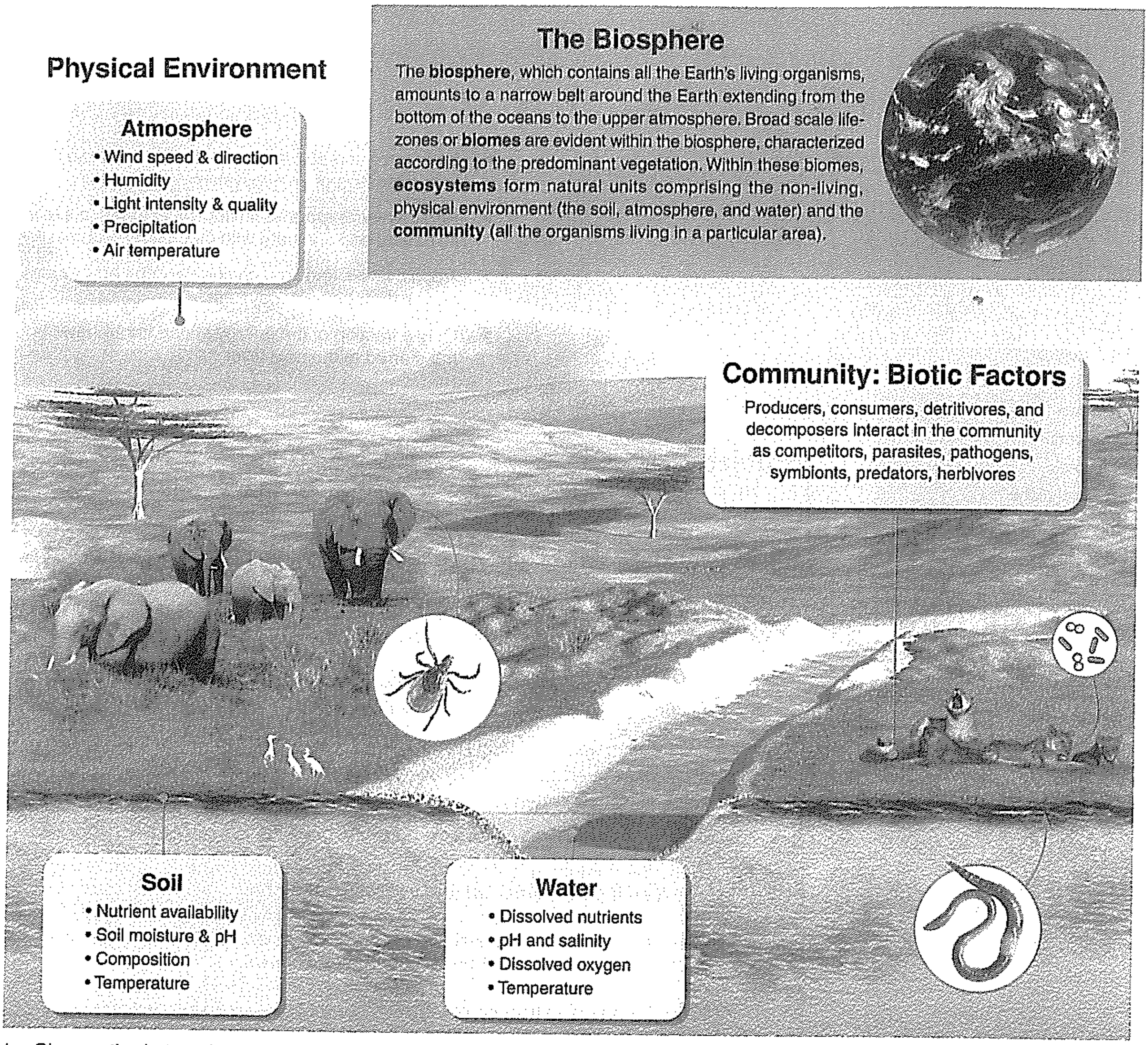
Components of an Ecosystem

The concept of the ecosystem was developed to describe the way groups of organisms are predictably found together in their physical environment. A community comprises all the organisms within an ecosystem. Both physical (abiotic) and biotic factors affect the organisms in a community, influencing their distribution and their survival, growth, and reproduction.



1. Choose the letter of the term that corresponds to each of the statements below:

   A Community **B** Population **C** Ecosystem **D** Physical factor

   (a) All the green tree frogs present in a rainforest: ______________________

   (b) An entire forest: ______________________

   (c) The humidity in a rainforest: ______________________

   (d) A community of organisms and their environment: ______________________

   (e) An association of different species interacting together: ______________________

2. Distinguish between biotic and abiotic factors: ______________________

____

____

____

____

Habitat

The environment in which a species population (or a individual organism) lives (including all the physical and biotic factors) is termed its **habitat**. Within a prescribed habitat, each species population has a range of tolerance to variations in its physical and chemical environment. Within the population, individuals will have slightly different tolerance ranges based on small differences in genetic make-up, age, and health. The wider an organism's tolerance range for a given abiotic factor (e.g. temperature or salinity), the more likely it is that the organism will be able to survive variations in that factor. Species **dispersal** is also strongly influenced by **tolerance range**. The wider the tolerance range of a species, the more widely dispersed the organism is likely to be. As well as a tolerance range, organisms have a narrower **optimum range** within which they function best. This may vary from one stage of an organism's development to another or from one season to another. Every species has its own optimum range. Organisms will usually be most abundant where the abiotic factors are closest to the optimum range.

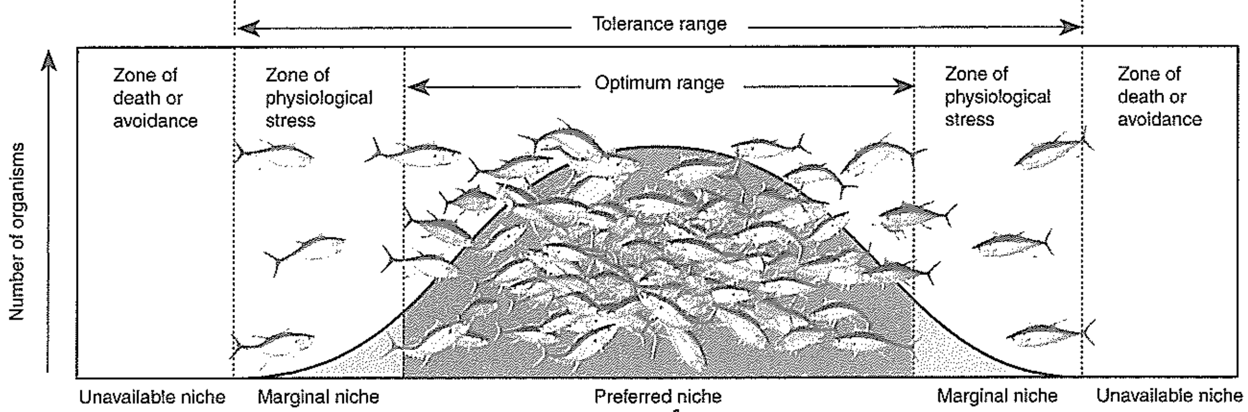
Habitat Occupation and Tolerance Range

Examples of abiotic factors influencing niche size:

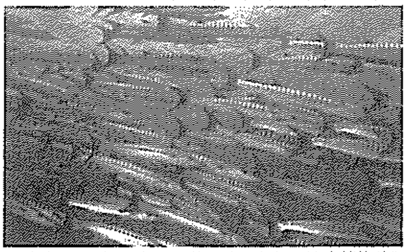
Too acidic ← pH → *Too alkaline*

Too cold ← Temperature → *Too hot*

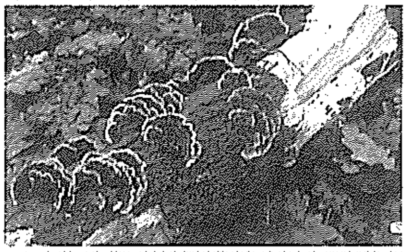
The law of tolerances states that *for each abiotic factor, a species population (or organism) has a tolerance range within which it can survive. Toward the extremes of this range, that abiotic factor tends to limit the organism s ability to survive*.



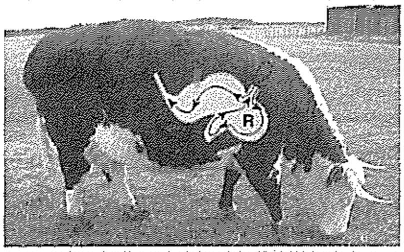
The Scale of Available Habitats



A habitat may be vast and relatively homogeneous, as is the open ocean. Barracuda (above) occur around reefs and in the open ocean where they are aggressive predators.



For non-mobile organisms, such as the fungus above, a suitable habitat may be defined by the particular environment in a relatively tiny area, such as on this decaying log.



For microbial organisms, such as the bacteria and protozoans of the ruminant gut, the habitat is defined by the chemical environment within the rumen (R) of the host animal, in this case, a cow.

1. Explain how an organism's habitat occupation relates to its tolerance range: ______________________________

____

____

2. (a) Identify the range in the diagram above in which most of the species population is found. Explain why this is the case:

____

____

(b) Describe the greatest constraints on an organism's growth and reproduction within this range: ______________

____

3. Describe some probable stresses on an organism forced into a marginal niche: ______________________________

____

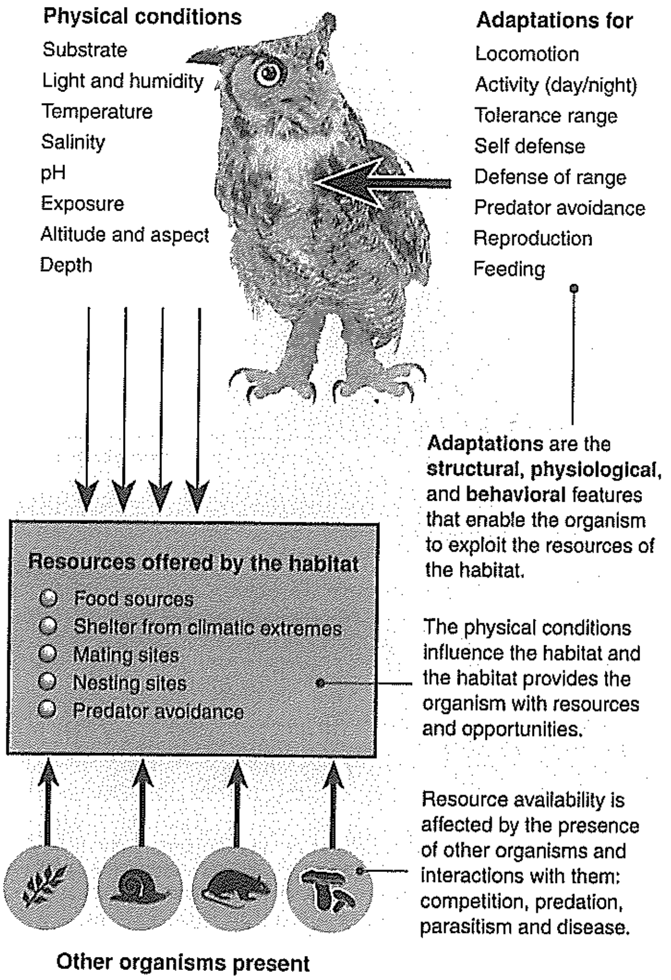
____

Related activities: Ecological Niche

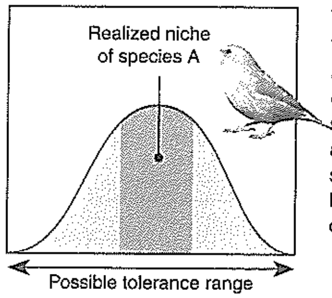
Ecological Niche

The **ecological niche** describes the functional position of a species in its ecosystem; how it responds to the distribution of resources and how it, in turn, alters those resources for other species. The full range of environmental conditions (biological and physical) under which an organism can exist describes its **fundamental niche**. As a result of direct and indirect interactions with other organisms, species are usually forced to occupy a niche that is narrower than this and to which they are best adapted. This is termed the **realized niche**. From the concept of the niche arose the idea that two species with the same niche requirements could not coexist, because they would compete for the same resources, and one would exclude the other. This is known as **Gause's competitive exclusion principle**. If two species compete for some of the same resources (e.g. food items of a particular size), their resource use curves will overlap (below, right). Within the zone of overlap, competition will be intense.

