Animal Adaptations

The ocean depths and shores provide homes to an array of creatures with a variety of shapes and sizes that adapt each creature to a different habitat, a different way of catching food and a different mode of protection.

The colorful and diverse sea life has caught the fancy of writers, poets and musicians. But in science we look at the hows and whys of these adaptations. We examine the mathematics of speed in water and the complexities of the surface/volume relationships. And yet we remain full of wonder for the marvelous intricacy of the organisms and their suitability to their environments.
ACTIVITY 1
Plankton, Nekton and Benthos—
Their Underwater Environment

Purpose
To investigate absorption as a nutritional technique in marine organisms.

Background
Marine creatures come in different sizes and shapes, but all must adapt to flowing water. Before examining the principles of fluid flow and how it affects marine organisms, you should become familiar with fundamental aspects of life in the ocean.

The ocean can be divided roughly into three basic habitats: planktonic, nektonic and benthic. Organisms that drift passively in water are called plankton. (See Figure 1. Copy and use as overhead transparency.) Many can swim but not strongly enough to go against currents and tides. Most plankton are very small (microscopic), but some can be large. For example, a jellyfish may be several feet in diameter, a diatom, only a few microns across. Plankton float in the surface layers of the ocean where light and food are relatively abundant. It is important that they do not sink into the deeper waters.

Figure 1 Some examples of plankton

diatom
dinoflagellate
crustacean copepod jelllyfish medusa
crustacean zoa larva
Organisms that move independently of currents and are capable of long migrations are called "nekton" (Figure 2). These include fish, whales, sharks, squids and turtles. Nekton are usually large and built for rapid, efficient swimming. They must be able to locate and capture food.

Organisms that live along the ocean bottom are called "benthos" (Figure 3). Some crawl along the sea floor; some burrow into it; and some live permanently attached to it. Benthic animals depend on food falling from the waters above them or being transported in water flowing along the bottom. Examples of benthic animals are starfish, sea anemones, corals and clams.

Animals that live in these habitats use three methods of feeding: absorbing, filtering and grabbing.

Absorbing is the most common method by which plankton obtain food. The one-celled creatures use simple diffusion and osmosis to draw nutrients from the seawater (example: diatoms).

Because seawater is often filled with plankton and other organic matter, many organisms filter their food from the water by pumping it over gills, mucus nets or other sieve-like structures (example: clams).

Grabbing is a familiar predation mechanism that occurs when one organism attacks and eats another organism. This is an active response rather than a passive one like filtering. The predator may have complex sensory organs to stalk its prey. It needs teeth, suckers or stingers to capture and eat it. Examples of animals that use this method are sharks, tuna and octopuses.

These three feeding methods and habitat affect, to a large degree, the size and shape of marine organisms.

Figure 2 Nekton

Figure 3 Benthos
Basic principles of fluid flow

Because all marine life must cope with movement of water around them, it is important to understand some basic ways that scientists describe fluid flow. Here are some fundamentals:

All organisms live in a fluid, either liquid (water) or gas (air). When the fluid moves, it imposes forces on the organism that tend to carry the organism downstream. These forces are called drag. Underwater, drag does three things:

1. It helps organisms move downstream through a fluid (plankton and nekton).
2. It dislodges or breaks organisms that live attached to things (benthos).
3. It slows down organisms trying to swim fast (nekton).

Most organisms in the sea depend on moving water to bring them food and oxygen. Therefore, marine organisms reach a compromise between the benefits of moving water and the disadvantages of drag.

There are several types of drag:

Laminar is a slow, smooth flow of water (Figure 4). No mixing occurs between layers of water. The drag is due to viscosity, which is the tendency of water molecules to stick together.

Form drag is a faster flow of water, and it causes a wake behind the organism (Figure 5). It also creates a boundary layer. This is a thin layer of slowly moving water next to a surface. It’s caused by viscosity.

Turbulent drag is a very fast flow of fluid (Figure 7). It causes the boundary layer to become turbulent.

