It Takes All Kinds

Below are suggested additions to the It Takes All Kinds (Lawrence Hall of Science MARE 1994) to incorporate information learned from Dr. Jensen's presentation and subsequent discussion. Components of the activity were adapted from A Fishy Twist on Adaptations (Duncan Wilson, San Celmente High School and the Woodrow Wilson National Fellowship Foundation).

Fish Adaptation Chart

EYES	PROTECTION
Large (feeds by sight)	Spines
Small (feeds off bottom, uses other senses to find food like barbels)	Bright colors (sometimes when poisonous)
On same side of the head (lives on bottom)	

Adaptation Questions (thinking about evolution)

Engage your students in a discussion about adaptations. Does the coloration of an animal affect its chances for survival? Do feeding mechanisms alter an organism's chance of living? How would an organism's reproductive strategy affect the individual? How would it affect the species? Throughout time, people have marveled at the great amount of diversity found in nature (there are roughly 30,000 species of fish known today). It is adaptations, however, that have led to this vast array of variation and which have resulted in the enormous variety among species. Adaptations can be classified as any feature that increases an organism's reproductive success (fitness) in its environment. In this activity, you will be studying the effects that an adaptation has on a fish's success in different habitats.

As they are looking at the different species, have them answer the following questions.

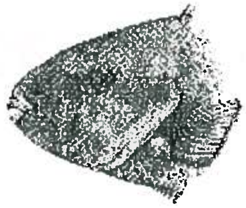
1. How do adaptations increase the likelihood for an animal's survival?
2. List and justify any adaptations that will limit the success of your fish in its habitat.
3. List and justify any adaptations that will enhance the success of your fish in its habitat.
4. Which adaptation is most important for the survival of the individual fish? Explain your reasoning.
5. Which adaptation is most important for the survival of your fish's species? Explain your reasoning.
6. What role do adaptations play in Darwin's Theory of Natural Selection? (Be specific)

Adaptation Cards

Consider passing out these cards to have your students think further about adaptations in jaw shape, body size, coloration, and reproductive strategies.

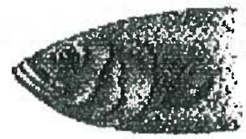
Beak-like mouth

Used to graze on small algae



Large mouth

Typically filter plankton by swimming
With their large mouths open.



Hermaphrodite

Able to fertilize their own eggs, usually breed
With one or more other individuals, ensuring
Fertilization between different individuals.
Found among deep-water fishes, an adaptation
To the depths of ocean where difficult to
Find members of opposite sex

Migrate to specific Breeding grounds

Come together during breeding season.
Many fishes change color to advertise their
Readiness to breed.

Internal fertilization

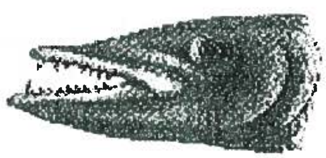
Fish generally have specialized reproductive
organs that allow male to deposit sperm
into the female during ritualized courtship

Broadcast spawners

Produce up to 100 million eggs each time it
Spawns– this insures that at least some hatch
and make it to adulthood. Often found fishes
living around coral reefs and other inshore
environments

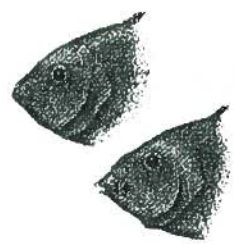
Large mouth/sharp teeth

Used to tear off chunks of prey



Protrusible mouth

Used to feed on relatively small prey



Jaw-shape

Jaw-shape

Reproductive behavior

Reproductive behavior

Reproductive behavior

Reproductive behavior

Jaw Shape

Jaw Shape

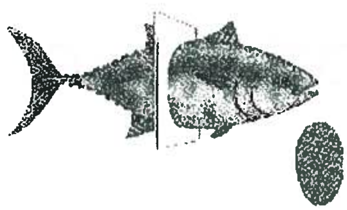
Warning Coloration
Brightly colored. Advertise that they are dangerous, poisonous, or taste bad

Cryptic Coloration
Blend with environment.
Can sometimes change coloration to match surroundings

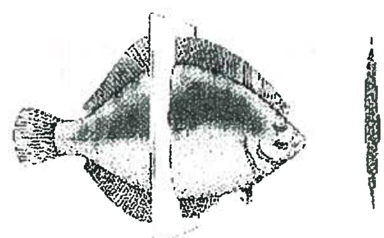
Disruptive Coloration
Presence of color stripes, bars, or spots that help to break up outline of a fish

Counter-shading
A form of disguise in open water.
When viewed from below-light belly blends with bright light from surface.
The dark back blends into ocean's color As seen from above

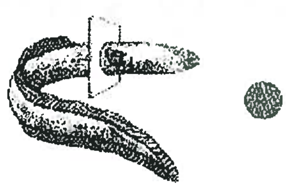
Streamlined
For fast swimming as in Tunas



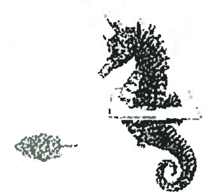
Flatfish
Often found in bottom dwellers



eel-like
common among fish that live in rocks or vegetation



Elongated on vertical plane
feature of a slow-swimmer



Coloration

Coloration

Coloration

Coloration

Body Shape

Body Shape

Body Shape

Body Shape

43
BONY FISH DIVERSITY: FISH MORPHOLOGY

To appreciate the diversity of marine bony fish, one needs to investigate the features that are common to most fish. The grouper, or sea bass, pictured here, is considered to be unspecialized, and has a basic fish morphology. In this plate, we will identify the major external body structures and introduce their function, and outline the internal support and muscle systems. In the next plate, we will explore the variety of body form and locomotion found in bony fish.

Begin by coloring the body of the sea bass in the two upper drawings. Color the external parts of the sea bass as they are mentioned.

The shape of the sea bass is fusiform—a streamlined shape offering the least resistance to movement through the water. The prominent fins are obvious in both the lateral and front view. The *caudal fin* usually provides the main thrust used in swimming. Also located in the midline are two unpaired fins, the *dorsal* and *anal fins*. These fins are used to stabilize the fish in the water and to lessen its tendency to pitch, especially while swimming slowly. They are also useful in preventing the fish from rolling over while turning at high speeds. The *pectoral fins* are located on the sides of the fish, behind the opening of the gill cavity, and *pelvic fins* are located ventrally, in front of the anal fin. These paired fins are used as stabilizers, but assist in turning and stopping as well. Fins are supported by fin rays of two types: bony pointed spines; and soft rays, which are jointed. The dorsal, anal, and pelvic fins have both spines and soft rays; the remaining fins consist of soft rays only.

In front of each pectoral fin is a large bony flap called the *operculum*, which covers the gill cavity that opens just behind it. Running the length of the fish, from the operculum to the base of the caudal fin, is the *lateral line*. The line consists of a series of very small canals that open to the surface and contain pressure-sensitive receptors. When the fish encounters movement in the water, such as the bow wave of an approaching fish, the water pressure pushes against the fish, entering the lateral line canals and triggering the pressure receptors. The lateral line, called the "sense of distant touch," is extremely sensitive and allows the fish to move in turbid water by "feeling" its way around obstacles, even when vision is greatly impaired. Other prominent external morphological features are the *eyes* (fish have fair vision), *nostrils*, and the bones of the *jaw*. Generally, fish have two nostrils on each side, which open to an olfactory pit and are used for scent, not for respiration.

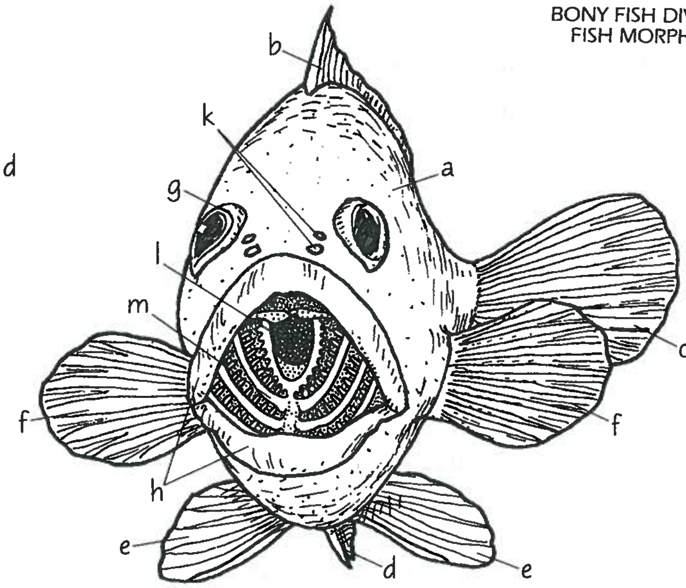
The shape, size, and position of the jaws vary considerably in different fish, and are related to the type of feeding. The sea bass is a generalist carnivore, feeding on a wide range of prey and has a large *mouth* that opens terminally (at the front). Inside the stout jaws of the sea bass is the folded opening of the *esophagus*, which leads to the gut. Adjacent to and in front of the esophagus are the *gills*, whose arched gill bars support the gill rakers, sometimes used in feeding, and gill filaments, which provide the respiratory surface (Plate 49).

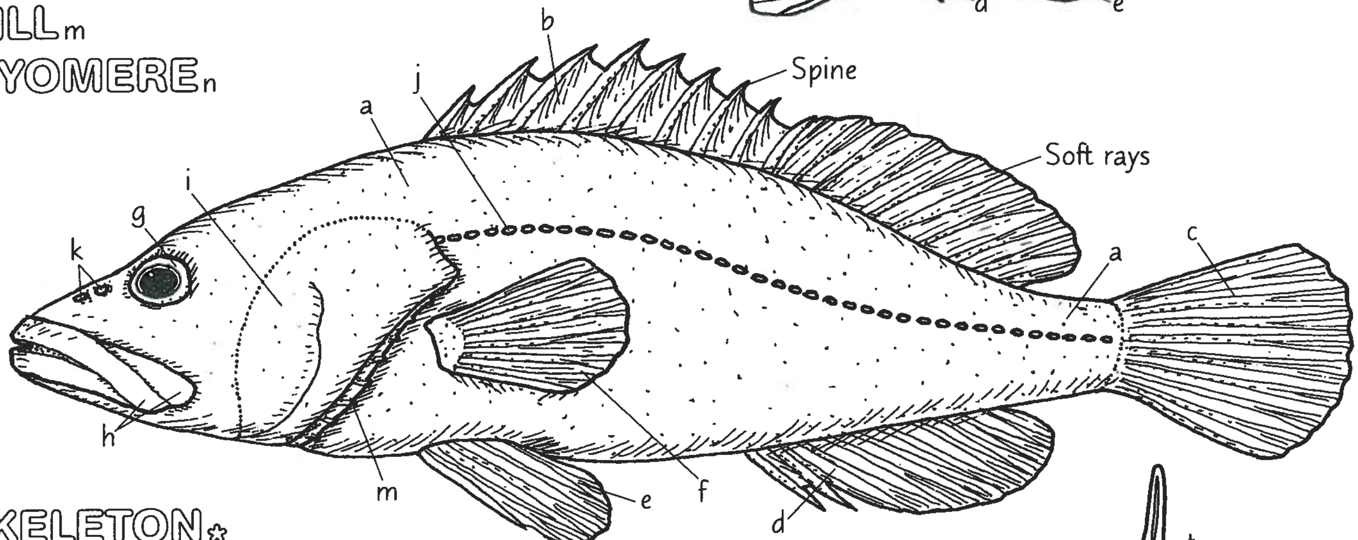
Now color the view showing the fish's skeleton. Note only a small region of the body musculature is illustrated. Color the fins the same colors as you used above. You may wish to color the pectoral and pelvic girdles with shades of the colors of their respective fins.

The bony fish's skeleton provides protection for the head and internal organs and support for the muscles. Prominent in the skeleton are the jaws, the fused bones of the *head*, the flat bones of the operculum, and the *supports* for the spinous and soft dorsal rays. The pectoral and pelvic fins are supported by girdles of bone, the *pectoral* and *pelvic girdles* respectively, that are anatomical homologues of our shoulders and hips. Also note the region just in front of the caudal fin known as the *caudal peduncle*, which is the pivoting point of the caudal fin. Notice how the vertebral column, or axial skeleton, is located towards the center of the fish instead of along the back as in ourselves and other terrestrial vertebrates. Because the fish lives in water, a buoyant medium, the skeleton does not have to support the body against the pull of gravity. Relieved of this chore, the axial skeleton is positioned more centrally to provide maximum support for the role of the trunk musculature in swimming (Plate 44). In the cross-sectional view of a single *vertebra*, the single *dorsal process* and articulated *ribs* show the sites of muscle attachment. The body musculature is organized into units called *myomeres*. The individual myomeres nest together like a series of stacked cones along the length of the fish.

FISH MORPHOLOGY

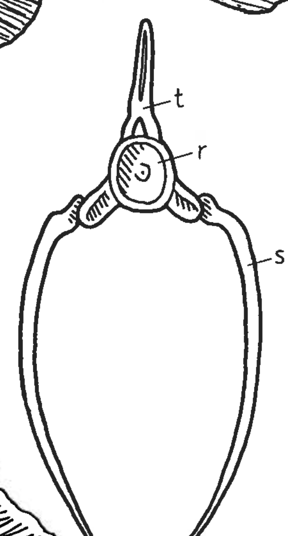
BODY a
FINS *
DORSAL b CAUDAL c ANAL d
PELVIC e PECTORAL f
EYE g
JAWS/MOUTH h
OPERCULUM i
LATERAL LINE j
NOSTRIL k
ESOPHAGUS l
GILL m
MYOMERE n

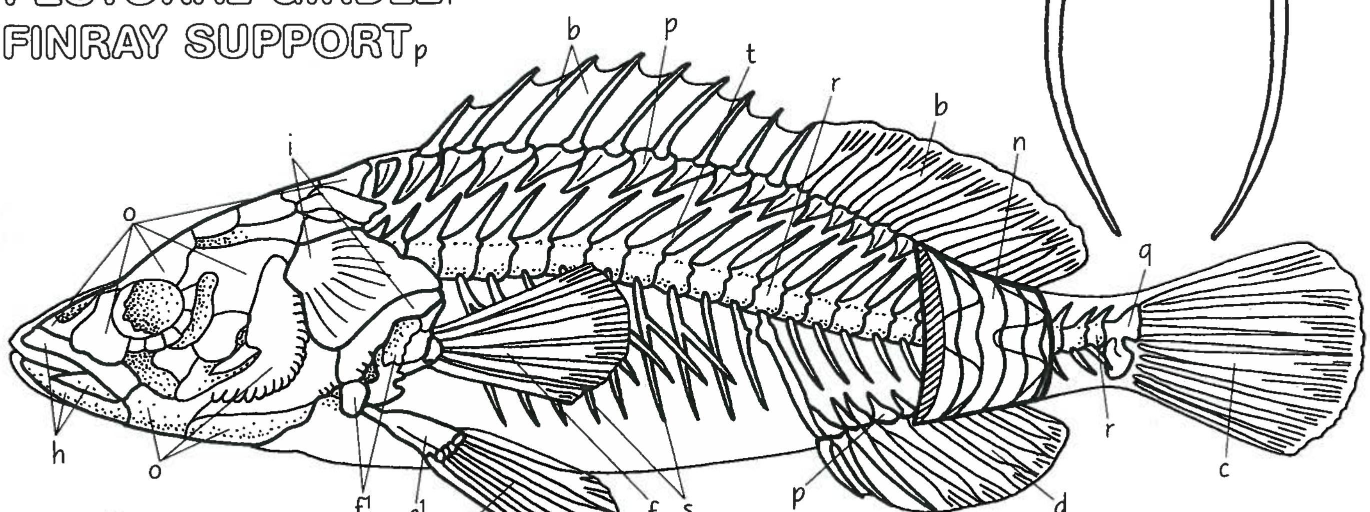




SKELETON *
JAW h HEAD o
OPERCULUM i
PELVIC GIRDLE e^1
PECTORAL GIRDLE f^1
FINRAY SUPPORT p

CAUDLE PEDUNCLE q
VERTEBRA r RIB s
DORSAL PROCESS t





44
BONY FISH DIVERSITY: LOCOMOTION

Moving through water requires more energy than moving through air. The forces of friction and drag resistance are much greater on a body moving through water. Also, as a fish moves, it displaces water that flows around the body. A streamlined body shape is required to improve this flow. The fusiform or tear-drop shape of the sea bass shown here represents an effective morphological compromise to meet these demands.

Color the illustration of the swimming sea bass at the top left, noting the flexing of the body and the resulting thrust forward. Note that the myomeres are exposed on either side of the curve in the fish's body. Those on the inside of the curve are contracted while those on the outside are relaxed and are being stretched. You may wish to color the fins the same colors as used in Plate 43. Color the small illustrations of the moray eel and tuna moving across a grid to show the body undulations.

Most fish swim by undulating their body so that the *caudal fin* is whipped very rapidly from side to side in a sculling motion resulting in a powerful forward *thrust*. Beginning at the head, there is a sequential contraction of blocks of *myomeres* along the length of the fish. These waves of contraction alternate on opposite sides of the fish causing the axial skeleton to flex, the body to undulate, and the caudal fin to pivot at the *caudal peduncle* and scull through the water. The degree of undulation varies among species and depends on the stiffness of the vertebral column and the connection between the myomeres. The extremes can be seen in the body movement of elongate fish like *moray eels,* which have serpentine undulations, compared to a *tuna* whose body remains very rigid with only the caudal fin undulating rapidly.

Now color the different types of caudal fins.

The caudal fin usually provides the main thrust used in swimming. The size and shape of the fin is an indicator of the fish's ability to move through the water. The sea bass has a *rounded* caudal fin that is soft and flexible, but it also has considerable surface area. This fin gives effective acceleration and maneuvering, but is inefficient for prolonged, continuous swimming as it creates too much drag which tires the fish. A *forked* caudal fin produces less drag, and is efficient for more rapid swimming. Long-distance, continuous swimmers such as the tuna have *lunate* caudal fins, which are rigid for high propulsive efficiency and have a relatively small surface area to reduce drag. However, the rigid fin is ineffective for maneuvering.

Color the illustrations of the tuna, barracuda, and butterflyfish, noting the differences in the body shape and caudal fin.

Not all fish are engaged in rapid, *continuous swimming* like the pelagic tunas whose sustained swimming speeds range from 8–16 km/h, 5–10 mph (Plate 45). A fish's unique lifestyle places other demands on its body form and locomotion abilities. A fish such as the barracuda that swims leisurely in wait, then runs down its prey (Plate 109), relies on quick *acceleration* and short bursts of rapid swimming provided by its elongate muscular body and large caudal fin. Barracudas have been estimated to accelerate to 80 km/h (50 mph) in pursuit of prey.

The butterflyfish (Plate 47) needs great dexterity and *maneuverability* to capture its small prey. The body is compressed (flattened laterally) and disc-shaped in outline. The *dorsal* and *anal fins* are large and run along most of the body, providing excellent control in turning. They can be rapidly flexed for quick acceleration should escape be necessary. The *pectoral* and *pelvic fins* are also very large and maneuverable.

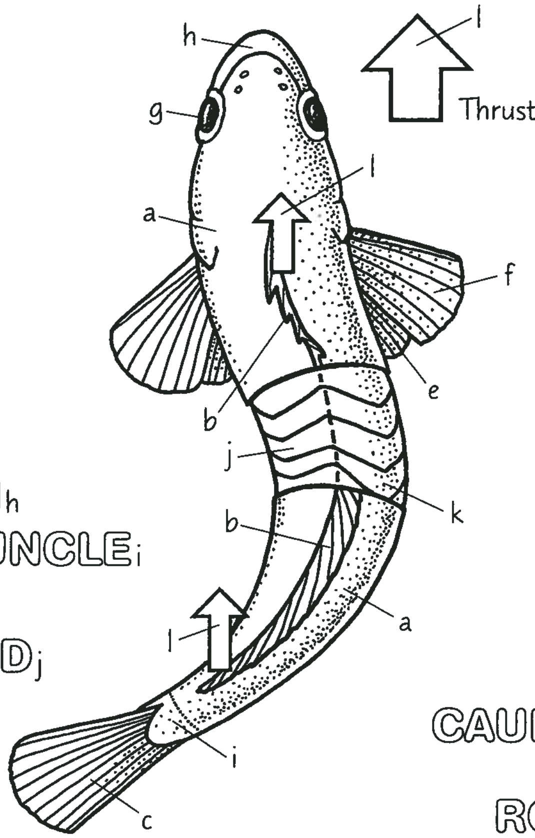
Finally, color the drawings illustrating different methods of propulsion. Color only the fins involved in propulsion.

Locomotion, in most fish, is a compromise among the demands for sustained swimming, quick bursts of acceleration, and maneuverability. Not all fish rely on the caudal fin for swimming propulsion. Electric fish swim by waves of undulations along the anal fin. Triggerfish use their dorsal and anal fins for locomotion. Sculpins and wrasses propel themselves using the sculling action of their pectoral fins. Seahorses and pipefish swim vertically, sculling through the water with their dorsal fins.

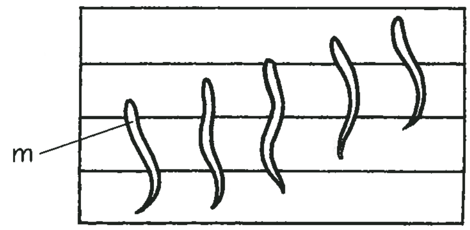
LOCOMOTION

SWIMMING*
- BODY$_{a}$
- FINS*
  - DORSAL$_{b}$
  - CAUDAL$_{c}$
  - ANAL$_{d}$
  - PELVIC$_{e}$
  - PECTORAL$_{f}$
- EYE$_{g}$
- JAWS/MOUTH$_{h}$
- CAUDAL PEDUNCLE$_{i}$
- MYOMERE*
  - CONTRACTED$_{j}$
  - RELAXED$_{k}$

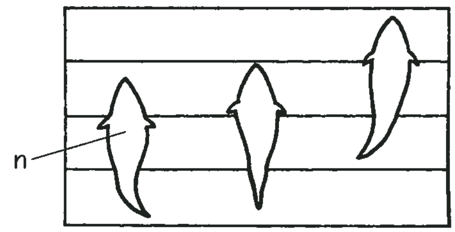
THRUST$_{l}$



MORAY EEL$_{m}$

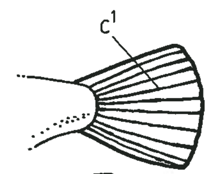


TUNA$_{n}$

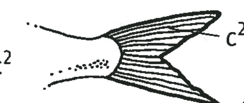


CAUDAL FINS*

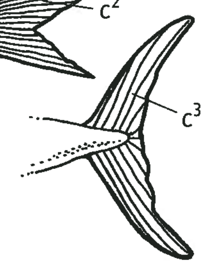
ROUNDED$_{c^1}$



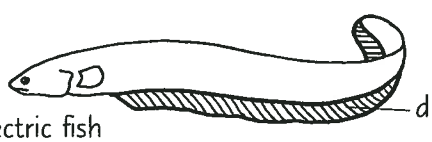
FORKED$_{c^2}$



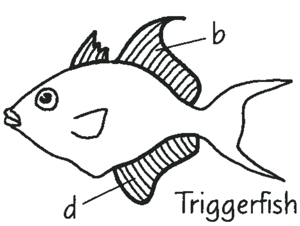
LUNATE$_{c^3}$



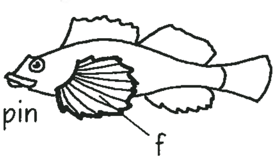
PROPULSION*



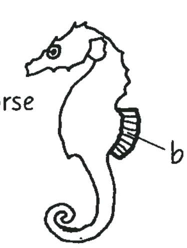
Electric fish



Triggerfish

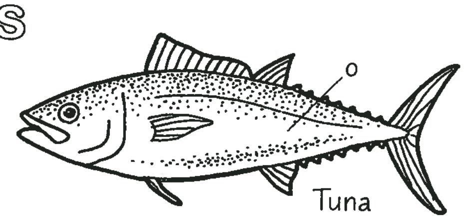


Sculpin



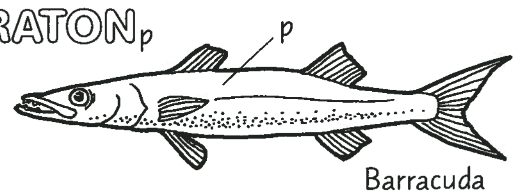
Seahorse

CONTINUOUS SWIMMING$_{o}$



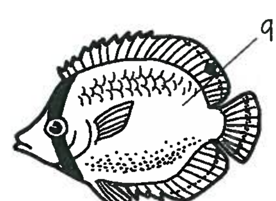
Tuna

ACCELERATON$_{p}$



Barracuda

MANEUVERABILITY$_{q}$



Butterflyfish

63
COLORATION IN FISH: THE ADVERTISERS

Coloration in fish (and in many other animals) serves a variety of important functions. These will be investigated in the following seven plates, which offer an opportunity to employ some of your brightest colors. This plate is concerned with fishes that call attention to themselves: that is, they advertise.

Color the garibaldi and lionfish. Color the entire garibaldi, including fins, a golden orange or golden yellow, also color the center portion of the traffic light on the fish's right. On the lionfish, color red the dotted, striped areas only. Don't be too concerned about accuracy in coloring the confusing pattern. Color the skull and cross-bones red.

One type of advertisement is seen in the bright, golden orange *garibaldi* of southern California. This fish uses solid, bright color to advertise its presence, warning other garibaldis not to encroach on its closely guarded territory. Male garibaldis most vigorously defend a small patch of red algae in the center of their territory. It is here that the females are enticed to lay the eggs which the male defends until they hatch (Plate 87). Many brightly colored reef fishes are thought to use their colors in this kind of territorial display.

Warning coloration also functions between species (interspecifically), as in the case of the golden boxfish in Plate 47. The butterfly *lionfish* of the tropical Pacific has showy red and white stripes on its body, pectoral fins, and highly venomous dorsal spines. The contrasting red and white colors give warning to predators, especially those that have felt the sting of those poisonous spines before. Interspecific advertisement is not always negative; one example being that of the cleaner wrasses (Plate 92), which advertise their availability with bright color patterns.

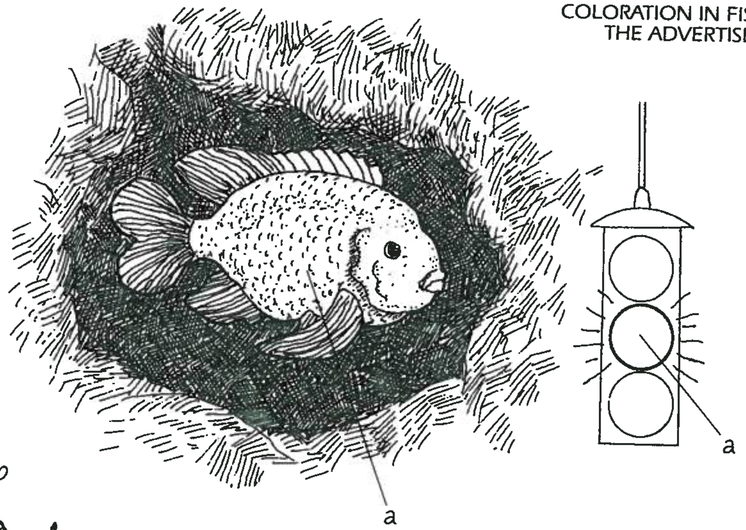
Now color the angelfish and the butterflyfish. The larger angelfish on the left receives a yellow color in the areas marked (c), as does the officer's insignia in the drawing on the right. The areas labeled (d) are given a bright blue color. For the juvenile angelfish, use bright blue (d) in the striped areas that are drawn in light lines. The heavily lined stripes are left blank. The remainder of the smaller fish is colored black. In the copperband butterflyfish, the stripes marked (e) receive a pink- or orange-tinted copper color. The well-advertised (but false) eye is colored black. Leave the rest of the fish uncolored. The false bottom of the bottle represents false advertising in that the apparent amount in the full bottle is not, in fact, the true amount.

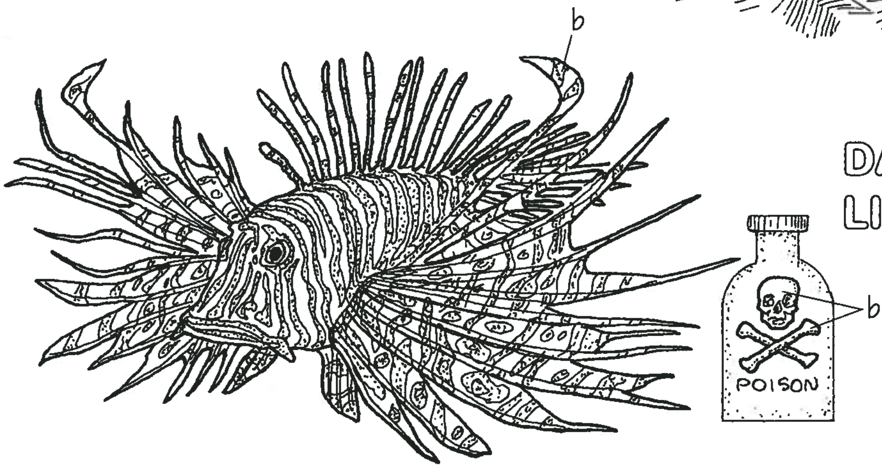
Coloration may also play a role in species recognition, especially when many closely related fish species are living near one another, such as on a Pacific coral reef. Many fish have a different color pattern in their juvenile phase, sometimes strikingly so. Illustrated here is the *Koran angelfish*, which as a juvenile is black with blue and white semicircles, and as an adult is light yellow with darker yellow spots and light blue on the fins and operculum. These distinct color patterns allow quick recognition and serve to clarify social behavior within a species. In many species of angelfish, the distinctive coloration of the adults facilitates a very tight bond between mated pairs, which are almost always seen swimming together, rarely out of sight of one another.

Coloration can make a fish appear to be something it isn't. Eye-bars, broad stripes, and other tricks are often employed in such "false advertising." The beautiful *copperband butterflyfish* possesses a black eyespot (ocelus) near its tail which potential predators mistake for an eye. The predator will "lead" its prey (just as a human hunter will lead a moving target) and plan its strike for the head, only to gobble empty water or a small piece of dorsal fin that the butterflyfish can regenerate. The eyespot trick is employed by several types of fish and appears throughout the animal kingdom in groups as diverse as moths and octopuses.

