FISH

AMPHIBIANS

REPTILES

INVERTEBRATES

ANNA COMSTOCK'S

HANDBOOK OF NATURE-STUDY

Handbook of Nature-Study:

Reptiles, Ambphibians, Fish and Invertebrates

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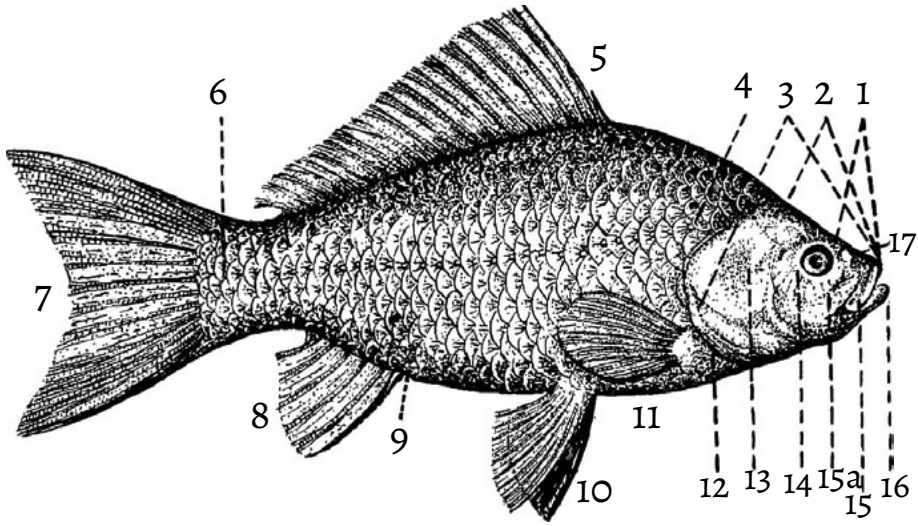
The Goldfish

Teacher's Story

ONCE upon a time, if stories are true, there lived a king called Midas, whose touch turned everything to gold. Whenever I see goldfish, I wonder if, perhaps, King Midas were not a Chinese and if he perchance did not handle some of the little fish in Orient streams. But common man has learned a magic as wonderful as that of King Midas, although it does not act so immediately, for it is through his agency in selecting and breeding that we have gained these exquisite fish for our aquaria. In the streams of China the goldfish, which were the ancestors of these effulgent creatures, wore safe green colors like the shiners in our brooks; and if any goldfish escape from our fountains and run wild, their progeny return to their native olive-green color. There are many such dull-colored goldfish in the Delaware and Potomac and other eastern rivers. It is almost inconceivable that one of the brilliant colored fishes, if it chanced to escape into our ponds, should escape the fate of being eaten by some larger fish attracted by such glittering bait.

Feeding the fish at a trout hatchery

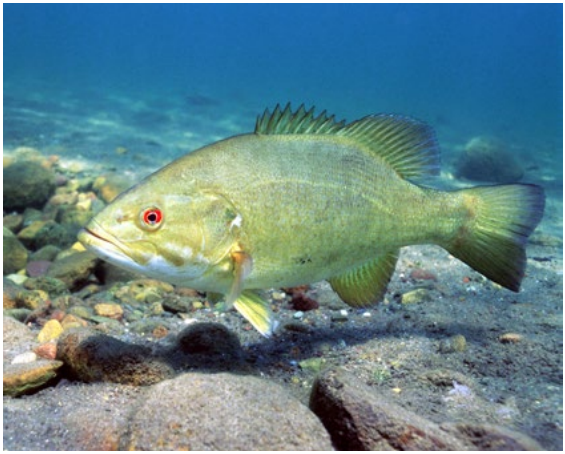


PARTS OF A GOLDFISH

1. Snout	2. Distance from snout to nape		3. Head
4. Lateral line	5. Dorsal fin	6. Base of caudal fin	7. Caudal fin
8. Anal fin	9. Anus	10. Ventral fin	11. Pectoral fin
12. Branchiostegals		13. Operculum	14. Eye
15a. Preorbital	15. Upper jaw	16. Lower jaw	17. Nostril

The goldfish, as we see it in the aquarium, is brilliant orange above and pale lemon-yellow below; there are many specimens that are adorned with black patches. And as if this fish were bound to imitate the precious metals, there are individuals which are silver instead of gold: they are oxydized silver above and polished silver below. The goldfish are closely related to the carp and can live in waters that are stale. However, the water in the aquarium should be changed at least twice a week to keep it clear. Goldfish should not be fed too lavishly. An inch square of one of the sheets of prepared fish food, we have found a fair daily ration for five medium sized fish; these fish are more likely to die from overfeeding than from starving. Goldfish are naturally long-lived; Miss Ada Georgia has kept them until seven years old in a school aquarium; and there is on record one goldfish that lived nine years.

Too often the wonderful common things are never noticed because of their commonness; and there is no better instance of this than the form and movements of a fish. It is an animal in many ways similar to animals that live on land; but its form and structure are such that it is



Smallmouth Bass
Micropterus dolomieu

perfectly adapted to live in water all its life; there are none of the true fishes which live portions of their lives on land as do the frogs. The first peculiarity of the fish is its shape. Looked at from above, the broader part of the body is near the front end which is rounded or pointed so as to cut the water readily. The long, narrow, hind portion of the body with the tail acts as a propeller. Seen from the side, the body is a smooth, graceful oval and this form is especially adapted to move through the water swiftly, as can be demonstrated to the pupil by cutting a model of the fish from wood and trying to move it through the water sidewise.

