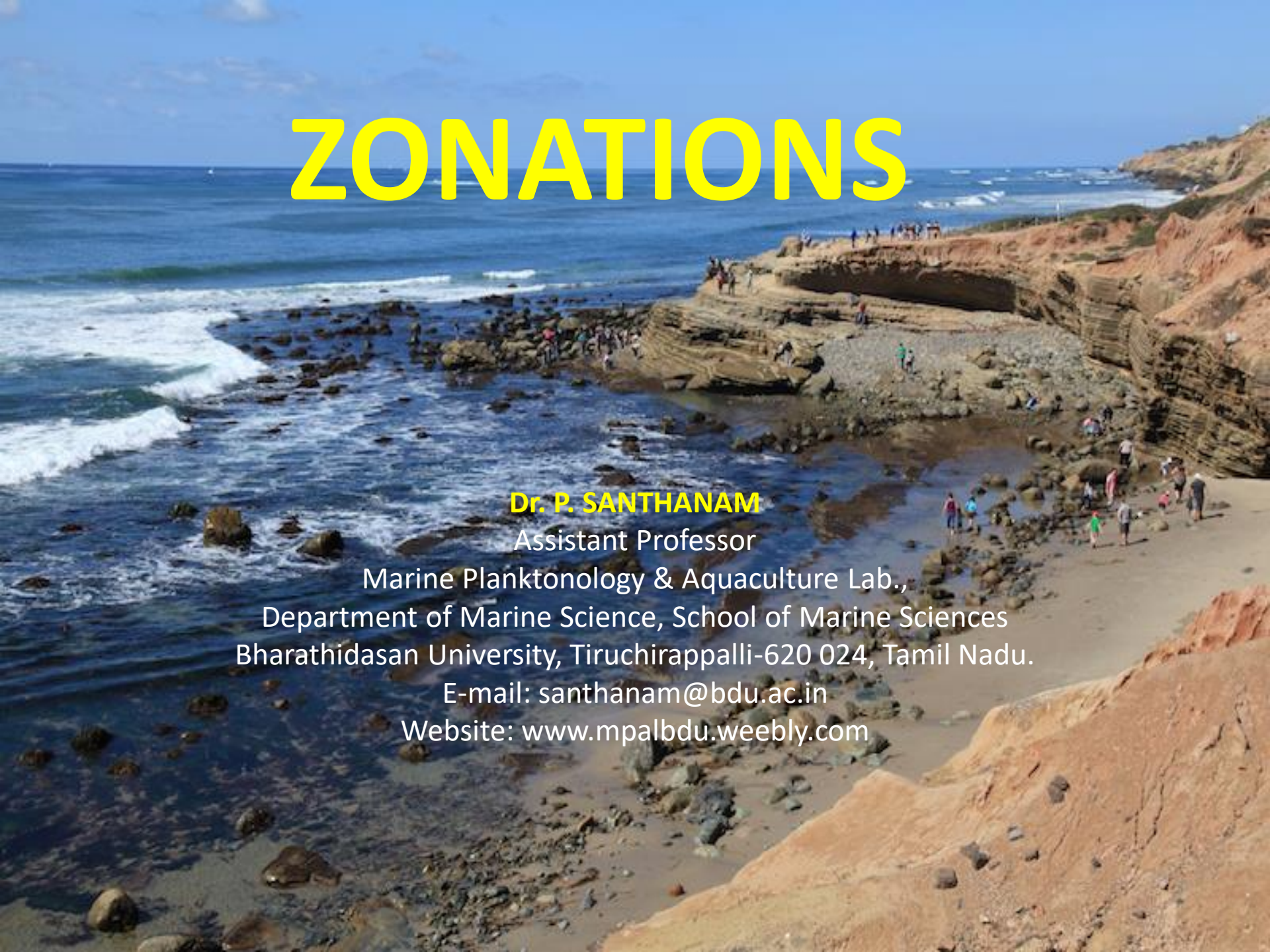


ZONATIONS



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ROCKY SHORE

A rocky shore is an intertidal area that consists of solid rocks. It is often a biologically rich environment and can include many different habitat types like steep rocky cliffs, platforms, rock pools and boulder fields.

