**An overview about Insect Physiology & Ecology**

**Insect Physiology:**

**Physiology:** Physiology is the branch of the biological sciences dealing with the functioning of organisms.

**Physiology:** The scientific study of an organism's vital functions, including growth and development, the absorption and processing of nutrients, the synthesis and distribution of proteins and other organic molecules, and the functioning of different tissues, organs, and other anatomic structures.

**Physiology**: studies the normal mechanical, physical, and biochemical processes of animals and plants.

**Physiology**: The biological study of the functions of living organisms and their parts.

**Physiology**: All the functions of a living organism or any of its parts.

**Insect physiology:** It includes the [physiology](http://en.wikipedia.org/wiki/Physiology) and [biochemistry](http://en.wikipedia.org/wiki/Biochemistry) of [insect](http://en.wikipedia.org/wiki/Insect) [organ systems](http://en.wikipedia.org/wiki/Organ_system).Although diverse, insects are quite similar in overall design, internally and externally. The [insect](http://en.wikipedia.org/wiki/Insect) is made up of three main body regions (tagmata), the head, thorax and abdomen. The head comprises six fused segments with [compound eyes](http://en.wikipedia.org/wiki/Compound_eyes), [ocelli](http://en.wikipedia.org/wiki/Ocelli), [antennae](http://en.wikipedia.org/wiki/Antenna_(biology)) and mouthparts, which differ according to the insect’s particular diet, e.g. grinding, sucking, lapping and chewing. The thorax is made up of three segments the pro, meso and meta thorax, each supporting a pair of legs which may also differ, depending on function, e.g. jumping, digging, swimming and running. Usually the middle and the last segment of the thorax have paired wings. The abdomen generally comprises eleven segments and contains the digestive and reproductive organs (McGavin, 2001).

**Insect Ecology**

**Definition:** As a term ecology appears to have first been used in latter half of 19th century**.** This term ecology is derived from the Greek word ‘Oikos’ means house and `logos’ means study. Thus literally Ecology is the study of organisms in home. Many authors and scientist has defined the term ecology in many ways but the most appropriate definition is given by Begdn, Harper and Townsend in 1986 as **“Ecology may be defined as the scientific study of the interaction between organisms and their environment”**

**The Ecology related to Insects’ life is called Insect Ecology.**

Since four ecological disciplines are closely related to ecology such as genetics, evolution, physiology and behavior.

**Ecology:**The science of the relationships between organisms and their environments. Also called *bionomics*.

**Ecology:**The relationship between organisms and their environment.

**Ecology:**The branch of sociology that is concerned with studying the relationships between human groups and their physical and social environments. Also called *human ecology*.

**Ecology:**The study of the detrimental effects of modern civilization on the environment, with a view toward prevention or reversal through conservation. Also called *human ecology*

**Ecology:**Ecology is concerned with patterns of distribution (where organisms occur) and with patterns of abundance (how many organisms occur) in space and time. It seeks to explain the factors that determine the range of environments that organisms occupy and that determine how abundant organisms are within those ranges. It also emphasizes functional interactions between co-occurring organisms. In addition to being a unique component of the biological sciences, ecology is both a synthetic and an integrative science since it often draws upon information and concepts in other sciences, ranging from physiology to meteorology, to explain the complex organization of nature.

**Environment:** is all of those factors external to an organism that affect its survival, growth, development, and reproduction. It can be subdivided into **physical or abiotic factors** and **biological or** [**biotic**](http://www.answers.com/topic/biotic) **factors**. The physical components of the environment include all non biological constituents, such as **temperature**, **wind**, [**inorganic**](http://www.answers.com/topic/inorganic) **chemicals** and **radiation**. The biological components of the environment include the **organisms**.

**Habitat :** A somewhat more general term is habitat, which refers in a general way to where an organism occurs and the environmental factors present there.

A recognition of the unitary coupling of an organism and its environment is fundamental to ecology; in fact, the definitions of organism and environment are not separate. Environment is organism-centered since the environmental properties of a habitat are determined by the requirements of the organisms that occupy that habitat. For example, the amount of inorganic nitrogen dissolved in lake water is of little immediate significance to zooplankton in the lake because they are [incapable](http://www.answers.com/topic/incapable) of utilizing inorganic nitrogen directly. However, because [**Phytoplankton**](http://www.answers.com/topic/phytoplankton) are capable of utilizing inorganic nitrogen directly, it is a component of their environment. Any effect of inorganic nitrogen upon the **Zooplankton**, then, will occur indirectly through its effect on the abundance of the phytoplankton that the zooplankton feed upon. Just as the environment affects the organism, so the organism affects its environment.

**Ecology** is concerned with the processes involved in the interactions between organisms and their environments, with the mechanisms responsible for those processes, and with the origin, through evolution, of those mechanisms.

**Major subdivisions of ecology** by organism include:

**Plant ecology**, **Animal ecology**, and [**Microbial ecology**](http://www.answers.com/topic/microbial-ecology)**, Terrestrial ecology**, the study of organisms on land;[**Limnology**](http://www.answers.com/topic/limnology)**,** the study of fresh-water organisms and habitats; and [**Oceanography**](http://www.answers.com/topic/oceanography)**,** the study of marine organisms and habitats. **Autecology** is the study of individuals, **Population ecology** is the study of groups of individuals of a single species or a limited number of species, [**Synecology**](http://www.answers.com/topic/synecology) is the study of communities of several populations, and [**Ecosystem**](http://www.answers.com/topic/ecosystems-1) or **Simply systems ecology** is the study of communities of organisms and their environments in a specific time and place. Higher levels of organization include **Biomes** and the **[Biosphere](http://www.answers.com/topic/biosphere" \t "_top).** **Biomes** are collections of ecosystems with similar organisms and environments and, therefore, similar ecological properties. All of Earth's coniferous forests are elements in the coniferous forest biome. Although united by similar dynamic relationships and structural properties, the biome itself is more abstract than a specific ecosystem. The **Biosphere** is the most inclusive category possible, including all regions of Earth inhabited by living things. It extends from the lower reaches of the atmosphere to the depths of the oceans.

**The principal methodological approaches to ecology are descriptive, experimental, and theoretical.**

**Descriptive ecology** concentrates on the variety of populations, communities, and habitats throughout Earth.

**Experimental ecology** involves manipulating organisms or their environments to discover the underlying mechanisms governing distribution and abundance.

**Theoretical ecology** uses mathematical equations based on assumptions about the properties of organisms and environments to make predictions about patterns of distribution and abundance.

**The concept of ecology has always had three separate dimensions.**

**(1)** It refers the study of the system of interactions involving living things.

**(2)** But it is also used to refer to the system itself: the reality of causal relationships between species.

**(3)** Finally, ‘ecology’ has always been used by some people, though not generally by professional ecologists, as a whole.

**Digestive Systems of Insects & Nutrition**

Like all other living organisms, various foods of diversified forms are taken by insects, these foods are subsequently digested through a definite process and finally insects get nutrition.

The alimentary canal is the main organ of the digestive system. Usually the alimentary canal is the continuous tube running from the mouth to anus and the gut is supported in the body by muscles or by connective tissues.

The alimentary canal is divided into three main region:-

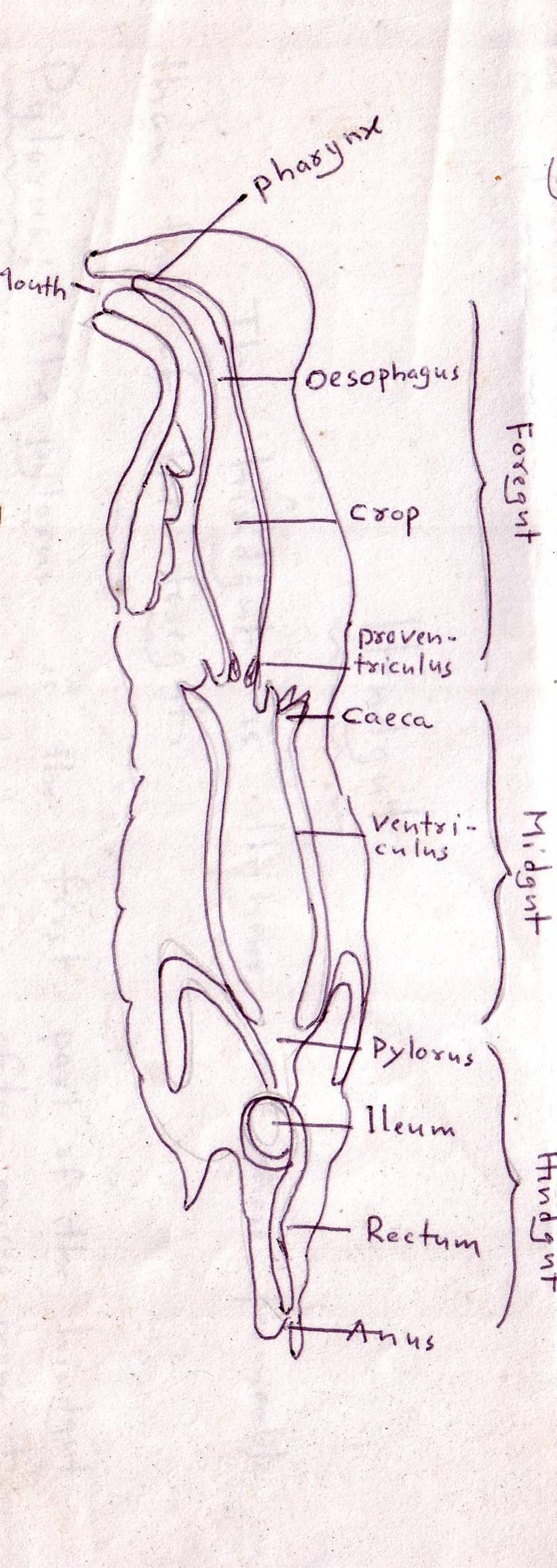
1. **Foregut or stomodoeum**
2. **Midgut or mesentron**
3. **Hindgut or proctodoeum**

In many insects these regions are sub divided into various functional parts such as: **Pharynx, Esophagus, Crop & Proventriculus in the foregut**

**Caeca and Ventriculus in the midgut**

**Pylorus,Ileum and Rectum in the hindgut**

Figure: Digestive system with other organs of a typical female Insect.

**A**- Head **B**- Thorax **C**- Abdomen; 1. Antenna 2. Ocelli ( lower) 3. Ocelli (upper) 4. Compound eye 5. Brain ( Cerebral ganglia) 6. Prothorax 7. Dorsal artery 8. Tracheal tubes ( trunk with spiracles) 9. Mesothorax 10. Metathorax 11. First wing 12. Second Wing 13. Midgut ( Stomach) 14. Heart 15. Ovary 16. Hindgut ( Intestine, Rectum & Anus) 17. Anus 18. Vagina 19. Nerve Chord (Abdominal ganglia) 20. Malpighian tubules 21. Pillow 22. Claws 23. Tarsus 24. Tibia 25. Femur 26. Trochanter 27. Fore gut (Crop, Gizzard) 28. Thoracic ganglion 29. Coxa 30. Salivary gland 31. Subesophageal ganglion 32. Mouthparts

**Foregut or stomodoeum**

**Pharynx:** This is the first part of the foregut posses food mouth to the Esophagus.

**Esophagus:** This is undifferentiated part of the foregut serving to pass food from **Pharynx** to the **Crop**

**Crop:** The crop is an enlargement of the foregut in which food is stored.

**Proventriculus:** This part is modified into different insects. Proventriculus as a whole controls the passage of food from the crop to the midgut.