THE ADVERTISERS

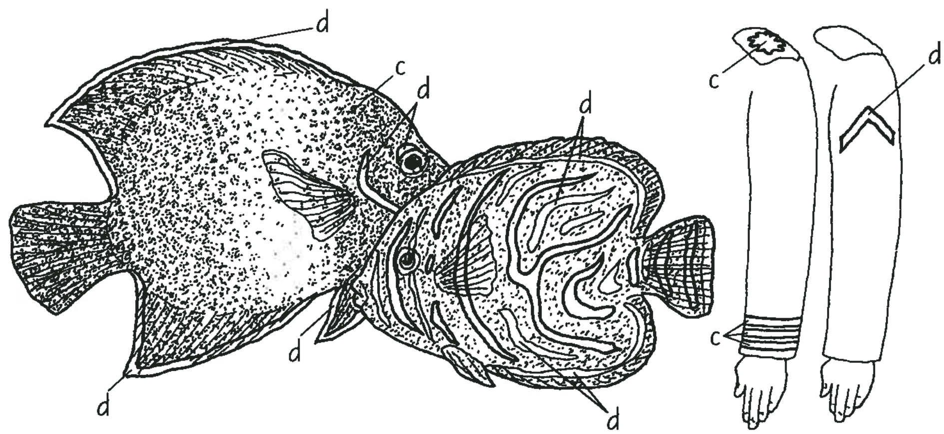
TERRITORIAL WARNING*
GARIBALDI a

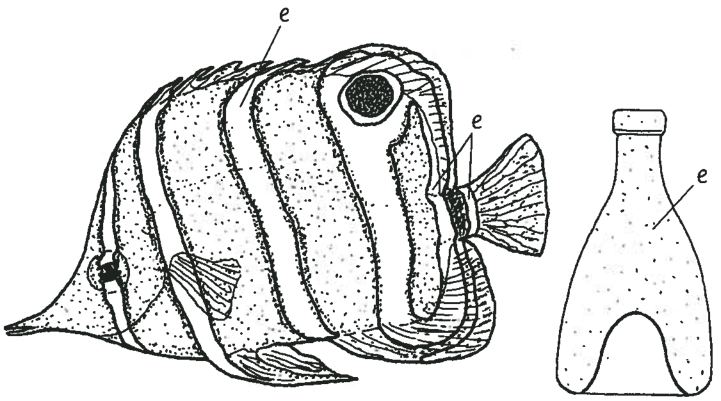




DANGER WARNING*
LIONFISH b

SOCIAL STATUS*
KORAN
ANGELFISH c, d





FALSE ADVERTISING*
COPPERBAND
BUTTERFLYFISH e

64
COLORATION IN FISH: THE CRYPTIC ONES

Color the countershading of the mackerel in the drawing at top right (above the rectangle) and the related title dark blue (a). Do not color its white or silvery underside. On the left, color the entire grouper and related title orange (b). Now color the rectangle representing sea water blue-green (d), but do not color the fish. Then color the top half of the grouper (above the dotted line) a light orange (b), or leave small areas within the colored area white. This is to suggest the lightening of the top half of the fish by light shining down from the surface. Color the bottom half solid orange (b), and then color over the bottom half with gray (c) to simulate the darkening of the bottom side that would be in shadow. Color the mackerel the same blue-green as the water on top (d), and shadow the bottom surface (c).

There are several modes of cryptic (hiding) coloration among fish. Many fish of the upper pelagic zone, such as the common mackerel of the North Atlantic seen here, have a coloration pattern known as obliterative countershading. These fish are green to blue-black on their dorsal surface and grade into a silver to almost white underneath. Viewed from above, they blend with the dark void below; seen from below they blend with the bright, sunlit surface water. Viewed from the side (upper illustration), it is apparent that the surface normally directed toward the light is *countershaded* by the dark color on the fish's back, while the ventral (belly) surface, which would normally be in shadow, is counterlighted. The sides have tones that grade between these colors. As a result, the fish is rendered optically flat and reduced in visibility. This type of countershading is employed not only by fish, but also by many birds, mammals, reptiles, and amphibians. Compare the mackerel's color pattern with that of the *non-countershaded* grouper (upper left). One can easily see how the grouper, which inhabits coral reefs, would stand out in open water.

Within the rectangle labeled "disruptive coloration," color the anemonefish (including fins) to the right, bright orange (b[1]), but do not color the two stripes on the body of the fish or the tubular coral surrounding it. On this grouper, to the left, color the dotted patches and stripes (e) brown and the body (f) tan or dull yellow. Color the coral marked (g) red, (h) pink, (e) brown, and (i) dull green. Color the sea water blue-green (d).

Another type of color pattern widely employed by fish is disruptive coloration. A familiar object is recognized by a specific contour or outline that shows an obvious surface continuity. The orange garibaldi against a dark bottom is a good example. Disruptive coloration conceals a particular recognizable form by employing contrasting colors in different-sized patches that effectively break up and distract from a recognizable outline, such as the camouflage employed on military equipment. Fish that live in a habitat with a high degree of surface relief, like a coral reef or a kelp forest, take advantage of its many shapes, shadows, and colors to blend into the background.

The grouper on the left has patches of color in irregular shapes and positions all over its body, including its fins and lips. Standing alone against a solid background it would be easily recognized. However, when the fish remains still against a highly colorful and irregular coral reef habitat, the shadows and light areas tend to blend with the fish's coloration, and it no longer presents a clear outline to the viewer. Furthermore, groupers are capable of quickly changing their color patterns and background colors to match the changes in lighting and habitat encountered as they swim.

The clown anemonefish also employs disruptive coloration. When seen against a solid background, the small fish's body, vivid orange with boldly contrasting white stripes, is clearly obvious. However, among the tubular coral and finger sponges of coral reefs, the broad white stripes blend with the background, effectively disrupting the outline of the fish and making it much less recognizable.

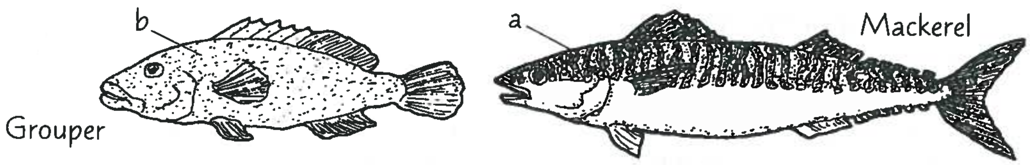
Color the stonefish in the middle of the bottom drawing brown (e) and the surrounding rocks (e[1]) brown with various red accents (g) that are surrounded by dark lines. Color the bottom (f) tan or dull yellow.

The deadly stonefish mimics and blends into its rocky background with the aid of its coloration. Its body is lumpy and unstreamlined to further conceal its motionless presence among the encrusted stones, from which it cannot be distinguished by humans or prey fish (aggressive mimicry). Like its relatives the lionfish and scorpionfish, this fish has extremely venomous spines; they have caused death to humans who inadvertently stepped on them while wading on shallow Pacific coral reefs.

THE CRYPTIC ONES

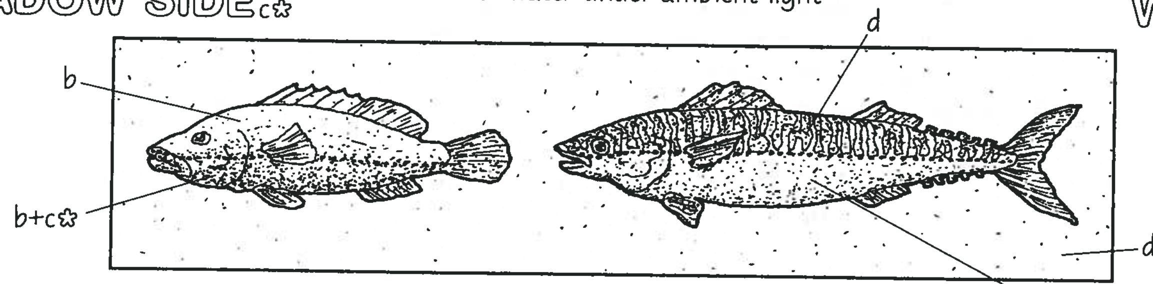
OBLITERATIVE COUNTERSHADING*

NON-COUNTERSHADED b
COUNTERSHADED a



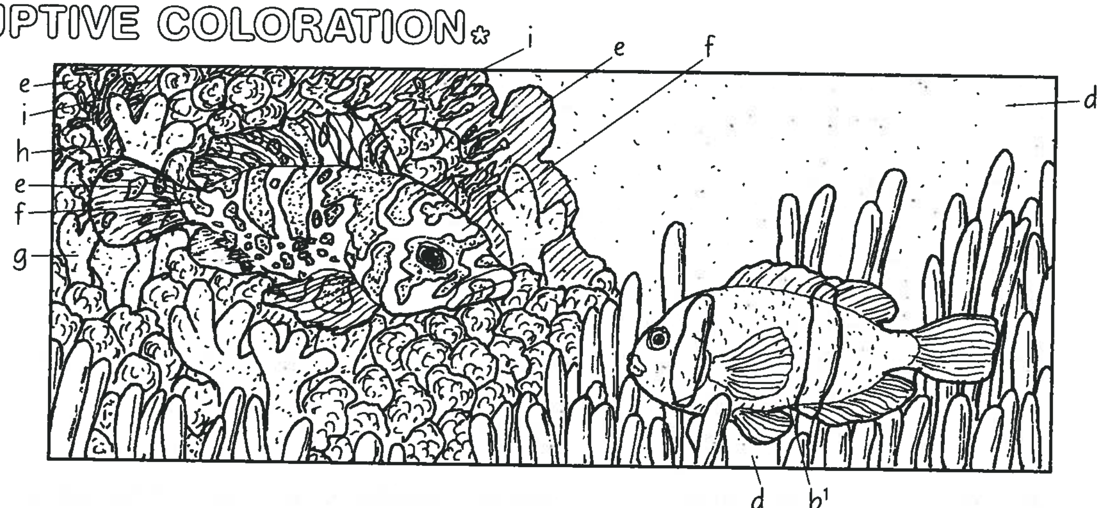
Out of water under ambient light

SHADOW SIDE c*
WATER d

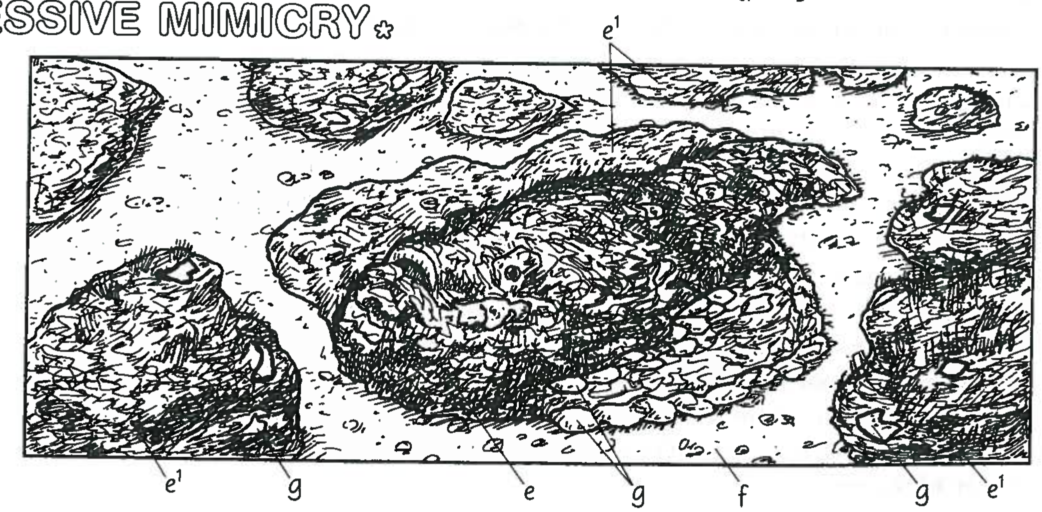


As seen in the water with light falling from above

DISRUPTIVE COLORATION*



AGGRESSIVE MIMICRY*



65
COLORATION IN FISH: CHANGING COLOR

This plate explores the source of color in fishes and how coloration can be changed in certain situations.

Begin at the bottom of the plate with the patches of skin. Both squares are of the same magnification and represent enlarged views of skin chromatophores. Choose pale yellow, tan, or light grey for the base skin color (a). Then use dots of color for the chromatophores as follows: (b) red, (c) orange, (d) yellow, and (e) black.

In the large illustration of the flatfish, begin with the left half, coloring the skin of the fish with (a) only. This is usually very close in color to that of the sandy bottom, which receives the same color. This base color is also the base color of the fish in the pebbly environment, and, since there is sand between the pebbles, color over the entire area with the base color first. Then use (b), (c), (d), or (e) in any combination you wish on both the fish and the pebbly substrate. To get the optimum effect, if you do not want to color the entire illustration, color small adjacent sections of each illustration completely. The pigmented areas in the fish on the sandy bottom are so highly concentrated that they cannot be seen.

Fishes take their color from two types of pigment cells that are located in various layers of the skin. One type of cell, the iridocyte (mirror cell) contains guanin, a substance that reflects light and color from the environment outside the fish. The iridocytes give rise to the pearly white color and the silvery, iridescent blues and greens often seen in fishes.

The *chromatophore* is a second type of color cell, which contains its own pigment particles of red, orange, yellow, and black. The cell body itself is highly branched and, in order for color to be seen, pigment granules must be dispersed throughout the branches (expanded pigment). When the pigment is concentrated in the center of the cell, very little color shows. Fishes can produce other than the pigment colors by activating a mixture of chromatophore types. Green, for example, can be obtained by combining black and yellow chromatophores.

Fishes change color depending on the color of their surroundings, the stage of their life cycle, or even a state of excitement. A startled fish will often blanch, the colors appearing to wash out of its skin as the pigment concentrates in the chromatophores. An angry fish may turn bright red as the pigment disperses in its red chromatophores. Some fishes change color pattern between night and daytime. A courting male fish may put on a "suit" of dazzling nuptial colors to attract a mate. Billfishes, making leaping "tail walks" when hooked, are observed "lighting up" in flashes of chromatophore color.

The best-studied color change in fishes deals with their response to surroundings. Surrounding colors may change due to variations in incoming and reflected light or because the fish moves from one habitat to another. Many fishes are able to assume the color of their background, and some are actually able to mimic its pattern. Flatfish are especially adept at this. As shown in the left drawing, the flatfish concentrates the pigments in its chromatophores, enabling it to blend with the sandy bottom. When it moves to a pebbly bottom, clusters of chromatophores expand their pigments to match the size of the pebbles encountered.

Some fishes change color with startling quickness, while others take minutes or even days. The color change is controlled by the nervous system or by the endocrine (hormonal) system. Rapid changes are controlled by direct neural impulses to the chromatophores, while slower changes are brought about by blood-borne pituitary hormones. Short-term changes in color involve the concentration and dispersion of pigment granules in established chromatophores. Long-term changes, such as those brought about by a permanent or lengthy change in surroundings, are the result of an increase or decrease in the number of chromatophores.

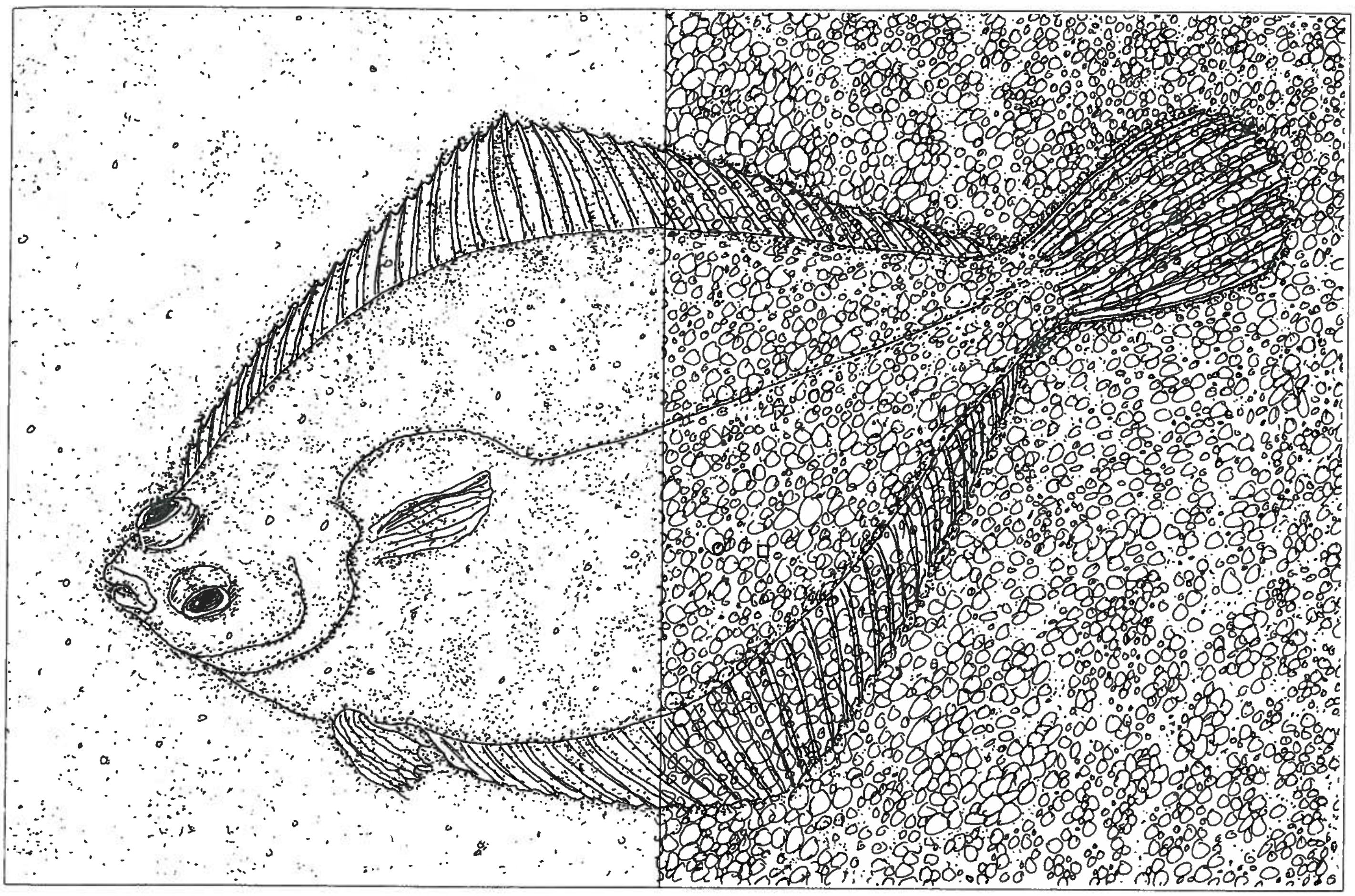
The ability to register and recognize mood, sexual readiness, or social status by color has allowed fishes to develop highly complex behavior patterns that are still only partly understood.

CHANGING COLOR

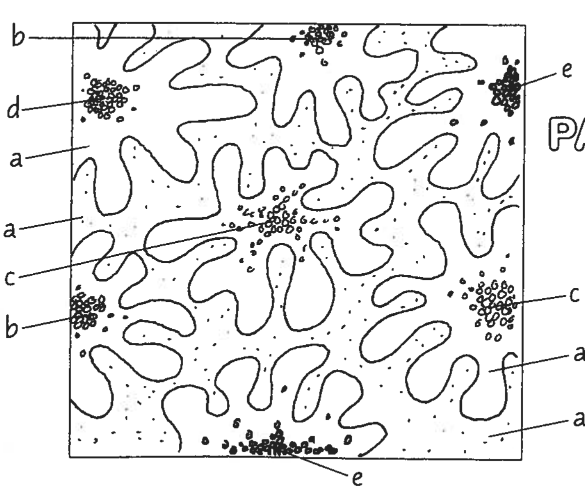
BASE COLOR OF SKIN a
CHROMATOPHORES b, c, d, e

SANDY BOTTOM a¹

PEBBLY BOTTOM b, c, d, e

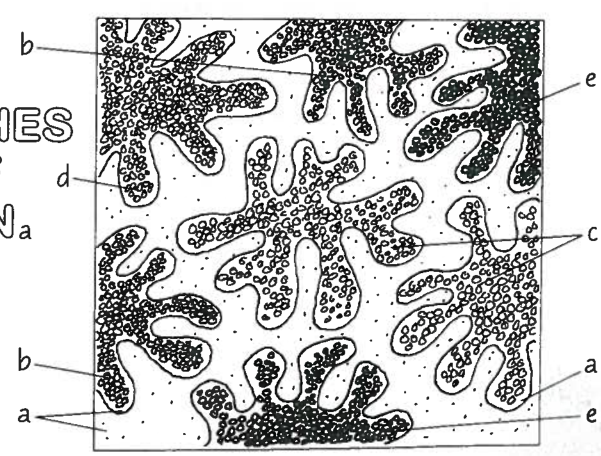


CONTRACTED PIGMENT *



PATCHES OF SKIN a

EXPANDED PIGMENT *



85
REPRODUCTION IN ELASMOBRANCHS: SHARKS AND SKATES

Begin by coloring the shark's pelvic fin and clasper; use the male color (c) for the body. Next, color the copulating (mating) spotted dogfish sharks.

Sharks, skates, and rays practice internal fertilization, which is a more efficient and less wasteful means of fertilization than releasing gametes into the environment. To accomplish the transfer of sperm, *male* elasmobranch fishes have special intromittent organs (transfer organs) called *claspers*. The upper drawing shows the clasper of a horn shark; the clasper is derived from the shark's *pelvic fin*. During copulation, the clasper is inserted into the *female's* genital opening, and the *spur* is erected to insure that the sharks stay coupled long enough for sperm transfer to occur. In spotted dogfish sharks, the male wraps his body around the female, inserts a clasper and transfers his sperm. In sharks that are less supple than the spotted dogfish, the male and female lie side by side. The male holds onto the female's pectoral fin, erects the clasper at a right angle to his body, and inserts it into the female.

Color the female skate and its egg case, embryo, and yolk sac. Note that in the drawing on the right, the embryo is large and well developed. Note also that only the intact egg cases are to be colored. Then color the female horn shark and its egg case.

Once the eggs have been fertilized within the female, one of three possible patterns of development occurs, depending on the species of fish. In one pattern, the fertilized eggs are packaged in a special *egg case* and released by the female to develop outside her body. In this situation, each egg is provided with a large amount of yolk to nourish the developing *embryo* during its growth. Skates employ this reproductive strategy that frees the female from prolonged maternal care. The illustration shows a female *skate* swimming away from her large (23 cm, 9 in) egg case, sometimes called a "mermaid's purse." Inside this egg case are one or several developing embryos. The two drawings of opened egg cases show the embryos increasing in size and their *yolk sacs* dwindling as the yolk is used for nourishment. Under normal conditions, the egg case gradually deteriorates and begins to fall apart as the young skate is ready to emerge and begin a life of its own.

Some sharks also produce an egg case, exemplified by the spiral egg case of the *horn shark* shown here. The young sharks emerge from this case when they are about 12 cm (4.7 in) long and appear as miniature adults.

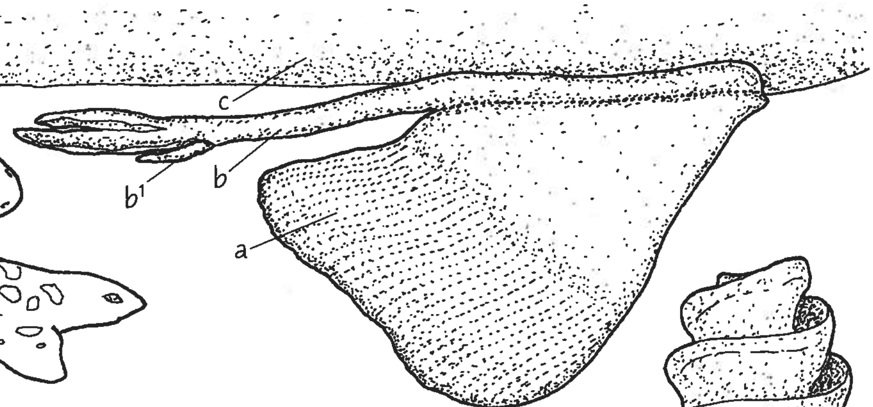
A second developmental pattern seen in elasmobranchs is the retention of developing fertilized eggs inside the female's reproductive tract (not shown). Upon completing their development, the young are released as fully formed juveniles. This type of development is known as ovoviviparity (ovo: egg, viviparity: live birth). These eggs are also provided with a yolk sac that serves as their source of nourishment; the female is simply protecting the embryos within her body.

Now color the embryonic shark within the mother's uterus. Note that the "placenta" and "umbilical cord" receive shades of the same color as the yolk sac from which they derived.

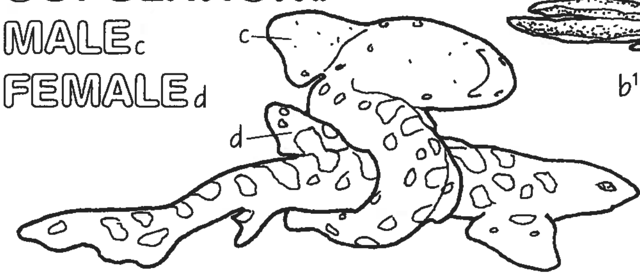
Some sharks undergo a third type of development known as viviparity. In this situation, the mother provides the developing embryos with nourishment in addition to the yolk within the egg. Supplying this nourishment may occur in a number of different ways. The drawing shows a method that resembles the mammalian placental connection between female and embryo. A smoothhound shark embryo is shown folded in an *embryo sac* within its mother's *uterus*. An *"umbilical cord"* and *"placenta"* containing embryonic blood vessels connect the embryo to the wall of the uterus. The "placenta" receives nourishment from the mother's circulatory system, and it is transferred to the developing embryo through the "umbilical cord." Actually the "placenta" here is a modified yolk sac, and the "umbilical cord" is the elongated connection between the yolk sac and the embryo. The result of this arrangement is the direct provision of nutrients by the mother to the embryo.

SHARKS AND SKATES

PELVIC FIN$_a$
CLASPER$_b$
SPUR$_{b^1}$



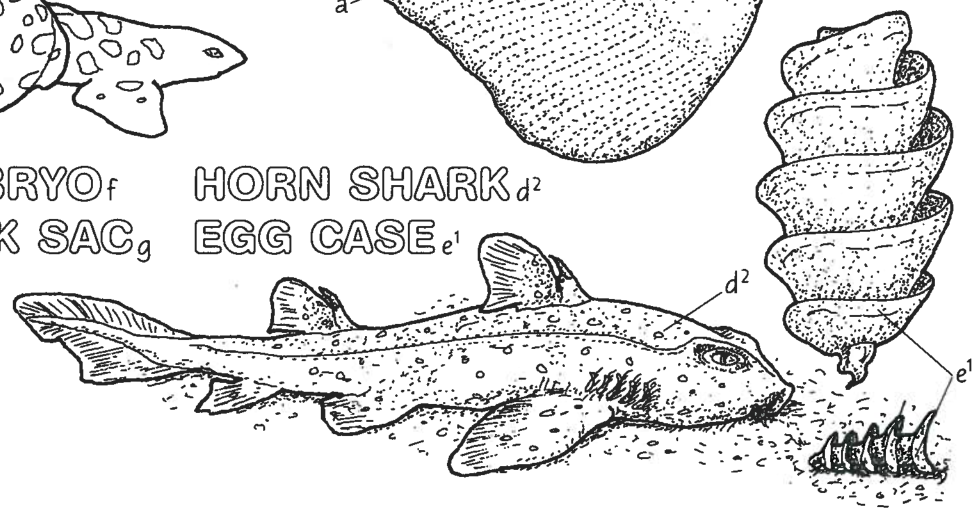
COPULATION*
MALE$_c$
FEMALE$_d$

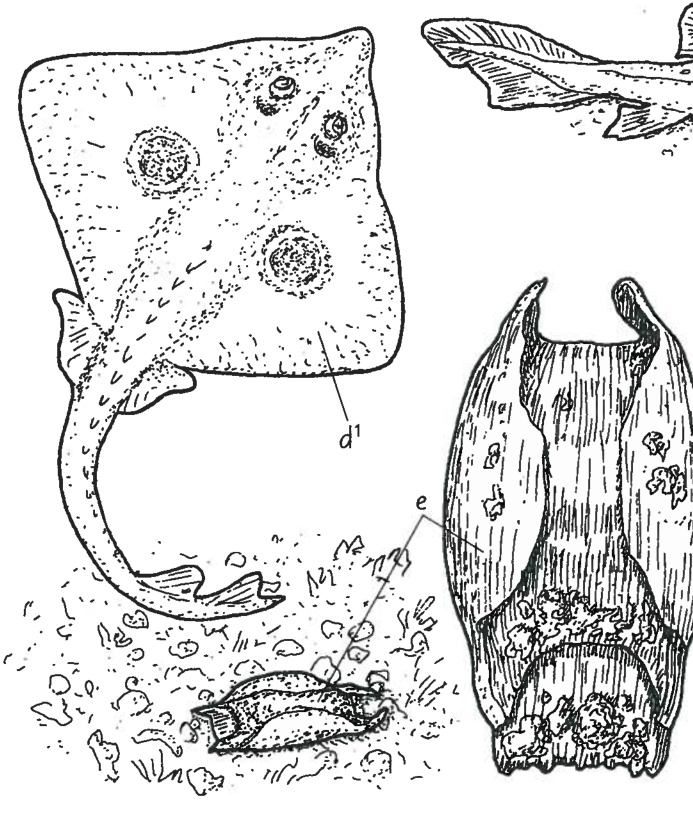


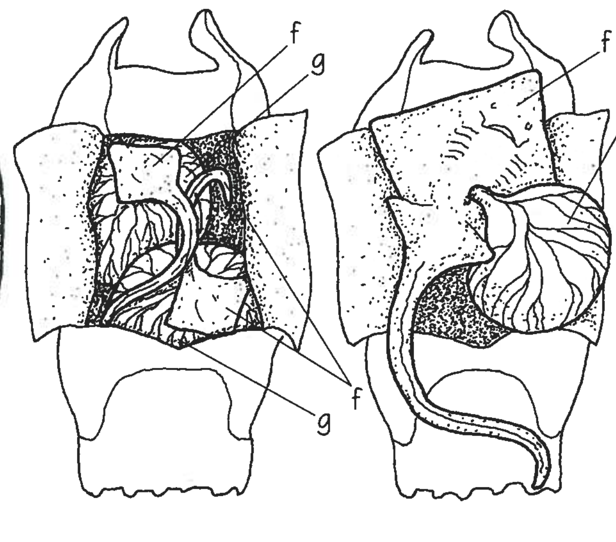
SKATE$_{d^1}$
EGG CASE$_e$

EMBRYO$_f$
YOLK SAC$_g$

HORN SHARK$_{d^2}$
EGG CASE$_{e^1}$

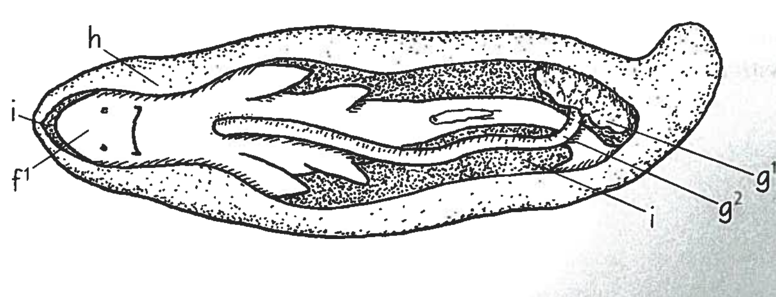






UTERUS$_h$
EMBRYO SAC$_i$
EMBRYO$_{f^1}$
PLACENTA$_{g^1}$
UMBILICAL CORD$_{g^2}$

"PLACENTAL" ARRANGEMENT*



86
REPRODUCTION IN BONY FISHES: LIVE BEARERS AND BROODERS

Bony fishes employ a variety of reproductive strategies to ensure continuation of their species. Some of these methods of reproduction are discussed in this and the next two plates.