Normally, the fish has seven fins, one along the back called the dorsal, one at the end of the tail called the tail or caudal fin, one beneath the rear end of the body called the anal, a pair on the lower side of the body called the ventrals, and a pair just back of the gill openings called the pectorals. All these fins play their own parts in the movements of the fish. The dorsal fin is usually higher in front than behind and can be lifted or shut down like a fan. This fin when it is lifted gives the fish greater height and it can be twisted to one side or the other and thus be made a factor in steering. The anal fin on the lower side acts in a similar manner. The tail fin is the propeller and sends the body forward by pressing backward on the water, first on one side and then on the other, being used like a scull. The tail fin varies in shape very much in different species. In the goldfish it is fanlike, with a deeply notched hind edge, but in some it is rounded or square.

The paired fins correspond anatomically to our arms and legs, the pectorals representing the arms, the ventrals the legs. Fins are made up of rays, as the bony rods are called which support the membrane;

these rays are of two kinds, those which are soft, flexible, many jointed and usually branched at the tip; and those which are bony, not jointed and which are usually stiff spines. When the spines are present in a fin they precede the soft rays.

Fishes' eyes have no eyelid but the eyeball is movable, and this often gives the impression that the fish winks. Fishes are necessarily near-sighted since the lens of the eye has to be spherical in order to see in the water. The sense of smell is located in a little sac to which the nostril leads; the nostrils are small and often partitioned and may be seen on either side of the snout. The nostrils have no connection whatever with breathing, in the fish.

Ken-ichi Ueda (cc by-sa 4.0)

A chain pickerel
Esox niger

The tongue of the fish is very bony or bristly and immovable. There is very little sense of taste developed in it. The shape, number and position of the teeth vary according to the food habits of the fish. The commonest type of teeth are fine, sharp and short and are arranged in pads, as seen in the bullhead. Some fish have blunt teeth suitable for crushing shells. Herbivorous fishes have sharp teeth with serrated edges, while those living upon crabs and snails have incisor-like teeth. In some specimens we find several types of teeth, in others the teeth may be entirely absent. The teeth are borne not only on the jaws but also in the roof of the mouth, on the tongue and in the throat.

A yellow perch
Perca flavescens

The ear of the fish has neither outside form nor opening and is very imperfect in comparison with that of man. Extending along the sides of the body from head to tail is a line of modified scales containing small tubes connecting with nerves; this is called the lateral line and it is believed that it is in some way connected with the fish's senses, perhaps with the sense of hearing.

Since fishes must push through water, which is more difficult than moving through air, they need to have the body well protected. This protection is, in most fishes, in the form of an armor of scales which are smooth and allow the body to pass through the water with little friction. These scales overlap like shingles in a roof and are all directed backward. The study of the fish scale shows that it grows in layers.

In order to understand how the fish breathes we must examine its gills. In front, just above the entrance to the gullet, are several bony ridges which bear two rows of pinkish fringes; these are the gill arches and the fringes are the gills. The gills are filled with tiny blood vessels, and as the water passes over them, the impurities of the blood pass out through the thin skin of the gills and the life-giving oxygen passes in. Since fish cannot make use of air unless it is dissolved in water, it is very important that the water in the aquarium jar should often be replenished. The gill arches also bear a series of bony processes called gill-rakers. Their function is to prevent the escape of food through the gills while it is being swallowed, and they vary in size according to the food habits of the fish. We note that the fish in the aquarium constantly opens and closes the mouth; this action draws the water into the throat and forces it out over the gills and through the gill openings; this then, is the act of breathing.

Lesson

Leading thought— A fish lives in the water where it must breathe, move and find its food. The water world is quite different from the air world and the fish have developed forms, senses and habits which fit them for life in the water.

Method— The goldfish is used as a subject for this lesson because it is so conveniently kept where the children may see it. However, a shiner or minnow would do as well.

Before the pupils begin the study, place the diagram on the blackboard, with all the parts labelled; thus the pupils will be able to learn the parts of the fish by consulting it, and not be compelled to commit them to memory arbitrarily. It would be well to associate the goldfish with a geography lesson on China.

Observations—

1. Where do fishes live? Do any fishes ever live any part of their lives on land like the frogs? Could a salt-water fish live in fresh water, or vice versa?

2. What is the shape of a fish when seen from above? Where is the widest part? What is its shape seen from the side? Think if you can in how many ways the shape of the fish is adapted for moving swiftly through the water.

3. How many fins has the fish? Make a sketch of the goldfish with all its fins and name them from the diagram on the blackboard.

4. How many fins are there in all? Four of these fins are in pairs; where are they situated? What are they called? Which pair corresponds to our arms? Which to our legs?

5. Describe the pectoral fins. How are they used? Are they kept constantly moving? Do they move together or alternately? How are they used when the fish swims backwards?

6. How are the ventral fins used? How do they assist the fish when swimming?

7. Sketch a dorsal fin. How many spines has it? How many soft rays are there in it? What is the difference in structure between the stiff spines in the front of the dorsal fin and the rays in the hind portion? Of what use to the fish are these two different kinds of fin supports?

8. Sketch the anal fin. Has it any spines in front? How many rays has it? How is this fin used when the fish is swimming?

9. With what fin does the fish push itself through the water? Make a sketch of the tail. Note if it is square, rounded, or notched at the end. Are the rays of the tail fin spiny or soft in character?

10. Watch the goldfish swim and describe the action of all the fins while it is in motion. In what position are the fins when the fish is at rest?

11. What is the nature of the covering of the fish? Are the scales large or small? In which direction do they seem to overlap? Of what use to the fish is this scaly covering?

12. Can you see a line which extends from the upper part of the gill opening, along the side to the tail? This is called the lateral line. Do you think it is of any use to the fish?

13. Note carefully the eyes of the fish. Describe the pupil and the iris. Are the eyes placed so that the fish can see in all directions? Can they be moved so as to see better in any direction? Does the fish wink? Has it any eyelids? Do you know why fish are near-sighted?

14. Can you see the nostrils? Is there a little wart-like projection connected with the nostril? Do you think fishes breathe through their nostrils?

15. Describe the mouth of the fish. Does it open upward, downward, or directly in front? What sort of teeth have fish? How does the fish catch its prey? Does the lower or upper jaw move in the process of eating?

