Lecture 19 - Benthos & Invertebrates

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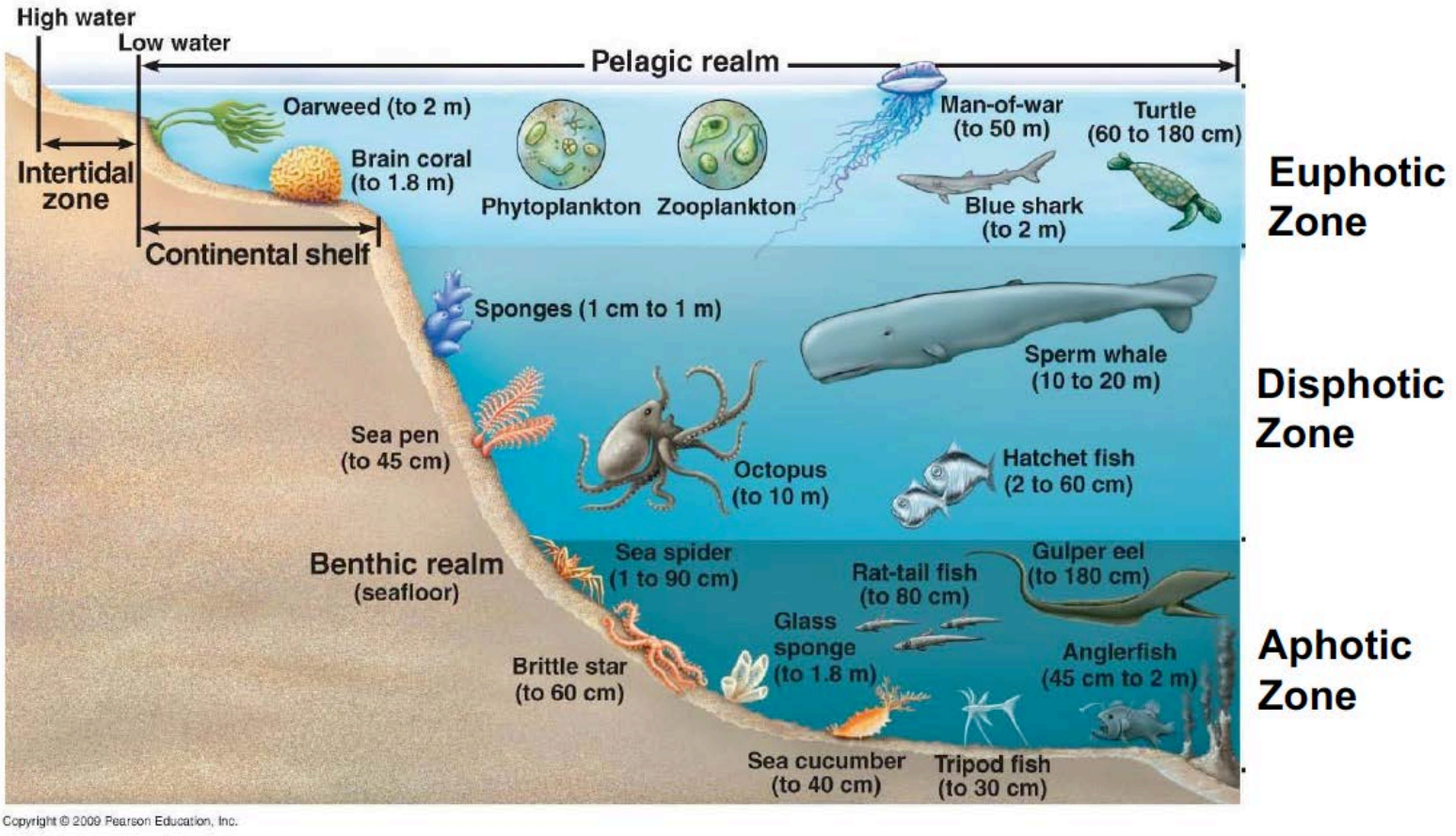
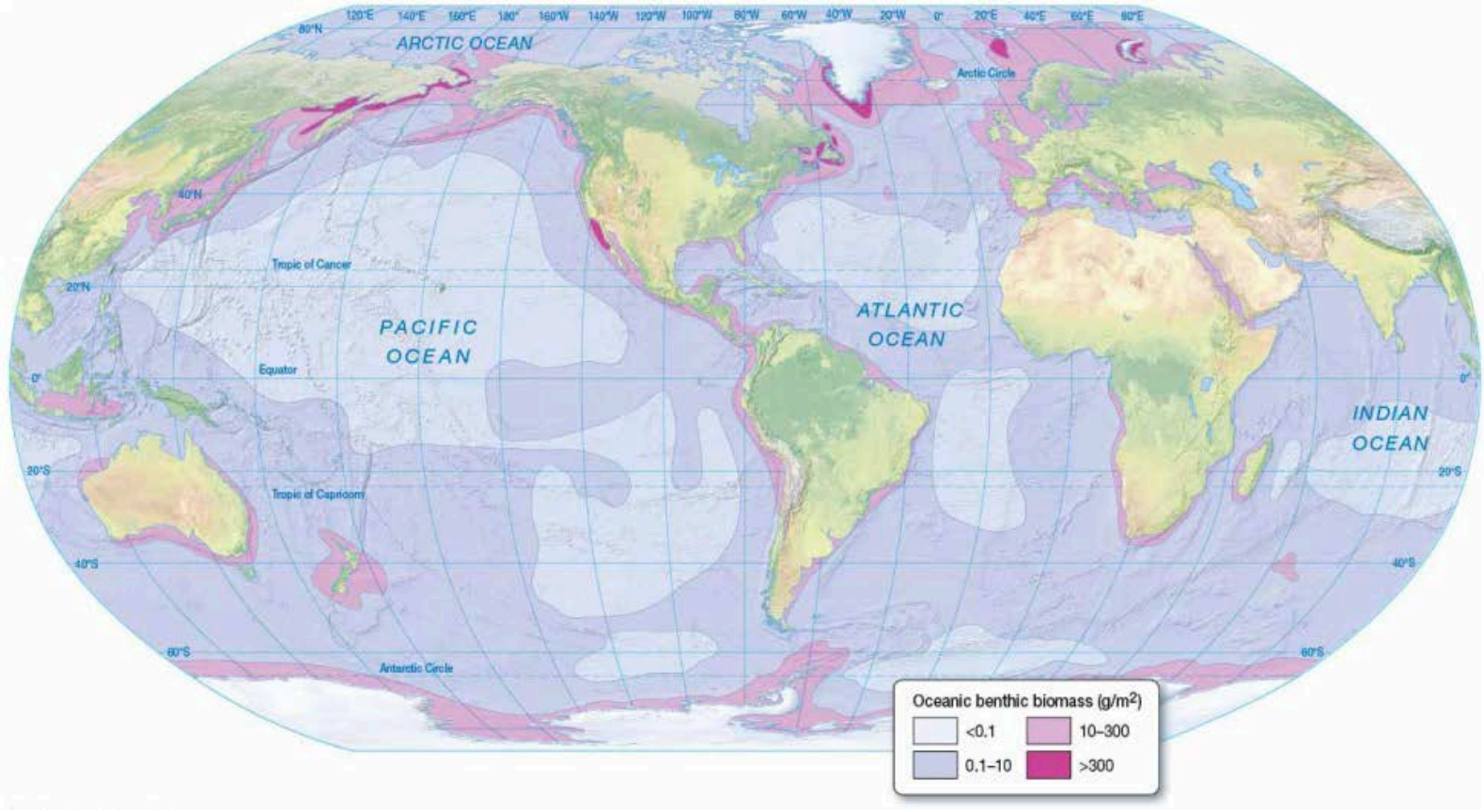
So far we have discussed plankton (the floating plants and animals that are largely at the whim of the ocean currents) and the nekton (the swimming animals that can overcome ocean currents to get around). We will now talk about the benthos. The term benthos refers to organisms that live on or in the bottom of the ocean. The epifauna are those animals that live on the surface of the bottom, sometimes attached to thinks like rocks or shells on the bottom, while the infauna are the animals that live in the bottom, buried in sand or mud.