The wake you see in form drag is caused by a combination of the boundary layer and “the Bernoulli effect.” This occurs when fluid flows around a round or oval object (Figure 6). It has to slow down to round the curve. When the fluid slows down, the pressure caused by moving water decreases. The change in pressure actually stops the water in the boundary layer, sometimes moving it backwards. This creates the wake at the back of the organism and a mixing of water layers.

“Reynold’s number” describes the viscosity of water in relation to the size of an organism. A small organism has a low Reynold’s number. That means the water seems thick (like butterscotch) when the organism is very small. A large organism has a high Reynold’s number. To a large creature, water seems thin, like air.

At low Reynold’s numbers, drag due to skin friction is not significantly affected by the shape of the organism. But at high Reynold’s numbers, any size, shape or orientation that reduces the size of the wake caused by the organism reduces drag.
Background

Plankton Size

Plankton come in a wide range of sizes, but a significant portion are very tiny, from one micron to one centimeter. One advantage of this is their small surface area to volume ratio. Most tiny one-celled plankton use absorption as a feeding method. This is handy because they don’t need any special food gathering apparatus. But this method also restricts their size. For example, look at the two cubes in Figure 8.

Figure 8 Two cubes

Cube A

1 cm

10 cm

Cube B

Determine its volume by multiplying

1 cm \times 1 cm \times 1 cm = \_\_\_\_cm^3.

Determine its surface area by multiplying

1 \, cm \times 1 \, cm = \_\_\_\_\_cm^2 \text{ (area of 1 side)}

1 \, cm^2 \times 6 \, sides = \_\_\_\_\_\_cm^2 \text{ (total surface area)}

Now determine the surface area to volume ratio for this cube:

Surface Area: \_\_\_\_\_

Volume: \_\_\_\_\_

If Cube A were a planktonic animal, it would have six units of surface to absorb food. Yet it has only one unit of internal space to feed. With six times as much food gathering capacity as body to feed, this creature will never have difficulty feeding itself as long as food is abundant in the surrounding water.

Cube B is 10 centimeters on all sides. Determine its volume by multiplying

10 \, cm \times 10 \, cm \times 10 \, cm = \_\_\_\_\_\_cm^3.

Determine its surface area by multiplying

10 \, cm \times 10 \, cm = \_\_\_\_\_\_\_cm^2 \text{ (area of 1 side)}

100 \, cm^2 \times 6 \, sides = \_\_\_\_\_\_\_\_\_\_cm^2 \text{ (total surface area)}

Write the surface area to volume ratio for this cube:

Surface Area: \_\_\_\_

Volume: \_\_\_\_

If Cube B were a planktonic animal, it would only have 6 units of surface through which to absorb food to feed one unit internal space. This organism would die of starvation.

This example shows that if an organism relies on absorption for food, it cannot be large. This explains why most plankton are so small.

Another reason has to do with sinking. Plankton survive best in the upper, lighted layers of the ocean. There, the sun’s light is used for photosynthesis, and organic matter is formed. To sink below this area means almost certain death. But the plankton’s small size slows sinking. Too tiny plankton, the water is as thick as butterscotch. But to a large creature, the water is almost as thin as air.

Plankton Shape

Shape can play a big role in an organism’s rate of sinking. Notice the shape of some of the plankton in Figures 1 and 2. Note the long, feathery appendages and ornate spiny skeletons. By increasing surface area, plankton not only increase their food absorption but keep themselves from sinking too fast.

Examine Figure 9. In a liquid (or gas), if you drop a penny and a feather at the same time, the penny will fall faster. This is because a penny has less surface area for its volume. This makes it more dense and less resistant to sinking. However, the feather has more surface area than volume. It pushes on more liquid as it goes down, giving it more resistance to sinking.

In a vacuum where no liquid or gas is present, a penny and a feather would fall at the same rate. There is no substance to provide resistance.

Figure 9 Sinking objects

Cylinders A and B A feather and a penny dropped at the same time in air.

Cylinders A and B A feather and a penny dropped at the same time in a vacuum.
Nekton Size

If you were a scuba diver exploring the middle of the Atlantic Ocean, you would probably encounter several schools of large fish (tuna), and an occasional shark, whale or dolphin. What do all these animals have in common? They are all large and have basically the same shape.

