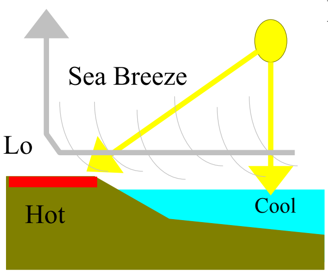
Coastal Environmental Phenomena

Local Variations in Wind (Land and Sea Breezes)

Sea Breezes - movement of air across water (wind) from the sea to the land is a **sea breeze** (winds are named from where they come)

- produced by change in temperature between land and sea
- during day, sea breeze blow inland because land is relatively hot compare to sea



Land

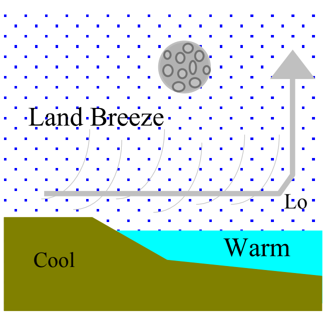
- land is opaque and sunlight can only heat the uppermost surface
- land has limited ability to conduct heat downward or store heat and so most of the excess heat warms the air above land creating less dense air and an area of low pressure on the land
- heated air is pushed upward by cooler denser air flowing in from over the sea
- this air in turn is heated and also displaced

Water

- water is largely transparent and sunlight penetrates it heating a large volume of water
- water also conducts and convects, storing excess heat in an even greater volume of water and therefore remains relatively cool during the day
- air above the water remains cool and dense

- *sailing ships arrive during the day so as to use the sea breeze*

Land Breezes



- flow of air from land to the sea is a **land breeze**

Land

- at night land cools quickly because it has stored little heat during the day
- air above the land cools and becomes denser

Water

- heat stored by the water during the day is release slowly all night
- air above water is warmed and expands
- air from the land flows seaward, displacing the warm sea air forming a weak low pressure area and the land breeze

- *sailing ships usually left port at night so as to use the land breeze*

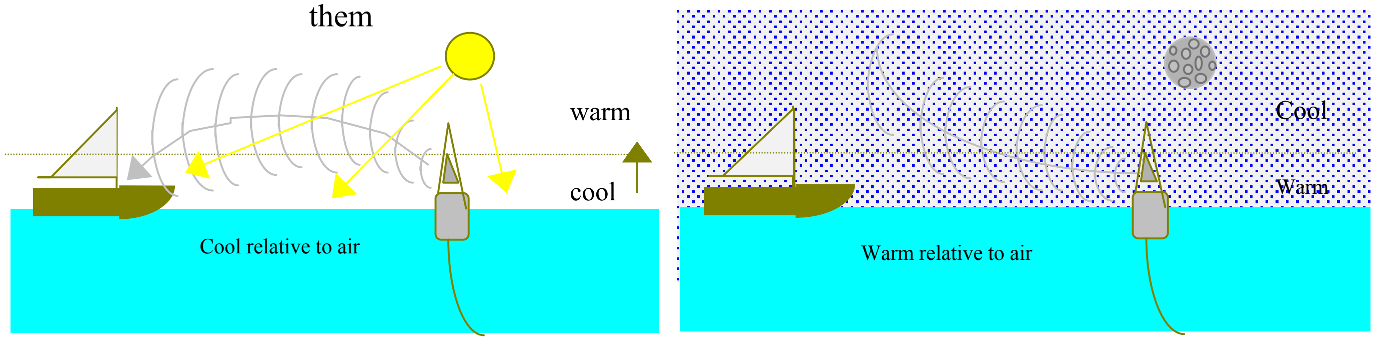
- Sea breezes are stronger than land breezes because the difference in temperature and air density between the land and the sea is greater during the day than at night

Sound above the Sea

- speed of sound in air is a function of temperature
- higher the temperature the faster the air molecules move and the faster sound travels $V_s = 20\sqrt{T^oK}$ where V_s is velocity of sound in air and $T^oK = 273 + {}^oC$
- because sound travels as a wave, it is refracted into a medium where it travels slower, i.e. it is refracted into cooler, denser air
- when air directly above the water is cooler than higher air, sound is refracted downward toward the sea surface

- this is common during the day and during the summer because the water is generally cooler than the air and chills the lower air layers
- sound waves are refracted downward toward the surface and can be heard at a greater distance

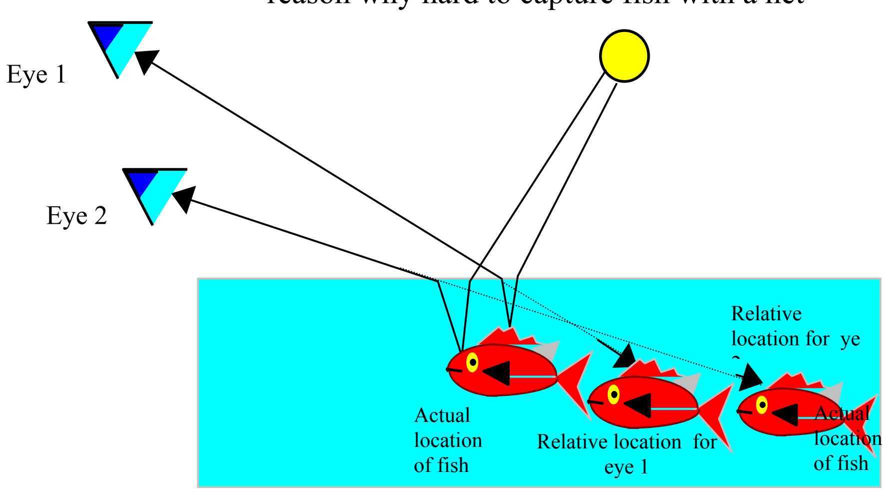
- when air directly above the water is warmer than higher air, sound is refracted upwards away from the water
    - this is common at night and during winter because water tends to store heat and release it slowly to the air directly above it, whereas higher air looses its heat rapidly
    - sound waves are refracted upwards and listener must be much closer to hear them

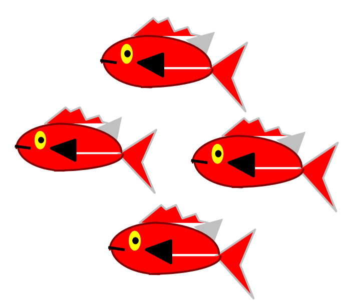


Light

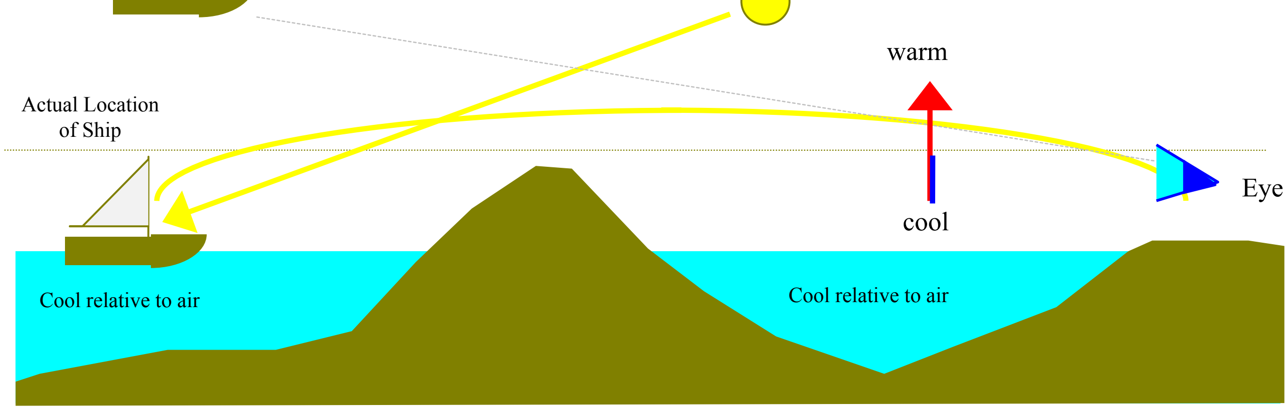
- because light travels in the forms of waves, it is refracted into a medium where it travels slower, usually a medium that is more dense

1. *Seeing an object submerged in water*
    - light is refracted (bent) as it enters and leaves water
    - when viewing object that is submerged in water, the angle of observation to the water surface is critical
    - if looking straight down at a submerged object, the position of the object is true and refraction is insignificant
    - as the angle of observation approaches the horizontal, refraction becomes increasingly important and the location of the image of the object shifts away from the viewer and the actual location of the object
    - because the mind interprets light as traveling in a straight line, the object will appear to be behind its actual position and at a different depth
        - reason why hard to capture fish with a net

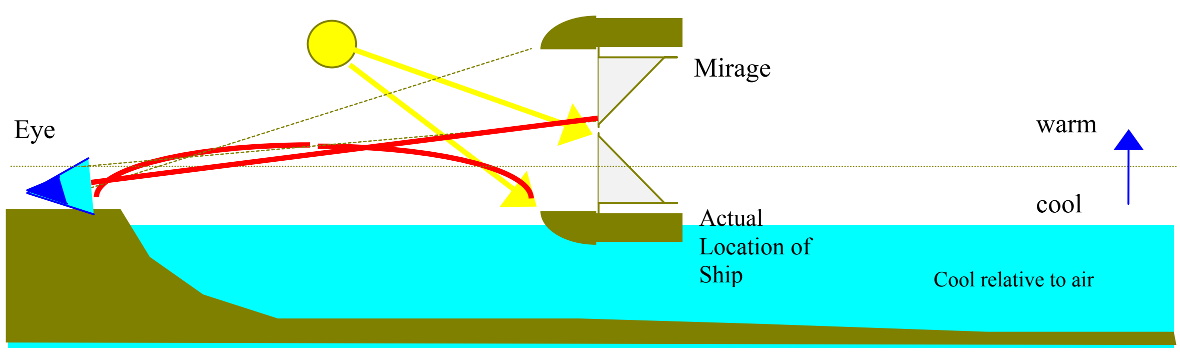




2. **Looming** - ability to see objects beyond obstructions or the curvature of earth because of the refraction of light
- light is refracted into cold air because it is more dense and the light travels slower
- when the air above the water is cooler than higher air, as during the day and summer, light will be refracted downward toward the water surface
- some of the light striking an object initially begins to travel upwards, but if condition are suitable, the light will be refracted downward and an object located beyond the curvature of the Earth may be visible.
- may also allow an object that should be obscured from vision by an island to be visible
- because the mind interprets light as traveling in a straight line, the object appears high in the sky, floating above objects that are closer to the observer



3. **Mirages** - image of object seen inverted above position of true object
- if an object is within the radius of curvature of the Earth, refraction of light can produce a mirage
- if air directly above the sea surface is colder than air above, light is refracted downward
- amount of refraction decreases with distance above the sea surface because of temperature gradient decreases
- an inverted duplicate view of the object will appear above the spot where the object is located because the refraction of the light is greater at the bottom than the top because of the thermal gradient



COASTS AND SHORELINE PROCESSES

Coastal Ocean (Pericontinental Sea and Epicontinental Sea)

- sea that floods edge of continent and occupies the continental shelf (**pericontinental sea**) and/or floods the interior of the continent (**epicontinental sea**)
- depth varies from 0 m (shoreline) to 200 m (edge of shelf)
- circulation generally more restricted than in open ocean because of shallowness and possible partial isolation by land
- differs from open ocean in temperature and salinity

Temperature)

- shows seasonal and daily variation (especially in mid-latitudes
    - Daily
        - coolest at dawn and warmest in mid-afternoon
    - Seasonal

        winter - **isothermal**; well mixed throughout (overturn) unless covered by ice because ice prevents the wind from mixing the water downward