Let's consider for a moment the types of benthic habitats that are available to these bottom dwelling critters. If we start off at the edge of the ocean, we are in the 'intertidal zone'. The intertidal is the area that is periodically under water, and exposed to air as the tides move up or down. As we move further into the ocean, we cross the continental shelf. The benthic habitats along the continental shelves tend to be relatively shallow and are largely within the euphotic zone, which means that sunlight can penetrate to the bottom or benthos. Next, we cross the shelf break (continental slope), out to the abyssal plains. These deeper benthic habitats occupy parts of the ocean that are dark (called the aphotic zone) or mostly dark (disphotic zone). The changes in the amount of light available to the benthos in these different habitats mean that the animals and plants living there will differ. The benthos communities that inhabit the shallower regions where sunlight is present tend to support more biomass because photosynthesis can occur there (recall the lecture about productivity), whereas the deep, aphotic zone benthos tend to be lower biomass because they rely on food and nutrients that fall to the bottom from upper portions of the ocean. The benthos of the abyssal have to make a living with only 1 to 3% of the euphotic food, however, they benefit from very stable temperatures and salinities (you should recall those temperatures and salinities from previous lectures). Because of the scarcity of food, the abyssal benthos often ▸ e highly specialized adaptations for finding and capturing food.

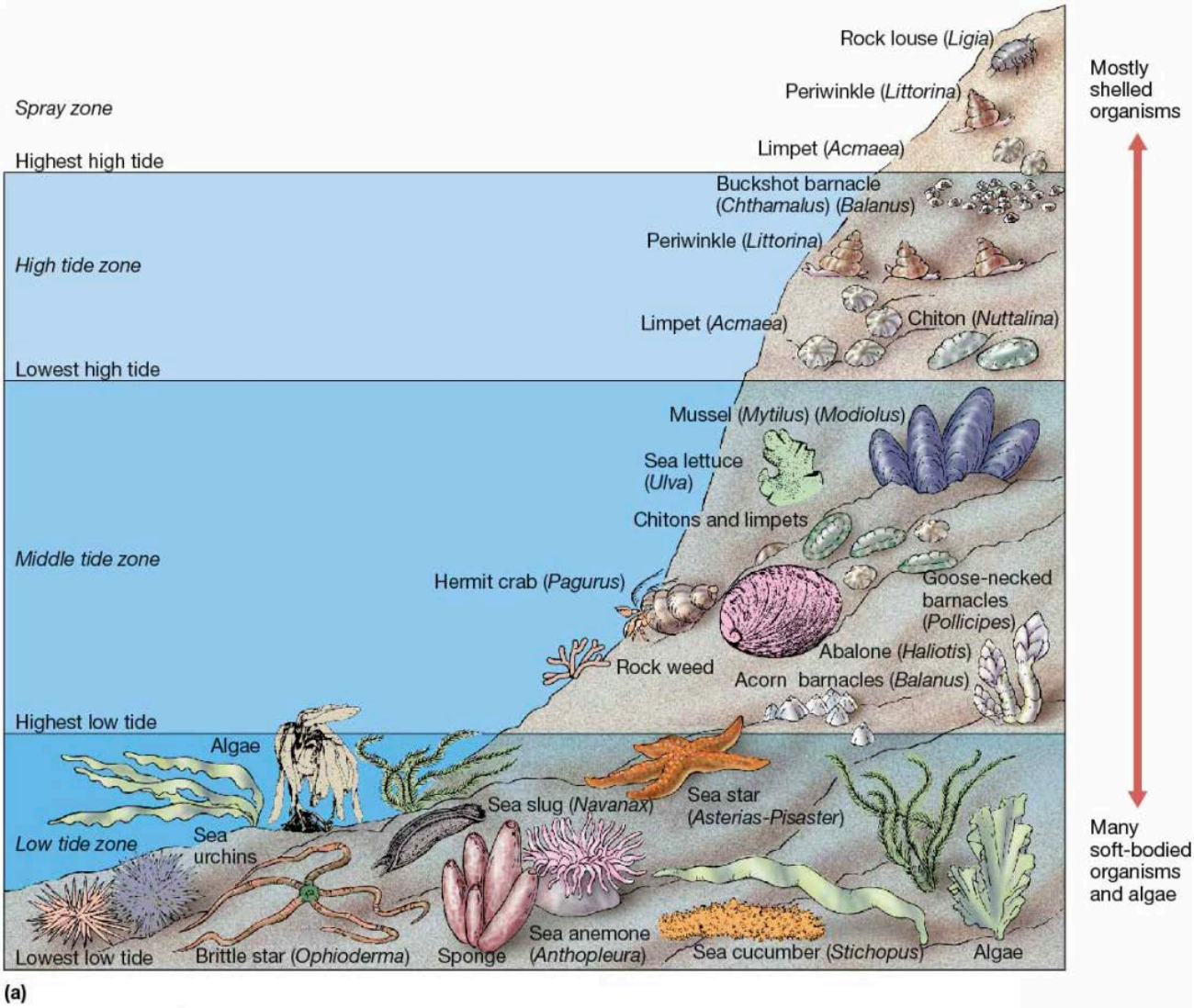
The Benthic Realm



The vast majority, more than 98%, of the species known to live in the ocean are part of the benthos. Most of these live on the continental shelf – we discussed above why that would be the case. The distribution of these benthic species around the world's oceans are affected by surface ocean currents, with the patterns of highest benthic biomass matching closely with the patterns of surface chlorphyll distribution (productivity!). You may want to circle back to prior lectures about surface currents to refresh your memory about how surface currents support higher or lower productivity zones.



Intertidal: Because it includes habitats that switch from submerged to exposed to air regularly, intertidal habitats create unique assemblages of benthos. The further away from the ocean, along the edges that are only under water for a short time have species that are relatively drought resistant (meaning they can withstand desiccation) and can tolerate a wide range of temperatures. This highest area of the intertidal is sometimes called the spray zone, and it sits above the area of the intertidal that the spring tide reaches. In the intertidal, there is a gradient of habitats that goes from the high tide zone which is more dry than it is wet, through the middle tide zone which is mostly balanced between being underwater and exposed, and the lower intertidal that is usually under water. The species of benthos that occupy these zones also have a gradient from dessication tolerant in the high tide zone, to the most dessication sensitive in the lower intertidal. See the image below to see a typical rocky intertidal habitat that shows these gradients.



(a)

These same kinds of intertidal gradients exists on intertidal sandy or cobble beach habitats like those along the New Jersey shore, and the same concepts apply. Higher up in the high tide zone, you find animals that can handle drying out for periods of time, while the animals that are very sensitive to dessication are found further down the beach in the low tide – animals like sea cucumbers. These wave swept intertidal beach habitats are among the most hostile environments on earth. The benthos that survive there are adapted to burrow very quickly into the bottom (some species of clams, worms, and crabs). Another pretty amazing benthic critter that can thrive in these harsh environments are Tardigrades – also known as Water Bears. They are microscopic, and live among the sand grains on the beach. Despite their tiny size, they are super tough! They can survive freezing, boiling, they can live in the vacuum of space, or under high pressure or extremely dry conditions. Tardigrades live almost everywhere, and are really cute –
see for yourself (https://youtu.be/WDak9-Xd-Jo)

(https://youtu.be/WDak9-Xd-Jo)