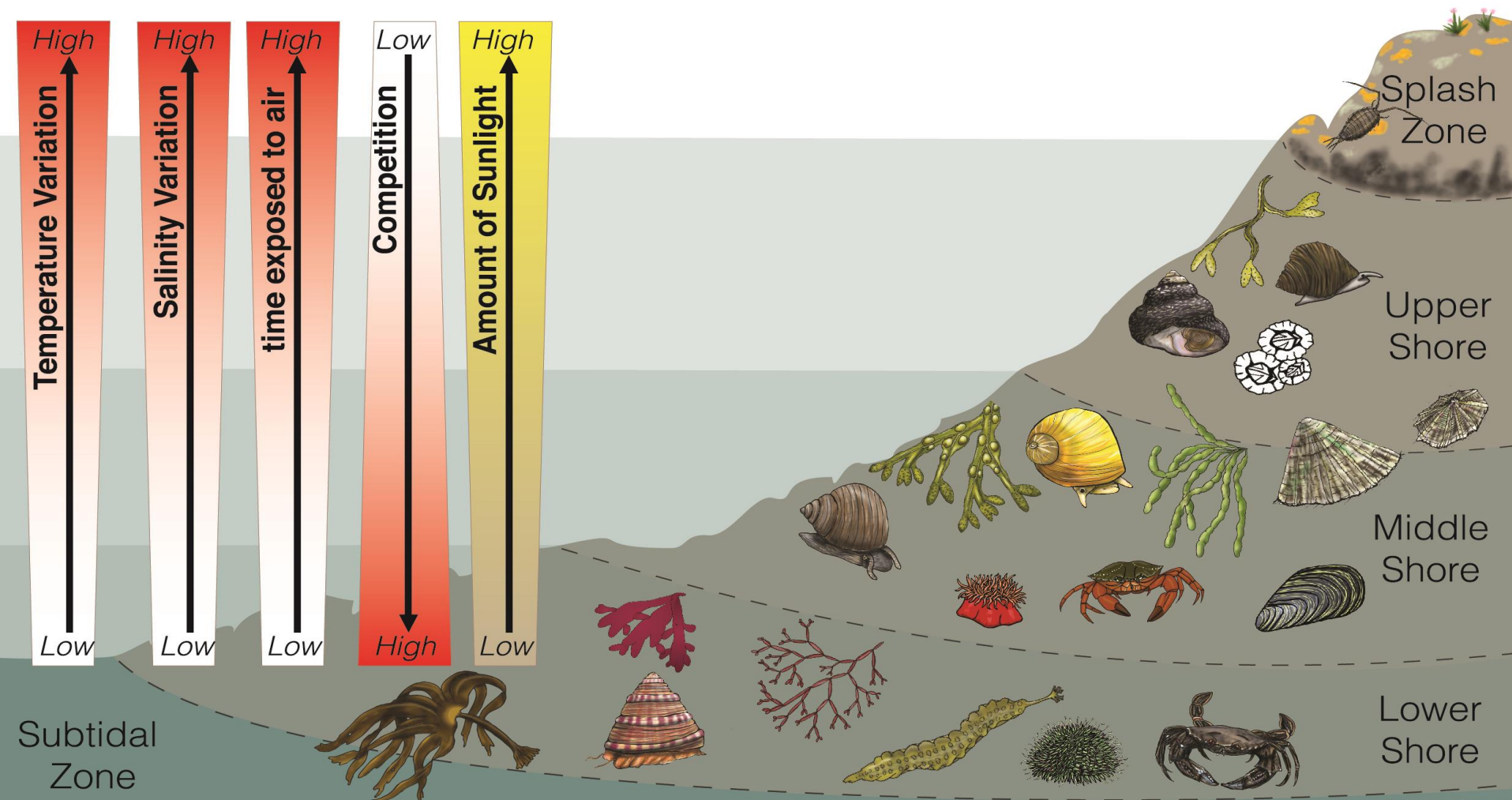
Because of the continuous action of the tides, it is characterized by erosional features. Together with the wind, sunlight and other physical factors it creates a complex environment.

Organisms that live in this area experience daily fluctuations in their environment. For this reason, they must be able to tolerate extreme changes in temperature, salinity, moisture and wave action to survive.



Zonation

Each region on the coast has a specific group of organisms that form distinct horizontal bands or zones on the rocks. The appearance of dominant species in these zones is called vertical zonation. It is a nearly universal feature of the intertidal zone.





Supratidal zone

When the tide retreats, the upper regions become exposed to air. The organisms that live in this region are facing problems like gas exchange, desiccation, temperature changes and feeding. This upper region is called the **supratidal or splash zone**.

It is only covered during storms and extremely high tides and is moistened by the spray of the breaking waves. Organisms are exposed to the drying heat of the sun in the summer and to extreme low temperatures in the winter. Because of these severe conditions, only a few resistant organisms live here.

Common organisms are lichens. They are composed of fungi and microscopic algae living together and sharing food and energy to grow. The fungi trap moisture for both themselves and their algal symbiont. The algae on the other hand produce nutrients by photosynthesis. Green algae and cyanobacteria can also be found on the rocks of the North Atlantic coasts. They are capable of surviving on the moisture of the sea spray from waves.

