LIFE IN THE OCEAN

The earth forms about 4.5 billion years ago. The geological evolution of the earth. Life appears about 3.8 billion years ago. The history of life on Earth is rather long. Since then life has undergone many changes and different kinds of organism have come and gone. Organisms range from extremely small microscopic animals to huge dinosaurs like the Titanosaurs – the largest animal that we know of. The blue whale is the largest animal in the world today.

CLASSIFICATION SYSTEMS

We need to know about these so that we can understand the basis on which organisms are grouped together Because of this enormous variation, there are literally millions of organisms that need to be named. Worse still, many languages and even dialects call the same kind of organism by different names. As a result, ultimately scientists decided to give animals a "scientific name" which would be constant among scientists of all nations and cultures. These scientific names come in two parts called a "genus" and "species" name, and this is known as the Linnaean system named after its inventor. For example, people are known as Homo sapiens. The genus name is always capitalized, the species name is not. (You should note at this point that there is an "s" at the end of sapiens, which is not a plural maker). The house cat is known as "Felis domestica"; Horseshoe crabs are called "Limulus polyphemus".

Species are normally defined as members of a group that can mate and produce viable offspring – that is to say, the offspring themselves are fertile. This is a good definition although it breaks own with organisms that do not reproduce sexually.

The genus level shows a close relationship between species. One might think of this as a group of animals that historically might have been a single species, but has developed enough variation that interbreeding and producing viable offspring is no longer possible.

Higher and higher levels of classification have been organized and we now often talk about a TAXONOMIC classification system in which there are levels of organization in which lower groups are "nested" into larger ones. Basically, the taxonomic levels are:

Level	Humans	Chimpanzees	Sea cucumber
Kingdom	animalia	animalia	animalia
Phylum	chordata	chordata	echinodermata
Class	mammalia	mammalia	holothuroidea
Order	primate	primate	synallactia
Family	hominid	pongid	stichopodidae
Genus	Homo	Pan	Stichopus
Species	sapiens	paniscus	herrmanni

From this you can see that humans and chimps are closely related, while humans and sea cumbers are related only at the level that they are both animals.

In addition to the levels listed above, there a sub levels (subphylum, subclass, suborder etc.). One sublevel in the chordates is "vertebrata" – animals with backbones. Super levels exist as well (superclass, superorder). In addition, there are infra forms that rank below the sub forms! Each level is defined in specific ways. So for example, animals are often defined by five characteristics:

(1) Multicellular (must have more than one cell)

(2) Motile at some point in their life cycle (move)

(3) Reproduce sexually or asexually

(4) Lack a cell wall

(5) Are heterotrophic (need to eat)

Chordates have a stiffening rod that runs down the dorsal (back) side of the animal; vertebrates have a backbone.

The classification of organisms by taxonomic levels was the most common way scientists used to classify organisms, but another classification system called cladistics is becoming more popular. This form talks about "clades" or

groups of organisms making up a common descent group. These are usually based on genetics rather than gross anatomical structure.

