Animal Behavior & Special Environments (Soil Ecosystem)

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For/ Fourth year students/ Zoology department

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Animal behavior

Introduction

The response of organisms to their environment is a crucial part of survival, and, as we have seen, a key component of ecology. For example, plant roots must grow toward sources of water and nutrients, while plant leaves and stems must grow to effectively capture sunlight. Bacteria, on the other hand, may increase or decrease their rates of cell division in response to fluxes of nutrients in their environment. In all forms of life one finds such coordinated responses to environmental stimuli that allow organisms to more effectively interact with their surroundings. In the animal kingdom, such responses are often fairly complex or elaborate, and are referred to by scientists as ***behavior***. Behavior can refer to many aspects of animal activity, from physiological responses, such as the production of hormones at a certain time of year, to physical activity, such as migration.

Ethology: is the scientific study of animal behavior.

Behavior: is what animal do.

- **Or**: refers to all externally recognizable changes in movements, colour, odour or sounds.
- **Or**: The response of living matter to some form of stimulus or actions performed in response to stimulus.

A Brief History of animal behavior

In the middle of the twentieth century, the study of animal behavior became an independent scientific discipline, called ethology, mainly through the efforts of two biologists, the Austrian Konrad Lorenz (1903–89) and the Dutchman Niko Tinbergen (1907–88). It can be said that Lorenz was the more philosophical, theoretical of the two, whereas Tinbergen was very much an experimentalist, who together with his students and collaborators conducted an extensive series of field and laboratory experiments on the behavior of animals of many different species. Lorenz put forward a number of theoretical models on different aspects of animal behavior such as evolution and motivation.

He was also the more outspoken of the two men, and some of his publications met with considerable controversy. In 1973 Lorenz and Tinbergen were awarded the Nobel Prize for Physiology and Medicine. They shared their prize with Karl von Frisch (1886–1982), an Austrian comparative physiologist and ethologist who had pioneered research into the “dance language” of bees.

Methods of studying Ethology

- Ethology is a combination of laboratory and field science.

1- **Observation** of the animal in its natural field without causing any disturbance and record all external factors surrounding the animal.

2- Laboratory experiments on the animal in environment nearly as natural.

3- Analyze each behavior in order to understand the roles of development, ecology, physiology and evolution in shaping that behavior.

Why is it necessary for us to study animal behavior?

1- Majority of people come to contact with animals.
2- Hunter has to know the ways of animal which is hunted.
3- Farmer must be aware of the habits of his farm animals.
4- Knowing the behavior of insects and rodents that damage our crops helps in controlling.
5- Industries like cattle breeding and fishery have been developed after understanding behavior of these animals.
6- Can be important in animal training.

Why do animal behave?

- Animals behave for their benefit and survive.

Example:

- The male of stickle-back (a small fish) (fig. 1) builds a tubular nest of grass and weeds for fertilized eggs and guards them by swimming around the nest and fanning the eggs with the pectoral fins for continuous fresh dissolved oxygen. As the eggs grow the male increase fanning for more oxygen and form a number of holes in the roof of the nest. If the male is removed, the eggs will die.

Fig. (1)

What is the stimulus?

Stimulus: something that elicits a response and can be divided to:

External stimulus: Something outside the animal.

- Ex.: Sound, sight, touch, smell, taste, heat, light, chemicals, colors, pressure, presence of another animal.

Internal stimulus: Something inside the animal.

- Ex.: Hunger, fatigue, feeling hot/cold, hormones.

Animal motivation

Animals generally do not simply react to the immediate stimuli available from the environment, but maintain also an internal state, which together with the external (sensory) stimuli determine which action to take. Behaviors which depend on an internal state are said to be **motivated**, and the study of animal motivation is an important part of ethology. Motivational states include thirst, hunger, fear and the urges to migrate, mate, nest-build and dust bathe. These motivations are internal states which vary in magnitude from one moment to the next, and that help determine which stimuli animals will react to and which they will not; which goals they seek out and which they do not. For example: a hungry dog would get up, look around for food, at this time **motivational level** or the urge for eating is at **the highest level**. When it finds goal (food) it starts eating and after that the motivational level goes down to the **minimum level.** This dog will not eat for next few hours. By this time the motivational level rises again gradually. Thus the dog would respond to food differently when it is hungry or full. There seems to be **an internal drive** to elicit a particular behavior at particular time.

General forms of animal behavior

1-Foraging = feeding

e. g. locate, obtain & consume food

2. **Parental Care** = ensuring survival of young

e. g. carrying, nursing, cuddling, holding young

3. **Courtship** = attracting a mate

e. g. courtship displays, bright feathers, songs, other vocalizations, head butting, fighting

4. **Reproductive** e.g. mating, giving birth

5. **Offensive/Defensive** = aggression, submissive behavior, defense from aggressors

e. g. hiding, fighting, escape, threatening

6. **Territorial** = protect a resource for exclusive use

e. g. scenting / marking, birdsong, protection of mate / offspring, space, food or water source

Animal behavior can be classified to:

- 1- **Innate** Behavior: natural, inborn and acquired through inheritance.
- 2- **Learned** Behavior: acquired through experience.
- 3- **Complex** Behavior: a blend of innate and learned components.

