

The Secret of the Bladderwort

This Carnivorous Aquatic Plant Is An Efficient Trapper of Small Animals. The Mechanism of Its Trap, A Unique Device Which Operates by Suction, Has Recently Been Discovered

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ONE of the fundamental differences between plants and animals is in the manner in which they obtain their nourishment. Plants fill all of their material requirements with relatively simple substances which they draw quietly, imperceptibly from the soil and air, and for their energy they imprison a portion of the force of the sun's rays. The whole process of the nutrition of plants is so silent, so unobtrusive, involves particles so far removed from the limits of even microscopic vision, that mankind had eaten plants, cultivated plants and bred plants for untold centuries before he obtained the slightest inkling of what plants actually do require for their nourishment.

Animals, on the other hand, must seek gross particles of complex substances such as grass or fruit or flesh, and whether the beast be carnivorous or vegetarian, we can, in the final analysis, trace the food to its source in plants.

A MORE thorough study of the physiology of plants reveals to us that it is only the green plants which are self-sustaining in the strictest sense. Already, when we have picked our first mushroom, if we read its story rightly, we learn that all plants are not the splendidly independent organisms which others seem to be, but some have degenerated to the point where they must derive sustenance from the decaying bodies of others, or even of animals.

These scavengers of the vegetable world we call saprophytes. Others, the parasites of the plant world, prey upon the living tissues of other plants, or in some cases upon living animals. Yet both saprophytes and parasites appropriate their nourishment in particles beyond the limits of microscopic vision, and do not, like animals, gulp down tangible portions of food.

There is a small but immensely interesting group of plants which

approaches still more closely the habits of animals in matters of diet, in that they capture and in some cases actually engulf living creatures. These have been called the insectivorous plants, but such an appellation is not strictly correct, for many of the small animals which fall a prey to these plants belong in other classes; and so it is more proper to term our plants carnivorous.

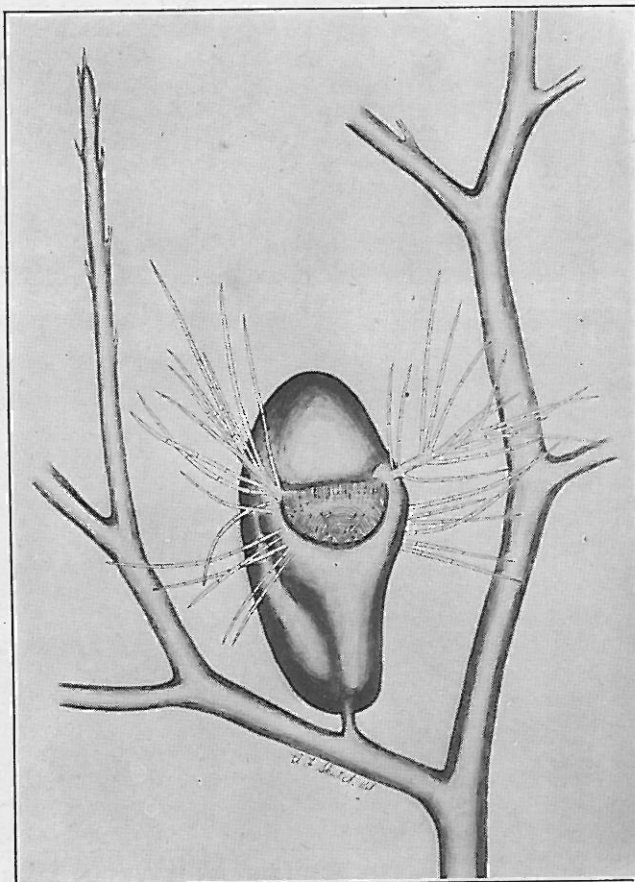
It is of considerable significance that all of the carnivorous plants belong to the group of flowering plants, and practically all of them are provided with the green pigment chlorophyll, so that they are able to build up carbohydrates and to secure their own energy from the rays of the sun. This circumstance sets them off sharply from the great host of wholly dependent saprophytic and parasitic fungi, and from most of the parasitic flowering plants. Their carnivorous diet merely supplements the nourishment they are able to synthesize from the substances they draw from the soil, or water, and the air. It seems that they entrap small animals primarily to meet a deficiency of nitrates and other salts which is felt in their native soil or water, by utilizing animal proteins, which are a rich source of the necessary elements.