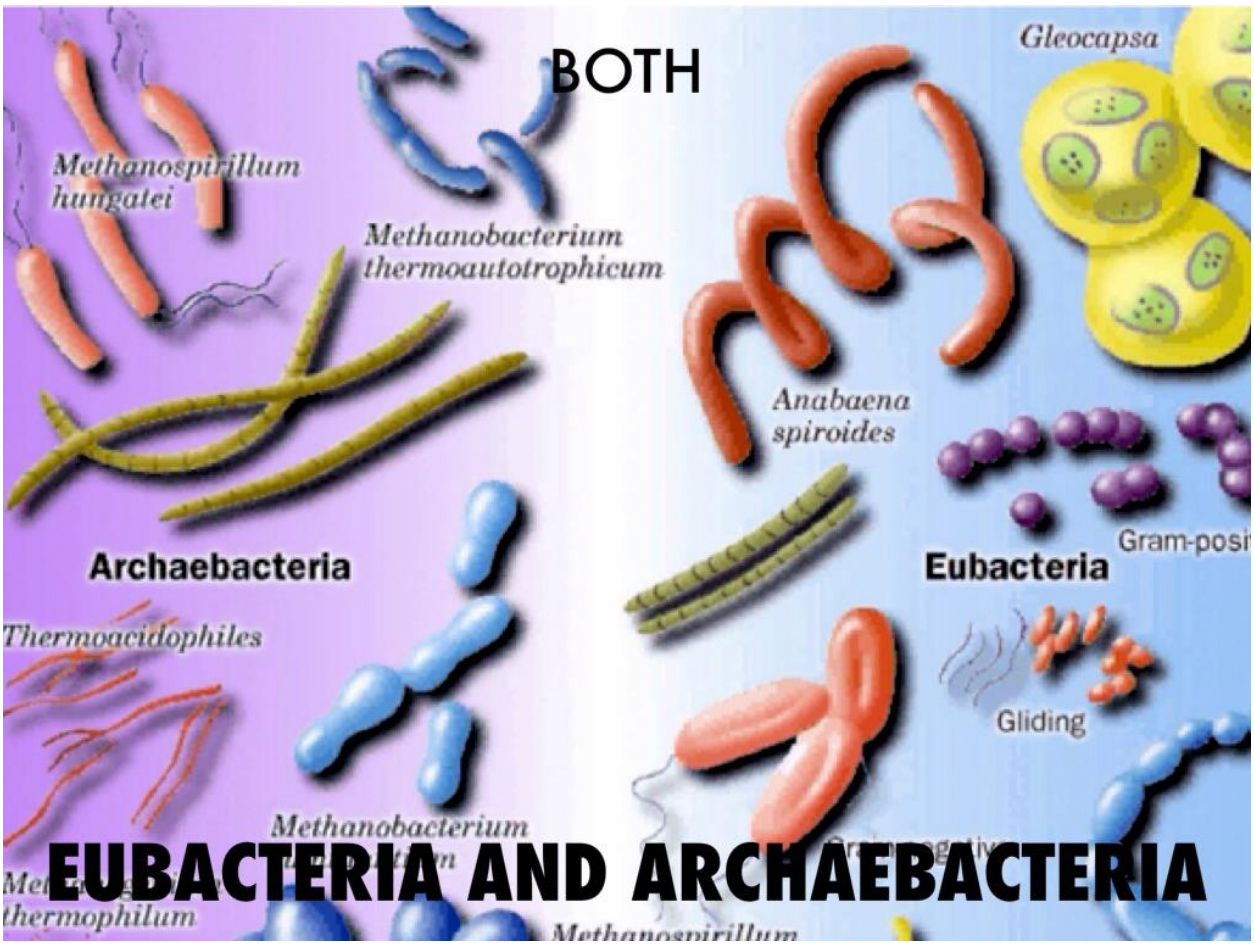
As we have said many times, science changes as new data comes in and in this, there have been many regroupings of organisms. Probably the most dramatic have been changes in the higher levels of classification.

Traditionally organisms were divided into 2 kingdoms called “plants” and “animals”. Many one-celled organisms were difficult to classify as either plants or animals. As a result, a third kingdom was defined called “Protista” which contained all the single celled organisms. Another group of organisms, which seem like plants but do not photosynthesize were separated off and called “Fungi”. These are mushrooms, molds and the like.

More recently, biologist discovered that some of the one-celled organisms did not have a nucleus and did. This led to a division between organisms with a nucleus with a membrane and those without. Organisms without a nuclear membrane were called “Prokaryotes” while those with them were called “Eukaryotes”.

Since plants animals and fungi all have a nuclear membrane, they become part of a “Domain” called Eukaryotes while “bacteria” were seen as ‘Prokaryotes”. Finally, the prokaryotes were found to contain two significantly different groups Archaea and Bacteria. So currently, the thought is that organisms are divided as follows:

PROKARYOTES	EUKARYOTES
Archaea Bacteria	Protists Fungi Plants Animals



Many biologists feel that the Archaea are more closely related to the Eukaryotes, than the Bacteria are.

An important member of the bacteria are the cyanobacteria (sometimes erroneously called “blue green algae”). They are the only prokaryotes that photosynthesize and produce oxygen. It is thought that they transformed the earth’s atmosphere into an oxidizing one. This radically changed the earth and led to the near extinction of the anaerobic life on earth. In effect, Oxygen, a pollutant given off by the cyanobacteria changed the environment causing a mass extinction but made life possible for the organisms we know today.

They are also “nitrogen fixing” which means they are able to convert nitrogen into a form that is usable by other organisms. Nitrogen is needed

by living organisms but is inert. It needs to be made into some form the organisms can use (usually Ammonia)

Why do we need to know this? Since people are alive and are heterotrophs (need to eat) and seafood constitutes part of what we eat, we need to know something about how the system works that makes life possible – especially for humans.