Parental care of the young is expensive in terms of the parents' time and energy, but it does tend to ensure the survival of a high percentage of offspring. The strategy is to produce relatively few young—that is, a number that can be cared for—and protect them until they are able to take care of themselves (a very different situation from the free spawning of various invertebrates, as discussed earlier). This approach also ensures that juveniles will be "turned loose" in the proper habitat.

Color the various fishes gray, except for the areas located within circles and the seahorse's pouch. Within the large circles below each fish, color only those structures outlined with a heavy line. Begin with the live-bearing surfperch, and then color each fish separately as it is discussed in the text.

As seen in the previous plate, all of the elasmobranch fishes (sharks, rays, skates) practice internal fertilization followed by some protection of the developing young, either within the female or in an elaborate egg case. The retention of developing young within the parent's body (or in some special brooding area on the parent) is the most effective way to secure the safe development of the offspring. As mentioned above, however, it is costly to the adults engaged in such activities. This type of reproduction is practiced by several families of bony fishes, most of which are called *live bearers*.

The surfperches, common along the Pacific coast of North America, are classic examples of live bearers. The female surfperch is inseminated by the male following rather complicated mating behaviors. The fertilized eggs are retained in the female's ovary where they develop into miniature adults during a five-month gestation period. During development, nourishment is provided by the mother in the form of a nutrient-rich secretion from the highly vascularized (richly supplied with blood vessels) ovarian wall. The secretion is absorbed by the young through their hindgut and their enlarged fins which are also richly supplied with blood vessels for this function.

Young surfperch are quite large (about 50 mm, 2 in) when released compared to the young of other groups of live bearers. For example, rockfishes of the very large genus *Sebastes* are also live bearers, but the individual juveniles are tiny in comparison to surfperch (about 5 mm, 0.2 in) and are still referred to as larvae by many because of their small size. The female surfperch produces a small number of eggs because the individual embryos grow to such a large size. A two-year-old female barred surfperch may produce a clutch of 20 embryos while a four year old might produce 70 embryos. This is compared to a clutch of several thousand embryos produced by a female rockfish.

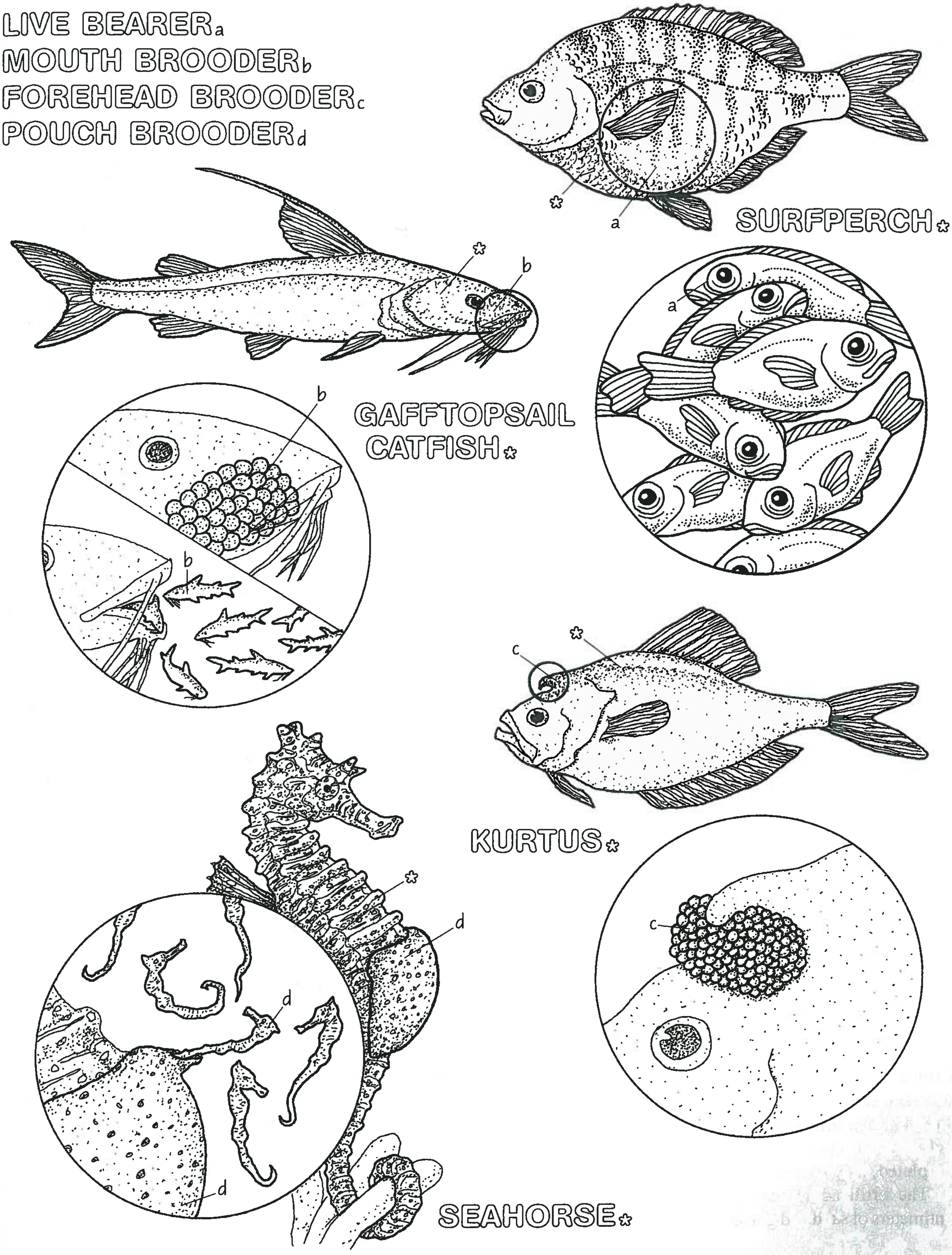
A number of other strategies involve protecting the developing embryos either in some sort of nest (Plate 87) or by means of a special brooding area on the adult fish. The gafftopsail catfish of the Gulf of Mexico is an example of a *mouth brooder*. As the name indicates, the fertilized eggs are brooded within the parent's mouth, in this instance the male's. The male carries 40 to 60 marble-sized eggs in his mouth for about nine weeks while the young develop to the hatching stage. After hatching, the juveniles may stay with the father for an additional month, during which time they enter and leave the mouth at will, thus remaining protected until finally venturing off on their own. This exceptional gesture of parenthood is especially impressive in that the male catfish does not eat during the entire brooding period.

There are a variety of other brooding methods among the bony fishes. The *Kurtus* of the South Pacific uses its head. Again, it is the males which carry the embryos; they are called *forehead brooders*. The male *Kurtus* has a special hook on its forehead to which he attaches a mass of fertilized eggs. In this case, the adult can continue to feed while he protects the embryos until they hatch.

A very effective brooding technique is seen in the seahorses and pipefishes. In these small, slender fishes, the female lays her eggs into the special *pouch* on the ventral surface of the male, who then fertilizes and broods the eggs, out of harm's way. The young remain within this pouch, nourished by their father's blood supply, until they are fully formed young juveniles. The male then "gives birth" by writhing to and fro and flexing the pouch muscles, forcing the young fish out on their own.

LIVE BEARERS AND BROODERS

LIVE BEARER a
MOUTH BROODER b
FOREHEAD BROODER c
POUCH BROODER d



87
REPRODUCTION IN BONY FISHES: NEST BUILDERS

Many species of bony fish prepare some type of nest or protected area in which to deposit their fertilized eggs. Three very different types of nesting behavior are discussed in this plate.

Reserve bright blue for the male and dull blue for the female damselfish. Begin by coloring the nesting female and spawning male salmon using bright red for the body (a) and grayish green for the head (b). The jaw, pelvic fins, pectoral fins, ventral surface, and the edge of the caudal fin in the adult salmon are very light. You may leave them uncolored. Color the other stages in the life cycle. The alevin, the parr, and the smolt are light gray in life.

Nest building by the sockeye salmon is only a small part of this fish's remarkable life cycle. After spending two to four years at sea in the North Pacific, the adult sockeye return to their home stream in the late summer to reproduce (spawn). This journey involves a migration from the ocean, through estuarine areas, into freshwater rivers and streams. Some of these fish travel as far as 2400 km (1500 miles) to eventually return to the small tributaries where they themselves were hatched years earlier. Scientists believe the salmon employ a number of cues to guide them in their journey, including the earth's magnetic field and the unique chemical make up of the home stream which they are able to discern with their acute sense of smell.

As the adult sockeye salmon move upstream, their silver-blue sea-run colors change to bright red mating colors. The *male's* jaws become grotesquely hooked, and he develops a pronounced hump on his back just ahead of the dorsal fin. When the *female* reaches her home stream, she uses her tail to prepare a shallow trough or nest in the gravel bottom. The male joins her over the nest, and they simultaneously release sperm and *eggs*, which drop into the depression. After a short time, the female moves upstream and digs another nest; the materials from which are carried downstream by the current and cover the eggs retained in the first nest. The female may prepare a half-dozen nests until she has released 3000 or more eggs. The combined series of nests with their fertilized eggs is called a "redd." After migrating and spawning, the formerly sleek sockeyes are emaciated and very weak; their mission completed, they soon die.

The fertilized salmon eggs remain buried under several centimeters of sand and gravel through the winter. By spring, each embryo has developed into a 2.5 cm (1 in) *alevin* that still carries the remainder of the egg's yolk in the attached *yolk sac*. The alevin grows into a *parr*, which remains in fresh water for about two years. Toward the end of this period, it matures to a 15 cm (6 in) *smolt*, which moves downstream and out to sea where it feeds and grows to adulthood.

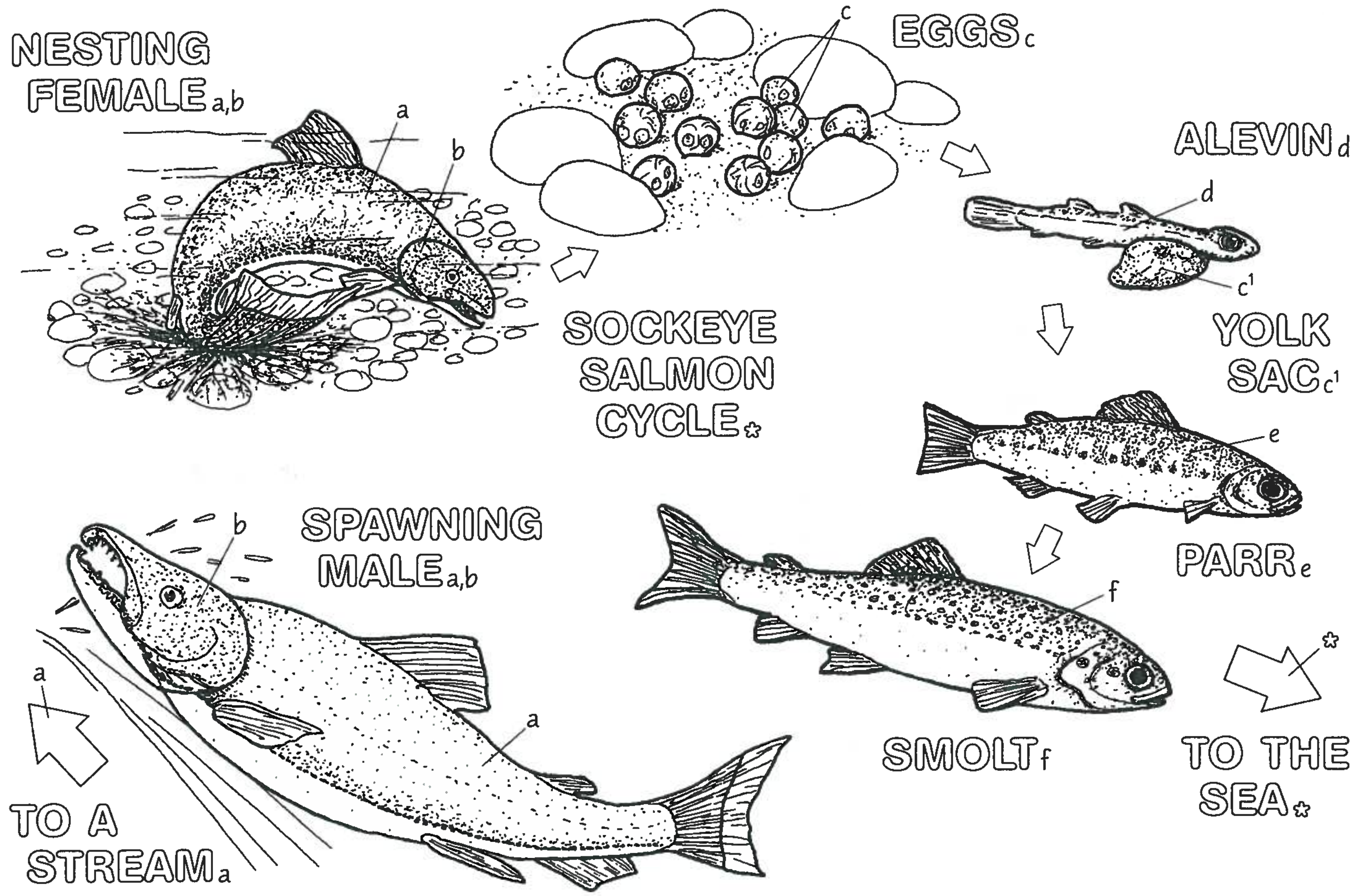
Color the grunion spawning cycle. These figures represent a bird's eye view of the edge of a sandy beach.

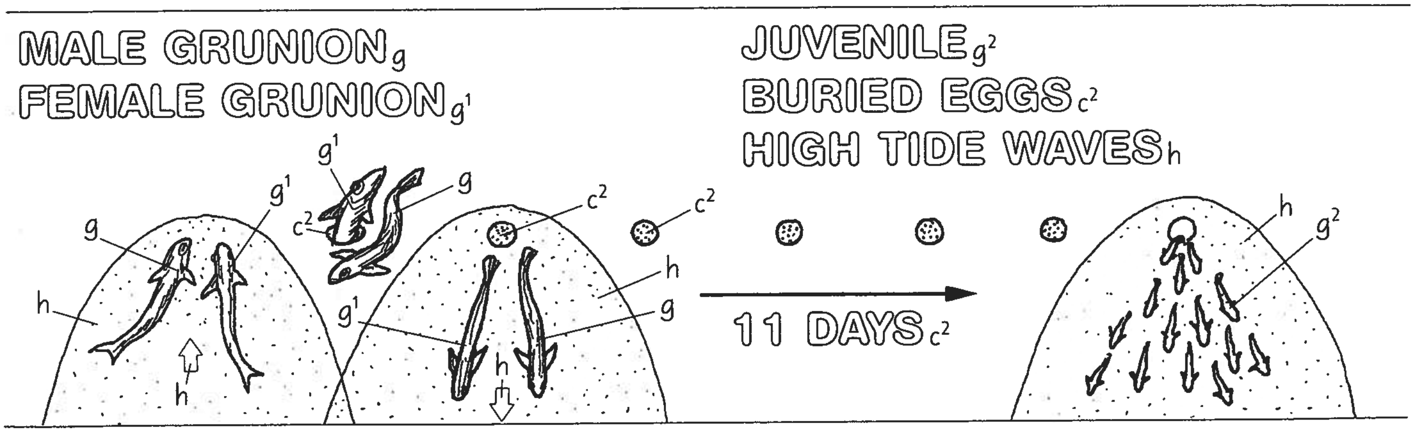
The California *grunion* lay their eggs high up on sandy beaches during the spring and summer and let the warm southern California sun incubate the developing embryos. For this strategy to be successful, the activity must coincide with the season's highest (spring) tides. For three or four nights following the highest tide (the highest tides are always at night during the spring and summer in southern California), male and female grunion ride inshore on *waves* at the peak of the *high tide*. As the wave recedes, the female wriggles tail first into the sand, and one or more males wrap themselves around her. She releases her eggs into the tunnel "nest" she has made, and the males release their sperm (spawning). The adults swim off at the next high wave, and the nest is buried by the waves' action. It is important that the grunion accomplish their egg laying immediately following the highest tide of a cycle so that no more waves will reach the nests for at least 10 to 12 days. When the waves do finally wash over the nests, the *juveniles* burst out of their protective membranes, wriggle to the sand's surface, and swim to sea with the receding wave. They will return to breed the next year as 12.5–15 cm (5–6 in) adults.

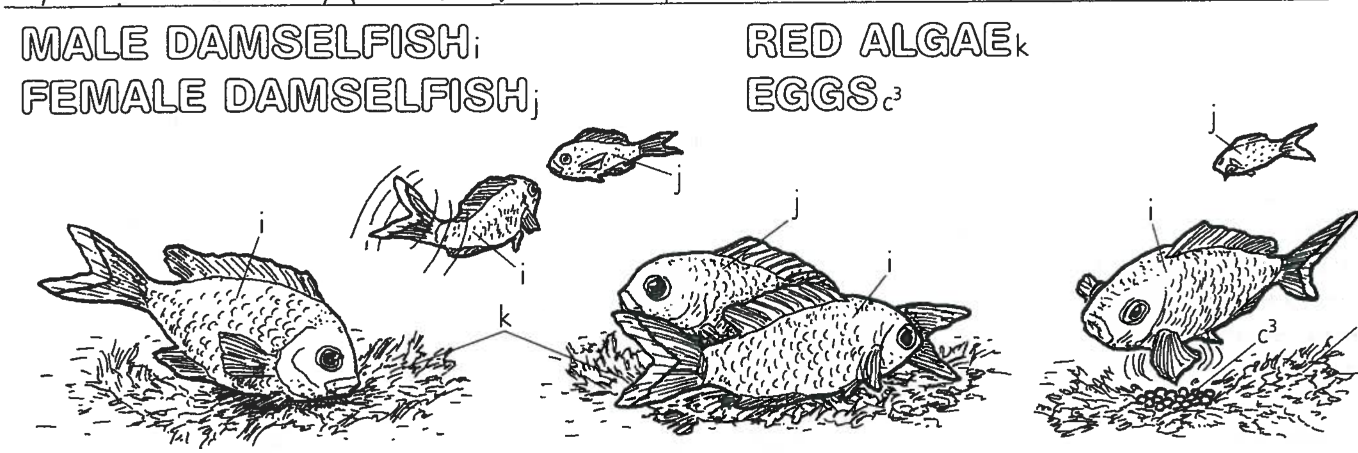
Color the damselfish cycle. Leave the edge of the male's caudal fin uncolored.

As the season for reproduction approaches, the *male damselfish* takes on bright breeding colors and busies himself preparing a patch of *red algae* on the coral reef. He then attracts a prospective mate by special movements of his white-edged caudal fin. The *female damselfish* is enticed into his nest of red algae and releases her eggs, which the male fertilizes by releasing sperm over them. The female then leaves the nesting site (the male may even chase her away), and the male begins a several-week-long vigil, guarding the eggs and fanning them with his fins to keep them clean and well oxygenated during development.

NEST BUILDERS







88
REPRODUCTION IN BONY FISHES: BROADCASTERS

Many marine fishes neither carry their young nor build nests for their protection. Instead, these fishes release their gametes into the water, where fertilization and development take place without further parental involvement. Such fishes are commonly called "broadcasters," as their gametes are distributed, or broadcast, by the waves and currents.

A number of factors contribute to the success or necessity of broadcasting as a reproductive strategy. Pelagic fishes (Plate 45) are generally not associated with a suitable substratum for nest building and cannot stop swimming to brood their young. The release of gametes directly into the water takes advantage of the ocean's free dispersal service and the rich supply of plankton potentially available to young fishes (Plate 75). The reproductive habits of two species of broadcasting fishes are discussed in this plate.

Color the male and female herring and their sperm and eggs. The larval herring are not drawn to scale with the adults.

The northern herring (Plate 45) is found in the Atlantic Ocean, and a closely related subspecies occurs in the Pacific. Herring range widely in both oceans, often in shoals of millions of fish. The herring is a pelagic fish that feeds on zooplankton and usually lives over deep water. It is a broadcaster and usually moves into shallow water to spawn. Along the Pacific coast of the United States, herring come into estuaries and shallow bays. *Females* release their *eggs* near *males*, which then release *sperm*. The fertilized eggs are heavier than water (termed demersal eggs) and sink to the bottom, where they adhere to *algae* and eel grass. Within 10 to 15 days, the *attached embryos* hatch as *yolk-sac larvae* at a length of 6 to 8 mm (0.24–0.32 in). The yolk-sac larvae remain near their hatching site for a few days, feeding on reserves of yolk. As they grow into larger *larvae* (29 mm, 1.2 in), they swim upward into the water, where currents carry them away. The herring larvae continue to grow into *prejuveniles* (about 40 mm, 1.6 in) that soon join other herring in the open water. These young fish will mature to spawn in two to seven years.

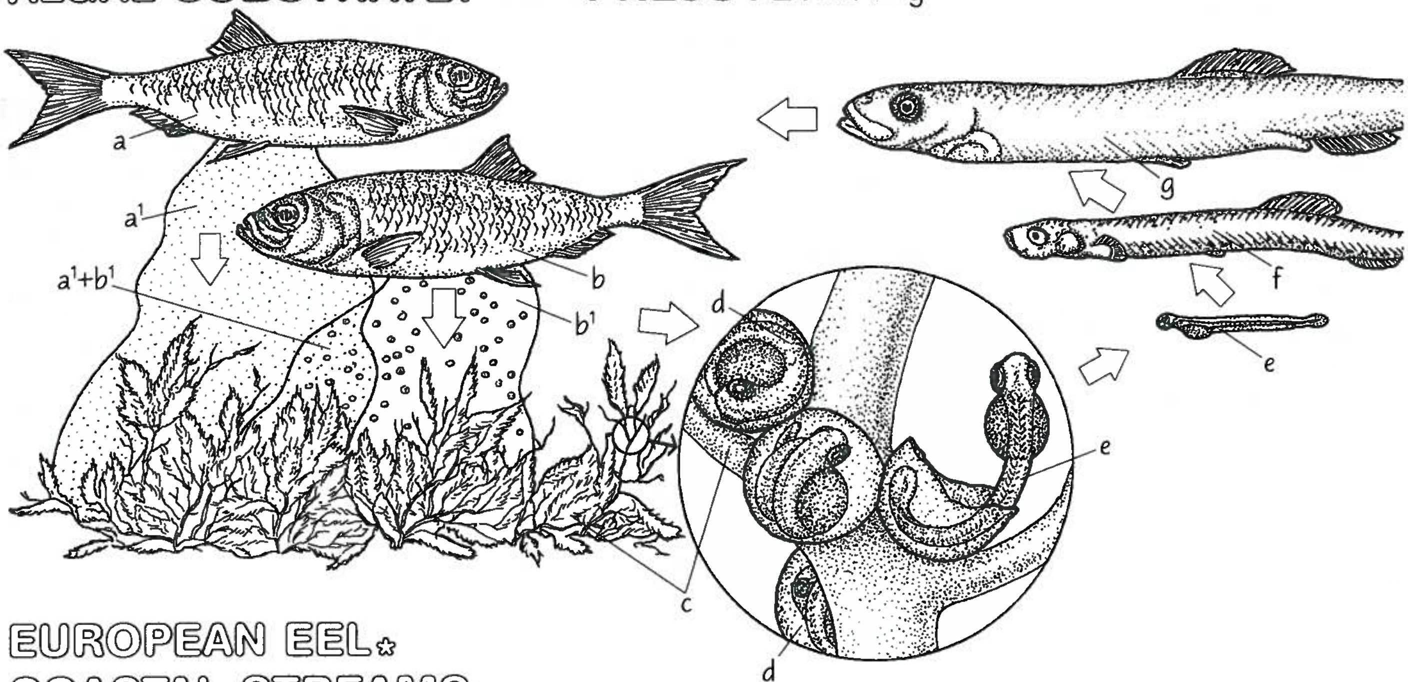
Color the migration routes and life history stages of the European eel. The small eel on the map receives the separate colors of the three advanced stages of the eel: glass, yellow, and silver, which occur in and around the coastal streams of Europe. The map includes the coastal waters and streams inhabited by the American eel as well.

The common or European eel is a catadromous fish; that is, it lives in fresh water and migrates to the ocean to spawn (the reverse of salmon, which are termed anadromous; Plate 87). The migration of these eels is truly amazing. In European fresh water *streams*, the adults change from the common *"yellow eel"* to the silver-white *"silver eel,"* with enlarged eyes and reduced mouths. These silver eels migrate across the Atlantic Ocean to an area known as the *Sargasso Sea*, a floating "island" of the seaweed *Sargassum* (a brown alga), located in a calm area of the western Atlantic near Burmuda. Details of the journey are not known, but once at their destination, the silver eels spawn in deep water (500 meters, 1640 ft) and die. The *eggs* slowly float to the water's surface, and an exotic-looking larva called the *leptocephalus* (thin head) emerges in the spring. This transparent, leaf-shaped larva then sets off back toward Europe, a migration of more than 4000 km (2500 miles) that takes two years or more to complete. As it swims and drifts eastward in the Gulf Stream current, it grows much larger, becoming a 7.5 cm (3 in) *"glass eel,"* or elver, by the time it reaches the European coast. The glass eel enters coastal streams and acquires the yellow adult pigmentation. Young eels migrate upstream by the thousands, sometimes over a distance of many kilometers. The urge to migrate comes again when the eels are anywhere from four to twenty years old, and the adults begin their journey back to the Sargasso Sea to breed.

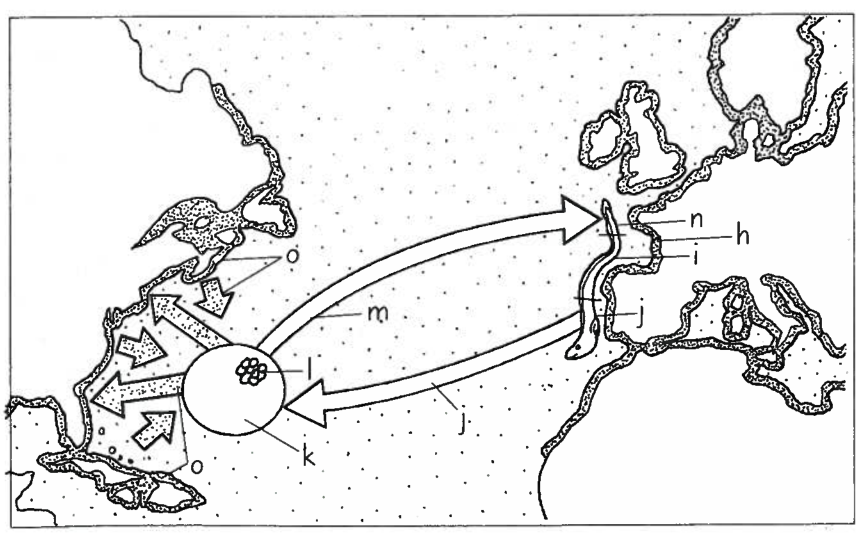
The life cycle of the European eel is still imperfectly understood. Few adult eels have been caught offshore in the Atlantic along the proposed migration route. The entire migration has been inferred from the distribution of the leptocephalus larvae; small ones are found in the Sargasso Sea, and progressively larger ones are found as one moves eastward towards Europe. *American eels* spawn in the same area of the Sargasso Sea as the European eel, but their larvae reach the coast of North America in only one year. There has been some question whether the European eel and American eel are separate species. Recent studies of molecular variation in DNA support the contention the two eels are genetically isolated and should be considered two species.

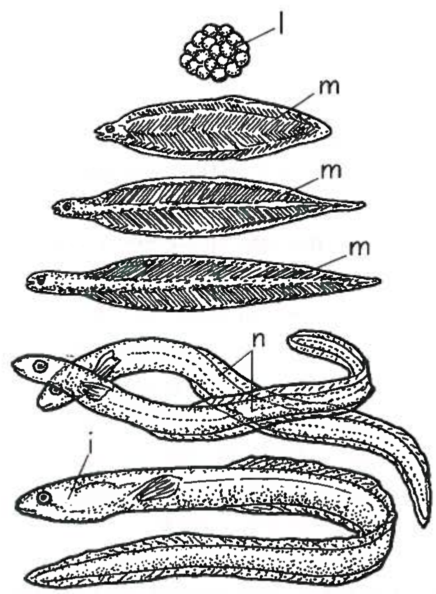
BROADCASTERS

HERRING*
MALE a SPERM a1
FEMALE b EGGS b1
ALGAL SUBSTRATE c
ATTACHED EMBRYO d
YOLK-SAC LARVA e
LARVA f
PREJUVENILE g



EUROPEAN EEL*
COASTAL STREAMS h
YELLOW EEL i
SILVER EEL j
SARGASSO SEA k
EGGS l
LEPTOCEPHALUS LARVA m
GLASS EEL n
AMERICAN EEL o





102
DEFENSE MECHANISMS: SPINY TRICKS

The defense mechanisms of fish often involve the use of spines. We have already seen the poisonous spines of the lionfish (Plate 63), stonefish (Plate 64), and stargazer (Plate 46), which provide a deadly and effective deterrent. Spines are utilized in a variety of ingenious mechanisms, as this plate illustrates.

Begin with the normal and inflated (top right) porcupinefish. In the inflated porcupinefish (with erect spines), note that the spines and body both receive the color used for the spines; the fish's body is light grayish brown in life. In the lower illustration of the porcupinefish, the spines lie flat; color the body and spines the color chosen for the body; this should also be a light brown color.