16. Is the mouth kept always in motion? Do you think the fish is swallowing water all the time? Do you know why it does this? Can you see a wide opening along the sides of the head behind the gill cover? Does the gill cover move with the movement of the mouth? How does a fish breathe?

17. What are the colors of the goldfish above and below? What would happen to our beautiful goldfish if they were put in a brook with other fish? Why could they not hide? Do you know what happens to the colors of the goldfish when they run wild in our streams and ponds?

18. Can you find in books or cyclopedias where the goldfish came from? Are they gold and silver in color in the streams where they are native? Do you think that they had originally the long, slender, swal-

low tails which we see sometimes in goldfish? How have the beautiful colors and graceful forms of the gold and silver fishes been developed?

"I have my world, and so have you,
A tiny universe for two,
A bubble by the artist blown,
Scarcely more fragile than our own,
Where you have all a whale could wish,
Happy as Eden's primal fish.
Manna is dropt you thrice a day
From some kind heaven not far away,
And still you snatch its softening crumbs,
Nor, more than we, think whence it comes.
No toil seems yours but to explore
Your cloistered realm from shore to shore;
Sometimes you trace its limits round,
Sometimes its limpid depths you sound,
Or hover motionless midway,
Like gold-red clouds at set of day;
Erelong you whirl with sudden whim
Off to your globe's most distant rim,
Where, greatened by the watery lens,
Methinks no dragon of the fens
Flashed huger scales against the sky,
Roused by Sir Bevis or Sir Guy;
And the one eye that meets my view,
Lidless and strangely largening, too,
Like that of conscience in the dark,
Seems to make me its single mark.
What a benignant lot is yours
That have an own All-out-of-doors,
No words to spell, no sums to do,
No Nepos and no parlyvoo!
How happy you, without a thought
Of such cross things as Must and Ought—
I too the happiest of boys
To see and share your golden joys!"

—*"The Oracle of the Goldfishes," Lowell.*

The Turtle

Teacher's Story

Fredlyfish4 (cc by-sa 3.0)
Mud turtle, Kinosternon subrubrum hipocrepis, *viewed from above. Many species of mud turtles are found in the eastern, central, and southern United States. The one pictured is found from Alabama to Texas and north to Kansas. When in captivity, mud turtles will eat lettuce and meat*

Fredlyfish4 (cc by-sa 3.0)
Mud turtle viewed from below

A TURTLE is at heart a misanthrope; its shell is in itself proof of its owner's distrust of this world. But we need not wonder at this misanthropy, if we think for a moment of the creatures that lived on this earth, at the time when turtles first appeared. Almost any of us would have been glad of a shell in which to retire, if we had been contemporaries of the smilodon and other monsters of earlier geologic times.

When the turtle feels safe and walks abroad for pleasure, his head projects far from the front end of his shell, and the legs, so wide, and soft that they look as if they had no bones in them, project out at the side, while the little, pointed tail brings up an undignified rear; but frighten him and at once head, legs and tail all disappear, and even if we turn him over, we see nothing but the tip of the nose, the claws of the feet and the tail turned deftly sidewise. When frightened, he hisses threateningly; the noise seems to be made while the mouth is shut, and the breath emitted through the nostrils.

The upper shell of the turtle is

called the carapace and the lower shell, the plastron. There is much difference in the different species of turtles in the shape of the upper shell and the size and shape of the lower one. In most species the carapace is sub-globular but in some it is quite flat. The upper shell is grown fast to the backbone of the animal, and the lower shell to the breast bone. The markings and colors of the shell offer excellent subjects for drawing. The painted terrapin has a red-mottled border to the shell, very ornamental; the wood turtle has a shell made up of plates each of which is ornamented with concentric ridges; and the box-turtle has a front and rear trap-door, hinged to the plastron, which can be pulled up against the carapace when the turtle wishes to retire, thus covering it entirely.

Suzanne L Collins (CNAH) (cc by-sa 1.0)
Painted turtle, or terrapin, Chrysemys belli marginata. *The painted turtle pictured is found from the Mississippi River eastward; but species can be found anywhere in the Unite States except in deserts and very high mountains. This turtle often swims about rocks and logs that protrude above the water*

The turtle's head is decidedly snakelike. Its color differs with different species. The wood turtle has a triangular, horny covering on the top of the head, in which the color and beautiful pattern of the shell are repeated; the underparts are brick-red with indistinct yellowish lines under the jaw. The eyes are black with a yellowish iris, which somehow gives them a look of intelligence. The turtle has no eyelids like our own, but has a nictitating membrane which comes up from below and completely covers the eye; if we seize the turtle by the head and attempt to touch its eyes, we can see the

Chicken turtle, Deirochelys reticularia. *This turtle is at home on the coastal plain from North Carolina to Mississippi. Its high shell may reach a length of eight inches; its neck is long and snakelike.*

Diamond back terrapin, Malaclemys centrata. *The home of the diamond back is in salt marshes from Florida to Massachusetts. In captivity it will eat lettuce, oysters, beef, chopped clams, or fish. Its flesh is used as meat and for making soup*

use of this eyelid. When the turtle winks, it seems to turn the eyeball down against the lower lid.

The sense of smell in turtles is not well developed, as may be guessed by the very small nostrils, which are mere pin-holes in the snout. The mouth is a more or less hooked beak, and is armed with cutting edges instead of teeth. The constant pulsation in the throat is caused by the turtle swallowing air for breathing.

The turtle's legs, although so large and soft, have bones within them, as the skeleton shows. The claws are long and strong; there are five claws on the front and four on the hind feet. Some species have a distinct web between the toes; in others, it is less marked, depending upon whether the species lives mostly in water or out of it. The color of the turtle's body varies with the species; the body is covered with coarse, rough skin made up of various-sized plates.