Animals have to eat and hence they need food. We need food for energy. Almost all energy comes from the sun, so there must be some organisms that can convert sunlight into energy. Any organism that can change sunlight into energy for biological use is called an AUTOTROPH. Organisms that cannot do that are called HETERTROPHS. Most autotrophs convert sunlight into biological energy, although some can do it from chemical reactions. These autotrophs perform chemosynthesis as opposed to photosynthesis.

So at the bottom of the food chain (that is the lowest "trophic level") are autotrophs.

Although chemosynthesis and photosynthesis allow for production of bioenergy, nutrients are also needed. These are chemicals like phosphorous and nitrogen that have to be incorporated into the organism.

What is important to remember here is that these bacteria not only started the oxygenation of the atmosphere, but also a major force in making nitrogen available to living organisms.

Because all nutrients are NOT available in limitless or equal quantities, those that are scarce limit the amount of activity they are needed for. Suppose for example that you want to make cakes. Each cake requires 2¼ cups of flour, 1½ cups of sugar, 3 teaspoons of baking powder, 1 teaspoon of salt, ½ cup soft shortening, 1-cup milk, 1½ teaspoons flavoring and 2 eggs. You have available 100 pounds of flour, 50 pounds of sugar, 10 pounds of baking powder, 5 pounds salt, 5 pounds of soft shortening, 5 gallons of milk, 1 gallon of flavoring and 4 eggs. How many cakes can you make? Answer 2. Since there are only 4 eggs and you need 2 per cake, the eggs becoming the limiting factor.

So when an autotrophic organism produces food it needs some energy source like sunlight and nutrients. If nitrogen is one of the necessary

nutrients then its availability may be a limiting factor. While there is a great deal of nitrogen available in the atmosphere, most organisms cannot make use of it in its atomic or molecular, but need it in some compound lime ammonia. This is one of the major things the cyanobacteria do.

Over the billions of years that life has been on Earth it has changed. When a person is born, they are relatively small, they cannot walk on two legs, they do not talk and so on. Over the course of years, people grow bigger, become bipedal, learn to speak a language and so on. This process is called "development". When a species changes over time, it is called "evolution". One example we have already mentioned is the development of organisms that photosynthesized and gave off oxygen as a by-product. This caused major changes in the nature of the Earth's atmosphere. Many organisms died off because of the oxygen, while others were able to change or adapt to the new circumstances.

Darwin postulated a way in which such change could have happened. He noticed that in any species, there is a certain amount of variation that occurs naturally. For example, there is a good deal of variation in the lengths of people's noses.

If, for some reason, longer noses would help people survive longer and produce more offspring, then more and more members of the population would have longer noses. If somehow, some of the animals spread out into different environments, then in some areas, longer noses might be an advantage and in other areas, shorter noses might be advantageous. Ultimately, the two groups would develop to the point where they could no longer interbreed and produce viable offspring and would have become two different species. This processes is called speciation

As organisms changed (evolved) over time they became more and more varied. As we move up from the species level, there are often arguments among scientists as to just how the classification of any particular animal should be made. Generally there is pretty good agreement at the Genus and species level, but above that things sometimes get a bit hectic. The older taxonomic classification system (Linnaean) tended to work with "gross morphology" – how the animals looked and functioned. The cladistics approach tends to rely more heavily on genetics and descent groups.

For example, in the Linnaean system, reptiles and birds are seen as being the same level (Class) (along with mammals, amphibians and fish). Now the feeling among cladists is to link the birds and reptiles together as a single unit. This is why birds have become "dinosaurs". Unfortunately this has led to the problems of having to talk about "non avian" and "avian" dinosaurs which seems to mirror "reptiles" vs. "bird". You are more and more likely to hear about cladistics classifications currently, along with the older Linnaean system! You will see some of this in the American Museum of Natural History.

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It is significant that at different periods of time in recent human activity, there are periods where certain ideas tend to dominate. We have all heard the terms like the "renaissance", "the enlightenment", "the reformation" and so on. Each of these deals with a change in the way people looked at things in general. The Renaissance was a periods from the 14^{th} to 17^{th} Century in Europe. Its actual time varies from place to place and it bridges the Middle Ages (5^{th} to 15^{th} Centuries) to the Age of the Enlightenment (18^{th} Century).

The Renaissance rediscovers the classic periods of Greece and Rome and a kind of "humanism" which impacts art, science, politics, literature and so on.