The first, and by far the most spiny fish to be considered, is the porcupinefish. This fish is cosmopolitan in warm waters and can grow quite large (about 1 meter, 3 ft). Under normal circumstances, the porcupinefish goes about its business of hunting among the crevices of coral reefs for molluscs, crustaceans, and echinoderms that it crushes with its stout, beaklike *jaws*. Its protective *spines* are folded nearly flat with their tips facing toward the back. When molested or threatened, the porcupinefish rapidly inflates its *body* by swallowing water and becomes nearly spherical in shape. The once-flattened spines now become fully erect and stick out in a menacing, pin-cushion fashion. Once the danger has passed, the porcupinefish quickly expels the water and resumes its normal activities. The erect spines can cause serious puncture wounds. South Pacific Islanders once used the spiny skins of porcupinefish for helmets.

Color the surgeonfish and the inset magnified view of the hinged spine protruding from its body wall. The fish's body is silver gray and the spine is surrounded by bright orange.

The surgeonfish is another familiar resident of coral reefs. This medium-sized (15–60 cm, 6–24 in) fish nibbles on filamentous algae with its small terminal *mouth*. When bothered by an intruder, this peaceful herbivore erects a pair of lancelike spines located on either side of the base of the tail. The spines are actually pairs of modified scales hinged on the posterior end, so that their sharp inner edge faces forward when erect. When not in use, the spines retract into horizontal grooves. The spines are razor sharp and have inflicted many a nasty wound on unsuspecting fishermen. They may possibly be used to slash other fish, or perhaps only as a threat display. Many surgeonfish species have the spines boldly outlined in a color that contrasts with the surrounding body color. A warning sweep of the tail, flashing these colors and the erect spines often deters a would-be transgressor.

Color the triggerfish and note that the spines under discussion are actually part of the dorsal fin. The inset above the fish shows the spines folded. Be careful to leave the outlined spots and bands on the triggerfish white to maintain the high contrast against its black body. The triggerfish's mouth is outlined in orange and a black and yellow reticulate saddle is found on its back.

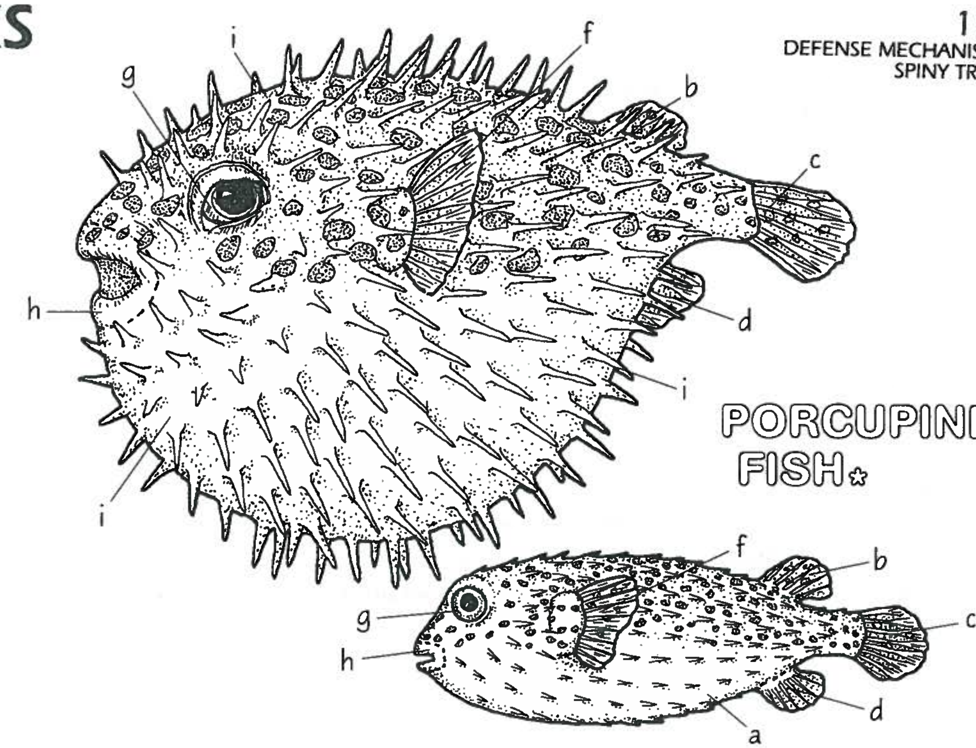
When trouble courts the clown triggerfish (25–50 cm, 10–20 in) of the tropical Pacific it quickly finds shelter in a small cave or crevice in the coral reef. Once there, the triggerfish erects the long first spine of its *dorsal fin* and locks it into place from behind with the smaller second dorsal spine, thus wedging itself tightly in place. The triggerfish cannot be removed from its cave without breaking the stout, dorsal spine. To fold the first spine backward, the smaller second spine (the "trigger") must be depressed. The triggerfish will also raise its dorsal fin in any situation of attack or defense. This presents a more formidable posture and makes the fish look bigger.

Now color the shrimpfish's black stripe and the black spines of the sea urchin. The fish's body is transparent.

The last spiny trick considered here is most unusual. The shrimpfish is a small (15 cm, 6 in) inhabitant of coral reefs and sea grass beds of the tropical Pacific. Shrimpfish have a long snout and are very highly compressed laterally. They are encased in a transparent armor consisting of separate plates that taper rearward into a long point which is the first spine of the dorsal fin. Shrimpfish swim by undulations of their fins and always in a vertical position, head down. When feeding on small invertebrates—and especially when it is not moving—this long, thin shape is hard to distinguish from the blades of sea grass. On the coral reef the shrimpfish borrows the spiny protection of long-spined sea urchins. Its small size and elongated form allow the shrimpfish to fit comfortably among the spines—a relationship that deters most predators. This spiny trick is not unique to the shrimpfish, but its shape and the long, black stripe along its body make urchin spines an especially effective hiding place for this species.

SPINY TRICKS

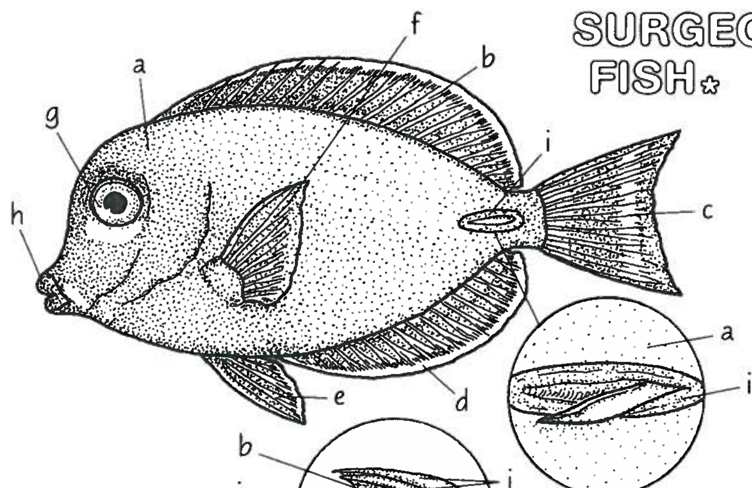
BODY$_a$
FINS$_*$
DORSAL$_b$
CAUDAL$_c$
ANAL$_d$
PELVIC$_e$
PECTORAL$_f$
EYE$_g$
JAWS/MOUTH$_h$
SPINE$_i$

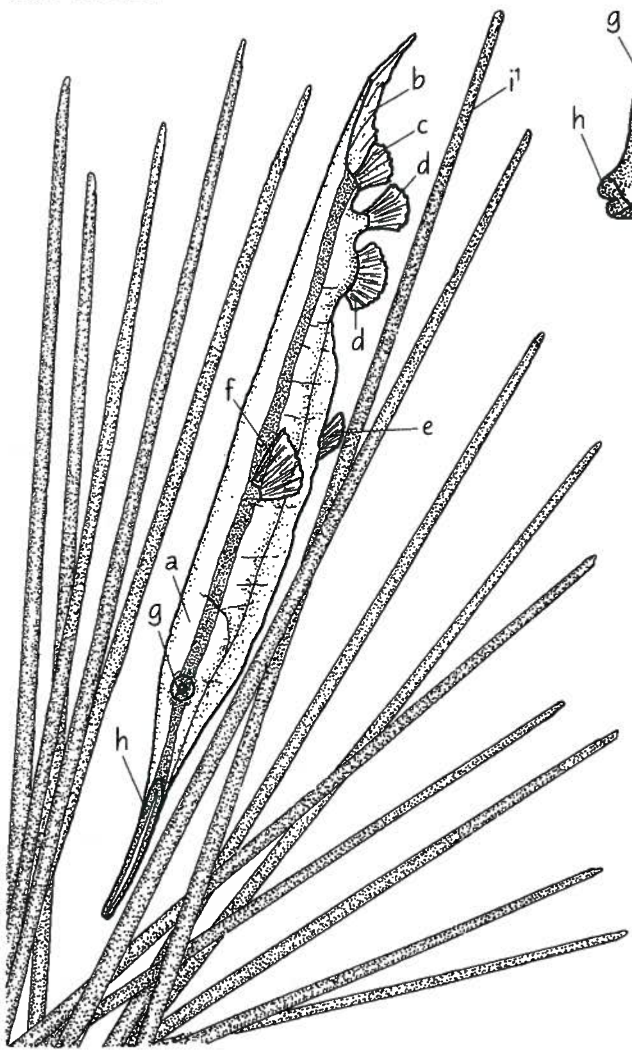


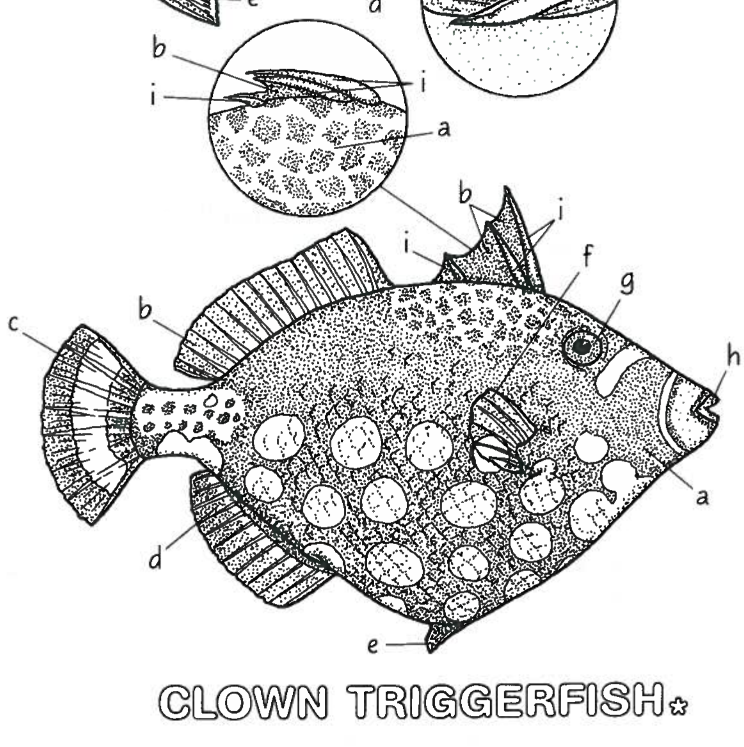
PORCUPINE-FISH$_*$

SHRIMPFISH$_*$
SEA URCHIN$_*$
SPINE$_{i^1}$

SURGEON-FISH$_*$







CLOWN TRIGGERFISH$_*$

109
FEEDING IN BONY FISHES: ATTACKERS AND AMBUSHERS

Seeing a marine habitat such as a coral reef for the first time, one is invariably entranced by the beauty and variety of fish present (Plate 47). Upon seeing so many different kinds of fish in such numbers, one wonders how the habitat can support such a wide diversity of fish without severe competition. Part of the answer lies in the variety of ways marine fishes feed. In the next three plates, different kinds of feeding strategies of marine fish will be explored, along with the corresponding range of behavioral and morphological adaptations.

Color each predatory fish separately as it is discussed in the text. The prey fish can be left uncolored or colored gray. The shark on the right side of the page, although an attack-type predator in its own right, is left uncolored. Bluefish are blue-green above and paler on the ventral surface. Note that the frogfish has a lure, which is a modified dorsal fin spine, and receives the dorsal fin color.

The most well-known feeding strategy is that of the pursuing carnivore that "runs down" its prey (usually other fish or active invertebrates), attacks, and devours them. Such fish are usually highly visible. One example is the great barracuda which is found worldwide in warm and temperate waters except the eastern Pacific and Mediterranean. This silver-white fish is very long (up to 3 meters, 10 ft), streamlined, muscular, and possesses a large falcate (scythe-shaped) *caudal fin*, which is used for quick acceleration and rapid swimming over short distances. The barracuda is a crafty, curious fish and often approaches divers, but always remains just out of reach. Any quick movement toward it results in a swift departure. The barracuda has long *jaws* with long sharp teeth (many of which curve backward) for seizing and holding prey fishes. When a fish is too large, the barracuda may bite it in two and return to gulp the pieces.

This slashing attack is also characteristic of the bluefish schools of the western Atlantic. So swift and menacing is this medium-sized (75 cm, 30 in) predator that it is accused of tearing into schools of terrified bait fish and killing far more than it can eat.

Other pursuing predators are the jacks, which are capable of amazing acceleration and speed. They have been observed stealing meals out of the mouths of sharks feeding on fish tossed from boats. Pictured here is the greater amberjack, known in all tropical and subtropical seas. The amberjack usually has a brass-colored stripe along the body at the level of the eye; it is olive to brownish above the stripe and silvery white below. This fish can get quite large; there are hook-and-line records of 1.4 meters (4.6 ft) and over 63.5 kilograms (140 lb). The amberjack exemplifies the body form of a fast-swimming pelagic fish with its torpedo-shaped *body* and large lunate caudal fin. Jacks tend to swim in groups and range over large areas. Though not residents of coral reefs, they will swim over reefs and feed on local fishes.

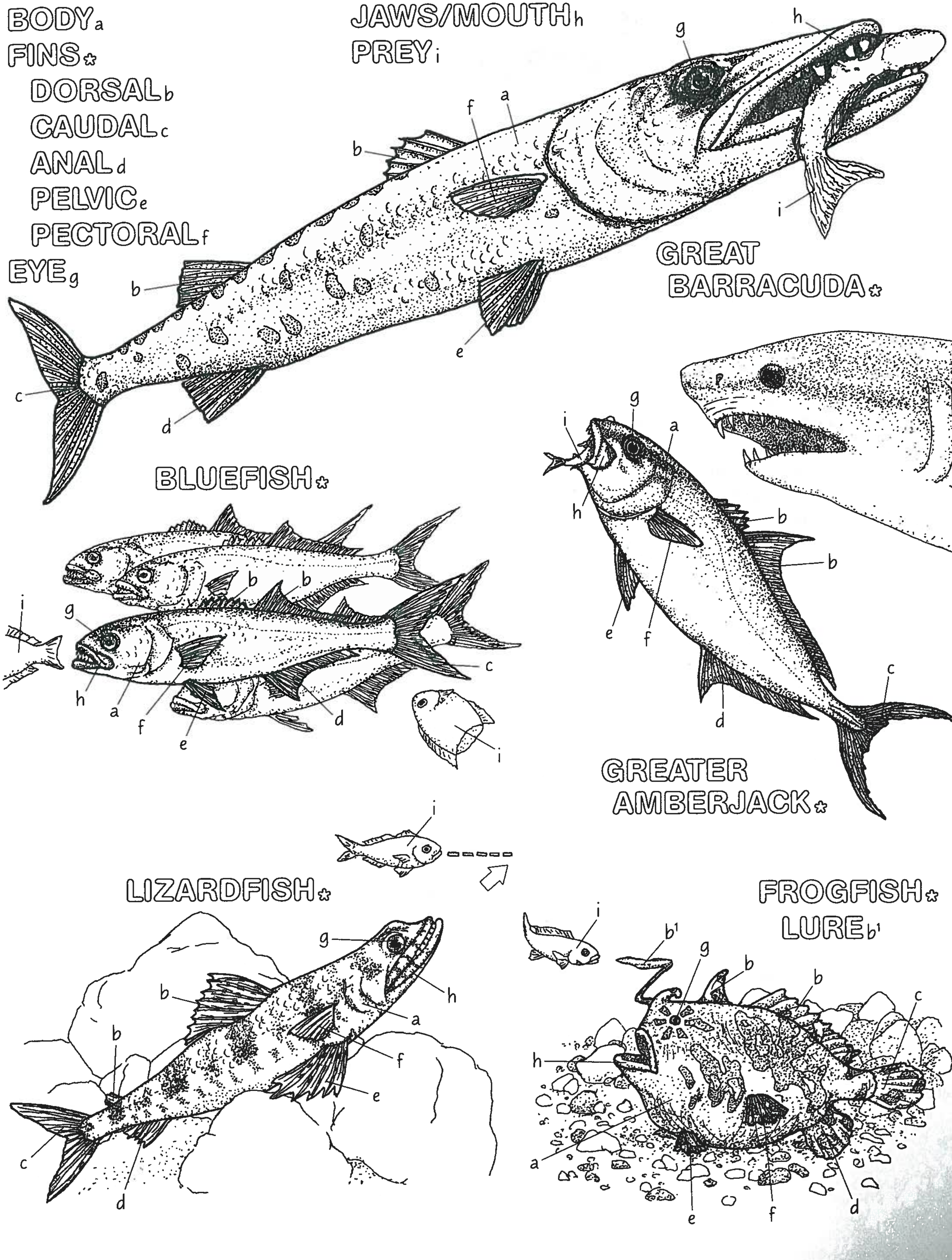
A more leisurely predation strategy is to "sit and wait." The odd-looking trumpetfish (Plate 47) employs this tactic, as does the lizardfish. Appropriately named, this slender, lizard-shaped fish has a big *mouth* full of reptilelike teeth. The fish illustrated here (the rockspear lizardfish) occurs on both sides of the Atlantic and reaches a length of 33 cm (13 in). It is basically silver-white in color with mottled reds and browns, and it blends in with the mud and sand bottoms that it frequents. Lizardfish sit quietly on the ocean floor, sometimes partially buried, and wait for small fish to swim overhead, at which time they dart upward and seize their prey in their well-equipped mouths.

A slight variation on this ambush technique involves the trick of aggressive mimicry (Plate 64) and is seen in a strange group called the frogfish. These fishes, represented here by the splitlure frogfish, have a modified first dorsal fin spine on their snouts called an illicium. The illicium functions as a moveable fishing rod with an attached *lure*. The lure, or esca, is wiggled about enticingly to attract unsuspecting fish. The frogfish remains immobile on its peculiar stumpy *pelvic fins*, looking like a black-streaked, light brown sponge on a coralline-algae-encrusted rock. When a fish comes in to grab the lure, the frogfish sucks the entire prey into its cavernous mouth by rapidly expanding its mouth cavity. Studies of related frogfish species have shown that they can expand their mouth cavity to 12 times its normal resting volume within 6 to 10 milliseconds. This is one of the fastest of all capture mechanisms in the animal kingdom.

ATTACKERS AND AMBUSHERS

BODY a
FINS *
DORSAL b
CAUDAL c
ANAL d
PELVIC e
PECTORAL f
EYE g

JAWS/MOUTH h
PREY i



110
FEEDING IN BONY FISHES: PICKERS, PROBERS, AND SUCKERS

In this and the next plate, fishes that feed on a variety of prey besides other fish will be considered. Many fishes ("generalists") feed somewhat opportunistically, on whatever is available, and many others will eat a small variety of prey species. Placing fishes into feeding categories is sometimes arbitrary, and there may be considerable overlap between categories.

Begin by coloring the California sheephead and its prey. Color the drawing of the pipefish and the inset to the left showing its mouth and prey. Follow the same procedure for the filefish and the butterflyfish. Finally, color all views of the triggerfish and its sea urchin prey.

The California sheephead is a familiar sight in the kelp forests of California (Plate 11). This large (up to 1 meter, 3 ft) fish feeds on invertebrates and is considered a generalist. The male California sheephead is dark gray in color, with a pink-orange midsection and white lower jaw. The female is solid pink-orange. Sheepheads have stout *jaws* and large protruding *teeth* for crushing a variety of *prey*. They are known to feed on sea urchins, sand dollars, mussels, scallops, abalone, lobsters, crabs, hermit crabs, octopus, tube-dwelling polychaetes, or any small- to moderate-sized marine invertebrate they find in the kelp habitat.

Prey selection is much more limited for the pipefish. Pipefishes and the closely related seahorses are delicate suctorial feeders. They use their tubelike snouts and small *mouths* to ingest food by a rapid intake of water, as if sucking on a straw. They have prehensile grasping tails that they use to anchor themselves on algae and other substrata. Their *eyes* can move independently, like those of a chameleon, allowing them to scan the water for their small prey from their anchored perches. Pipefishes are poor swimmers; their *caudal fins* are reduced and the *dorsal* and *pectoral fins* provide the main swimming thrust. Pelvic fins are absent. There are approximately 150 species of pipefishes, found mostly in the shallow waters of tropical and subtropical seas; a few are freshwater inhabitants. They are generally small (15 cm, 6 in), with the largest reaching 50 cm (20 in) and are brown or green above and cream-colored ventrally.

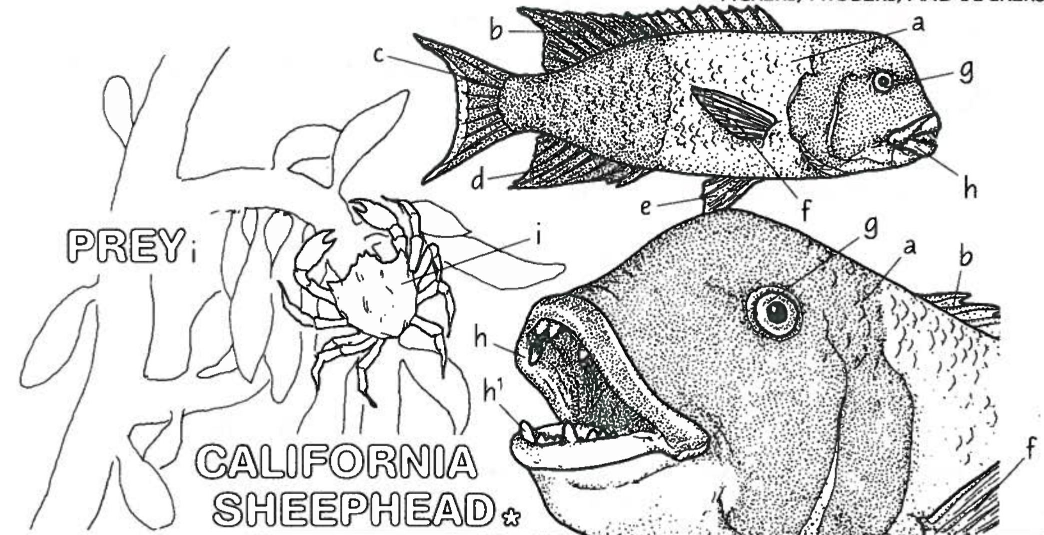
The reef filefish of the tropical Pacific feeds on small reef invertebrates by probing into crevices with its elongated snout and using its small, sharp, incisorlike teeth to pick out prey. This small (10–30 cm, 4–12 in), brightly colored (green with orange spots) fish is often seen among the branches of various species of coral and is known to feed primarily on coral polyps. Filefish are closely related to triggerfish; they have a similarly large first dorsal spine, but lack the triggerfish's locking mechanism (Plate 102). Their skin is rough to the touch and was once utilized as a kind of sandpaper.

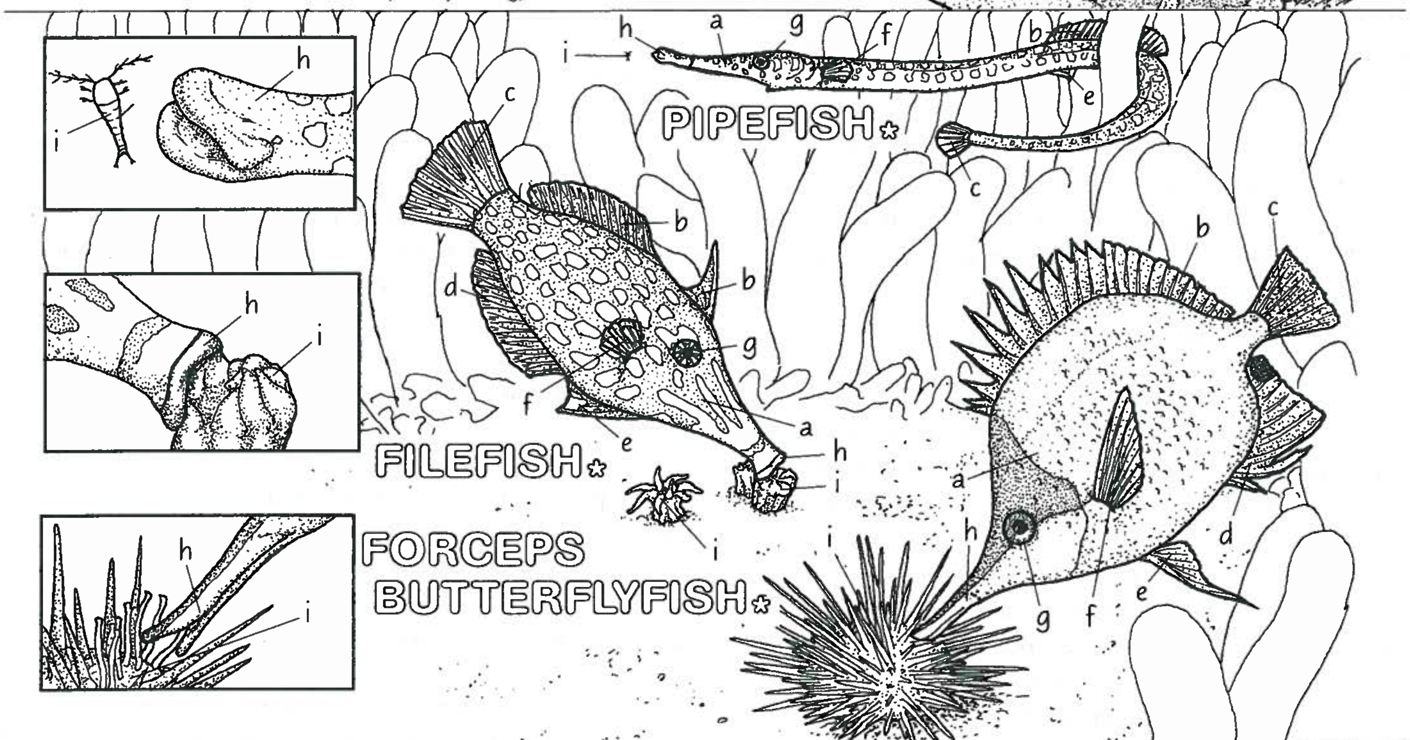
The bright yellow forceps butterflyfish of Pacific coral reefs also picks and probes for food. Sporting the familiar butterflyfish eyespot (Plate 63), this small fish (10–15 cm, 4–6 in) has an elongated gray-brown snout and pointed jaws with sharp teeth that are used like a pair of forceps to extract small morsels from tight quarters. Its principal food items are the tentacles of tube-dwelling polychaetes, coral polyps, and tube feet and pedicellariae plucked from between the spines of sea urchins. Like many butterflyfishes, this species raises its stout dorsal fin spines as a defense mechanism, presenting an unappetizing mouthful to swallow.

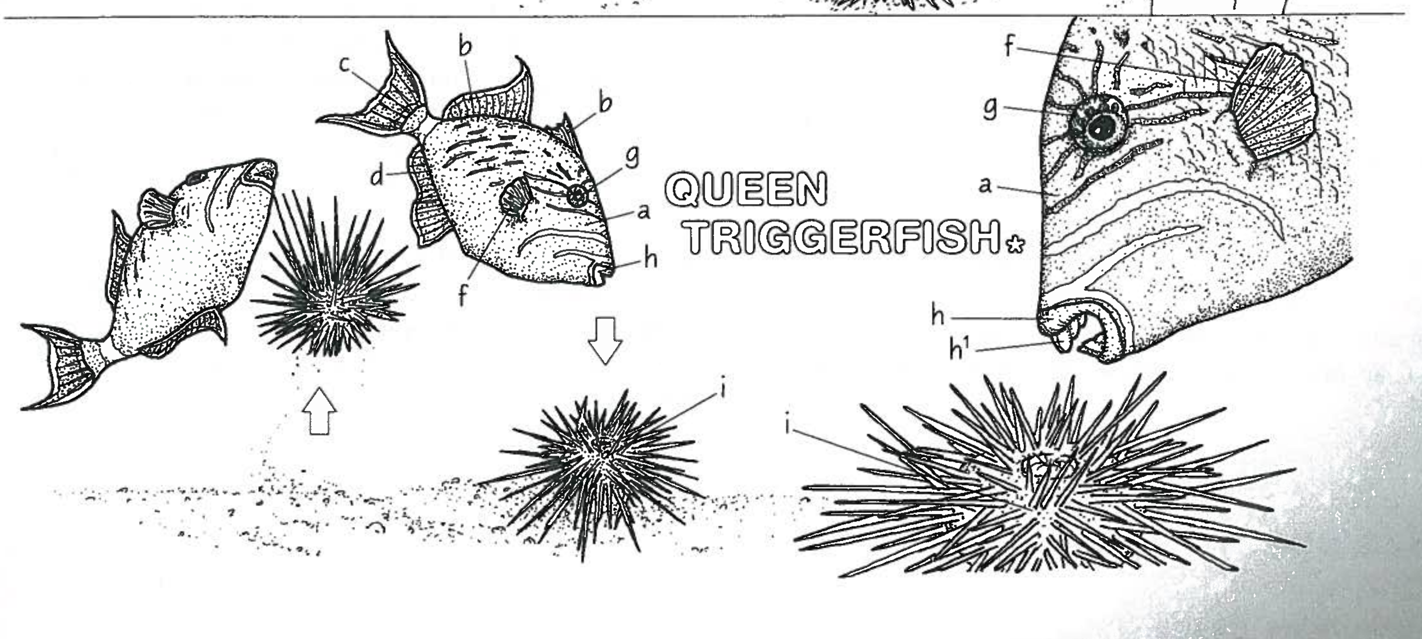
The queen triggerfish of the Caribbean Sea is a relatively large fish (up to 26 cm, 10 in) and a generalist feeding on invertebrates. The bands around the mouth and eyes are light blue and the background is yellowish brown. Instead of the large jaws of the sheephead, it has a smaller mouth with short, stout jaws, each with eight protruding incisorlike teeth. It uses this equipment to render the hard portions of its molluscan and crustacean prey into small pieces. The queen triggerfish prefers the long-spined sea urchin, which presents a formidable defensive posture. Triggerfishes have a tough leathery hide made of bony scales that provide a flexible armor against the sea urchin's spines. The queen triggerfish lifts the urchin by a single spine, carries it up off the substratum, and drops it. The urchin usually lands oral side down, but after repeated upheavals the urchin will eventually fall with its vulnerable oral area exposed. The queen triggerfish then darts in between the shorter oral spines, quickly bites through the soft mouth area, and proceeds to eat the urchin from the inside out.