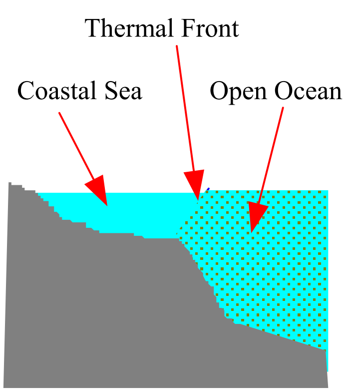
        spring - surface layer warms but mixed downward by winds

        summer - thermocline develops isolating warmer surface water from cooler, deeper layers

        fall- surface cools and mixing occurs
- heated throughout if turbidity low and light reaches bottom
- can reach very high temperatures in restricted seas where circulation is inhibited

Salinity

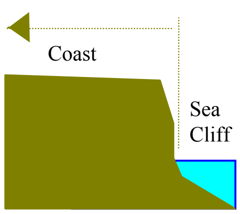
- warm summer land breezes increase evaporation and raise salinity
- cooler winter winds decrease evaporation and lowers salinity
- greatly influence by precipitation and inflow from land (rivers/springs)



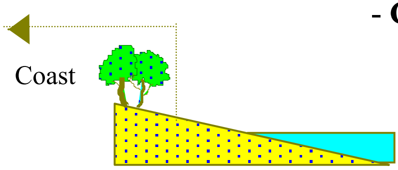
- **Thermal Front** - temperature-salinity related density barrier may develop between open ocean and coastal waters in mid-latitudes
    - inhibits mixing with open ocean

Coastal Currents - horizontal movement of water that flows parallel to shoreline

- driven by waves (**longshore currents**), river discharge and/or winds
- tends to be variable over relatively short periods of time
- strongest when runoff is high, wind is strong and waves are large and constant in direction
- may be related to upwelling and downwelling



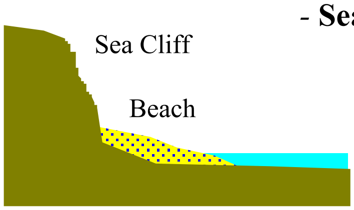
Types of Sea Shores



- **Coast** - a strip of land of indefinite width (up to several kilometers) extending landward from the base of the sea cliff or stable vegetation to change in topography (landscape)
    - type of sea shore that develops depends upon:

1. exposure to open ocean (determines average wave size)
2. composition and homogeneity of coast material
3. steepness of coast and offshore regions
4. tidal range
5. changing wave pattern and wave strength
6. time

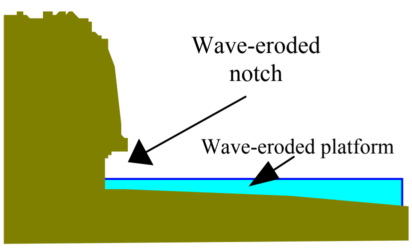
1. **Cliffted Coast** - shoreline characterized by steep incline from land (coast) down to sea level



- **Sea Cliff** - usually erosional feature
    - steep slope to vertical drop produced by wave erosion of elevated land
    - may be directly at edge of sea or set back and separated from the sea by a beach

Development of wave-cut platform and other features from sea cliff

- differential erosion produces irregular coastline
- easily eroded areas become **coves** and **bays**
- resistant areas become **headlands** as adjacent areas erode back
- sea usually at base of sea cliff at headland, but separated from the cliff by a beach in coves
- waves pounding at the base of sea cliffs eventually erode it producing several features

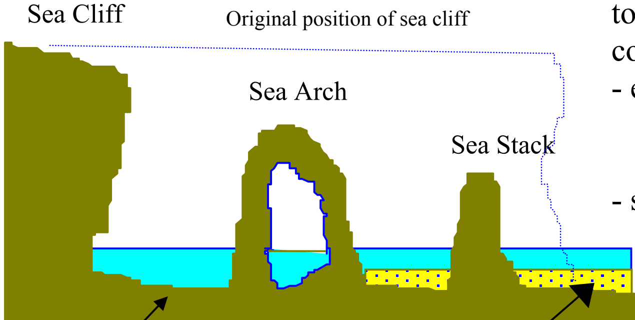


a. **wave-eroded notch** about as high as the average tidal range for the area
   - as notch erodes back into the cliff, support is removed for material above and periodically the face of the cliff collapses
   - material is ground-up by waves and removed

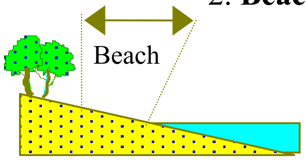
b. as the cliff retreats a flat, featureless inclined surface, called a **wave-eroded platform**, is produced in front of the sea cliff

c. resistant parts of headlands may become **sea arches** if waves erode around the basal part of the sea cliff creating an archway of rock

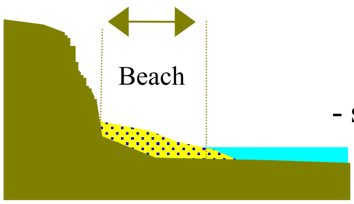
d. sea arches eventually become **sea stacks** when the top of the arch collapses and leaves an isolated columns of rock
   - eventually even the sea stacks erode, collapse and become part of the wave-eroded platform
   - some of sediment generated from the erosion of the sea cliff is deposited offshore below wave base and forms a gently inclined **wave-deposited platform**



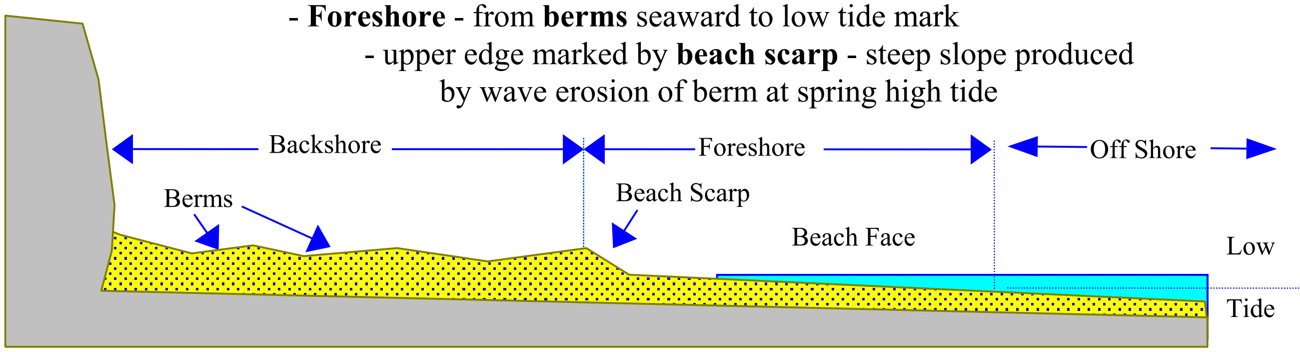
2. **Beaches**



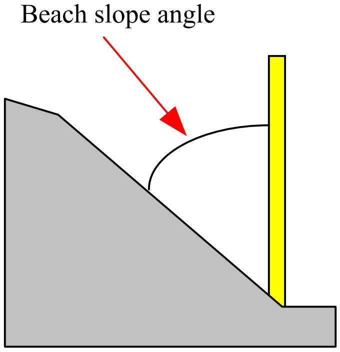
- area extending from base of sea cliff or first stable vegetation to low water (low tide)
- consists of coarse (sand to boulders) sediments
- attached to the coast along its length
- material composing beach mainly determined by source:
    - continent - quartz (chemically, very stable grains)
    - volcanic islands - rock fragments (individual minerals weather away)
    - coral islands - coral fragments



- subdivided into foreshore and backshore
    - **Backshore** - from base of sea cliff or first stable vegetation to seaward extent of **berms** - small terraces with low ridges
        - **berm crest** on the seaward edge and built by summer waves and storms
    - **Foreshore** - from **berms** seaward to low tide mark
        - upper edge marked by **beach scarp** - steep slope produced by wave erosion of berm at spring high tide



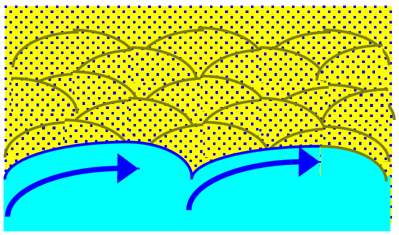
- **Beach Face** - sloping, generally featureless part of beach between the base of the beach scarp and **low tide terrace** (flat area transitional with the continuously submerged offshore area)
    - beach face is generally featureless because of constant reworking by waves
    - slope of face depends on:
        1. size of sediment
        2. sorting,
        3. permeability
    - as size of material increases, **beach slope angle** (angle with the vertical) decreases (*beach face becomes steeper*) because smaller particles weigh less and are easily moved about by waves and there is less infiltration with more water flowing down the beach face after the wave breaks and this moves small grains about easily:



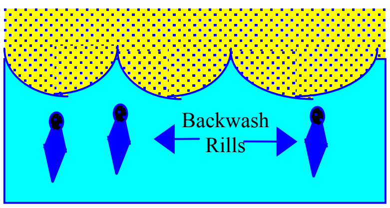
size (mm)		angle
.12 - .25	(fine sand)	30^{o}
4 - 64	(pebble)	15^{o}
64 - 256	(cobbles)	10^{o}

Features found on the beach face

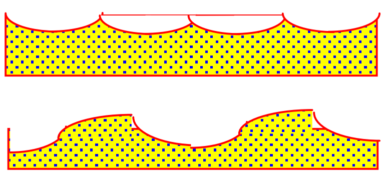
- although beach faces is generally featureless, some temporary features can be formed, but are usually destroyed by the next wave, tide or storm



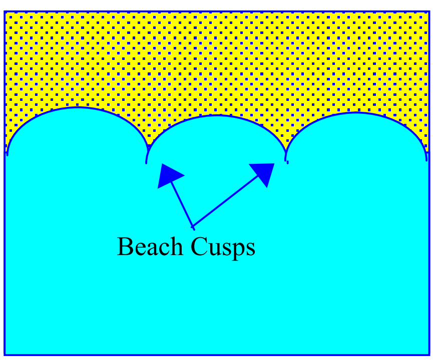
- **Swash Marks** - swash refers to the waves washing across the beach face and then flowing back into the sea
  - swash marks are lines of sediment and debris washed up the beach face by the incoming waves and stranded at the forward edge of the wave because there is insufficient velocity to remove them as the water flows back (remember Hjulstrom's Diagram)



- **Backwash Rills** - diamond-shaped rill channels developed during **backwash** (water flowing down beach face as wave recedes)
  - best developed around pebbles or other objects too large for the backwash to remove.