The Enlightment or Age of Reason stressed reason as the "source for authority". There was an emphasis on scientific reasoning and a questioning of religious orthodoxy which to some degree opposed it. Sapere aude "dare to know" was a phrase to catch that spirit of the times. The term "Zeitgeist" is often used to express the idea of "the spirit of the times" whatever times

they may be. There were many organizations formed for the dissemination and discussion of ideas – academies, Masonic lodges, and so on. Science develops dramatically in this period and the enlightenment emphasized free speech and thought over religion and traditional authority. The Enlightment continues to have an impact into the 19th Century (and beyond) . The scientific involvements of people like Darwin and part of this later phase.

By Darwin's time, the idea of change over time (evolution) had been growing Lyell had postulated geological evolution, Darwin and Wallace would do the same for biology and social scientists would also look at social evolution.

All of this caused a certain amount of turmoil as old ideas were overthrown and new ones appeared. Some strongly religious people want to show that evolution was not real and planned a voyage around the world to show this. They hired a young naturalist to go along named Charles Darwin.

Darwin left on a ship called "The Beagle" captained by a man named Fitzroy. The trip took more than 4 years. On the way, Darwin made many observations of natural phenomenon (including the formation of atolls discussed earlier) but also noted the large number of animals that were remarkably similar but were none the less in separate species. He wanted to understand how this might have happened.

Darwin postulated a way in which such change could have happened. He noticed that in any species, there is a certain amount of variation that occurs naturally in any species. For example, there is a good deal of variation in the lengths of people's noses. Some have long noses, some short, some broad some narrow.

If, for some reason, longer noses would help people survive longer and produce more offspring, then more and more members of the population would have longer noses. If somehow, some of the animals spread out into different environments, then in some areas, longer noses might be an advantage and in other areas, shorter noses might be advantageous. Ultimately, the two groups would develop to the point where they could no longer interbreed and produce viable offspring and would have become two different species. This processes is called speciation

Darwin phrased this in four steps:

Natural variation (there is variation in any trait in a population)

Struggle for existence (the environment can only support a limited number of organisms)

Natural selection (Some of these organisms do better in the environment than others, because of the traits they have)

Survival of the fit. (those that fit better, do better)

Darwin had been puzzled by the number of kinds of finch species he found in the Galapagos Islands on his trip around the world. Let us say some finches have beaks that differ from those in other species. Some of these beaks allowed finches with one kind of beak to get to food others could not

Darwin could not explain the natural variation and fell back on another scientist named Lamarck who postulated that organisms passed on ACQUIRED characteristics. Giraffes stretch their necks to reach higher in the trees and the longer necks are passed on to their offspring. This we know now is not true. So the Darwinian Theory has been modified to add genetics as the way in which variation takes place.

Remember that the environment is not simply the geography, but it includes other living things around it. So as one organism changes, it changes the environment for other organisms living around it. In effect, all things in the environment are the environment for other things! It just depends where your focus is. Consider a bird that eats a specific plant. The plant is in the bird's environment and the bird is part of the plant's environment! As the bird may develop better ways to eat the plant, the plant may develop better ways to block the bird from eating it!

This is important because organisms become more and more adapted to specific environments and if those environments are suddenly altered, the organisms living in them may not be able to adapt quickly enough(remember human vs. geological time). It also is important because organisms adapt often to very specific environments. They have an "ecological niche". The result is environmental biologist and others may define many different kinds of environments. Places where the water meets the land are divided into many different types – coral reefs, mangrove swamps, estuaries and the like. Each of these supports a variety of organisms that are adapted to this particular environment. We will look at some of these shortly.

Since in any population, breeding may be relatively random, those that have the ability to get their genes into more offspring, will lead the "direction" of the evolution. Sudden environmental shifts can be catastrophic because there is not enough time to "evolve" into the new environment. Most geological evolution is relatively slow so changes in organisms have time to move in the direction of the environmental changes.

Back to the life forms!

Organisms are divided (or classified) into different groupings. Eukaryotes and prokaryotes are further subdivided down into kingdoms, phyla (singular is phylum) classes, orders, families, genera (singular = genus) and species along with sub super and infer groups ad infinitum ad nasuseum!. Among the animals there are perhaps 20 or more phyla of animals ranging from "Porifera" (the sponges) to the "Chordates" (animals with a stiff rod running down their backs). The chordate phylum includes the sub phylum "vertebrata" (vertebrates) – animals with backbones. The vertebrates includes the fish, amphibians, reptiles, birds and mammals. Sometimes people talk about vertebrates as opposed to invertebrates, in effect setting up an opposition between a sub phylum with the rest of the animal kingdom!