The enemies of turtles are the larger fishes and other turtles. Two turtles should never be kept in the same aquarium, since they eat each others' tails and legs with great relish. They feed upon insects, small fish, or almost anything soft-bodied which they can find in the water; they are especially fond of earthworms. The species which frequent the land, feed upon tender vegetation and also eat berries. In an aquarium, a turtle should be fed earthworms, chopped fresh beef, lettuce leaves and berries. The wood turtle is especially fond of cherries.

The aquarium should always have in it a stone or some other object projecting above the water, so that the turtle may climb out, if it chooses. In winter, turtles bury themselves in the ooze at the bottom of ponds and streams. Their eggs have white leathery shells, are oblong or round, and are buried by the mother in the sand or soil near a stream or pond. The long life of turtles is a well authenticated fact, dates carved upon their shells show them to have attained the age of

thirty or forty years.

The following are, perhaps, the most common species of turtles:

(a) *The Snapping Turtle*— This sometimes attains a shell 14 inches long and a weight of forty pounds. It is a vicious creature and inflicts a severe wound with its sharp, hooked beak; it should not be used for a nature-study lesson unless the specimen is very young.

MatthewHoobin (cc by-sa 4.0)
Florida snapper, Chelydra osceola, *viewed from above. Snappers live in slow-running streams, ponds, or marshes; the female often goes some distance from her regular home to bury her round, white eggs—usually about two dozen in number.*

(b) *The Mud Turtle*— The musk turtle and the common mud turtle both inhabit slow streams and ponds; they are truly aquatic and only come to shore to deposit their eggs. They cannot eat, unless they are under water, and they seek their food in the muddy bottoms. The musk turtle when handled, emits a very strong odor; it has on each side of the head two broad yellow stripes. The mud turtle has no odor. Its head is ornamented with greenish yellow spots.

Spotted turtle, Clemmys guttata. The range of the spotted turtles extends from Michigan to Maine and south to Florida. In captivity they often become very tame; they prefer raw food—earthworms, aquatic insects, ground beef, or fish.

(c) *The Painted Terrapin, or Pond Turtle*— This can be determined by the red mottled border of its shell. It makes a good pet, if kept in an aquarium by itself, but will destroy other creatures. It will eat meat or chopped fish, and is fond of earthworms and soft insects.

(d) *The Spotted Turtle*— This has the upper shell black with numerous round yellow spots upon it. It is common in ponds and marshy

Wilfried Berns (cc by-sa 2.0)
A young wood turtle. Glyptemys insculpta

Eveha (cc by-sa 3.0)
Box turtle, Terrapene major. *One or more species of box turtle can be found in almost any portion of the United States from the Rocky Mountains eastward.*

Johnskate17 (cc by-sa 4.0)
Soft-shelled turtle, Amyda emoryi. *The species pictured is found in Florida. Other species may be found from Canada south to the Gulf and as far west as Colorado.*

streams and its favorite perch is, with many of its companions, upon a log. It feeds under water, eating insect larvae, dead fish and vegetation. It likes fresh lettuce.

(e) *The Wood Terrapin*— This is our most common turtle; it is found in damp woods and wet places, since it lives largely upon the land. Its upper shell often reaches a length of six and one-half inches and is made up of many plates, ornamented with concentric ridges. This is the turtle upon whose shell people carve initials and dates and then set it free. All the fleshy parts of this turtle, except the top of the head and the limbs, are brick-red. It feeds on tender vegetables, berries and insects. It makes an interesting pet and will soon learn to eat from the fingers of its master.

(f) *The Box-Turtle*— This is easily distinguished from the others, because the front and rear portions of the lower shell are hinged so that they can be pulled up against the upper shell. When this turtle is attacked, it draws into the shell and closes both front and back doors, and is very safe from

its enemies. It lives entirely upon land and feeds upon berries, tender vegetation and insects. It lives to a great age.

(g) *The Soft-shelled Turtle*— These are found in streams and canals. The upper shell looks as if it were of one piece of soft leather, and resembles a griddle-cake. Although soft-shelled, these turtles are far from soft-tempered, and must be handled with care.

Saperaud (cc by-sa 3.0)
Tortoise eggs hatching.

Lesson

Leading thought— The turtle's shell is for the purpose of protecting its owner from the attack of enemies. Some turtles live upon land and others in water.

Method— A turtle of any kind, in the schoolroom, is all that is needed to make this lesson interesting.

Observations—

1. How much can you see of the turtle when it is walking? If you disturb it what does it do? How much of it can you see then? Can you see more of it from the lower side than the upper? What is the advantage to the turtle of having such a shell?

2. Compare the upper shell with the lower as follows: How are they shaped differently? What is their difference in color? Would it be a disadvantage to the turtle if the upper shell were as light colored as the lower? Why? Make a drawing of the upper and the lower shell showing the shape of the plates of which they are composed. Where are the two grown together?

3. Is the border of the upper shell different from the central portion in color and markings? Is the edge smooth or scalloped?

4. How far does the turtle's head project from the front of the shell? What is the shape of the head? With what colors and pattern is it marked? Describe the eyes. How are they protected? How does the

A snapping turtle.

turtle wink? Can you discover the little eyelid which comes up from below to cover the eye?

5. Describe the nose and nostrils. Do you think it has a keen sense of smell?

6. Describe the mouth. Are there any teeth? With what does it bite off its food? Describe the movement of the throat. Why is this constant pulsation?

7. What is the shape of the leg? How is it marked? How many claws on the front feet? Are any of the toes webbed? On which feet are the webbed toes? Why should they be webbed? Describe the way a turtle swims. Which feet are used for oars?

8. Describe the tail. How much can be seen from above when the turtle is walking? What becomes of it, when the turtle withdraws into its shell?

9. How much of the turtle's body can you see? What is its color? Is it rough or smooth?

10. What are the turtle's enemies? How does it escape from them? What noise does the turtle make when frightened or angry?