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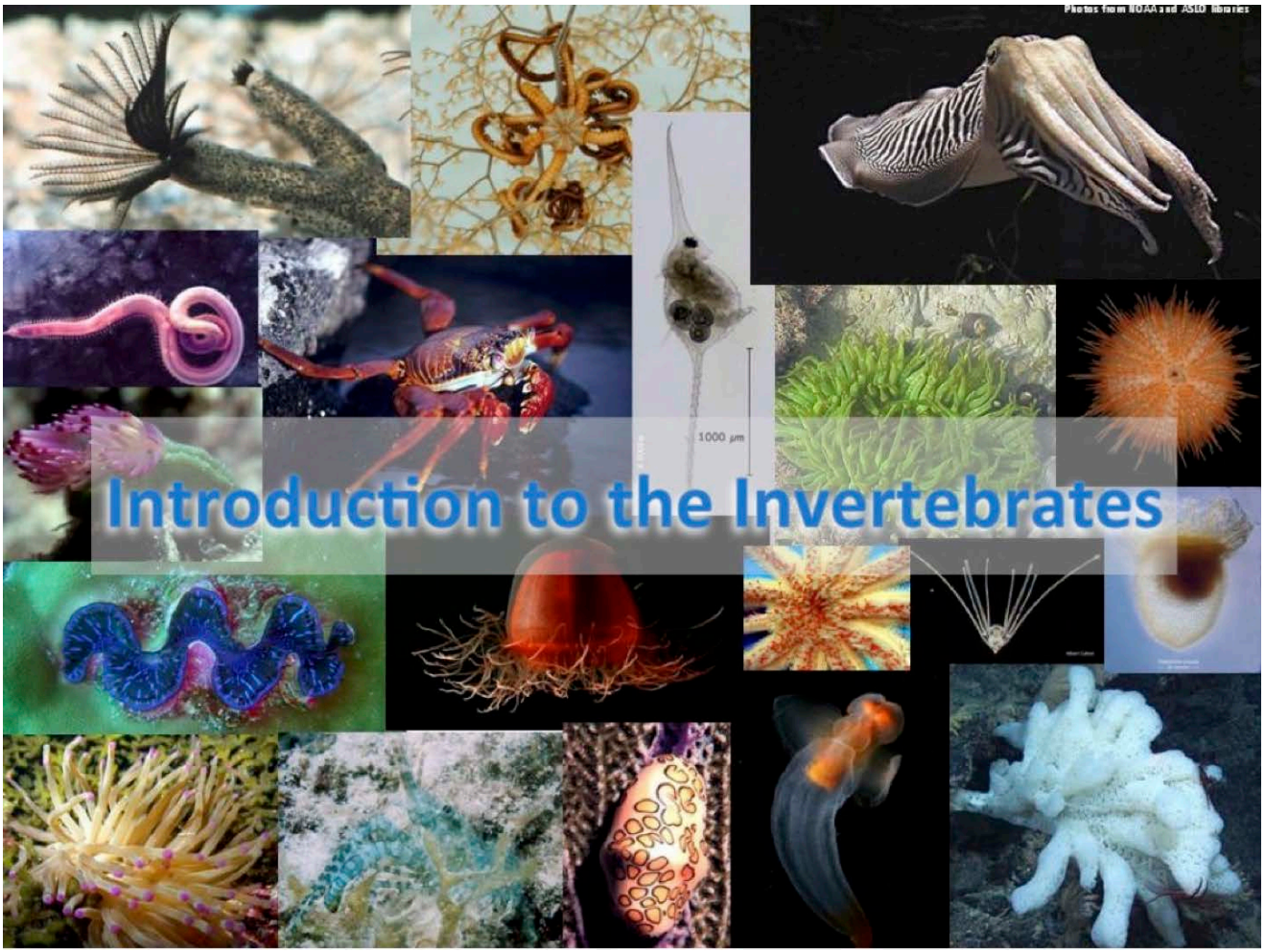
Next Up: Invertebrates

As we learned in the last lecture about zooplankton, there is a lot more to the marine animal world than you might think. The distinction between ‘invertebrates’ and ‘vertebrates’ is somewhat arbitrary and human-centric. The invertebrates are all animals without a ‘backbone’ and the vertebrates are those animals with bones. This leaves the invertebrates as a category containing everything that is not a mammal, reptile, bird or fish. To many of you, that might sound like there isn’t much left, but let me assure you that there is. The invertebrates represent nearly 97% of all of the animal species we know of, and they have a stunning array of body shapes, plans and sizes.