What a most amazing array of ingenious pitfalls and snares are presented to our observation and thought by these carnivorous plants! The leaves of

the marsh-dwelling sundew are covered by a number of tentacles which radiate from the upper surface like pins from a pincushion, and are expanded at the ends into spherical glands—the pin heads. The glands are enveloped in a sticky fluid which they secrete, so that they glisten in the sunlight like so many morning dew-drops, whence the name. If an unsuspecting insect, either by chance or attracted by the shining dew-drops, alights upon the leaf, it is held fast by the sticky secretion.

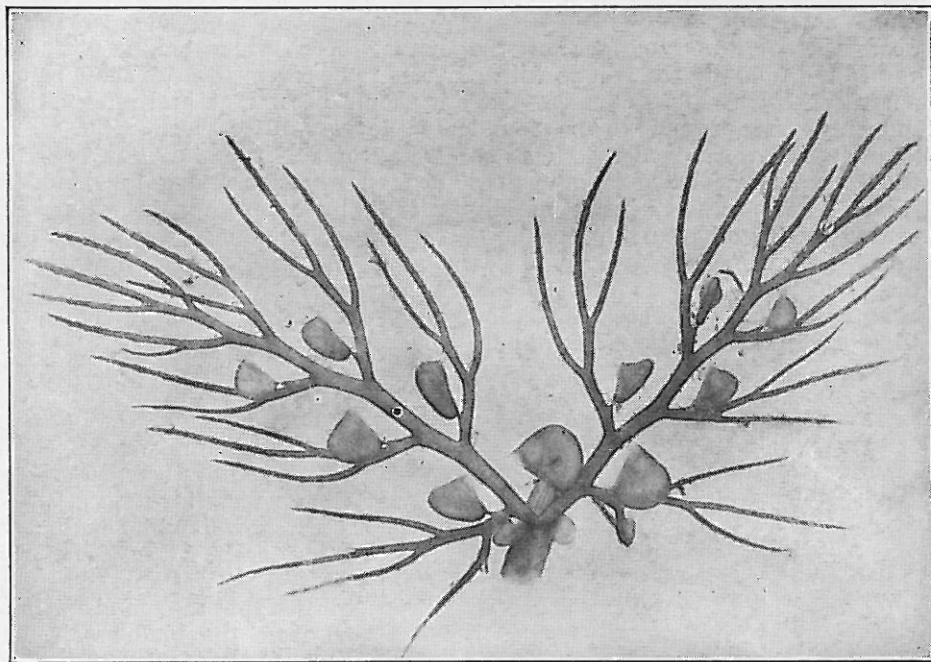
ITS struggles to regain freedom result only in stimulating more of the tentacles to bend their sticky heads over it and hold it in a firmer embrace, so it is the old story of Br'er Rabbit and the Tar Baby over again. This octopus of plants long anticipated the tactics of the fowler with his bird lime. The insect is digested by a secretion which the versatile glands pour over it, and by these its nitrogenous compounds are absorbed into the leaf.

Then there is the Venus's fly-trap, a small, white blossomed herb which is confined to a restricted portion of the Carolinas. The leaves are hinged in the middle, and each half bears several peculiar bristles upon its upper surface. When an insect, crawling over the leaf, happens to bend one of the bristles, the two halves spring



THE TRAP SET FOR A CAPTURE

Here the bladder is enlarged about 15 times. The valve with its four bristles and its many glandular hairs shows plainly



A SINGLE LEAF OF THE GREATER BLADDERWORT

Enlarged about three times, with the attached bladders, viewed from behind. Over 100 bladders have been counted upon a single leaf of the plant; usually, however, there are only about a dozen

rapidly together, the long comb-like teeth which cover the margins interlock, and the prey is firmly entrapped. To compare our plant again with man-made devices, one thinks first of the cruel steel trap.

The pitfall has been developed to a high degree of perfection by several genera of carnivorous plants. The most familiar is our pitcher or side-saddle plant, a denizen of cold sphagnum bogs of eastern North America. The trumpet- or pitcher-shaped leaves of these plants all operate on the same principle: the animal crawling over the mouth of the trumpet ventures onto the slippery inner wall, where it loses its footing and glides down to the bottom. Its escape from the bottom of the pitcher is made difficult by bristles all pointing downward. Once inside, the animal decays, in our native pitcher-plant, through the agency of bacteria, and its nutritious residues are absorbed into the leaf.

THE bladderworts, with their minute suction traps, are in many respects the most remarkable of all animal-trapping plants. Our most common native species, the greater bladderwort, grows in ponds and sluggish streams throughout most of the eastern and central portions of our country, while an almost identical form is found in Europe, the temperate regions of Asia, and our own northwest. During the mild seasons, the long, slender, green stems, clothed with delicate, many-parted leaves, float just beneath the surface of the quiet water. They grow continuously through the warm weather and may attain a yard or more in length.