11. Do all turtles live for part of the time in water? What is their food and where do they find it? Write an account of all the species of turtles that you know.

12. How do turtle eggs look? Where are they laid? How are they hidden?

Supplemental reading—"Turtle Eggs for Agassiz," Dallas Lore Sharp, Atlantic Monthly, Feb., 1910.

The Crayfish

Teacher's Story

WHEN I look at a crayfish I envy it, so rich is it in organs with which to do all that it has to do. From the head to the tail, it is crowded with a large assortment of executive appendages. In this day of multiplicity of duties, if we poor human creatures only had the crayfish's capabilities, then might we hope to achieve what lies before us.

The most striking thing in the appearance of the crayfish is the great pair of nippers on each of the front legs. Wonderfully are its "thumb and finger" put together; the "thumb" is jointed so that it can move back and forth freely; and both are armed, along the inside edge, with saw teeth and with a sharp claw at the tip so that they can get a firm grip upon an object. Five segments in these great legs can be easily seen; that joining the body is small, but each successive one is wider and larger, to the great forceps at the end. The two stout segments behind the nippers give strength, and also a suppleness that enables the claws to be bent in any direction.

The legs of the pair behind the big nippers have five segments readily visible; but these legs are slender and the nippers at the end

are small; the third pair of legs is armed like the second pair; but the fourth and fifth pairs lack the pincers, and end in a single claw.

But the tale of the crayfish's legs is by no means told; for between and above the great pincers is a pair of short, small legs tipped with single claws, and fringed on their inner edges. These are the maxillapeds, or jaw-feet; and behind them, but too close to be seen easily, are two more pairs of jaw-feet. As all of these jaw-feet assist at meals, the crayfish apparently always has a "three fork" dinner; and as if to provide accommodations for so many eating utensils, it has three pairs of jaws all working sidewise, one behind the other. Two of these pairs are maxillae and one, mandibles. The mandibles are the only ones we see as we look in between the jaw-feet; they are notched along the biting edge. Connected with the maxillae, on each side, are two pairs of threadlike flappers, that wave back and forth vigorously and have to do with setting up currents of water over the gills.

Thus we see that, in all, the crayfish has three pairs of jaw-feet, one pair of great nippers and four pairs of walking feet, two of which also have nippers and are used for digging and carrying.

When we look upon the crayfish from above, we see that the head and thorax are fastened solidly together, making what is called a cephalothorax. The cephalothorax is covered with a shell called the carapace, which is the name given also to the upper part of the turtle's shell. The suture where the head joins the thorax is quite evident. In

Mlogic (cc by-sa 3.0)
*A Snow White Crayfish (*Procambarus sp.*) and a mystery snail are fighting over for food*

looking at the head, the eyes first attract our attention; each is black and oval and placed on the tip of a stalk, so it can be extended or retracted or pushed in any direction, to look for danger. These eyes are like the compound eyes of insects, in that they are made up of many small eyes, set together in a honeycomb pattern.

The long antennae are as flexible as braided whiplashes, large at the base and ending in a threadlike tip. They are composed of many segments, the basal ones being quite large. Above the antennae on each side, is a pair of shorter ones called antennules, which come from the same basal segment; the lower one is the more slender and is usually directed forward; the upper one is stouter, curves upward, and is kept always moving, as if it were constantly on the alert for impressions. The antennae are used for exploring far ahead or behind the creature, and are often thrust down into the mud and gravel at the bottom of the aquarium, as if probing for treasure. The antennules seem to give warning of things closer at hand. Between the antennae and antennules is a pair of fingerlike organs, that are hinged at the outer ends and can be lifted back, if we do it carefully.

In looking down upon a crayfish, we can see six abdominal segments and the flaring tail at the end, which is really another segment greatly modified. The first segment, or that next to the cephalothorax, is narrow; the others are about equal in size, each graceful in shape, with a widened part at each side which extends down along the sides of the creature. These segments are well hinged together so that the abdomen may be completely curled beneath the cephalothorax. The plates along the sides are edged with fringe. The tail consists of five parts, one semicircular in the center, and two fan-shaped pieces at each side, and all are margined with fringe. This tail is a remarkable organ. It can be closed or extended sidewise like a fan; it can be lifted up or curled beneath.

Looking at the crayfish from below, we see on the abdomen some very beautiful featherlike organs called swimmerets. Each swimmeret consists of a basal segment with twin paddles joined to its tip, each paddle being narrow and long and fringed with hairs. The mother crayfish has four pairs of these, one pair on each of the second, third, fourth and fifth segments; her mate has an additional larger pair on

the first segment. These swimmerets, when at rest, lie close to the abdomen and are directed forward and slightly inward. When in motion, they paddle with a backward, rhythmic motion, the first pair setting the stroke and the other pairs following in succession. This motion sends the body forward, and the swimmerets are chiefly used to aid the legs in forward locomotion. A crayfish, on the bottom of a pond, seems to glide about with great ease; but place it on land, and it is an awkward walker. The reason for this difference lies, I believe, in the aid given by the swimmerets when the creature is in water. Latter says: "In walking, the first three pairs of legs pull and the fourth pair pushes. Their order of movement is as follows: The first on the right and the third on the left side move together, next the third right and the first left, then the second right and fourth left, and lastly the fourth right and second left."

When the crayfish really wishes to swim, the tail is suddenly brought into use; it is thrust out backward, lays hold of the water by spreading out widely, and then doubles under with a spasmodic jerk which pulls the creature swiftly backward.

The crayfish's appearance is magically transformed when it begins to swim; it is no longer a creature of sprawling awkward legs and great clumsy nippers; now, its many legs lie side by side supinely and the great claws are limp and flow along in graceful lines after the body, all obedient to the force which sends the creature flying through the water. I cannot discover that the swimmerets help in this movement.

