CHAPTER 10 OCEANIC ENVIRONMENT AND PRODUCTION

Key Concepts

Major Concept (I) *The marine environment is divided into two major zones, the water and the sea floor, each of which is further divided into a number of distinct zones.*

Related or supporting concepts:

- Figure 10.1 illustrates the different subdivisions of the marine environment. This subdivision of the marine environment was proposed by Joel Hedgpeth in 1957.
- The two major (and most obvious in terms of their differences) zones in the marine environment are the "pelagic zone," which is the water, and the "benthic zone," which is the sea floor. Each of these is further subdivided into a number of smaller zones.
- The pelagic zone consists of two subdivisions; the "neritic zone" (water lying above the continental shelf), and the "oceanic zone" (the main body of water that lies off the continental shelf). The oceanic zone is vastly larger than the neritic. The relatively small neritic zone is distinguished from the rest of the water realm because of the tremendous variations found in this shallow environment.
- The oceanic zone is then further subdivided on the basis of depth into the following zones:

Zone	Depth Range (m)
epipelagic	0 - 200
mesopelagic	200 - 1000
bathypelagic	1000 - 4000
abyssopelagic	4000 - deepest depths

- The surface layer of water where there is enough sunlight to support plant growth, or photosynthesis, is called the photic zone. The photic zone extends to a depth of 50 - 100 m (150 - 300 ft) depending on how clear the water is.
- Beneath the photic zone is the aphotic zone where there is either too little light for photosynthesis or no light at all.
- The benthic zone is divided into the following zones:

Zone	Depth Range (m)
supralittoral (splash)	area just above the high water mark.
littoral (intertidal)	area between low and high tide.
sublittoral (subtidal)	the rest of the continental shelf below low tide level.
bathyal	200 - 4000
abyssal	4000 - 6000
hadal	6000 - deepest depths

- The first three zones; supralittoral, littoral, and sublittoral, are all in the photic zone.
- In general there is greater variation in physical properties in the shallow, coastal zones than in the deeper, open ocean zones.
- In the shallow benthic zones the substrate may be sand, rock, or mud and it can change rapidly over short distances. In deep regions the substrate is more uniform over large areas.
- In shallow water the temperature will be a function of latitude. In deep water the temperatures are uniformly cold everywhere.
- The salinity of the water can change quickly in coastal regions, and even in the open ocean salinity will vary with latitude as climate conditions change.

Major Concept (II) *Because the water provides a great deal of support, marine organisms are often more delicate than land organisms. Marine organisms have different mechanisms for increasing buoyancy and flotation in order to maintain vertical position in the water.*

Related or supporting concepts:

- Many marine organisms have an overall density that is not that much greater than seawater.
- The relatively small difference in density increases the buoyancy of organisms. This makes it easier for shallow-water organisms to remain near the surface. It also supports benthic organisms and reduces the amount of energy expended by nekton.
- Many marine organisms have adapted mechanisms to increase their flotation. Some examples include:
  - a. the production and storage of gas in the case of:
    - i. some types of seaweed or kelp that have gas filled floats to keep them in sunlit water,
    - ii. one type of snail that generates intestinal gases,
    - iii. some jellyfish that store gas in floats,
    - iv. the chambered nautilus that produces and stores nitrogen in its shell (see fig. 10.2a),
    - v. the cuttlefish (see fig. 10.2b), a relative of the squid, and
    - vi. many fish that store gas in swim bladders;
  - b. the production and storage of oil:
    - i. by many plankton as small droplets that serve as food reserves, and
    - ii. in the liver and muscle tissue, as in the case of sharks and other types of fish;
  - c. the production of blubber, a low-density fat, by whales, walruses, and seals; and
  - d. the formation of skeletal spines or appendages by small plankton to increase frictional drag with the water and decrease sinking rate.
- Fish with swim bladders are able to maintain vertical position in the water by becoming neutrally buoyant. They change the pressure of the gas in their swim

bladders when they change depth.