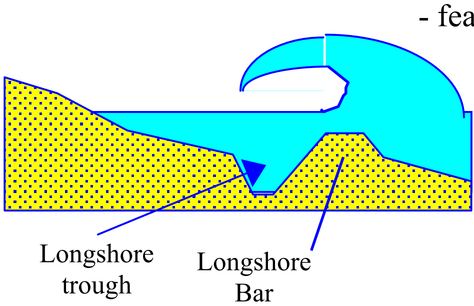


- **Ripple Marks** - low ridges of sand created by currents of wind or water or by oscillatory motion of waves
  - may be **symmetrical** (wave-generate) or **asymmetrical** (current-generated)



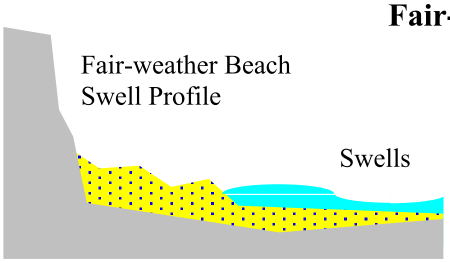
- **Beach Cusps** - uniformly spaced, tapering ridges separated by rounded embayments formed by the wave-erosion of the berms
  - upper part is the beach scarp
  - spacing related to height of waves
    - higher waves - wider spacing
  - origin not well understood
  - spacing may vary from a few meters to 1000 kms.
    - arrangements of barrier islands and beaches along some coasts seem similar to beach cusps

- **Offshore** - area from low tide (shoreline) seaward
  - not part of beach
  - features formed by waves



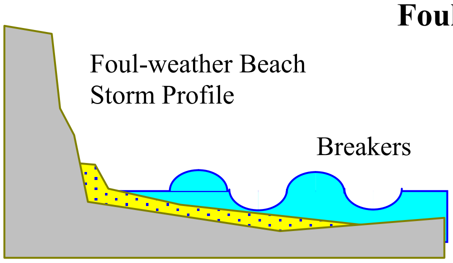
  - **longshore trough** - erosional depression paralleling shoreline formed where waves break and erode seafloor
    - transfer sediment seaward
  - **longshore bar** - depositional ridge of sediment formed seaward of the longshore trough
    - composed mainly of sediment eroded from the longshore trough
    - encourages the continued breaking of waves in this area by making water shallower

Seasonality of Beaches



Fair-weather beaches

- typical of summer because fewer storms and less destructive waves
- waves are generally low swells which transport sediment shoreward
- water at crest is deeper, friction is less and more sediment is transports shoreward than is transported seaward at trough when friction is greater and retards the back flow of water along the base of the wave
- shoreward accumulation of sediment constructs berms which expands beach seaward and buries coarser sediment
- *intertidal area becomes narrower and steeper*
- produces **swell profile**



Foul-weather beaches

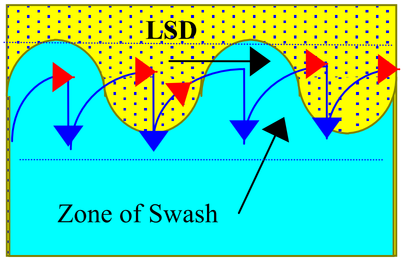
- typical of winter because winter storms generate large, high waves
- waves are highly erosive when they break, transport large amount of water to the shore which then carries sediment seaward in the backwash and undertow
- berms erode and *intertidal area becomes broad and flat*
- beach becomes narrower and composed mainly of coarser material too large for the waves to erode
- produces **storm profile**

Sand (Sediment) Budget - estimate of sediment input and losses for a section of a beach and how the beach profile is altered

- can be applied to sediment of any size, not just sand
- *budget = input - loss*
    - **input** - sediment contributed to beach by rivers, sea cliff erosion, onshore transport by waves and longshore currents, transport of sediment from the coast to the beach by wind and runoff
    - **loss** - beach sediment transport seaward by wind, erosion by waves and removal by currents
- if input>loss - **positive budget**
    - beach profile expands as beach extends seaward and becomes wider
    - swell profile results from a positive budget
- if input<loss - **negative budget**
    - beach profile becomes narrower as beach erodes
    - storm profile results from a negative budget
- if input = loss - **dynamic equilibrium**, profile remains constant, but sediment keeps changing

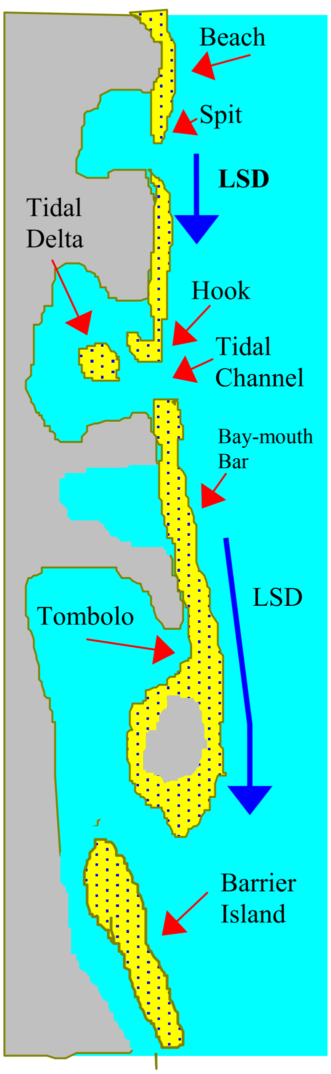
BEACH AND BEACH MATERIAL MOVEMENT

Movement of Grains along Beach



- waves and currents move grains parallel to shore in the **zone of swash** - part of beach where waves wash back and forth
  - refraction bends the waves as they approach the shore so that they break *almost* parallel to the shoreline
  - waves wash up the beach face at a slight angle as wave breaks
  - after wave's energy is spnt pushing water up the beach, gravity causes the water to flow straight down beach face to the sea
    - less water flows back because some infiltrates
  - sediment is moved along the beach in a zig-zag motion called **longshore drift (LSD)**
    - direction of drift is function of wave direction
    - always away from headlands and towards coves
    - offshore the sediment is transported along the shore by longshore currents and then seaward by rip currents

Beach Migration - gradual transport of beach material along the shore by various processes including longshore drift and longshore currents



- beach initially forms in area where there is a positive sediment budget, but then migrates and/or expands laterally into other areas
- if offshore is shallow and slope gentle, variety of coastal depositional features may form, usually where there is a marked change in geometry of coast

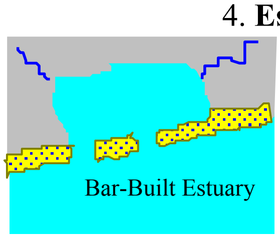
- *Depositional Beach Features*:
  1. **Spit** - linear ridge of sediment attached to land at one end and extending outward into the sea
     - points in the direction of long shore drift and terminates in open water
  2. **Cuspate spit**, **hook** or **cape** - tip of spit curves to produce a pronounced hook
     - formed when drift is directed abruptly laterally by refraction
  3. **Bay Mouth Bar** (**Barrier Bar**) - spit built across the opening of a bay and isolating it from the sea
  4. **Tombolo** - spit connecting island to another island or mainland
  5. **Barrier island** - long island that parallels the coast and is composed of sediments
     - may be formed from spit by the erosion of a channel that separates part of the spit from the land mass or the upward growth of an offshore bar
     - establishment of vegetation helps to ensure endurance
     - migrates along the coast with longshore drift and landward with rising sea level

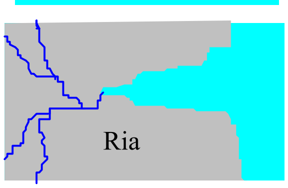
- storms wash over island and transport sediment from seaward side to the coastal side (**washover fans**)

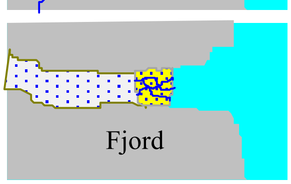
6. **Tidal Deltas** - low accumulation of sediment formed at one or both ends of a **tidal channel** - a channel through which the tides flood and ebb
    - swift flow of the ebb and flood current in channel scours sediment, but as current enters bay or open ocean velocity decreases and sediment is deposited
    - generally only barely emergent
    - may have vegetation
    - more common on the bay side than ocean side because of large waves and longshore current on ocean side

3. **Lagoon** - semi-enclosed body of water that receives little inflow of fresh water and is more saline than the ocean
    - most commonly located around 30^{o}N,S
    - generally broad, but shallow
    - types:
        - A. **Bar-built Lagoon**- where spits, barrier islands and/or tombolos have partially isolated the body of water
        - B. **Tectonic** - where isolation has been caused by uplift of the seafloor
        - C. **Organism-constructed** - where growth of coral reefs has isolated the body of water
            - atolls

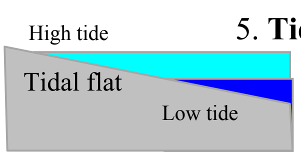
4. **Estuaries** - semi-enclosed coastal body of water that receives large amount of inflow and contains brackish water







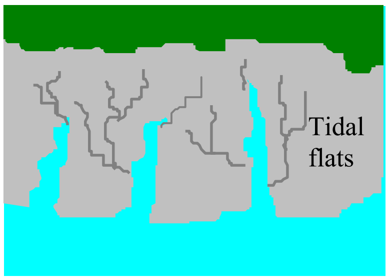
- most commonly form in coastal areas flooded by rising sea level and/or sinking of land
- generally have delta where river enters
- temporary feature that will be filled with sediment if sea level is stationary and/or subsidence ceases
- types:
    - A. **Bar-built Estuary** - shallow body of water partially isolated by the formation of spits, barrier islands and/or tombolos
      Example: Pamlico Sound, N.C.
    - B. **Ria** - flooded mouth of river and/or river valley
      Example: Chesapeake Bay
    - C. **Fjord** - flooded glacial valley
      Example: Pudget Sound
    - D. **Tectonic Bay** - bays isolated by uplift of young mountain range
      Example: San Francisco Bay



5. **Tidal Flats** - generally low, flat coastal areas protected from surf and periodically inundated by tides

- commonly develop in lagoons, estuaries and on the coastal side of barrier islands
- dissected by tidal-flat channels which drain the flat during ebb tide
- major controlling factors in formation and longevity:
    1. tide range (larger the range the better)
    2. slope of the land
    3. rate of sedimentation
    4. type of sediment
    5. change in sea level relative to land
    6. ability of plants to live in the environment
        - plants inhibit tidal flow and trap sediment, aiding in filling the area faster

        Example: in 30 years, mangrooves filled in 1500 acres of Biscayne Bay, Florida

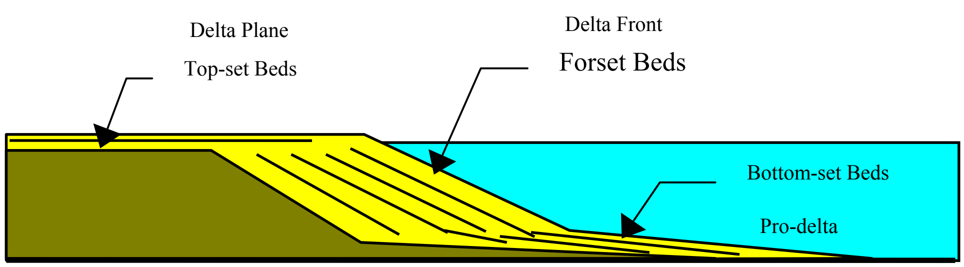


- types:
    A. **Mudflats** - little or no vegetation
        - can occur anywhere

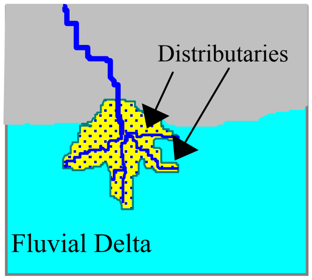
    B. **Marshes** - inhabited mainly by grasses
        - mainly in the temperate climate, not in polar or subpolar

    C. **Swamps** - inhabited by mangrooves
        - only in the tropics

6. **Deltas** - land areas built by deposition of sediment at the mouths of rivers
    - parts of a delta:
        - **bottomset beds** - beds of fine clays and silts deposited in front of the advancing delta mass
            - exposed surface of bottomset beds called the **prodelta**
        - **foreset beds** - beds of coarser sediment that corm the bulk of the delta mass and overlies the bottom set beds
            - exposed surface is called the **delta front**
            - material collects at the top of the delta front and periodically cascades downward
        - **topset beds** - beds of clays and silts deposited on the top of the foreset beds and in some areas are emergent
            - exposed surface of the topset beds is called the **delta plane**



- type of delta that forms is determined by dominant process: waves, tides or fluvial deposition