The mother crayfish has another use for her swimmerets; in the spring, when she is ready to lay eggs, she cleans off her paddles with her hind legs, covers them with waterproof glue, and then plasters her eggs on them in grapelike clusters of little dark globules. What a nice way to look after her family! The little ones hatch, but remain clinging to the maternal swimmerets, until they are large enough to scuttle around on the brook bottom and look out for themselves.

The breathing apparatus of the crayfish cannot be seen without dissection. All the walking legs, except the last pair, have gills attached to that portion of them which joins the body, and which lies hidden underneath the sides of the carapace or shell. The blood is forced into these gills, sends off its impurities through their thin walls and takes

Gailhampshire (cc by-sa 2.0)
A land crab, a relative of the crayfish. Note the eye-stalks

in the oxygen from the water, currents of which are kept steadily flowing forward.

Crayfishes haunt still pools along brooksides and river margins and the shallow ponds of our fresh waters. There they hide beneath sticks and stones, or in caves of their own making, the doors of which they guard with the big and threatening nippers, which stand ready to grapple with anybody that comes to inquire if the folks are at home. The upper surface of the crayfish's body is always so nearly the color of the brook bottom, that the eye seldom detects the creature until it moves; and if some enemy surprises one, it swims off with terrific jerks which roil all the water around and thus covers its retreat. In the winter, our brook forms hibernate in the muddy bottoms of their summer haunts. There are many species; some in our Southern States, when the dry season comes on, live in little wells which they dig deep enough to reach water. They heap up the soil which they excavate around the mouth of the well, making well-curbs of mud; these are ordinarily called "crawfish chimnies." The crayfishes find their food in the flotsam and jetsam of the pool. They seem fond of the flesh of dead fishes and are often trapped by its use as bait.

The growth of the crayfish is like that of insects; as its outer covering is a hard skeleton that will not stretch, it is shed as often as necessary; it breaks open down the middle of the back of the carapace, and the soft-bodied creature pulls itself out, even to the last one of its claws. While its new skin is yet elastic, it stretches to its utmost; but this skin also hardens after a time and is, in its turn, shed. Woe to the crayfish caught in this helpless, soft condition after molting! For

Scott Akerman (cc by-sa 2.0)
Fiddler crabs, so called from the position in which the male often holds the enlarged claw, are burrowing crabs of the Atlantic coast

it then has no way to protect itself. We sometimes find the old skin floating, perfect in every detail, and so transparent that it seems the ghost of a crayfish.

Not only is the crayfish armed in the beginning with a great number of legs, antennae, etc., but if it happens to lose any of these organs, they will grow again. It is said that, when attacked, it can voluntarily throw off one or more of its legs. We have often found one of these creatures with one of the front claws much larger than the other; it had probably lost its big claw in a fight, and the new growth was not yet completed.

I have been greatly entertained by watching a female crayfish make her nest in my aquarium which has, for her comfort, a bottom of three inches of clean gravel. She always commences at one side by thrusting down her antennae and nippers between the glass and stones; she seizes a pebble in each claw and pulls it up and in this way starts her excavation; but when she gets ready to carry off her load, she comes to the task with her tail tucked under her body, as a lady tucks up her skirts when she has something to do that requires freedom of movement. Then with her great nippers and the two pairs of walking feet,

also armed with nippers, she loads up as much as she can carry between her great claws and her breast. She keeps her load from overflowing by holding it down with her first pair of jaw-feet, just as I have seen a schoolboy use his chin, when carrying a too large load of books; and she keeps the load from falling out by supporting it from beneath with her first pair of walking legs. Thus, she starts off with her "apron" full, walking on three pairs of feet, until she gets to the dumping place; then she suddenly lets go and at the same time her tail straightens out with a gesture which says plainly, "There!" Sometimes when she gets a very large load, she uses her second pair of walking legs to hold up the burden, and crawls off successfully, if not with ease, on two pairs of legs,—a most unnatural quadruped.

I had two crayfishes in a cage in an aquarium, and each made a nest in the gravel at opposite ends of the cage, heaping up the debris into a partition between them. I gave one an earthworm, which she promptly seized with her nippers; she then took up a good sized pebble in the nippers of her front pair of walking legs, glided over to the other nest, spitefully threw down both worm and pebble on top of her fellow prisoner, and then sped homeward. Her victim responded to the act by rising up and expressing perfectly, in his attitude and the gestures of his great claws, the most eloquent of crayfish profanity. In watching crayfishes carry pebbles, I have been astonished to see how constantly the larger pair of jaw-feet are used to help pick up and carry the loads.

Lesson

Leading thought— The crayfish, or crawfish, as it is sometimes called, has one pair of legs developed into great pincers for seizing and tearing its food and for defending itself from enemies. It can live in mud or water. It belongs to the same animal group as do the insects, and it is a near cousin of the lobster.

Method— Place a crayfish in an aquarium (a battery jar or a two-quart Mason jar) in the schoolroom, keeping it in clear water until the pupils have studied its form. It will rise to explore the sides of the aquarium at first, and thus show its mouth parts, legs and swimmer-

ets. Afterwards, place gravel and stone in the bottom of the aquarium, so that it can hide itself in a little cavity which it will make by carrying pebbles from one side. Wash the gravel well before it is put in, so that the water will be unclouded and the children can watch the process of excavation.

Observations—

1. What is there peculiar about the crayfish which makes it difficult to pick it up? Examine one of these great front legs carefully and see how wonderfully it is made. How many parts are there to it? Note how each succeeding part is larger from the body to the claws. Note the tips which form the nippers or chelae, as they are called. How are they armed? How are the gripping edges formed to take hold of an object? How wide can the nippers be opened, and how is this done? Note the two segments behind the great claw and describe how they help the work of the nippers.

2. Study the pair of legs behind the great claws or chelae, and compare the two pairs, segment by segment. How do they differ except as to size? How do the nippers at the end compare with the big ones? Look at the next pair of legs behind these; are they similar? How do the two pairs of hind legs differ in shape from the two pairs in front of them?

