Challenges of the Marine Environment

Evolution via Natural Selection

Physical Factors in the Marine Environment – Light and Floatation

Graphic: Tuna. Courtesy of United Nations Food and Agricultural Organization.

Life in the Ocean

<u>Living things:</u>

Contain matter in an organized state

Can capture, store and transmit energy

Can reproduce and change through time

Can adapt to their environment

Graphic: Christmas tree worms, spirobranchus giganteus, on Elbow Reef. Photograph by J.Guttuso, courtesy National Marine Sanctuaries Collection.

What is a Species?

Species = a group of potentially interbreeding organisms that is reproductively isolated from all other living things

Graphic: (top) Elephant seals, Weddell seals, J.Roletto, photographer, NMS collection. (bottom) Weddell seals, Cmmdr. J.Bortniak, photographer, NOAA Corps collection.

Theory of Evolution by Natural Selection

1. More offspring are produced than can survive

2. Random genetic variations occur in offspring, some of these increase chances for survival

3. Carriers of favorable traits are more successful and have more offspring - favorable traits accumulate in the population

4. Isolation of sub-populations can lead to new species as sub-populations become genetically distinct

Graphic: Garrison, Fig. 13.22.

Developing the Theory

In Darwin's day:

Features of organisms

Ancestry

Distribution of organisms

Today:

Genetics (e.g., population studies, gene sequencing)

Biochemistry/molecular biology

Discovery of a more complete fossil record with more transitional forms

Graphic: (top) Galapagos sea lion and iguana, R.Cohen, NODC, NOAA, (center) DNA's double helix, NIH, (bottom) genetics laboratory, NIH.

Evolution and Natural Selection

Evolution = the maintenance of life under constantly changing conditions by continuous adaptation of successive generations of a species

Natural selection is the process by which life evolves

Graphic: Whale evolution, courtesy of Arizona State University.

Evolution and Natural Selection in Action

Adaptive mutations: **e.g., drug-resistant bacteria**

Co-evolution: **Simultaneous reciprocal evolution of species e.g., clams/drilling snails**

Convergent evolution: **Evolution of similar characteristics in species of different ancestry, e.g., front appendages of various marine organisms**

Graphics: (top) *Salmonella typhimurium* (red) invading cultured human cells, Rocky Mountain Laboratory, NIAID, NIH, (bottom) Garrison, Fig. 13.23.

Vertebrate Evolutionary Tree

Vertebrates evolved over 500 million years ago

All classes are found in the modern ocean except amphibians

Graphic: Garrison, Fig. 15.23.

Cartilaginous Fish

- Ancient group

- Includes sharks, skates and rays

- Bony teeth

- Cartilage skeletons

Many are top-level predators

- feeding by these species helps maintain ecological balance

Others restructure their environment

- many skates and rays burrow into sediments for food, displacing some organisms and creating habitat for opportunists

Graphics: (top) Eagle ray, M.White Nat. Marine Sancturaries, (bottom) blue shark, S.Anderson, photographer, courtesy of Channel Islands National Marine Sanctuary.

Bony Fish

- Bony skeleton

- Dominant marine invertebrate

- Very diverse class

Ray-finned fish

- jointed, bony rays support fins

- most common type of bony fish

Lobe-finned fish

- fins supported by fleshly lobes with bones

- ancestors of amphibians

Graphic: (top) See Garrison, Fig. 16.16, (bottom) Garrison, Fig. 15.29.

Coelacanth: The Fish That Time Forgot

Group of fish that first evolved

about 410 Ma

Adults ~2m long, ~100kg, with four distinct lobe fins that can support its weight (possibly an adaptation that led to the development of walking appendages on land)

Until 1930's, believed to have gone extinct ~65Ma, but found recently in waters off Madagascar and Indonesia

Graphics from www.dinofish.com.

Natural Selection and the Environment

A species' response to its environment is central to its survival

Chemical environment: nutrients

pH

Physical environment: temperature, light

Biological interactions:

predation

competition

Graphic: Loggerhead turtle babies, courtesy of NOAA.

Physical Factors in the Marine Environment

Physical factor = Any aspect of the physical environment that affects living organisms

Examples:

- Light*

- Acid-base balance

- Temperature

- Hydrostatic pressure

- Salinity

- Negative buoyancy (floatation)*

- Dissolved nutrients - Viscosity (ease of movement)*

- Dissolved gases

Each physical factor presents unique challenges to a species

Light in the Ocean

Sunlight is the energy source for most marine communities

- Sunlight penetrates deeper in clearer water

- Most sunlight is absorbed in the top 100-600 m

Graphic: Garrison Fig. 13.14.