- Fish are restricted somewhat in their vertical movement by the capacity of their swim bladders and their ability to regulate the pressure in them. If a deep-water fish came to the surface too fast, the gas would expand rapidly and burst the swim bladder. If a shallow-water fish dove too quickly, the increasing pressure would collapse the swim bladder and the fish would sink rapidly.

Major Concept (III) *Marine organisms whose body fluids have a significantly different salt content than the water must expend energy to keep a constant body fluid chemistry or they will lose too much moisture from their tissues by osmosis.*

Related or supporting concepts:

- Many marine organisms have body fluids with salt contents lower than seawater.
- Water molecules will move through cell membranes from the body of the organism to the seawater in a process called osmosis.
- In osmosis, the water molecules are passing from fluids with a high concentration of water, the lower salinity body fluids, to a fluid with a low concentration of water, the higher salinity seawater.
- The cell membranes are semi-permeable. They will allow the passage of water molecules but not salts.
- If fish did nothing to regulate their fluid chemistry this process would cause dehydration.
- To prevent dehydration marine fish ingest seawater constantly and excrete salt across their gills.
- Some organisms have body fluid chemistries with salinities that are very similar to seawater, such as:
  a. sharks,
  b. rays,
  c. sea cucumbers, and
  d. sponges.

  These organisms do not have to expend energy to prevent dehydration.
- Many organisms have a low tolerance to large changes in salinity. They cannot maintain their body fluid salinity if the seawater salinity changes too drastically. These organisms are called stenohaline organisms.
- Other organisms, called euryhaline organisms, can tolerate large salinity changes. Some examples include:
  a. salmon that are hatched in fresh water and as adults live in the oceans,
  b. Atlantic eels that spawn in the oceans where the juveniles live up to three years and then move into fresh water to live as long as 10 years as adults, and
  c. many different fish and crustaceans that breed in low-salinity estuaries and then live in the open ocean.

Major Concept (IV) *Some marine organisms produce light biochemically. This is called bioluminescence.*

Related or supporting concepts:

- Bioluminescence is caused by a biochemical reaction between a compound called luciferin and an enzyme called luciferase.
- The reaction that produces bioluminescence is 99 percent efficient.
- A variety of organisms are capable of producing light in this fashion, including small plankton in shallow water. Ships passing through the water disturb these small organisms and they will glow, lighting the wake of the boat at night.
- Larger organisms, such as jellyfish, that feed on these plankton can glow also as a result of ingesting them.
- Squid, shrimp, and some fish are also able to produce light biochemically.
- Many mid-water and deep dwelling fish have organs that produce light. Among the uses fish have for bioluminescence are:
  - a. the ability to identify organisms by the pattern of light,
  - b. light producing organisms on the ventral, or bottom, side of fish may make them hard to see from below against lighter surface water, and
  - c. some use these organs to attract prey.

Major Concept (V) *Marine organisms come in many different colors; some are even transparent. The color of an organism is usually used for some advantage by the organism.*

Related or supporting concepts:

- The appearance of marine organisms varies widely from those that are transparent to others exhibiting bright colors and many that are very drab. In each case the organism uses its appearance to help it survive.
- Many surface dwelling organisms, including jellyfish and small plankton, are transparent. This makes them very difficult to see.
- In very clear water where visibility is not a problem, many fish are very brightly colored and often have multi-colored patterns. Bold patterns can act to hide the outline of the fish making it difficult to identify. In addition, prominent "false eyes" such as dark round spots can fool a predator into mistaking a non-vital part of the fish, like the tail, for the head.
- Bold, easily identified colors can also warn other fish that may be poisonous, have a foul taste or sharp spines, or that sting.
- Fish that swim near the surface typically have dark backs and light bottoms (see fig. 10.4). This makes it difficult to see them from either above against the dark, deep water or from below against the shallow, light water. Examples include salmon, cod,

tuna, and herring.

- In coastal waters where the turbidity is high, organisms are often very drab, allowing them to blend in with the bottom and surrounding water.
- One particularly interesting type of fish is the flatfish, such as the flounder. Figure 10.5 is an amazing example of the ability of this fish to change color to blend in with the bottom.
- We do not yet understand how marine organisms see colors and we may not yet know all of the roles that color plays in the marine environment.
- We do believe that color is important in:
    a. species recognition,
    b. camouflage,
    c. courtship, and
    d. perhaps in keeping schools of fish together.