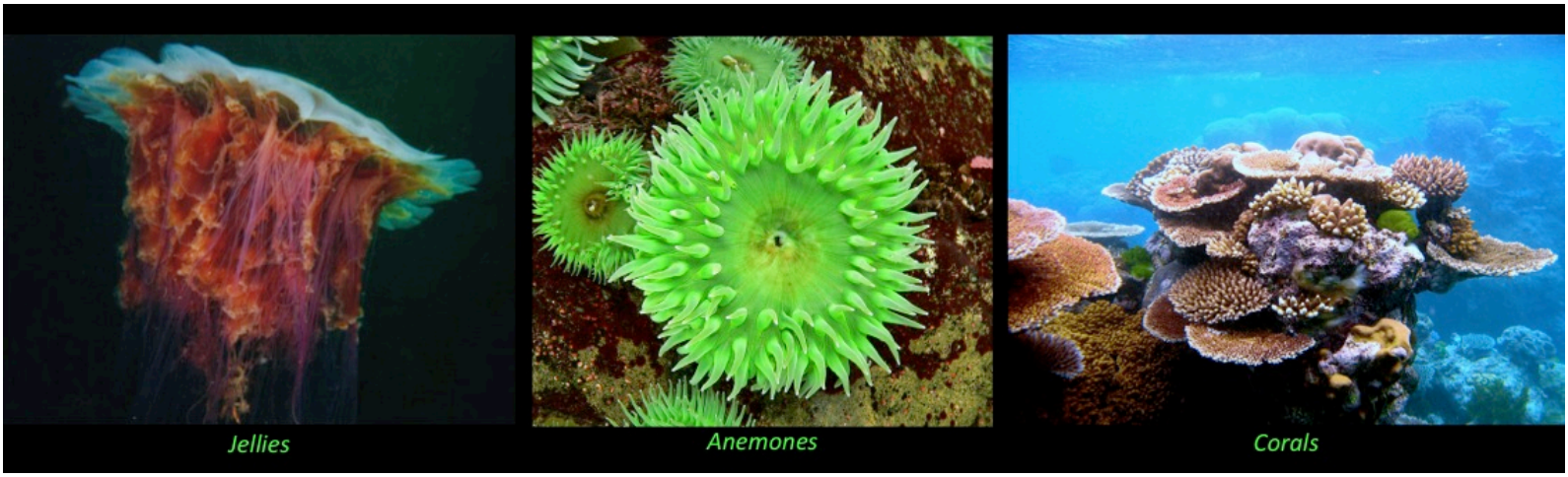


The diversity of body types of the invertebrates allows them to take on impressive physiology. One species of ribbon worm can grow to 30 m (~100 feet). Barnacles have the longest penises in the animal world; they can be inflated to five times their own body length. And a species of marine worm has an tongue with daggers on the end that is 350 times its body length that it can shoot from its mouth to impale prey. Unfortunately, we won’t have time here to even scratch the surface of the diversity in the amazing invertebrate world. Instead I will focus on a few of the more common or ecologically important groups to give you an idea of their characteristics and their value to humans and the ocean. First, why should we care about these ‘spineless’ critters?

Well, as we learned in the last lecture, they can be found in massive densities (recall the krill example) and can be a critical link in marine food webs. They are also species of importance to world economies either as fishery resources, or as important ecosystem engineers or pests. Invertebrates are the basis of a number of major world fisheries or are the food resources that major fisheries rely on. For example, the number one most valuable single-species fishery in the US is lobster with landings valued at $624,228,000. Sea scallops are the

second most valuable at $523,294,000 (these values are reported for 2018). In New Jersey, over 85% of all commercial fishery landings are from invertebrate fisheries including, among others, clams, oysters, crabs, scallops and squid. Other invertebrate species can act as what are called 'ecosystem engineers', effectively creating habitat in the ocean that other species use. Some examples of these are oysters that create reef habitats in temperate zones, or corals that do the same in tropical waters. The establishment of hard surfaces by oysters and corals provides a place for other species to attach and grow into a benthic reef community. One of the biggest costs (>$6 Billion US each year) to the global marine shipping trade is the cost of controlling what is called 'biofouling'. Boat hulls, moorings and other marine instruments act just like oysters and corals in providing a surface that other marine animals will attach to and live on. When this 'fouling' happens on a boat, it increases the surface drag on the hull, making it harder to move the boat through the water and thereby increasing fuel costs.

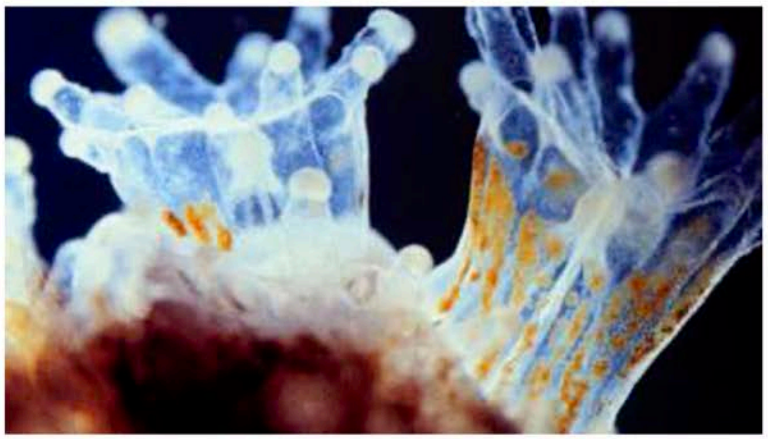
Corals



Corals are part of the phylum Cnidaria (if you have forgotten about what phyla are, reread the section in the previous zooplankton lecture about what phyla are). We will talk about them here because of their importance as oceanic habitat-makers. Corals are a type of ecosystem engineer called autogenic engineers – these are organisms that change their environment by their own growth and presence in the system. The group to which they belong, the Cnidaria, have all sorts of forms beyond just corals. The group includes jellyfish and anemones too. Above is a picture of a jelly, an anemone and a coral – they don't seem very similar do they? Two major features link the animals in this group. One is that they have no head end, just a mouth attached to a sack that acts like a stomach. The second is that they have stinging cells that they use to catch prey. You probably already know that jellyfish can deliver a painful sting, and you may have also heard about stings from touching corals. The stings of the two are from the same sort of cell, a nematocysts cell. These cells act like coiled up arrows on a barbed sting, packaged in pressure packs. When the trigger is hit by either physical or chemical stimulus that set it off, the top opens and the arrow flies into whatever is nearby. The arrow sometimes delivers a toxin – that is the stinging part - and is attached to the animal with a long thread. Not all cnidarians have toxins on their stinging cells. Some, like many anemones, only feel sticky to the touch – that is because of all of the threads that are in your skin holding you to the anemone tentacle. Here is
a video about (https://youtu.be/7WJCnC5ebf4)