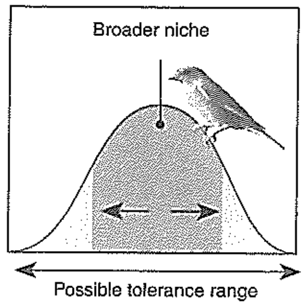
The Ecological Niche



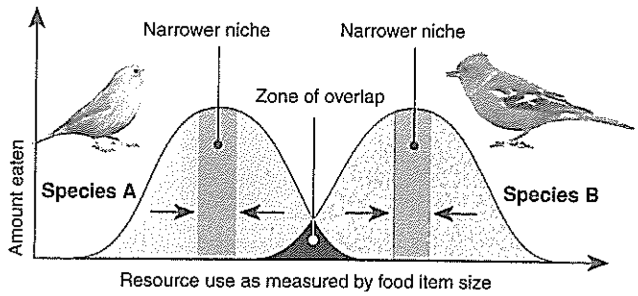
Competition and Niche Size



The realized niche
The tolerance range represents the potential (**fundamental**) niche a species could exploit. The actual or **realized** niche of a species is narrower than this because of competition with other species.



Intraspecific competition
Competition is strongest between individuals of the same species, because their resource needs exactly overlap. When intraspecific competition is intense, individuals are forced to exploit resources in the extremes of their tolerance range. This leads to expansion of the realized niche.



Interspecific competition
If two (or more) species compete for some of the same resources, their resource use curves will overlap. Within the zone of overlap, resource competition will be intense and selection will favor niche specialization so that one or both species occupy a narrower niche.

1. (a) Explain in what way the realized niche could be regarded as flexible: ______________________

____

____

(b) Describe factors that might constrain the extent of the realized niche: ______________________

____

2. Explain the contrasting effects of interspecific competition and intraspecific competition on niche breadth:

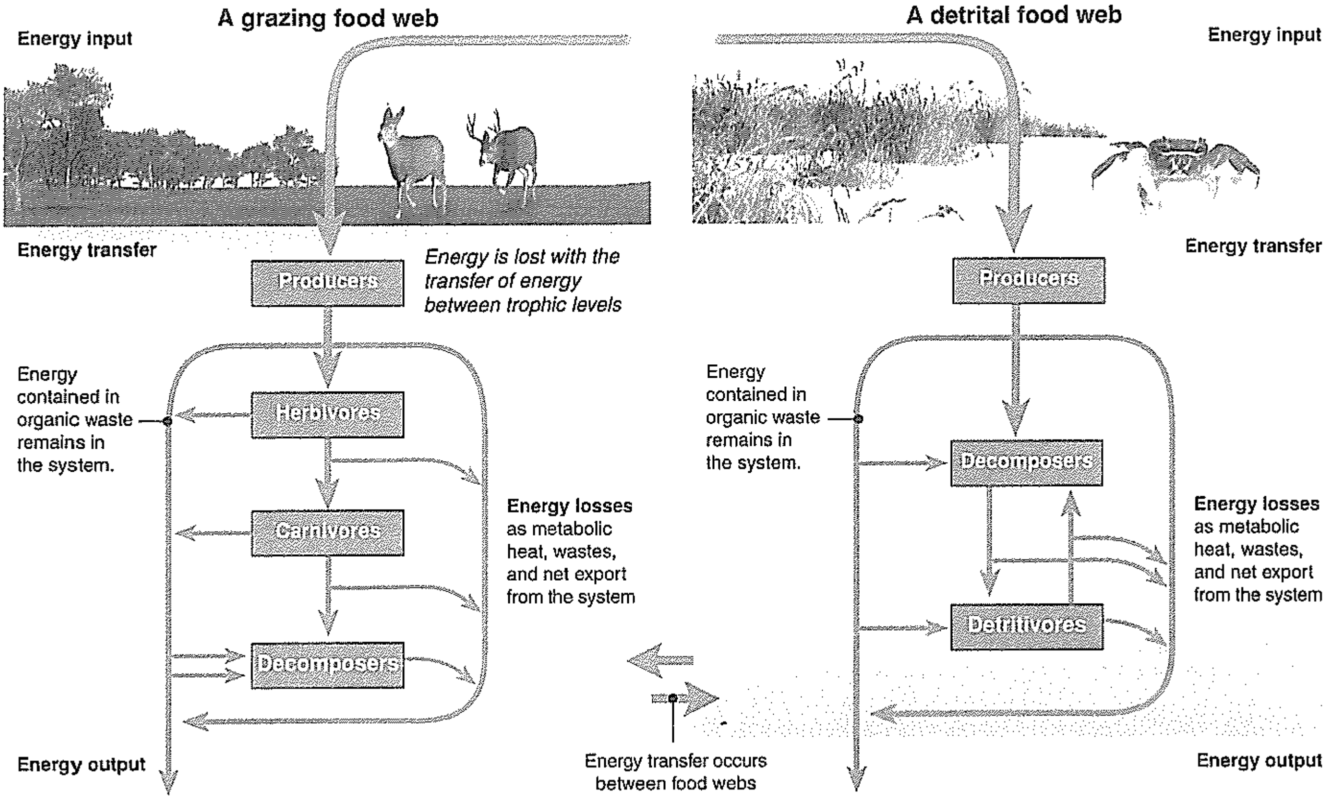
____

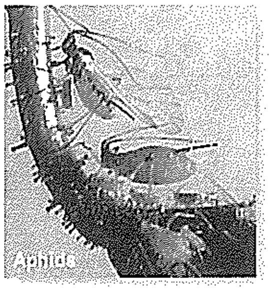
____

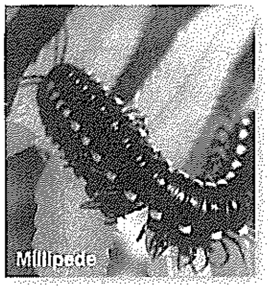
____

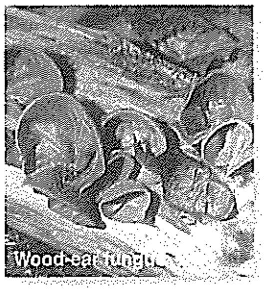
Energy Inputs and Outputs

Within ecosystems, organisms are assigned to **trophic** levels based on the way in which they obtain their energy. **Producers** or **autotrophs** manufacture their own food from simple inorganic substances. Most producers utilize sunlight as their energy source for this, but some use simple chemicals. The **consumers** or **heterotrophs** (herbivores, carnivores, omnivores, decomposers, and detritivores), obtain their energy from other organisms. Energy flows through trophic levels rather inefficiently, with only 5-20% of usable energy being transferred to the subsequent level. Energy not used for metabolic processes is lost as heat.









Producers (green plants, algae, and some bacteria) make their own food from simple inorganic carbon sources (e.g. CO_2). Sunlight is the most common energy source for this process.

Consumers: Consumer organisms (animals, non-photosynthetic protists, and some bacteria) rely on other living organisms or organic particulate matter for both their energy and their source of carbon. **First order consumers**, such as aphids (left), feed directly on producers. **Second** (and higher) **order consumers**, such as ladybugs (center) feed on other consumers. **Detritivores** consume (ingest and digest) detritus (decomposing organic material) from every trophic level. In doing so, they contribute to decomposition and the recycling of nutrients. Common detritivores includes millipedes (right), woodlice, and many terrestrial worms.

Decomposers (fungi and some bacteria) obtain their energy and carbon from the extracellular breakdown of (usually dead) organic matter (DOM). Decomposers play a central role in nutrient cycling.