PICKERS, PROBERS, AND SUCKERS

BODY a
FINS *
DORSAL b
CAUDAL c
ANAL d
PELVIC e
PECTORAL f
EYE g
JAWS/MOUTH h
TEETH h¹







111
FEEDING IN BONY FISHES: GRAZERS AND GRUBBERS

Some fishes, like the barracuda or the sheephead, attack, chase, and consume prey whole. Other fishes, like the reef filefish and forceps butterflyfish, probe and pick away at parts of their prey. In this plate, fish that graze (like the continual browsing of cows or sheep), and those that grub through soft substrata seeking their prey, are considered.

Color each fish and the diagram of its mouth. Note that the trunkfish lacks pelvic fins. The bat ray's mouth is not visible in the larger view; in the smaller view, it is shown from the ventral surface. The bat ray lacks caudal and anal fins.

The northern anchovy represents a group of grazers that utilize the vast pasture of the plankton. These small fish (to 22.5 cm, 9 in) swim through the plankton-rich water with their large *mouths* open and trap the plankton on their gill rakers. They will occasionally go after a larger plankter and snap it up. Anchovy species are found in all the world's oceans, and are important as bait and food fish.

The parrotfishes of Caribbean and Pacific coral reefs are also grazers. These medium to large electric blue fish (25–100 cm, 10–40 in) are primarily herbivores, feeding on the low growth of algae found on coral rock. The parrotfish's *teeth* are fused into a stout beak with sharp cutting edges. These are used to scrape the algal growth from coral rock, and sometimes to ingest living coral as well, supposedly for the plant cells contained in the coral polyps (Plate 91). The ingested algae and coral are ground up by a "pharyngeal mill" consisting of molarlike teeth on the floor and roof of the throat. This feeding activity turns coral rock into coral sand and, in local areas, can account for substantial sediment increase and coral reef destruction. A single parrotfish may turn a ton of coral reef into sand in a year's time.

Many marine invertebrates live within the soft substrata that form the dominant types of ocean bottom. This infauna includes clams, crustaceans, polychaetes, and many others. Frequently, the predator's problem is simply finding them. Fishes that feed on these buried, bottom-living forms are often called grubbers, suggesting the chore of sorting through sand or mud to find food.

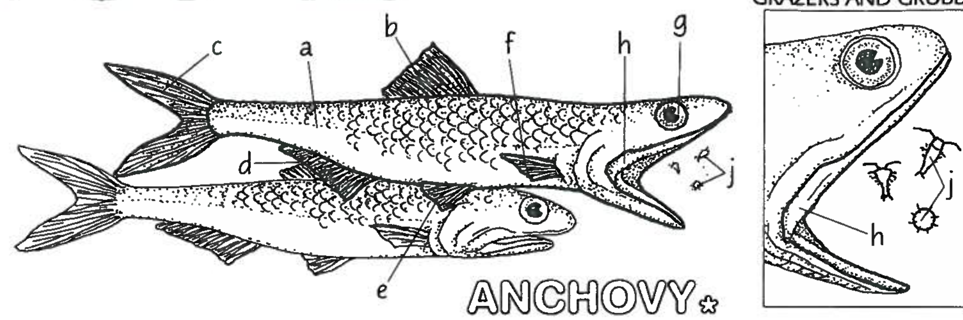
The brownish-colored trunkfishes are sophisticated grubbers. Instead of mucking about in the substratum, they swim almost vertically above it and direct jets of water from their mouths downward onto the surface of the substratum. This removes the upper sediment layer and exposes the buried prey, which are then consumed. Trunkfish feed primarily on small crustaceans and polychaete worms.

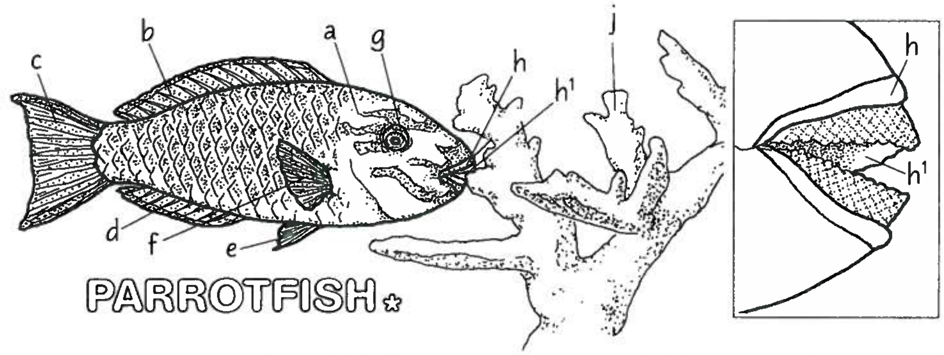
The gray-brown bat ray is a most determined grubber. This large, 1 meter (3 ft) wide, 95 kg (210 lb) elasmobranch fish uses its winglike *pectoral fins* to fan away the substratum and expose burrowed prey. It feeds primarily on bivalves and crustaceans, which are readily crushed by its stout *jaws* and flat pavementlike teeth. The bat ray has been reported to use the undersurface of its wing like a giant suction cup to suck buried prey out of their burrows.

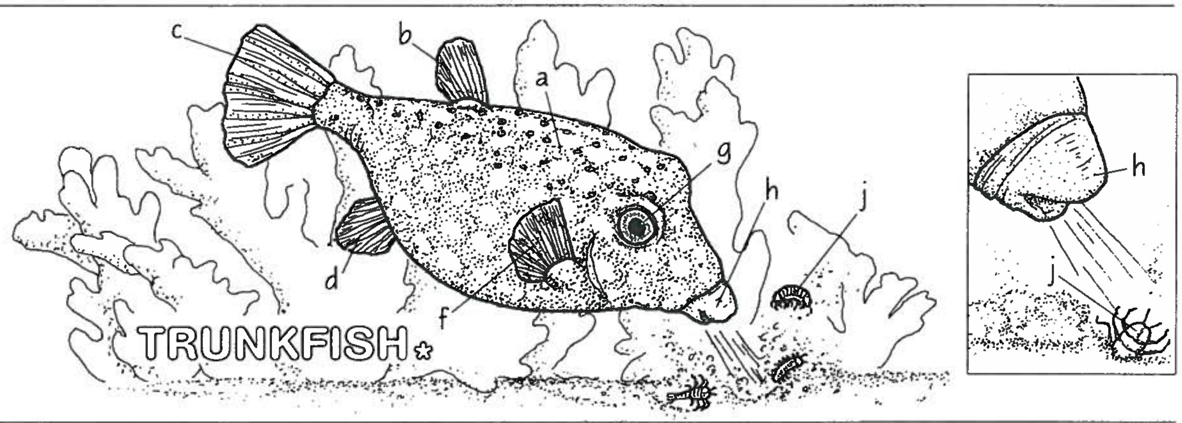
More grubbing finesse is demonstrated by the familiar goatfish of tropical waters. These medium-sized fish (25–50 cm, 10–25 in) possess a pair of chemosensory appendages called *barbels* that hang from their lower jaws like chin whiskers. The flexible barbels are moved rapidly over the substratum or through it, detecting buried *prey* (small crustaceans and worms), which are quickly excavated and devoured by the small, downward-facing mouth. There are approximately 50 species of goatfish, and most of them are found inshore in shallow water. Individual species show specific feeding preferences for sand or mud substrata and also for feeding times (some are nocturnal feeders). Many species are characterized by group feeding in moderate-sized schools of 25 to 50 individuals. Goatfish are yellow on the dorsal surface and silver-white below.

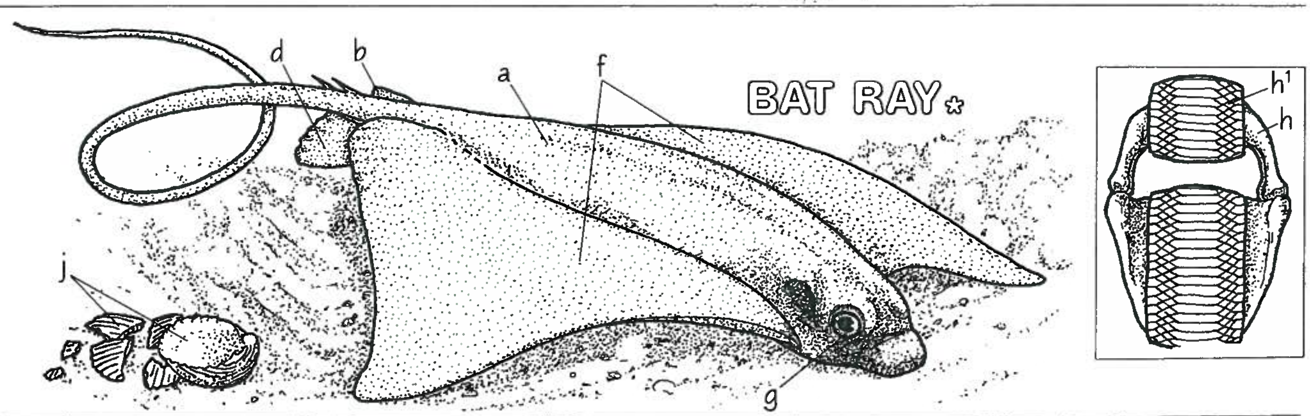
GRAZERS AND GRUBBERS

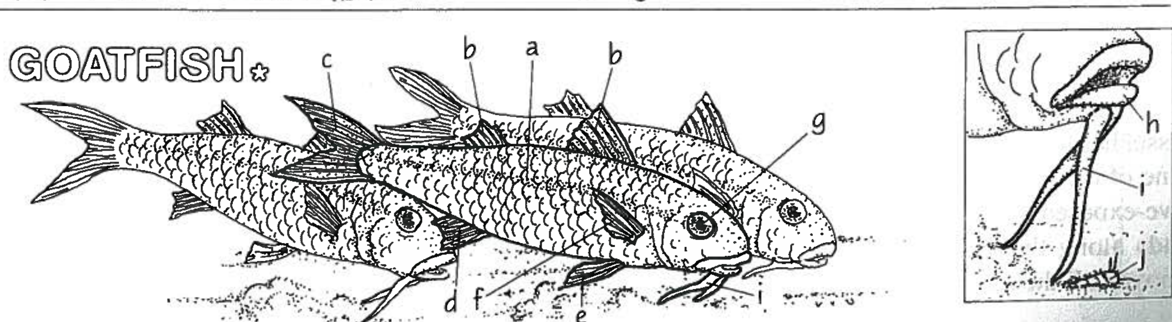
BODY a
FINS ☆
DORSAL b
CAUDAL c
ANAL d
PELVIC e
PECTORAL f
EYE g
JAWS/MOUTH h
TEETH h¹
BARBELS i
PREY j











IT TAKES ALL KINDS!

The MARE Teachers' Guide to the KELP FOREST
Discipline: Biology
Theme: Scale and Structure

KEY CONCEPT: Fish come in a great array of forms, colors and shapes which can be used to predict the habitat and lifestyle to which they are adapted.

SYNOPSIS: Students observe color and shape adaptations in diverse fish and use this information to predict fish habitat and lifestyle.

FOR THE TEACHER:
Fish are one of the most successful of the groups of animals with backbones—the vertebrates—and consist of over 50% of all the living vertebrate species. In addition to being one of the most numerous groups, they are also among the most diverse. The incredible variety of forms and behavioral adaptations for survival seen in fish are a reflection of the complex and diverse habitats available to them in their ocean home.

The tremendous diversity in fish is the result of numerous adaptations since fish first evolved over 500 million years ago. The interplay of these adaptations has shaped fish in countless ways, but each form or shape has evolved to allow fish to successfully feed, swim, escape predators, and reproduce in their habitat. These adaptations can be grouped into categories of size, shape of body and tail, coloration patterns, location of mouth and size of teeth, and gill rakers. Close observation of these fish adaptations can lead to predictions about their behavior and choice of habitat within the ocean environment.

The shape and the position of fish fins are related to their body shape and the location of the center of buoyancy of the fish. The differences between fish in their fin shape and location are adaptations for their habitat and lifestyle and are reflected in their locomotion and maneuvering abilities. For example, the lower part of the tail fin in bottom dwellers such as rays is usually reduced, but it is enlarged in the flying fish which may use it to help them jump out of the water. Other examples of adaptations include the dorsal fin of remoras, which is modified as a sucker to allow it to hitchhike on sharks, and the dorsal fin of anglerfishes, which attracts prey to its large mouth.

Fish usually have the streamlined—or fusiform—shape, which is very efficient in the water, but they do show a great range of departures from this typical shape. Each of these departures is an adaptation to a specific way of life which puts a premium on something other than fast swimming.

SCIENCE PROCESS SKILLS:
observing, communicating, comparing, categorizing, relating, inferring

SOCIAL SKILLS:
cooperation, checking for understanding

VOCABULARY:
adaptation, camouflage, evolution, fins: (anal, caudal or tail, dorsal, pectoral, pelvic), gill rakers, predator, prey

MATERIALS:
INTO THE ACTIVITIES
small pictures of a variety of fish (cutout from magazines or calendars)
flip chart, butcher paper, blackboard or overhead projector
videotape of fish (use visual images of various colorful fish to show the tremendous variety in their size, shape, color and habitat)
drawing paper for each student

THROUGH THE ACTIVITIES
One fresh fish for each small group of 5-6 students.
It works best if there is a diversity of fish, with each group concentrating on a different one. Asian markets are a wonderful source for many different local and exotic fish. Make sure that the fish are not scaled or gutted and that they are fresh! The following fish make good examples:

mackerel or bonita, salmon, eels, herring, rockfish, flatfish (such as halibut, sanddabs, flounder), pompano or other exotic fish

copies of Fish Feature Worksheet for each group
paper plates, trays or newspaper for each fish
pictures, books, slides, videotape and/or posters of various fish
Fish Adaptation Charts (4) for Body Shape, Tail Shape, Mouth/Teeth/Gill Rakers and Coloration Patterns. See sample charts in THROUGH activity.
Optional:
reference books on fish
8 1/2" x 11" sheet blank paper for Mini-Book
paper quilt square (one per student), glue, book-binding tape (2 colors), construction paper (various colors)

INTO THE ACTIVITY

Tea Party

1. Share your favorite memory about fish.
2. What different kinds of fishes can you think of?
3. Describe a fish and tell how it swims.
4. Tell all the things a fish needs to obtain in order to survive.
5. Tell as many ways as you can that people interact with fishes.
6. What kinds of places do fish live in?
7. Tell a tall fish tale.

Have students sit with their a partner and list and/or draw as many things as they can remember from the Tea Party. *Alternatively, you can have each student do their own recording to use for individual assessment.* Lead a class discussion about the group's ideas.

Anticipatory Chart

1. Have students sit in small groups where they can quietly discuss the video they are about to watch. Have one student in each group act as the recorder and count the number of people in their group who answer yes, no or maybe to each of the questions below **before they watch the video**. Encourage the students to discuss the questions with each other as the recorder counts their answers. Have them even make up their own sentence or question. *The questions should reflect what is actually being shown on your particular videotape.*

Anticipatory Chart

What do you think?:	YES	NO	MAYBE
1. Fish all seem to have the same tail shape.			
2. Fish with squared tails swim the fastest.			
3. Some fish hide by lying flat on the bottom.			
4. The body shape of fish tells us about where it might live.			
5. Long, skinny fish usually can be found swimming out in the open.			
6. Slow moving fish don't have any protection against being eaten.			
7.			

2. Turn on the video—but leave the sound off. Again encourage the students to discuss the video and questions in their small groups as the video is playing.

3. Have students fill in this Extended Anticipatory Chart after watching the video. Tell them they can change their answers.

Extended Anticipatory Chart

Now what do you think?			If you decided to change your answer, explain what you saw in the video to make you change your mind.
YES	NO	MAYBE	
1.			
2.			
3.			

Ask if there are questions for which we still don't have an answer? What other questions do we now want to answer? Make a list of these questions where everyone can see them. Refer to this list throughout the activity.

Sketch a Fish

Place posters/pictures/books of various fish around the room. Have students draw a picture of a fish. It could be their favorite fish or one they just find interesting. Tell them they can use the pictures and posters around the room for ideas.

Silent Mingle

Have students walk around the room silently, holding their drawing or another picture of a fish they have chosen from their table. Have students discuss the following questions with the closest student when you say "Pair-up."

1. Show your fish picture to your partner. Why is this your favorite (or most interesting) fish? Describe to your partner what it looks like and why it is interesting to you.
2. How do you think this fish captures its food? What do you think it eats?
3. Look at the mouths of the fish around you. How are they different from one another? How many different mouths can you see?
4. Describe the body shape of your fish. How many fish with that body shape do you see on the posters/pictures/books near you?
5. Describe the fins that you see. How many fins come in pairs? Look at the different tail fins—how many different shapes can you find?

Think, Pair, Share

1. Have students Think about the following two questions, jotting down some ideas in words or pictures:

What are some adaptations that all fish seem to have in common?

In what ways do fish seem to differ and do you think these differences have something to do with where they live in the ocean? Why or why not?
2. Now have each student Pair up with another and compare/discuss their ideas. They can add to their notes after discussion with their partner it they like.
3. Finally, have each pair Share their ideas with another pair of students.
4. Lead a class discussion and record the group's responses on a class chart.

ASSESSMENT

Teacher observation of participation in Tea Party and Silent Mingle
At least 5 items recorded from Tea Party
Participation in Group Anticipatory and Extended Anticipatory Chart
Fish Sketch
Individual recording of "Think" in Think, Pair, Share

THROUGH THE ACTIVITY

Fish Adaptation Charts

Use the four fish adaptation charts you made *(see below for example charts, be sure to add a sketch for each listed word)* to describe the body and tail shapes, coloration patterns and mouth shape, size and location including the teeth and gill rakers. Describe how these adaptations can be used to determine their food and habitat. As you introduce each color or shape on the fish charts, have cooperative groups of 5–6 students find those features on the posters/pictures/books at their table. Have groups share their findings with the class.

(See attached for examples of fish adaptation sketches and representative fish to use when making your charts).

FISH ADAPTATION CHARTS

BODY SHAPE	TAIL SHAPE	COLOR PATTERNS	MOUTH, TEETH, GILL RAKERS
Fusiform	Lunate	Camouflage	Location
Depressed	Forked	Disruptive	Size & Shape
Sphere	Squared	Countershading	Teeth (Size & Shape)
Ribbon	Rounded	Advertising	Gill Rakers
Compressed	Tapered	Deceiving	Size & Shape

Group Brainstorm
Pick out a few representative fish from the posters and have students help you use the new vocabulary from the fish charts to describe their features. Have groups hypothesize about the fishes habitat and what it might eat. Have groups share their speculations with the class. As an example you might want to complete the Fish Feature Worksheet for one of these fish or with a fresh fish if you have enough.

Fish Feature Worksheet and Mystery Fish
1. Distribute a Fish Feature Worksheet and one fresh fish to each group and have them make drawings of the adaptations they see, including those listed on the Worksheet and two other features of this fish that they find interesting (such as size of scales, fleshy appendages, spines, size of eye). Remind them to use the new vocabulary to label their drawings. Everyone in the group must agree on the label chosen to describe the adaptations.

2. Based on these adaptations, have the groups discuss and complete the worksheet for their fish, including where they think it lives and what it eats.

3. Have the groups share their findings, drawings and hypotheses about the adaptations, diet and lifestyle of their fish with the entire class. (Optional): use a reference book to help students find a description of their fish and lead a discussion of the similarities and differences between their hypotheses and how the fish was described in the literature.

Mini-Book on Fish Diversity and Adaptations
1. Have individual students create a mini-book that includes words and graphic information about what they learned. Have students fold an 8 1/2" x 11" sheet of plain paper siee to side and then into thirds. Open it up all the way and cut along two of the folds halfway across the page so a book is formed with three pages that open vertically. (Please see the pattern at the end of this activity.)

2. With the book folded shut and only the cover showing, have students write a name for their book on the cover. Open the cover and on the first page (title page) write the author's name. Open the title page and label each of the sections: Adaptations, Habitat, and Lifestyle. Now flip up each section and draw a picture in one subsection and write text in the other. The drawings can represent the fresh fish or those seen on posters or in books The written descriptions can be about something they learned from this activity about adaptations, habitat, and/or lifestyles pertaining to the drawing on that subsection.

Quilt Story
Have each student contribute a quilt square to a class paper quilt representing the vast array of fish diversity and adaptations.

1. Distribute a blank paper quilt square, colored construction paper, and glue to each student and instruct them to make a fish in its habitat. The attributes of the fish should reflect its adaptations to its habitat. They should also name their fish. Be sure to have them leave a 1" border around the outside.
2. Once the blocks are completed, have each student work with a partner to learn about their partner's fish including habitat, adaptations, lifestyle, and name. Have them introduce each other's fish and how it lives to the class.
3. Once all the fish have been described, have the class designate some "master quilters" to piece them together using different colors of book binding tape to form the lattice strips and the border.

ASSESSMENT:
Teacher observation of participation in each activity
Teacher observation of Checking for Understanding and Cooperation
Group Fish Feature Worksheet and Drawing and Labeling of Mystery Fish
Individual Mini-Book and Quilt
Verbal Description of Partner's Quilt Square

BEYOND THE ACTIVITY

Create a Fish
a. Have students pick adaptations from each of the following categories and use these attributes to design their own unique fish.

> Color, body and tail shape, mouth size and position, size of teeth and gill rakers, unique structures (such as lures, bioluminescence, fleshy appendages, suckers), size, speed, behavior, etc.

b. Have students draw the fish and its habitat and then describe its adaptations and lifestyle. Also have them label and name their fish. Students could then make their fish in 3-D using miscellaneous craft supplies and/or vegetables.
c. Have students form partners and make predictions of lifestyle, diet, and name of their partners creation. The "predictor" and "creator" then make presentations to the class, switching roles as their creation is introduced.

Gyotaku (fish printing).
Use the finished prints to show different species adaptations for speed, defense, and food capture. Label the print with the species name.

Charting Fish Behavior and Movement
If possible, set up a classroom aquarium so students can observe and keep daily logs of behaviors, patterns of movement, individual variations in feeding, growth and breathing patterns. (See Mapping Fish Habitats, GEMS, Lawrence Hall of Science, UC Berkeley).

Field Trips
Visit an aquarium, aquarium store, or fish market to observe the great diversity of fish. Take a fishing trip to a local pier. Note the various kinds of fishing techniques and bait used by different fisherpersons.

Dissection
Dissect the fish used in this activity to compare their internal anatomy. Try to make correlations between the internal anatomy and their lifestyle, e.g. tuna have mostly red muscle, reflecting their ability at long distance swimming, and flatfish have no gas bladder, thereby allowing them to lie motionless on the bottom.

Student Posters
Have each group select one of the following topics to discuss and represent graphically on a poster. Have students share their poster with the rest of the class.
Topics:
1. What sort of adaptations do people have that help us to be successful land dwellers? How are people adapted to be good predators of fish? What have people invented to help us capture fish?
2. If you were an ichthyologist (someone who studies fish), how would you determine the lifestyle and habitat of a fish brought to you by a fisherperson who wanted to know all about it? What sort of questions would you ask the fisherperson? What would you do next to find out all you could about the fish?
3. If you could turn yourself into a fish, how would you have to change? What kind of fish would you be? What special adaptations would you have? Where would you live? How would you escape from fisherpersons and other predators?
4. What do the expert fisherpersons need to know about fish in order to capture them in great enough numbers to be successful? What should they keep in mind so that they can continue to capture fish year after year? What might affect the number of fish they capture from year to year?
5. Compare fish and whales. How are they similar? What adaptations do they have in common? In what ways are they different? Many species of both groups have been hunted in great numbers. Some whales have become extinct and some are endangered. Do you think fish have this same problem? Why/Why not?

Consequence Charts
Have students work in cooperative groups to complete charts in which they describe consequences over time given the following scenario:

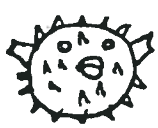
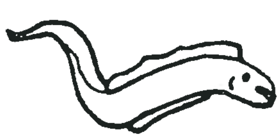
> **What would be the immediate, short term, medium term, and long term consequences on fish, invertebrate, and plant diversity in the kelp forest if hunters killed off the sea otters which eat the sea urchins which munch on the giant kelp?**

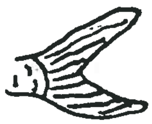
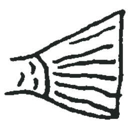
What would be the immediate, short term, medium term, and long term consequences on fish populations if their habitat became polluted with a toxic spill?

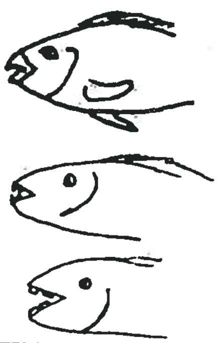
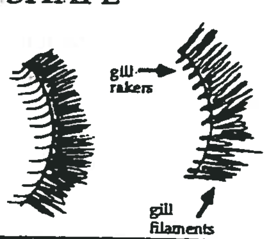
Debriefing

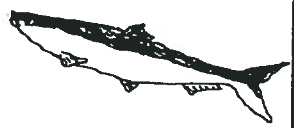
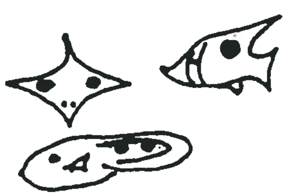
Have students debrief their favorite/least favorite part of the activity. What did they learn the most from? What was a waste of time? How would they change the activity if they were the teacher?

EXAMPLES OF FISH ADAPTATIONS

BODY SHAPE	DESCRIPTION	EXAMPLE
FUSIFORM 	streamlined and cylindrical; very fast and can swim continuously for long distances	bonita, mackerel, anchovy
DEPRESSED 	flattened from back to belly like a pancake; ambush prey with short bursts of speed; burrows into sand	skates, rays, goosefish
SPHERE 	rounded, globe-like; slow swimmers; may attract prey to them with light and lures	porcupine fish, puffer fish, anglerfish
RIBBON 	snake-like; slow swimmers but easily move through crevices; hide under rocks or in cracks, and ambush prey that comes too near their hideout	wolf eels, monkeyface eel
COMPRESSED 	flattened side to side; sharp, quick turns and very maneuverable; viewed head-on they almost seem to disappear	surf perch, opaleye, halibut, flounder

TAIL SHAPE	DESCRIPTION	EXAMPLE
LUNATE  (fastest)	fastest swimmers, maximum speed with minimum effort over long distances	marlin, mackeral, dolphinfish, swordfish
FORKED 	moderately fast, continuous swimmers	anchovy, herring
SQUARED 	very maneuverable, capable of bursts of speed for short distances	rockfish
ROUNDED 	very maneuverable, capable of bursts of speed for short distances	senorita, goby, flatfish
TAPERED  (slowest)	slow swimmers, use body undulations to swim	moray eel

MOUTH, TEETH, GILL RAKERS	DESCRIPTION	EXAMPLE
MOUTH ORIENTATION 	1. oriented upwards denotes surface feeder or feeds on prey above it; 2. downwards suggests bottom-grubber	1. stargazer, stonefish 2. sturgeon
MOUTH SIZE & SHAPE 	1. large jaws engulf prey; 2. jaws which can protrude suck in prey; 3. elongate jaws reach into crevices; 4. elongate lower jaw feeds on prey seen above	1. lingcod 2. rockfish 3. butterflyfish 4. halfbeak
TEETH SIZE & SHAPE 	1. fish eaters have pointed, knife-like; 2. snails and clam eaters have plate-like grinders and crushers; 3. choppers on plants and corals have fused, beak-like	1. barracuda 2. bat ray 3. parrotfish
GILL RAKERS SIZE & SHAPE 	1. comb-like gill rakers filter food; 2. large, coarse gill rakers protect gills when they eat from large prey items	1. anchovy 2. lingcod

COLOR PATTERNS	DESCRIPTION	EXAMPLE
CAMOUFLAGE	match surroundings to blend in and hide	halibut, cabezon
DISRUPTIVE COLORATION 	spots, stripes, and patches of color breakup and diffuse the actual outline	kelpfish, sergeant-major
COUNTER-SHADING 	dark back and lighter belly hides fish from predators as sunlight penetrates from above	anchovy
ADVERTISING 	1. warning to stay away from poisons or spines; 2. attract mates, defend territories 3. clean other fish	1. lionfish 2. California Sheephead 3. senorita
DECEIVING 	1. false eyespots confuse predators into attacking the wrong end or miscalculating size/shape of fish; 2. fish resembles objects of no interest to enemies; 3. fish mimics something: a. helpful like a cleaner or b. dangerous like a poisonous seasnake	1. Big Skate, butterfly fish 2. stonefish, sargassum fish 3. a. blenny, b. snake-eel

The following table compares the adaptations of four diverse fish:

FISH FEATURE CHART

	MACKEREL	ROCKFISH	FLATFISH	ANCHOVY
BODY SHAPE	FUSIFORM	COMPROMISE-CHUNKY HEAD, SLENDER BODY	COMPRESSED	FUSIFORM
TAIL SHAPE	CRESCENT	SQUARISH OR ROUNDED	ROUNDED	FORKED
MOUTH, TEETH, GILL RAKERS	LARGE MOUTH, SHARP TEETH, NOT FINE GILL RAKERS	FAIRLY LARGE MOUTH & SHARP TEETH, NOT FINE GILL RAKERS	SMALL MOUTH, SHARP TEETH, NOT FINE GILL RAKERS	EXTREMELY LARGE MOUTH, TINY TEETH, FINE GILL RAKERS
COLORATION PATTERNS	COUNTER-SHADING	DISRUPTIVE & CAMOUFLAGE	CAMOUFLAGE	COUNTER-SHADING

Based on the above table, the fish can be predicted to have the following lifestyles:

food	fish	fish & crabs	fish, shrimp & clam siphons	microscopic plankton
habitat	open ocean	kelp forest, rocks	bottom, sand covered	open ocean

The **mackerel** appears to be an open water fish based on its countershade coloration. Its streamlined body and crescent shaped tail denotes it to be an active, fast swimmer. Its sharp teeth indicates it to be a fish eater.
The **rockfish** is camouflaged to match kelp growing on rocks. The chunky body and squared tail shows it can achieve only short spurts of speed to capture prey that comes too near its hiding place and large mouth.
The **flatfish** is extremely well camouflaged while lying on a sandy bottom. These fish are flattened side-to-side (compressed) with both eyes on one side of their head. It uses quick bursts of speed achieved with its rounded tail and strong tail muscles to capture small fish and shrimp that swim too near.
The **anchovy** is a fast swimming, open water fish based on its countershade coloration, streamlined body, and forked tail. The extremely large mouth, tiny teeth and very fine gill rakers allow it to filter-feed on microscopic plankton.
10/94

FISH FEATURE CHART

	Fish #1	Fish #2	Fish #3	Fish #4
BODY SHAPE				
TAIL SHAPE				
MOUTH, TEETH, GILL RAKERS				
COLORATION PATTERNS				
I PREDICT: FOOD: HABITAT:				
TWO OTHER INTERESTING FEATURES				
NAME OF FISH (Look it up!)				