Zones of Light Penetration

Euphotic zone:

Enough light for photosynthesis and vision (0-70 m)

Disphotic zone:

Enough light for vision only (70-600 m)

Aphotic zone:

Insufficient light for photosynthesis and vision (below ~600 m)

Graphic: Garrison, Fig. 13.15.

Marine Plants - Limited by Light Availability

Marine plants:

- Require sunlight to grow

- Are restricted to areas near the ocean's surface

Light availability limits marine plant growth

Because plants are the base of most marine food chains, most sea life lives near the ocean's surface

Graphic: Left: Marine phytoplankton (plants). Images courtesy of NASA/Goddard Space Flight Center.

Some Typical Marine Plants and Animals

Most marine plants and animals are small due to the challenges of light availability and floatation

Graphics: (top left) Chaetoceros concavicornis, courtesy of NOAA, (top right) krill, courtesy of National Marine Fisheries Service, (bottom left) copepod, courtesy of NOAA.

Adaptations to Light Availability - Marine Animals

Upper ocean **"normal" eyes**

Lower disphotic **large eyes**

Deep aphotic **small, non-functioning or no eyes**

Graphics: Courtesy of National Marine Fisheries Service, Historic Collection

Making Your Own Light - Bioluminescence

<u>Bioluminescence = production of light by living creatures</u>

At mid- to deep depths, bioluminescence can be used to:

- Lure prey

- Avoid predators

Graphic: Black dragon fish (female). Bauer 1906.

Alternatives to Vision: Echolocation

Sound is easily transmitted through seawater

Echolocation:

Using sound to determine the location of objects

Usually used to find prey and avoid obstacles

Graphic: Garrison, Fig. 15.40.

Alternatives to Vision: Electricity and the Sea

Some marine animal have receptors that can detect minute electrical currents

- Pores in a shark's head contain a jelly that detects weak electrical fields produced by muscle contractions

- Electroreceptors help marine animals navigate using the Earth's magnetic field

Graphic: Blue shark, courtesy of Channel Islands National Marine Sanctuary, and NOAA.

Alternatives to Vision: Vibration and the Lateral Line

Lateral Line - A network of fluid-filled vessels along the sides of the body under the scales or skin

Detects the intensity and location of vibrations

Helps animals locate prey or evade predators

Graphic: White perch, J.Gunderson, photographer, courtesy of Minnesota Sea Grant.

Floatation - A Matter of Survival for Marine Plants

Marine plants must be near the surface to survive

Various adaptations:

- Small size

- Shapes less prone to sinking

- Air-filled sacs

- Oil or waxes in cells

- Spines and other body projections

- Replace heavy chemicals with lighter ones

Graphic: Kelp forest. Courtesy of Channel Islands (California) National Marine Sanctuary.

Sink or Swim...
Floatation and Marine Animals
Many marine animals are more dense than seawater

Adaptations:

- Swim bladders (bony fish)

- Oily flesh (salmon)

- Strong swimming abilities (mackerel, bonita, sharks)

- Fins and tails that provide lift when swimming (sharks)

- Storing air in feathers or fur (penguins, otters, fur seals)

Graphic: Thrasher shark. Courtesy of National Marine Fisheries Service Historic Collection.

The Drifters...
Floatation and Marine Animals
Smaller and less rigid marine animals rely on more passive means for floatation

Adaptations:

- Air filled sacs (Portugese man of war)

- Lack of skeletons (jellyfish)

- Spines and other body projections (copopods)

Graphic: Cyanae jellyfish. P.Auster, photographer. Courtesy of National Undersea Research Program and Univ. of Conn.

Life in a Viscous Fluid

Viscosity = a fluid's internal resistance to flow

High viscosity = motion is difficult

Ease of movement is related to the shape and size of an object and the properties of the fluid

Graphic: Garrison, Fig. 15.30a-c.

Reducing Drag

Streamlining reduces drag due to viscosity, allowing the swimmer to use less energy

Streamlined bodies are smooth, elongated and tapered from mid-section to tail

Other strategies:

- friction-reducing mucus or oil

- skin texture

Graphic: (top) Monk seal, Dr. J.P. McVey, NOAA Sea Grant, (bottom) Dolphins in bow wake. Cmmdr. G. Tuell, NOAA Corps. Both courtesy of NOAA.

Building a Better Fish - Propulsion

Forward motion requires effort from body and fins

Eels - move entire bodies to move forward

(less efficient)

Advanced fishes - move tails and fins

(more efficient)

Graphic: Garrison, Fig. 15.31.

Form and Function in Swimming
Next Lecture
Life in the Ocean: Marine Plants and Animals

Energy transfer

Food Web Dynamics

Graphics: (top) "Mystery Squid", NOAA and Science, (middle) Lima sea star, K.Evans, photographer. Courtesy of National MarineSanctuaries Photo Gallery. (bottom) Red shrimp. National Ocean Service Photo Gallery.