Roots of any kind are totally lacking, and the unattached plants drift at the mercy of wind and currents.

During the height of the summer, the slender flower stalks are raised above the surface of the water, where each supports from five to a dozen conspicuous yellow flowers in the sun and air. In the autumn, after the seeds have matured, the stem ceases to elongate and develops a compact mass of leaves, resembling a bud, at its tip. The leaves and stem behind the bud die off, and finally it sinks to the bottom, where it survives the winter months among the mud and fallen leaves and decaying pond vegetation. With the return of spring, the resting bud is called into renewed growth by the rising temperatures. Becoming buoyant again, it rises to the surface and expands into a new shoot, which repeats the cycle of its precursor of the previous year.

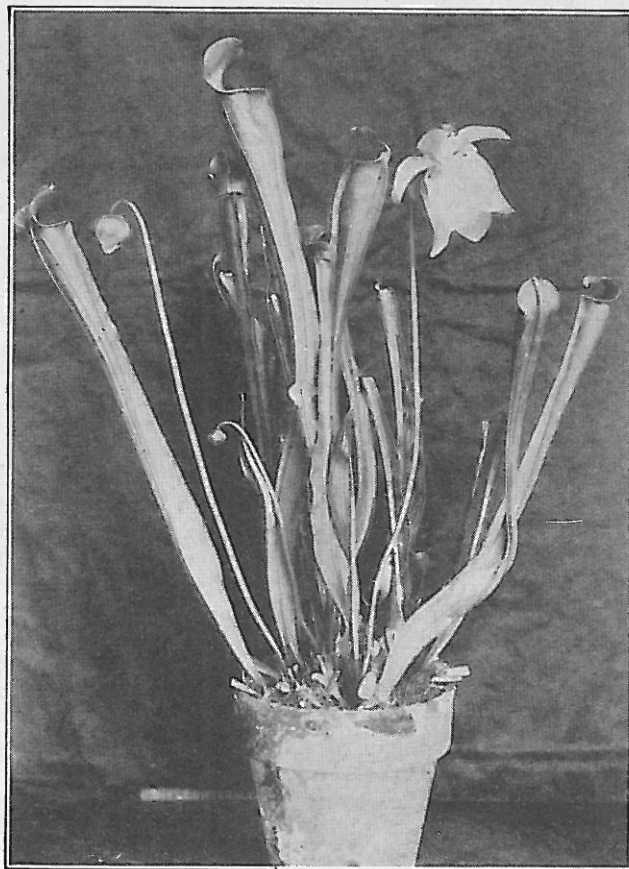
The bladders, which are the traps of the plant, are borne upon the richly branched leaves. In warm weather these leaves become very long, and during the height of the summer over a hundred bladders have been counted upon a single

leaf; but this is a rather unusual number, and only a dozen or so are more commonly found.

The accompanying figures should convey an adequate idea of their form; their length is about one eighth of an inch. The transparency of the light green walls, which are only two cells in thickness, gives the bladders an appearance of delicacy. The long, much branched appendages, which spring from either corner of the mouth, were termed "antennae" by Darwin, from their resemblance to the antennae of a small crustacean. These and the slender bristles below them probably serve to guide the prey to the entrance.

THE valve, or door which gives access to the interior, which is situated at the end opposite the stalk, is roughly semicircular in outline, and is attached by its curved upper margin. The free margin rests upon a thickened pad or sill in such a manner that the valve may be pushed inward but not outward. The surface which faces outward is strongly convex, and bears, near its free margin at the middle, four bristles, two long and two short. Stalked glands, which secrete a mucilaginous substance, are numerous on the valve and on the sill.

Turning to the inside of the bladder, we find that its walls are studded with numerous four-armed hairs arranged at regular intervals. We have not



INSECT PITFALLS

Sarracenia Catesbaei, a pitcher plant from our southern states. The pitchers are deadly pitfalls for many insects

mentioned nearly all of the bewildering variety of appendages of the bladder, but for our present purposes these will be sufficient.

The trap-like construction of the bladder is obvious. A small aquatic animal, pushing against the valve from the outside, may force it inward and so enter the bladder, but once within it cannot retrace its path, for to press against the valve from the inside results only in forcing it more firmly against the sill. Apparently it is all as simple as the principle of the cage rat trap, which no one but the rat finds it difficult to understand.