36
BONY FISH DIVERSITY: PELAGIC FISHES

In the marine environment, fish live either in the water column, or on the ocean bottom. The body structure of the fish is specially adapted to life in one or the other of these environments. Fish that live in the sunlit, open waters, constantly free of the ocean bottom, are called *pelagic fishes.*

All of the fish illustrated here have a similar coloration pattern: dark on the top half, light colored on the bottom. It is suggested that the body of each fish be colored a dark gray-blue on the top half, and a silver or white on the bottom. Structures B through H may be colored the same colors that you used on the previous plate on fish morphology. Color each fish separately as it is discussed in the text.

The flying fish has the capability of becoming airborne, gliding just above the water's surface. If pursued from below by a predator, the flying fish breaks the surface of the water at speeds up to 40 miles per hour. The enlarged *pectoral fins* are stretched out at right angles to the body, and act as a gliding "wing." The *pelvic fins* are similarly enlarged to increase the gliding surface. When the flying fish begins to slow down, it alights on the water, tail first, and the enlarged lower lobe of the *caudal fin* rapidly sculls the surface at a rate of 50 beats per second. The fish picks up speed and it again becomes airborne. Flying fish are found in the warm waters of the Atlantic and Pacific oceans. The largest species reaches a length of 46 centimeters, and is fished commercially off the southern California coast.

The northern herring is a very important small fish feeding on zooplankton, especially copepods. The northern herring occurs on both sides of the Atlantic; a subspecies lives in the Pacific Ocean. The herring forms tremendous schools (shoals) comprising billions of fish. These schools migrate to shallow breeding grounds, where, on the Atlantic grounds alone, two to three million tons of herring are caught yearly. Young herring are canned and sold as sardines; the older fish may reach a length of 0.3 meters, and are either canned or used for oil. Ownership of fishing rights to herring breeding grounds is highly contested, and several European contries have come close to war over this issue.

The swordfish is found in tropical and warm temperate seas worldwide. It is a continuous swimmer, following schools of mackerel, herring, and sardine. The swordfish swims through a school of fish, thrashing its upper *jaw,* or *bill,* and stuns the fish, which it then eats. The swordfish's *bill* may be as large as one third of the fish's entire body length, which averages 1.8 to 3.6 meters. Some swordfish as large as 6 meters have been taken.

The streamlined tapering of the swordfish makes it an excellent swimmer. The swordfish lacks pelvic fins, and the long, low-slung *pectoral fins* are kept folded against the body during rapid swimming. The *dorsal fin* is tall and remains permanently erect. The rigid *caudal fin* is lunate, or crescent shaped, for maximum swimming efficiency; the *caudal* area is strongly reinforced by a bony *keel.*

The sunfish is highly compressed (flattened laterally), and is a slow swimmer. This fish grows to be quite large (3–4 meters) and is the heaviest of the bony fish at 2,000 kilograms (4,400 pounds). The sunfish is usually seen on the surface of the water "sunning" itself on its side, slowly flapping its small *pectoral fins.* Recent studies indicate, however, that the sunfish normally lives quite deep in the ocean's waters, and that those fish seen on the surface are actually quite abnormal.

The sunfish lacks pelvic fins, and the *anal* and *dorsal fins* are very large and set well back on the *body,* where they provide the swimming thrust. The *caudal fin* exists as a narrow band, but is not effective in swimming. The sunfish feeds on jellyfish and other small planktonic forms.

The albacore is a small tuna that averages 4.5 kilograms (10 pounds) and is highly prized as a sport and commercial fish. Albacore schools are found in the Atlantic and Pacific, where they range into temperate waters and spawn near the equator. Like the swordfish, the albacore is a continuous swimmer, with a rigid lunate *caudal fin* and reinforcing *keel.* Besides the *anal* and *dorsal fins,* a series of smaller "finlets" are present and add to the hydrodynamic efficiency of the fish. The long *pectoral fins* are a unique feature of the albacore among the tuna family.

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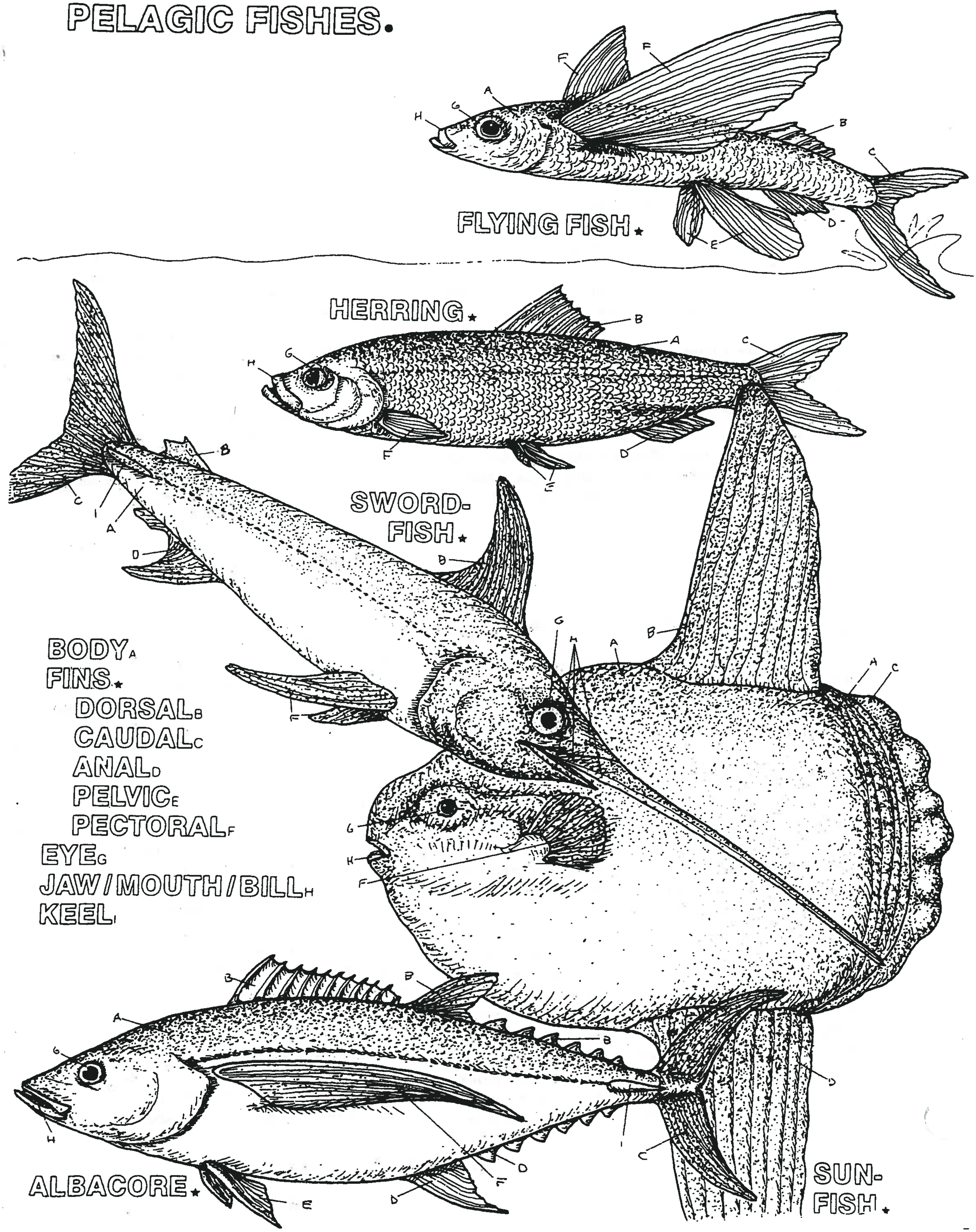
PELAGIC FISHES.



37

BONY FISH DIVERSITY: BOTTOM DWELLERS

Fish that live on, or very close to, the bottom (benthic fishes) do not need a streamlined body form for continuous swimming. This plate considers the body modifications of the tidepool sculpin, the sea robin, the stargazer, and the highly modified starry flounder.

Color each fish as it is discussed in the text. The body color varies in these species, but generally, they are a dark gray or brown in the stippled areas, and light colors elsewhere. Structures B through H are, again, the same colors as on the two previous plates. The electric organs of the stargazer are located under the skin; they should receive a separate color, and then be colored over.

The tidepool sculpin is a small (8 cm) fish, commonly found in Pacific coast tidepools of the United States. The sculpin forages for small crustaceans and other invertebrates among the rocks and algae of tidepools. Its coloration varies from mottled reds to greens and grays, and this mottled coloration breaks up its profile against the heterogeneous background. The sculpin usually sits motionless on its enlarged *pectoral fins*, but it can dart about rapidly in the water for short distances. Tidepool sculpins are representative of a number of small, elongate, relatively unspecialized benthic fishes (such as blennies, clinids, and gobies), all of which frequent rocky areas.

The sea robin has a large head, encased in an armor of rough, bony plates. Sea robins walk along the bottom using the first three rays of their *pectoral fins*, balancing the *body* using the remainder of the *pectoral* and *pelvic fins*. These three rays are articulated, and the fish uses them somewhat like fingers, pulling itself along and turning over rocks to uncover the crustaceans and molluscs on which it feeds. Sea robins are usually found on sand or sand–mud bottoms, at depths between 19 and 45 meters. Species occur in most oceans except the very coldest; they are generally small, although some large species grow to 1 meter in length. In places where they occur abundantly, sea robins are sometimes fished commercially.

The stargazer, a medium-sized fish (up to 51 centimeters), is a poor swimmer and usually lies buried in mud or sand. The Greeks called them "holy fish" because their small *eyes*, set on top of a rather square head, seemed to look toward the heavens. Some stargazer species have a fleshy lure attached to the floor of their large *mouth*. The lure attracts fish to within striking distance of the stargazers' *electric organs* whose discharge then stuns the prey. The *electric organs*, located behind the *eyes*, are thought to be derived from eye muscles and the optic nerve; they are capable of producing a stunning shock of 50 volts.

Another characteristic of these fishes is the presence of poisonous spines (not shown), located just behind the operculum and above the *pectoral fins*. These spines are grooved, with poison sacs at their base. Some species are believed to have a poison that can cause death in humans.

A far more benign, but equally specialized fish is the starry flounder which is a member of the family of left-eyed flatfish: both *eyes* are located on the left side of the fish. During its larval development, the right *eye* gradually migrates from its normal position to the other side of the *body*, while the *mouth* remains in the normal position. These fish are highly compressed and lie on one side on sandy bottoms, often with only their *eyes* and opercular opening uncovered. When the flounder swims, it does so in a sideways position. The starry flounder is very common in shallow, temperate waters of the Pacific, and is often found in nearly fresh water, especially when young. They grow to lengths of 90 centimeters and weigh as much as 9 kilograms (20 lbs). Starry flounders, unpigmented on their underside, get their name from the stellate scales that cover their body.

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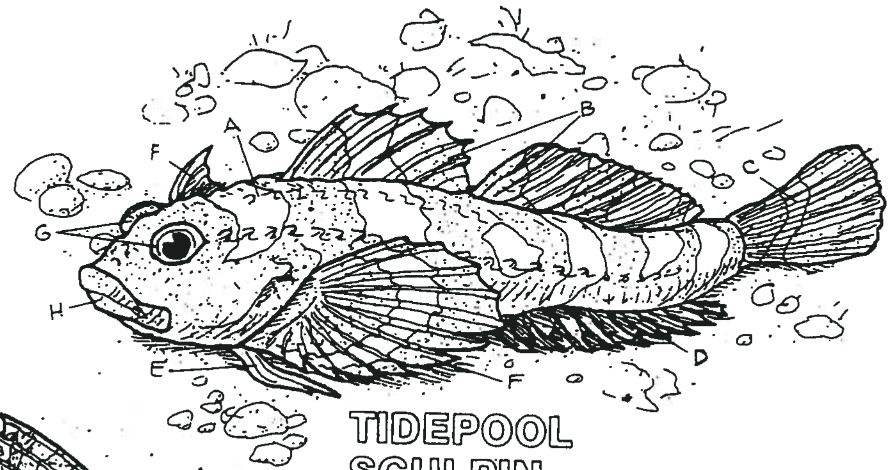
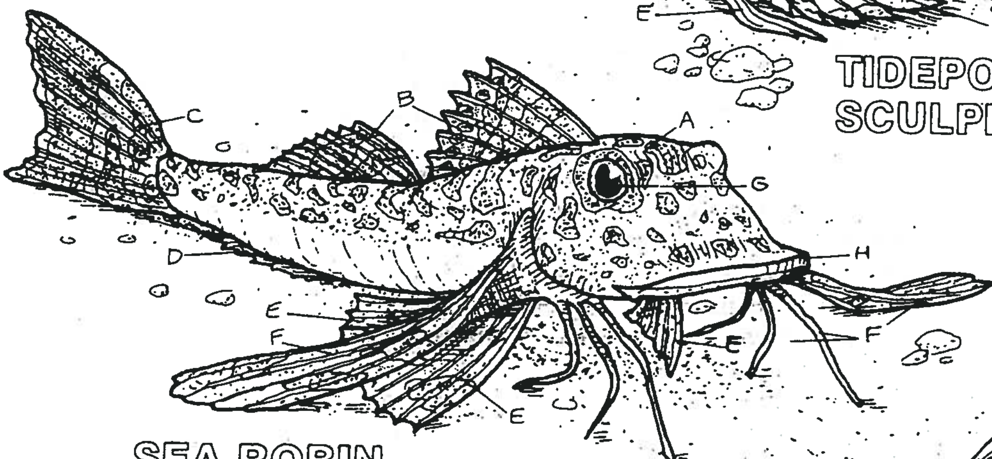
BOTTOM DWELLERS.

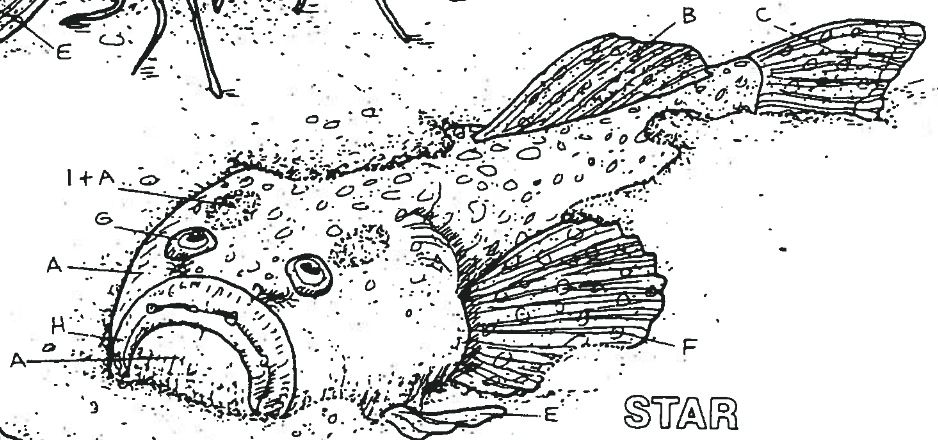
BODY A
DORSAL FIN B
CAUDAL FIN C
ANAL FIN D
PELVIC FIN E
PECTORAL FIN F
EYE G
JAWS/MOUTH H
ELECTRIC ORGANS I



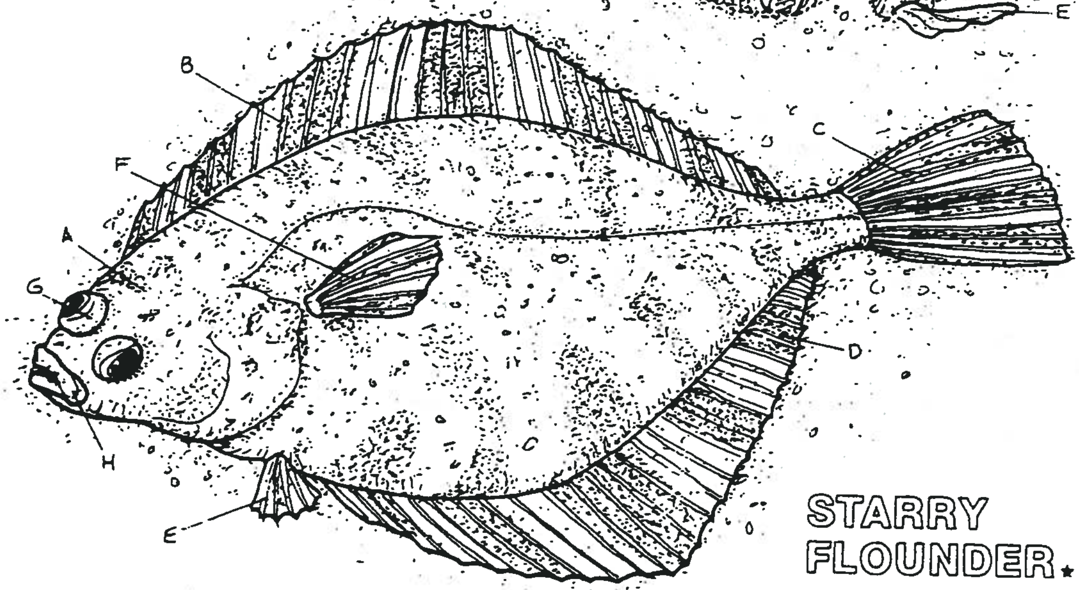
TIDEPOOL SCULPIN*



SEA ROBIN*



STAR GAZER*



STARRY FLOUNDER*

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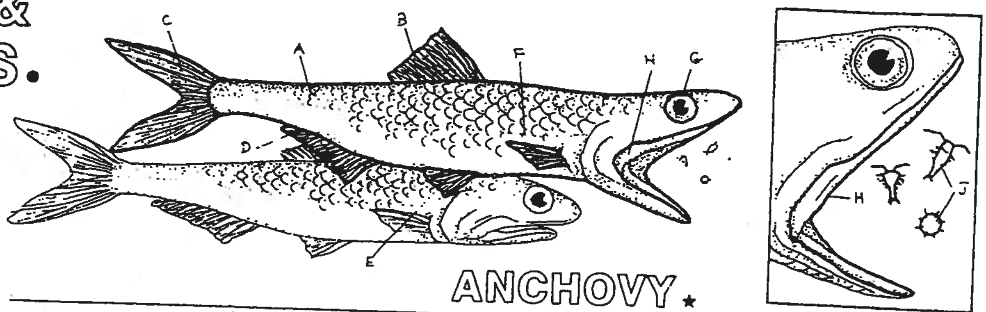
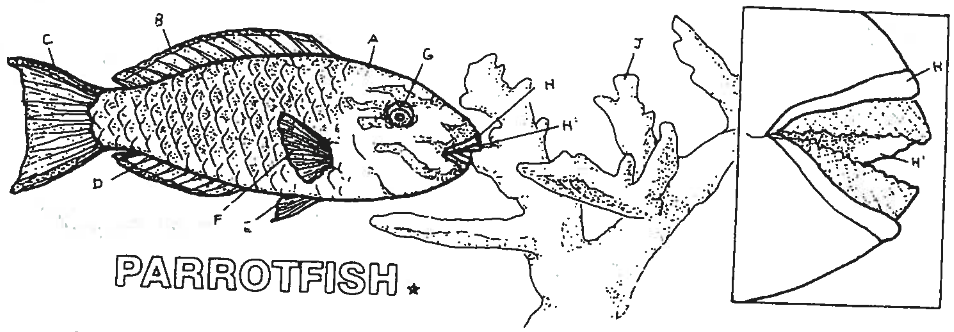
GRAZERS & GRUBBERS.

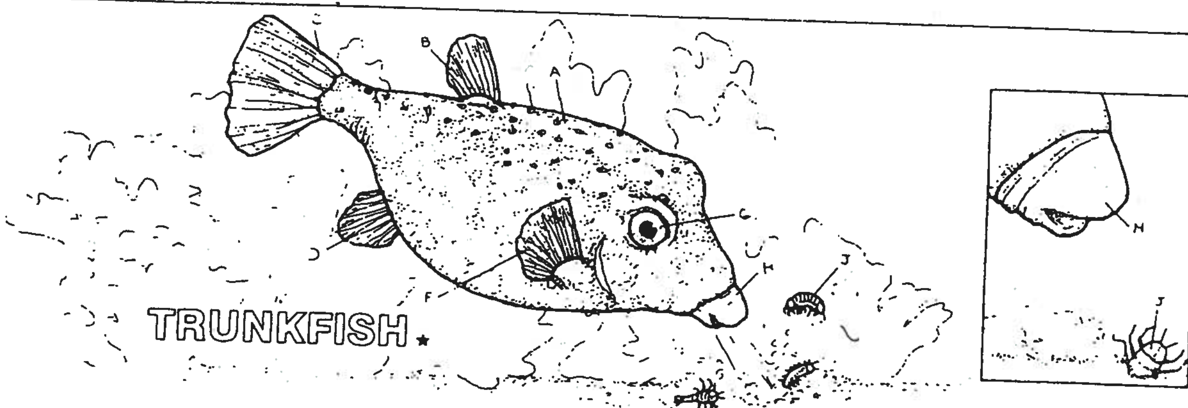
BODY A
FINS ★
- DORSAL B
- CAUDAL C
- ANAL D
- PELVIC E
- PECTORAL F

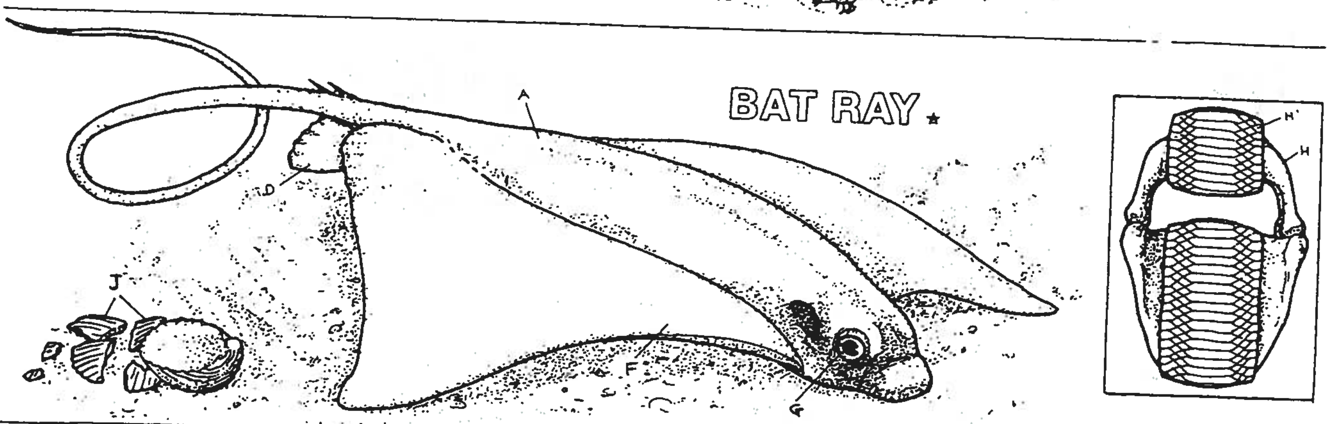
EYE G
JAWS/MOUTH H
- TEETH H'

BARBELS I
PREY J ★

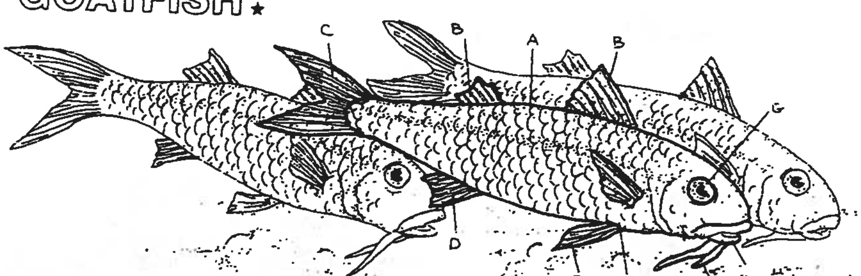








GOATFISH ★



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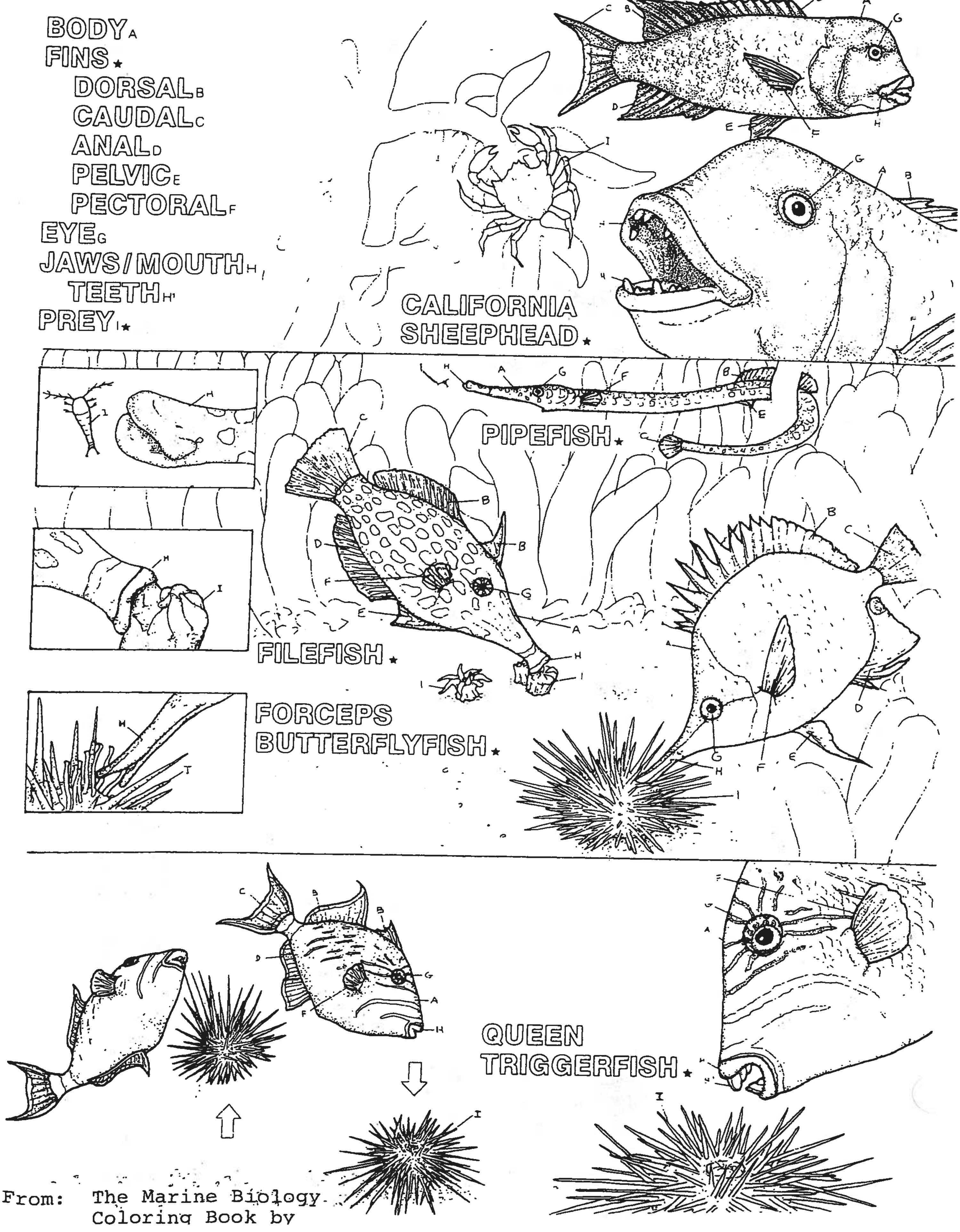
PICKERS, PROBERS & SUCKERS.