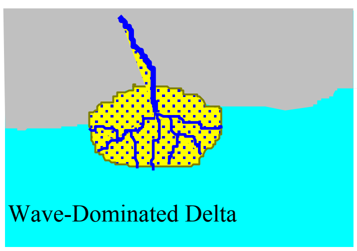


A. **Fluvial deltas** (**bird's foot delta**) - deposition is major process; tides and waves less important

Example: Mississippi River

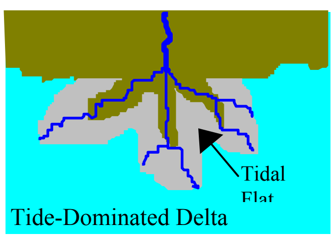
- near the mouth of the river, the river subdivides into a series of **distributaries** - subdivisions of the main channel
- emergent ridges of sediment form parallel to the distributaries from repeated flooding and extend out into the sea
- areas between the distributaries remain low and occupied by marshes, swamps or lakes
- emergent areas continuously subsiding because of compaction and only remain above sea level if additional layers of sediment are added periodically
- when river changes course and no sediment is added to older areas, these areas subside and are flooded

B. **Wave-dominated Delta** - waves are major influence and redistribute sediment along the shoreline



- finger-like extensions formed along the distributaries act as headlands and refraction of waves around them quickly erode them and redistribute the sediment filling areas between distributaries
- delta tends to be triangle in shape with beach and ridges along delta front

Example: Nile Delta



C. **Tide-dominated Delta** - ebb and flood of tides are the major process determining the shape of the delta

- tidal currents redistribute sediment into a series of elongate tidal flats and bars that radiate out from the mouth of the river

Example: Ganges River

COASTLINE CLASSIFICATION

- there are various ways to classify coasts:
  - emergent vs. submergent
    - based upon relative change in sea level
  - advancing edge vs. trailing edge
    - based upon relationship to plate tectonics
  - generic
    - based upon dominant factor (terrestrial or marine) responsible for features seen
- Generic Classification

  A. **Primary Shoreline and Coasts**
  - configuration of shoreline results from terrestrial agents of erosion, deposition, or structural deformation
  - short-lived because almost as soon as forms begins to be altered by marine processes

- types:
    1. **Subaerial Erosion Coastlines**
        - coastline developed by erosional agents on land such as streams and glaciers
        - land later submerged by rising sea or subsidence of the land
        - includes: ria, fjord
    2. **Subareal Deposition Coastlines** -
        - coastline developed by terrestrial depositional agents and later submerged by rising sea or subsidence of land
        - includes: fluvial deltas, deposits of glaciers, landslides, wind etc.
    3. **Tectonically-shaped Coast**
        - coastline developed by uplift of previously submerged areas
        - usually identified by presence of sea-formed features located high above high tide mark
    4. **Volcanic Coast** - characterized by composition of rock and irregular shape with possible tongue-like extensions (lava flows) radiating outward from central vent or fissure

B. **Secondary Coastlines** - configuration of shoreline result from marine deposition or erosion
    1. **Wave-erosional coast** - shaped by wave action
        - may be straight or irregular depending upon relative age, nature of rock and structural control
        - if not homogenous rock and long subjected to erosion by waves, will develop headlands and coves, wave-cut platform and sea cliff and possibly arches and stacks
        - over time irregular coasts will becomes straight as headlands erode and sediments fill bays and coves.
    2. **Marine Depositional Coasts** - deposits built by waves and or tides
        - includes: spits, hooks, bay-mouth bars, tidal deltas, tombolos, mudflats, tide-dominated and wave-dominated deltas
    3. **Organism-Constructed Coasts** - coastlines in which the presence of organisms play an important role in forming the coast
        - includes: reefs, marshes, swamps

MODIFICATION OF COASTS BY MAN

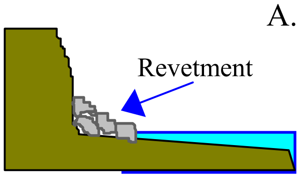
- reasons for modification of coastal area:
    1. improve areas as harbor or for shipping

2. filling of shallows to create land for industry, airport or housing
3. prevention of erosion

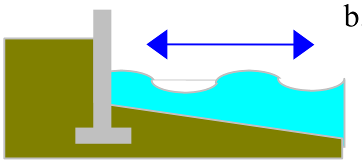
- includes modification by:
    a. structures
    b. dredging
    c. replenishment

1. Modifications by structures

A. *Parallel to shore*

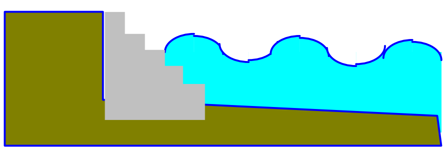


a. **Revetment** - low, sloping apron of concrete, concrete blocks or rock fragments (**riprap**) at foot of sea cliff
- material too large for the waves to remove
- waves expend energy against revetment and protects cliff base from erosion



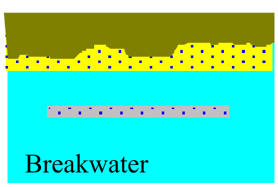
Reflective Sea Wall

b. **Sea wall** - massive structure built to withstand high waves or prevent erosion
- usually associated with revetment at base to prevent undermining of sea wall
- types:
    1. **Reflective** - vertical wall against which waves strike and are reflected
    2. **Breaking** - usually a series of stairs against which the waves break and expend their energy
        - cause wave to dissipate energy gradually



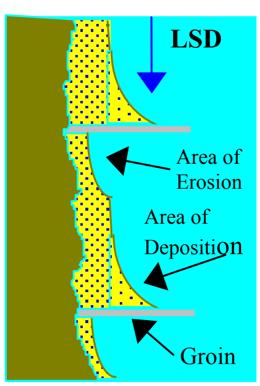
Breaking Sea Wall

c. **Bulkhead** - wall built to prevent sliding of land or fillinto the water and to reduce erosion

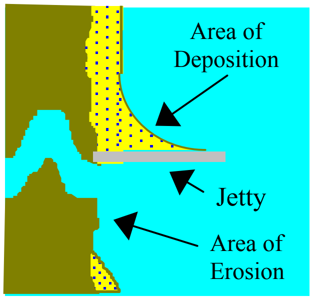


d. **Breakwater** - barrier constructed offshore and parallel to the coastline
- waves expend energy against breakwater and only smaller refracted waves reach area behind the breakwater

B. *Perpendicular to Shore* - mainly serve to disrupt longshore drift and trap sediments



a. **Groins** - wall extending from shore out to a depth of about 2 meters
- traps about 80% of sediment transported by longshore drift on the updrift side, but causes corresponding erosion on the downdrift side
- used to restore or enlarge beach
- two types:
    1. **permeable** - allows some sediment to past through gaps in the groin
        - traps less sediment updrift and causes less erosion downdrift
    2. **impermeable** - attempts to trap all sediment until beach extends almost to the edge of the groin



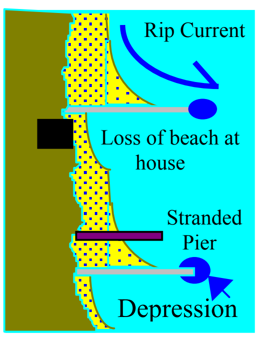
b. **Jetties** - longer than groin and extends into water greater than 2 meters deep because attempts to trap all sediment transported by longshore drift and longshore current
- used to stabilize mouth of stream or tidal channel or in combination with breakwater to create an artificial harbor

2. **Dredging** - removal of sediment from the bottom
   - used mainly to deepen shallow channels and shallow bays, to create new channels or bays or to obtain sediment for other uses

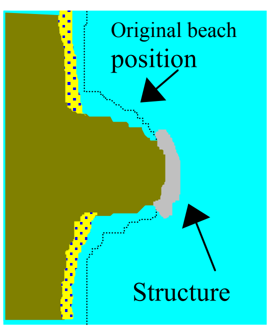
3. **Replenishing Beach** - add sand to expand a beach
   - sand may be hauled from inland, dredged from offshore or obtain from coastal sand dunes

Possible consequences of Coastal modifications

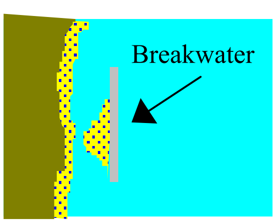
Groins & Jetties - trap sediment updrift allows erosion downdrift



- expanding beaches may strand piers and other coastal structures on updrift side
- erosion of beach downdrift can cause the undermining of coastal structures
- because direction of longshore drift changes as the direction from which approaching waves change, placement of structures must consider seasonal variations
- can deflect longshore current seaward as rip current
- can cause deep hole to eroded in sea floor at seaward end of structure because incoming waves will compress the current there, forcing it to flow faster and be more erosive.



Revetment and seawalls - stop erosion where placed, but erosion will still occur around ends
- erosion of coast is one of major source of sediment input for beaches
- if erosion stopped, negative sand budget will result in erosion of beach
- can reflect waves to another area where combines with regular waves to become more erosive



Breakwater - creates area of small waves behind it and this becomes area of deposition
- area behind breakwater begins to fill in with sediment becoming shallower and breakwater may eventually be connected to land by a tombolo

Dredging - nearshore dredging creates depressions in the sea floor which can become sediment traps and can lead to erosion of beach down drift because it will be deprived of sediment
- can lead to the reintroduction of pollutants buried in the sediments
- creates a problem of sediment disposal when dredging to deepen channels and bays
- *dredging to create channel to inland freshwater lakes:*
    - denser saltwater will flow in and displace freshwater
    - as lake fills with saltwater, it will contaminate the ground water, polluting wells and killing vegetation
    - entire ecosystem will be altered

Replenishing Beach - expanded beach will act as headland causing waves
to refract around it and redistribute sediment to the sides causing adjacent areas to expand and replenished area to erode
- can strand coastal structures

Possible consequences of inland modifications of rivers

Dams on rivers - causes sediment to be trapped in the lake that otherwise would be transported to the coast
- reduced input of sediment to beach may cause beach to erode

Clearing land along river, mining, forest fires, etc.
- liberate large quantities of sediment which can be transported to coast and cause the expansion of the beaches
- can lead to stranding of coastal structures

Example of Modification and Consequences

BIOLOGICAL OCEANOLOGY

Marine Environment compared to Terrestrial Environment

a. three dimensional
    - organism can live throughout entire water column

b. organisms nearly same density as water so need no heavy skeletal or cellulose structure for support because water provides support

c. fairly stable environment
    - no sudden major changes in temperature and salinity, except near shore

d. salinity of ocean is approximately equal to salinity of organisms body; therefore, many organisms need no protective structure to prevent water loss or gain

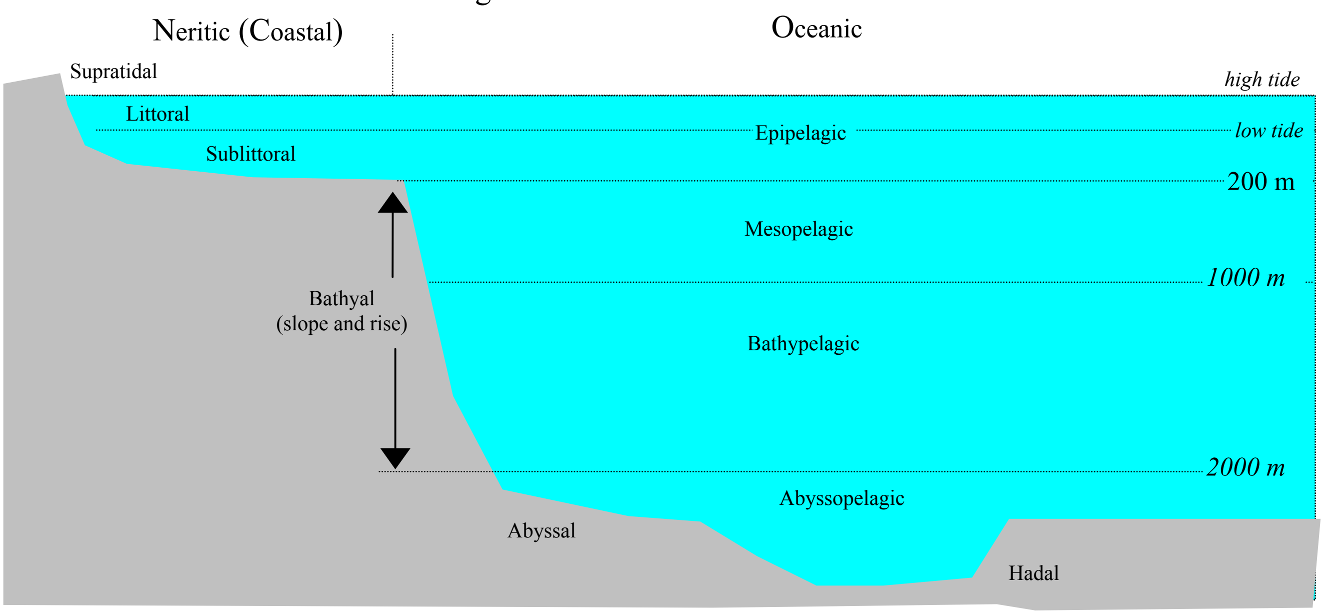
e. unlike terrestrial organisms, marine organisms living in the water column have a problem of sinking
- most organisms, especially plants, require living at certain level because of light, temperature or pressure