But why should the animal enter the bladder, since no living creature voluntarily immolates itself? The rat enters the trap for the cheese, but is there anything desirable within the tightly sealed bladder which is sensed by the animal on the outside, and stimulates it to force its entry? This is a problem which has interested botanists ever since, in 1858, the Crouan brothers, pharmacists and amateur botanists of Brest in France, communicated to the scientific world their discovery that the bladders often contain imprisoned animalcules.

CHARLES DARWIN was the first and greatest biologist to consider seriously how and why the animals which are entrapped in such large numbers enter the bladders. In spite of long and painstaking observations, which he describes in detail in his great work "Insectivorous Plants," he failed to arrive at a satisfactory explanation. He suggested that the animals might be attracted to the bladder to feed on the mucilage abundantly secreted by the many glands surrounding the orifice, and might even "habitually seek to intrude themselves into every small cavity, in search of food or protection," but he ends with the unsatisfactory conclusion that "animals enter merely by forcing their way through the slit-like orifice, their heads serving as a wedge." And in the years which followed, many other able botanists endeavored to penetrate the mystery of the bladderwort, with results equally inconclusive.

Then, about 20 years ago, the Swiss entomologist Frank Brocher became dissatisfied with the generally accepted theory of Darwin. He believed that no one had followed in sufficient detail the entry of an animal into the bladder, and determined to do this for himself. He pushed about small crustacea, injured so that they

could not too readily swim away, upon the upturned surface of the valve, and followed the results with a microscope. In a few cases they suddenly disappeared, to be found later inside the bladder. Next he tried shooting small crustacea against the valve from a fine pipette, usually with no interesting result. Once, however, the animal disappeared inside the bladder, and with it went a bubble of air to which it had become attached while within the pipette. This minute bubble of air was the revealing evidence which unlocked the whole mystery! It told Brocher that the bladder

The secret of the bladderwort once having been penetrated, it was destined to be revealed thrice again before it should become general information. In the year 1916, the late Dr. C. L. Withycombe, then a boy of 18, noticed while observing the bladders with a hand lens that they expand actively on engulfing their prey. This was in England, but in India in the same year another naturalist made the discovery for himself under quite different circumstances.

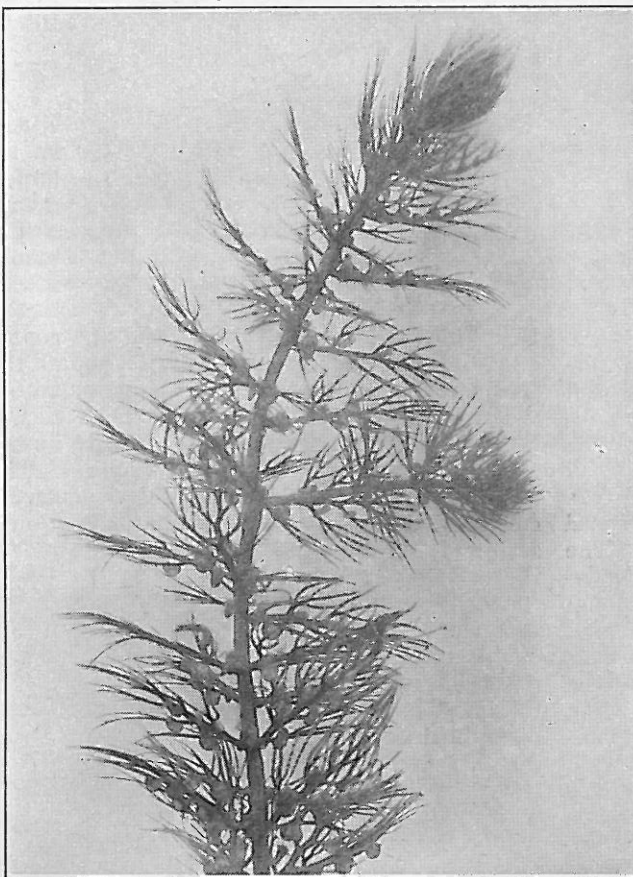
While distributing for class study specimens of an Indian bladderwort with very large bladders, the botanist T. Ekambaram was attracted by crackling sounds, somewhat resembling the ticking of a watch, which he heard as he lifted each spray from the water. He was able to satisfy himself that the sound emanated from the bladders, which expanded suddenly and sucked in air as they were drawn through the surface film of the water, and he recognized that this almost explosive dilation was their method of capturing prey.