During the winter, they are found lower on the intertidal rocks. The algae growing higher on the rocks gradually die when the air temperature changes. At the lower edge of the splash zone, rough snails (periwinkles) graze on various types of algae. These snails are well adapted to life out of the water by trapping water in their mantle cavity or hiding in cracks of rocks. Other common animals are isopods, barnacles, limpets,...



Intertidal zone

The **intertidal zone** or **littoral zone** is the shoreward fringe of the sea bed between the highest and lowest limit of the tides.

The upper limit is often controlled by physiological limits on species tolerance of temperature and drying.

The lower limit is often determined by the presence of predators or competing species. Because the intertidal zone is a transition zone between the land and the sea, it causes heat stress, desiccation, oxygen depletion and reduced opportunities for feeding.

At low tide, marine organisms face both heat stress and desiccation stress. The degree of this water loss and heating is determined by the body size and body shape. When body size increases, the surface area decreases so the water loss is reduced. Shape has a similar effect. Long and thin organisms dry up much faster than spherical organisms.

Intertidal organisms can avoid overheating by evaporative cooling combined with circulation of body fluids. Higher-intertidal organisms are better adapted to desiccation than lower-intertidal organisms, because they encounter more hours of sun.

The organisms are exposed directly to the air or they are enclosed in burrows. This results in oxygen depletion, so they can't get rid of their metabolic waste. A solution for this problem is to reduce the metabolic rate.



Intertidal zone

The intertidal zone can be divided in three zones:

High tide zone or high intertidal zone. This region is only flooded during high tides. Organisms that you can find here are anemones, barnacles, chitons, crabs, isopods, mussels, sea stars, snails,...

Middle tide zone or mid-littoral zone. This is a turbulent zone that is (un)covered twice a day. The zone extends from the upper limit of the barnacles to the lower limit of large brown algae (e.g. *Laminariales*, *Fucoidales*). Common organisms are snails, sponges, sea stars, barnacles, mussels, sea palms, crabs,...

Low intertidal zone or lower littoral zone. This region is usually covered with water. It is only uncovered when the tide is extremely low. In contrast to the other zones, the organisms are not well adapted to long periods of dryness or to extreme temperatures. The common organisms in this region are brown seaweed, crabs, hydroids, mussels, sea cucumber, sea lettuce, sea urchins, shrimps, snails, tube worms,...



TIDAL POOLS

Tidal pools are rocky pools in the intertidal zone that are filled with seawater.

They are formed by abrasion and weathering of less resistant rock and scouring of fractures and joints in the shore platform. This leaves holes or depressions in where seawater can be collected at high tide.

They can be small and shallow or deep. The smallest ones are usually found at the high intertidal zone, whereas the bigger ones are found in the lower intertidal zone. When the tide retreats, the pool becomes isolated. Because of the regular tides, the pool is not stagnant and new water regularly enters the pool.

This is necessary to avoid temperature stress, salinity stress, nutrient stress,... Pools that are located higher on the beach are not regularly renewed by tides.

These pools are basically freshwater or brackish water communities. It has different characteristics in comparison with other coastal habitats. Several taxa are more abundant in pools than the surrounding environment.

These taxa are members of the algae and gastropods. There is also a difference between high and low located pools for the composition. In low located pools, whelks, mussels, sea urchins and *Littorina littorea* are common. Periwinkles and *Littorina rudis* are found in high located pools.

Other organisms that are commonly found in pools are flatworms, rotifers, cladocerans, copepods, ostracods, barnacles, amphipods, isopods, chironomid larvae and oligochaetes. Vertical zonation also has been documented in tidal pools.





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Subtidal zone

The **subtidal zone** or **sublittoral zone** is the region below the intertidal zone and is continuously covered by water.

This zone is much more stable than the intertidal zone. Temperature, water pressure and sunlight radiation remain nearly constant.

Organisms do not dry out as often as organisms higher on the beach. They grow much faster and are better in competition for the same niche.

More essential nutrients are acquired from the water and they are buffered from extreme changes in temperature.