**Midgut or mesentron**

Anatomically midgut is usually a simple tube undifferentiated except for the presence of 4, 6, or 9 caeca at the anterior end. In some **Diptera** the midgut is undifferentiated into an anterior cardiac chamber and a long ventriculus. The most characteristics midgut cells are tall and columnar contain extensive endoplasmic reticulum with ribosome concerned with the synthesis of digestive enzyme and with the absorption of the products of digestion.

**Hindgut or proctodoeum**

The hindgut is thinner and more permeable than that of the foregut.

**Pylorus:** The Pylorus is the first part of the hindgut and the malpighians tubules are often arises from it in some insects it forms a valve between the midgut and hindgut.

**Ileum:** In the most insects ileum is an undiffertiated tube running to the rectum and in some insects(e.g. termite) it forms a pouch of flagellates concerned with celluose digestion. In some insects (e.g.Heteroptera) it is concerned with the removal of water.

**Rectum:**The rectum is often enlarged sac and is thin walled. The rectum and in particular rectal pad are important in the reabsorption of water, salts and amino acids from the urine. In addition in some Aquatic insects, there are some tracheal gills in the rectum. The gills are constantly renewed and by the forcible ejection of water the insect is able to propel itself forwards rapidly.

**Nutrition**

The foods ingested and digested by the insects must fulfill its nutritional requirements for their normal growth and development. These requirements are complex and although most nutrition must be present in the diet but some may be obtained from other source. Some nutrition may be carried over from the earlier stage of development, other may be synthesized by the insects from different dietary constituents, some other may be supplied by micro organisms. A number of amino acids, carbohydrates and vitamins are essential for any development and other non essential nutrients are necessary for optimal development.

**Nutritional Requirements:**

Most insects have qualitatively similar nutritional requirements, since the basic chemical composition of their tissues and basic metabolic processes are generally similar.

**Specific Requirements:**

**Carbohydrate:** Carbohydrate serve as a source of energy and must be converted to fat for storage. They may also produce amino acids. But Carbohydrate are not always essential- they can be replaced by protein or fat. This depends on the abality of the insects to convert the protein of fats to immediate products suitable for energy transformation cycles.

**Amino Acids:** Amino acids are required for the production of structural proteins and enzymes. They are commonly present in the diet as protein. Protein or amino acids are always essential for developing insects and optimal growth requires a relatively high concentration. Although some 20 amino acids are needed for protein production, only 10 are essential in the diet: the others 10 are synthesized from these 10. The 10 essential amino acids are **(1) Arginine, (2) Lysine, (3) Leucine, (4) Iso-leucine, (5) Tryptophan, (6) Histidine, (7) Phenylalanine, (8) Methione, (9) Valine and (10) Threonine.**

**Fatty Acids:** Fats are the chief form in which energy is stored. Only small quantities of fat are present in the leaves so it would not normally form an important sources of energy of phytophagus insects. In some insects abnormal molting and wing formations are found due to lack of this components.

**Vitamins:** Vitamins are organic substances which are required in very small quantity since they can not be synthesized. The water soluble B vitamins thiamine, riboflavin, nicotinic acid, pyridoxine, and pantothenic acid are essential to most insects. In some insects some B vitamins are associated with micro organism. B carotene ( Provitamin A) is probably essential in the diet of all insects, since it is a component of visual pigment.

**Inorganic Salt:** Inorganic salt is essential as a dietary source of insects. It maintain the ionic balance between the living cells if the insects body. Essential inorganic salts are sodium, calcium, potassium, magnesium, chloride and phosphorus. known essential trace elements are iron, copper, iodine, manganese, cobalt, zinc and nickel.

**Circulatory System of Insects**

Insects have an open circulatory systems as because the blood directly goes to the body cavity or haemocoel. Blood is circulated mainly by the activity of a contractile longitudinal vessel which opens into the haemocoel.

**Dorsal vessel:** The dorsal vessel is the principal organ responsible for blood circulation. The dorsal vessel runs along the dorsal midline just below the terga. The dorsal vessel is divided into the major divisions which are;-

1. A posterior heart
2. An anterior aorta

Aorta

Heart

Ostia

Alary muscles

Figure: A typical dorsal Vessel of insect.

The heart is usually closed at its posterior end and bears a lot of valvular openings or ostia, which allows haemolymph to enter (incurrent ostia) or exit from(current ostia) from the heart. On either side of the heart there are a segmented arrangement called alary muscles or `wing’. The heart may be extended into the thorax but generally it is confined to the abdomen. The aorta extends anteriorly from the heart and opens behind or beneath the brain. In addition to the pumping activities of the heart, various accessory pulsatile structures help the movement of haemolymph. These pulsatile structures are found at the base of the antennae, at the base and within the legs and wings and within the meso and metathorax.

**Circulation of the Blood:** The heart is the principal pulsatory organ and undergoes rhythmical contraction by the muscles fibrilliae of its wall. The frequency and amplitude of the heart beat are influenced by nervous stimuli. During diastole the blood enters into the heart by the incurrent ostia and during systolic pressure blood leaves the heart by the excurrent ostia and goes to the various organs through a definite process.

**Circulation in the appendages:**

**Antennae:** Orthoptera and probably many other insects have a small ampulla ( sac like structure) at the base of each antenna. This communicates the haemocoel by the valved opening and extends into antennae through a vessel.

**Wings:** Normally blood passes out along the anterior veins subsequently to the posterior veins by cross veins. In absence of the wing circulation, the wing structure become dry and brittle.

**Legs:** In some insects ( some Odonata , many Diptera) have independent pumps force blood into the legs.

**Haemolymph:**

The blood or Haemolymph circulates round the body cavity between various organs. It consists of a fluid plasma with blood cells or haemocytes. Insect blood is usually colorless sometimes it is yellowish and green in color due to the presence of some pigments. Some exception are the red haemolymph of some midges (Diptera) larvae, certain species of the backswimmers (Hemiptera) and Horse fly (Diptera) all of which contain pigment hemoglobin.

**Chemical Composition of Blood:**

**Water:** Water is the major component of insect blood. About 90% of the insect blood is water.

**Inorganic constitutes:** Chloride is the most abundant inorganic anion in the insect blood. Sodium is also abundant. Various metallic trace elements are also found in insect blood. The most frequent are Potassium, Magnesium, Copper, Zinc, Iron, Manganese etc.

**Organic constitutes: I**nsect blood is characterized by the high level of amino acids present in the plasma constituting 33-65% of non-protein N2. The concentration of amino acids may changes at different stages of life cycle.

**Types of Haemocytes:** Many different types of haemocytes have been described but a comprehensive classification is difficult because individual cell can have very different appearances under different condition. However, Jones (1962,1964) recognizes 4 main types of cell which have been distinguished in most of the insect studied:

1. **Prohaemocytes:** are small rounded cells with relatively large nuclei.
2. **Plasmocytes:** are frequently the most abundant cell type. They are variable in forms.
3. **Granular haemocytes:** are characterized by the acidophilic granules which are seen to be membrane bounded in the electron microscope.
4. **Cystocytes(Coagulocytes):** When viewed with the phase contrast microscope have a small and sharply defined nucleus. In addition there are other types of cell which only occur in certain insects.

**Functions of Haemocytes:**

**Phagocytosis:** An important functions of haemocytes is phagocytosis of foreign particles and microorganisms (Protozoa, Fungi, Bacteria etc)

**Encapsulation:** Particles such as metazoan parasites which are too large to phagocytose are encapsulated by large numbers of haemocytes

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**Secretation and metabolism:** Some haemocytes may be involved in the formation of the fat body and are concerned in the intermediate metabolism.

**Wound healing:** damaged tissues are phagocytosed and thus concerned with the wound healing.

**Insect Excretory System**

Excretory system is involved in the maintenance of a constant level of salts, water and osmotic pressure in the haemolymph and the elimination of toxic nitrogenous wastes derived from protein and metabolism and other toxic compounds which may be observed from food.

**Excretory Organ:** The typical insects excretory system consist of the malpighian tubules intestine and rectum.

**Malpighian Tubules:** Malpighion tubules are long, thin blindly ending tubes arising from the gut near junction of midgut and hindgut and lying freely in the body cavity.

Malpighian tubules are absent from collembola and aphids and represented only by papillae in the Diptera, Protura and Strepsiptera but they are present in all other insects varying in number ranging from 2 to 250.

**Nephrocytes:** Nephrocytes are cells which take up foreign chemicals of relatively high molecular weight which malpighian tubules may be incapable of dealing with. They take up dyes and colloidal proteins but not bacteria. In larval Odonata they are scattered throughout the fat body.

**Excretory Products:** Ammonia is the primary product of N2 metabolism but it is highly toxic except extreme dilutions.

For most terrestrial insects water conservation is essential and loss of water must be maintained to a optimal level because it is necessary to produce a less toxic substances.

The excretory product Uric acid is relatively harmless and in soluble. As a result it tends to crystallize out of solution and can be retained as a solid. Uric acid is often present as free acid. Most of the insects excrete 80-90 % of their waste N2as uric acid.

Apart from these, other nitrogenous containing substances are sometimes present in the excreta. Thus in Glossina (Diptera) arginine and histidine from the blood of the host are excreted. These substances are highly nitrogenous content which would require a considerable expenditure of energy if they were to be metabolized through the normal pathway

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**Excretion from the Malpighian Tubules:** The products of nitrogenous excretion are eliminated from haemolymph viaMalpighian Tubules. The rate of movement depends on the size of the particles. As a result urea passes more rapidly than uric acid.

**Storage Excretion:** Waste materials may be retained in the body in a harmless form; this is known as storage of deposit secretion. It is observed in Collembola which lack inMalpighian Tubules . Although *Periplanata* hasMalpighian Tubules, but they are not involved in the secretion of uric acid; instead this accumulates in the fat body.

**Excretion of ingested organic molecules:** In the course of feeding insects may ingest potentially toxic materials and some of these may be observed. This may involved chemical detoxification or excretion. The way in which the insect excretes them depend on the molecular size. Large molecule and colloidal particle are ingested by nephrocytes in which they may be metabolized. Other smaller molecules may be actively secreted by the Malpighian Tubules.

**Water Regulation:** The water content of insects varies from about 50-90% of the body weight. Reduction of water content from the living tissues leads to death. For instance *Rhodnius* and *Tenebrio* may die when their water content of the body falls from 75-60 %. Water content of the insect body varies according to their habitat.

**Terrestrial Insects:** Terrestrial Insects lose water by evaporation from the general body surface, the respiratory body surface as well as in the urine. If they are to survive they must kept their water losses to a optimal level.

The rate of evaporation of water from the insect cuticle at a constant temperature is proportional to the saturation of surrounding environmental air and water content. Water losses also restricted by the lipid of the epicuticle.

The permeable respiratory surface of insects are the potential sources of water loss. The loss of water from this surface may be reduced by the invagination of respiratory system. The loss of water from the spiracles may be lower in comparison the loss through the cuticle when the insect is at rest; but it is higher when the insect is actively ventilating the tracheal system.

The major losses of water from insects body through urine and faeces. The amount of water loss from the insect body depends on the rate of secretion by the malpighian tubules and also the extent of reabsorption in the rectum. By regulating the activity of these two processes the insect is able to maintain its water balance at an appropriate level. Insects living in very dry environment such as *Tenebrio* larvae can reduce the water content of the faeces to about 15%.