FINALLY, in 1925, Professor R. W. Hegner, of Johns Hopkins University, who was studying the fate of minute protozoa entrapped within the bladders, incidentally made the discovery that the bladders capture their prey by suction. Thus the secret guarded so long was revealed on four separate occasions by four different workers in as many different countries, none of whom was at the time of his discovery familiar with the work of the others.

These observations told us how the victims are sucked into their green charnels, but the answer to this question only raised another: How does this rapid expansion come

about? What is its mechanism? To make the complete discovery of the secret of the bladderwort a thoroughly international affair, as all good science is, it happens that we owe our explanation of how the snares work to the recent labors of two German botanists, Edmund M. Merl and A. T. Czaja. It is evident from their studies that the release of the set trap is not, like the folding together of the leaf of the Venus's fly-trap, connected with a specialized, sensitive motor organ, but is as purely a mechanical process as the springing of a mouse trap. Let us choose a bladder which has just expanded and follow its subsequent behavior.

After the entry of the first victim, the valve, in virtue of its outward



BLADDERWORT—LATE SUMMER

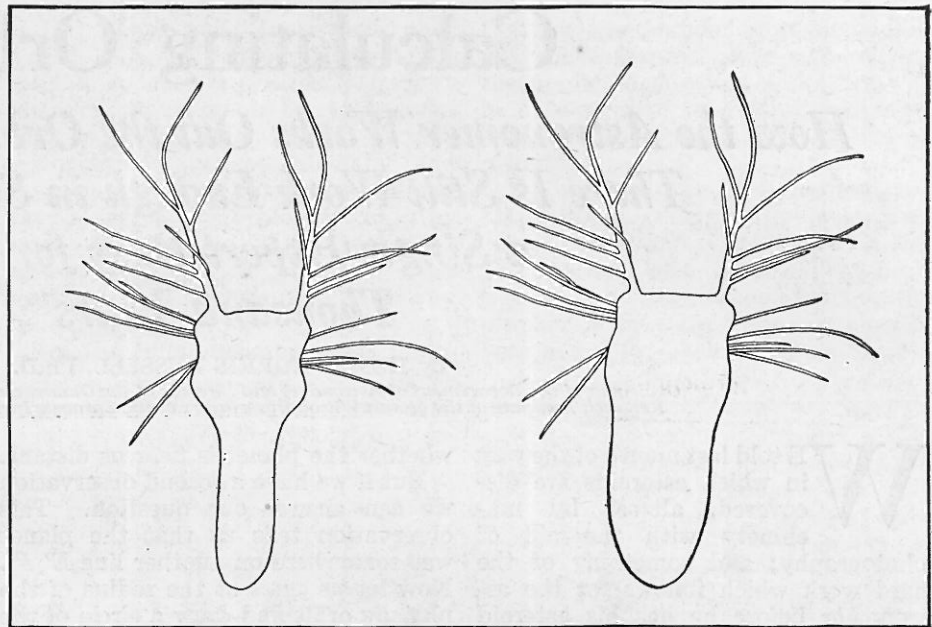
The bladderworts have no roots but they have flowers and they mature seeds. The plants' whole life cycle is unusual

expands as it captures its tiny prey.

Following this clue, he was able to observe that the bladder becomes suddenly distended when one touches with a needle the valve or one of the four bristles which it bears. The same thing would of course occur if the valve or its bristles were disturbed by the impact of a small animal. In expanding, the bladder sucks in a current of water, which carries with it the small creature which made the unfortunate collision. So the bladder is a suction trap, and draws in its prey exactly as the biologist picks up a small swimming organism by releasing the pressure on the bulb of his pipette at the proper moment, or as one fills a medicine dropper, or even his fountain pen.

convexity, springs forward against the sill, where it forms a tight seal because of the thick, slimy covering. The four armed hairs studding the inner wall continue to absorb water from the cavity of the bladder, and this is by some unknown method conveyed outside the plant. Since the tight seal makes it impossible for more water to enter, the side walls are slowly forced together by the pressure of the atmosphere and the overlying water, just as the cheeks are forced against the teeth when one closes his lips tightly and sucks the air from his mouth. The sides of the bladder are elastic and tend to expand, which would draw in the valve and admit more water if the outward curvature of the former, intensified by the pinching of the indrawn walls, did not resist the excess pressure on the exterior.