INTERTIDAL ECOLOGY

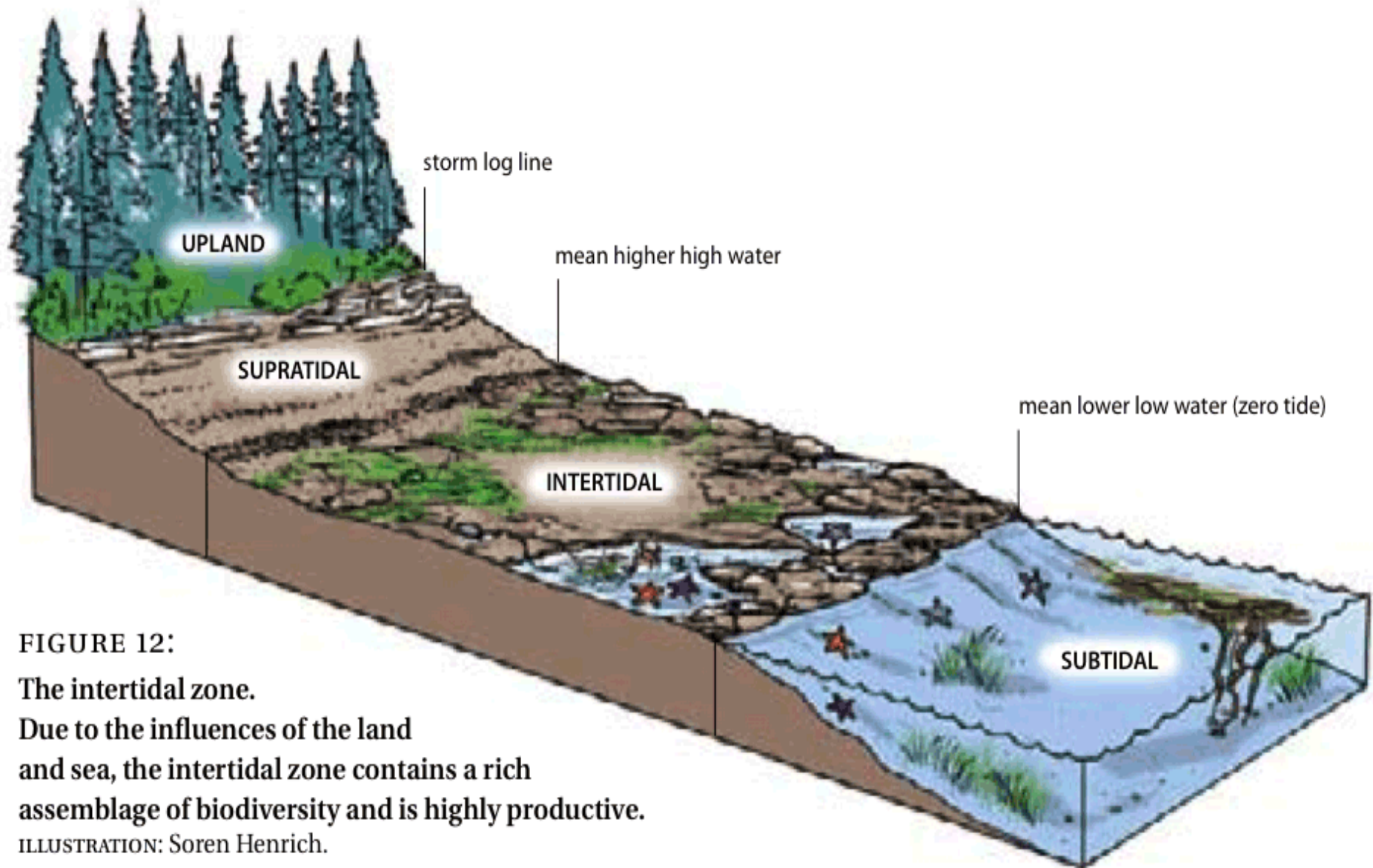
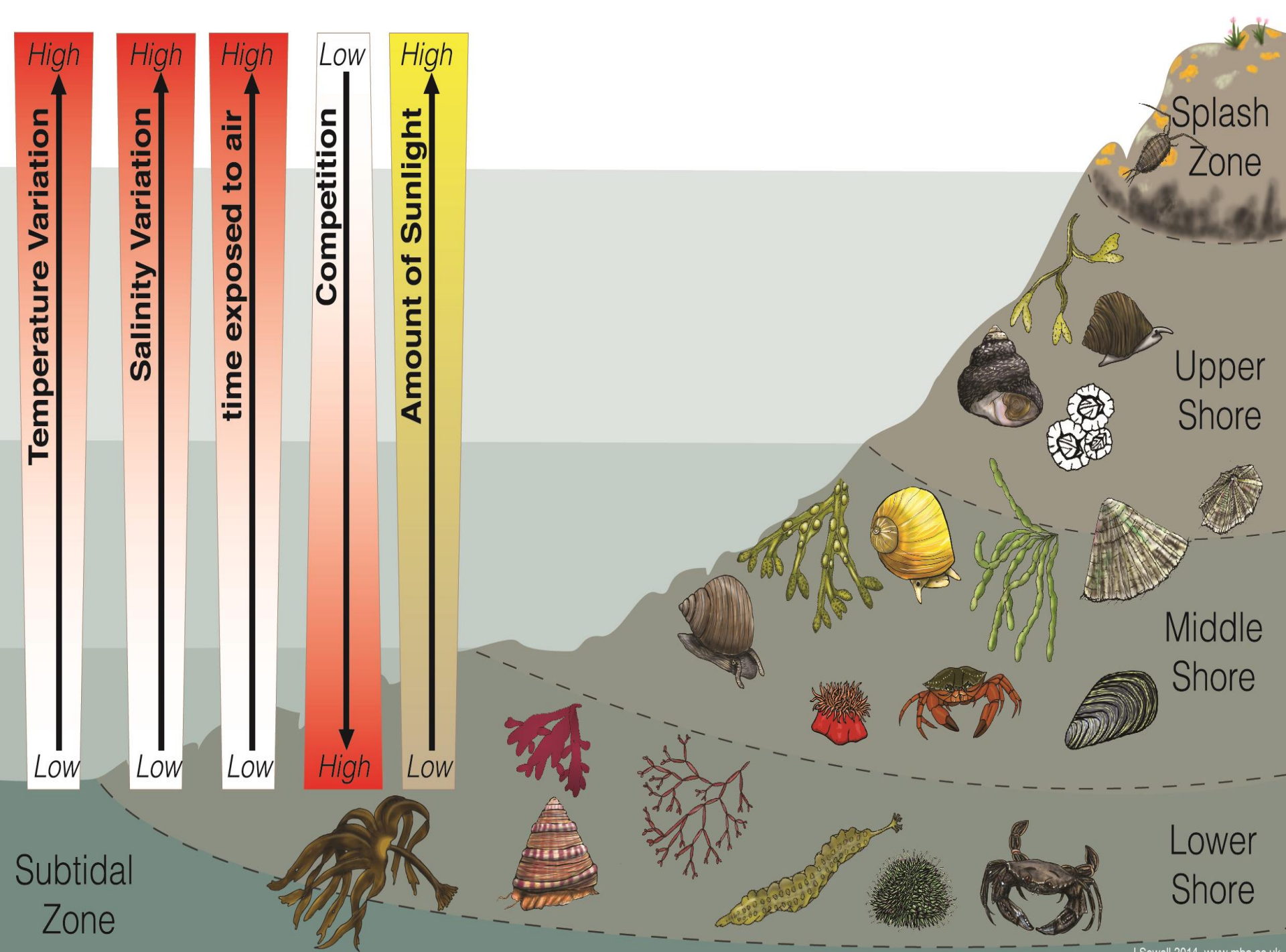