Major Life Styles of Organism

- **Planktonic (Pelagic)** - organisms that float, with or without limited ability to propel themselves
    - include: **phytoplankton** (plants), **zooplankton** (animals) and **bacteria**
- **Necktonic** - organism capable of swimming against current
- **Benthonic** - bottom dwellers
    - **sessile** - attached to bottom
    - **vagrant** - move about on bottom
    - **epipelagic** - benthonic organisms that are attached to floating objects

Major Marine Habitats

habitat - where an organism lives



Photic Zone (**Euphotic**) - zone of light penetration sufficient to allow growth and reproduction of plants
- maximum depth about 200 m, usually shallower because of turbidity
- depth to base depends upon atmospheric conditions, turbidity, surface conditions, time of day and season of year

Dysphotic - light present, but not enough to support plants

Aphotic Zone - below euphotic zone
- permanent darkness

Marine Ecosystem - mutual relationship between organisms and their environment, including exchange of matter and energy between organisms and **abiotic** (non-living) components of the environment
- two major ecosystems:

1. Solar-based - relies on energy from sun
   - major one on Earth and includes 99.999999% of all life
2. Earth-based - relies on geothermal energy from the Earth
   - included the deep sea vent communities

- Population - members of a given species inhabiting a particular area or region

- Biotic Community - all populations inhabiting a common ecosystem and interacting with one another
- biotic part of ecosystem

- Niche - position in ecosystem occupied by an organism
- what organism does to survive

Autotrophs - **producers**
- use solar energy (or chemical compounds)
- produce organic matter from inorganic compounds
- **plants** (most commonly)

Heterotrophs - consumers
- animals that consume organic matter as food and energy source for growth and reproduction
- types:
  - **herbivore** - plant eater
  - **carnivore** - meat eater
  - **omnivore** - plant and meat eater
- mode of feeding:
  - **filter feeder** - filters water for food
  - **deposit feeder** - eats food in sediments
    - **selective** - sorts through sediments and ingests only organic material in sediments
    - **non-selective** - ingests both organics and sediments
  - **scavengers** - eat dead and dying organic matter
  - **predator** - actively pursues and kills prey
  - **parasite** - live on prey without immediately killing
    - **endoparasites** - live inside the body of the host
    - **ectoparasites** - live on the host's body surface

Decomposer - breaks down organic matter into basic inorganic components
- bacteria

Food Chain - passage of energy and matter from producers through a sequence of consumers and finally a decomposer

light	Example:
Autotroph (primary producers)	- phytoplankton
Omnivores and Herbivores (primary consumers)	- zooplankton
Omnivores and Carnivores 1. secondary consumer	- shrimp
Omnivores and Carnivores 2. tertiary consumer	- fish
Omnivores and Carnivores 3. quarternary consumer	- man
Decomposer terminal consumer	- bacteria

Respiration, Excretion and Heat

↓

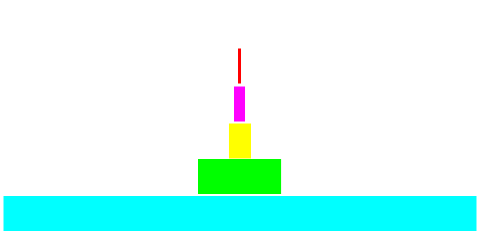
Lost energy and matter

Food web - complex group of interrelated food chains
Trophic Levels - nourishment (energy) level in a food chain or web
- first level - autotrophs
- intermediate levels - heterotrophs
- terminal levels - decomposers

Biomass - total weight of organic matter (in a given trophic level)
- is not a number of organism, but weight of organisms
- same biomass often can produce a few large organisms or many smaller ones

Ecologic Efficiency - efficiency of energy transfer from one trophic level to another
- percentage of biomass used for growth, increase in biomass
- formula
  (biomass in trophic level [x + 1]/ biomass in trophic level x) x 100%
- maximum ecological efficiency is about 10-20%
- 90-80% of energy at each level is spent to gain food, generate heat
- also energy lost because some ingested structures may be indigestible

Biomass Pyramid - graphical representation of biomass (energy) transfer from one trophic level to next in a food chain
- importance is that it demonstrates that the size of the populations in an ecosystem is ultimately dependent upon the abundance of plants at the base of the pyramid



Trophic level		*Energy Units*
Decomposer	6. Bacteria	0.01
Carnivore 3	5. Killer whales	0.1
Carnivore 2	4. Tuna	1
Carnivore 1	3. Anchovy	10
Herbivore	2. Zooplankton	100
Autotrophs	1. Phytoplankton	1,000
Light	50,000	

Controls on population of autotrophs
- because autotrophs form the base of the biomass pyramid, what controls their population controls populations of all other trophic levels
- largely controlled by nutrients and light
- major limiting nutrients NO_3 (nitrate), PO_4 (phosphate), SiO_2

Nutrients in the Ocean
- **Nutrients** - any element or chemical compound needed for growth and the reproduction
  - **micronutrient** - requires on minute amount
    - locally can become limited and restrict growth and reporduction

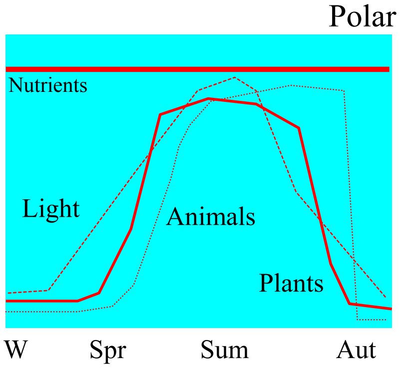
- **macronutrient** - large amount required
    - regionally can become limited and restrict growth and reporoduction

Standing Crop - biomass present in ocean at any one time
- measured in gm of C/m^2 sea surface
- carbon used because indicates amount of photosynthesis

Productivity - rate at which organic material is generated (Photosynthesis)
- measured in grams of carbon/m^2 of sea surface/time
- average for ocean is about 50 gm C/m^2/yr
- dependent upon:
    - solar radiation
    - nutrients availability
    - restricted to euphotic zone

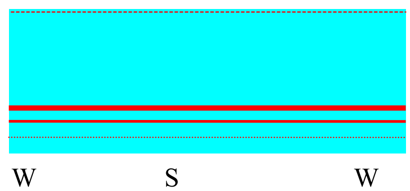
Geographical Variation of Productivity
- mainly influenced by sunlight
- most infrared radiation is converted to heat in upper 2m of sea water and thus surface water is warmed and thermocline develops
- actual position of thermocline is lower because of mixing by waves
- thermocline limits mixing of nutrient-rich deep water with nutrient-poor surface water
- thermocline presence, strength and persistence is variable with latitude

Polar Regions (Arctic)



- no thermocline and nutrients present at the surface all year
- light greatly reduced in winter and is limiting factor
- maximum standing crop of plants (phytoplankton) occurs in early spring before herbivores become abundant and while light is not restricted
- maximum standing crop of animals is in summer when food is abundant
- animals over produce food source so that in late summer and early fall, their population crashes as the food gives out because of decreasing light and plant growth
- through winter, plants are more abundant than animals because animal population is restricted by food resource (biomass pyramid)

Tropical Regions (15°N to 15°S)

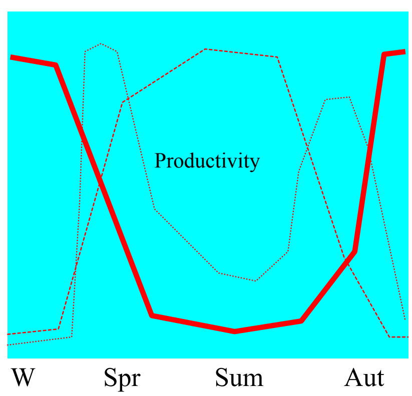


- permanent well-developed thermocline
- little mixing and nutrients are the limiting factor
- productivity compensation depth is fairly deep
- steady low rate of productivity all year except in areas of upwelling

Temperate Regions

- controlled by both nutrient supply and solar radiation in a complex relationship

Winter - sun low, much light reflected and little penetration
- water isothermal and well mixed
- nutrients abundant
- standing crop is small because plants are limited by solar radiation and animals by plants

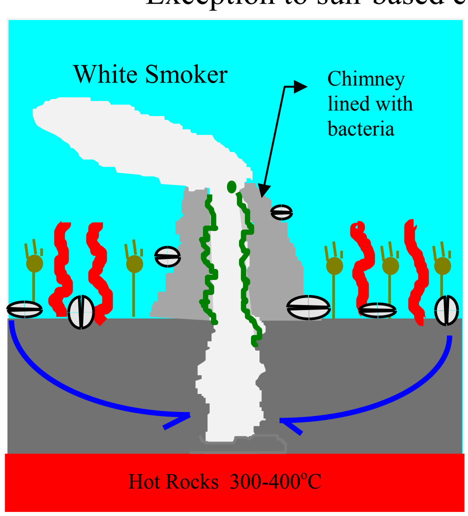


Spring - sun higher; more light penetrates
- "**spring bloom**" - abundant plants and animals
- nutrients still abundant
- gradually thermocline begins to develop

Summer - sun high; maximum light penetration
- well-developed, deep thermocline - no mixing
- nutrients depleted in photic zone because as organisms die, they sink below thermocline decompose and their nutrients are released in deep water
- organisms become increasingly scarce with time

Fall - sun lower; increased reflection, less penetration
- thermocline begins to break down and allow mixing of nutrient-rich deep water
- "**fall bloom**" - not as spectacular as Spring

Exception to sun-based ecosystems



Deep Sea **Volcanic Vent Communities**
- an exception to dependency on sun
- relies on geothermal heat and dissolved minerals
- water infiltrates into the sea floor and is heated to (300-400 °C) but can not boil because of pressure and becomes rich in dissolves minerals
- water expands as it heats and escapes from submarine vents deep on the ocean floor
- as the water cools, the minerals precipitate creating clouds of turbid water near the vent and some accumulates to form tall **chimney**-like spires
- some minerals produced dark clouds and the vents are

called **black smokers**, whereas others produce white clouds and are called **white smokers**
- anaerobic bacteria in the vents obtain energy and food by oxidizing hydrogen sulfide (H_2S) gas dissolved in the water through a process called **chemosynthesis**
- the bacteria thrive in the vents, but as they multiply into larger masses, escaping water tear them free and disperse them into the water
- filter-feeders catch and consume the bacteria as their major food source
- there are also communities of large worm-like creatures which live attached to the sea floor near the vents
- these worms are **symbiotic** with the bacteria and use them as their only source of food
- when circulation of water through the vents ceases, the bacteria and associated communities die