1. Describe the differences between **producers** and **consumers** with respect to their role in energy transfers:

____

____

2. With respect to energy flow, describe a major difference between a detrital and a grazing food web: ______________

____

____

3. Distinguish between detritivores and decomposers with respect to how their contributions to nutrient cycling:

____

____

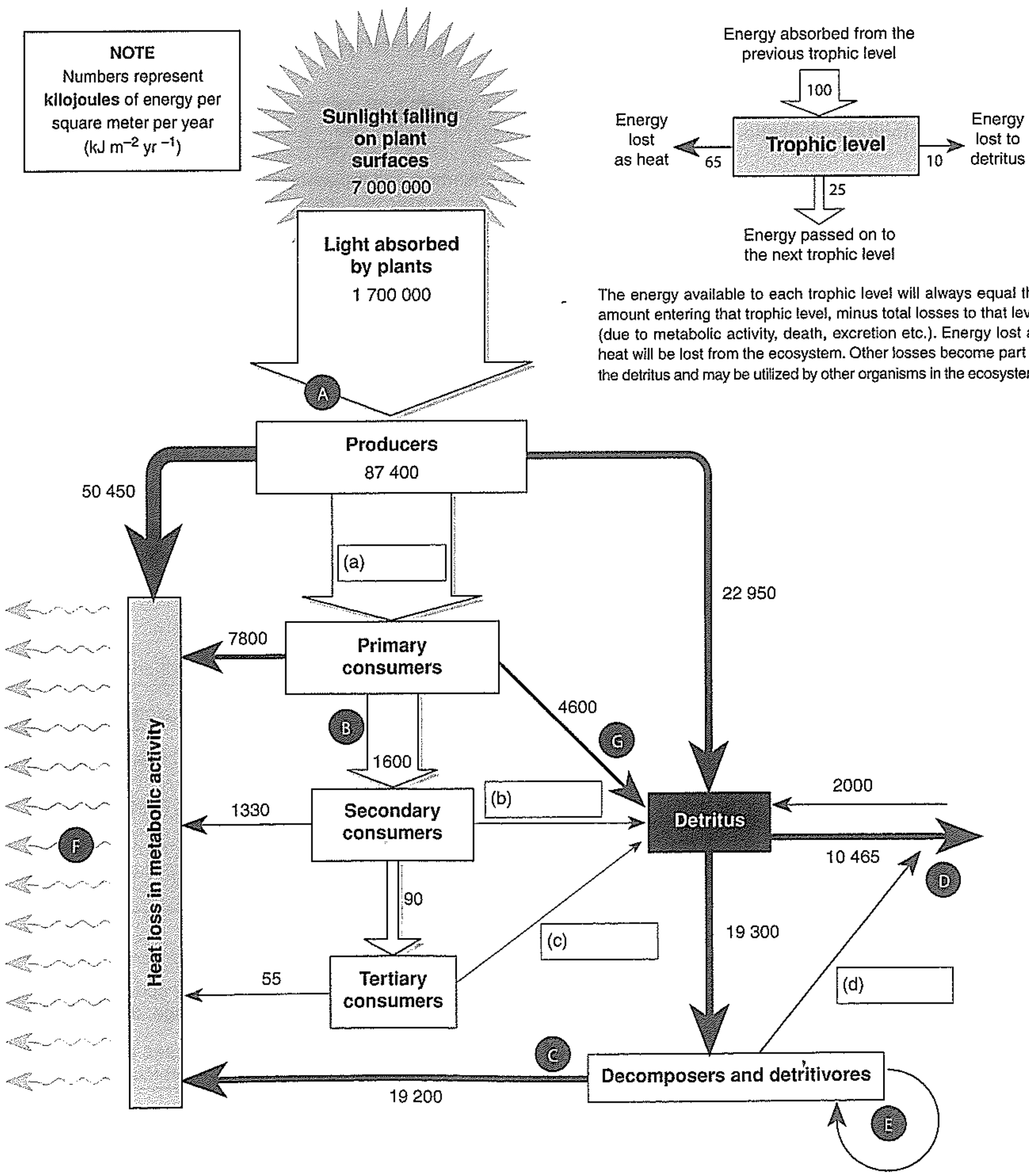
Energy Flow in an Ecosystem

The flow of energy through an ecosystem can be measured and analyzed. It provides some idea as to the energy trapped and passed on at each trophic level. Each trophic level in a food chain or web contains a certain amount of biomass: the dry weight of all organic matter contained in its organisms. Energy stored in biomass is transferred from one trophic level to another (by eating, defecation etc.), with some being lost as low-grade heat energy to the environment in each transfer. Three definitions are useful:

- **Gross primary production**: The total of organic material produced by plants (including that lost to respiration).
- **Net primary production**: The amount of biomass that is available to consumers at subsequent trophic levels.
- **Secondary production**: The amount of biomass at higher trophic levels (consumer production). Production figures are sometimes expressed as rates (productivity).

The percentage of energy transferred from one trophic level to the next varies between 5% and 20% and is called the **ecological efficiency** (efficiency of energy transfer). An average figure of 10% is often used. The path of energy flow in an ecosystem depends on its characteristics. In a tropical forest ecosystem, most of the primary production enters the detrital and decomposer food chains. However, in an ocean ecosystem or an intensively grazed pasture more than half the primary production may enter the grazing food chain.

Energy Flow Through an Ecosystem



The energy available to each trophic level will always equal the amount entering that trophic level, minus total losses to that level (due to metabolic activity, death, excretion etc.). Energy lost as heat will be lost from the ecosystem. Other losses become part of the detritus and may be utilized by other organisms in the ecosystem.

1. Study the diagram on the previous page illustrating energy flow through a hypothetical ecosystem. Use the example at the top of the page as a guide to calculate the missing values (a)–(d) in the diagram. Note that the sum of the energy inputs always equals the sum of the energy outputs. Place your answers in the spaces provided on the diagram.

2. Describe the original source of energy that powers this ecosystem: ______________________

3. Identify the processes that are occurring at the points labelled **A – G** on the diagram:

A. ______________________ E. ______________________

B. ______________________ F. ______________________

C. ______________________ G. ______________________

D. ______________________

4. (a) Calculate the percentage of light energy falling on the plants that is absorbed at point **A**:

Light absorbed by plants ÷ sunlight falling on plant surfaces x 100 = ______________________

(b) Describe what happens to the light energy that is not absorbed: ______________________

____

5. (a) Calculate the percentage of light energy absorbed that is actually converted (fixed) into producer energy:

Producers ÷ light absorbed by plants x 100 = ______________________

(b) State the **amount** of light energy absorbed that is **not** fixed: ______________________

(c) Account for the difference between the amount of energy absorbed and the amount actually fixed by producers:

____

____

6. Of the total amount of energy **fixed** by producers in this ecosystem (at point **A**) calculate:

(a) The total amount that ended up as metabolic waste heat (in kJ): ______________________

(b) The percentage of the energy fixed that ended up as waste heat: ______________________

7. (a) State the groups for which detritus is an energy source: ______________________

(b) Describe by what means detritus could be removed or added to an ecosystem: ______________________

____

8. In certain conditions, detritus will build up in an environment where few (or no) decomposers can exist.

(a) Describe the consequences of this lack of decomposer activity to the energy flow:

____

____

(b) Add an additional arrow to the diagram on the previous page to illustrate your answer.

(c) Describe three examples of materials that have resulted from a lack of decomposer activity on detrital material:

____

____

____

9. The **ten percent law** states that the total energy content of a trophic level in an ecosystem is only about one-tenth (or 10%) that of the preceding level. For each of the trophic levels in the diagram on the preceding page, determine the amount of energy passed on to the next trophic level as a percentage:

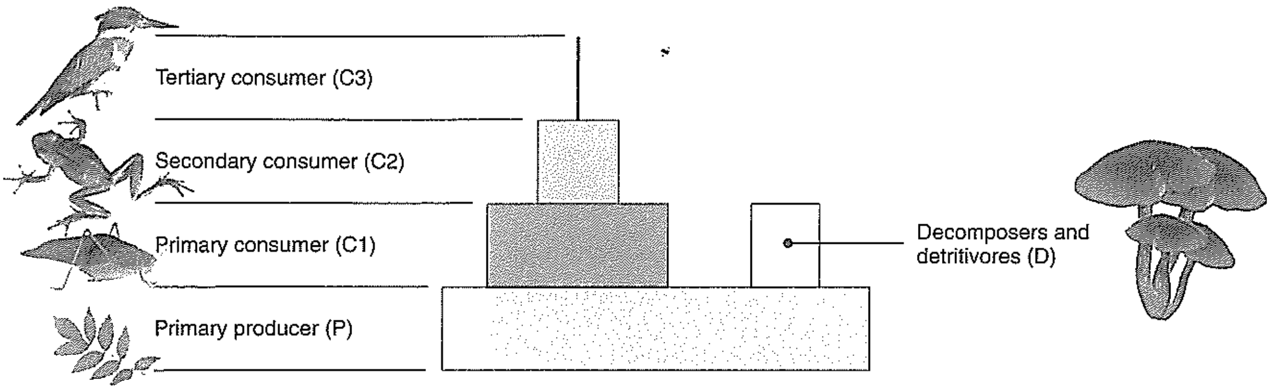
(a) Producer to primary consumer: ______________________

(b) Primary consumer to secondary consumer: ______________________

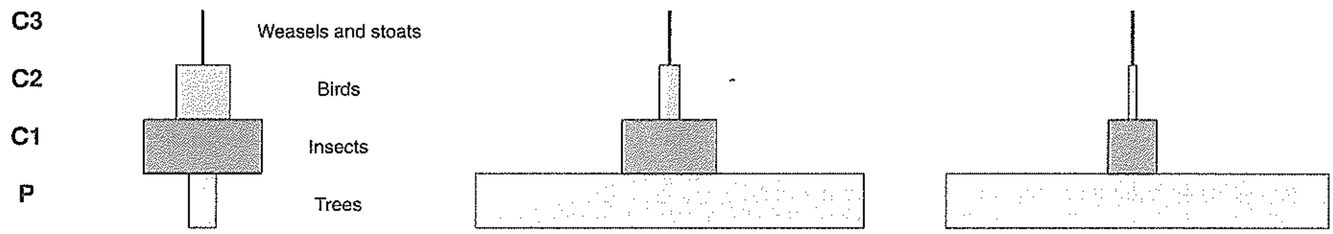
(c) Secondary consumer to tertiary consumer: ______________________

Ecological Pyramids

The trophic levels of any ecosystem can be arranged in pyramid of increasing trophic level. The first trophic level is placed at the bottom and subsequent trophic levels are stacked on top in their 'feeding sequence'. Ecological pyramids can illustrate changes in the numbers, biomass (weight), or energy content of organisms at each level. Each of these three kinds of pyramids tells us something different about the flow of energy and movement of materials between one trophic level and the next. The type of pyramid you choose in order to express information about an ecosystem will depend on what particular features of the ecosystem you are interested in and, of course, the type of data you have collected.



The generalized ecological pyramid pictured above shows a conventional pyramid shape, with a large number (or biomass) of producers forming the base for an increasingly small number (or biomass) of consumers. Decomposers are placed at the level of the primary consumers and off to the side. They may obtain energy from many different trophic levels and so do not fit into the conventional pyramid structure. For any particular ecosystem at any one time (e.g. the forest ecosystem below), the shape of this typical pyramid can vary greatly depending on whether the trophic relationships are expressed as numbers, biomass or energy.



Numbers in a forest community

Pyramids of numbers display the number of individual organisms at each trophic level. The pyramid above has few producers, but they may be of a very large size (e.g. trees). This gives an 'inverted pyramid' although not all pyramids of numbers are like this.

Biomass in a forest community

Biomass pyramids measure the 'weight' of biological material at each trophic level. Water content of organisms varies, so 'dry weight' is often used. Organism size is taken into account, so meaningful comparisons of different trophic levels are possible.

Energy in a forest community

Pyramids of energy are often very similar to biomass pyramids. The energy content at each trophic level is generally comparable to the biomass (i.e. similar amounts of dry biomass tend to have about the same energy content).

1. Describe what the three types of ecological pyramids measure:

   (a) Number pyramid: ______________________

   (b) Biomass pyramid: ______________________

   (c) Energy pyramid: ______________________

2. Explain the advantage of using a biomass or energy pyramid rather than a pyramid of numbers to express the relationship between different trophic levels:

   ____

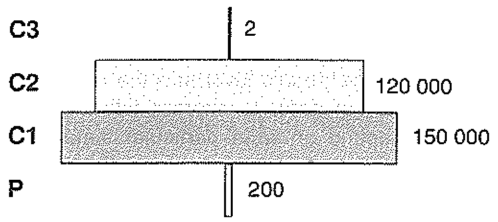
   ____

   ____

3. Explain why it is possible for the forest community (on the next page) to have very few producers supporting a large number of consumers:

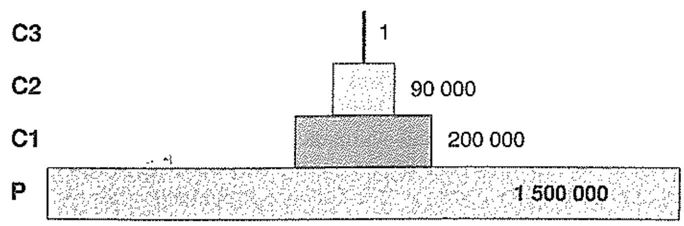
   ____

   ____



Pyramid of numbers: forest community

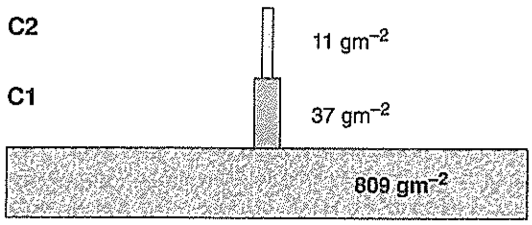
In a forest community a few producers may support a large number of consumers. This is due to the large size of the producers; large trees can support many individual consumer organisms. The example above shows the numbers at each trophic level for an oak forest in England, in an area of 10 m^2.