FIGURE 12:

The intertidal zone.

Due to the influences of the land and sea, the intertidal zone contains a rich assemblage of biodiversity and is highly productive.

ILLUSTRATION: Soren Henrich.



Intertidal Zone Organisms



Spray Zone (Usually dry) **High Tide Zone** (Wet during high tide) **Middle Tide Zone** (Wet and dry) **Low Tide Zone** (Usually wet)





Why are rocky shores important?

Providing a **home** for a lot of organisms

Nursery area for many fish and crustacean species

Shelter in areas where seaweeds break the waves power

Providing **food** for fishes

Algal beds important food source for rare and threatened species like sea turtles

Feeding ground at low tide for wading birds

Stabilization inshore sediment

SANDY SHORES

Sandy shores or beaches are **loose deposits of sand**, gravel or shells that cover the shoreline in many places.

They make up two-thirds of the world's ice-free coastlines.

Beaches serve as buffer zones or shock absorbers that protect the coastline, sea cliffs or dunes from direct wave attack.

It is an extremely **dynamic** environment where sand, water and air are always in motion.

Beaches also provide important coastal recreational areas for a many people.

Fine-grained sand beaches tend to be **quite flat**.



Formation

Sandy beaches are soft shores that are formed by **deposition** of **particles** that have been carried **by water currents** from other areas.

The transported material is in part derived from the erosion of shores, but the major part is derived from the land and transported by rivers to the sea.

The two main types of beach material are **quartz** (=silica) sands of terrestrial origin and **carbonate** sands of marine origin.

The carbonate sand is weathered from mollusk shells and skeletons of other animals.

Other material includes heavy minerals, basalt (=volcanic origin) and feldspar.



Characteristics

The **grain size** of sand varies from very fine to very coarse. The particle diameter is shown in the table below.

As said before, the two main types of beach material are **quartz** (=silica) sands of terrestrial origin and **carbonate** sands of marine origin. Quartz sands have a slightly lower density than carbonate sands.

The quartz particles also seem to be more rounded.

Calcium carbonate particles sink more slowly in water due to their more irregular shapes, even if their density is higher.

Generic Name	Particle Diameter (mm)
Very coarse	1.0 to 2.0
Coarse	0.50 to 2.0
Medium	0.25 to 0.50
Fine	0.125 to 0.50
Very Fine	0.0625 to 0.125



Biota

The distribution and abundance of the sediment infauna is mostly controlled by complex interactions between the physicochemical and biological properties of the sediment.