Major Concept (VI) *Marine organisms can be prevented from moving anywhere they wish by "invisible" barriers. These barriers include changes in the physical properties of the water such as temperature, salinity, density, and the availability of sunlight. Other barriers involve currents, vertical motion in the water, and geological features.*

Related or supporting concepts:

- Rapid changes in physical properties such as water temperature, salinity, density, and the intensity of sunlight can act as barriers to movement for marine organisms.
- These physical properties are generally more variable in shallow water than in deeper water and hence are more effective barriers at shallower depths.
- As the water depth increases, the physical characteristics of the water become more uniform. Deep water tends to be uniformly cold and have fairly constant salinity. In addition, at depths below the photic zone there is no sunlight so it is constantly dark.
- Horizontal barriers also exist between different water masses or between regions characterized by upwelling and downwelling.
- Powerful surface currents such as the Gulf Stream can separate waters of very different temperatures, thus acting as horizontal barriers between two regions.
- Geological features such as oceanic ridges, trenches, and seamounts can create subenvironments that range in size from quite small to very large. Oceanic ridges can segment the deep sea floor into isolated basins. Trenches create elongate, deep environments that are isolated from the rest of the sea floor. Seamounts can create small shallow-water environments in the open ocean.

Major Concept (VII) *At the very base of the food chain are the small phytoplankton that must remain in near-surface waters where sunlight is available for photosynthesis. The production of plant matter by these organisms is* *called primary production.*

Related or supporting concepts:

- Marine organisms that have little or no mobility of their own are called plankton. Plankton float or drift with currents in the water and include both plants and animals.
- Plankton that are plants are called phytoplankton.
- Most phytoplankton are single-celled organisms.
- Phytoplankton require the following things for growth:
    - a. sunlight,
    - b. nutrients (fertilizers),
    - c. carbon dioxide gas, and
    - d. water.
- Plants are able to use sunlight to produce new plant material because of the presence of chlorophyll. Chlorophyll is a pigment that allows plants to trap energy from the sun to fuel the process of photosynthesis.
- In photosynthesis, plants convert carbon dioxide and water, with solar energy trapped by chlorophyll, to produce sugar and oxygen. The sugar is used to build new plant cell material.

$$6CO_2 + 6H_2O + (\text{sunlight/chlorophyll}) \rightarrow C_6H_{12}O_6 + 6O_2$$

$$\text{carbon dioxide + water} \rightarrow \text{sugar + oxygen}$$

- The total amount of organic material produced in a region per unit time is called the gross primary production for the region.
- Some of the sugars produced by the plants are broken down to provide the energy they require to survive. The sugars are combined with oxygen to produce energy, carbon dioxide, and water in a process called respiration.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{life-support energy}$$

$$\text{sugar + oxygen} \rightarrow \text{carbon dioxide + water + life-support energy}$$

- Animals also use respiration to produce energy for survival.
- The net primary production for a region is the difference between the gross primary production and the amount of plant mass that is consumed in respiration.
- The amount of plant material available as a source of food for organisms higher in the food chain is equal to the net primary production.
- The total amount of organic matter produced in an area is the biomass of that area. The biomass can be measured as either the number of organisms in the area or, more accurately, the weight of organic carbon. Biomass is usually reported as the dry weight of organic carbon in grams present under a square meter of sea surface

(gC/m^2).

- The units used to express primary production, or the rate at which biomass changes, are typically grams of carbon per square meter of sea surface per unit time (gC/m^2/time).
- The total plant biomass in a region at any given time is the standing crop of the area at that time.
- The standing crop is a function of the rate of growth, reproduction, death, and consumption.
- Figure 10.6 illustrates how the standing crop in a region can remain reasonably constant when herbivores are consuming plants at a rate roughly equal to the rate of net primary production.