Problem of Sinking

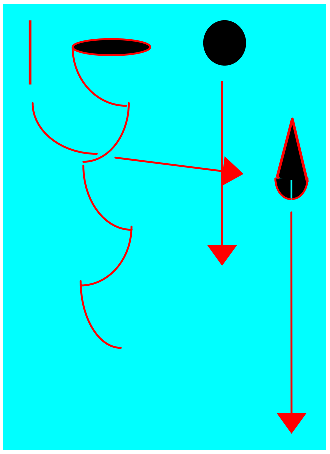
Adaptation of Plant and Animal Groups to the Marine Environment

A. - Phytoplankton
- Diatoms, coccolith, sargassum weed, dinoflagellates (floating plants)
- require light and must stay in photic zone
- have little or no ability to swim and are denser than sea water, thus have tendency to sink

B. - Zooplankton
- Foraminifera, radiolarians, copopods, jellyfish, pteropods
- depends on phytoplankton for food
- same problem of sinking as for phytoplankton

- *Adaptation to stop sinking*:

1. Surface Area
   - as water flows across the surface, friction slows rate of sinking
   - greater the surface area, slower the rate of descent
   - can greatly increase surface area with minimal increase in weight with spines
   - **cyclomorphosis** - ability to alter body form to accommodate conditions
     - some organisms have the ability of changing spines in response to changes in water density
     - warm water is less dense and spines become longer, more abundant or thinner
     - cold water is more dense and spines are shorter, fewer and thicker
2. Size/weight
   - small objects weight less than larger objects and sink slower
   - reduction of size decreases rate of sinking (settling velocity)
3. Shape



- shape can determine the path followed by a object as it sinks and the speed with which is sinks by controlling the ease with which water flows around the object
    - sphere - allows object to follow straight path to bottom
        - rounded front surface smoothly parts water, but rounded back surface creates turbulence that retards sinking
    - Tear-drop - allows straight path to bottom
        - rounded front smoothly parts water and wedge-shaped back allows water to flow smoothly together
        - shape that allows fastest sinking
    - Straight needle - allows straight to inclined path to bottom depending on orientation
    - Curved needle - creates spiraling path to bottom slowing descent greatly
    - Disk-shaped - flat front creates great resistance to flow and flat back generates great turbulence both of which slows descent
        - follows a wobbling zig-zag path

4. Density - way to decrease weight
    - contain oil or gas sack to decrease density
    - can store food as oils
    - have very high water content in body

    Example: jellyfish

5. Mobility
    - means of locomotion
    - muscular action using appendages - bristles, spines, antennae, cillia
    - jet action by expulsion of water (Example: jellyfish)
    - **flagellum** - whip-like tail on a cell
    - if spines are asymmetrically distributed will keep cell oriented with flagellum directed so can be used to drive upward

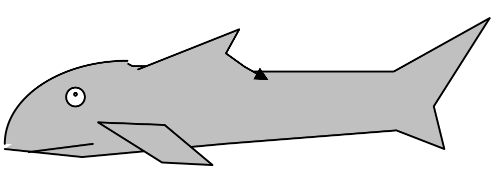
C. **Nekton**

- fish and others (whale, dolphins, squids, turtles, snakes)
- many restricted to depth by pressure and other parameters
- mostly predaceous, highly mobile
- streamlined bodies
    - fish reduces wake with slimy substance over body to reduce resistance
- well developed nervous system
- camouflaged - dark atop, light below
- two major habitats

    pelagic - those live above and independent of bottom

    demersal - live near or on the bottom and have special adaptations to lifestyle
- type of bottom material may be important
- *Fishes*

    1. Cartilagenous - no calcified bones, only cartilage
        - no air bladder, therefore cannot remain motionless without sinking

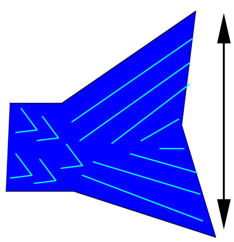


- structural modifications in tail and fin so that forward motion propells upward (fins act as wings of airplane)

2. Bony - skeleton of bones and cartilage
   - possess air bladder (help maintain position in water column and orientation of body)
   - paired fins for stabilization
   1. *Demersal Bony Fish* - bottom dweller
      - generally ventral side of body is flattened
        Example: catfish
   2. Pelagic Bony Fish
      - possess air bladder that decreases buoyancy and keeps fish with top side up
      - deep water fish have very small air bladders

Mammals and reptiles
- lungs are filled with air and this greatly increases buoyancy

Fish Tails (**Caudal Fin**)

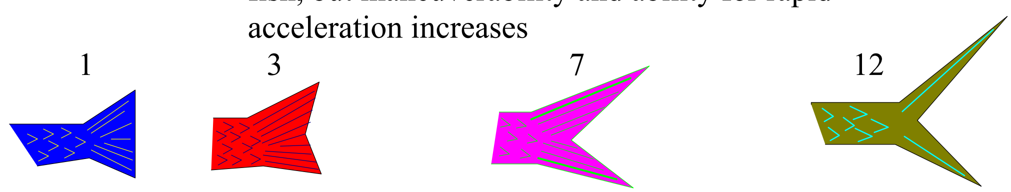


- the tail of a fish can tell much about the way the fish lives
- Speed and agility
  - how rapidly a fish swims is a function of *body length*, *beat frequency* (lateral body undulation) and **aspect ratio**
  - aspect ratio is the ratio of the square of the height of the caudal fin divided by the area of the caudal fin

    $\mathbf{AR = (CF_h)^2/Cf_a}$

    where AR = aspect ratio; CF_h = caudal fin height
    Cf_a = caudal fin area
  - as AR decreases, drag (friction) increases and slows the fish, but maneuverability and ability for rapid acceleration increases

AR = 1 3 7 12



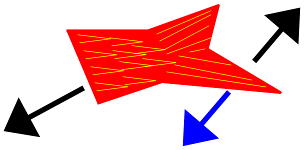
Drag HIGH → LOW
Acceleration FAST → SLOW
Speed Maintenance POOR → GOOD*
Maneuverability GREAT** → POOR

* Starts slowly, but once moving can maintain speed with little effort
** Uses friction against tail to make sharp turns and rapid acceleration

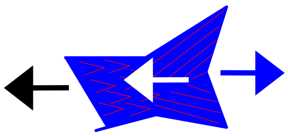
- fish with low AR can display ability for very rapid darting bursts and sharp turns to capture food or escape predators, but on a long chase they tire rapidly
  - tend to live near reefs and obstructions
- fish with high AR start slowly, but once speed is reached they can maintain it for long periods of time, but can not make sharp turns

- tend to live in open ocean

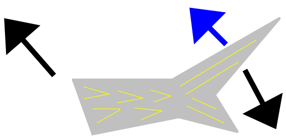
Three basic shapes of CAUDAL FINS:



1. **hypocercal** - lower part of caudal fin is enlarged compared to upper
    - as fin beats, water is driven downward which pushes tail area upwards which drives front of body downwards

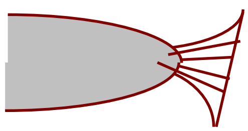


2. **homocercal** - upper and lower parts of the fin are equal in size
    - provides only a forward driving force
    - direction of movement is controlled by lateral fins



3. **heterocercal** - upper part of caudal fin is enlarged compared to lower
    - as fin beats, water is driven upward which pushes tail area downwards which drives front of body upwards

4. Mammals
    - includes seals, walrus, sea lion, fur seals, sea otter, whales, dolphins, porpoises
    - tail (**fluke**) is horizontal
        - unlike fish in which the body undulates laterally as they swim, mammals undulate vertically
        - no external ears (increase streamlining)



Fluke

MARINE RESOURCES

Major resources include:

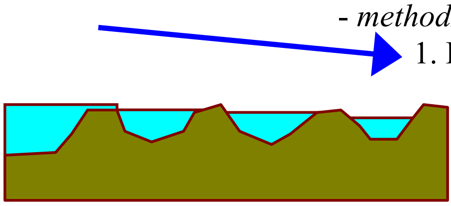
1. Minerals from sea water
2. Fresh water from sea water
3. Bottom minerals
4. Fisheries and mariculture

Resources from Sea water

- Sea water contains large quantities of useful salts, including:

salt	*% of salt used world-wide from ocean*
halite (NaCl)	29%
bromide salts (Br)	70%
magnesium salts (Mg)	67%

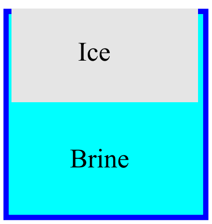
- value about 1 billion dollars/yr
- advantages of extraction of salts from ocean:
    1. abundance of seawater
    2. unlikely to be depleted because replaced from continents



- *methods of recovery:*

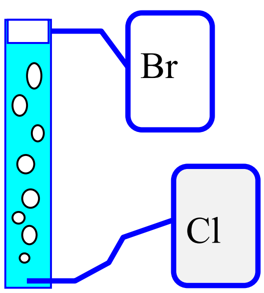
1. Evaporation - isolated evaporating basins located in relatively dry coastal regions using solar energy (30^{o}N,S)
   - series of basins allowing sufficient water to flow through so that only one type of salt can precipitate in each basin
   - can only use for abundant minerals
   - very dilute ones cost too much

     Example: There are about 4 gm of gold in each million tons of seawater and about 5 million tons in ocean
     - would cost 20 times the value of the gold to recover it



2. Freezing - as seawater freezes the ice that forms is pure water and the salts are concentrated in the remaining brine which can then be processed for the salts

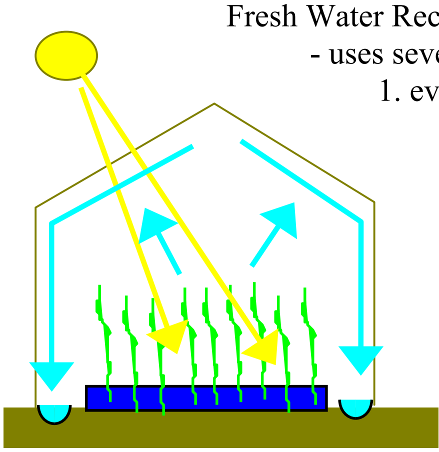
3. Precipitation - Add chemicals to seawater that lowers solubility of a material causing it to precipitate from solution
   - precipitate can then be processed and material recovered



4. Volatilization - mainly used for bromine
   - atoms of bromine and chlorine are similar and can easily replace each other
   - injecting chlorine gas into sea water displaces bromine gas which is then released and recovered

Fresh Water Recovery

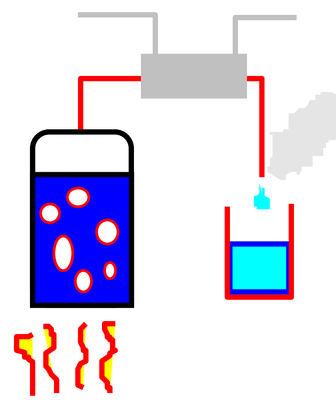
- uses several of the same methods employed for salt recovery



1. evaporation - (naturally or artificially)
   - major problem is that as the salts are concentrated in the remaining water it becomes more difficult and inefficient to attempt to recover additional water

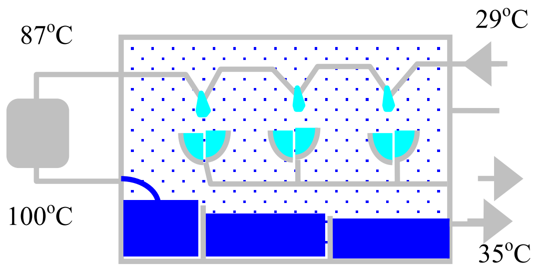
   A. Greenhouse (hothouse)
   - glass enclosed structure over shallow ponds
   - sun heats the water and the internal space causing the water to evaporate during day
   - at night the glass cools and the water vapor condenses and collects in troughs along the walls
   - efficiency can be increased by growing tropical plants and salt-tolerant plants in the green house because they release water through transpiration
   - can also grow plants in tropical-like conditions for food