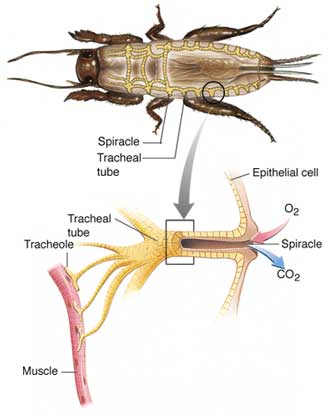
Water balance is the net result of various gains and losses experienced by the insect. A net gain is necessary for normal growth and development; a net loss will lead to death. The balance will vary with the quantity of food, the environmental conditions and physiological capabilities of insects.

**Fresh Water Insects:** The insects living in the fresh water, the problem of salt and water regulation are quite different from the terrestrial insects. Since the haemolymph is hypertonic to the water, there is a tendency for water to pass into the insect through the cuticle.

**Malpighian tubules others functions:** The malpighian tubules of larval *Chrysopa* (Neuroptera) become thickened distally and the neuclei of the cells become branched after the second instar. These region produce silk which is used to form the pupal cocoon. Chrysomelid beetles produce a sticky substances in the malpighian tubules for covering the eggs. In the larva of the fly Bolitophila luminosa the enlarged distal ends of the malpighian tubules for luminous organ.

**Respiratory System of Insects**

Insects require oxygen just as we do, and must "exhale" carbon dioxide, a waste product of cellular respiration. Oxygen is delivered to the cells directly through respiration, and not carried by blood as in vertebrates.



Along the sides of the thorax and abdomen, a row of small openings called spiracles allow the intake of oxygen from the air. Most insects have one pair of spiracles per body segment. Small flaps or valves keep the spiracle closed until there is a need for oxygen uptake and carbon dioxide discharge. When the muscles controlling the valves relax, the valves open and the insect takes a breath.

All insects are aerobic organisms they must obtain oxygen ( O2 ) from their environment in order to survive.   They use the same metabolic reactions as other animals ( glycolysis, Kreb's cycle, and the electron transport system ) to convert nutrients (e. g . sugars ) into the chemical bond energy of A T P.   During the final step of this process , oxygen atoms react with hydrogen ions to produce water , releasing energy that is captured in a phosphate bond of ATP.

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| hemo2a The respiratory system is responsible for delivering sufficient oxygen to all cells of the body and for removing carbon dioxide (CO2) that is produced as a waste product of cellular respiration.   The respiratory system of insects trachea(and many other arthropods) is separate from the circulatory system.   It is a complex network of tubes (called a **tracheal system**) that delivers oxygen-containing air to every cell of the body.  Air enters the insect's body through valve-like openings in the exoskeleton.   These openings (called [spiracles](http://www.cals.ncsu.edu/course/ent425/tutorial/respire.html#1#1)) are located laterally along the thorax and abdomen of most insects -- usually one pair of spiracles per body segment.   Air flow is regulated by small muscles that operate one or two flap-like valves within each spiracle -- contracting to close the spiracle, or relaxing to open it.  After passing through a spiracle, air enters a longitudinal [tracheal trunk](http://www.cals.ncsu.edu/course/ent425/tutorial/respire.html#1#1), eventually diffusing throughout a complex, branching network of [tracheal tubes](http://www.cals.ncsu.edu/course/ent425/tutorial/respire.html#1#1) that subdivides into smaller and smaller diameters and reaches every part of the body.   At the end of each tracheal branch, a special cell (the **tracheole**) provides a thin, moist interface for the exchange of gasses between atmospheric air and a living cell.   Oxygen in the tracheal tube first dissolves in the liquid of the tracheole and then diffuses into the cytoplasm of an adjacent cell.   At the same time, carbon dioxide, produced as a waste product of cellular respiration, diffuses out of the cell and, eventually, out of the body through the tracheal system.  Each tracheal tube develops as an invagination of the ectoderm during embryonic development.   To prevent its collapse under pressure, a thin, reinforcing "wire" of cuticle ( the [taenidia](http://www.cals.ncsu.edu/course/ent425/tutorial/respire.html#1#1)) winds spirally through the membranous wall.   This design ( x-sect2similar in structure to a heater hose on an automobile or an exhaust duct on a clothes dryer ) gives tracheal tubes the ability to flex and stretch without developing kinks that might restrict air flow.  The absence of taenidia in certain parts of the tracheal system allows the formation of collapsible [air sacs](http://www.cals.ncsu.edu/course/ent425/tutorial/respire.html#1#1), balloon-like structures that may store a reserve of air.   In dry terrestrial environments, this temporary air supply allows an insect to conserve water by closing its spiracles during periods of high evaporative stress.   Aquatic insects consume the stored air while under water or use it to regulate buoyancy.   During a molt, air sacs fill and enlarge as the insect breaks free of the old exoskeleton and expands a new one.   Between molts, the air sacs provide room for new growth -- shrinking in volume as they are compressed by expansion of internal organs.  Small insects rely almost exclusively on passive diffusion and physical activity for the movement of gasses within the tracheal system.   However, larger insects may require active **ventilation** of the tracheal system (especially when active or under heat stress).   They accomplish this by opening some spiracles and closing others while using abdominal muscles to alternately expand and contract body volume.   Although these pulsating movements flush air from one end of the body to the other through the longitudinal tracheal trunks, diffusion is still important for distributing oxygen to individual cells through the network of smaller tracheal tubes.   In fact, the rate of gas diffusion is regarded as one of the main limiting factors (along with weight of the exoskeleton) that prevents real insects from growing as large as the ones we see in horror movies! |
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# Respiration in Aquatic Insects

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| Aquatic insects need oxygen too!  They are equipped with a variety of adaptations that allow them to carry a supply of oxygen with them under water or to acquire it directly from their environment.  Read each of the following sections to learn about these adaptations and how insects use them to obtain oxygen and maintain an aquatic lifestyle.   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Dissolved Oxygen**  Although water is a liquid, it usually contains a significant amount of dissolved oxygen (DO) plus small amounts of other gasses.  Icy cold water (0oC) can hold as much as 4.9% oxygen by volume.  However, as the water's temperature increases its ability to hold oxygen decreases.  The chart below lists the maximum amount of oxygen that can be dissolved in water at different temperatures:   |  |  | | --- | --- | | **Temperature (Celsius)** | **Oxygen (Max. % by volume)** | | **0** | **4.9** | | **10** | **3.8** | | **20** | **3.1** | | **30** | **2.6** |   DO is highest in cold mountain streams where the water is aerated by waterfalls and rapids.  Insects living here can usually rely on gills, plastrons, or cuticular respiration to meet their metabolic demand for oxygen.  Shallow lakes and ponds with warm, quiet water have less potential to hold DO so insects may need to rely more heavily on air bubbles or snorkel-like breathing tubes.  In water polluted by organic wastes, bacteria consume nearly all of the DO and create a near-anaerobic environment.  Insects that manage to survive under these conditions usually get all of their oxygen directly from the atmosphere. |    Cuticular Respiration Many aquatic species have a relatively thin integument that is permeable to oxygen (and carbon dioxide).  Diffusion of gasses through this body wall (cuticular respiration) may be sufficient to meet the metabolic demands of small, inactive insects -- especially those living in cold, fast-moving streams where there is plenty of dissolved oxygen.  Larger insects, more active ones, or those living in less oxygenated water may need to rely on other adaptations (see below) to supplement cuticular respiration. Biological Gills A **biological gill** is an organ that allows dissolved oxygen from the water to pass (by diffusion) into an organism's body.   |  | | --- | | gills02 |   In insects, gills are usually outgrowths of the tracheal system.  They are covered by a thin layer of cuticle that is permeable to both oxygen and carbon dioxide.  In mayflies and damselflies, the gills are leaf-like in shape and located on the sides or rear of the abdomen.  Fanning movements of the gills keep them in contact with a constant supply of fresh water.  Stoneflies and caddisflies have filamentous gills on the thorax or abdomen.  Dragonflies differ from other aquatic insects by having internal gills associated with the rectum.  Water is circulated in and out of the anus by muscular contractions of the abdomen.  This rectal gill mechanism doubles as a jet propulsion system.  A sudden, powerful contraction of the abdomen will expel a jet of water and thrust the insect forward -- a quick way to escape from predators! Breathing Tubes  |  | | --- | | siphon02 |   Although many aquatic insects live underwater, they get air straight from the surface through hollow breathing tubes (sometimes called **siphons**) that work on the same principle as a diver's snorkel.  In mosquito larvae, for example, the siphon tube is an extension of the posterior spiracles.  An opening at the end of the siphon is guarded by a ring of closely spaced hairs with a waterproof coating.  At the air-water interface, these hairs break the surface tension of the water and maintain an open airway.  When the insect dives, water pressure pushes the hairs close together so they seal off the opening and keep water out.  Water scorpions (Hemiptera: Nepidae) and rat-tailed maggots (larvae of a Syrphid fly) are two more examples of aquatic insects that have snorkel-like breathing tubes.  Many aquatic plants maintain their bouyancy by storing oxygen (a waste product of photosynthesis) in special vacuoles.  A few insects (*e.g.* larvae of *Mansonia* spp. mosquitoes ) insert their breathing tubes into these air stores and obtain a rich supply of oxygen without ever swimming to the surface of the water.   |  |  |  | | --- | --- | --- | | Air Bubbles  |  | | --- | | Atmospheric **AIR** is mostly a mixture of nitrogen (80%) and oxygen (20%).  All other gasses, including carbon dioxide, amount to less than 1% of the total volume. |   Some aquatic insects (diving beetles, for example) carry a bubble of air with them whenever they dive beneath the water surface.  This bubble may be held under the elytra (wing covers) or it may be trapped against the body by specialized hairs.  The bubble usually covers one or more spiracles so the insect can "breathe" air from the bubble while submerged.   |  | | --- | | bubble02 |   An air bubble provides an insect with only a short-term supply of oxygen, but thanks to its unique physical properties, a bubble will also "collect" some of the oxygen molecules dissolved in the surrounding water.  In effect, the bubble acts as a "physical gill" -- replenishing its supply of oxygen through the physics of passive diffusion.  The larger the surface area of the bubble, the more efficiently this system works.  An insect can remain under water as long as the volume of oxygen diffusing into the bubble is greater than or equal to the volume of oxygen consumed by the insect.  Unfortunately, the size of the bubble shrinks over time as nitrogen slowly diffuses out into the water.  When the bubble's surface area decreases, its rate of gas exchange also decreases.  Eventually, the bubble becomes too small to keep up with metabolic demands and the insect must renew the entire bubble by returning to the water's surface. |  Plastrons A **plastron** is a special array of rigid, closely-spaced hydrophobic hairs (setae) that create an "airspace" next to the body.  Air trapped within a plastron operates as a physical gill (just like air in a bubble) but this airspace cannot shrink in volume because the fortress of setae prevents encroachment of surrounding water.  When the insect consumes oxygen, it creates a partial pressure deficit inside the plastron.  This deficit is "corrected" by dissolved oxygen that diffuses in from the water.  As nitrogen gradually diffuses out of the bubble, it creates a similar partial pressure deficit.  But there is very little dissolved nitrogen present in water (it has a lower solubility potential than oxygen), so some of the nitrogen's partial pressure deficit is "corrected" by oxygen.  In effect, the plastron "trades" some of the nitrogen for oxygen -- keeping a constant volume of gas that may slowly become "enriched" with oxygen. The constant volume of a plastron's air supply eliminates the periodic need to surface and replenish the bubble.  Insects that remain permanently submerged (ex. riffle beetles, family Elmidae) or lack the ability to reach the surface (ex. eggs of floodwater mosquitoes) are likely to have plastrons.  These structures are often visible underwater as thin, silvery films of air covering parts of the body surface.    |  | | --- | | bloodworms |   **Hemoglobin**  Hemoglobin is a respiratory pigment that facilitates the capture of oxygen molecules.  It is an essential component of all human red blood cells, but it occurs only rarely in insects -- most notably in the larvae of certain midges (family Chironomidae) known as bloodworms.  These distinctive red "worms" usually live in the muddy depths of ponds or streams where dissolved oxygen may be in short supply.  Under normal (aerobic) conditions, hemoglobin molecules in the blood bind and hold a reserve supply of oxygen.  Whenever conditions become anaerobic, the oxygen is slowly released by the hemoglobin for use by the cells and tissues of the body.  This back-up supply may only last a few minutes, but it's usually long enough for the insect to move into more oxygenated water.  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| **Sense Organ of Insects** |