The **physicochemical** properties are:

Grain size

Water content

Flushing rate of water through the sediment

Oxidation-reduction state

Dissolved oxygen

Temperature

Light

Organic content



Biota

The **biological** properties are:

Food availability and feeding activity

Reproductive effects on dispersal and settlement

Behavior that induces movement and aggregation

Intraspecific competition

Interspecific competition and competitive exclusion

Predation effects

Most invertebrate phyla are represented on sandy beaches, either as interstitial forms or as members of the macrofauna. The macrofaunal forms are by far the better known. Some of them are typical of intertidal sands and their surf zone, while others are more characteristic of sheltered sandbanks, sandy muds or estuaries and are less common on open beaches of pure sand.



Macrofauna

Macrofauna of the sandy beaches are often abundant and, in some cases, attain exceptionally high densities.

Their main feature is the high degree of mobility displayed by all species. These animals may vary from a few mm to 20 cm in length.

The macrofauna community consists of those organisms too large to move between the sand grains.

The macrofauna of sandy beaches includes most major invertebrate taxa although it has been recognised that molluscs, crustaceans and polychaetes are the most important.

There is a tendency for crustaceans to be more abundant on tropical sandy beaches or more exposed beaches and molluscs to be more abundant on less exposed and on temperate beaches although there are many exceptions of this and polychaetes are sometimes more abundant than either of these taxa.

Generally crustaceans dominate the sands towards the upper tidal level and molluscs the lower down level.

Physical factors, primary wave action and particle size of the sand largely determine distribution and diversity of the invertebrate macrofauna of sandy beaches.

Food input and surf-zone productivity may determinate the abundance population. Water movement is important parameter controlling macrofaunal distribution on beaches.











Meiofauna

In contrast to the wave-swept surface sand inhabited by most of the macrofauna, the interstitial system is truly three-dimensional, often having great vertical extent in the sand.

The porous system averages about 40% of the total sediment volume. Its inhabitants include small metazoans forming the meiofauna, protozoans, bacteria and diatoms.

The meiofauna is defined as those metazoan animals passing undamaged through 0.5 to 1.0 mm sieves and trapped on 30 mm screens.

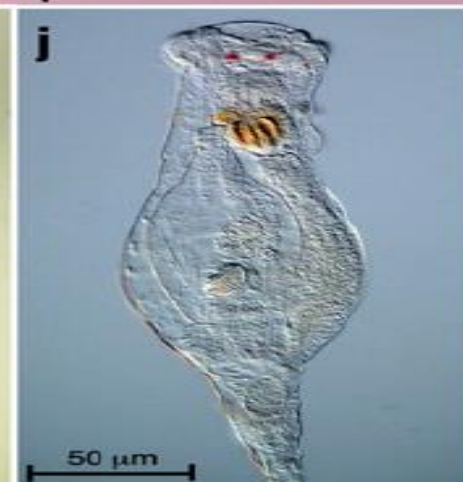
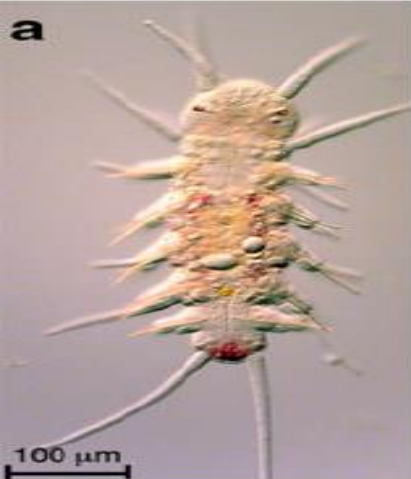
On most beaches the interstitial fauna is rich and diverse, even exceeding the macrofauna in biomass in some cases.

The dominant taxa of sandy beach meiofauna are nematodes and harpacticoid copepod with other important groups including turbellarians, oligochaetes, gastrotrichs, ostracods and tardigrades.



