially in one in New Zealand, where it is a real eye placed in the middle of the forehead between the other two. Several American lizards also have this extra eye, though it isn't good for much seeing, among them the "horned toad" of California, which of course isn't a toad at all. So, just because a few lizards want three eyes to see with, the rest of the four-footed animals and we human beings have to have an extra eye that we don't want, tucked away in pitch darkness inside our heads.

But that's the way things are managed—salt blood, and gill slits, tails and gills in the egg and not out, extra lungs for the snakes, and extra eyes for us all, like Little Three Eyes in the story. It's like the extra legs and tails on the lizard, and the extra heads on the planarian. Nature gets started making things, and doesn't seem to be able to stop.

XLIX

Horses' Fingers

The horse does have fingers—as one can easily see by counting up the parts of his legs. Let's start with the fore-leg, and begin at the top next the body.

The sharp ridge just in front of the place where the saddle goes, between that and the beginning of the mane, is mostly backbone, the same part that we feel under our coat collars at the backs of our necks. The horse's shoulders, against which the collar rests when he pulls his load, are mostly shoulder-blades, for the chest of all four-footed beasts is narrow, and the shoulder-blades, instead of being on their backs, as ours are, are at their sides. The upper arm, between the shoulder and elbow is short, and is buried in muscle so that one doesn't notice it. So the first joint that shows, where the fore-leg joins the body, is not the shoulder but the elbow. The upper half of the arm is inside the skin.

The upper half of the horse's fore-leg, then, is our fore-arm, between elbow and wrist; and sure enough, that bone in the horse is double just as it is in us, and in all animals that can twist their hands round, tho the double bone isn't the slightest use to the horse. What we call the horse's knee, then, is his wrist—and again, like our wrists, it has a lot of little bones which make our wrists supple so that we can bend them in all sorts of ways, but which also are no use at all to the horse.

Then there is the horse's shin—which isn't shin at all, but the palm-bone of the middle finger, which in us runs from the wrist to the knuckle. The rest of the leg is the middle finger, with the proper three joints, which every finger ought to have, and a gigantic finger nail, which is the hoof. So the horse has a hand, and a very large hand too; only he has lost all his fingers except one, so that he really stands up and runs on the nail of his middle finger. Nevertheless, the horse hasn't quite lost the rest of his hand; because along the sides of this middle-finger-palm-bone, which we call the shin, lie two other little bones, too small to be any use, which are the palm-bones of the first finger and the third. But once in a long while a colt is born with two little hoofs on these bones, so that it has three fingers instead of one. The rhinoceros, on the other hand, has three fingers, all nearly the same size; while the elephant keeps all five.

Now if you will notice the fore-leg of a cow, you will see that it is just about like that of a horse, till you get down to the wrist. Below that point, the cow, instead of having one palm-bone and one finger, has two. Of course, then, it has two finger nails. The deer has two fingers like the cow, and then two little ones besides, and so does the pig. But the hippopotamus has all four fingers and lacks only the thumb.

All of which, if you keep your eyes open, you can make out for yourselves and more. Only I wish somebody would tell me why all the animals that have horns at the side of their heads—cows and sheep and goats and deer and buffaloes and I don't know what all—have either two fingers or four; and why the creatures that have one finger, or three fingers, or all five, never have such horns. That is something that nobody has yet been able to find out.

So much then for the horse's hand—and what a whacking big hand it would be, by the way, if it did have all five fingers instead of only one! Let's see what we can make out about the horse's foot.

The thigh, as you can easily make out when the horse moves, starts close up to the tail, and like the upper arm, is almost wholly inside the skin. So the first joint that shows is the knee, and the great muscles which, as you sit behind to drive, you see pulling you along so strongly, are those of the calf of the leg. The joint that comes nearest the driver's feet, which we call the gambrel, is then the heel. It certainly does look like a heel; and the rest of the leg is the middle one of the five long bones of the foot, with the middle toe on the end of it. So the horse stands on the end of his middle toe, and his hind hoof is his middle toenail.