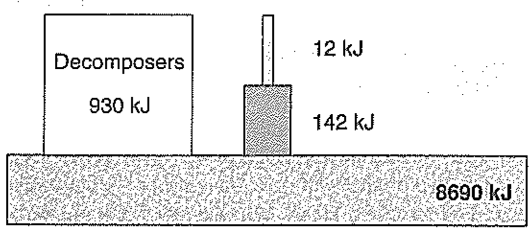
Pyramid of numbers: grassland community

In a grassland community a large number of producers are required to support a much smaller number of consumers. This is due to the small size of the producers. Grass plants can support only a few individual consumer organisms and take time to recover from grazing pressure. The example above shows the numbers at each trophic level for a derelict grassland area (10 m^2) in Michigan, United States.

Pyramids for a Plankton Community



Biomass



Energy

The pyramids of biomass and energy are virtually identical. The two pyramids illustrated here relate to the same hypothetical plankton community. A large biomass of producers supports a smaller biomass of consumers. The energy at each trophic level is reduced with each progressive stage in the food chain. As a general rule, a maximum of 10% of the energy is passed on to the next level in the food chain. The remaining energy is lost due to respiration, waste, and heat.

4. Determine the **energy transfer** between trophic levels in the plankton community example in the above diagram:

   (a) Between producers and the primary consumers: ____________________

   (b) Between the primary consumers and the secondary consumers: ____________________

   (c) Explain why the energy passed on from the producer to primary consumers is considerably less than the normally expected 10% occurring in most other communities (describe where the rest of the energy was lost to):

   ____

   ____

   (d) After the producers, which trophic group has the greatest energy content: ____________________

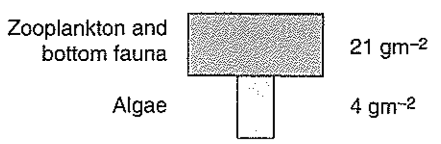
   (e) Give a likely explanation why this is the case: ____________________

   ____

   ____

An unusual biomass pyramid

The biomass pyramids of some ecosystems appear rather unusual with an inverted shape. The first trophic level has a lower biomass than the second level. What this pyramid does not show is the rate at which the producers (algae) are reproducing in order to support the larger biomass of consumers.



Biomass

5. Give a possible explanation of how a small biomass of producers (algae) can support a larger biomass of consumers (zooplankton):

   ____

   ____

   ____

KEY TERMS: Mix and Match

INSTRUCTIONS: Test your vocabulary by matching each term to its definition, as identified by its preceding letter code.

ABIOTIC FACTORS ....

BIOME ....

BIOSPHERE ....

BIOTIC FACTORS ....

COMMUNITY ....

CONSUMER ....

DETRITIVORE ....

ECOLOGICAL NICHE ....

ECOLOGY ....

ECOSYSTEM ....

ENVIRONMENT ....

FOOD CHAIN ....

FOOD WEB ....

HABITAT ....

INTERSPECIFIC ....

INTRASPECIFIC ....

MICROHABITAT ....

PHOTOSYNTHESIS ....

POPULATION ....

PRODUCER ....

REALIZED NICHE ....

RESPIRATION ....

SAPROTROPH ....

SPECIES ....

TROPHIC LEVEL ....

A The niche size that is actually occupied by an organism or species and is usually, as a result of competition, narrower than it could potentially occupy.

B A complex series of interactions showing the feeding relationships between organisms in an ecosystem.

C A naturally occurring association of different species living within the same environment and interacting together.

D Factors that include all living things within an environment. E.g. consumers, producers.

E The area surrounding the Earth in which life is able to exist.

F The study of the distribution, abundance and interrelationships of organisms and their interactions with the environment.

G An organism that obtains its carbon and energy from other organisms.

H The total number of individuals of a species within a set habitat or area.

I A major regional ecological community.

J The functional role of an organism or a species in the ecosystem, including its relationships with other species.

K Interactions occurring between different species.

L A group of related individuals able to breed together to produce viable offspring.

M A sequence of steps describing how an organism derives energy from the ones before it.

N The part of the environment which an organism occupies, e.g. stream or grassland.

O Interactions occurring between members of the same species.

P An organism that obtains energy from dead material by extracellular digestion.

Q The surroundings in which an organism lives, including biotic and abiotic factors.

R A subdivision of a habitat that possesses its own specific features.

S A community of interacting organisms and the environment (both biotic and abiotic) in which they both live and interact.

T An autotrophic organism, usually a photosynthetic plant. Synthesizes organic matter from inorganic matter.

U Any non-living (chemical or physical) part of the environment, e.g. wind, rain, temperature.

V An organism the feeds on decaying matter (detritus).

W Process by which gases (O_2 and CO_2) are exchanged between an organism and its surroundings.

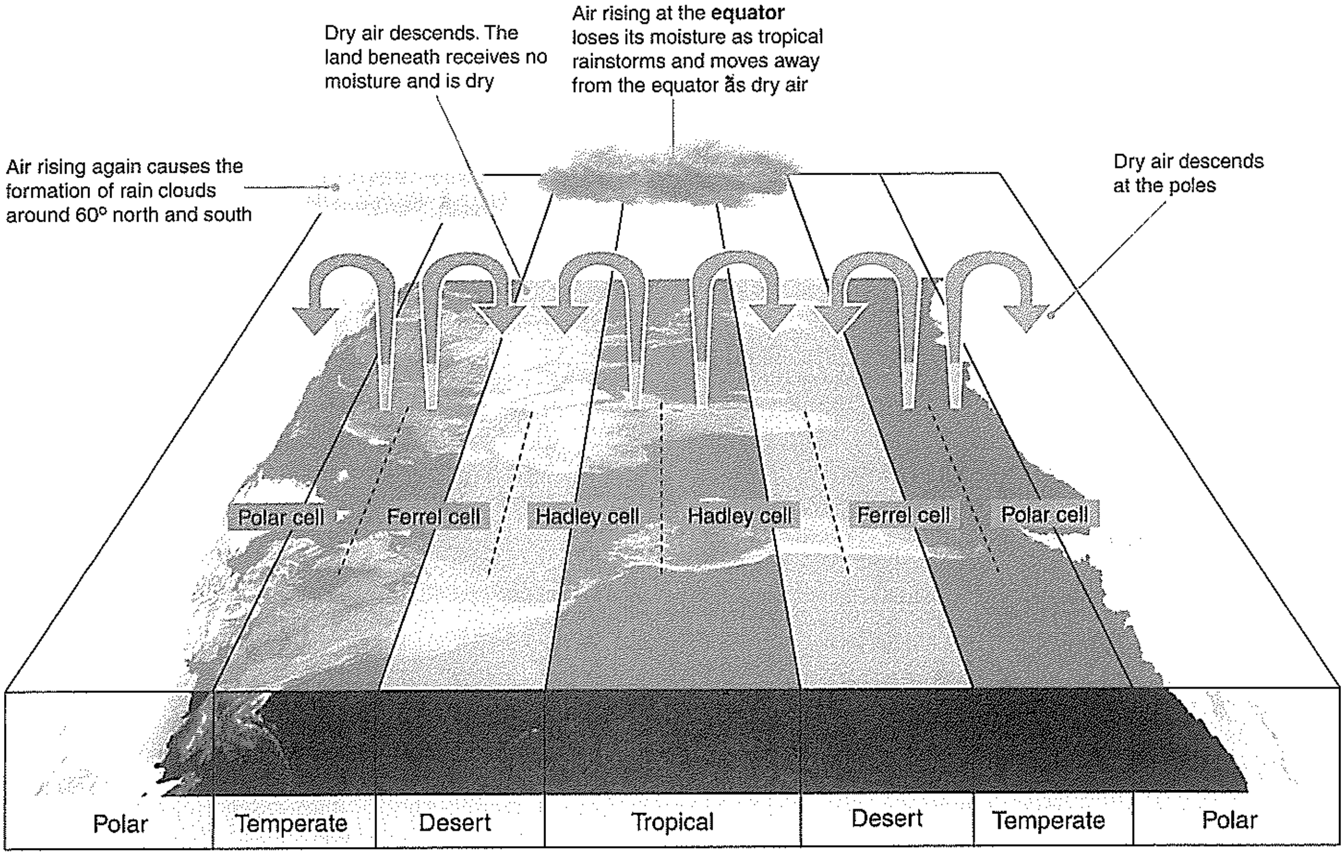
X The biochemical process that uses light energy to convert carbon dioxide and water into glucose molecules and oxygen.

Y Any of the feeding levels that energy passes through as it proceeds through the ecosystem.

Factors Affecting Biome Distribution

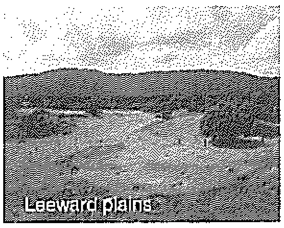
Biomes represent large areas with the same or similar climate and vegetation characteristics. These biomes exist in part because of the regular arrangement of weather conditions around the planet. The Earth is circled in the Northern and Southern hemispheres by three air cells. The interaction of these cells plays a major in the formation of biomes. The cells form areas of rising or descending air, affecting the amount of rainfall. Surface features, such as oceans and mountain ranges, affect the final positions and size of these biomes but four general areas in each hemisphere can be identified.

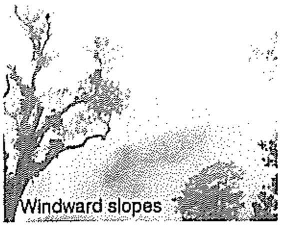
Earth's Climate and Biomes

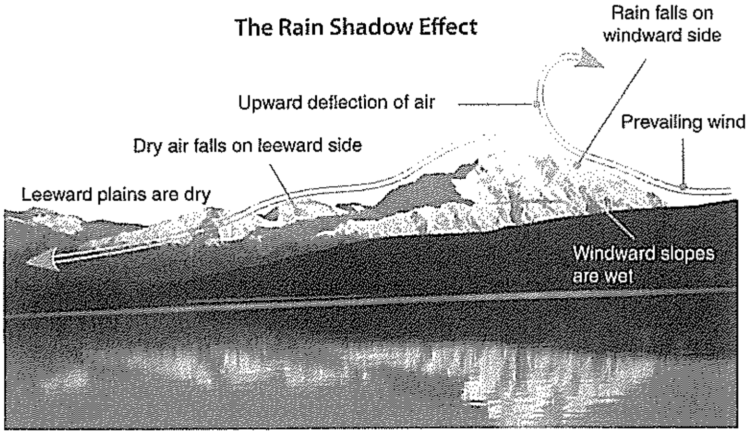


Biomes and Landscapes

Climate is heavily modified by the landscape. Where there are large mountain ranges, wind is deflected upwards causing rain on the windward side and a **rain shadow** on the leeward side. The biome that results from this is considerably different from the one that may have appeared with no wind deflection. Large expanses of ocean and flat land also change the climate by modifying air temperatures and the amount of rainfall.