(https://youtu.be/7WJCnC5ebf4)
how the stinging cells of a very dangerous species of jellyfish, the box jelly, work (bear with the beginning of the video, there is amazing microscope video at the end).

You can think of corals like colonies of tiny jellyfish, flipped upside down with tentacles and mouth pointing up. They deposit calcium carbonate – the hard parts of the coral – through a partnership with algae that are held in special cells in their tentacles. These algae, also called zooxanthellae, live in the protection of the cells of the coral polyp (the polyp is the fleshy part with the tentacles). The flesh of the coral is transparent enough to allow sunlight in to the algae, kind of like a greenhouse, and the algae can photosynthesize. Through photosynthesis, the algae provide the coral with its food and helps with formation of the calcium carbonate skeleton so that the coral can build itself more habitat. The algae are also what give corals their spectacular color. When a coral is considered 'bleached', it is because the algae that was living in it's cells have died or made a run for it. Below left is a close-up picture of a coral polyp with zooxanthellae in it (the rusty colored parts). On the right is a coral reef with one large bleached coral in the middle.



When you think about it, the way that the coral keeps the algae in its own cells, then uses the algae for photosynthesis is a little like a farm. Corals can control the number and productivity of algae by keeping them from reproducing which holds them in a very high photosynthesis stage, which means they make more food. This is sort of like a farmer putting fertilizer on a crop, or growing seeds from a faster-growing variety of plant. There are also chemicals that the coral releases that cause the algae to leak out some of the products of photosynthesis to make them available to the coral (sort of like a dairy farmer harvesting milk from her cows). Every once in a while there may get to be too many algae, and in that case the coral digests the extras to keep the algae population in check (sort of like a beef farm). So in one tiny coral polyp, you have all of the stages of a corn, dairy and beef farm! Amazing.

These symbiotic algae living within the coral polyps allow corals to thrive in areas of very low nutrients. The waters of the tropical and equatorial ocean are very clear, are low in nutrients and suspended particles (recall from previous lectures why this is so?), and are home to very productive and diverse coral reef communities. Coral reefs are important places for commercial fishing, supporting nearly $7 billion annually. They also are important cultural places supporting tourism and diving sectors in many places around the world, and in many

places they also protect shorelines from erosion and storm damage. Unfortunately, our changing climate threatens these fragile reef systems through bleaching (mentioned above) which is exacerbated by high temperature, by ocean acidification which weakens the carbonate skeleton of the coral, and by nutrient pollution from runoff which stimulates growth of seaweeds which overgrow the corals.

Echinoderms

This is a completely marine group - all known species the Echinoderms are found in the ocean. The animals in this phylum include things like urchins, sand dollars, sea stars and cucumbers. It is a weird group and the shells they leave behind after they die (more appropriately called tests than shells) are iconic image of seashore life and can be found decorating many a bathroom. Although we don't often eat these animals in the US, they are important fishery and aquaculture species. In some cases they are eaten raw (urchins and cucumbers are eaten this way), or dried (cucumber), and sea stars are sometimes captured and used as high quality chicken feed. Their bodies have hard plates under their skin that helps defend them from predators; these are called ossicles. Sometimes they also have long spines (like the urchin above) for further protection; in fact, the name of the group 'Echinoderm' means spiny skin. Another very cool defining feature of the group is their feet. They have thousands of tiny tube feet that they use to hold onto rocks, pull open food items, and walk. Their tube feet are long fleshy tubes that they can extend out from their bodies. The have what looks like little suction cups on the end that can hold tightly to whatever they apply it to, then they can retract that tube to pull on whatever they are holding onto. It has long been thought that these 'feet' worked by suction of the disc on the end of the tube, but new evidence is emerging that there is some sort of adhesive used as well (or instead…) – stay tuned! When these animals live in places with lots of crashing waves, these tube feet are the way that they keep from being washed off the rocks. If you have ever tried to pull a star fish from a rock, you know just how strong these little feet can be! Here is a
short video (https://youtu.be/pvUv7GEMUkg)