Another phylum is the Cnidaria which include most the jellyfish and corals. Others of interest to us this term are Mollusks (clams, mussels, squid, octopus), Arthropods (joint legged creatures – insects, crabs, spiders and so on) Echinoderms (starfish, sea urchins, sea cucumbers) and a number of other phyla contain a variety of worms (flatworms, round worms, segmented worms). We will talk about some of these later.

There are also a number of phyla within the other kingdoms, some of which have thousands of species within them.

There are certain groups we are going to be more interested in than others, although the others are not less important. But if you want to know more about them, the biology department gives a course in zoology which you can take. We will talk largely about certain phyla and only mention some of the others in passing.

You should be aware of the two groups in the prokaryotes – Archaea and Bacteria and what the cyanobacteria do.

Among the animals, you should be aware that sponges and corals, are animals and not made out of plastic or rock! Two of the other major phyla to be aware of are the arthropods and the mollusks. The arthropods are the joint legged animals like crabs, lobsters, insects and spiders; the mollusks contain the "shell fish" and include the squid and the octopus.

The echinoderms are yet another phylum which contains the star fish, sea urchins, and sea cucumbers.

Finally there is the chordate phylum which contains (in the Linnaean system, but not the cladistics one) the class known as the fish, amphibians, reptiles, mammals and birds.

A few other terms to remember (some of which we have mentioned before)

(a) Plankton (zooplankton (heterotrophic) and phytoplankton (autotrophic) unable to swim

(b) Nekton: can swim against a current

(c) Algae: autotrophic (photosynthetic) one celled organisms and some multicellular plants that lack true roots, flowers and the like (sea weeds, kelp)

(d) Sea weeds: macroscopic, multicellular, marine algae

(e) Kelp: a kind of sea weed which can grow 30 to 80 meters in length (100 feet to over 260 feet).

Plankton refers to organisms that are unable to swim against a current. These include phytoplankton which are photosynthetic and zooplankton which includes larvae and small animals like krill.

Nekton refers to animals that can move against a current.

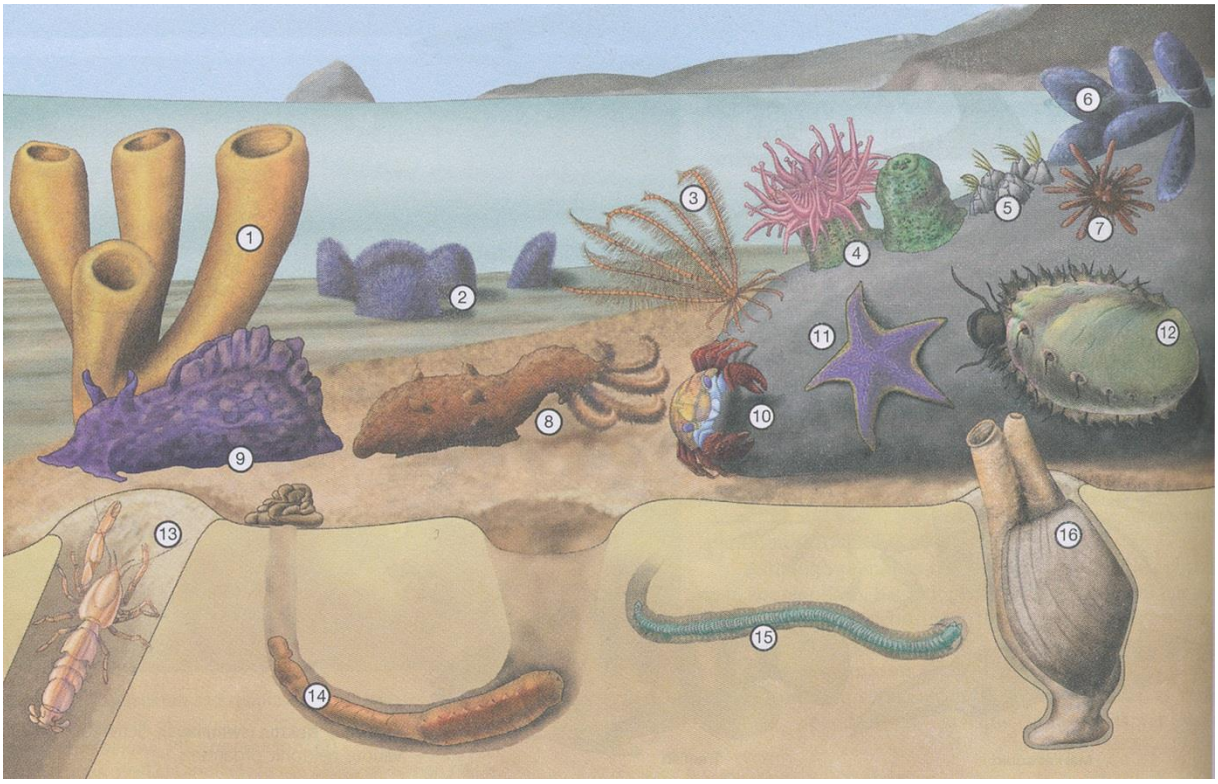
Algae is not a taxonomic classification, (nor are plankton or nekton). It refers to photosynthetic organisms, usually small, like phytoplankton, but some are quite large like the seaweeds, including kelp. It refers to simple nonflowering plants of a large group that includes the seaweeds and many single-celled forms. Algae contain chlorophyll but lack true stems, roots, leaves, and vascular tissue. Many algae are brown, red or other colors, but all have chlorophyll – their color results from other pigments in the cells.