1. Explain why the tropics tend to be both hot and wet: ______________________________

____

____

2. Explain why the distribution of biomes in the Northern Hemisphere is similar, but not identical to, the distribution of biomes in the Southern Hemisphere:

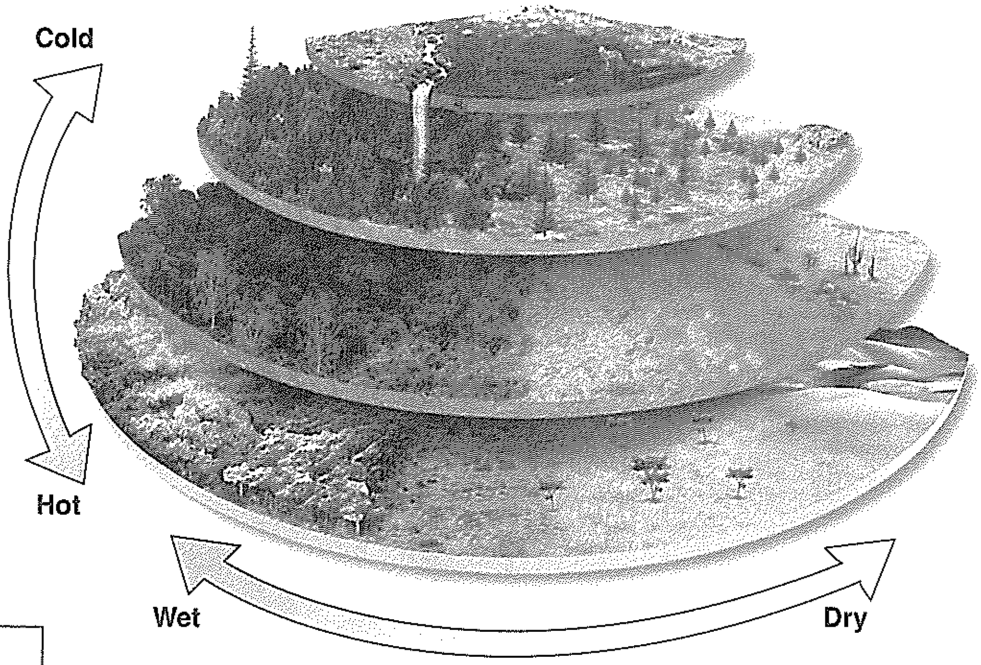
____

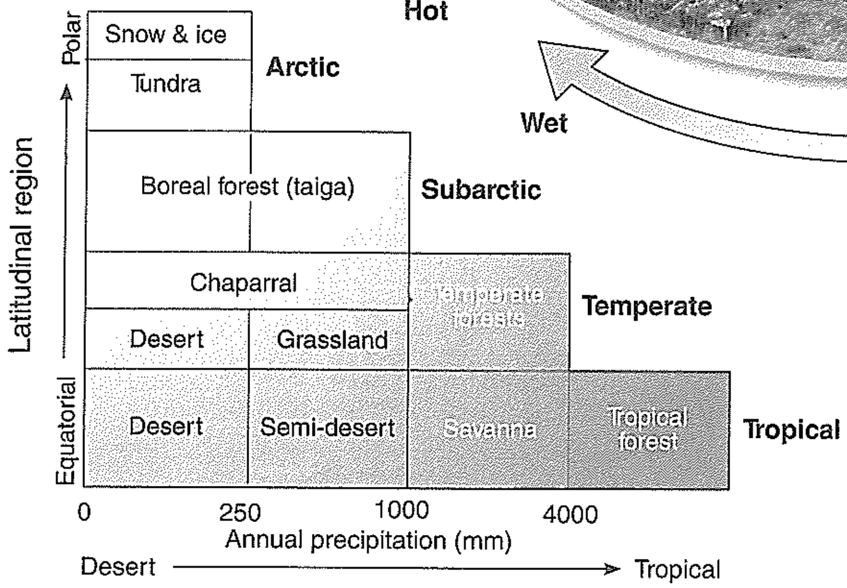
____

The Effect of Temperature on Biomes

Latitude directly affects solar input and temperature. As the Earth curves towards the poles, solar energy is spread out over an ever increasing area. This energy must also travel through a greater amount of the atmosphere, expending more energy than at low latitudes.

Within a single latitudinal region, the level of precipitation (rainfall) governs the type of plant community found. Note that the effect of altitude is similar to that of latitude (ice will occur at high altitudes even at low-latitudes).





Temperature and precipitation are excellent predictors of biome distribution. Temperature decreases from the equator to the poles. Temperature and precipitation act together as limiting factors to determine the type of desert, grassland, or forest biome in a region.

1. Explain how temperature and rainfall affect the distribution of biomes: ______________________

2. Explain why biomes are not evenly distributed about the globe: ______________________

3. Explain how the landscape can modify climate: ______________________

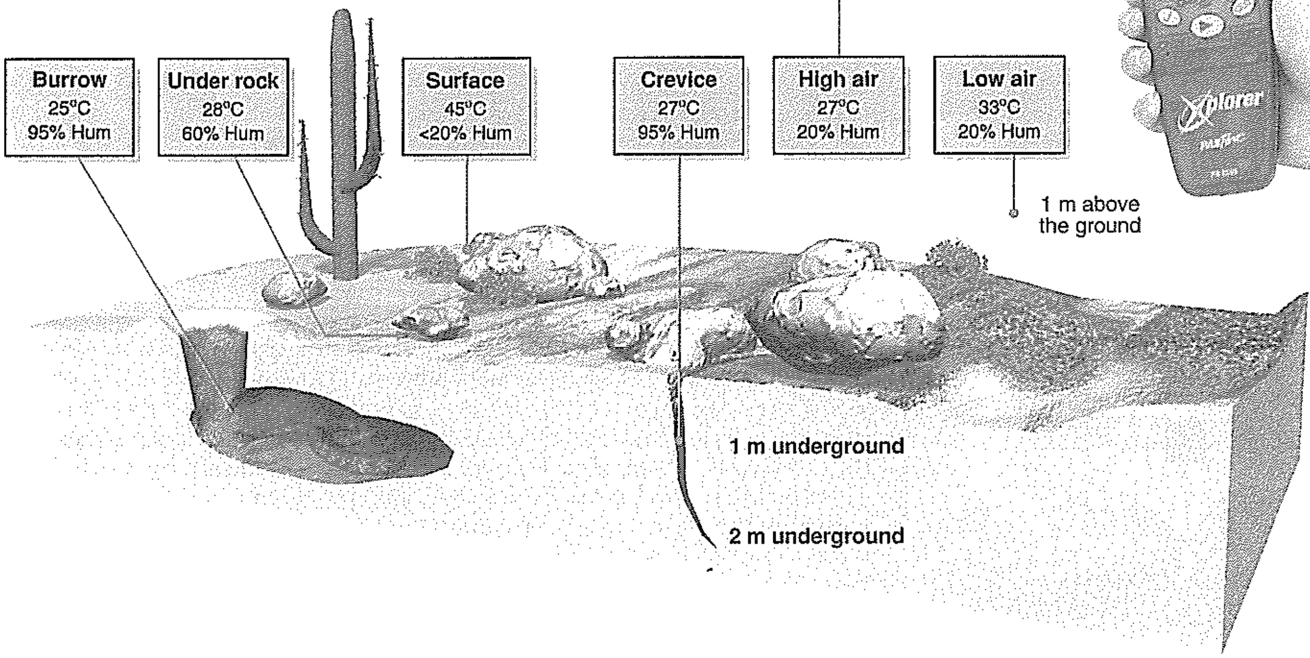
4. Explain why higher latitudes receive less solar energy than lower latitudes: ______________________

Physical Factors and Gradients

Gradients in abiotic factors are found in almost every environment; they influence habitats and microclimates, and determine patterns of species distribution. This activity, covering the next four pages, examines the physical gradients and microclimates that might typically be found in four, very different environments. Note that **dataloggers** (pictured right), are being increasingly used to gather such data. The principles of their use are covered in the topic *Investigating Ecosystems*.

A Desert Environment

Desert environments experience extremes in temperature and humidity, but they are not uniform with respect to these factors. This diagram illustrates hypothetical values for temperature and humidity for some of the microclimates found in a desert environment at midday.



1. Distinguish between **climate** and **microclimate**: ____________________

2. Study the diagram above and describe the general conditions where high humidity is found: ____________________

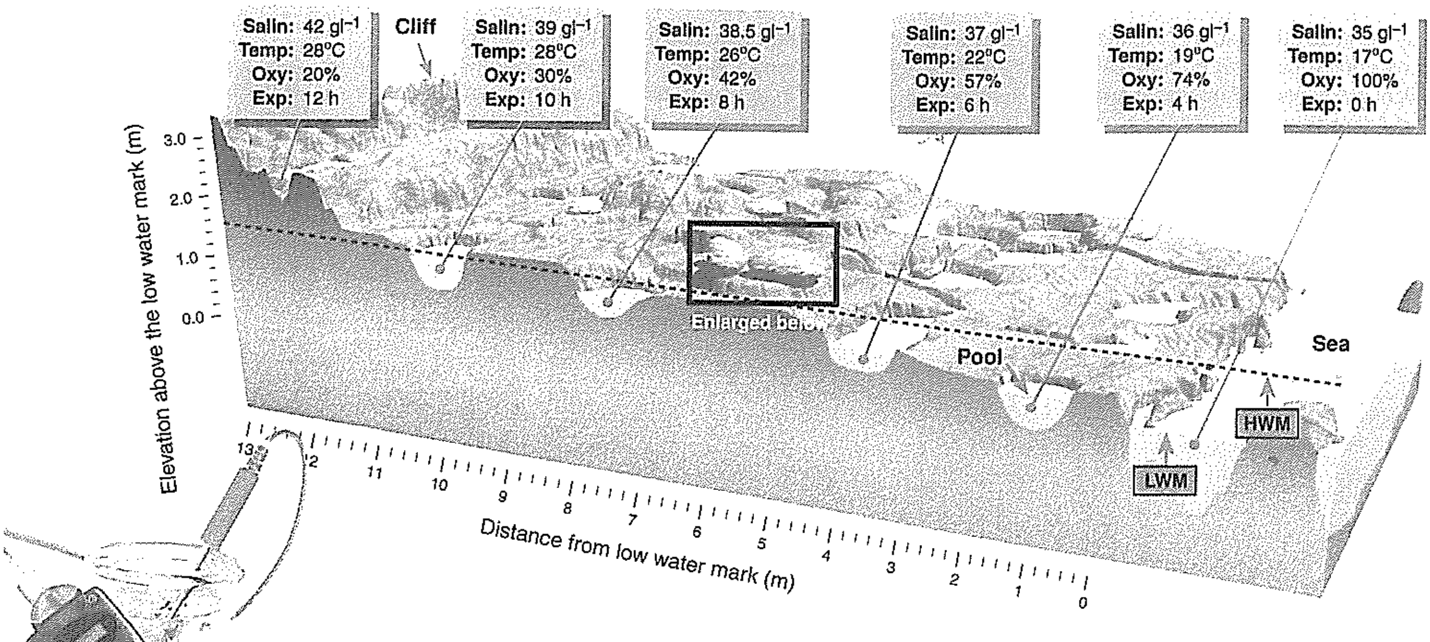
3. Identify the three microclimates that a land animal might exploit to avoid the extreme high temperatures of midday:

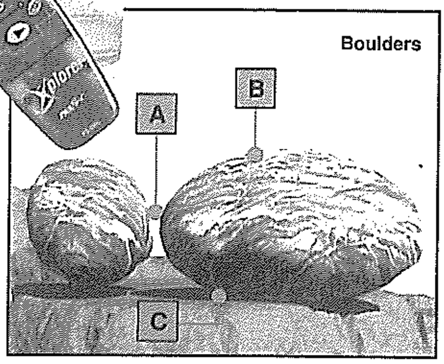
4. Describe the likely consequences for an animal that was unable to find a suitable microclimate to escape midday sun:

5. Describe the advantage of high humidity to the survival of most land animals: ____________________

6. Describe the likely changes to the temperature and relative humidity that occur during the night: ____________________

Physical Factors at Low Tide on a Rock Platform





The diagram above shows a profile of a rock platform at low tide. The **high water mark** (HWM) shown here is the average height the spring tide rises to. In reality, the high tide level will vary with the phases of the moon (i.e. spring tides and neap tides). The **low water mark** (LWM) is an average level subject to the same variations due to the lunar cycle. The rock pools vary in size, depth, and position on the platform. They are isolated at different elevations, trapping water from the ocean for time periods that may be brief or up to 10 – 12 hours duration. Pools near the HWM are exposed for longer periods of time than those near the LWM. The difference in exposure times results in some of the physical factors exhibiting a **gradient**; the factor's value gradually changes over distance. Physical factors sampled in the pools include salinity, or the amount of dissolved salts (g) per liter (**Salin**), temperature (**Temp**), dissolved oxygen compared to that of open ocean water (**Oxy**), and exposure, or the amount of time isolated from the ocean water (**Exp**).