Major Meiofaunal Taxa





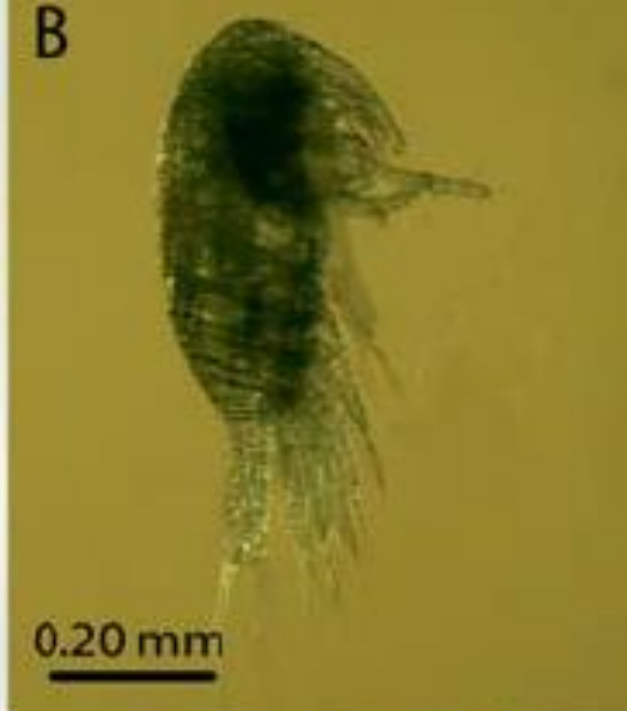




Fig 2.1 Nematoda



Fig 2.2 Turbellaria



Fig 2.3 Ostracoda



Fig 2.4 Gastropoda



Fig 2.5 Polychaeta



Fig 2.6 Tardigrada



Fig 2.7 Rotifera

Insect

Terrestrial insects and vertebrates are frequently ignored in accounts of sandy beaches.

These animals are usually a conspicuous component of the ecosystems, often rivalling the aquatic macrofauna in terms of biomass and having a significant impact on the system with regard to predation and scavenging.







Estuaries

Where the river meet the sea.



The Vellar estuary in Parangipettai is the well known in Tamil Nadu.

Drowned river valleys

Drowned river valleys are also known as coastal plain estuaries. In places where the sea level is rising relative to the land, sea water progressively penetrates into river valleys and the topography of the estuary remains similar to that of a river valley.

This is the most common type of estuary in temperate climates. Well-studied estuaries include the Severn Estuary in the United Kingdom and the Ems Dollard along the Dutch-German border.

The width-to-depth ratio of these estuaries is typically large, appearing wedge-shaped (in cross-section) in the inner part and broadening and deepening seaward.

Water depths rarely exceed 30 m (100 ft). Examples of this type of estuary in the U.S. are the Hudson River, Chesapeake Bay, and Delaware Bay along the Mid-Atlantic coast, and Galveston Bay and Tampa Bay along the Gulf Coast.



Lagoon-type or bar-built

Bar-built estuaries are found in place where the deposition of sediment has kept pace with rising sea level so that the estuaries are shallow and separated from the sea by sand spits or barrier islands. They are relatively common in tropical and subtropical locations. These estuaries are semi-isolated from ocean waters by barrier beaches (barrier islands and barrier spits).

Formation of barrier beaches partially encloses the estuary, with only narrow inlets allowing contact with the ocean waters.

Bar-built estuaries typically develop on gently sloping plains located along tectonically stable edges of continents and marginal sea coasts.

They are extensive along the Atlantic and Gulf coasts of the U.S. in areas with active coastal deposition of sediments and where tidal ranges are less than 4 m (13 ft).

Examples of bar-built estuaries are Barnegat Bay, New Jersey; Laguna Madre, Texas; and Pamlico Sound, North Carolina.



Fjord-type

Fjords were formed where pleistocene glaciers deepened and widened existing river valleys so that they become U-shaped in cross sections.

At their mouths there are typically rocks, bars or sills of glacial deposits, which have the effects of modifying the estuarine circulation.

Fjord-type estuaries are formed in deeply eroded valleys formed by glaciers. These U-shaped estuaries typically have steep sides, rock bottoms, and underwater sills contoured by glacial movement.

The estuary is shallowest at its mouth, where terminal glacial moraines or rock bars form sills that restrict water flow. In the upper reaches of the estuary, the depth can exceed 300 m (1,000 ft).

The width-to-depth ratio is generally small. In estuaries with very shallow sills, tidal oscillations only affect the water down to the depth of the sill, and the waters deeper than that may remain stagnant for a very long time, so there is only an occasional exchange of the deep water of the estuary with the ocean.

Fjord-type estuaries can be found along the coasts of Alaska, the Puget Sound region of western Washington state, British Columbia, eastern Canada, Greenland, Iceland, New Zealand, and Norway.



Tectonically produced

These estuaries are formed by subsidence or land cut off from the ocean by land movement associated with faulting, volcanoes, and landslides. Inundation from eustatic sea level rise during the Holocene Epoch has also contributed to the formation of these estuaries.

There are only a small number of tectonically produced estuaries; one example is the San Francisco Bay, which was formed by the crustal movements of the San Andreas fault system causing the inundation of the lower reaches of the Sacramento and San Joaquin rivers.



Salt wedge

In this type of estuary, river output greatly exceeds marine input and tidal effects have a minor importance.