The cow, of course, keeps two toes with their foot-bones. The dog has four. I don't think a dog ever puts his heel down so as to stand on the whole flat of his foot, except sometimes when he stands up to beg. But cats and rabbits often do, when they want to stand up on their hind legs to see as far as possible. Still they don't do it enough to have soles to their feet all the way back to the heel. But the bears and the monkeys and a lot of other animals that can't run very fast, do put the whole foot down on the ground, and do have a sole all the way back to the heel. In general, the faster an animal can run, the more it stands up on its fingers and toes, the longer its feet and hands are, the shorter its thighs and upper arms, and the fewer fingers and toes it has. That's why the horse, which I suppose is about the fastest animal there is, has his fore-leg at least half hand, and his hind leg mostly foot.

Some learned men devote their entire lives to making out just this sort of correspondence between the various bones and muscles and other parts of one animal, and those of others and of man. A most fascinating game it is, too; and a game that everyone can play a little, and keep on playing as long as he lives and keeps learning more and more about animals.

L

How The Elephant Got His Trunk

According to the Just So Stories, in the high and far off times, before any elephant ever had any trunk, there was a certain Elephant's Child who was afflicted with an insatiable curiosity. And after this Elephant's Child had been spanked for this same insatiable curiosity by his tall aunt, the Ostrich, and by his tall uncle, the Giraffe, and by his broad aunt, the Hippopotamus, and by his hairy uncle, the Baboon, grievously and frequently, without stopping, for a long time, he started out for the banks of the great grey-green, greasy Limpopo River, to see what the Crocodile has for dinner And the Crocodile caught the Elephant's Child by the nose, which was just a common nose and not a trunk at all, and pulled and pulled and pulled, being minded to have Elephant's Child for the beginning of his dinner. And the Elephant's Child spread out his little four legs, and he pulled and pulled and pulled, until between them, they stretched out the Elephant's Child's nose into the first elephant's trunk that ever was. So all other elephants have had such trunks ever since.

This is Mr. Kipling's story of how the elephant got his trunk. This and several more like it of the Just So Stories, you must all read for yourselves, for altogether they are about as good stories as have been written by anybody this long time. Besides, something not so very different from this adventure of the Elephant's Child did really happen. Only it didn't happen in quite the same way; and instead of there being one Elephant's Child, there were many, many, many, one after another for hundreds of years, each with a nose a little more stretched out and a little more trunk-like than those which came before it.

So what really happened is something like this: The elephant that you feed peanuts to at the circus, now-a-days, is a strange sort of beast, with his long trunk, his hairless body, his tall legs like the stems of trees, and no front part to his jaws, so that he has only his back teeth. The parents of the elephants that you see were elephants like himself. So were his grand-parents; and their grand-parents in their turn. But if you could go back a very long time, back to the days when the first men appeared in Europe, you would find that the elephants of those days were somewhat more like other four-footed animals. For one thing, they had fur like other animals, while instead of having only four grinding teeth in use at once, they had nearly a full set as most other beasts have. These are the great mastodons and mammoths, whose bones are still dug out of the soil in the United States, in Europe, and in various other parts of the world, and whose bodies have been found frozen in the ice in Siberia, so well preserved that the dogs ate the flesh after they were dug out. There are none of these left alive now, but we still have the pictures of them which men long ago scratched on pieces of bone or sketched on the walls of the caves in which they lived before they knew enough to build houses.

Early man scratched pictures of the mammoth on pieces of its own bones.

Still older elephant-like creatures, whose bones we still find in the ground, had front teeth, and very long muzzles, longer even than the sharpest nosed dog, as long, let us say, as the bill of a duck, a snipe, or any long-nosed bird. These, of course, had no trunks, but snouts almost as long, with upper and lower jaw, and lips. Then gradually, generation after generation, these long-snouted creatures lost the front part of their jaws and their front teeth and their under lips. They kept two upper front teeth, which grew very large and became tusks. They kept also their long upper lip, without any bones to hold it in place, so that it hung down and became a trunk.

The elephant has lost the front of his face except his upper lip.