BODY A
FINS ★
DORSAL B
CAUDAL C
ANAL D
PELVIC E
PECTORAL F
EYE G
JAWS/MOUTH H
TEETH H'
PREY I ★



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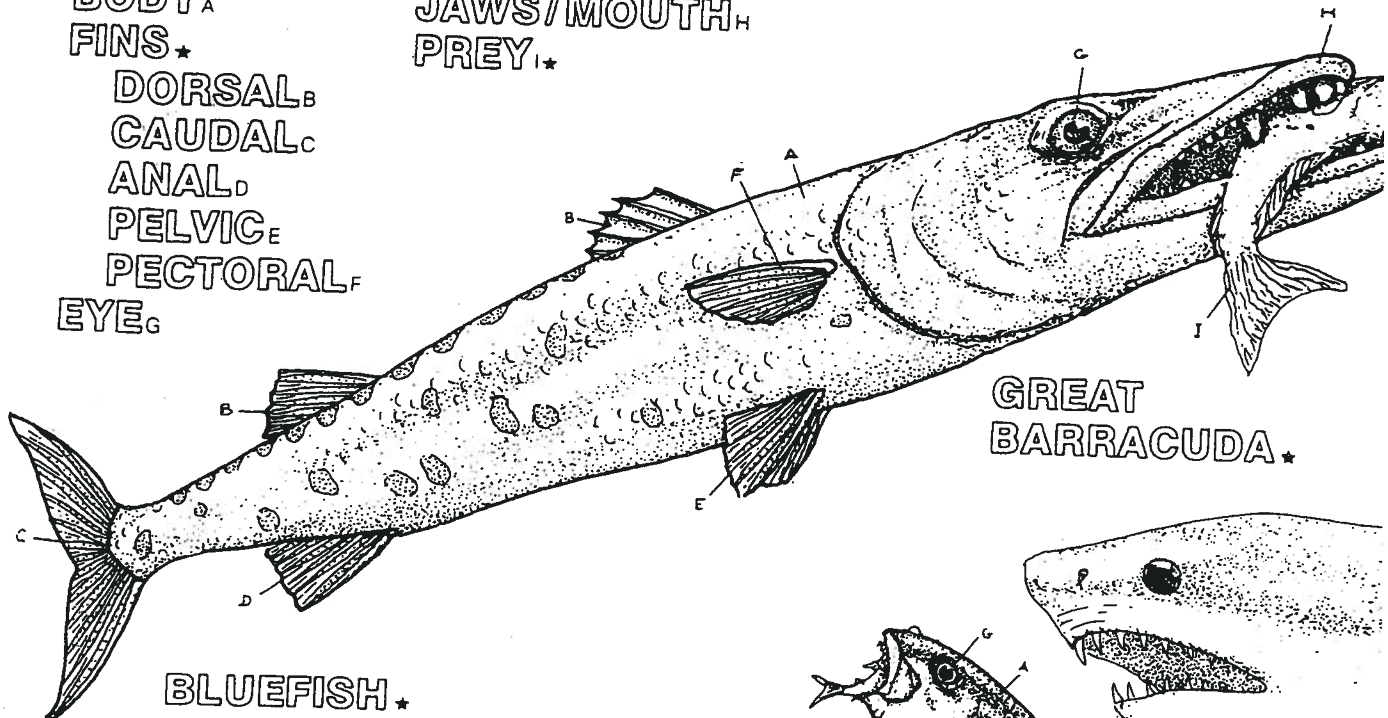
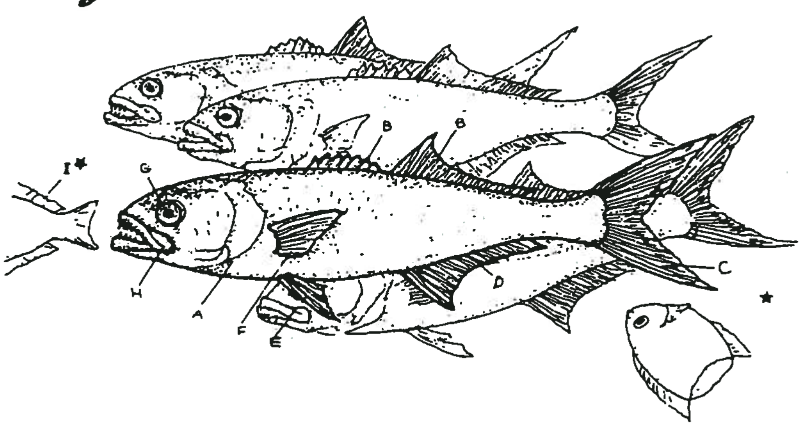
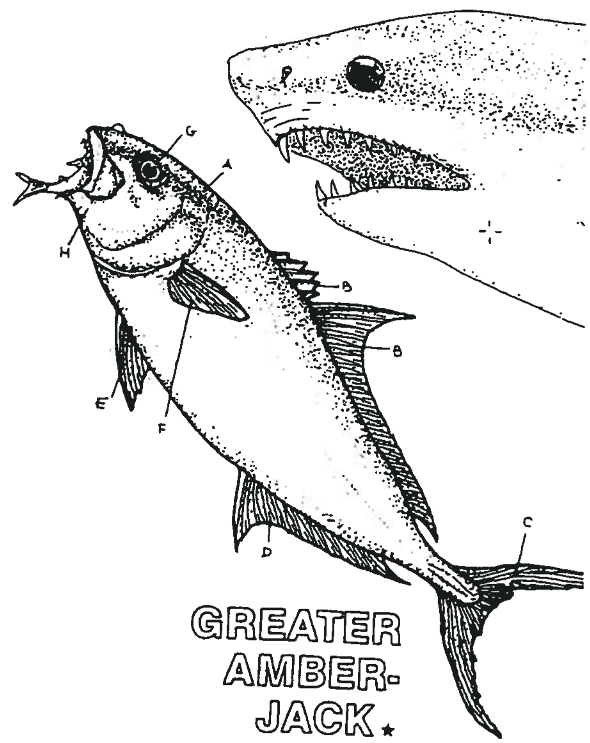
ATTACKERS & AMBUSHERS.

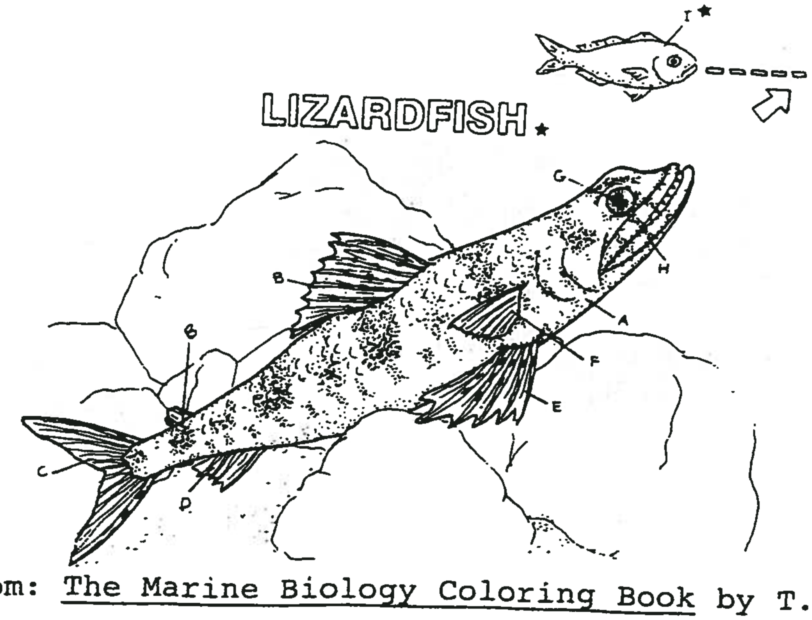
BODY A
FINS ★
- DORSAL B
- CAUDAL C
- ANAL D
- PELVIC E
- PECTORAL F

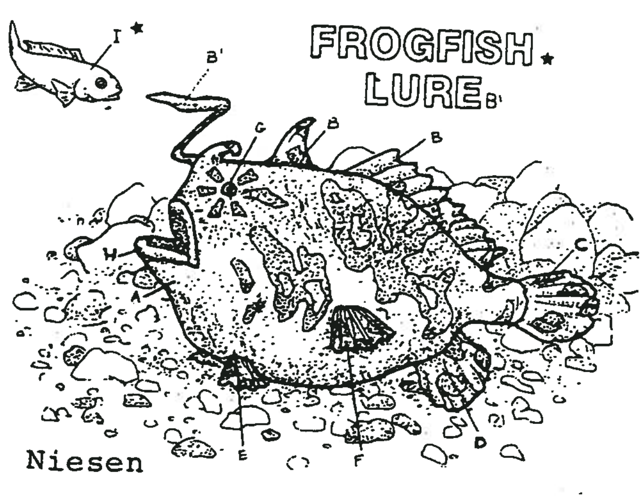
EYE G
JAWS/MOUTH H
PREY I ★









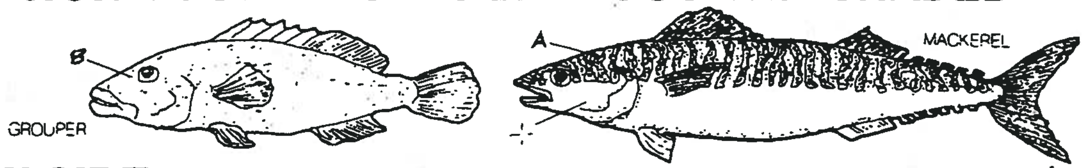


From: The Marine Biology Coloring Book by T. Niesen

THE CRYPTIC ONES.

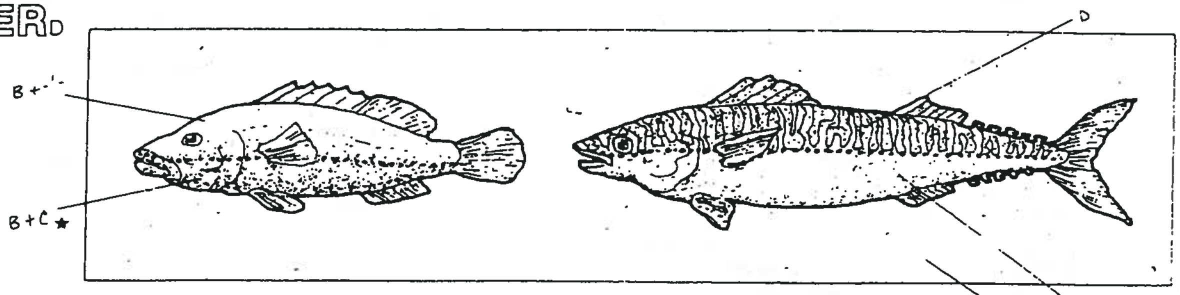
OBLITERATIVE COUNTERSHADING★

NON-COUNTERSHADED B   COUNTERSHADED A



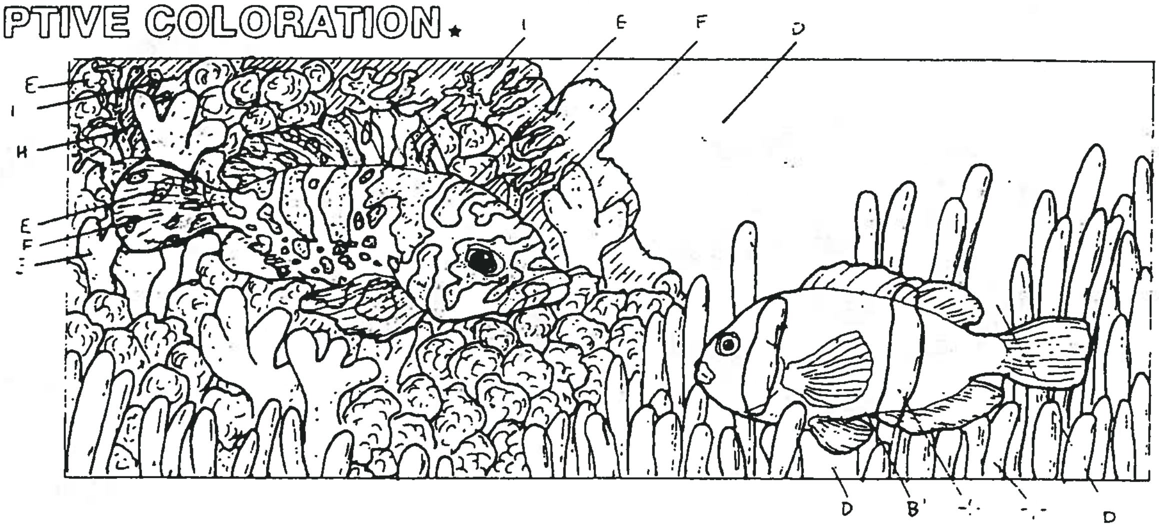
OUT OF WATER UNDER AMBIENT LIGHT

SHADOW SIDE C★
WATER D

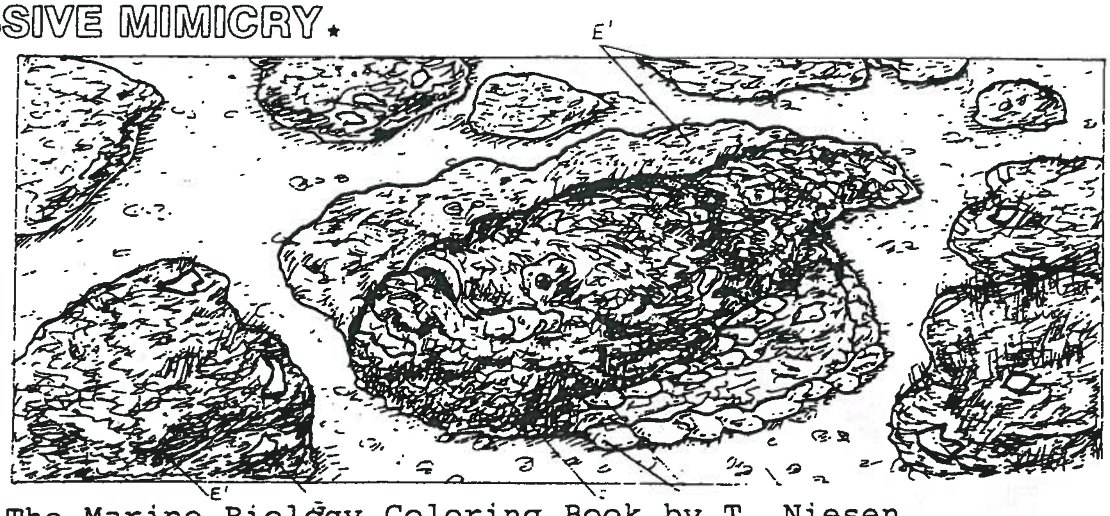


AS SEEN IN THE WATER WITH LIGHT FALLING FROM ABOVE

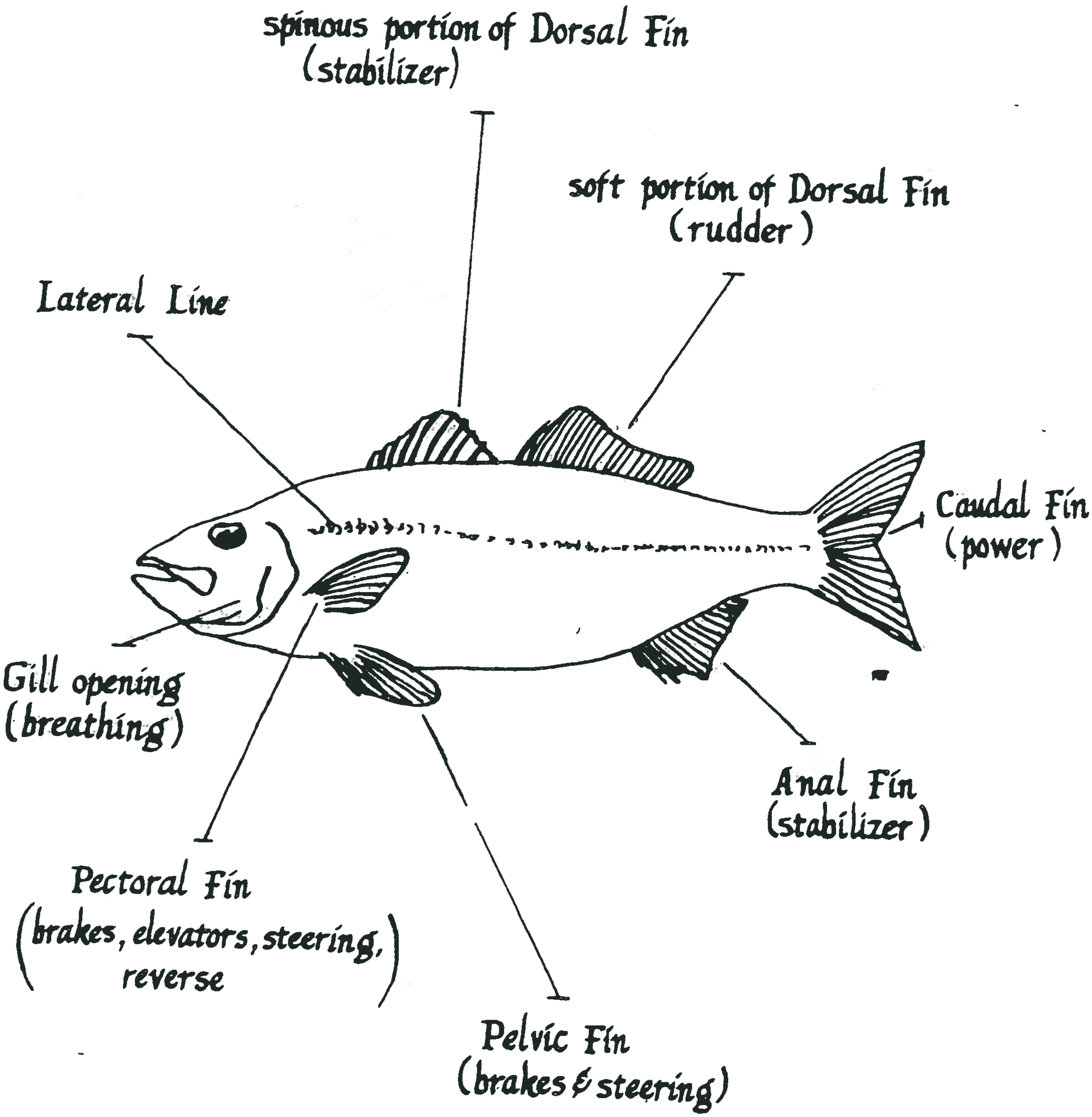
DISRUPTIVE COLORATION★



AGGRESSIVE MIMICRY★



From: The Marine Biology Coloring Book by T. Niesen

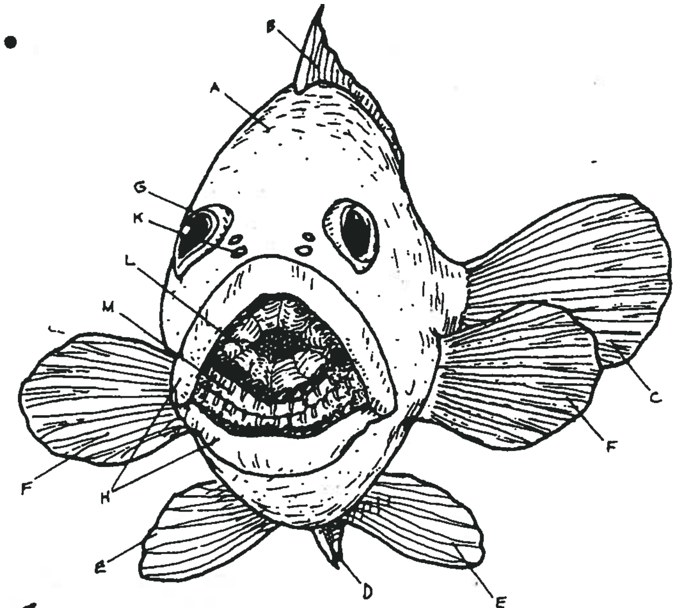


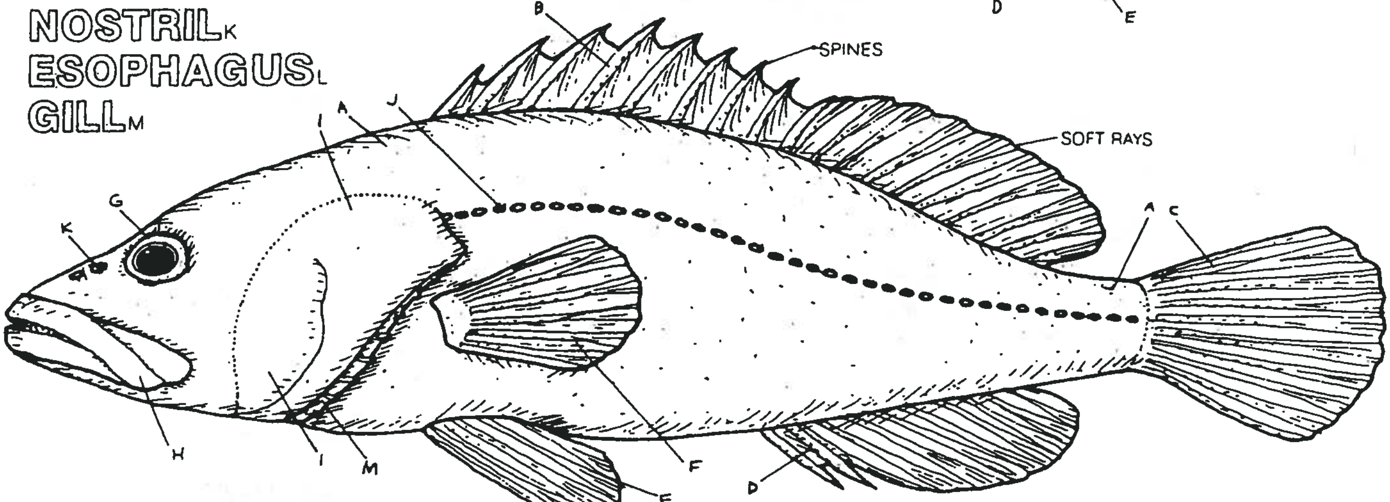
From Identifying Fish in the Estuary, Discovery Voyages

FISH MORPHOLOGY•

BODY A
FINS ★
- DORSAL B
- CAUDAL C
- ANAL D
- PELVIC (2) E
- PECTORAL (2) F

EYE G
JAWS/MOUTH H
OPERCULUM I
LATERAL LINE J
NOSTRIL K
ESOPHAGUS L
GILL M





From: The Marine Biology Coloring Book by T. Niesen

COMPARISON OF STRUCTURE:

BRAIN A
OLFACTORY LOBE A'
SPINAL CORD A²
NOSTRIL B
TONGUE C
GILL D
  GILL FILAMENT D'
  GILL RAKER D²
HEART E
KIDNEY F

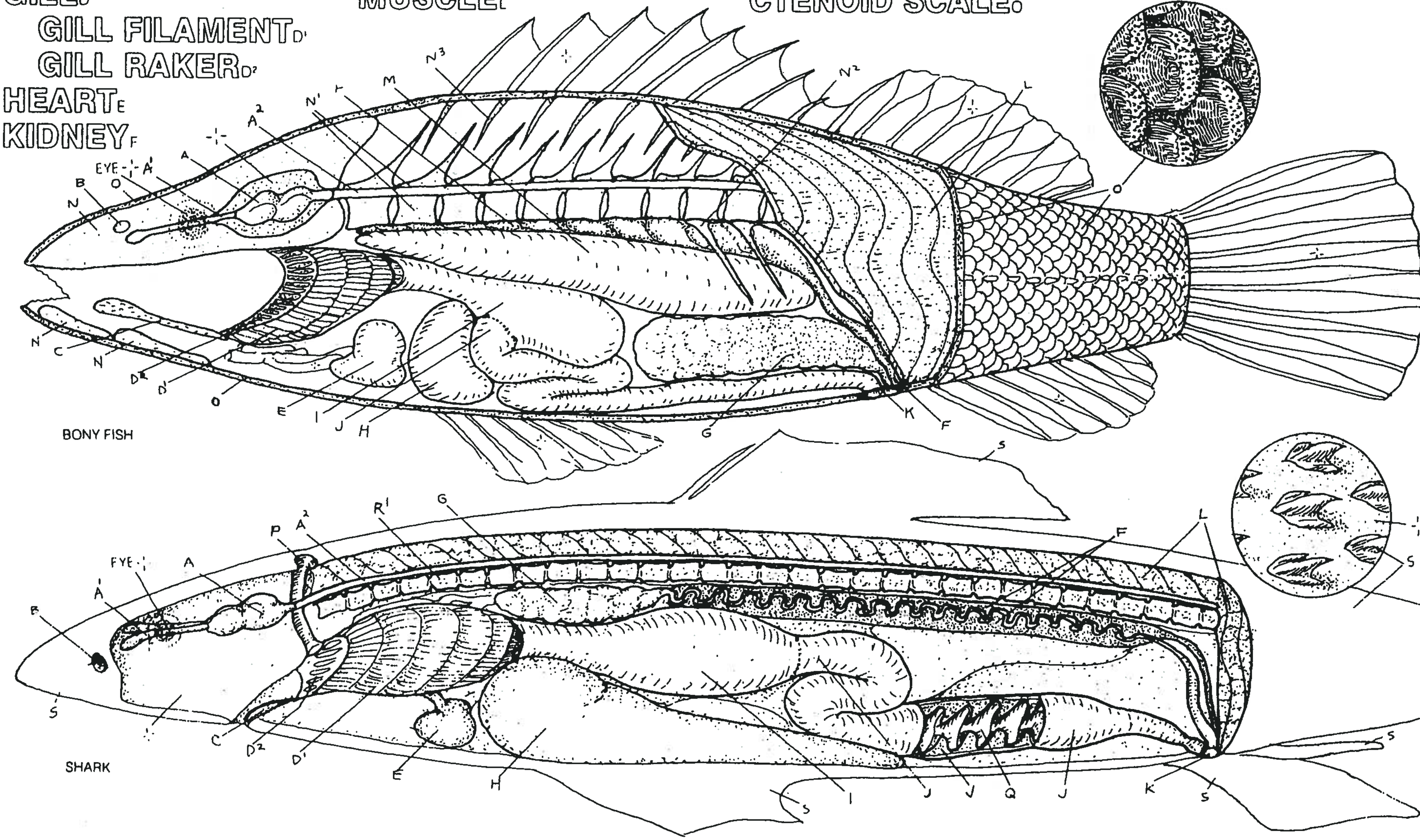
GONADS G
LIVER H
STOMACH I
INTESTINE J
ANUS K
MUSCLE L

BONY FISH.

SWIM BLADDER M
BONE N
  VERTEBRA N'
  RIB N²
  FIN SUPPORT N³
CTENOID SCALE O

SHARK.

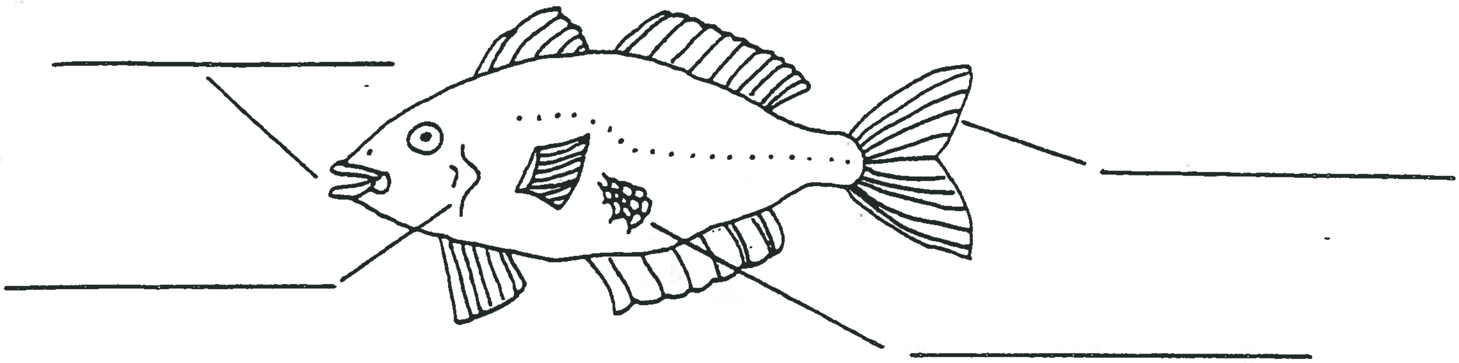
SPIRACLE P
SPIRAL VALVE Q
CARTILAGE R
  VERTEBRA R'
PLACOID SCALE S



From The Marine Biology Coloring Book

ANATOMY WORKSHEET

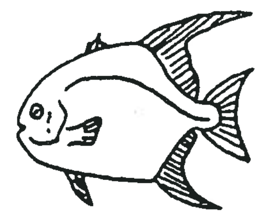
ACTIVITY 5



1. Study the picture above. Use the words below to fill in the blanks:

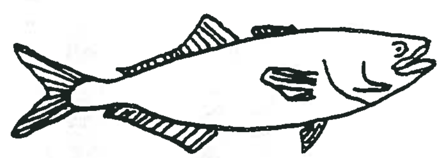
Tail Fin
Scales
Gills
Mouth

2. What body parts are used to help the fish:



a. breathe ______________________________

b. swim ______________________________



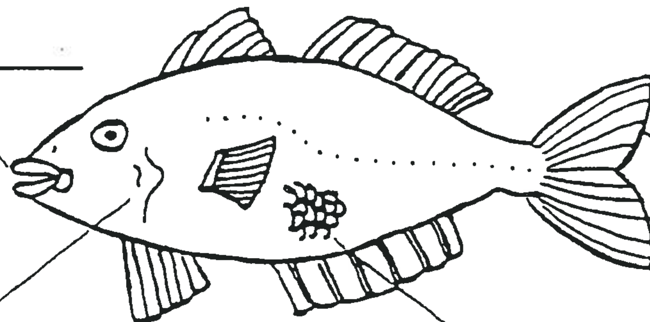
c. protect its body ______________________________

3. Fish come in many shapes and sizes. Why do you think some fish are round and flat? Why are some long and torpedo shaped?

From Beach Treasures!, Virginia Institute of Marine Studies

ANATOMY WORKSHEET (teacher's guide) ACTIVITY 5

MOUTH



Tail Fin

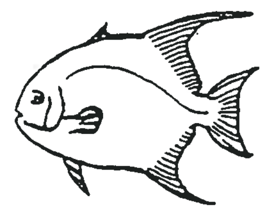
Gills

Scales

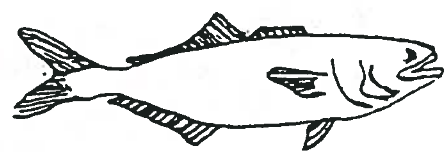
1. Study the picture above. Use the words below to fill in the blanks:

   Tail Fin
   Scales
   Gills
   Mouth

2. What body parts are used to help the fish:



   a. breathe Gills



   b. swim Fins

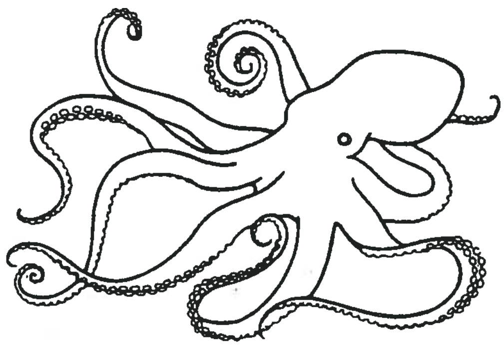
   c. protect its body Scales

3. Fish come in many shapes and sizes. Why do you think some fish are round and flat? Why are some long and torpedo shaped?

Have a discussion with your students about body shape and lifestyle. Fish that live in different parts of the ocean have different body shapes. A bluefish (long and torpedo shaped) lives in the open ocean and eats other fish. It must be fast to catch it's prey and to escape predators in this open environment. He is streamlined and built for speed. The spadefish (round and flat) lives closer to shore, usually in and around artificial reefs. Speed would be of little help in this environment, but maneuverability is important. The spadefish can maneuver around obstacles in the water (reef, pilings etc.) and hide from predators in small nooks and crevices.