   B. Distillation

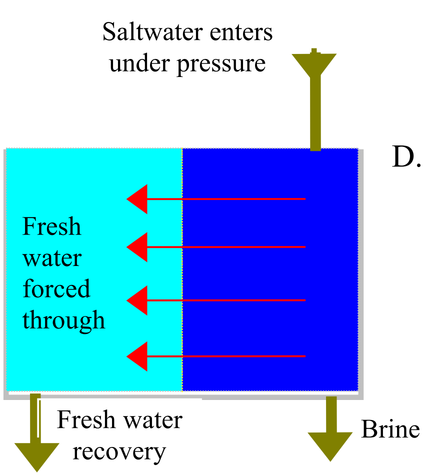


I. Simple
- seawater fed into closed container and heated
- water vapor collected and condensed
- remaining brine discharged (pollution problem)
- inefficiencies:
    - requires increasing amounts of heat to create vapor as salinity of remaining water increases
    - heat is wasted as water vapor condenses

II. **Flash Evaporation**
- closed container through which cold (29°C) sea water flows in a pipe which serves as a condenser for freshwater
- condensation of water vapor on the pipe heats the water in the pipe to about 87°C
- warmed seawater passes through heater where temperature rises to 100°C
- hot sea water flows back into the bottom of the container where vapor is released which condenses on the cold seawater inflow pipes and is collected
- brine leaves chamber at about 35°C and returned to sea
- if system under slight vacuum, water evaporates at lower temperature and efficiency increases



C. Freezing
- ice formed from sea water consists mainly of pure water
- salts are concentrated in remaining brine
- ice is washed to remove salt in cells and then melted



D. **Reverse Osmosis**
- process whereby water is forced to flow through a semipermeable membrane
- salts are not able to pass through membrane
- brine forms on one side as fresh water collects on other side
- method is slow and membranes delicate

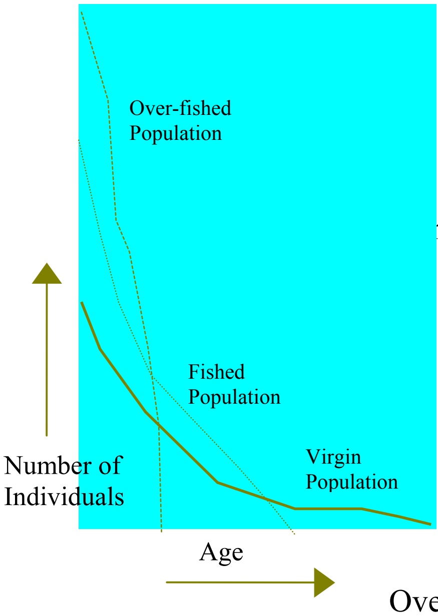
Bottom Minerals
- include deposits rich in Fe, Mn, Mg, Al; Ca, Ba, Si, C, S, Cl, Na, K
- most deposits can not be recovered economically at this time
- types of deposits;

1. **Authigenic** (form in place) or **Hydrogenic** (originates in water)
   - Ba - occurs in pelagic sediments
     - especially abundant in Pacific Ocean whereassociated with areas of high organic productivity
     - may occur as the mineral Barite ($BaSO_4$)
   - Al - abundant in marine brown clays
   - Phosphates - oolites to nodules in shallow marine environments characterized by upwelling
   - Manganese nodules
     - generally mixed with iron minerals
     - nodules from less than 1 cm to greater than 6 m diameter and weighting up to 775 kg
     - covers 20-50% of Pacific Ocean floor
     - especially concentrated in areas of upwelling
     - also contain concentration of many other elements: Ca, Ni, Cr, Cu, Moly, Zn, Y
     - rate of formation is greater today than 15,000 years ago because more abundant in recent sediment than older

2. **Detrital Deposits**
   - sediments derived from weathered rocks on land and transported to the sea
   - mainly dredged from offshore gravel and sand deposits
   - includes:
     - diamonds off West Africa
     - gold in Alaska
     - tin in Malaysia
   - building materials
   - major source for urban areas where other sources are not available
   - also used to repair beaches
   - includes: sand, gravel, shell, coral

Fisheries
- marine environment supplies 12% of world food
- in the US much goes to making cat and dog food
- previously used methods for fishing have now been replaced by mechanized industry, but leads to great problem of **overfishing** - removing fish faster than they reproduce
  - becoming a major problem in the world today and seeing markedly declining hauls of fishes

- *Changes in fish population as fishing industry develops*



Virgin Population

- population which has never been commercially fished
- dynamic balance between birth and death such that the overall population is in balance with the environment
- growth of young fish is balanced by death and predation of older fish
- large population of mature and older individuals exists

t of Fishing Industry

- older (larger fish) population is reduced because they are the most valuable and easily trapped
- as population of the largest fish is reduced, smaller (younger) fish are taken
- Number of fish in the population initially increases because more young survive to maturity because of less competition from larger adults
- overall biomass remains constant, but average size of fish declines

Overfishing

- fish are taken at smaller and smaller size and fewer survive to maturity and reproduce
- population begins to shrink rapidly
- critically small population is reached and population crashes because not enough to offset normal competition, predation and overfishing
- population becomes extinct

Example: Pacific Sardines of northwestern US

- within 60 years of the start of fishing, the population collapsed and no longer exists

- **Maximum Sustainable Yield** - maximum number of fish that can be taken out without damaging the population
    - anything beyond this is overfishing
    - only economically sensible to fish 70% of MSY because fishing becomes increasingly inefficient above this
    - above 70%, fish are becoming scarce and so must travel farther, use more boats and energy to catch just a few more fish (rate of increased yield/unit of fishing effort decreases rapidly)
    - requires twice the effort and resources to reach 100% MSY from 70% under normal conditions
    - prior to industrialized fishing and various scientific advancements, fishing above MSY was unlikely
        - sonar, remote sensing satellites, etc. now make it easy

        Example: Some schools of fish release minute traces of oils and/or iodine in the water as they swim. These can be detected by satellite and industrialized fishing ships can be dispatched to the exact location where the fish are located.

Mariculture

- marine fish farming (**aquiculture** is freshwater fish farming)
- mainly used for shell fish (oyster, clam, mussels) and a few fish types (eels, mullet)
  - shell fish work well because they are benthonic filter feeders
  - can create a three-dimensional habitat on which they can grow
  - eliminate natural predator (starfish)
  - maintain them in photic zone where food (phytoplankton) are abundant
- major problem is that most desirable fish are carnivores and difficult to provide sufficient and acceptable food.
  - many will not spawn out of natural habitat very well
- proposals to increase natural fish populations by creating areas of artificial upwellings in tropics and subtropics
  - pump deep nutrient rich water into bays and estuaries to produce phytoplankton bloom, and therefore increase the size of the base of the biomass pyramid and increase all subsequent trophic levels
  - to construct artificial artificial reefs to provide sanctuary for fishes and provide more habitats in shallow water

New Food Sources

- to compensate for declining fish populations, has been proposed that other marine resources be tapped for food

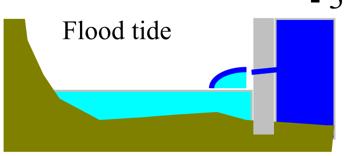
1. phytoplankton and zooplankton
   - begin to harvest zoo and phytoplanton as protein additives
   - because lower level of pyramid, much greater biomass exists

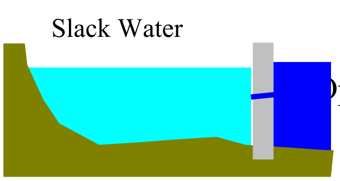
- problems:
    - population generally sporadically distributed
    - must remove poisonous varieties from catch or render them non-toxic

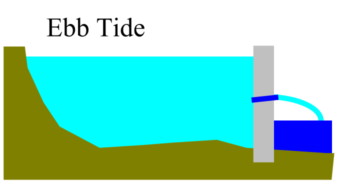
2. **Fish Protein Concentrate** (FPC)
    - currently only a limited variety of fish are used for food and a portion of the fish is discarded
    - proposed to process entire fish (scales, head, bones) into a colourless, tasteless protein concentrated powder made from almost any type of fish;
    - FPC is a soft white powder that does not need refrigeration and has no fishy smell
    - 10 gm FPC provides the normal daily protein requirement for about 20 cents
    - although manufactured in the U.S. can not be used for human consumption here

Energy Sources from the sea

1. Tides
    - first was 1650 Boston grinding mill
    - 1970's - Rance Estuary in Brittany (electricity)
    - 1970's - Murmanak in U.S.S.R (electricity)
    - 3 factors limiting tidal power:



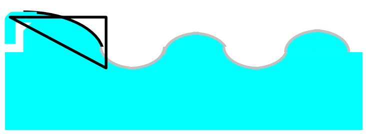




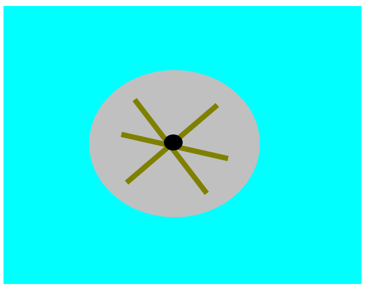
        1. large tidal range (must be greater than 5 m)
        2. suitable topography
            - larger the opening to bay, larger dam must be built
            - want a large bay that can hold much water
        3. timing of power generation varies with tidal cycle which will frequently not correspond with peak usage
        4. most areas with large tidal range are remote from users
    - Operation:
        - closed dam during flood tide until water has at least a 5m head
        - open floodway and allow water to operate turbines as flows into bay
        - as head drops, electric generation will decline and stop when head is below 5m, but continue allow water to enter until high tide.
        - at high tide close gates until sea level outside of gate is 5 meters below level in by
        - open gates and allow outflow to again turn turbines

2. Waves
    - in one meter of wave front of a wave 1.8 m high, 10 kilowatt power is spent as the wave breaks
    - in past wave energy has be used to power whistles, gongs or bell buoys
    - currently no economical use is being made of waves, but several proposals have been made

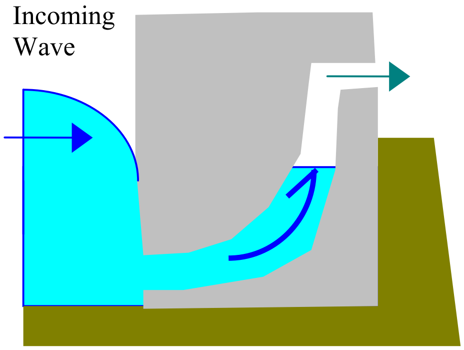
- Power from Waves



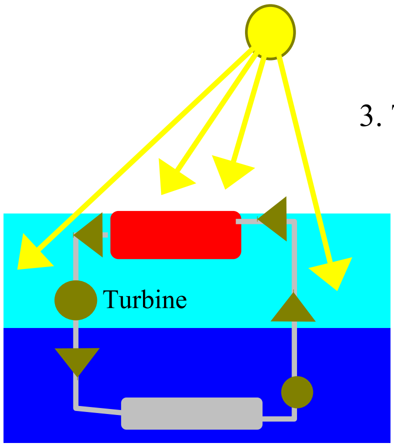
1. Half Cone
   - large half-cone on side increasingly confines wave and directs wave upward toward apex where wave cascades down over turbine
   - problem, cone must be facing direction from which wave is coming
2. **Dam-Atoll**



   - domal structure with guide vanes on top radiating out from a central at opening
   - does not matter from which direction wave is coming because one side is always facing that direction and domal shape will cause waves to refract around in toward the central opening on all other sides
   - vanes direct water toward opening where it cascades down turning turbines
   - domal shape causes waves to refract in toward opening regardless direction from which the are coming
   - should be able to provide continuous 1-2 megawatts of continuous power