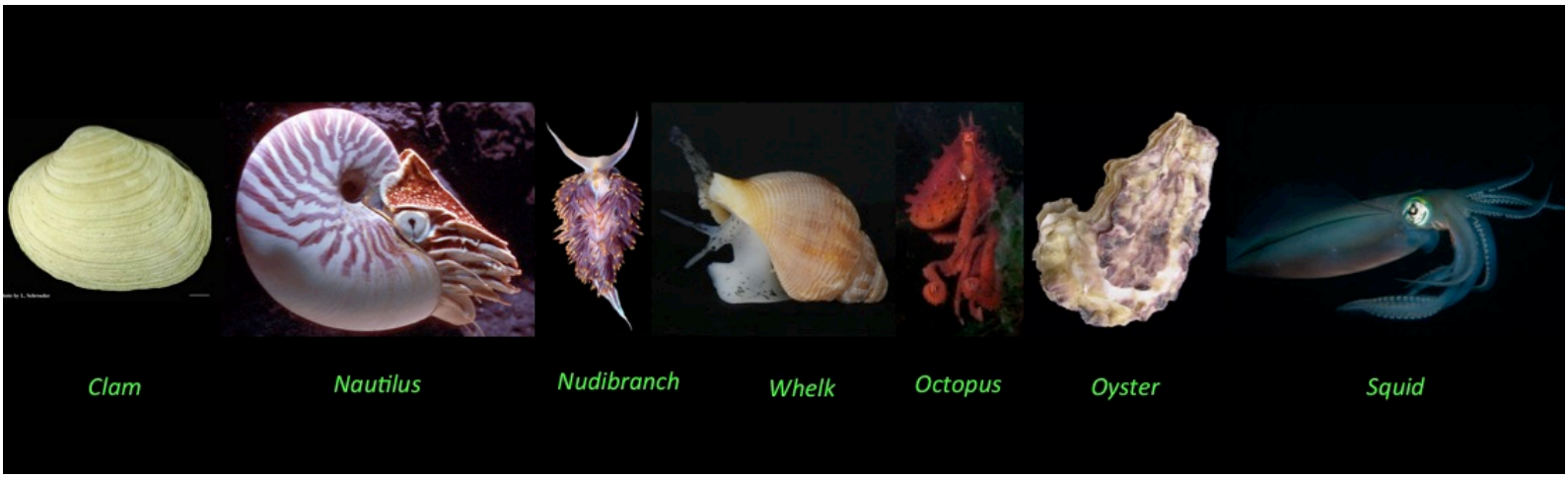
(https://youtu.be/pvUv7GEMUkg)
showing what tube feet look like in action.

Their impressive defenses, along with their effective predatory ability allow Echinoderms to reach very high population densities under certain conditions, making they a key ecosystem component. These population outbreaks often have enormous ecological impacts on the other animals in the ecosystem. Classic experiments on the Pacific coast of the US show that the presence of sea stars controls the structure of the ecosystem on the rocky shore. When the sea stars are removed from areas of the shoreline, the composition of the other species there changes dramatically and the shoreline becomes dominated by barnacles. Likewise, urchins have a strong influence on kelp ecosystems and can decimate entire kelp forest when they become too abundant. These areas where kelp forests have been 'mowed down' by urchins are called urchin barrens. The Crown of Thorn starfish is a species that lives along the Great Barrier Reef in Australia. Outbreaks of the Crown of Thorns starfish are a major threat to reefs in Australia.

This video clip (https://youtu.be/l6dnmLDu6Eg)

(https://youtu.be/l6dnmLDu6Eg)
shows a sunflower star (the biggest sea star in the world) eating a clam by ejecting their stomach onto prey. Wild!

Molluscs



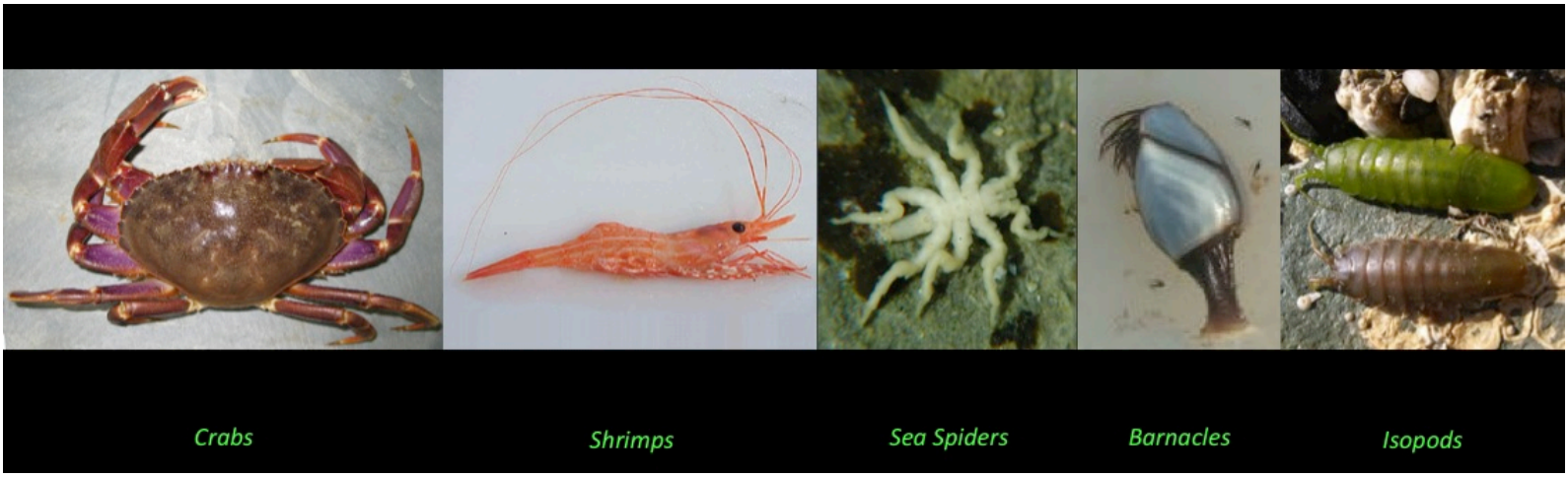
The molluscs are the 'shelled' invertebrates and their body forms vary widely from clams and scallops, snails and slugs, octopus and squid. This group is one of the most diverse groups of animals and is the basis of a number of major world fisheries. In New Jersey one of the biggest commercial fisheries is the ocean clam fishery that lands and processes literally millions of clams every week caught off the coast of NJ, and Long Island. The sea scallop fishery is currently the second most valuable single-species fishery in the U.S.. Shellfish, including clams, oysters, mussels, scallops and squid are a major marine resource and one that provides important food for the global demand for protein. Many species are very easy to grow on farms and are increasingly being produced in aquaculture operations around the world. More on this in an upcoming lecture.