7. Describe the environmental gradient (general trend) from the low water mark (LWM) to the high water mark (HWM) for:

   (a) Salinity: ______________________

   (b) Temperature: ______________________

   (c) Dissolved oxygen: ______________________

   (d) Exposure: ______________________

8. Rock pools above the normal high water mark (HWM), such as the uppermost pool in the diagram above, can have wide extremes of salinity. Explain the conditions under which these pools might have either:

   (a) Very low salinity: ______________________

   ____

   (b) Very high salinity: ______________________

   ____

9. (a) The inset diagram (above, left) is an enlarged view of two boulders on the rock platform. Describe how the physical factors listed below might differ at each of the labelled points **A**, **B**, and **C**:

   Mechanical force of wave action: ______________________

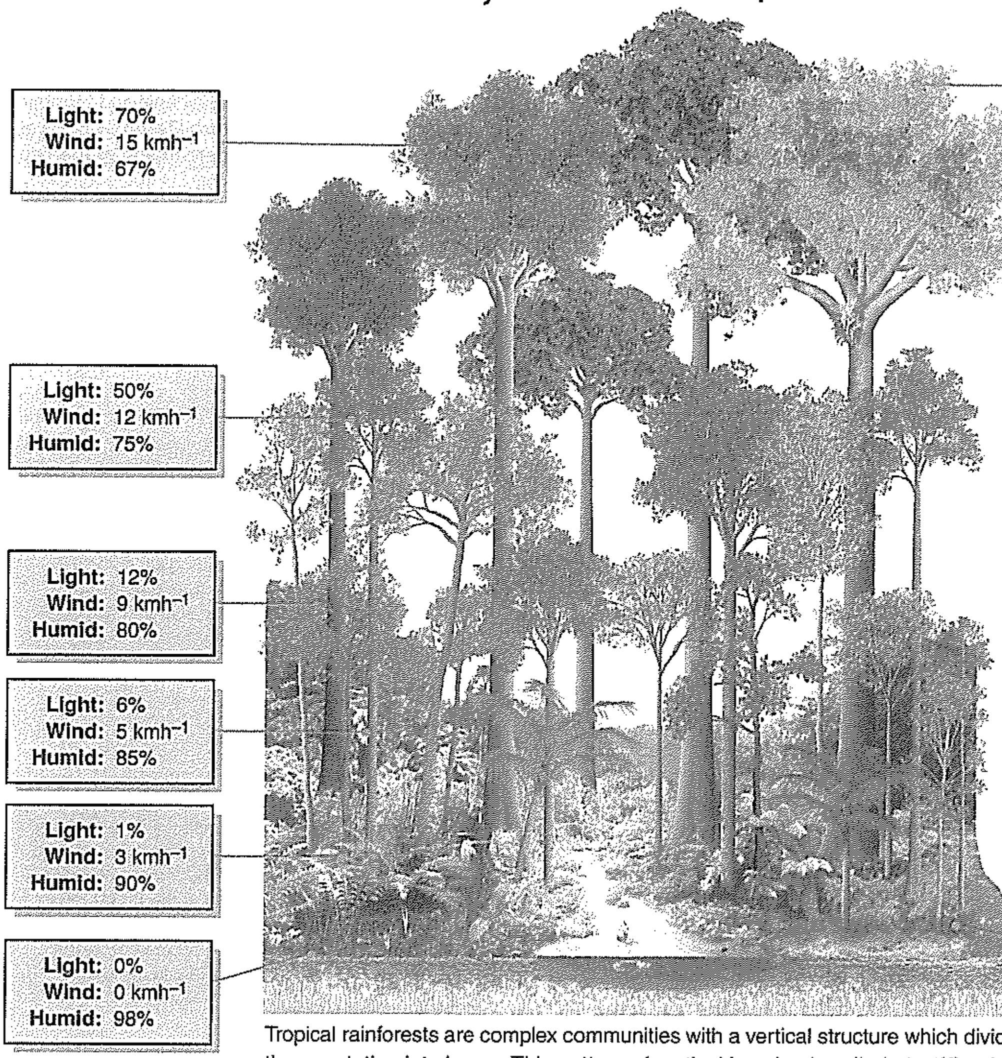
   ____

   Surface temperature when exposed: ______________________

   ____

   (b) State the term given to these localized variations in physical conditions: ______________________

Physical Factors in a Tropical Rainforest



A **datalogger** fitted with suitable probes was used to gather data on wind speed (**Wind**), humidity (**Humid**), and light intensity (**Light**) for each layer (left). Light intensity is given as a percentage of full sunlight.

Tropical rainforests are complex communities with a vertical structure which divides the vegetation into layers. This pattern of vertical layering is called **stratification**.

10. Describe the environmental gradient (general trend) from the canopy to the leaf litter for:

(a) Light intensity: ______

(b) Wind speed: ______

(c) Humidity: ______

11. Explain why each of these factors changes as the distance from the canopy increases:

(a) Light intensity: ______

(b) Wind speed: ______

(c) Humidity: ______

12. Apart from the light intensity, describe the other feature of light that will change with distance from the canopy:

______

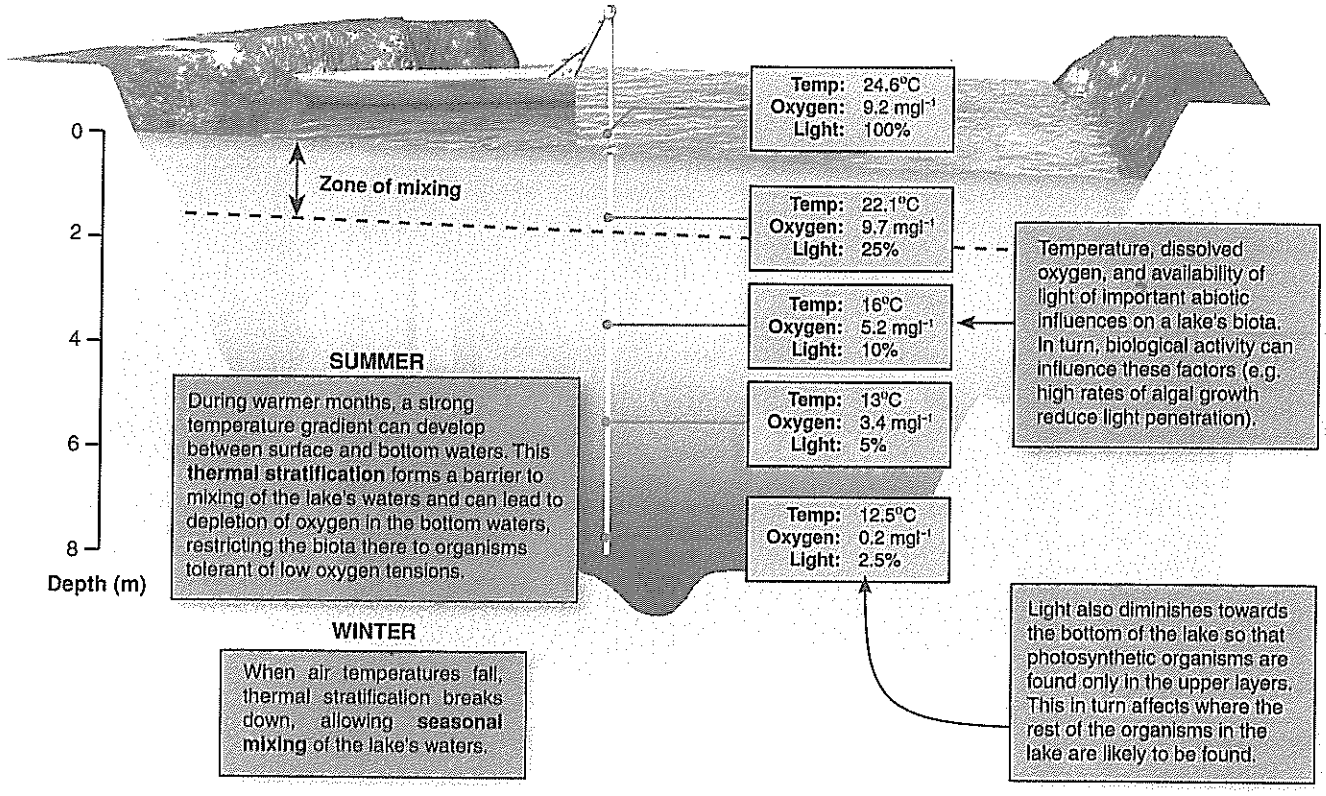
13. Plants growing on the forest floor have some advantages and disadvantages with respect to the physical factors.

(a) Describe one advantage: ______

(b) Describe one disadvantage: ______

Physical Factors in an Oxbow Lake in Summer

Oxbow lakes are formed from old river meanders which have been cut off and become isolated from the main channel following a change of the river's course. They are shallow (about 2-9 m deep) but often deep enough to develop temporary, but relatively stable, temperature gradients from top to bottom (below). Oxbows are commonly very productive and this can influence values for abiotic factors such as dissolved oxygen and light penetration, which can vary widely both with depth and proximity to the shore. Typical values for water temperature (**Temp**), dissolved oxygen (**Oxygen**), and light penetration as a percentage of the light striking the surface (**Light**) are indicated below.



14. With respect to the diagram above, describe the environmental gradient (general trend) from surface to lake bottom for:

(a) Water temperature: ______

(b) Dissolved oxygen: ______

(c) Light penetration: ______

15. During the summer months, the warm surface waters are mixed by gentle wind action. Deeper cool waters are isolated from this surface water. This sudden change in the temperature profile is called a **thermocline** which itself is a further barrier to the mixing of shallow and deeper water.