Seaweed is not a technical term but refers to a number of macroscopic algae! One of the seaweeds is “kelp” which often grown into a kind of “forest”

SINCE WE HAVE SOME IDEA OF THE WAYS IN WHICH ANIMALS ADAPT TO SPECIFIC ENVIRONMENTS WE NEED TO LOOK AT SOME OF THE OCEANIC ENVIRONMENTS

We have looked at the ones going out from the shore – littoral, neritic and pelagic as well as the ones dealing with different depths – epipelagic (euphotic), mesopelagic (dysphotic), bathypelagic (aphotic) and hadalpelagic (also aphotic).

We have noted that some animals can swim in the water column as are called nekton while others, called plankton cannot. Some organisms live at the bottom of the water column on the land below. Those are called "benthic". Some benthic animals live right on the surface of the ocean bottom (epifauna) while others burrow into the ground (infauna).



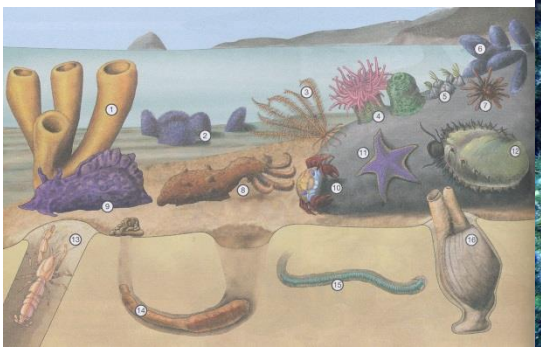
1. Sponge (porifera) 2. Sand dollars (echinoderms) 3. Crinoid (echinoderms) 4. Sea anemones - open and closed (Cnidarians) 5. Barnacles (arthropods crustaceans) 6. Mussels (mollusk bivalve) 7. Sea urchin (echinoderm) 8. Sea cucumber (echinoderm) 9. Sea hare (mollusk gastropod) 10. Shore crab (arthropod crustacean) 11. Sea star or star fish (echinoderm) 12. Abalone (mollusk gastropod) 13.

Ghost crab (arthropod crustacean) 14. Lug worm (annelid polychaetes) 15. Annelid worm 16. Clam (mollusk bivalve)

Animals (as well as plants) are most often thought of as a source of food, but many have other uses for humans as well. Shown here are "invertebrates" – animals without a backbone. We will mention several of these as well as some vertebrates during the term which you should have some familiarity with

SPONGES (PHYLUM PORIFERA)

Among the invertebrates the first are the sponges – the simplest perhaps of all animals. There are several thousand species but only about a dozen are used commercially. These are “picked” and known for their ability to clean. Now-a-days most sponges are not the animal, but rather made from cellulose which is derived from wood pulp, sodium sulphate and hemp fiber.



CNIDARIA

Cnidaria includes jellyfish, corals and sea anemones. They are equipped with stinging cells called nematocysts. Some jellies, like the box jelly are extremely dangerous and can be lethal to humans in less than a minute.
Some are very small and some (Nomura) measure as much as 4-6 feet across. These have had a huge impact on the fishing industry in Japan and are dangerous to the water cooling system of atomic reactors since they can block the intakes. Some people eat jellyfish but they need to be prepared carefully. Sea turtles also eat them alive
Some jellies, like the box jelly are extremely dangerous and can be lethal to humans in less than a minute.