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| **Sense Organs** |
| Insects have sense organs for taste, touch, smell, hearing, and sight--the same senses present in humans. Some insects have sense organs for temperature and humidity as well as stresses and movements of their body parts. |
| Most sense organs of insects are microscopic in size and are found on their body wall. Many are small hairs, and others are small domes or other shapes. Regardless of their shape, all sense organs have one or more nerves leading to them. These small sense organs are called sensilla (a sensillum is one sense organ). A single antenna of an insect can have more than five thousand sensilla. |
| Sense organs, or sensilla, that function for taste and smell always have at least one small hole, or pore, through which the chemical molecules enter the organ. A single sense organ on the antenna of the polyphemus moth can have 18,000 pores for the chemicals to enter. There are always two or more nerves inside these sensilla that respond to the chemical. |
| Sense organs that respond only to mechanical touch or vibration do not have holes in them, and they only have one nerve. Some of these sensilla respond to changes in the body wall when the insect moves. |
| **Taste** |
| The organs of taste may be found on all parts of the insect's body, but they are located mainly on mouthparts and their feet (or tarsi). Some insects, including bees and wasps, have taste organs on their antennae. Wasps and crickets know where to lay their eggs because they have taste organs on their ovipositor. |
| Most insects have the same four taste sensations as humans--salty, bitter, sweet, and sour. Many insects have taste organs for particular chemicals found in only a few plants. The cabbage butterfly, for example, has a taste organ for mustard. |
| **Smell** |
| Antennae sometimes are called "feelers." However, antennae are primarily "smellers"--they are the insect's "nose" because they are covered with many organs of smell. These organs help the insect to find food, a mate, and places to lay eggs. Insects even can decide which direction to fly by using their sense of smell. |
| The organ of smell of an insect does not detect as many different odors as a human's nose, but the insect's organ is tuned more finely. It can detect differences between very similar chemicals, and it can smell much smaller amounts of a scent. In fact, the male of the lesser emperor moth can smell the chemical pheromone of the female at a distance of more than six miles. |
| Social insects, like ants and bees, know when an unwanted visitor enters their nest because they recognize the members of their own colony with their sense of smell. |
| **Touch** |
| Most of the sense organs that respond to touch are small hairs with a nerve at their base. The insect can sense the movement of this hair if it touches another object. These sensory hairs also help honey bees orient to the earth's gravity when they are upside down on their hive. |
| These sense organs of touch can respond even to the wind or a gentle breeze. This is one reason why it is difficult to catch a fly. The fly can sense the air being pushed towards it when your hand is moving. One species of grasshopper can feel air that is moving less than one-tenth mile per hour. |
| **Hearing** |
| Insects can hear sound passing as vibrations through the air as well as through the ground, water, or the leaf of a plant. Some insects can hear sounds that people cannot. Insects have many different kinds of "ears" or hearing organs. The most simple hearing organs are the same hair-like sense organs that respond to touch. Some insects, such as cicadas and crickets, detect sound with a tympanum, a large membrane like the ear drum in humans. |
| Bats make sound that will echo from a flying insect, and the bats use this echo-location to catch their food. Many different moths have a tympanum on their wings, thorax, or abdomen. These moths can hear the clicking sounds of the bats and take evasive action by dropping in the air or changing their flight path to avoid being caught. |
| Many insects have hearing organs inside their legs. These ears in legs respond to vibrations passing though the ground or a plant. This is why ants will come out of their nest if you stomp the ground. |
| **Sight** |
| Adults and nymps of insects have two compound eyes and up to three simple eyes on their head. Larvae of insects with complete metamorphosis, such as caterpillars and grubs, do not have compound eyes, but they may have 1-6 simple eyes. |
| A simple eye is a single lens that tells the difference between light and dark. Larvae can also see rough shapes with their simple eyes. |
| A compound eye includes many lens that have six sides and fit together like the cells of a honeycomb. Compound eyes differ among insects in their ability to see, but some can see sharp images and different colors. All insects can see movement better than shape. |
| Insects with large compound eyes, like cockroaches and dragonflies, have a wide field of view of 360 degrees. Color vision in insects differs from that in humans. Many insects can see the ultraviolet color not visible to humans, but most insects cannot see the red color. If a red plastic film is placed over a flashlight, insects can be observed at night without their detecting the light. |
| **Other Senses** |
| Insects have special organs for sensing their movements which cause internal changes in pressure and stress inside their body. These sense organs are similar to those for touch, except they are dome-shaped and have no hair. Insects have many of these pressure and stress organs on their wings and legs, and they could not walk or fly without them. |
| **Instinct and Learning** |
| Insect behavior is mostly instinctive. Instinct is determined by genes before the insect hatches from the egg. A caterpillar does not make a conscious choice of which plant to eat. Rather, the caterpilar is programmed to eat a certain kind of plant, even though other nutritious plants might be available. Likewise, a wasp does not choose to sting a person. The wasp is reacting by instinct to a threat or invasion of its territory. |
| Insects also have the ability to learn. Some moths first locate flowers instinctively by their scent. These moths later learn to identify the flower by their vision. Some kinds of wasps make orientation flights to learn landmarks near their nest, and these landmarks are remembered so they can find their nest after a longer flight. |
| Honey bees can be trained, or conditioned, to associate sugar water with a particular color or aroma. honey bees also learn to come to food at certain times during the day when there is nectar available. |
| Insects can also learn by "trial and error." When Colorado Potato Beetles first attempt to mate, they are not very good at identifying their own species or even distinguishing the head from the tail ends of the body. With repeated attempts and mistakes, they learn to recognize their own species and to tell the head from the tail end. |

# MECHANORECEPTORS

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| Insect mechanoreceptors can be found almost anywhere on the surface of an insect's body.   They may act as **tactile** receptors, detecting movement of objects in the environment, or they may provide **proprioceptive** cues (sensory input about the position or orientation of the body and its appendages).   These receptors are innervated by one or more sensory neurons that fire in response to stretching, bending, compression, vibration, or other mechanical disturbance.   Some mechanoreceptors produce a **phasic response** when stimulated -- that is, they fire once when activated and again when deactivated.   Other receptors generate a **tonic response**, firing repeatedly as long as a stimulus persists.   Neural processing centers in the brain or segmental ganglia interpret the combinations of tonic and phasic signals sent from nearby receptors.  **Trichoform sensilla** are probably the simplest mechanoreceptors.   These are **tactile hairs** (setae) that are innervated by a sensory neuron.   Dendrites of the neuron attach near the base of the hair and generate a nerve impulse whenever they detect movement.   **Hair beds** (clusters of tactile setae) are often found behind the head, on the legs, or near joints where they respond to movements of the body. | tricho |

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| **Campaniform sensilla** are flattened oval discs that usually serve as **flex receptors** in the exoskeleton.   They respond whenever mechanical stress causes the exoskeleton to bend.   Campaniform sensilla are found throughout the body -- especially on the legs, near the base of the wings, and along sutures where two sclerites of the exoskeleton meet.  **Stretch receptors** are multi-polar neurons that usually accompany muscle or connective tissue.   They are commonly embedded in intersegmental membranes and in the muscular walls of the digestive system.   Some insects may stop feeding when the gut expands enough to stimulate stretch receptors in the crop.   In others, oviposition may begin when mature eggs stimulate stretch receptors in the reproductive system.  **Pressure receptors** provide sensory information about an aquatic insect's depth in the water.   These receptors are usually associated with a cushion of air against the body or within the tracheal system.   Increasing water pressure deflects hair-like processes within the receptor and stimulates tonic and phasic impulses. | campan |

**Chordotonal organs** include several types of mechanoreceptors in which one or more bipolar neurons bridge a gap between two internal surfaces of the exoskeleton.

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| chordoton |

Each neuron is usually accompanied by two other cells which form a sheath (the scolopale cell) and a point of attachment (the cap cell).   Together, these three cells create a unit (called a scolopidia) that may occur singly or in groups.   Common types of chordotonal organs include:

**Subgenual organs** -- located in the legs of many insects, these receptors contain relatively few scolopidia yet they appear to be very sensitive to substrate vibrations.   Insects may lack specialized sound receptors, yet they can still "hear" vibrations transmitted through the substrate.

**Tympanal organs** -- lie beneath a drum-like membrane (the tympanum) where they respond to sound vibrations.   These "ears" may be located on the thorax (in some Hemiptera), on the abdomen (in grasshoppers, cicadas, and some moths), or on the front tibia (in crickets and katydids).

**Johnston's organs** -- found within the pedicel of each antenna.   In some insects, they function as a proprioceptors, supplying information on position or orientation of the antennae.   In mosquitoes and midges, they respond to certain frequencies of airborne sound by detecting resonant vibrations in antennal hairs.   (Shorter hairs near the tip of the antennae resonate to higher frequencies than longer hairs near the base).

# CHEMORECEPTORS

Insects have the ability to sense various chemical substances in their environment.   When these chemicals are present in gaseous form (at relatively low concentrations), they may be detected as odors (smells) by **olfactory receptors**.   When they are in solid or liquid form (usually at higher concentrations) they are perceived as tastes by **gustatory receptors**.   In general, the sense of taste involves direct contact with a substrate (contact chemoreception) whereas olfaction usually implies detection of compounds in gaseous or airborne form (remote chemoreception).

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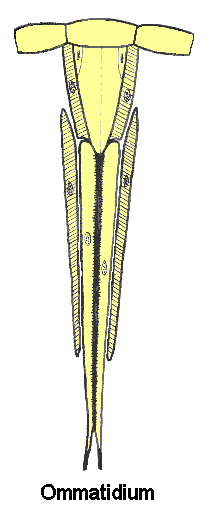
**Common chemical sense**

High concentrations of irritant compounds (*e.g.* ammonia, chlorine, acids, essential oils, etc.) simulate avoidance reactions and cleaning behavior.   Insects can detect these compounds even when all known chemoreceptors have been covered or destroyed.   The irritants evidently trigger a generalized response from other types of sensory neurons.

# PHOTORECEPTORS

## compound1aCompound Eyes

A pair of **compound eyes** are the principle visual organs of most insects; they are found in nearly all adults and in many immatures of ametabolous and hemimetabolous orders.   As the name suggests, compound eyes are composed of many similar, closely-packed facets (called **ommatidia**) which are the structural and functional units of vision.   The number of ommatidia varies considerably from species to species:   some worker ants have fewer than six while some dragonflies may have more than 25,000.

Externally,each ommatidium is marked by a convex thickening of transparent cuticle, the [**corneal lens**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1).   Beneath the lens, there is often a [**crystalline cone**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1) secreted by a pair of [**semper cells**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1).   Together, the lens and the crystalline cone form a [**dioptric apparatus**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1) that refracts incoming light down into a receptor region containing visual pigment.