Look at Figure 5 and note the size of most nekton in comparison to plankton and benthos. Although the drawing is not to scale (plankton are actually much smaller), you can see that most nekton are large creatures. Size is a reflection of efficient food capturing.

The upper middle layers of the ocean are rich in plankton and nekton. Blue whales, for example, are the largest animals on earth (up to 100 feet long). They survive by filtering small “krill” from the water. In one day, they eat several tons of krill simply by traveling through the right area.

Whales and large tuna migrate to areas where food is seasonally abundant. Sharks, however, are efficient predators and do not need to migrate. They can detect blood and vibrations from long distances, and their sharp teeth are almost impossible to escape. These abilities allow sharks to home in on prey in their vicinity.

Nekton Shape

Virtually every marine organism that spends most of its time swimming has a streamlined, fish shape. Fish-shaped creatures reduce drag by decreasing turbulence at the back and creating lift in the middle (Figure 10).

Sharks have rigid fins on either side (like airplane wings) and an asymmetrical tail. These shapes help with lift. Although sharks do not have an internal swim bladder to keep them buoyant like other fish, their liver does assist in buoyancy.

This reduction of drag and increase of lift benefits fish in other ways. For example, the bluefish’s eye is located at the exact point where high pressure turns to low (Figure 11). It experiences neutral pressure. Therefore, the eyeball is not flattened by high pressure or sucked out by low pressure.

The heart also is located at a zone of minimum pressure so it can work more efficiently. Another way that drag reduction and increased lift help nekton can be seen in squid. A squid swims by jet propulsion. It takes water into its expandable mantle and shoots it out a siphon. Think of a balloon when you let go of the opening. It travels very quickly around the room. You blow air into a balloon, but how does a squid fill its mantle with water? It’s not muscular enough to do it on its own (Figure 12).

The low pressure in the middle allows the mantle to expand. The faster the squid swims, the lower the pressure and the more the mantle can hold. This enables the jet of water to become even more powerful and the squid to move even faster.

The speed of water as it flows around a fish slows in the middle as it goes over the hump. This reduces pressure, which creates a lift for the animal and allows it to swim even faster.

Figure 11 Drag reduction

The point of change in pressure

Figure 12 Drag reduction

Squid moves in this direction

siphon water pushed
Benthos Size

Organisms that live on the bottom of the ocean are often subjected to strong currents and other water movement because the greatest concentration of benthic life is along the shore where breaking waves and storms cause rapid flow of water. The forces of moving water often determine the size and shape of benthic organisms.

Organisms that are attached to the substrate can be subjected to forces generated by water slowing down as it travels over them. If the creature is asymmetrically shaped, water will flow faster around one side than the other and tend to pull the organism toward the slow side.

If the water slows down, speeds up or changes direction, it causes an acceleration reaction. This pushes the organism in the direction that the water is accelerating.

In constructing equations expressing the drag, lift and acceleration forces on an organism, you discover that the more volume and surface area an organism has, the stronger the forces. This explains why benthic organisms living in quiet, steady conditions are usually larger than those living in turbulent areas. The larger the creature, the more drag it must overcome.

Benthic Shape

Like fish, benthic creatures can use shape to reduce drag and benefit from water flow. Sea anemones live permanently attached to the sea floor. In California, great green anemones live in surge channels where waves crash and water rushes in and out. These anemones feed on mussels, sea urchins and other organisms knocked down by waves. Yet they remain undamaged by taking advantage of the boundary layer. They contract their bodies into a 1-inch tall pancake (Figure 13). This keeps them in the slow-moving layer of water near the bottom and away from the harsh drag and turbulence above. In more protected habitats, great green anemones are usually 3 inches tall.

Figure 13 Green anemones

Anemones can also minimize drag by keeping most of their surface parallel to the flow. The fluffy anemone has an umbrella crown of tentacles it uses to filter feed. When water flows slowly, the tentacles lean at right angles so the anemone can filter the most water (Figure 14). In faster moving water, this could be a high drag situation. But the anemone can alter its shape for fast water. The crown collapses like an inside-out umbrella to make the surface parallel to the flow.