Major Concept (VIII) *The rate of primary productivity is variable in the oceans. Among the many variables that affect it is the availability of sunlight and the ability of phytoplankton to remain in the photic zone.*

Related or supporting concepts:

- Since photosynthesis depends on the availability of sunlight, the rate of primary productivity is related to the amount and intensity of sunlight at different latitudes and seasons.
- In order for phytoplankton to use available sunlight they must remain in the upper part of the water column where the intensity of the light is high enough to support photosynthesis. This is called the photic zone. The average depth of the photic zone is about 50 - 100 m (150 - 300 ft).
- The rate of primary production as a function of time varies with latitude and season, as shown in figure 10.7.
- At high latitudes:
    a. the intensity and availability of sunlight is the limiting factor for primary productivity,
    b. the growing season is very short and peaks in the summer when there is almost constant sunlight, although the intensity of the light is relatively low at these high latitudes, and
    c. the melting of summer sea ice adds low density fresh water to the surface layer which creates a weakly stable water column that helps phytoplankton remain near the surface in the photic zone.
- In middle latitudes:
    a. the intensity of sunlight varies markedly with the seasons,
    b. lower surface water temperatures and stronger storms in the winter can increase the mixing of surface water to greater depths, inhibiting the rate of primary productivity, and
    c. warming in the spring can stabilize the water column and keep plants near the surface in the photic zone to produce an early spring increase in plant biomass.

- In tropical regions:
  - a. sunlight is not a limiting factor, and
  - b. warm, low density surface water creates a very stable water column with little overturn or mixing.

Major Concept (IX) *Primary productivity is also a function of the availability of nutrients in the water.*

Related or supporting concepts:

- At high latitudes:
  - a. the growing season is so short that there is always an adequate supply of nutrients for the phytoplankton, consequently
  - b. nutrients are not a limiting factor.
- In middle latitudes:
  - a. the cooling of the surface water in the winter increases the density of the surface layer and contributes to overturn. Combined with stronger storms and mixing, this creates an unstable water column where nutrients at depth are brought to the surface to replenish diminished supplies.
  - b. grazing herbivores will decrease the standing crop of phytoplankton in the spring bloom and recycle nutrients back into the water column to support the summer bloom, and
  - c. the ongoing production through the summer gradually depletes the supply of nutrients in the water and the rate of production decreases.
- In tropical regions:
  - a. there is little overturn of water due to the extreme stability of the water column caused by high surface temperatures, and
  - b. the constant depletion of nutrients in the water results in low plant biomass despite the constant high level of sunlight.
- Dead organisms are broken down to basic molecules such as carbon dioxide, nutrients, and water by decomposers (bacteria and fungi) that release these components back into the water column.
- Because earth is essentially a closed environment, living systems must recycle inorganic molecules to form the organic compounds needed for their systems and life processes.
- Two important soluble nutrients used by phytoplankton are nitrogen and phosphorus.
- Nitrogen is essential to form proteins.
- Phosphorus is used energy reactions, cell membranes, and nucleic acids.
- Nitrogen is present in the water in the form of nitrates and phosphorus is present in the form of phosphates.
- Nitrogen gas cannot be used directly by plants. The gas is converted first to ammonia, then to nitrite, and finally to nitrate by microorganisms.
- Nitrogen and phosphorus are cycled into animals as they feed on plants.

- The nitrogen and phosphorus cycles are shown in figures 10.9 and 10.10.
- There are other inorganic nutrients that can also control phytoplankton growth, or primary production. One of these is soluble iron. The addition of soluble iron to sea water initially increases primary production but then phytoplankton growth slows and levels off as the iron reacts with other chemical constituents in the water and sinks.