The light-sensitive part of an ommatidium is called the [**rhabdom**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1).   It is a rod-like structure, secreted by an array of 6-8 specialized neurons ( [**retinula cells**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1)), and centered on the optical axis just below the crystalline cone.   The rhabdom contains an array of closely packed microtubules where light-sensitive pigments (e.g. rhodopsin, etc.) are stored.   These pigments absorb certain wavelengths of incident light and generate nerve impulses through a photochemical process similar to that of vertebrates.

Most diurnal insects have [**pigment cells**](http://www.cals.ncsu.edu/course/ent425/tutorial/photo.html#1#1) surrounding each ommatidium.   These cells limit a facet's field of view by absorbing light that enters through adjacent corneas.   Each facet points toward a slightly different part of the visual field -- in composite, they render a **mosaic-like** impression of the environment.   Nocturnal and crepuscular insects have pigment cells that do not completely isolate each facet.   Their ommatidia are stimulated by light from larger fields of view.   This produces a brighter but theoretically less distinct mosaic image.

Since insects cannot form a true (*i.e.* focused) image of the environment, their visual acuity is relatively poor compared to that of vertebrates.   On the other hand, their ability to sense movement, by tracking objects from ommatidium to ommatidium, is superior to most other animals.

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Temporal resolution of flicker is as high as as 200 images/second in some bees and flies (in humans, still images blur into constant motion at about 30 images/second).   They can detect polarization patterns in sunlight, and discriminate wavelengths in a range from ultraviolet to yellow (but not red).

## Ocelli -- Simple eyes

Two types of "simple eyes" can be found in the class Insecta:   **dorsal ocelli** and **lateral ocelli (=stemmata)**.   Although both types of ocelli are similar in structure, they are believed to have separate phylogenetic and embryological origins.

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| **Dorsal Ocellus** |
| dorsalocell |

**Dorsal ocelli** are commonly found in adults and in the immature stages (nymphs) of many hemimetabolous species.   They are not independent visual organs and never occur in species that lack compound eyes.   Whenever present, dorsal ocelli appear as two or three small, convex swellings on the dorsal or facial regions of the head.   They differ from compound eyes in having only a single corneal lens covering an array of several dozen rhabdom-like sensory rods.   These simple eyes do not form an image or perceive objects in the environment, but they are sensitive to a wide range of wavelengths, react to the polarization of light, and respond quickly to changes in light intensity.   No exact function has been clearly established, but many physiologists believe they act as an "iris mechanism" -- adjusting the sensitivity of the compound eyes to different levels of light intensity.

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| stemma |

**Lateral ocelli (=stemmata)** are the sole visual organs of holometabolous larvae and certain adults (*e.g.* Collembola, Thysanura, Siphonaptera, and Strepsiptera).   Stemmata always occur laterally on the head, and vary in number from one to six on each side.   Structurally, they are similar to dorsal ocelli but often have a crystalline cone under the cornea and fewer sensory rods.   Larvae use these simple eyes to sense light intensity, detect outlines of nearby objects, and even track the movements of predators or prey.   Covering several ocelli on each side of the head seems to impair form vision, so the brain must be able to construct a coarse mosaic of nearby objects from the visual fields of adjacent ocelli.

## *Extra-ocular Photoreception*

Some (perhaps most) insects respond to changes in light intensity even when all known photoreceptive structures are rendered inoperative.   This **dermal light sense** has been attributed to the response of individual neurons in the brain and/or ventral nerve cord.   There is also convincing evidence that some insects can perceive infrared radiation (heat), although specific receptors for this ability have not been described.

**Auditory Organ:**

The organs of insects which are being used as hearing aid are called auditory organ. Before knowing this we should have to know can insect hear? If yes, how can insect hear?

Answer: Most hearing insects have a pair of **tympanal organs**. Think of a tympani, the large drum used in the percussion section of an orchestra. Like the tympani, the tympanal organ consists of a membrane stretched on a frame, over an air-filled cavity. When the percussionist hammers on the membrane of the tympani, it vibrates and produces a sound. The insect's tympanal organ vibrates as it catches sound waves in the air. The insect also has a special receptor called the chordotonal organ, which senses this vibration of the tympanal organ, and translates the sound into a nerve impulse. Insects that use tympanal organs to hear include [grasshoppers and crickets](http://insects.about.com/od/grasshoppersandcrickets/p/char_orthoptera.htm), cicadas, and some [butterflies and moths](http://insects.about.com/od/butterfliesmoths/p/char_lepidopter.htm).

For many insects, a receptor on the antennae called the **Johnston's organ** collects auditory information. Sensory cells on the pedicel, which is the second segment from the base of the antennae, detect vibration of the segment(s) above. Mosquitoes and fruit flies hear using the Johnston's organ.

The larvae of [Lepidoptera](http://insects.about.com/od/butterfliesmoths/p/char_lepidopter.htm) and [Orthoptera](http://insects.about.com/od/grasshoppersandcrickets/p/char_orthoptera.htm) use small hairs, called **setae**, to gather the vibrations of sound. Caterpillars often respond to such sounds by exhibiting defensive behaviors. Some will stop moving completely, while others may contract their muscles and rear up in a fighting posture.

A structure in the mouths of certain hawkmoths enables them to hear ultrasonic sounds, such as those produced by echolocating bats. The **labral pilifer**, a tiny hair-like organ, is believed to sense vibrations at specific frequencies. Scientists note a distinctive movement of the insect's tongue when they subject the captive hawkmoths to those sounds. In flight, the hawkmoths can avoid a pursuing bat by listening for these frequencies

**Gustatory Receptors**:

Gustation is an omnipresent sense in virtually all organismsand is used in finding and securing the quality of food, aswell as avoiding toxic items. In selecting food and ovipositionsites, female insects use gustatory receptor neurons (GRNs)located in contact chemosensilla on various parts of the body. In the moth *Heliothis virescens* (Lepidoptera: Noctuidae), contactchemosensilla are located on the antennae (*sensilla chaetica*),the proboscis (*sensilla styloconica*), and the tarsi. A contact chemosensillum typically contains 2–4GRNs with dendrites extending toward the tip of the sensillumhair, and one mechanosensory neuron attached to the hair base, and the antennal *s. chaetica* has 4 GRNs and onemechanosensory neuron . When themoth antennates, taste stimuli are detected by the GRNs of *s.chaetica* that are especially abundant at the antennal tip. Informationfrom the antennal GRNs is conveyed by their primary axons tothe subesophageal ganglion (SOG) (Jørgensen et al. 2006[Go](http://chemse.oxfordjournals.org/cgi/content/full/32/9/863#BIB39#BIB39)),where it is transmitted to interneurons and motorneurons involvedin the proboscis extension reflex (PER). Phagostimulants likesucrose, applied to the antennae, release PER when the mothis hungry and motivated to feed, whereas deterrents inhibitthe release of PER. During feeding, GRNs on the proboscis arestimulated and convey information to the tritocerebrum, controlling ingestion. Despite the importanceof antennal GRNs in feeding, few studies of these neurons havebeen performed. The honeybee *Apis mellifera* have particularGRNs on the antennae detecting sucrose, but not the bitter substancestested . AntennalGRNs of the cockroach *Periplaneta americana* seem to detect fruitjuices, surface- and tergal extracts, but not sucrose, whereasin *Periplaneta brunnea* they detect sucrose .

Detection of tastants has evolved differently in various organisms,depending on diet breadth and habitat. Sugars, an importantenergy source, are detected by particular gustatory cells, presentin many species. In mammals, the 2 coupled receptor proteins,T1R2 and T1R3, seem to detect all natural sugars and artificialsweeteners tested

**Temperature & Humidity Receptors**:

Many insect species rely heavily on the temperature sense. Theirlow body weight makes heat exchange with the environment veryrapid. To maintain body temperature, insects must actively tracka suitable thermal environment. The sensory cells responsiblefor detection of ambient temperature are located on the surfaceof the antennae within cuticular extensions termed *sensilla*.Two physiologically different types of thermoreceptive cellsare distinguished: cold and warm cells. Both types respond tothe same temperature changes, but in the opposite direction.The same cooling raises impulse frequency of the cold cell andlowers it in the warm cell. Correspondingly, opposite effectsare produced by warming.

Cold cells and warm cells were rarely reported occurring alonein a sensillum. The rule in insects is combinations of sensorycells of different modalities, most often a cold cell with twohygroreceptive cells. Within this category, several examples ofhighly sensitive cold cells have been observed. In the stickinsect *Carausius morosus*, calculations of the resolving powerof the cold cell show that it can differentiate between twosuccessive temperature drops when they differ by as little as0.4°C . In the cave beetle *Speophyeslucidulus*, the sensitivity of the cold cell defies the imagination:a temperature change of 0.0005°C/s can trigger a response! This highsensitivity is coupled with the observation that more than onemodality determines the response. Impulse frequencies of thecold cells in the stick insect and the cave beetle do not riseonly when the air temperature suddenly drops; they also risewhen the partial pressure of water vapor is suddenly reduced.

Changes in the water vapor pressure were previously tested todetermine the properties of the two hygroreceptive sensory cellsoccurring in the same sensillum with the cold cell. These hygroreceptors are knownas moist cells or dry cells, depending on whether their impulsefrequency increases when the partial pressure of water vaporincreases or decreases. Identification of the three cells wascomplicated because they all are activated by changes in thepartial pressure of water vapor and two of them by changes intemperature. In the stick insect *Carausius morosus*, the problemwas solved by the different manners in which the three cellsrespond to these changes .