So the elephant's nose isn't his nose only, but his nose and his upper lip and part of the roof of his mouth. Next time you go to the circus, you watch the elephant when he lifts his trunk so that you can see the under side, and notice the rough cross markings that other beasts have on the roofs of their mouths, and that you yourselves can see in the mirror or feel on the roof of your own mouth with your tongue. Then, when the elephant opens his mouth to take a peanut, see whether his mouth doesn't look as if his under lip and the whole front of his jaws had been taken off just as I say it has. But the proof of what I say, is there have been found near Cairo, Egypt, the bones of the original elephant who didn't have a trunk, but did have a very long snout; and of other elephants besides, the great-great-great-grandchildren of these, and the great-great-great-grandfathers of the mammoths and mastodons, who had begun to lose their long muzzles, and to turn their upper lips into trunks.

It's the same way with any other animal that is different from the rest; his great-grandfather's great-grandfather's great-grandfather many times removed wasn't nearly so different from other animals as he is. Take for instance, the horse. He is a good deal different from other beasts, with his great size and speed, and his strange single-fingered hand, and his strange single-toed foot, and himself standing up on the nails of his middle fingers and toes.

Our single-toed horse has been made over from a four-toed one.

But out in Wyoming and thereabouts they dig out of the ground the bones of old horses that had their middle finger nails and their middle toe nails, which are their hoofs, considerably smaller than our horses have them; while at the same time, the little splint bones, which are the remnants of the fingers and toes next the middle, are much larger than they are now-a-days. Still deeper in the ground, are the bones of still older horses, which had three hoofs on each foot, but the middle one was largest and the two at the side did not touch the ground, just as they don't in the deer. These horses were only as large as the smallest ponies.

Lower in the ground, still, come the bones of yet older and smaller horses, with three hoofs on each foot, all about the same size; but the hoof has become more like a regular toe with a nail, about like a pig's, which are about half way between hoofs and toes. Buried even deeper in the earth are the bones of horses no bigger than large dogs, that look like horses, and yet look something like dogs also, and something like sheep; which have four toes on their front feet, that are real toes, only just beginning to turn into hoofs. Last of all, there are the oldest horses of all, no larger than cats, with four toes on their front feet, and the splint bone belonging to the thumb, with claws like a dog's that are not hoofs at all, horses that had a tail like a dog's, and looked almost as much like a dog as like a horse, only it had grinding teeth and ate herbs.

So gradually, one little change at a time, this creature that was almost as much dog as horse, lost one toe after another, increased in size, got up on his toes, and became a modern trotter. At the same time, another animal that looked much like one of these little dog-horses, only he was on the whole a little more like a dog, kept on getting more and more dog-like, with smaller claws and sharper teeth and slenderer nose, till he became something that was neither dog nor wolf nor fox, but a general mixture of all three, with some cat and some hyena thrown in.

They find out in Wyoming, also, the bones of another creature that has been called "the father of cats"—*Patriofelis* as they say it in Latin. But the father of cats is also a great deal like a seal, and something like an otter—at least he used to take readily to the water, as our modern cats certainly do not.

In short, if any of us had lived in North America at a time not so very long before the first human beings actually did live somewhere on the earth, we should be surely put to it to tell one sort of beast from another. The horses looked like dogs, and the dogs looked like cats, and the cats looked like seals, and there were pigs that looked like wolves, and camels that suggested sheep, to say nothing of cows that you couldn't tell from deer. Each beast used to be a general mixture of all beasts, and only since there have been men in the world have the beasts changed into all the various sorts which we know.

Extinct Reptiles, which looked like a mixture of Alligator, Rhinoceros and Kangaroo, but their Bones were more like the Bones of Birds.

The snakes used to have legs. In fact, a snake is not much more than a lizard that has left off his legs for the sake of crawling into smaller holes. But the snakes and lizards are much older than the beasts; so that there were plenty of both in the world long before there were horses and cows and dogs and cats and all the rest of the beasts with fur—and still longer, naturally, before there were any elephants or men.

The early birds, too, were a good deal like lizards. They had teeth like a crocodile, and long tails with feathers stuck in the sides, and tho they had wings like a proper bird, they had also claws on their wings, which were really three-fingered hands with feathers growing on them. But even our modern birds still keep the old lizard scales on their legs, tho they have long ago changed them to feathers on their bodies.