Major Concept (X) *There are a number of different methods that can be used to obtain estimates of the rate of primary production.*

Related or supporting concepts:

- The amount of plant material in the water can be measured by filtering out the phytoplankton from a water sample of known size, counting the number of phytoplankton cells, and multiplying the number of cells by their average mass. This is a reasonably accurate method but it can be very time consuming.
- Another method is to remove the chlorophyll from a sample of water and measure its concentration in the water.
- When chlorophyll is exposed to certain wavelengths of light it will fluoresce. Measuring the intensity of the fluorescence will provide an estimate of the amount of chlorophyll.
- An expensive, but accurate, method is to introduce radioactive carbon-14 to a water sample and after a period of time filter out the phytoplankton and measure the amount of carbon-14 that the plants have taken into their cells.
- It is possible to measure gross primary production, net primary production, and respiration by sampling phytoplankton populations at different depths and light levels and then measuring the concentration of oxygen in the samples as a function of time.
- Satellites have been used to measure sea surface chlorophyll concentrations for a number of years (see fig. 10.12).

Major Concept (XI) *There is a distinct pattern in global primary production in the oceans. In general, near-coastal regions, especially on the eastern sides of ocean basins, are very productive waters, while the lowest levels of productivity are found in the centers of the central ocean gyres.*

Related or supporting concepts:

- Coastal waters often have very high rates of primary productivity because:
    a. nutrient supplies are very high, having been added to the water by continental runoff,
    b. regions of upwelling along coasts bring nutrients and dissolved gas to the surface, and
    c. freshwater runoff creates a stable low density surface layer that keeps plants from sinking below the photic zone.

- Some of the highest rates of primary productivity occur in zones of upwelling along the eastern margins of ocean basins. This can be seen in figures 10.11 and 10.12. These regions have plenty of available sunlight, high concentrations of nutrients and dissolved gas, and represent some of the richest fisheries in the world.
- Regions of upwelling are generally about four times more productive than typical coastal waters and five times more productive than the open ocean for the same area and time (see table 10.1).
- The total surface area represented by zones of upwelling, coastal regions, and open ocean is very different. There is roughly 150 times more coastal water and 900 times more open ocean than water in zones of upwelling.
- The huge area of the open ocean compensates for its low rate of productivity. Consequently, most of the organic carbon produced in photosynthesis is made at slow rates in the open ocean.
- In table 10.2 you can see that productivity levels in the open ocean are similar to continental deserts, coastal oceans have rates of primary productivity analogous to pastureland and forests, and some upwelling zones and estuaries are similar to the most heavily cultivated land.
- Most of the organic carbon produced by phytoplankton is produced at low rates over large areas of the open ocean.
- The most productive regions in the marine environment are estuaries where shallow water and high nutrient levels create very productive waters with large amounts of phytoplankton and a variety of sea grasses. When these organisms die and decay, they form an organic litter known as detritus that is another source of nutrients.

Major Concept (XII) *Food energy and nutrients pass through one organism to another, from plants to animals along pathways that are often referred to as a food chain or food web.*

Related or supporting concepts:

- The passage of food energy through the plant and animal kingdoms is often illustrated in terms of a pyramid such as the one shown in figure 10.15. Each successive step higher on the pyramid is called a trophic level.
- At the very base of the pyramid, the first trophic level or link in the food chain is primary productivity by phytoplankton and other marine plants. The production of organic material by photosynthesis is the very first step in feeding nearly every other organism on the planet.
- Plants are called producers because they directly produce organic material through photosynthesis.
- Animals are called consumers because they do not produce organic material themselves; they consume plant material or other animals.
- Animals that eat plants are called herbivores while animals that eat other animals are called carnivores.

- The second step in the food chain is occupied by herbivorous zooplankton, small animals that feed directly on phytoplankton. These are primary consumers.
- While food chains are often illustrated as consisting of fairly simple steps from one trophic level to the next, the pattern of feeding in the oceans is usually more complex and better illustrated with the concept of a food web, such as those illustrated in figures 10.13 and 10.14.
- Species may change levels in the food chain or web at different stages of their life cycle and consumers may feed at multiple levels.
- At the highest trophic level in the oceans we find animals such as the shark and killer whale that do not have any predators that feed on them.
- As a rule, as you go to higher trophic levels you:
    a. increase the size of the organisms, and
    b. decrease the numbers and biomass of the organisms.
- The largest biomass of organisms is at the lowest trophic levels because of the large numbers.
- Only about 10 percent of the available energy is successfully transferred up each trophic level. The remaining 90 percent of the energy is lost in supporting the metabolism of the organisms, feeding, breathing, moving, reproduction, and heat loss.
- Trophic efficiency can vary in different environments. In areas with abundant phytoplankton, organisms at higher levels can feed more efficiently and the energy transfer up the food chain increases.
- Trophic efficiency does not necessarily remain constant in all environments at all times. Efficiency can be influenced by such things as:
    a. El Niño,
    b. coastal pollution, and
    c. coral bleaching.
- The largest biomass of organisms is at the lowest trophic levels because of the large numbers.