# THE NERVOUS SYSTEM

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| * neuronsAn insect's nervous system is a network of specialized cells (called **neurons**) that serve as an "information highway" within the body.   These cells generate electrical impulses (action potientials) that travel as waves of **depolarization (**In biology, **depolarization** is a decrease in the absolute value of a cell's membrane potential. Thus, changes in membrane voltage in which the membrane potential becomes less positive or less negative are both depolarizations. In neurons and some other cells, a **depolarization** large enough may result in an action potential). * **)** along the cell's membrane.   Every neuron has a nerve [**cell body**](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#1#1) (The enlarged portion of a neuron containing most of the organelles.), where the nucleus is found and filament-like processes ([**dendrites**](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#1#1)= are the branched projections of a neuron that act to conduct the electrochemical stimulation received from other neural cells to the cell body, or soma, of the neuron from which the **dendrites** project. Electrical stimulation is transmitted onto **dendrites** by upstream neurons via synapses which are located at various points throughout the dendritic arbor.   , [axons](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#1#1)= are in effect the primary transmission lines of the nervous system, and as bundles they help make up nerves. Individual **axons** are microscopic in diameter, or [collaterals](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#1#1)) that propagate the action potential.   Signal transmission is always [unidirectional](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#1#1) -- moving toward the nerve cell body along a dendrite or a collateral and away from the nerve cell body along an axon.  Neurons are usually divided into three categories, depending on their function within the nervous system:   1. **Afferent** (sensory) neurons -- these bipolar or multipolar cells have dendrites that are associated with sense organs or receptors.   They always carry information toward the central nervous system. 2. **Efferent** (motor) neurons -- unipolar cells that conduct signals away from the central nervous system and stimulate responses in muscles and glands. 3. **Internuncial** (association) neurons -- unipolar cells (often with several collaterals and/or branching axons) that conduct signals within the central nervous system.   Individual nerve cells connect with one another through special junctions, called **synapses**.   When a nerve impulse reaches the synapse, it releases a chemical messenger (**neurotransmitter** substance) that diffuses across the synapse and triggers a new impulse in the dendrite(s) of one or more connecting neurons.   Acetylcholine, 5-hydroxytryptamine, dopamine, and noradrenaline are examples of neurotransmitters found in both vertebrate and invertebrate nervous systems.  Nerve cells are typically found grouped in bundles.   A **nerve** is simply a bundle of dendrites or axons that serve the same part of the body. A **ganglion** is a dense cluster of interconnected neurons that process sensory information or control motor outputs. The Central Nervous System  |  | | --- | | sideview  Central Nervous System | | **Side view of body showing relative position of circulatory (yellow), digestive (green), and nervous (blue) systems.** |   Like most other arthropods, insects have a relatively simple central nervous system with a dorsal [brain](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2) linked to a [ventral nerve cord](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2) that consists of paired **segmental ganglia** running along the ventral midline of the thorax and abdomen.   Ganglia within each segment are linked to one another by a short medial nerve ([commissure](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2)) and also joined by [intersegmental connectives](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2) to ganglia in adjacent body segments.   cnsIn general, the central nervous system is rather ladder-like in appearance:   commissures are the rungs of the ladder and intersegmental connectives are the rails.   In more "advanced" insect orders there is a tendency for individual ganglia to combine (both laterally and longitudinally) into larger ganglia that serve multiple body segments.  An insect's **brain** is a complex of six fused ganglia (three pairs) located dorsally within the head capsule.   Each part of the brain controls (innervates) a limited spectrum of activities in the insect's body:  [Protocerebrum:](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2)   The first pair of ganglia are largely associated with vision; they innervate the compound eyes and ocelli.  [Deutocerebrum:](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2)   The second pair of ganglia process sensory information collected by the antennae.  [Tritocerebrum:](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2)   The third pair of ganglia innervate the labrum and integrate sensory inputs from proto- and deutocerebrums.   They also link the brain with the rest of the ventral nerve cord and the stomodaeal nervous system (see below) that controls the internal organs.   The commissure for the tritocerebrum loops around the digestive system, suggesting that these ganglia were originally located behind the mouth and migrated forward (around the esophagus) during evolution.  Located ventrally in the head capsule (just below the brain and esophagus) is another complex of fused ganglia (jointly called the [subesophageal ganglion](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2)).   Embryologists believe this structure contains neural elements from the three primitive body segments that merged with the head to form mouthparts.   In modern insects, the subesophageal ganglion innervates not only mandibles, maxillae, and labium, but also the hypopharynx, salivary glands, and neck muscles.   A pair of [circumesophageal connectives](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2) loop around the digestive system to link the brain and subesophageal complex together.  In the thorax, three pairs of [thoracic ganglia](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2) (sometimes fused) control locomotion by innervating the legs and wings.   Thoracic muscles and sensory receptors are also associated with these ganglia.   Similarly, [abdominal ganglia](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#2#2) control movements of abdominal muscles.   Spiracles in both the thorax and abdomen are controlled by a pair of lateral nerves that arise from each segmental ganglion (or by a median ventral nerve that branches to each side).   A pair of terminal abdominal ganglia (usually fused to form a large **caudal ganglion**) innervate the anus, internal and external genitalia, and sensory receptors (such as cerci) located on the insect's back end.  **The Stomodaeal Nervous System**  stomodaealAn insect's internal organs are largely innervated by a stomodaeal (or stomatogastric) nervous system.   A pair of [frontal nerves](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#3#3) arising near the base of the tritocerebrum link the brain with a [frontal ganglion](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#3#3) (unpaired) on the anterior wall of the esophagus.   This ganglion innervates the pharynx and muscles associated with swallowing.   A [recurrent nerve](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#3#3) along the anterio-dorsal surface of the foregut connects the frontal ganglion with a [hypocerebral ganglion](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#3#3) that innervates the heart, corpora cardiaca, and portions of the foregut.   [Gastric nerves](http://www.cals.ncsu.edu/course/ent425/tutorial/nerves.html#3#3) arising from the hypocerebral ganglion run posteriorly to ingluvial ganglia (paired) in the abdomen that innervate the hind gut.  In comparison to vertebrates, an insect's nervous system is far more de-centralized.   Most overt behavior (*e.g.* feeding, locomotion, mating, etc.) is integrated and controlled by segmental ganglia instead of the brain.   In some cases, the brain may stimulate or inhibit activity in segmental ganglia but these signals are not essential for survival.   Indeed, a headless insect may survive for days or weeks (until it dies of starvation or dehydration) as long as the neck is sealed to prevent loss of blood! |

**Insect Endocrine System**

A **hormone** is a chemical signal sent from cells in one part of an organism to cells in another part (or parts) of the same individual.   They are often regarded as ***chemical messengers*.** Although typically produced in very small quantities, hormones may cause profound changes in their target cells.   Their effect may be stimulatory or inhibitory.   In some cases, a single hormone may have multiple targets and cause different effects in each target.

Insects have several organs that produce hormones, controlling [reproduction](http://en.wikipedia.org/wiki/Reproduction), [metamorphosis](http://en.wikipedia.org/wiki/Metamorphosis) and [moulting](http://en.wikipedia.org/wiki/Moulting). It has been suggested that a [brain](http://en.wikipedia.org/wiki/Brain) hormone is responsible for [caste](http://en.wikipedia.org/wiki/Caste) dermination in [termites](http://en.wikipedia.org/wiki/Termites) and [diapause](http://en.wikipedia.org/wiki/Diapause) interruption in some insects .

  There are at least four categories of hormone-producing cells in an insect's body.

1. **Endocrine glands** -- secretory structures adapted exclusively for producing hormones and releasing them into the circulatory system.
2. **Neurohemal organs** -- similar to glands, but they store their secretory product in a special chamber until stimulated to release it by a signal from the nervous system (or another hormone).
3. **Neurosecretory cells** -- specialized nerve cells (neurons serve as a link between the nervous system and the endocrine system.
4. **Internal organs** -- hormone-producing cells are associated with numerous organs of the body, including the ovaries and testes, the fat body, and parts of the digestive system.

Together, these hormone-secreting structures form an **endocrine system** that helps maintain homeostasis, coordinate behavior, and regulate growth, development, and other physiological activities.

In insects, the largest and most obvious endocrine glands are found in the prothorax, just behind the head.   These [prothoracic glands](http://www.cals.ncsu.edu/course/ent425/tutorial/endocrine.html#1#1) manufacture **ecdysteroids**, a group of closely-related steroid hormones (including ecdysone) that stimulate synthesis of chitin and protein in epidermal cells that culminates in molting.   For this reason, the **ecdysteroids** are often called "molting hormones".   Once an insect reaches the adult stage, its prothoracic glands atrophy (¶‡q hvq) and it will never molt again.

Prothoracic glands produce and release ecdysteroids only after they have been stimulated by another chemical messenger, **prothoracicotropic hormone** (PTTH ).   This compound is a peptide hormone secreted by the [corpora cardiaca](http://www.cals.ncsu.edu/course/ent425/tutorial/endocrine.html#1#1), a pair of neurohemal organs located on the walls of the aorta just behind the brain.

The [corpora allata](http://www.cals.ncsu.edu/course/ent425/tutorial/endocrine.html#1#1), another pair of neurohemal organs, lie just behind the corpora cardiaca.   They manufacture **juvenile hormone** (JH ), a compound that inhibits development of adult characteristics during the immature stages and promotes sexual maturity during the adult stage.   [**Neurosecretory cells**](http://www.cals.ncsu.edu/course/ent425/tutorial/endocrine.html#1#1) in the brain regulate activity of the corpora allata -- stimulating them to produce JH during larval or nymphal instars, inhibiting them during the transition to adulthood, and reactivating them once the adult is ready for reproduction

The [**Neurosecretory cells**](http://www.cals.ncsu.edu/course/ent425/tutorial/endocrine.html#1#1) are found in clusters, both medially and laterally in the insect's brain.   Axons from these cells can be traced along tiny nerves that run to the corpora cardiaca and corpora allata. The cells produce and secrete **brain hormone**, a low-molecular-weight peptide that appears to be the same as (or very similar to) prothoracicotropic hormone (PTTH) manufactured by the corpora cardiaca.   Insect physiologists suspect that brain hormone is bound to a larger carrier protein while it is inside the neurosecretory cell, and some believe that each cluster of cells may produce as many as three different brain hormones (or hormone-carrier combinations).   Large numbers of neurosecretory cells also occur in the ventral ganglia of the nerve cord, but their function is unknown.

Many other tissues and organs of the body also produce hormones.   Ovaries and testes, for example, produce gonadal hormones that have been shown to coordinate courtship and mating behaviors.   Ventral ganglia in the nervous system produce one compound (eclosion hormone) that helps an insect shed its old exoskeleton and another compound (bursicon) that causes hardening and tanning of the new one.   There are still other hormones that control the level of sugar dissolved in the blood, adjust salt and water balance, and regulate protein metabolis

►**Homeostasis:** In biology, overall term for the tendency of biological systems to maintain a state of equilibrium. The concept was first advanced in the 19th century by the French physiologist Claude Bernard. Examples of homeostasis include the body's self-regulation of hormone and acid-base levels, the composition of body fluids, and cell growth and body temperatur

►**Diapause:** is a [physiological](http://en.wikipedia.org/wiki/Physiological) state of [dormancy](http://en.wikipedia.org/wiki/Dormancy) with very specific triggering and releasing conditions. It is used as a means to survive predictable, unfavourable environmental conditions, such as temperature extremes, drought or reduced food availability. There are various definitions and contexts in which the term is used, but its most common application is in [arthropods](http://en.wikipedia.org/wiki/Arthropod), especially [insects](http://en.wikipedia.org/wiki/Insect). One of the most explicit definitions, covering many of the important features, is the following:

*"a* [*neurohormonally*](http://en.wikipedia.org/wiki/Neurohormone) *mediated, dynamic state of low* [*metabolic*](http://en.wikipedia.org/wiki/Metabolic) *activity. Associated with this are reduced* [*morphogenesis*](http://en.wikipedia.org/wiki/Morphogenesis)*, increased resistance to environmental extremes, and altered or reduced behavioral activity. Diapause occurs during a genetically determined stage(s) of* [*metamorphosis*](http://en.wikipedia.org/wiki/Metamorphosis)*, and its full expression develops in a species-specific manner, usually in response to a number of environmental* [*stimuli*](http://en.wikipedia.org/wiki/Stimulus_(physiology)) *that precede unfavorable conditions. Once diapause has begun, metabolic activity is suppressed even if conditions favorable for development prevail."*[[1]](http://en.wikipedia.org/wiki/Diapause#cite_note-Tauber-0#cite_note-Tauber-0)

Of primary importance is that diapause is not only induced in an organism by specific stimuli, but once it is initiated, only certain other stimuli are capable of releasing the organism from this state. The latter is essential in distinguishing diapause as a different phenomenon from other forms of [dormancy](http://en.wikipedia.org/wiki/Dormancy) such as [hibernation](http://en.wikipedia.org/wiki/Hibernation).

A similar phenomenon occurs in the [seeds](http://en.wikipedia.org/wiki/Seed) or other resting stages of various [plants](http://en.wikipedia.org/wiki/Plant). In the eggs of various [vertebrates](http://en.wikipedia.org/wiki/Vertebrate) there is a phenomenon sometimes known as "[embryonic diapause](http://en.wikipedia.org/wiki/Embryonic_diapause)", which is also termed "delayed implantation," and is not directly equivalent to the phenomenon in arthropods, though in both cases there is a cessation of metabolic activity.