In the picture you can see a clown fish swimming among anemones to which they have immunity. The clown fish develops an immunity toward the anemones, and is able to hide in the tentacles for protection. The clownfish also eats the dead tentacles of the anemone keeping the area clean around it.

The clown fish in return, lures fish to the sessile anemone and helps it to get food.

This process wherein 2 organisms help one another is often called symbiosis or mutualism. The terms are often used interchangeably. Technically, **mutualism** is an ecological interaction between at least two species (=partners) where both partners benefit from the relationship.

Symbiosis on the other hand is defined as an ecological interaction between at least two species (=partners) where there is persistent contact between the partners.

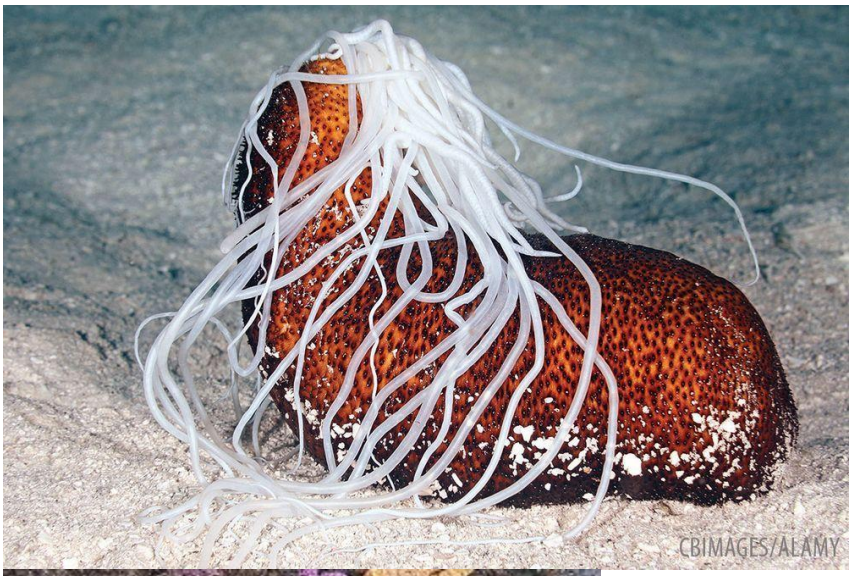
WORMS

Several different phyla Nematodes, Platyhelminthes, annelids etc) .

Some people do eat worms but several kinds are parasitic and there are dangers in doing this. Many marine animals will eat worms.

ECHINODERMS

Some examples: Star fish, sea cucumbers, crinoids
Possible to eat, but not much meat! More likely eaten by other animals. Interesting regenerative powers.



ARTHROPODS (joint legged animals)
Some examples: Crabs, lobsters and so on. Some are edible. Insects are arthropods and many people in the world eat them. Horseshoe

crabs, are here too but are more closely related to the spiders than to the crabs proper.

Lobster

crab

Barnacles

Horseshoe crab

MOLLUSKS

Examples: Clams, mussels , snails

Clams and other mollusks are regularly eaten around the world. Oysters produce pearls as well.

Sea hare

Abalone

Oyster with pearl

Clams

VERBRATES

Fish

Anchovies

Salmon

Haddock

Shark

Alaskan pollok

Chondrichthyes: Sharks, rays, etc. – cartilaginous. Very old. Edible. Often just the fin is used. Bear young alive but without placental connection (ovoviviparous). The eggs are held in the mother's body. Over 300 species some dangerous to humans others not. Some, like the largest shark, the whale shark, are filter feeders.

Bull shark

Tiger shark

Osteichthyes or "bony fish". This class has the largest number of vertebrates in it over