Not only are they delicious, molluscs are also important ecosystem components. Many shellfish species like clams and oysters, feed by filtering water through their gills. They do this to collect the tiny phytoplankton that is

suspended in the water (if you don't recall what phytoplankton are, you should go back to the previous lecture on productivity in the ocean). When they are filtering the water to get their phytoplankton dinner, they also remove other small particles from the water, package it up and put it on the seafloor (we call this biodeposition). By doing this, these shellfish essentially help to 'clean' the water. Some species, like oysters and mussels, can also help to stabilize the shoreline and provide hard substrate that can act as habitat for other marine animals. In this way, these species are like the corals we talked about earlier – they are ecosystem engineers. You can watch and read about exciting initiatives happening here at Rutgers and New Jersey **at this link (http://delawareestuary.org/science-and-research/living-shorelines/)** that take advantage of these shellfish ecosystem engineers to help prevent loss of marshes due to erosion.

Some of the smartest molluscs (and maybe some of the smartest of all animals), are the octopus. They are masters of disguise and can very quickly change colour, shape and texture to match seamlessly with their surroundings. They appear to be emotional, with some aquarium keepers sharing stories of them changing colour to indicate their mood on a given day, or their happiness about being fed. Octopus are easily trained and learn very quickly, but they are also deadly clever predators. Octopus and squid are related to clams and oysters, but you might wonder how this could be if they don't have a shell. In the octopus and squid groups, the fleshy part of the body is very big, while the shell is very reduced (sometimes absent), making them seem less related to shellfish than they are.

Arthropods



The Arthropods are another very diverse and delicious group. They include things like crabs, lobsters, barnacles and shrimp. The group also includes land insects (much of the group's diversity comes from these), but since this is an ocean course we will leave those for now and focus on their marine brethren. These, like the molluscs, are a major marine food resource for humans. There are large fisheries for many crab and shrimp species around the world, and a farming has been increasing steadily over the past decades.

A defining characteristic of this group is that they have a segmented and hardened outer skeleton (called an exoskeleton) that provides them with protection and support. This hard outer shell means that they are restricted in how much they can grow, so to get bigger, they grow a soft new shell under their hard one. Then they make a hole in the old shell and crawl out of that hole and inflate the new soft shell like a balloon to a bigger size. This is called moulting, and if you have ever eaten a softshell crab, you are eating a newly moulted

crab, before it had a chance to harden up the new shell. They also have many jointed legs. The joints allow the legs to be dexterous and the fact that they have so many means that they can use them for a number of functions in addition to walking. Many have legs that are adapted for feeding, filtering, swimming, chewing and even mating. The photo above shows the fuzzy legs of a barnacle extended up into the water to catch passing particles that it feeds on. Barnacles are small, sharp, shelled animals that live on the rocks along the shore – you probably have cut your feet on this while walking along a rocky shore at low tide. You can think of a barnacle as a tiny crab glued down on its back with its legs in the air and a big plated shell). And here is a funny video of a

shrimp on a treadmill (https://youtu.be/v2cr1bUHlBM)

(https://youtu.be/v2cr1bUHlBM)

that was made by researchers who were studying physiology of how these animals move. Their study showed that they use surprisingly greater endurance than predicted based what was previously understood of energy reserves in Arthropods.

Now for your dose of 'weird marine biology' – the invertebrate edition. It may not be obvious at first glance, but cone snails are incredibly skilled and dangerous assassins. They have a specialized tooth at the back of their mouth that is barbed, hollow and full of a potent venom. When a tasty looking fish swims too close, the snail shoots the harpoon from its proboscis (a sort of feeding tube). The prey is paralyzed quickly and the cone snail reels it in. Almost as amazing as the way it hunts is its ability to then swallow the entire fish and digest, spitting out the bones and other unwanted parts after digestion is over. The venom is a complex mix of chemical compounds and differs among species. The medical community is taking a close look at the use of these compounds in everything from painkillers to spinal injury to alzheimer's.

Here is a video (https://youtu.be/BMOSvz5mThM)

(https://youtu.be/BMOSvz5mThM)

that shows this deadly mollusk in action

The deadly California Cone Snail.