Major Concept (XIII) *Harvesting the oceans for food requires careful planning to maximize the efficiency of food energy transfer. It is much more energy efficient to harvest from low levels in the food chain or from higher levels in shorter food chains.*

Related or supporting concepts:

- Because of the enormous energy loss with each step higher in the food chain, it is more efficient to harvest food at low trophic levels than from higher levels (see table 10.3).
- Commercial fishing targets both high and low levels in the marine food chain. High trophic level fish include salmon, tuna, halibut, and swordfish. Lower trophic level organisms include herring, shellfish, and anchovy.
- Fish from higher trophic levels are invariably used directly as table food, while much

of the harvest of lower level organisms may be used for animal feed or fertilizers.

- High productivity regions such as zones of upwelling and estuaries often have shorter, more efficient food chains. Harvesting from these chains results in a more efficient transfer of food energy from the oceans to people.

Major Concept (XIV) *In deep water, there are diverse communities of organisms on ocean ridges that survive by depending on primary production that is driven by chemosynthesis rather than photosynthesis.*

Related or supporting concepts:

- The first deep-sea marine communities on mid-ocean ridge crests were discovered on the Galápagos Rift (a part of the East Pacific Rise) in March, 1977.
- These communities have been located in a number of different areas including the Pacific, the Atlantic, and the Gulf of Mexico at depths that have ranged from about 700 m to about 3300 m.
- The variety of organisms that populate these communities include filtering-feeding clams and mussels, anemones, worms, barnacles, limpets, crabs, and fish.
- Many of these organisms are unique in terms of their rate of growth and their size. Tube worms can reach lengths of 3 m (10 ft). Their growth rate can be nearly 1 m (3.3 ft) per year!
- Clams may grow at rates as great as 4 cm (2 in) per year.
- These communities have a biomass 500 - 1000 times greater than the biomass of the normal deep seafloor.
- At the base of the food pyramid in these communities are bacteria that produce organic material by chemical means using hydrogen sulfide and sulfur in the water that is ejected by vents along the ridge axis. This process, called chemosynthesis, is another form of primary production.
- Other isolated communities that rely on chemosynthetic bacteria are found in areas where oil and gas seep out of the sea floor. In these regions bacteria use methane gas to create organic matter.
- In 1990, salt seeps were found at a depth of 650 m (2000 ft) on the floor of the Gulf of Mexico. Depressions on the seafloor in this area are filled with brine more than 3.5 times the average salinity of seawater. These brine pools are surrounded by large communities of chemosynthetic mussels.
- Ninety-five percent of the approximately 300 species found in these areas are new to science and appear to be more directly related to ancient species than modern ones.

Major Concept (XV) *Microorganisms that thrive under environmental conditions that would kill other life forms are called extremophiles.*

Related or supporting concepts:

- Extremophiles live under extreme conditions of high temperature, high levels of acid or salt, or lack of oxygen.
- Heat loving extremophiles require water temperatures in excess of 80ºC (176ºF) for maximum growth.
- Cold water organisms have been found in a variety of environments including
  a. at all latitudes at depths greater than 100 m (330 ft),
  b. in deep-sea sediments, and
  c. in the guts of deep-sea cucumbers.