It is exactly the same with our own ancestors as with the ancestors of any beast or bird or reptile. The bones of early men are still found in the caves of Europe, mixed with the bones of the animals which they ate, and buried in the earth and stone that have fallen from the roof. These men were true and proper human beings, who walked on their hind legs and, I suppose, talked. But they were not quite such men as we are, for their skulls were a little flatter on top, the bony ridges over their eyes were a little heavier and their teeth a little larger.

These ancient men, like nearly all Indians before White Men came, and for that matter, like our own prehistoric ancestors in Europe, had no metal tools, and used only stone for hammers, axes, and arrowheads. So there are found, all over Europe, vast numbers of stone tools and weapons, cruder as they are older, until the very earliest are only common pebbles that have been banged by use.

No skeletons are known of these early men, but only skulls, commonly a good deal broken. So we do not know very much about these people. But for the most part the hollow in the brain-case is just a trifle larger over the left ear, as if even they had a speech center, were right-handed, and could talk.

On the other hand, some very ancient apes had skulls and teeth more like ours than any modern gorilla or chimpanzee ever has. So it seems to be a general rule that, just as young animals and plants tend to be more like one another than they will be when they grow up, so very ancient creatures tend to be less unlike each other than their present-day descendants are.

LI

Something Nobody Understands

Now, my reader, we have come to the last chapter of this book, which is going to be the hardest chapter of all, and I think, the most important. For though it is going to be about something that nobody quite understands, and something that the more one thinks about, the more he doesn't understand it, nevertheless it is something that you will have to think about many times in your lives hereafter, and you might as well make a beginning. Besides, though you won't understand all that I am going to say—largely I am afraid, because I don't understand it myself—still I trust that you will remember some of it; and by and by when you are sorely puzzled over these matters, perhaps it will help you out.

If you will think back over what I have already told you in this book about animals and plants, and recall also what you have yourselves seen, and what you have learned about your own bodies and the way they work, I think you will agree with me, that of all the strange and wonderful things in this most strange and wonderful world, a living thing is the strangest and the most wonderful.

Think, for example, how a little egg, no bigger, it may be, than the head of a pin, with no help from outside, except perhaps a little fresh air and a little warmth, just goes ahead and makes itself over into a grown animal. Consider, too, how well it does the job—every scale and feather and tooth and bone and gland and muscle and claw and nail and blood vessel and nerve and hair, all just in the right place, and just of the right size. When one builds a house, the owner consults the architect, and the architect advises with the contractor, and the contractor puts some of the work on the sub-contractor, and the contractor and the sub-contractors direct the workmen; and among them, in a year or so, they manage to get the house together. But in the world of living things, one little fleck of living protoplasm goes ahead all by itself, and builds a whole living animal, sometimes in a few days. Yet there are more different parts to be made and fitted together in one of your little fingers, than in any common dwelling house, even tho you count the laths behind the plastering and the shingles on the roof—yes, and the nails that hold them on. As for your brains, they are, each one of them, for complexity, like all the parts of all the houses in a fair-sized city, with all the furniture, and all the tableware, and all the pots and pans in all the kitchens thrown in for good measure. If you think that a watch or a battleship is a complicated affair, think what goes on in the brain of a tiny ant.

Think, too, how resourceful an egg is. It tries its best to grow into a proper animal; but if somebody interferes, to prevent that, then the egg goes pluckily ahead and makes the best it can of a bad matter. If it gets jarred apart so that it cannot make one animal, why then it makes two, or four, or eight. When it can make neither one animal nor two proper and separate twins, it doesn't give up, but makes some sort of double monster, that at least manages to keep alive. For my own part, I feel a sincere respect for eggs. I wish more of us had their pertinacity.

After the egg has made itself into a grown animal, consider how well fitted out that animal is. It has, usually, eyes, nose, mouth, ears, sense of touch, of heat and cold, of taste, and the rest. It has born in it the instincts to find its proper food, to find or build its shelter, to take care of its young, to escape its enemies, and in general to like the things which it is best for it to do. Yet if it doesn't happen to have these sense organs and instincts and the rest, still it always has something nearly as good, and manages somehow to get its living in the world.