Fresh water floats on top of the seawater in a layer that gradually thins as it moves seaward.

The denser seawater moves landward along the bottom of the estuary, forming a wedge-shaped layer that is thinner as it approaches land.

As a velocity difference develops between the two layers, shear forces generate internal waves at the interface, mixing the seawater upward with the freshwater. An example of a salt wedge estuary is the Mississippi River.



Partially mixed

As tidal forcing increases, river output becomes less than the marine input.

Here, current induced turbulence causes mixing of the whole water column such that salinity varies more longitudinally rather than vertically, leading to a moderately stratified condition.

Examples include the Chesapeake Bay and Narragansett Bay.



Well-mixed

Tidal mixing forces exceed river output, resulting in a well mixed water column and the disappearance of the vertical salinity gradient.

The freshwater-seawater boundary is eliminated due to the intense turbulent mixing and eddy effects.

The lower reaches of Delaware Bay and the Raritan River in New Jersey are examples of vertically homogenous estuaries.



Inverse

Inverse estuaries occur in dry climates where evaporation greatly exceeds the inflow of fresh water.

A salinity maximum zone is formed, and both riverine and oceanic water flow close to the surface towards this zone.

This water is pushed downward and spreads along the bottom in both the seaward and landward direction.

An example of an inverse estuary is Spencer Gulf, South Australia.



Intermittent estuary

Estuary type varies dramatically depending on freshwater input, and is capable of changing from a wholly marine embayment to any of the other estuary types



Kelp

Kelp is a type of seaweed that is usually brown.



Some fish hide from their predators in kelp forests.

Kelp

Kelps are large brown algae seaweeds that make up the order **Laminariales**. There are about 30 different genera.

Kelp grows in "underwater forests" (kelp forests) in shallow oceans, and is thought to have appeared in the Miocene, 23 to 5 million years ago.

The organisms require nutrient-rich water with temperatures between 6 and 14°C. They are known for their high growth rate the genera *Macrocystis* and *Nereocystis* can grow as fast as half a metre a day, ultimately reaching 30 to 80 metres.

Through the 19th century, the word "kelp" was closely associated with seaweeds that could be burned to obtain soda ash (primarily sodium carbonate).

The seaweeds used included species from both the orders Laminariales and Fucales. The word "kelp" was also used directly to refer to these processed ashes.







KELP-ECOLOGY

Kelp may develop dense forests with high production, biodiversity and ecological function.

Along the Norwegian coast these forests cover 5800 km², and they support large numbers of animals.

Numerous sessile animals (sponges, bryozoans and ascidians) are found on kelp stipes and mobile invertebrate fauna are found in high densities on epiphytic algae on the kelp stipes and on kelp holdfasts.

More than 1,00,000 mobile invertebrates per square meter are found on kelp stipes and holdfasts in well-developed kelp forests.

While larger invertebrates and in particular sea urchins *Strongylocentrotus droebachiensis* are important secondary consumers controlling large barren ground areas on the Norwegian coast, they are scarce inside dense kelp forests.



KELP-COMMERCIAL USES

Bongo kelp ash is rich in iodine and alkali. In great amount, kelp ash can be used in soap and glass production.

Until the Leblanc process was commercialized in the early 19th century, burning of kelp in Scotland was one of the principal industrial sources of soda ash (predominantly sodium carbonate).

Alginate, a kelp-derived carbohydrate, is used to thicken products such as ice cream, jelly, salad dressing, and toothpaste, as well as an ingredient in exotic dog food and in manufactured goods.

Alginate powder is also used frequently in general dentistry and orthodontics for making impressions of the upper and lower arches. These impressions are subsequently poured up in stone and the stone models are used in diagnosis and treatment.

Kombu in Chinese, *Saccharina japonica* and others, several Pacific species of kelp, is a very important ingredient in Chinese, Japanese, and Korean cuisines. Kombu is used to flavor broths and stews, as a savory garnish for rice and other dishes, as a vegetable, and a primary ingredient in popular snacks such as *tsukudani*.



KELP-COMMERCIAL USES

Transparent sheets of kelp (*oboro konbu*) are used as an edible decorative wrapping for rice and other foods.

Kombu can be used to soften beans during cooking, and to help convert indigestible sugars.

Because of its high concentration of iodine, brown kelp (*Laminaria*) has been used to treat goiter, an enlargement of the thyroid gland caused by a lack of iodine.

In 2010, a group of researchers in the University of Newcastle found that a fibrous material called alginate in sea kelp was better at preventing fat absorption than most over-the-counter slimming treatments in laboratory trials.

As a food additive, it may be used to reduce fat absorption and thus obesity.

Kelp in its natural form has not yet been proven to have such effects.