Key Terms and Related Major Concepts

At the back of the chapter in your book there are a number of key terms. You should be able to find the following terms referenced in the major concept indicated in parentheses.

pelagic(I)	net primary	photic zone(VIII)
benthic(I)	production(VII)	decomposers(IX)
photic zone(I)	gross primary	food chain(XII)
buoyancy(II)	production(VII)	herbivores(XII)
osmosis(III)	plankton(VII)	carnivores(XII)
stenohaline(III)	chlorophyll(VII)	zooplankton(XII)
euryhaline(III)	photosynthesis(VII)	food web(XII)
bioluminescence(IV)	biomass(VII)	trophic level(XII)
phytoplankton(VII)	respiration(VII)	chemosynthesis(XIV)
primary production(VII)	standing crop(VII)	extremophile(XV)

Test Your Understanding With The Following Questions:

FILL IN THE BLANK

1. The two major environmental zones are the water, or the ______________________ zone, and the sea floor, or the ______________________ zone.
2. Plankton that are plants are called ___________________.
3. The region over which there is sufficient light to support photosynthesis is called the ___________________ zone.
4. Each step on a food pyramid is called a ____________________________ level.
5. Zooplankton that feed on phytoplankton are called __________________________________.
6. The pigment plants use to trap the sun's energy is called ________________________________.
7. The breaking down of organic material to produce energy for life is called

______________________.

8. The total biomass in a given region is called the ________________________ ____________.

9. Another term for a food chain is a food ______________.

10. The base of the food chain is occupied by ______________ __________________.

TRUE - FALSE

1. Food chains in estuarine environments are longer than in open ocean environments.
2. Photosynthesis produces oxygen.
3. Organic material is broken down by decomposers to replenish nutrients.
4. The largest biomass of organisms is at the lowest trophic levels.
5. Zooplankton are responsible for primary production.
6. Photosynthesis produces sugars and carbon dioxide.
7. Phytoplankton are generally carnivorous.
8. Organisms in chemosynthetic communities do not require sunlight for primary productivity.
9. There is only one known way to measure primary productivity.
10. It is more efficient to harvest food from the top of the food chain than the bottom.

MULTIPLE CHOICE

1. Only about ____ percent of the available energy is transferred between each trophic level.
    a. 5
    b. 10
    c. 15
    d. 20
    e. 25
2. The level of productivity of the open ocean is equivalent to this region on land:
    a. rain forests
    b. pastures
    c. agricultural fields
    d. deserts
    e. deciduous forests
3. The base of the food chain in the oceans relies on this process:
    a. photosynthesis
    b. agrisynthesis
    c. chemosynthesis
    d. carbosynthesis
    e. a or c depending on the area
4. Primary productivity depends on:
    a. sunlight
    b. nutrients
    c. carbon dioxide gas

d. water
e. all of the above

5. The photic zone has an average depth of ________________ m.
   a. 50 - 100
   b. 1000 - 1200
   c. 500 - 750
   d. 10 - 40
   e. 150 - 200
6. The limiting factor for primary productivity at high latitudes is:
   a. temperature
   b. nutrient supply
   c. amount of dissolved gas
   d. availability and intensity of sunlight
   e. stability of the water column
7. Zones of upwelling:
   a. are regions of high productivity
   b. are regions of low productivity
   c. areas that typically have high nutrient concentrations
   d. a and c
   e. b and c
8. The largest mass of organic material produced in the oceans comes from:
   a. zones of upwelling
   b. the eastern sides of ocean basins
   c. the open ocean
   d. estuaries
   e. a and b
9. Respiration consumes:
   a. carbon dioxide
   b. oxygen
   c. water
   d. phosphorus
   e. nitrogen
10. The rate of primary productivity in zones of upwelling is about ____ times greater than in the open ocean.
    a. 5
    b. 10
    c. 2
    d. 20
    e. 15

Answer Key for 'Key Terms' and 'Test Your Understanding'

FILL IN THE BLANK

1. pelagic, benthic
2. phytoplankton
3. photic
4. trophic
5. herbivores
6. chlorophyll
7. respiration
8. standing crop
9. web
10. primary producers

TRUE - FALSE

1.F 2.T 3.T 4.T 5.F 6.F 7.F 8.T 9.F 10.F

MULTIPLE CHOICE

1.b 2.d 3.e 4.e 5.a 6.d 7.d 8.c 9.b 10.a