Yet I sometimes think that the most extraordinary thing about living things, both animals and plants, is the enormous number of different kinds of them. There are some twenty different sorts of cats, of various sizes from lions down; and twice as many different sorts of dogs, wolves, foxes and other dog-like creatures. There are thirty-two different kinds of willow trees in North America, thirty-six different kinds of pine trees, Sixty-three different oaks. As for insects, about three hundred thousand different sorts have already been given names; and there are at least ten times as many more that are still nameless. Do you know how many different races of men there are that you can tell apart by their looks?—Chinamen, Negroes, White men, Tartars, Eskimo, Indians, Malays, Arabs, and I don't know how many more, all alike in being human, and yet all different.

Why there should be such a lot of different animals and plants and men is something that nobody fully understands. We do know, however, and know very certainly, that there haven't always been all these various sorts in the world. If we could go back a sufficient number of thousand years, we should come to a time when, instead of twenty sorts of cat, there were only ten. Back of that, was a still more ancient time when there were only five. A long time before even that early day, there was only *Patriofelis*, “the father of cats,” and even he, as you know, was also a good deal like a seal.

So too there must once have been a “father of dogs” whose descendants have changed, some into proper dogs, and some into wolves, and some into foxes, and some into jackals, coyotes, dingos, fennecs, and the rest of the forty-odd sorts of wild dogs—to say nothing of all the various tame dogs, collies and terriers and mastiffs and bull dogs and setters, that you can count up for yourselves.

Once too, there was only one kind of man. He probably lived somewhere in southern Asia, and spread out from there, till he possessed the whole earth. Some of him went south-east into the Pacific Islands, and changed into Malays and Australians. Some of him went south-west into Africa and became Negroes. Some became Persians, Egyptians, Hindus, and Arabs. Those that kept on further and entered Europe turned various shades of white and became us. For very few white men are really white—only certain Swedes and Norwegians and Danes. The rest of us, who call ourselves white, are merely not quite so black as our very-many-times-great-grandfathers and our somewhat distant cousins, the Negroes.

Most of these early men, however, started north-east; and because they couldn’t very well cross the great mountains and deserts in central Asia, they ran round the eastern end, and then came back on the other side. On their way, they turned to Chinamen and Japanese. Those that got way up to the north under the Arctic circle became Eskimos. Some of them crossed over by way of Siberia and Alaska (for these countries have not always been as cold as they are now) and turned into American Indians.

Then, after these people had got north of the great Asian mountains, others of them turned west, and came clear across into Europe. In fact, they came near to overrunning Europe during the last days of the Roman Empire so that the famous Charlemagne had to fight them in the eighth century, as you will learn when you study history in school, or still better when you read stories of knights and paladins of the early Middle Ages. So part of us white men came to Europe, and then to America, directly from southern Asia. And part of us came round by way of China and Tartary and Russia; tho now we are all mixt up together so that no one can tell which from t’other. Yet even now, whenever you get up in the gallery and look down on the people’s heads, you can see that some white men have long, egg-shaped heads and narrow faces, and some have round bullet-shaped heads and broad faces. The long sort of head came straight up from India, by way of Asia Minor; and the round sort came round the end of the mountains and across central Asia. That’s the reason why, tho we are all white men, we can’t wear one another’s hats.

That’s about the way it is with all kinds of animals and plants. Each one starts somewhere, and spreads out in all directions as far as it can, gradually changing as it goes, until from being one sort of pine or oak, there come to be dozens, and instead of one kind of cat or dog there are a score. On the whole, too, the latest kinds of animals and plants are better than the earlier ones and there are a great many more of them. This is what we call Evolution—but why it all happens or what it is all for, Is just precisely “one of those things that no fellah can find out.”

Still one can’t help thinking that if we men can make as many things as we do out of iron—knives and saws and locomotives and bridges and sky-scrapers and battle-ships and all sorts of wonderful machinery, and make them better and better all the while, some wiser being than ourselves might make other and still more wonderful machines out of the life-jelly which we call protoplasm, and keep making them better and better and more and more kinds of them as the ages have gone on.

INDEX