Reptiles

Examples: Sea turtles – marginally alligators and crocodiles

ALLIGATOR

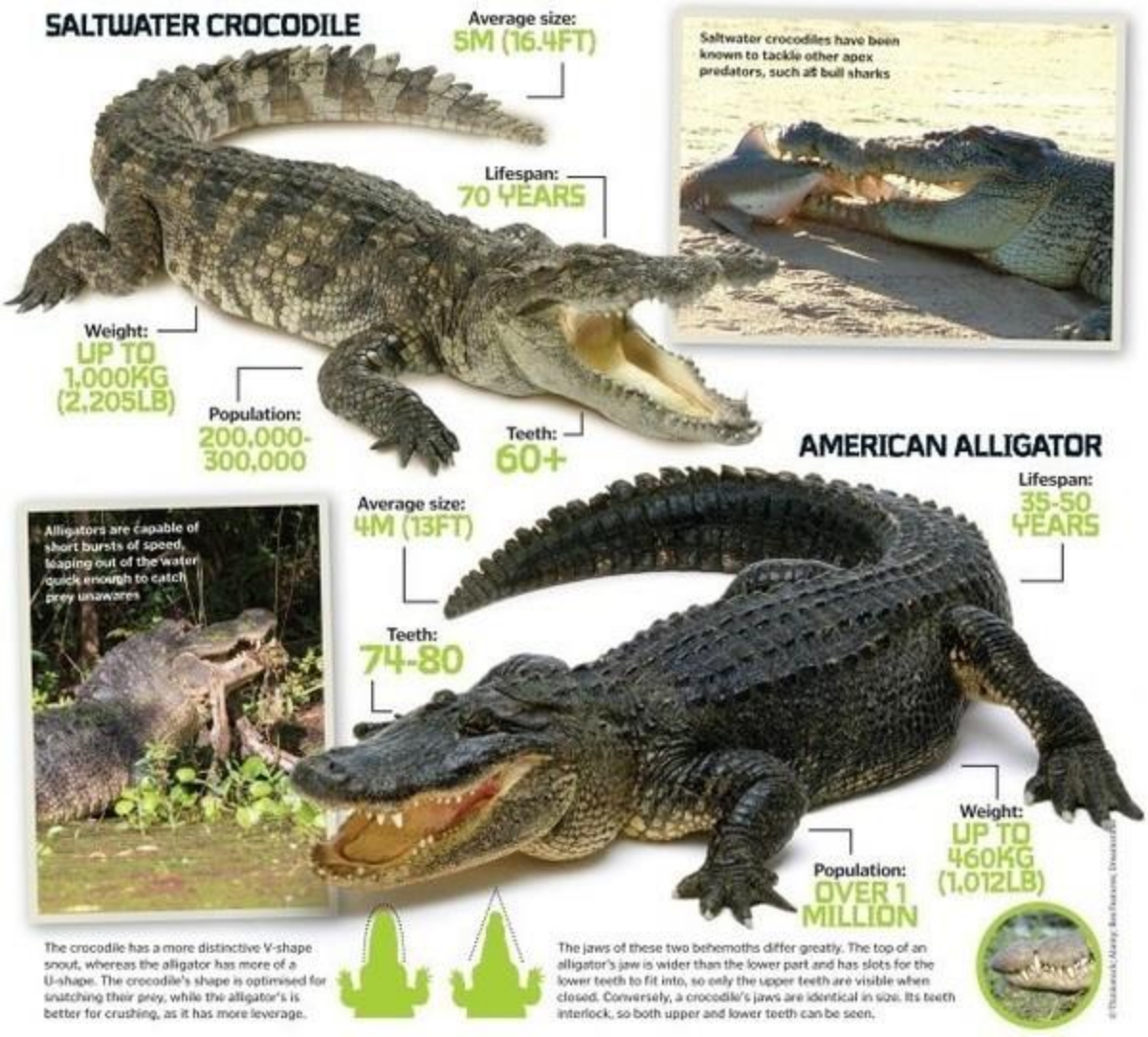
Residence:	mainly freshwater habitats
Jaw:	shaped like the letter 'U'
Teeth:	upper teeth visible when mouth is closed
Skin:	dermal pressure receptors located on the jaw

Photo: ©Luis Castaneda Inc./Riser/Getty

CROCODILE

Residence:	freshwater and saltwater habitats
Jaw:	shaped like the letter 'V'
Teeth:	upper and lower teeth visible when mouth is closed
Skin:	dermal pressure receptors located on the entire body

Photo: ©Raphael Van Butsele /The Image Bank/Getty



While in early times a number of huge reptiles dominated the oceans, most are now gone. Only the sea turtles are representing these animals at this time.

Crocodiles and alligators are more associated with rivers than the ocean, but in some cases, they may wander into the ocean near the shore.

While alligators can tolerate some salt water they are largely fresh water animals. Some crocodiles are salt water crocodiles but are not very good swimmers so they are usually close to the shore. There are reports of them far out to sea on occasion.