Figure 14 Fluffy anemones

Benthic marine organisms can also reduce the effects of drag by reducing "stress" (force per unit of surface area). The size and shape of an organism determines the amount of stress it will experience from a given amount of drag. Stress is the force that causes tissue to stretch or break.

The tall, narrow fluffy anemone actually experiences 45 times more stress than short, fat green anemones. The green anemone has fewer units of area to be affected by the drag force.

Procedure

In this activity, you will create your own organism. You will try to design a drag-proof, sink-proof or stress-proof marine creature.

Draw an imaginary marine organism that is built to avoid the disadvantages of living in a fluid and takes advantage of some of the benefits (such as the reduction of drag and the increase in lift). Label each part of your creature, and explain the good and bad points of its construction. Include a description of its habitat and feeding method, and don’t forget the texture and strength, too.

If your teacher has planned it, use paper, staples, balloons, modeling clay, pencils or any other available materials to build your organism.
Worksheet

Draw and label your organism

Characteristics   Advantages   Disadvantages

1. Where does your organism live?

2. How does your organism move?

3. How and what does your organism eat?

4. How does your organism reproduce?


6. What color is your organism? How does it protect itself?

7. Is your organism plankton, nekton or benthos? Explain.

Questions

1. Which of the following phrases describes nektonic animals?
   a. very small, float in the surface layers of the ocean.
   b. ultimately dependent on food from the water above.
   c. live permanently attached to rocks.
   d. large and built for rapid, efficient swimming.

2. Which of the following organisms do not use filtering as a feeding mechanism?
   a. baleen whale
   b. clam
   c. tuna
   d. oyster

3. Absorption, rate of sinking and surface area to volume ratios are important for:
   a. plankton
   b. nekton
   c. sea anemones
   d. benthos

4. When you drop a penny and a feather in a vacuum, 
   a. the penny falls more slowly
   b. the feather falls more slowly
   c. they fall at the same speed
   d. the feather never falls

5. Whales, dolphins and fish have similar shapes because:
   a. they are closely related
   b. it keeps them from being seen by predators at the surface
   c. it enables them to dive deeper
   d. it reduces drag and takes advantage of the Bernoulli effect.

6. The larger the creature, the more ____________ it must overcome when it lives in a moving fluid.

7. When water flows over an object, there is a zone very close to the object where the water moves slowly. This is called the ____________

8. Water seems thin to:
   a. plankton
   b. nekton
   c. benthos

9. The forces that tend to carry an organism downstream are called ____________

10. A cube has a side length of 5 centimeters. Calculate its surface area to volume ratio. Why would this cube not be successful as a member of the plankton?

11. Below is a drawing of two anemones. Describe the conditions surrounding each based on what you can see in their size and shape.

   A.  
   B.
12. Copepods are little shrimp-like animals that live in the plankton of the ocean. They eat tiny creatures in the surrounding water by using long, feathery projections. These copepods are small enough that water seems thick to them. Knowing what you know about water, do you think that copepods use their arms as filters or as scoops? Can they capture tiny things that would normally fit through the spaces in their arms? Explain your answer.
ACTIVITY 2
What Shapes Mean Speed

Purpose
To learn about how a fish swims, how it feeds and where it lives by looking at its body parts.

Procedure
Read the introduction for Activity 1.
Study the fish parts in Figure 15. Make an educated guess at speed value (1–3) for fish body parts in Figure 16. Test your estimates by adding part values on the drawings of the real fish.

Figure 15 Fish body parts

Figure 16 Speed values for fish body parts

<table>
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<tr>
<th>Tail fin (a)</th>
<th>Middle fins (bc)</th>
<th>Body shape (d)</th>
<th>Put it all together</th>
<th>Fast score</th>
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<td>Use numbers from a, b, c, d to judge fish's speed</td>
<td>Total of a, b, c, d</td>
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Competency Factors/References

Competency Indicators

Biology—

2.45 explain the special roles that water plays in living systems as solvent, transport medium and essential component;

4.1.1 support with examples, the principle that an organism's activity, size and habitat determine the nature of its morphology and internal systems: and

4.1.8 describe examples of systems in multicellular organisms that provide support and movement.

References