3. Air Pressure
   - rise and fall of water surface associated with waves causes changes in pressure in a container partially submerged and anchored to the bottom pressure rises with crest and falls with trough
   - a hole in the container at the to will allow air to enter and leave as the pressure changes
   - the larger the area covered by the container, the more air that can potentially enter and leave with each wave
   - a large enough structure with high enough waves can create sufficient air flow to turn turbines
4. Anchored Floats
   - floats rise and fall with each passing wave
   - the larger the wave, the greater the vertical displacement of the float
   - a float attached to a spring loaded cable attached to the bottom would pull the cable up, stretching the spring with the crest of the wave
   - the spring would then pull the cable back down with the trough of the wave
   - if the cable is wound about a pulley attached to a turbine, it can generate energy



3. Temperature Differences

- surface waters heated by sun to about 25°C in the tropics
- liquids, such as ammonia or carbon tetrachloried, placed in a container in the warm sea water will evaporate rapidly
- as liquid becomes gas the molecules move farther apart and increases atmospheric pressure in the container
- gas flows past turbines in a pipe that descends into deep cold water where the gases condense
- liquids are pumped back to the surface and recycled

4. Underwater "Windmills" (submerged hydrogenerators)

- works on the same principle as a wind mill (wind generator), as fluid flows past angled blades, the blades to begin to rotate
- would use water currents rather than wind
- water denser and has greater force, but moves more slowly therefore blades would have to be larger to obtain force needed to turn turbine at high speed
- major problem is that currents are relatively narrow and meander

4. Geothermal

- in areas of recent volcanism and rift valleys hot rocks or magma lie closer to the surface in the crust
- water pumped into the ground will be heated well above boiling point
- in recovery wells, water flashes into steam and can be used to drive turbines
- unfortunately most geothermal areas are distant from urban areas where power is needed and much of electrical energy lost in resistance of the transmission wires
- alternative is to use electricity to produce hydrogen at the geothermal source and pipe hydrogen gas as a fuel to boil water, generate steam and produce electricity where needed

5. Petroleum and Gas

- main currently produced ocean bottom resource
- primarily on continental shelves
- generated from the organic remains of ancient phyto- and zooplankton in areas where productivity was exceptionally high, bottom was poor poor in oxygen (**dysoxic** or **anoxic**) and rate of sedimentation considerable
- produced in source rock (clay or shale), but collects and is preserved in porous and permeable **trap rock** - a rock

layer whose configuration in association with adjacent rock layers and groundwater hydrology prevents the oil or gas from escaping to the surface

Pollution and the Sea

- **Pollution** - the unfavourable alteration of the environment, usually by man
  - typically involves the unnatural addition or subtraction of materials from the environment or the alteration of the physical properties of the environment

Oceanic pollution
  - three types: physical, chemical and biological
    - physical pollution - altering some physical aspect of the environment such as temperature, turbidity, sediment
    - chemical pollution - introduction of chemical into the environment such as oil, sewage, radioactive elements, heavy metals, pesticides or altering the normal balance of chemicals naturally in the environment, such as salinity, nutrients
      - if buried in the sediments, these can be re-introduced into the environment if the sediments are disturbed as in a storm or dredging
    - biological pollution - introduction of bacteria usually through sewage
    - typically all three forms of pollution occur at the same time

      Example: Dumping sewage into the ocean increases turbidity and sediment as the material sinks to the bottom (physical). The sewage releases chemicals into the water such as dissolved metals, pesticides, oils (chemical). Bacteria in the sewage are released into the oceanic environment (biological)
    - most pollution is knowingly allowed to happen because the ocean is used for disposal
      - was once thought that the ocean was so large it could never be polluted
      - was also believed that the deep ocean was lifeless and totally isolated from the surface waters, so that materials deposited in the deep ocean were removed from the ecosystem
      - now known that both are incorrect
        - ocean does not circulate uniformly so pollutants can becomes concentrated to high levels in some areas
        - bottom waters gradually mix with surface waters
        - many organisms dwell on the bottom and some travel to the surface
    - examples of specific pollutants:
      1. petroleum products - toxic to most organisms
         - lighter petroleum produces float for some time and so little direct contact with benthonic organisms except in shallow areas
         - but direct contact with surface organisms and at shoreline
         - thin layer of oil on surface is impermeable to gas exchange and so oxygen can not enter, nor CO_2 escape

- oil gradually dissolves into the water and eventually all organisms are contaminated
- sources:
  - natural seeps - were oil escapes from the sea floor,
  - spills - large ones are locally devastating, but minor compared to other sources
  - eliminated by ships - major source
- clean-up:
  - burning - generates air pollution
  - detergent - does not remove oil only disperses it into the water and makes it appear to have gone away
  - shredded polyurethane foam - soaks up the oil
  - skimming barges - skim water surface and actually removes the oil

2. Sewage -add nutrients (phosphates and nitrates) which cause algal blooms
   - when algae die, decomposition may consume most of the oxygen present in the bottom water, causing dysoxia or anoxia which leading to mass mortality of organisms
   - evidence also suggest that enrichment of nutrients may lead to red tides (proliferation of microscopic, toxic organisms which give the surface water a bright red colour) and proliferation of other unwanted organisms
   - can also add bacteria which contaminate shell fish and heavy metals which can contaminate all organisms with bacteria and make unsuitable for consumption
3. Thermal pollution
   - raising the temperature of coastal bodies of water
   - commonly results where water used as coolant for industry or nuclear power generation
   - produces a (sometimes permanent) thermocline which restricts mixing and redistribution of nutrients and oxygen
   - greatly reduces productivity

4. Sediment - great influx of sediment increases turbidity, which blocks sunligh and lowers productivity
   - can also bury some organisms.(clams, oysters) or their spawning areas and clog filters of filter feeders
   - generally restricted to nearshore area
5. Radioactive Contamination
   - relatively new since WWIl
   - sources include: nuclear testing disposal of nuclear wastes
   - can remain hazardous for centuries

Major Results of Pollution

1. directly kill organism
2. cause damage to certain cells within the organism which weakens it and leads to its death from predation, disease, organ failure, or cancer
3. inability to reproduce because of:
   - sterility
   - inability to produce structurally sound eggs
     (Example: shell formation in marine birds)
   - adverse mutation in offspring
   - destruction of breeding areas
4. malfunction of nonessential life function.

Bioaccumulation - the gradual increase of a material within an organism's body
- organisms have a natural ability to rid their bodies of unnatural substances, but this can be a slow process for substances to which an organism is not normally exposed
- if intake exceeds disposal, excess is stored in the body
- can make the organism begin to display poisoning or make it poisonous to eat

Biomagnification - the gradual increase in the concentration of a material within food chain
- level of pollutant may be low in the environment but because of bioaccumulation, at each trophic level it becomes increasing concentrated and near the top of the food chain being to produce adverse effects

MARINE LAW
- product of historical accident more than planned rules
- of major concern to governments because of oceans importance in
  - economic resources
  - defense
  - pollution
  - weather prediction
  - food source
  - research

Law of Sea

1400 - *Mare Clausum* (Closed Sea) - pope declares that he Atlantic Ocean is divided into two parts and gives one part to Spain and the other to Portugal

1588 - Spanish defeated by British and Dutch

1609 - Hugo Gratius - Dutch jurist established doctrine of *mare liberum*, claiming that the oceans are free to all nations

1627 - British establish 3 mile limit along coasts of their territorial waters (same as land)

1702 - *De dominio Maris* - principle established that a nation could control the sea for as far as cannon fired from on shore could reach
1945 - U.S. claimed jurisdiction to the edge of the continental shelf
1947 - Peru claimed control for 200mi offshore so as to protect it fisheries
1958 - United Nation Conference on Law of Sea in Geneva
- most present marine laws were established at this conference
- gave exclusive mineral rights to coastal nations to a 200 m depth or to a point where they can be exploited
- divide ocean into three parts:
    1. **territorial waters** - 3 mi. limit to which nation owns sea bottom and can control the waters and air above the same as they do on land
        - nation owns fish living on the bottom fishing, but not those living above
    2. **contiguous zone** - 12 mile limit in which nation can control fishing
    3. **high seas** - areas beyond 12 miles
        - belongs to no one and everyone
        - some proposed that high seas be changed into:
            a series of national "lakes" based on coastal exposure of a nation
            b convert possession to U.N. which would then lease it to obtain revenue

1960 - Second U.N. Conference on Law of Sea, but little was accomplished
1973 - 1982 - Third U.N. Conference on Law of the Sea, again little accomplished
1978 - there were 66 of 160 total nations that had coasts. Of these:
    12 had 200 mi exclusive fishing territory
    35 had 200 mi economic zone
    14 claimed 200 mi territorial zone (part of nation)

1982 - New Treaty on Law of the Sea
- favored by 130 to 4, 17 abstentions
- treaty addressed:
    1. coastal nations jurisdiction
        - uniform 12 mi territorial sea and exclusive 200 mi but up to 350 mi if shelf exceptionally wide, **exclusive economic zone** (EEZ)
        - nation controls mineral, fishing and pollution
    2. ships passage - rights of free passage of ships on high seas and within territorial seas through straits used for international navigation
    3. Deep Ocean Resources
        -exploitation of deep sea resources will be regulated by the **International Seabed Authority** (ISA) which will be co-chartered by U.N.
        - proceeds to be divided between U.N., nation exploiting resources and developing nations

Impact of Global Warming on the Ocean

1. Rising Sea Level
   - because of global warming, glaciers in Antarctica and Greenland, as well as mountain glaciers world-wide, are melting and sea level is rising (**eustatic rise**).
   - if all glaciers melted, sea level could rise as much as 500 feet, which would make St. Louis a coastal city and the Grand Avenue viaduct would be a bridge across a shallow bay
   - in addition to adding water in the ocean, warming of the ocean itself would cause the water to expand, occupy a greater volume and flood additional areas, further complicating the problem of determining how much sea level would rise
   - even just a rise of a few meters endangers most of the world's major coastal cities and a few entire nations such as Netherlands, Bangladesh and many island nations in the Pacific could vanish
   - rate of sea level rise is controversial because some scientist suggest that much of the ice in Antarctica could become detached from the continent and slide into the sea quite rapidly causing a rapid rise in sea level over just a few hours
   - rapid rise in sea level could lead to the drowning of reefs and destruction of the reef communities world wide
   - as sea water floods coastal freshwater habitats breeding grounds for many species would be eliminated possibly resulting in extinction
   - drinking water resources could be compromised in near future as salt water extends farther up rivers and into aquifers
   - storms become a greater threat to coastal communities which are now closer to sea level and more flood prone
   - submergence of low areas in Central America could allow mixing of the Atlantic and Pacific oceans and alter the current gyre in the Atlantic
     - it would also allow mixing of the fauna and flora between the two oceans resulting in competition of species and some extinctions

2. Warming of the oceans
   - as the oceans warm:
     - persistent thermocline would become stronger and spread poleward, thereby reducing or at least altering the areas which undergo winter **overturn** (wind- driven mixing of deep water and surface waters) which resupplies nutrients to the surface
     - greater density difference between surface water and deep water makes the pycnocline stronger and that much more difficult for the water masses to mix
     - if surface waters become too warm, convergences may cease because the water will not become cold and dense enough to sink
     - without major convergences, divergences can not exist and nutrients will become trapped in the deep waters, making surface waters less productive

  - this could lead to the extinction of many species which rely upon the zones of upwelling
- if oxygen is not replaced by water sinking at the convergences the deep ocean could become **anoxic** (without oxygen)
- warmer ocean water will provide more moisture to the air causing more rain and decreasing surface salinity thereby reinforcing the pycnocline
- warmer oceans and more moisture would allow hurricanes to grow stronger and travel farther poleward and into the interior of the continents
- warming of ocean would cause water to expand and thereby increase the amount of flooding
- today's inland cities which would becomes coastal cities would then be subjected to storms and the dangers of tsunamis