Activity levels of diapausing stages can vary considerably among species.[[1]](http://en.wikipedia.org/wiki/Diapause#cite_note-Tauber-0#cite_note-Tauber-0) Diapause may occur in a completely immobile stage, such as the pupae and eggs, or it may occur in very active stages that undergo extensive migrations, such as the adult [Monarch butterfly](http://en.wikipedia.org/wiki/Monarch_butterfly), *Danaus plexippus*. In cases where the insect remains active, feeding is reduced and reproductive development is slowed or halted

[**Moulting**](http://en.wikipedia.org/wiki/Moulting)**:** (In [biology](http://en.wikipedia.org/wiki/Biology), **moulting** (or **molting**, also known as **sloughing**, **shedding** or for some species, [**ecdysis**](http://en.wikipedia.org/wiki/Ecdysis)) signifies the manner in which an animal routinely casts off a part of its body (often but not always an outer layer or covering), either at specific times of year, or at specific points in its life-cycle.

Moulting can involve the [epidermis](http://en.wikipedia.org/wiki/Epidermis_(skin)) (skin), [pelage](http://en.wikipedia.org/wiki/Pelage) ([hair](http://en.wikipedia.org/wiki/Hair), [fur](http://en.wikipedia.org/wiki/Fur), [wool](http://en.wikipedia.org/wiki/Wool)), or other external layer. In some species, other body parts may be shed, for example, [wings](http://en.wikipedia.org/wiki/Wing) in some [insects](http://en.wikipedia.org/wiki/Insect). Examples include old [feathers](http://en.wikipedia.org/wiki/Feather) in [birds](http://en.wikipedia.org/wiki/Bird), old [hairs](http://en.wikipedia.org/wiki/Hair) in [mammals](http://en.wikipedia.org/wiki/Mammal) (especially [dogs](http://en.wikipedia.org/wiki/Dog) and other [canidae](http://en.wikipedia.org/wiki/Canidae)), old [skin](http://en.wikipedia.org/wiki/Skin) in [reptiles](http://en.wikipedia.org/wiki/Reptile), and the entire [exoskeleton](http://en.wikipedia.org/wiki/Exoskeleton) in [arthropods](http://en.wikipedia.org/wiki/Arthropod).

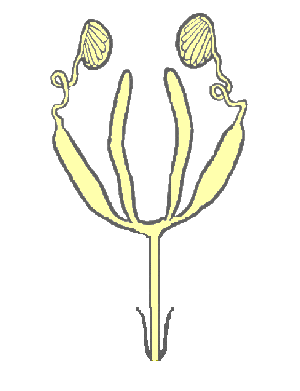
**Insect Reproduction & Development**

The reproductive organs of insects are similar in structure and function to those of vertebrates:   a male's testes produce sperm and a female's ovaries produce eggs (ova).   Both types of gametes are haploid and unicellular, but eggs are usually much larger in volume than sperm.

Most insect species reproduce sexually -- one egg from a female and one sperm from a male fuse (syngamy) to produce a diploid zygote.   But there are also many species that reproduce by parthenogenesis, asexual reproduction in which there is growth and development of an unfertilized egg.   Some species alternate between sexual and asexual reproduction (not all generations produce males), others are exclusively parthenogenetic (no males ever occur

**Male Reproductive System**

The male's reproductive system contains a pair of testes, usually located near the back of the abdomen.   Each testis is subdivided into functional units (called follicles) where sperm are actually produced.   A typical testis may contain hundreds of follicles, generally aligned parallel to one another.   Near the distal end of each follicle, there are a group of germ cells (**spermatogonia**) that divide by mitosis and increase in size to form **spermatocytes**.   These spermatocytes migrate toward the basal end of the follicle, pushed along by continued cell division of the spermatogonia. Each spermatocyte undergoes meiosis:   this yields four haploid **spermatids** which develop into mature **spermatozoa** as they progress further along through the follicle.

Mature sperm pass out of the testes through short ducts (vasa efferentia) and collect in storage chambers (seminal vesicles) that are usually little more than enlarged sections of the vasa.   Similar ducts (vasa deferentia) lead away from the seminal vesicles, join one another near the midline of the body, and form a single ejaculatory duct that leads out of the body through the male's copulatory organ (called an aedeagus).

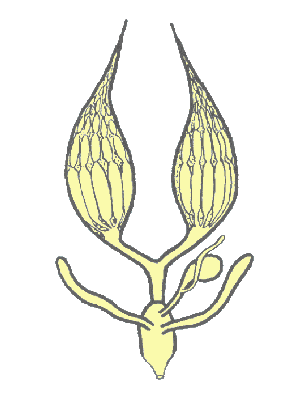
One or more pairs of accessory glands are usually associated with the male's reproductive system.   These are secretory organs that connect to the reproductive system by means of short ducts -- some may attach near the testes or seminal vesicles, others may be associated with the ejaculatory duct.   The glands have two major functions:

1. Manufacture of **seminal fluid**, a liquid medium that sustains and nourishes mature sperm while they are in the male's genital system.

2. Production of **spermatophores**, pouch-like structures (mostly protein) that encase the sperm and protect them as they are delivered to the female's body during copulation.

**Female Reproductive System**

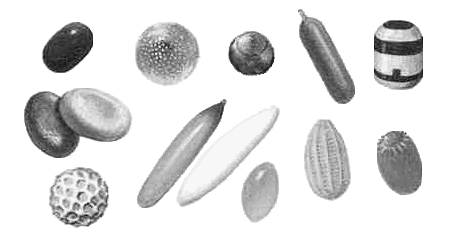
The female's reproductive system contains a pair of ovaries.   When the insect is actively reproducing, these organs swell with developing eggs and may nearly fill the abdomen.   Each ovary is subdivided into functional units (called ovarioles) where the eggs are actually produced.   A typical ovary may contain dozens of ovarioles, generally aligned parallel to one another.   Near the distal end of each ovariole, there are a group of germ cells (**oogonia**) that divide by mitosis and increase in size to form **oocytes**. During active oogenesis, new oocytes are produced on a regular schedule within each ovariole.   These oocytes migrate toward the basal end of the ovariole, pushed along by continued cell division of the oogonia.   Each oocyte undergoes meiosis:   this yields four cells -- one egg and three polar bodies.   The polar bodies may disintegrate or they may accompany the egg as nurse cells. As developing eggs move down the ovariole, they grow in size by absorbing yolk (supplied by adjacent nurse cells or accessory cells).



Thus, each ovariole contains a linear series of eggs in progressive stages of maturation, giving the appearance of a "chain of beads" where each bead is larger than the one behind it.   By the time an egg reaches the base (calyx) of the ovariole it has reached full size -- often growing up to 100,000 times larger than the original oocyte.

Mature eggs leave the ovaries through short lateral oviducts.   Near the midline of the body, these lateral oviducts join to form a common oviduct which opens into a genital chamber called the bursa copulatrix.   Female accessory glands (one or more pairs) supply lubricants for the reproductive system and secrete a protein-rich egg shell (chorion) that surrounds the entire egg.   These glands are usually connected by small ducts to the common oviduct or the bursa copulatrix. During copulation, the male deposits his spermatophore in the bursa copulatrix.   Peristaltic contractions force the spermatophore into the female's spermatheca, a pouch-like chamber reserved for storage of sperm.   A spermathecal gland produces enzymes (for digesting the protein coat of the spermatophore) and nutrients (for sustaining the sperm while they are in storage).   Sperm may live in the spermatheca for weeks, months, or even years!

During **ovulation**, each egg passes across the opening to the spermatheca and stimulates release of a few sperm onto the egg's surface.   These sperm swim through the **micropyle** (a special opening in the egg shell) and get inside the egg.   **Fertilization** occurs as soon as one sperm's nucleus fuses with the egg cell's nucleus.   **Oviposition** (egg laying) usually follows closely after fertilization.   Once these processes are complete, the egg is ready to begin embryonic development.

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**Egg Structure**

In most insects, life begins as an independent **egg**.   This type of reproduction is known as **ovipary**.   Each egg is manufactured within the female's genital system and is eventually released from her body through an **ovipositor**, a tube-like, saw-like, or blade-like component of her external genitalia.   Production of eggs by the female's body is called **öogenesis** and the egg-laying process is known as **oviposition**.   Each insect species produces eggs that are genetically unique and often physically distinctive as well -- spherical, ovate, conical, sausage-shaped, barrel-shaped, or torpedo-shaped.   Yet regardless of size or shape, each egg is composed of only a single living cell -- the **female gamete**. An egg's **cell membrane** is known as the vitelline membrane .   It is a phospholipid bilayer similar in structure to most other animal membranes.   It surrounds the entire contents of the egg cell, most of which consists of yolk (food for the soon-to-develop embryo).   The cell's **cytoplasm** is usually distributed in a thin band just inside the vitelline membrane (where it is commonly called periplasm ) and in diffuse strands that run throughout the yolk ( cytoplasmic reticulum ).   The egg cell's nucleus (haploid) lies within the yolk, usually close to one end of the egg.   Near the opposite end, the öosome (a region of higher optical density) may be visible as a dark region in the more translucent yolk.   The egg's anterior/posterior polarity is determined by the relative positions of the nucleus and the öosome.

In most insects the egg is covered by a protective "shell" of protein secreted before oviposition by accessory glands in the female's reproductive system.   This egg shell, called the chorion , is often sculptured with microscopic grooves or ridges that may be visible only under the high magnification of an electron microscope.   The chorion is perforated by microscopic pores (called aeropyles ) that allow respiratory exchange of oxygen and carbon dioxide with relatively little loss of water.   The micropyle , a special opening near the anterior end of the chorion, serves as a gateway for entry of sperm during **fertilization**.

**Embryogenesis**

Embryogenesis is a developmental process that usually begins once the egg has been fertilized.   It involves multiplication of cells (by mitosis) and their subsequent growth, movement, and differentiation into all the tissues and organs of a living insect.   The field of insect embryology has recently yielded stunning insights into the developmental processes of humans and other vertebrate organisms.   There is remarkable similarity in genes responsible for organizing the fundamental body plan in vertebrates and invertebrates.   For example, *eyeless*, a gene needed for development of an insect's compound eyes is also necessary for development of a mouse's vertebrate eyes! Although much of insect embryology is still a mystery, there has been remarkable progress in knowledge over the past few years thanks to new methods in molecular biology and genetic engineering.   Fruit flies, silkworms, and hornworms are proving to be a "rosetta stone" for embryology. A female receives sperm from her male partner during the act of mating.   She can store that sperm for long periods of time in a special part of her reproductive system, the **spermatheca**.   As a developing egg moves past the opening to the spermatheca, a few sperm are released onto its surface.   The sperm swim toward the micropyle -- the first one to reach its destination enters and injects its nucleus into the egg.   The sperm nucleus quickly fuses with the egg nucleus (syngamy) to form a diploid zygote -- a one-celled embryo.   This event is known as **fertilization**.

After the egg is fertilized, it undergoes a period of rapid growth and development known as embryogenesis, literally the "embryo's beginning".

An insect's egg is much too large and full of yolk to simply divide in half like a human egg during its initial stages of development (imagine how much time and energy it would take just to build new cell membranes!).   Birds have this same problem -- think of the yolk in a chicken's egg.   Birds solve the problem by having the embryo develop within a tiny spot of cytoplasm (the blastodisc) on the surface of the yolk.   Insects solve the problem by "cloning" the zygote nucleus (mitosis without cytokinesis) through 12-13 division cycles to yield about 5000 daughter nuclei.   This process of nuclear division is known as **superficial cleavage** (in "true" cleavage entire cells divide).   As they form, the cleavage nuclei (often called "energids") migrate through the yolk toward the perimeter of the egg.   They settle in the band of periplasm where they engineer the construction of membranes to form individual cells.   The end result of "cleavage" is the **blastoderm** -- a one-cell-thick layer of cells surrounding the yolk.