(a) Explain the effect of the thermocline on the dissolved oxygen at the bottom of the lake: ______

(b) Explain what causes the oxygen level to drop to the low level: ______

16. Many of these shallow lakes can undergo great changes in their salinity (sodium, magnesium, and calcium chlorides):

(a) Name an event that could suddenly reduce the salinity of a small lake: ______

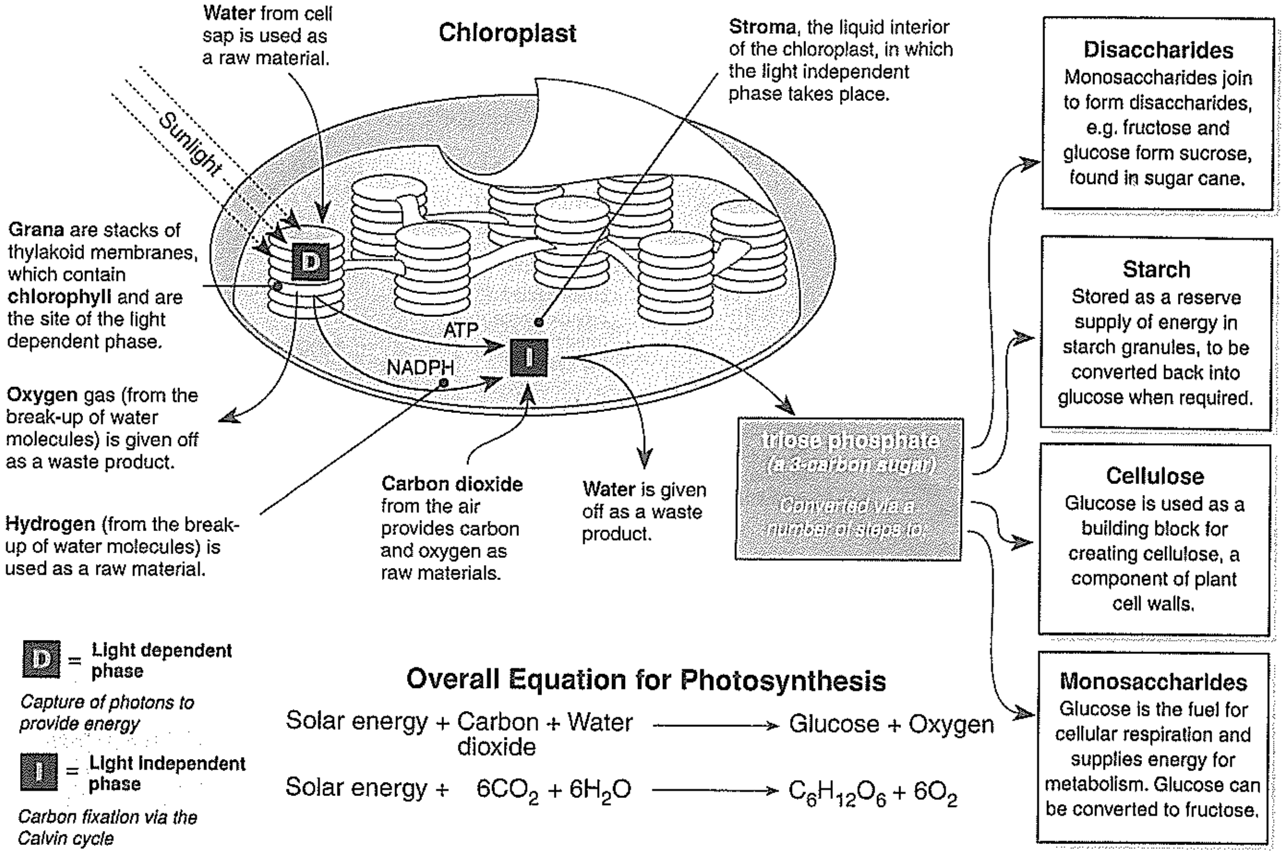
(b) Name a process that can gradually increase the salinity of a small lake: ______

17. Describe the general effect of physical gradients on the distribution of organisms in habitats: ______

Photosynthesis

Photosynthesis is of fundamental importance to living things because it transforms sunlight energy into chemical energy stored in molecules, releases free oxygen gas, and absorbs carbon dioxide (a waste product of cellular metabolism). Photosynthetic organisms use special pigments, called **chlorophylls**, to capture light energy by absorbing light of specific wavelengths. Visible light is a small fraction of the electromagnetic radiation reaching Earth from the Sun. Of this only wavelengths corresponding to red and blue are absorbed for photosynthesis. Other wavelengths, particularly green, are reflected or transmitted. Photosynthesis plays an important role in the cycling of carbon and oxygen, producing the oxygen used and removing the carbon dioxide produced during respiration of living organisms. It also helps fix carbon that may be buried and removed temporarily from the cycle.

Summary of Photosynthesis in a C_3 Plant



Overall Equation for Photosynthesis

Solar energy + Carbon dioxide + Water ⟶ Glucose + Oxygen

$$\text{Solar energy} + 6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

1. Explain why photosynthesis is so important for life on Earth: ____________________

____

____

____

2. Explain why plant leaves appear green: ____________________

____

3. Describe how plants use some of the end products of photosynthesis: ____________________

____

____

____

4. Describe how the following molecules are used or produced during photosynthesis:

(a) Oxygen: ____________________

____

(b) Carbon dioxide: ____________________

____

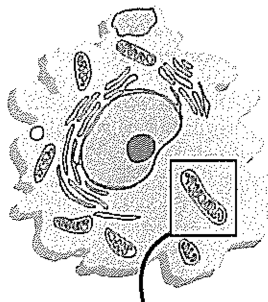
Cellular Respiration

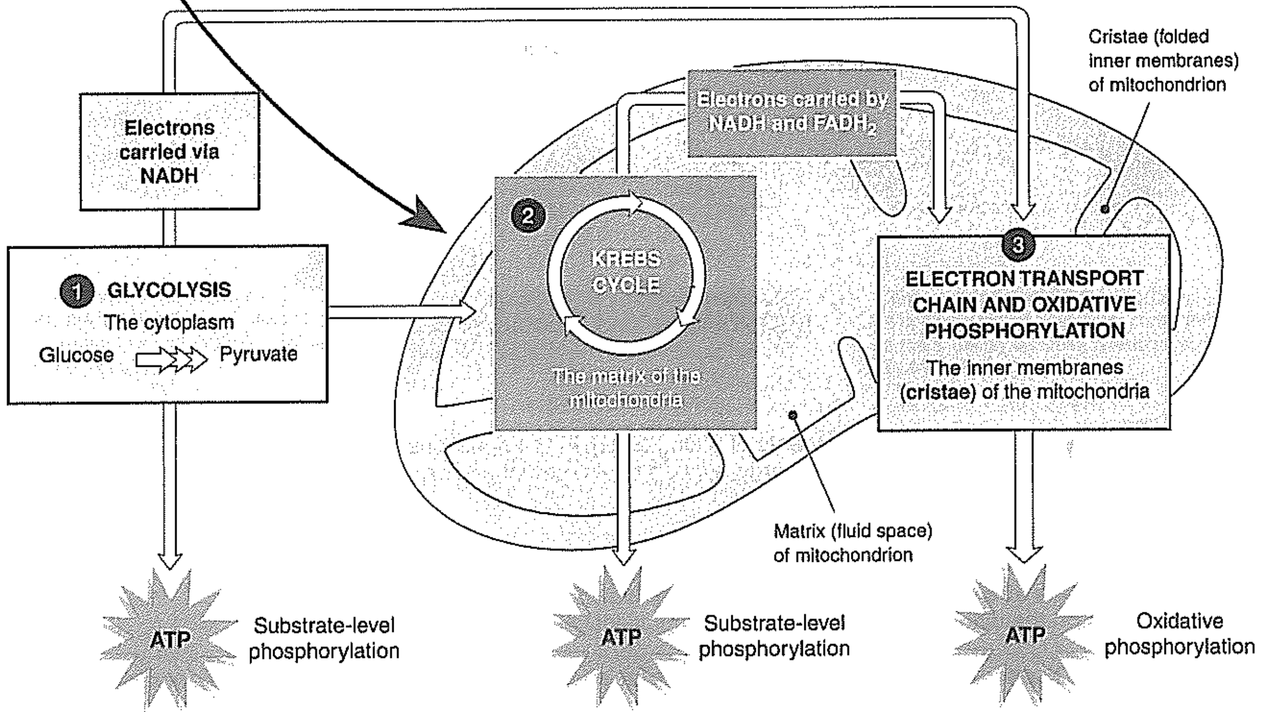
Cellular respiration is the process by which organisms break down energy rich molecules (e.g. glucose) to release the energy in a usable form (ATP). All living cells respire in order to exist, although the substrates they use may vary. **Aerobic respiration** requires oxygen. Forms of cellular respiration that do not require oxygen are said to be **anaerobic**. Some plants and animals can generate ATP anaerobically for short periods of time. Other organisms use only anaerobic respiration and live in oxygen-free environments. For these organisms, there is some other final electron acceptor other than oxygen (e.g. nitrate or Fe^{2+}). Respiration plays a part in the cycling of carbon by adding it to oxygen and releasing it to the atmosphere as carbon dioxide.

An Overview of Cellular Respiration

Respiration involves three metabolic stages. The first two stages decompose glucose and other organic fuels. In the third stage, the electron transport chain accepts electrons from the first two stages and passes these from one electron acceptor to another. The energy released at each stepwise transfer is used to make ATP. The final electron acceptor in this process is molecular oxygen.

1. **Glycolysis.** This occurs in the cytoplasm and involves the breakdown of glucose into two molecules of pyruvate.
2. **The Krebs cycle.** This occurs in the mitochondrial matrix, and decomposes a derivative of pyruvate to carbon dioxide.
3. **Electron transport and oxidative phosphorylation.** This occurs in the inner membranes of the mitochondrion and accounts for almost 90% of the ATP generated by respiration.





Overall Equation for Respiration:

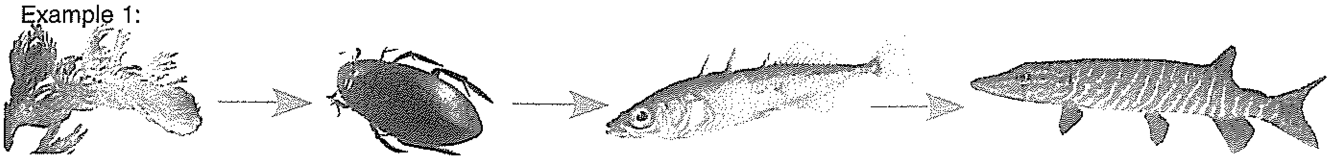
Glucose + Oxygen ⟶ Carbon dioxide + Water + Energy

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{Energy}$$

1. Describe precisely in which part of the cell the following take place:
   (a) Glycolysis: ______
   (b) Krebs cycle reactions: ______
   (c) Electron transport chain: ______
2. (a) Name the usable end product of cellular respiration: ______
   (b) Explain the importance of this molecule: ______

1. From the information provided for the lake food web components on the previous page, construct **ten** different **food chains** (using their names only) to show the feeding relationships between the organisms. Some food chains may be shorter than others and most species will appear in more than one food chain. An example has been completed for you.