IF now, 20 or 30 minutes after the snare made its previous capture, a small swimming creature impinges against the valve or its bristles, the whole unstable system is upset. The shock breaks the seal, and now the walls are able to relieve their strain by drawing in a current of water through the aperture, and the ill-omened creature which sprung the trap is carried along by this current. Let us return to our former example of the medicine dropper. We squeeze the bulb and then, putting a finger over the end of the glass tube, release the bulb. The latter remains compressed and corresponds to the set bladder; what happens when we remove the finger from the tube is precisely what occurs when a water animal breaks the seal of the bladder. The whole process occurs in the winking of an eye; one instant the animalcule is swimming against the bladder, the next it is beating against the prison walls in vain search of an



BEFORE AND AFTER SPRINGING THE TRAP

The bladder on the left is set. That on the right has been sprung by the touch of a needle. Sprung bladders contain 75 per cent more water than set bladders. Note difference in size.

avenue of escape from its death cell.

Once inside, the animal dies, but often not until after it has been several days a prisoner. It is slowly digested by a very weak digestive ferment, and its substance is absorbed by the four-armed hairs.

The same bladder may be sprung repeatedly, and resets itself each time in from 20 to 30 minutes, even while digesting its latest booty. Set bladders may be distinguished from sprung bladders by the empty appearance of the former and the full appearance of the latter.

If a hole is punched in the wall by a needle, or if a fine hair is inserted between the valve and the sill, so that water can enter freely, the bladder naturally can not become set again, but remains permanently distended. Cold and excessive heat and moderate amounts of poison may prevent the

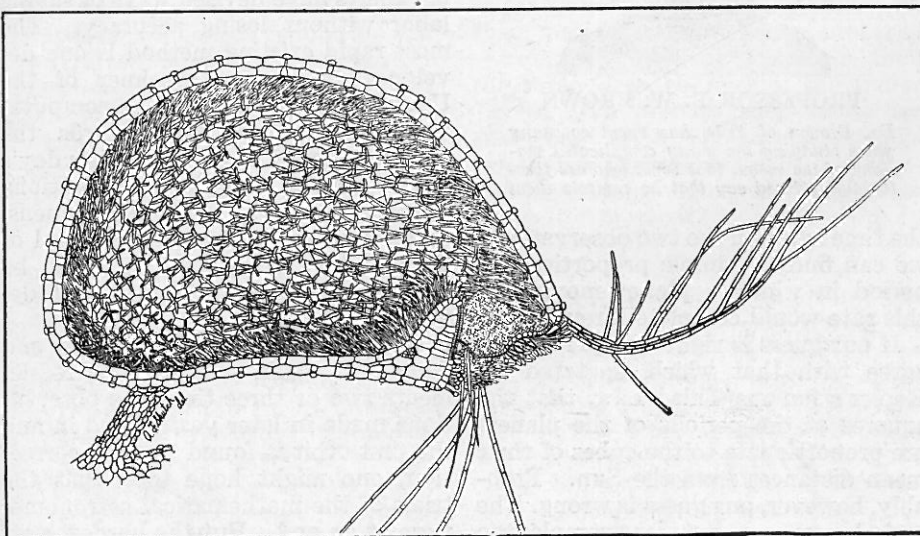
resetting of a sprung bladder, but do not prevent the springing of a set bladder, and this is considered sufficient proof that the springing of the trap is a purely mechanical process, although the setting of course involves the activity of living cells in absorbing water from the cavity.

THE prey of the bladderwort may include almost any of the animalcules which swim about in its native pond or ditch, and are at the same time small enough to pass through the orifice of the bladder.

Various small crustaceans, wheel-animalcules, eel-worms and infusorians constitute the most frequent prey. Mosquito larvae are often caught, and there are records of the capture of wrigglers which were so much longer than the bladder that they could get inside only by coiling up.

Occasionally a vertebrate falls prey to the carnivorous plant. There is extant a picture of several tadpoles being swallowed head first by as many bladders, and we have an isolated record of a school of newly-hatched roach fish which had an unfortunate encounter with the bladderwort. Some of the small fry were held prisoner by the head or tail, others by the still-attached yolk sac—surely a bizarre sight!

The number of animals held prisoner by a single plant at one time may be enormous. A large plant of the greater bladderwort with a combined length of main stem and branches of seven feet, bore approximately 14,000 bladders. The number of small crustacea in each of ten bladders ranged from six to 22, and it was estimated that the entire plant contained about 150,000 of these animals, in addition to numerous creatures of other kinds.



A BLADDER WITH ONE SIDE CUT AWAY

This makes clear the peculiar structure of the valve at the right; also the four-armed hairs which line the inner wall. Once caught, the insect is digested by secretions from the bladder.