The first cleavage nuclei to reach the vicinity of the öosome are "reserved" for future reproductive purposes -- they do not travel to the periplasm and do not form any part of the blastoderm.   Instead, they stop dividing and form **germ cells** that remain segregated thoughout much of embryogenesis.   These cells will eventually migrate into the developing gonads (ovaries or testes) to become primary öocytes or spermatocytes.   Only when the adult insect finally reaches sexual maturity will these cells begin dividing (by meiosis) to form gametes of the next generation (eggs or sperm).   Germ cells never grow or divide during embryogenesis, so DNA for the next generation is "conserved" from the very beginning of development.   This strategy has a clear selective advantage:   it minimizes the risk that an error in replication (a genetic defect) will accidently be passed on to the next generation.

Blastoderm cells on one side of the egg begin to enlarge and multiply.   This region, known as the germ band (or ventral plate), is where the embryo's body will develop.   The rest of the cells in the blastoderm become part of a membrane (the serosa) that forms the yolk sac.   Cells from the serosa grow around the germ band, enclosing the embryo in an amniotic membrane.

At this stage of development, when the embryo is not much more than a single layer of cells, a group of control genes (called homeotic selector genes) become active.   These genes encode for proteins that contain a special active site (the homeobox) for binding with DNA.   They interact with specific locations in the genome where they function as switches for activating (or inhibiting) the expression of other genes.   Basically, each selector gene controls the expression of certain other genes within a restricted domain of cells based on their location in the germ band.

By regulating activity within a suite of genes that produce hormone-like "organizer" chemicals, cell-surface receptors, and structural elements, the selector genes guide the development of individual cells and channel them into different "career paths".   This process, called differentiation, continues until the fundamental body plan is mapped out -- first into general regions along an anterio-posterior axis, then into individual segments, and finally into specialized structures or appendages.

As the germ band enlarges, it begins to lengthen and fold into a sausage shape with one layer of cells on the outside (the ectoderm) and another layer of cells on the inside (the mesoderm).   An important developmental milestone, called dorsal closure, occurs when the lateral edges of the germ band meet and fuse along the dorsal midline of the embryo's body.   Ectoderm cells grow and differentiate to form the epidermis, the brain and nervous system, and most of the insect's respiratory (tracheal) system.   In addition, the ectoderm invaginates (folds inward) at the front and rear of the embryo's body to create front and rear portions of the digestive system (foregut and hindgut).   Mesoderm cells differentiate to form other internal structures such as muscles, glands, heart, blood, fat body, and reproductive organs.   The midgut develops from a third germ layer (the endoderm) that arises near the fore- and hindgut invaginations and eventually fuses with them to complete the alimentary canal.

During its early development, the embryo's body is rather worm-like in appearance.   Individual segments first become visible near the anterior end (the protocephalon) where ectodermal tissue differentiates into the brain and compound eyes.   Bud-like swellings develop in front of the mouth opening.   They will eventually grow to form the labrum (front lip of mouthparts) and the antennae.   Segments behind the mouth also develop bud-like swellings.   Each of the first three post-oral segments form paired appendages that become mouthparts:   mandibles, maxillae, and labium.   The next three post-oral segments develop into the thorax -- they form appendages that become walking legs.   Segments of the abdomen also develop limb buds but these soon shrink and disappear -- perhaps they are vestigal remnants of abdominal appendages found in more primitive arthropods (like millipedes and centipedes).   Another pair of vestigal buds appears on the head, between the antennae and the mouthparts.   This pair, called the intercalaries, may be remnants of a second pair of antennae (found in members of the class Crustacea).

**Morphogenesis**

Once an insect hatches from the egg it is usually able to survive on its own, but it is small, wingless, and sexually immature.   Its primary role in life is to eat and grow.   If it survives, it will periodically outgrow and replace its exoskeleton (a process known as **molting**).  In many species, there are other physical changes that also occur as the insect gets older (growth of wings and development of external genitalia, for example).   Collectively, all changes that involve growth, molting, and maturation are known as **morphogenesis**.

**Some widely accepted Ecological terms**

**Organism:** An organism is a self regulating and self perpetuating physio-chemical entity that is in a state of perfect balance with the environment.

**Species:** A uniform interacting population spread over time and space.

**Environment:** The environment of any organism consisting of every thing in the universe external to the particular organism. The environment includes physical or abiotic (non living) and biotic(living) environment.

**Habitat:** The place where an organism lives or the place where one would go to find the particular organism or the range of environment in which a species occur is known as the habitat of the particular organism.

**Ecological niche:** The ecological niche describes how an organism or population responds to the distribution of resources and competitors (e.g. by growing when resources are abundant, and when predators, parasites and pathogens are scarce) and how it in turn alters those same factors (e.g. limiting access to resources by other organisms, acting as a food source for predators and a consumer of prey).

**Population:** A population is a collective group of organisms. It is the address and profession of the organisms.

**Biosphere:** The earth’s living organisms interacting with their physical environment may be considered as the biosphere or ecosphere.

**Vegetation:** The collective and continuous growth of the plant in space is called vegetation.

**Community:** A community is an assemblage of population living in a particular area.

**Ecosystem:** In a given area the biotic assemblage of all the organisms interacts with its physical environment in a definite manner known as ecological system or ecosystem.

**Agroecosystem:** An agroecosystem is basically the ecosystem of an area as modified by the practice of agriculture, horticulture or animal rearing.

**Ecological succession:** The development of the community by the action of vegetation on the environment leading to the establishment of new species is termed as ecological succession.

**Climax:** A climax is the final or stable community in a successional series.

**Herbivores:** Organisms feeding on the plant tissues and capable of converting energy stored in the plant tissue into animal tissue.

**Carnivores:** The flesh eaters are carnivores.

**Omnivores:** Organisms consume both plant and animals are omnivores:

**Food Chain, Trophic level, Food web:** The transfer of food energy from the source of in plants through a series of organisms with repeated stages of eating and being eaten is known as **Food chain**.

Each successive level of nourishment as represented by links of food chain is known as **Trophic level**.

In the same ecosystem under natural condition depending upon the variety of organisms as based on their food habits, generally operate a number of linear food chains at a same time. This chain are interlinked with each other at several points. This interlocking pattern of number of food chains forms a web link arrangement known as **Food web**.

**Ecotype:** Species with wide geographical ranges often develop locally adopted population called ecotype.

**Density dependent:** The tendency for the death rate in a population to increase or the birth or growth rate to increase as the density of the population increase.

**Density independent:** The tendency for the death rate in a population to neither rise nor fall as the density increase.

**Ecological consideration of Insects**

Most ecological studies concerning insect species fall into one or more of the three following categories:-

**I. Environmental Factors**

**II. Tropisms or Instinctive reaction**

**III. Population Dynamics.**

**I. Environmental Factors:** The most important environmental factors concerning the distribution and abundance of insects are Weather, Physical and Chemical conditions of the medium, **Food,** **Enemies** and **Competition**.

**Weather:** The weather form a blanket over the entire community and directly and indirectly affects condition. Weather is a composite condition of which light, temperature, relative humidity, precipitation and wind are most important ecological components. It is not the annual average of these components which affects the species population but conditions from day to day. A signal night’s frost may decimate a population of a sub tropical insect. Similarity local conditions differ notoriously and may result in great population differences in a short distances.

**Physical and Chemical Condition:** The medium in which insect live may either temper or accentuate weather conditions impose definite conditions peculiar to itself on the organisms living within it. From a practical standpoint 3 media are of paramount importance such as **terrestrial, subterranean and aquatic.**

**Food:** Food is one of the most important factors influencing the distribution and abundance of insect. For many insect species it is a factor that has been changed radically by man’s agriculture, travel and transportation.

**Enemies:** A wide array of organism prey on or parasitize insects. These enemies constitute an environmental factors having a definite effect on the abundance and sometimes distribution of the host species. Each stage of the host species may be subjected to attack by a different set of enemies or several stages may be attacked by the same one. As a rule predaceous enemies and plant enemies such as fungi are more general in their attack on various stages and internal parasites are restricted regarding the stage they attack.

**Competition:** If we suppose an individual of a species in a situation having suitable climate and conditions of the medium and food and further than it enemies are not a critical factor, that individual may discover that another individual having similar wants also. If there is only sufficient food for one them the two individuals are in a vital competition from which only one can emerge as a survivor. Among insects, competition may be between either individuals of the same species or individuals of the different species.

**II. Tropisms or Instinctive reaction:** Instinctive behavior plays an important role in the distribution of members of an insect population. The reaction of each individual to stimuli or to a pattern of stimuli causes the individual to remain in an environment compatible to its need. If the individual is removed from such an environment the reactions to the stimuli will enable it to return or find a new environment with the maximum compatible components.

The basis of instinctive behavior is in automatic responses to definite stimuli and each such response is called a tropism. Each insect species exhibits a wide range of tropism a great number relating to sexual behavior, mating and other relating to ecological factors of the environment.

**III. Population Dynamics:** The distribution and abundance of an insect species are measures of its success under the effect of the sum total of its environmental conditions. In usual years a number of conditions will be favorable and others unfavorable to the increase of the species. The two set of factors favorable and unfavorable tend to **“Balance”** each other and

“ **Balance out”.** As a result the abundance of a species in the wild area varies from year to year. Occasionally the favorable factors predominates and the insects multiply to unusual or outbreaks numbers. Frequently but not always by any means these favorable factors are the result of man’s changing of the environment.

Outbreaks may expand from a local start and follow an amoeboid type of distribution. Many outbreaks are not spectacular but nevertheless inflicts large monetary losses if they affect something valuable to man. The cause of outbreaks are therefore a matter of great interest

**Growth forms**

A population may be defined as a group of organisms of the some species occupying a particular space to a particular time. The ultimate constituents of the population are individual organisms that can potentially inbred. The population may be sub divided into **demes or local population** which are groups of inbreeding organisms, the smallest collective unit of population. A good deal of interest has centered on population as unit of study from both the field of ecology and the field of genetics. One of the fundamental principles of the modern evolutionary theory is that natural selection acts on the individual organism and through natural selection population evolve.

The population has various group characteristics which are statistical measures that can be applied to individuals. These group characteristics are the **size or density**, the 4 population parameters that affect the size are natality (birth). mortality (death), immigration and emigration. In addition to these attributes one can derive secondary characteristics of a population such as its age distribution, genetic composition and pattern of distribution.

**Polymorphism**

The existence of several distinctly different forms within the same species. The may be simply sex difference of age difference but there are also other genetics and environmental factors which may bring about polymorphism. Bees, ants, wasps and termite have different castes e.g. workers, drones, queens, soldiers etc. A few insect has multiple larval forms e.g. Blister beetle. The first larval form is often very active, usually searching for a suitable host (e.g. *Triungulin*); later instars may be relatively inactive (e.g. Scrabaeoid larvae). Plant lice such as aphids have winged sexual and wingless parthenogenesis forms. Locusts go through a solitary non migratory phase in which there is a distinct phase and a gregarious migratory phase in which there is a distinct changes in appearance as well as in habits. Many butterflies and other insects have regional variations of color which may be connected with mimicry. The African *Papilic dardanus*, for instance has forms Which mimic several different butterflies living in the same region. There are numerous other examples.