3. Look between the great front claws and see if you can find another pair of small legs. Can you see anything more behind or above these little legs?

4. When the crayfish lifts itself up against the side of the jar, study its mouth. Can you see a pair of notched jaws that work sidewise? Can you see two or three pairs of threadlike organs that wave back and forth in and out the mouth?

5. How many legs, in all, has the crayfish? What are the short legs near the mouth used for? What are the great nippers used for? How many legs does the crayfish use when walking? In what order are they moved? Is the hind pair used for pushing? What use does it make of the pincers on the first and second pairs of walking legs?

6. Look at the crayfish from above; the head and the covering of the thorax are soldered together into one piece. When this occurs, the

whole is called a cephalothorax; and the cover is called by the same name as the upper shell of the turtle, the carapace. Can you see where the head is joined to the thorax?

7. Look carefully at the eyes. Describe how they are set. Can they be pushed out or pulled in? Can they be moved in all directions? Of what advantage is this to the crayfish?

8. How many antennae has the crayfish? Describe the long ones and tell how they are used. Do the two short ones on each side come from the same basal segment? These little ones are called the antennules. Describe the antennules of each side and tell how they differ. Can you see the little fingerlike organs which clasp above the antenna and below the antennules on each side of the head? Can these be moved?

9. Look at the crayfish from above. How many segments are there in the abdomen? Note how graceful the shape of each segment. Note that each has a fan-shaped piece down the side. Describe how the edges of the segments along the sides are margined.

10. Of how many pieces is the tail made? Make a sketch of it. How are the pieces bordered? Can the pieces shut and spread out sidewise? Is the tail hinged so it can be lifted up against the back or curled under the body?

11. Look underneath the abdomen and describe the little fringed organs called the swimmerets. How many are there?

12. How does the crayfish swim? With what does it make the stroke? Describe carefully this action of the tail. When it is swimming, does it use its swimmerets? Why do not the many legs and big nippers obstruct the progress of the crayfish, when it is swimming?

13. When does the crayfish use its swimmerets? Do they work so as to push the body backward or forward? Do you know to what use the mother crayfish puts her swimmerets?

14. Do you know how crayfishes breathe? Do you know what they eat and where they find it?

15. Where do you find crayfishes? Where do they like to hide? Do they go headfirst into their hiding place, or do they back in? Do they stand ready to defend their retreat? When you look down into the brook, are the crayfishes usually seen until they move? Why is this?

Where do the crayfishes pass the winter? Did you ever see the crayfish burrows or mud chimnies?

16. If the crayfish loses one of its legs or antennas, does it grow out again? How does the crayfish grow?

17. Put a crayfish in an aquarium which has three inches of coarse gravel on the bottom, and watch it make its den. How does it loosen up a stone? With how many legs does it carry its burden of pebbles when digging its cave? How does it use its jaw-feet, its nippers, and its first and second pairs of walking legs in this work?

"A rock-lined, wood-embosomed nook,
Dim cloister of the chanting brook!
A chamber within the channelled hills,
Where the cold crystal brims and spills,
By dark-browed caverns blackly flows.
Falls from the cleft like crumbling snows,
And purls and splashes, breathing round
A soft, suffusing mist of sound."

—*J. T. Trowbridge.*

An orb web on a dewy morning

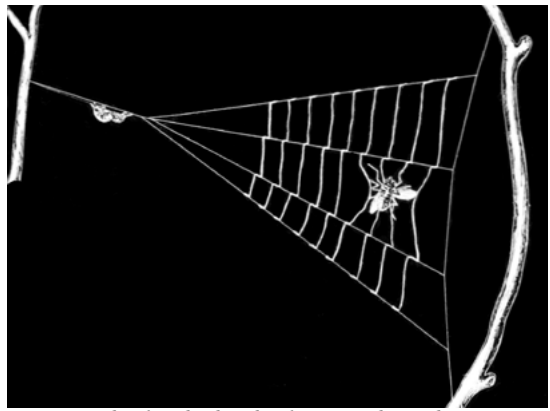
The Orb-Web

Teacher's Story

OF all the structures made by the lower creatures, the orb-web of the spider is, beyond question, the most intricate and beautiful in design, and the most exquisite in workmanship. The watching of the construction of one of these webs is an experience that brings us close to those mysteries which seem to be as fundamental as they are inexplicable in the plan of the universe. It is akin to watching the growth of a crystal, or the stars wheeling across the heavens in their appointed courses.

The orb-web of the large, black and yellow garden spider is, perhaps, the best subject for this study, although many of the smaller orbs are far more delicate in structure. These orb-webs are most often placed vertically, since they are thus more likely to be in the path of flying insects. The number of radii, or spokes, differs with the different species of spiders, and they are usually fastened to a silken framework, which in turn is fastened by guy-lines to surrounding objects. These radii

or spokes are connected by a continuous spiral line, spaced regularly except at the center or hub; this hub or center is of more solid silk, and is usually surrounded by an open space; and it may be merely an irregular network, or it may have wide bands of silk laid across it.



The finished web of a triangle spider

The radii or spokes, the guy-lines, the framework and the center of the web are all made of inelastic silk, which does not adhere to an object that touches it. The spiral line, on the contrary, is very elastic, and adheres to any object brought in contact with it. An insect which touches one of these spirals and tries to escape, becomes entangled in the neighboring lines and is thus held fast until the spider can reach it. If one of these elastic lines be examined with a microscope, it is a most beautiful object. There are strung upon it, like pearls, little drops of sticky fluid, which render it not only elastic but adhesive.