Example 1:



(a) ______________________________

(b) ______________________________

(c) ______________________________

(d) ______________________________

(e) ______________________________

(f) ______________________________

(g) ______________________________

(h) ______________________________

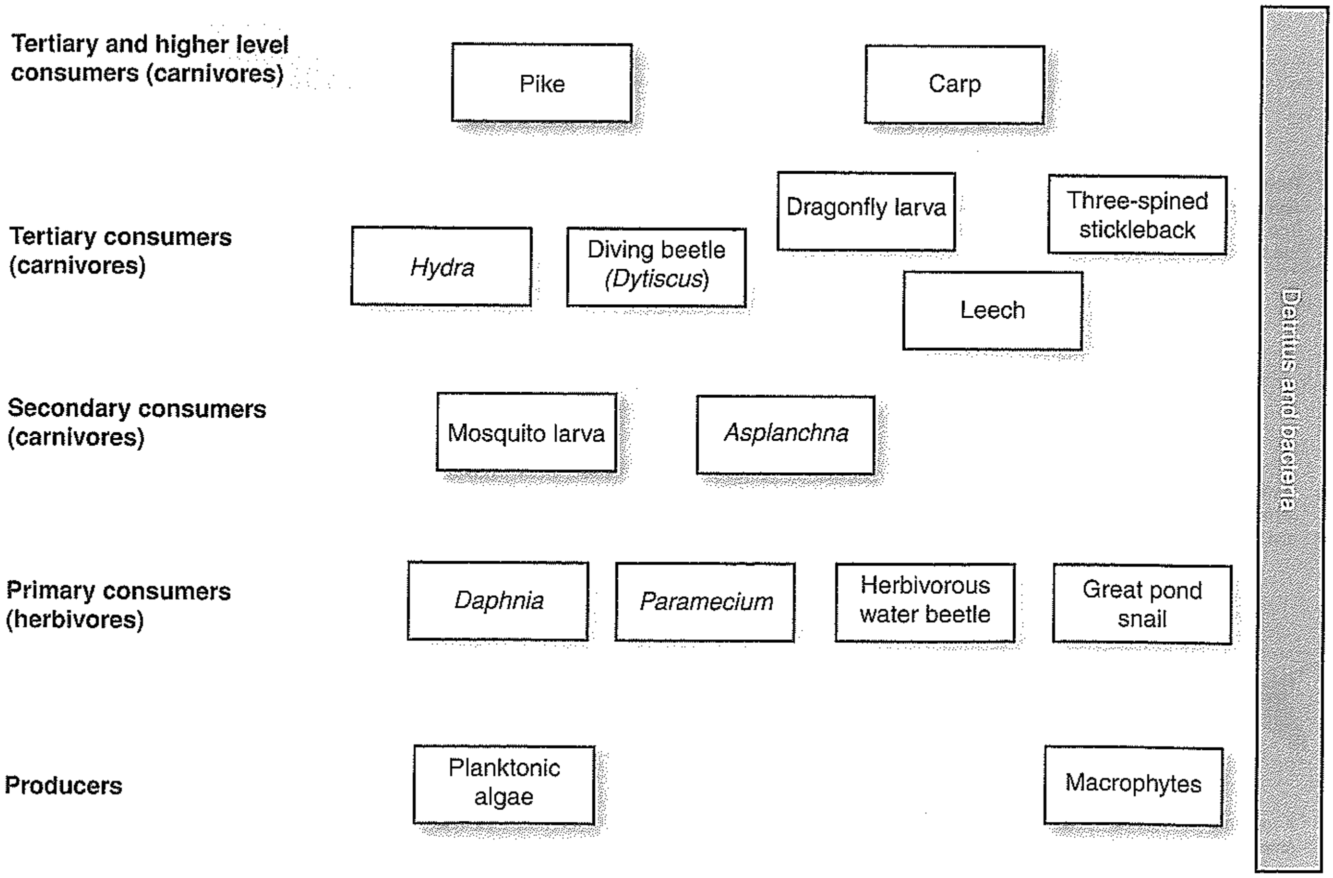
(i) ______________________________

(j) ______________________________

2. (a) Use the food chains that you have created above to help you to draw up a complete **food web** for this community. Use only the supplied information to draw arrows showing the flow of **energy** between species. (NOTE: Only energy **from** (not to) the detritus is required)

   (b) Label each species with the following codes to indicate its trophic level and status: Indicate:
   - Diet type: **P** = Producer, **H** = Herbivore, **C** = Carnivore, **O** = Omnivore (Note: based on the information given).
   - Position in the food chain as a consumer (1st, 2nd, 3rd, 4th order consumer): **1–4** (does not include producers).

   Example: Mosquito larva is **C2**



Primary Productivity

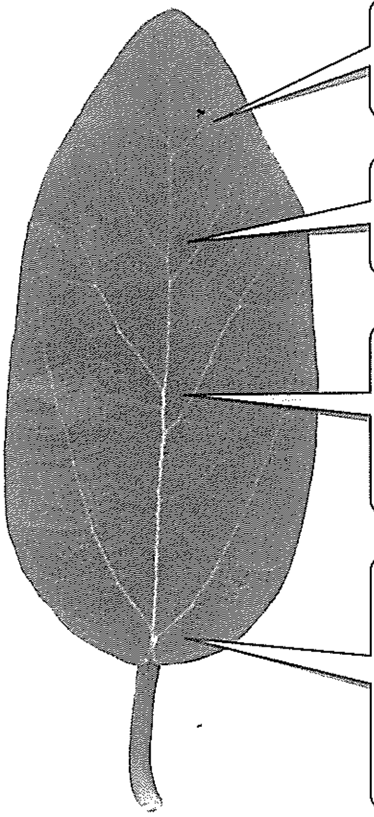
The energy entering ecosystems is fixed by producers in photosynthesis. The rate of photosynthesis is dependent on factors such as temperature and the amount of light, water, and nutrients. The total energy fixed by a plant through photosynthesis is referred to as the **gross primary production** (**GPP**) and is usually expressed as Jm^{-2} (or kJm^{-2}), or as gm^{-2}. However, a portion of this energy is required by the plant for respiration. Subtracting respiration from GPP gives the **net primary production (NPP)**. The **rate** of biomass production, or **net primary productivity**, is the biomass produced per area per unit time.

Measuring Productivity

Primary productivity of an ecosystem depends on a number of interrelated factors (light intensity, nutrients, temperature, water, and mineral supplies), making its calculation extremely difficult. Globally, the least productive ecosystems are those that are limited by heat energy and water. The most productive ecosystems are systems with high temperatures, plenty of water, and non-limiting supplies of soil nitrogen. The primary productivity of oceans is lower than that of terrestrial ecosystems because the water reflects (or absorbs) much of the light energy before it reaches and is utilized by producers. The table below compares the difference in the net primary productivity of various ecosystems.

Ecosystem Type	Net Primary Productivity $kcal\ m^{-2}\ y^{-1}$	$kJ\ m^{-2}\ y^{-1}$
Tropical rainforest	15 000	63 000
Swamps and marshes	12 000	50 400
Estuaries	9000	37 800
Savanna	3000	12 600
Temperate forest	6000	25 200
Boreal forest	3500	14 700
Temperate grassland	2000	8400
Tundra/cold desert	500	2100
Coastal marine	2500	10 500
Open ocean	800	3360
Desert	< 200	< 840

* *Data compiled from a variety of sources.*



Leaf Area Index (LAI)

Leaf area index is a measure of the total leaf area of a given plant.

Harvestable Dry Biomass

Used for commercial purposes, it is the dry mass of crop available for sale or use.

Relative Growth Rate (R)

Relative growth rate is the gain in mass of plant tissue per unit time.

$$R = \frac{\text{Increase in dry mass in unit time}}{\text{Original dry mass of the plant}}$$

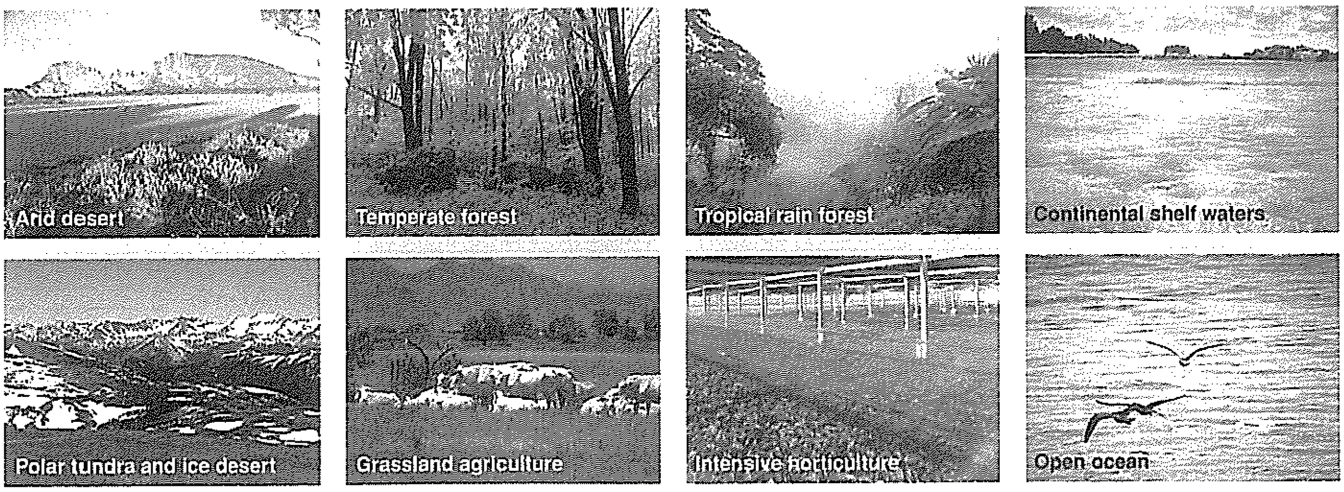
Net Assimilation Rate (NAR)

NAR is the increase in plant weight per unit of leaf area per unit time. Essentially it is the balance between carbon gain from photosynthesis and carbon loss from respiration.

$$NAR = \frac{\text{Increase in dry mass in unit time}}{\text{Leaf area}}$$

Net Primary Productivity of Selected Ecosystems (figures are in $kJ\ m^{-2}\ y^{-1}$)

< 2500 | < 12 500 – 42 000 | < 42 000 – 105 000 | 2500 – 42 000



1. Briefly describe three factors that may affect the primary productivity of an ecosystem:

(a) ______________________

(b) ______________________

(c) ______________________

2. Explain the difference between **productivity** and **production** in relation to plants: ______________________

____

____

3. Suggest how the LAI might influence the rate of primary production:

4. Using the data table on the previous page, choose a suitable graph format and plot the differences in the net primary productivity of various ecosystems (use either of the data columns provided, but not both). Use the grid provided, right. Include a title and axes.

5. With reference to the graph:

(a) Suggest why tropical rainforests are among the most productive terrestrial ecosystems, while tundra and desert ecosystems are among the least productive:

(b) Suggest why, amongst aquatic ecosystems, the NPP of the open ocean is low relative to that of coastal systems:

6. Estimating the NPP is relatively simple: all the plant material (including root material) from a measured area (e.g. 1 m^2) is collected and dried (at 105°C) until it reaches a constant mass. This mass, called the **standing crop**, is recorded (in kg m^{-2}). The procedure is repeated after some set time period (e.g. 1 month). The difference between the two calculated masses represents the *estimated* NPP:

(a) Explain why the plant material was dried before weighing:

(b) Define the term **standing crop**:

(c) Suggest why this procedure only provides an estimate of NPP:

(d) State what extra information would be required in order to express the standing crop value in kJ m^{-2}:

(e) Suggest what information would be required in order to calculate the GPP:

7. Intensive horticultural systems achieve very high rates of production (about 10X those of subsistence systems).

(a) Outline the means by which these high rates are achieved:

(b) Comment on the sustainability of these high rates (summary of a group discussion if you wish):