Importance of Color

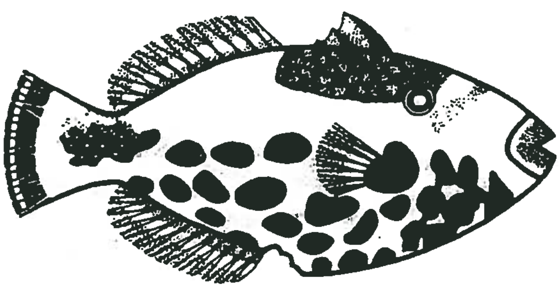
Coloration may help hide an animal or draw attention to its role in an animal community.



octopus

Camouflage

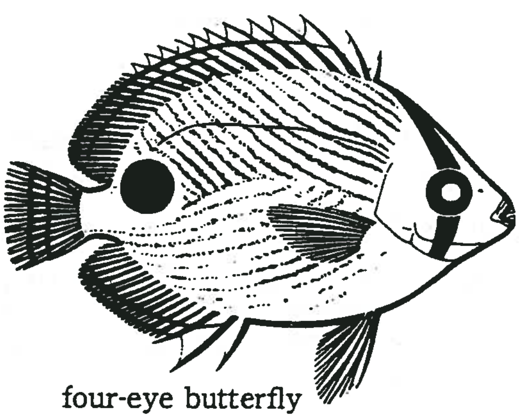
Camouflage coloration helps animals blend in with their surroundings. The octopus changes color instantly from black to gray to red to match its background. It can also change the texture of its skin, becoming bumpy or smooth to blend in with rocks and seaweeds.



clown triggerfish

Disruptive Coloration

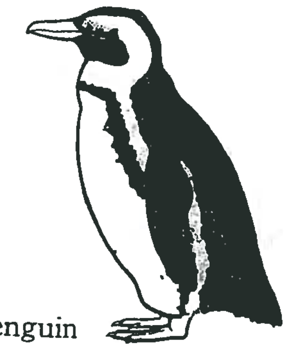
Spots and stripes break up the body shape of some fishes and conceal them against their backgrounds. This kind of camouflage, called disruptive coloration, is common in coral reef fishes.



four-eye butterfly

False Eye Spots

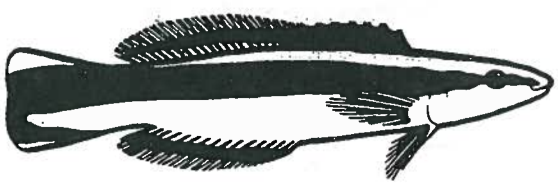
Unusual color patterns may hide vulnerable parts of an animal's body. The true eyes of a four-eye butterflyfish are hidden in a band of black, but near the tail are two prominent "false eyes." A confused predator may attack these instead of the real eyes, allowing the butterflyfish to escape in the opposite direction.



penguin

Countershading

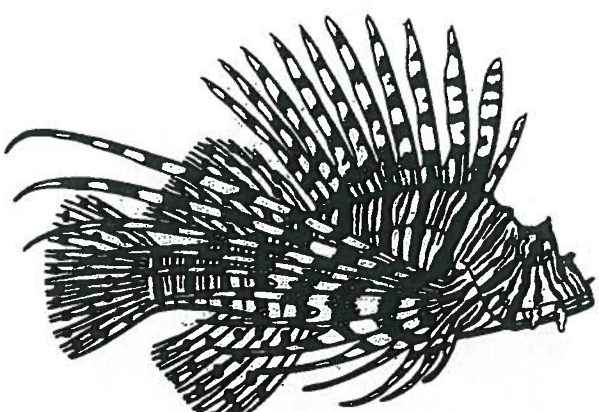
Many open ocean animals have dark backs and light bellies. This protective coloration is called countershading. Viewed from above, dark backs blend with the darkness of the deep ocean. From below, it is difficult for predators to see light bellies against bright sunlit surface waters.



cleaner wrasse

Advertising Coloration

Some animals have coloration that attracts attention and advertises a special service. Cleaner fishes help other fishes by removing harmful parasites from their skin. Predators recognize the bright color patterns of cleaners and do not harm them because of the useful service they perform.



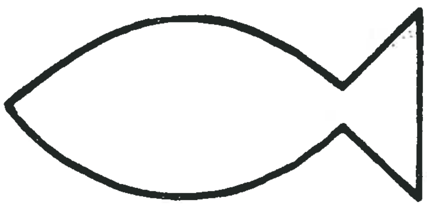
lionfish

Warning

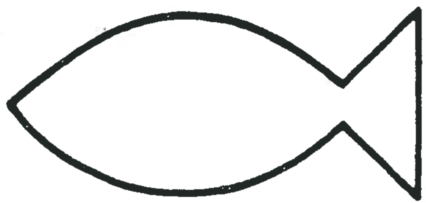
Some animals are so well protected with spines, poisons, and armor that their coloration is a warning for other species to stay away. The lionfish has brightly striped fins with poisonous spines that it displays to would-be attackers.

Worksheet: Coloration

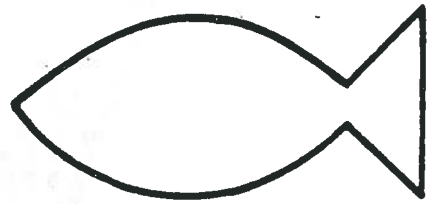
1. **Protective Coloration** helps animals survive in their natural habitats. Protect the fish below by giving them the proper coloration:



Countershading



Disruptive Coloration

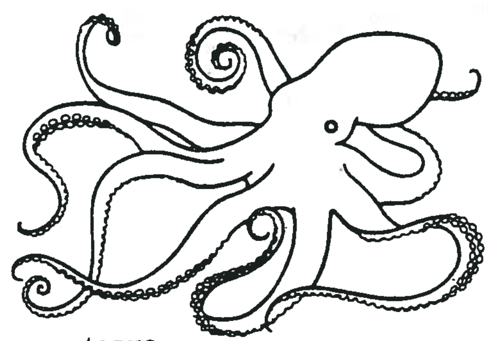


False Eye Spots

2. What is **Advertising Coloration** and how does it help an animal survive?

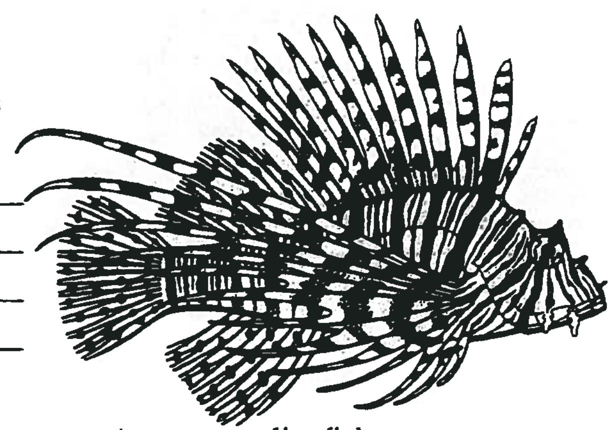
cleaner wrasse

3. What is **Camouflage** and how does it help an animal survive?



octopus

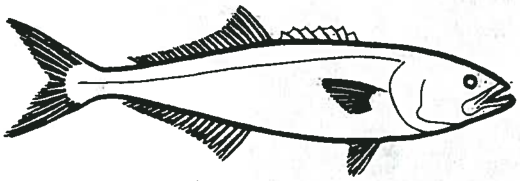
4. What is **Warning Coloration** and how does it help an animal survive?



lionfish

Importance of Shape

Body shapes give important clues about where fishes live and how they move.



bluefish

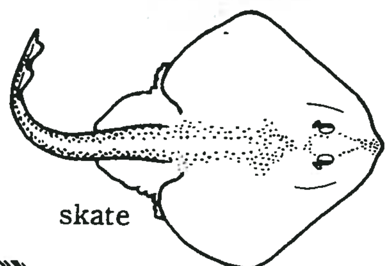
Fusiform: the swiftest of all fishes

Powerful tails help them chase prey and avoid predators. Many of them live in the open ocean and swim continuously, traveling thousands of miles in their lifetimes.

barracuda

Rod: elongated, arrow-like fishes

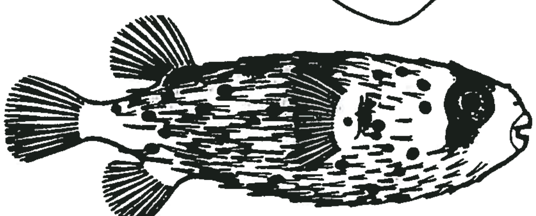
These hunters ambush their prey. They float motionless until a smaller fish swims near. Then they lunge out with lightning speed to seize their victim.



skate

Depressed: flat, pancake-shaped fishes

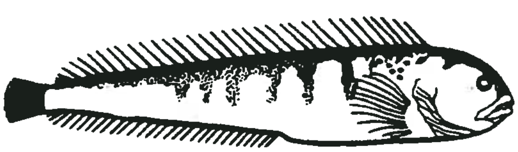
They use camouflage instead of speed for survival. To escape predators they burrow into the sand or mud. Many change the color of their skin to match their surroundings.



spiny puffer

Sphere: puffers and balloonfishes

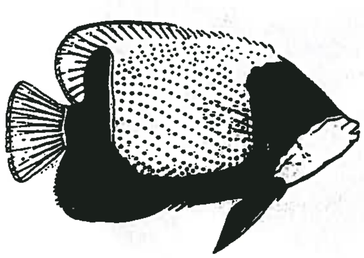
When threatened they fill their bodies with water or air, becoming too big to swallow. Some have spines all over their bodies for added protection.



wolffish

Ribbon: snake-like fishes

They are slow swimmers but move easily through cracks and crevices, under rocks and around aquatic plants. They are secretive, hiding from predators and ambushing prey that come too near their hiding places.

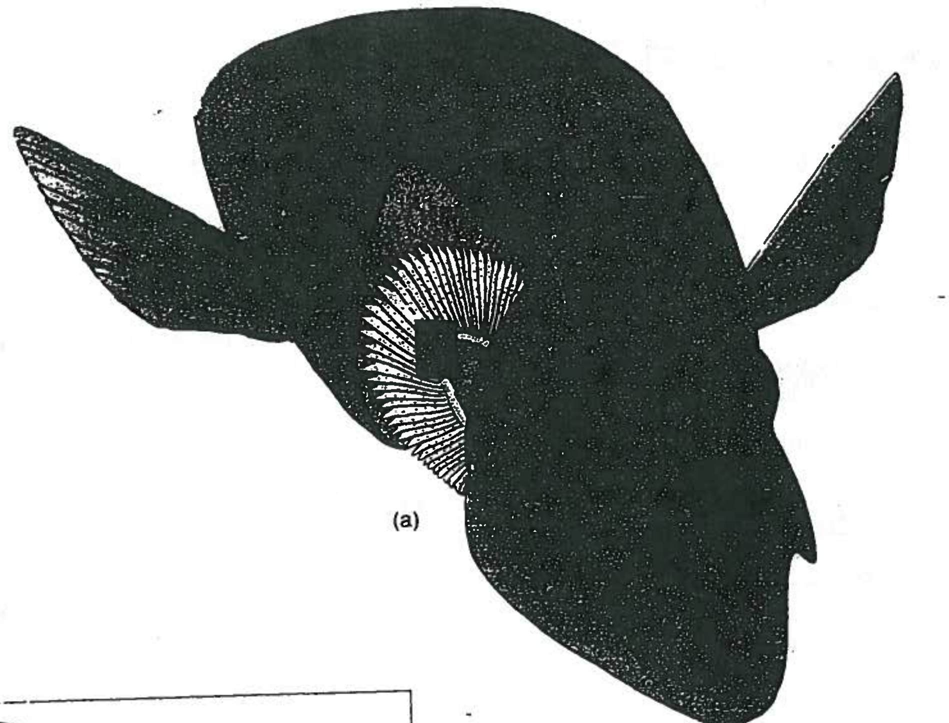


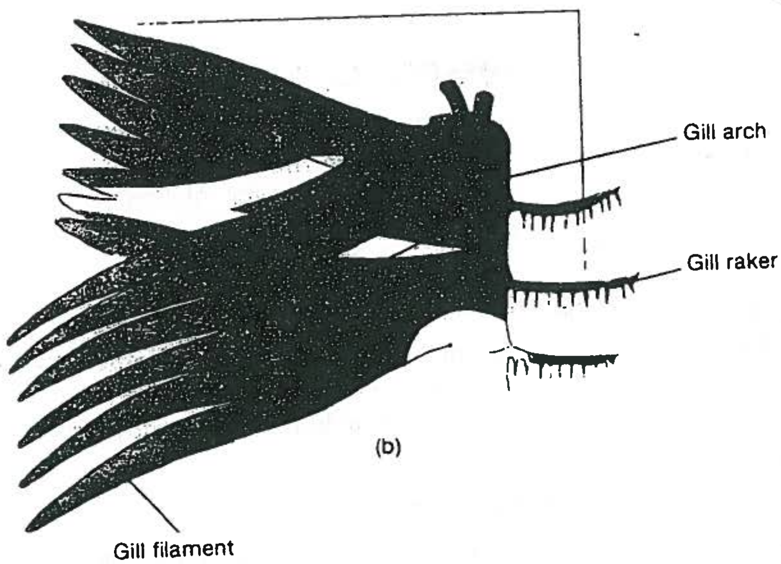
majestic angelfish

Compressed: fishes flattened from side to side

When viewed head-on these thin fishes almost seem to disappear. They are common on coral reefs. Their compressed bodies allow them to make quick sharp turns and dart in and out of hiding places.

Courtesy of New England Aquarium
From The Ocean Book, Center for Marine Conservation





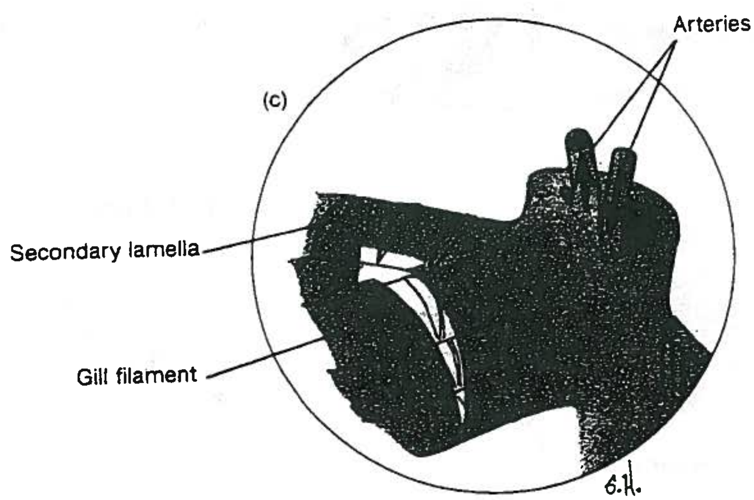
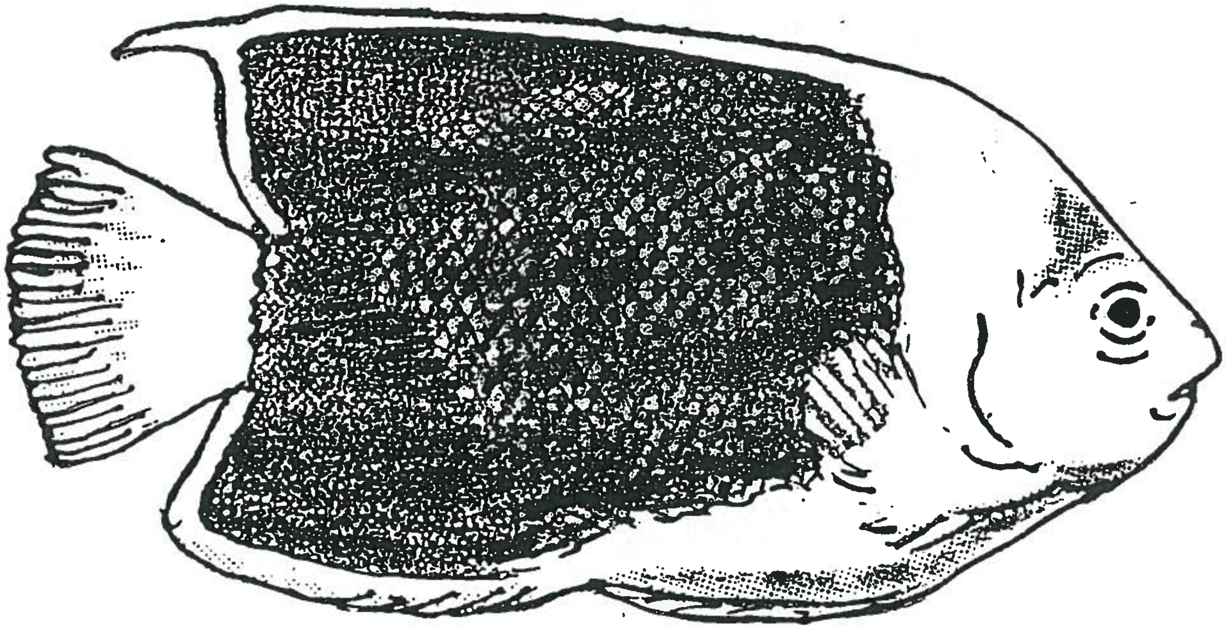
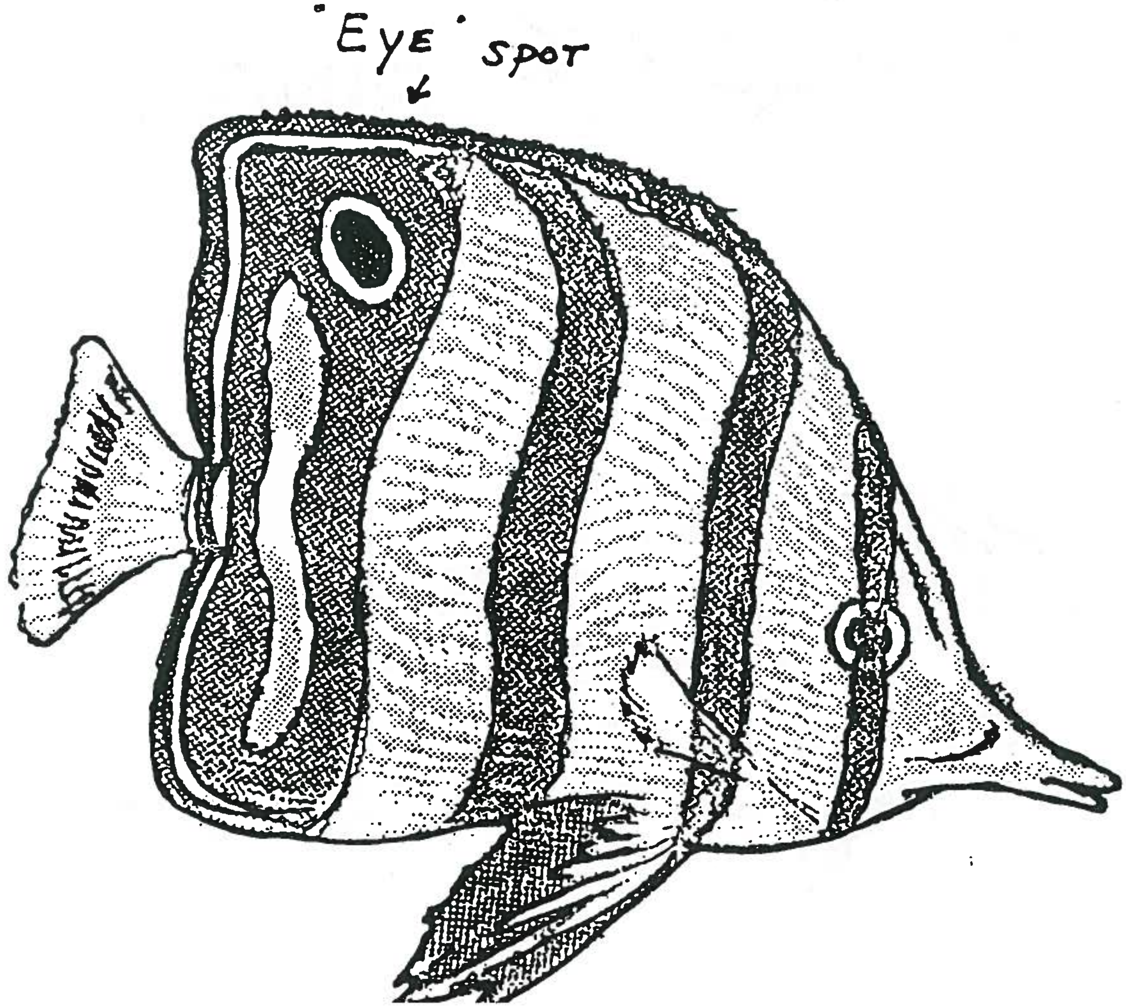


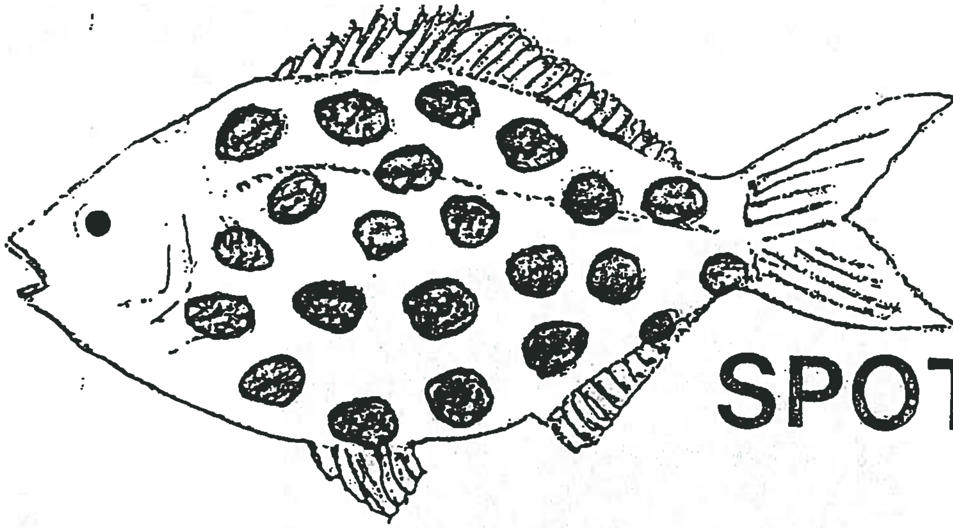
Fig. 10.9 Cutaway drawing of a mackerel showing the position of the gills (*a*). Broad arrows in (*b*) and (*c*) indicate the flow of water over the gill filaments of a single gill arch. Small arrows in (*c*) indicate the direction of blood flow through the capillaries of the gill filament in a direction opposite that of the incoming water.

From: <u>Biology of Marine Life</u> by J. Sumich

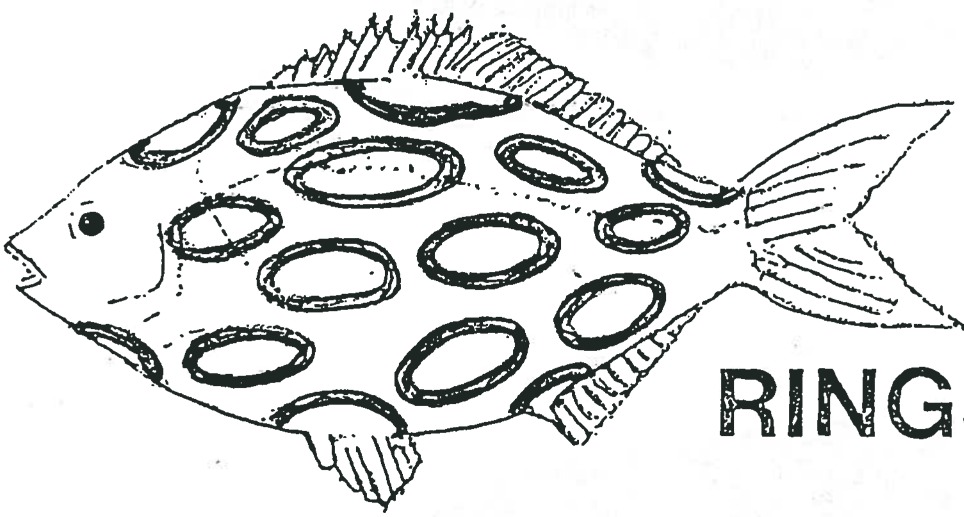
COLORATIONS



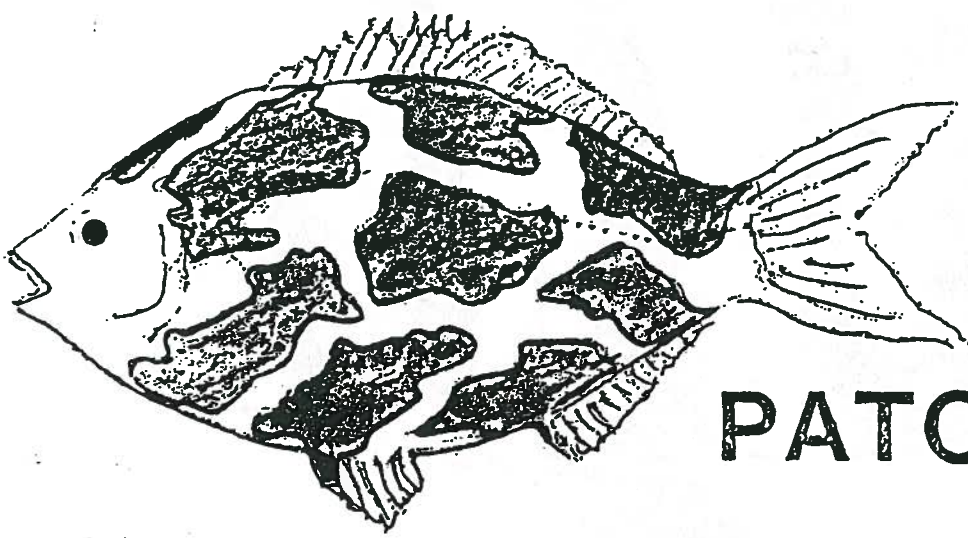




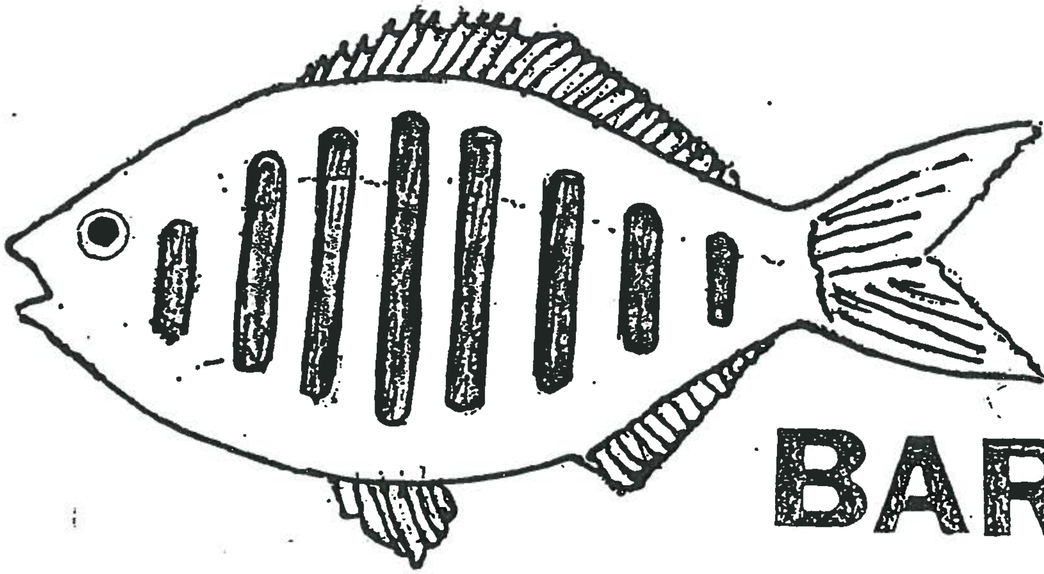
SPOTS



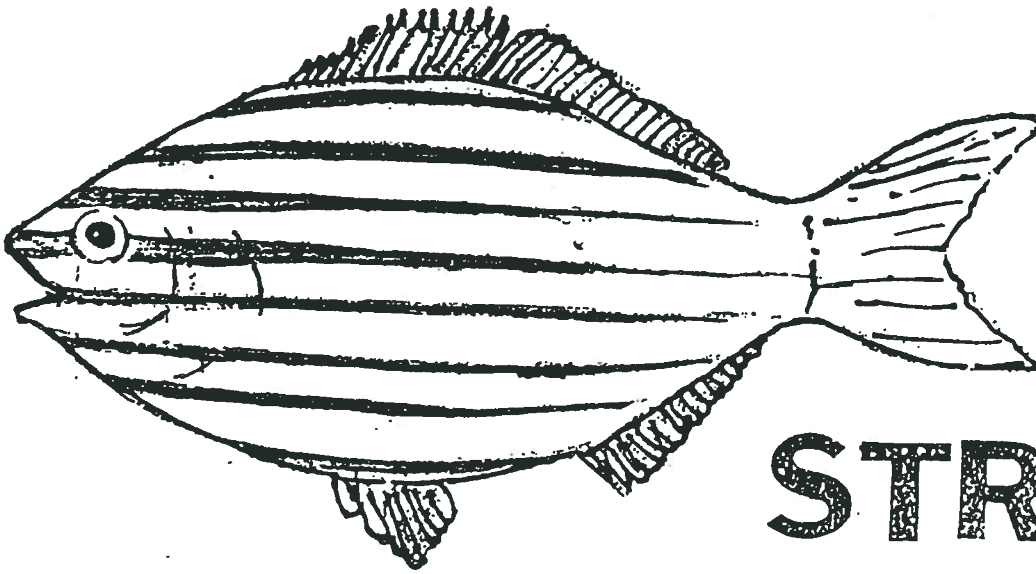
RINGS



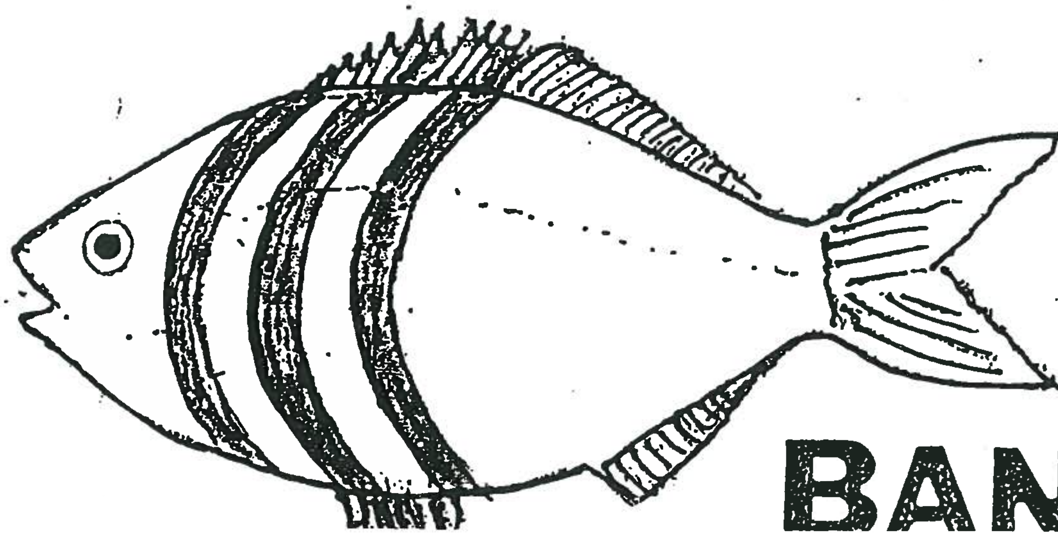
PATCHES



BARS



STRIPES



BANDS