Some species of orb-weavers remain at the center of the web, while others hide in some little retreat near at hand. If in the middle, the spider always keeps watchful claws upon the radii of the web so that if there is any jarring of the structure by an entrapped insect, it is at once apprised of the fact; if the spider is in a den at one side, it keeps a claw upon a trap line which is stretched tightly from the hub of the web to the den, and thus communicates any vibration of the web to the hidden sentinel. When the

Judy Gallagher (cc by-sa 2.0)

The triangle spider usually rests on the single line of the web

C Watts (cc by-sa 2.0)
Some of the orb weavers strengthen their orb webs by spinning a zigzag ribbon, as pictured above, across the center

insect becomes entangled, the spider rushes out and envelops it in a band of silk, which feat it accomplishes, by turning the insect over and over rapidly, meanwhile spinning a broad, silken band which swathes it. It may bite the insect before it begins to swathe it in silk, or afterwards. It usually hangs the swathed insect to the web near where it was caught, until ready to eat it; it then takes the prey to the center of the web, if there is where the spider usually sits, or to its den at one side, if it is a den-making species, and there sucks the insect's blood, carefully throwing away the hard parts.

The spider does not become entangled in the web, because, when it runs it steps upon the dry radii and not upon the sticky spiral lines. During the busy season, the spider is likely to make a new web every twenty-four hours, but this depends largely upon whether the web has meanwhile been destroyed by large insects.

Rosser1954 (cc by-sa 4.0)
The spinner of this web, Abaurobius, lives in a crevice in the cliff. The web was spun about the entrance.

The spider's method of making its first bridge is to place itself upon some high point and, lifting its abdomen in the air, to spin out on the

breeze a thread of silk. When this touches any object, it adheres, and the spider draws in the slack until the line is "taut;" it then travels across this bridge, which is to support its web, and makes it stronger by doubling the line. From this line, it stretches other lines by fastening a thread to one point, and then walking along to some other point, spinning the thread as it goes and holding the line clear of the object on which it is walking by means of one of its hind legs. When the right point is reached, it pulls the line tight, fastens it, and then, in a similar fashion, proceeds to make another. It may make its first radius by dropping from its bridge to some point below; then climbing back to the center, it fastens the line for another radius, and spinning as it goes, walks down and out to some other point, holding the thread clear and then pulling it tight before fastening it. Having thus selected the center of the web, it goes back and forth to and from it, spinning lines until all of the radii are completed and fastened at one center. It then starts at the center and spins a spiral, laying it onto the radii to hold them firm. However, the lines of this spiral are farther apart and much more irregular than the final spiral. Thus far, all of the threads the spider has spun are inelastic and not sticky; and this first, or temporary spiral is used by the spider to walk upon when spinning the final spiral. It begins the latter at the outer edge instead of at the center, and works toward the middle. As the second spiral progresses, the spider with its jaws cuts away the spiral which it first made, and which it has used as a scaffolding. A careful observer may often see remnants of this first spiral on the radii between the lines of the permanent spiral. The spi-

Phil (cc by-sa 2.0)
The irregular web of a dictynid

der works very rapidly and will complete a web in a very short time. The final spiral is made of the elastic and adhesive silk.

References— Comstock's Manual; Common Spiders, Emerton; The Spider Book, Comstock; Nature's Craftsmen, McCook.

Lesson

Leading thought— No structure made by a creature lower than man is so exquisitely perfect as the orb-web of the spider.

Method— There should be an orb-web where the pupils can observe it, preferably with the spider in attendance.

Observations—

1. Is the orb-web usually hung horizontally or vertically?

2. Observe the radii, or "spokes," of the web. How many are there? How are they fastened to surrounding objects? Is each spoke fastened to some object or to a framework of silken lines?

3. Observe the silken thread laid around the spokes. Is it a spiral line or is each circle complete? Are the lines the same distance apart on the outer part of the web as at the center? How many of the circling lines are there?

4. Is the center of the web merely an irregular net, or are there bands of silk put on in zigzag shape?

5. Touch any of the "spokes" lightly with the point of a pencil. Does it adhere to the pencil and stretch out as you pull the pencil away? Touch one of the circling lines with a pencil point, and see if it adheres to the point and is elastic. What is the reason for this difference in the stickiness and elasticity of the different kinds of silk in the orb-web?

6. If an insect touches the web, how does it become more entangled by seeking to get away?

7. Where does the spider stay, at the center of the web or in a little retreat at one side?

8. If an insect becomes entangled in the web, how does the spider discover the fact and act?

9. If the spider sits at the middle of the orb, it has a different method for discovering when an insert strikes the web than does the spider that hides in a den at one side. Describe the methods of each.

10. How does the spider make fast an insect? Does it bite the insect before it envelops it in silk? Where does it carry the insect to feed upon it?

11. How does the spider manage to run about its web without becoming entangled in the sticky thread? How often does the orb-weaver make a new web?

How an Orb-Web Is Made

Spiders may be seen making their webs in the early morning or in the evening. Find an orb-web with a spider in attendance; break the web without frightening the spider and see it replace it in the early evening, or in the morning about daybreak. An orb-weaver may be brought into the house on its web, when the web is on a branch, and placed where it will not be disturbed, and thus be watched at leisure.

A partially completed orb-web. a. the temporary spiral stay line; b. the sticky spiral line; c. the fragments of the temporary spiral hanging in a radius.

Observations—

1. How does the spider manage to place the supporting line between two points?

2. How does it make the framework for holding the web in place?

3. How does it make the first radius?

4. How does it make the other radii and select the point which is to be the center of the web?

5. How does it keep the line which it is spinning clear of the line it walks upon?

6. After the radii are all made, are they fastened at the center?

7. How and where does the spider first begin to spin a spiral? Are the lines of this spiral close together or far apart? For what is the first spiral used?

8. Where does it begin to spin the permanent spiral? Where does it walk when spinning it? By the way it walks on the first spiral, do you

think it is sticky and elastic? What does it do with the first spiral while the second one is being finished?

9. If the center of the web has a zigzag ribbon of silk, when was it put on?

10. How many minutes did it take the spider to complete the web?

Supplementary reading— "Argiope of the Silver Shield," Insect Stories, Kellogg.