Innate Behavior

- It is inherited behavior that comes naturally.
- Genetically programmed responses to stimuli.
- Innate= instinctive= inborn= inherent= consummatory action.

In general innate behaviors will always be:

- **Heritable** -- encoded in DNA and passed from generation to generation
- **Intrinsic** -- present in animals raised in isolation from others
- **Stereotypic** -- performed in the same way each time by each individual
- **Inflexible** -- not modified by development or experience
- **Consummate** -- fully developed or expressed at first performance.

How do we know if a behavior is innate?

By definition, an innate behavior is genetically built in to an organism rather than learned. But how do biologists figure out if a behavior is innate?

In general, scientists test whether a behavior is innate by seeing whether it is performed correctly by animals that have not had a chance to learn the behavior by experience. For instance, this might involve raising young animals separate from adults or without stimuli that trigger the behavior.

As an example, let's consider digging behavior in the deer mouse and the beach mouse. These species are closely related and can interbreed, but they live in different natural environments and have different burrow-digging behaviors.

- The deer mouse digs a small, short burrow.
- The beach mouse digs a long burrow with an escape tunnel or "back door" to get away from predators.
- Is this difference in burrow digging innate? To ask this question, researchers raised mice of both species in the lab with no exposure to sand or opportunity to burrow. Then, they provided them with sand, a cue for burrow construction.
- Given sand, each naive mouse dug exactly the type of burrow made by its species in the wild. That is, beach mice dug a long burrow with an escape tunnel, while deer mice dug a short burrow without an escape tunnel. The ability of the mice to construct their normal tunnels, without ever having seen such a tunnel before, showed that the burrowing behavior was indeed innate.

Another example:

Cuckoos, a type of North American forest birds, display a well-known example of innate behavior in the animal kingdom. In cuckoos, parents often lay their eggs in the nest of other birds, which in turn raise the cuckoo young as their own. However, as the cuckoo matures, it takes on the behavioral characteristics of its biological parents, rather than its surrogate parents.

Types of innate behavior

1- Refelxes

A **reflex** is an automatic response to a stimulus. When you touch a hot object, you quickly pull you hand away using the withdrawal reflex. The doctor uses a small rubber hammer to hit someone knee. When he does this, the leg immediately kicks up. Even though the patient hasn't had this done before, because reflexes are innate.

These are the steps:

- The stimulus is detected by **receptors** in the skin.
- These initiate nerve impulses in **sensory neurons** leading from the receptors to the spinal cord.
- The impulses travel into the spinal cord where the sensory nerve terminals synapse with **interneurons**.
    - Some of these synapse with **motor neurons** that travel out from the spinal cord entering mixed nerves that lead to the flexors that withdraw your hand.
    - Others synapse with inhibitory interneurons that suppress any motor output to extensors whose

contraction would interfere with the withdrawal reflex.

2- **Orientation Behaviors**

They are coordinated movements (walking, flying, swimming, etc.) that occur in response to an external stimulus. There are two types:

* **Kinesis** is non-directed orientation, that is, the animal exhibits a "random walk". An example of kinesis would be cockroaches in response to light (they run either towards or away from the light; completely random).

***Taxis** is a movement directly toward (positive) or away from (negative) a stimulus.

An example of taxis would be birds migrating south to a warmer environment.

Another example, sea turtle hatch and dig their way out of the buried hatchery at night. They struggle toward the sea. There is no parent present to tell them they must wait for nightfall or that they must get to the sea.

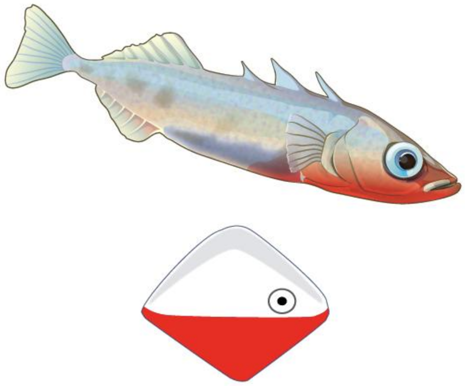
3- **Fixed Action Patterns (FAP)**

FAP is a sequence of coordinated movements that are performed together as a "unit" without interruption. Each FAP is triggered by a unique stimulus variously known as a **sign stimulus**, a **key stimulus**, or a **releaser.**

A classic example of a fixed action pattern comes from the three-spined stickleback, a small freshwater fish. During the breeding season, male sticklebacks develop a red belly and display innate aggressive behavior towards other males.

When a male stickleback spots another nearby male, he will launch into a fixed action pattern involving aggressive displays designed to scare off the stranger. The specific stimulus that triggers this fixed action pattern is the red belly coloration pattern characteristic of males during breeding season.

How do we know that this is the trigger? In the lab, researchers exposed male fish to objects that were painted red on their lower halves but didn't otherwise look like a fish, see below. The male sticklebacks responded aggressively to the objects just as if they were male sticklebacks. In contrast, no response was triggered by lifelike male stickleback models that were painted white.



By some accounts, this fixed action pattern has even been triggered by a fire truck driving past a male stickleback's tank.

Another example of a releaser is the beak movements in many bird species performed by the newly-hatched chicks, which stimulates the mother's regurgitating process to feed her offspring.

Ex.: (fig. 2) a goose rolls a displaced egg near its nest back to the others with its beak. The sight of the displaced egg triggers this mechanism.

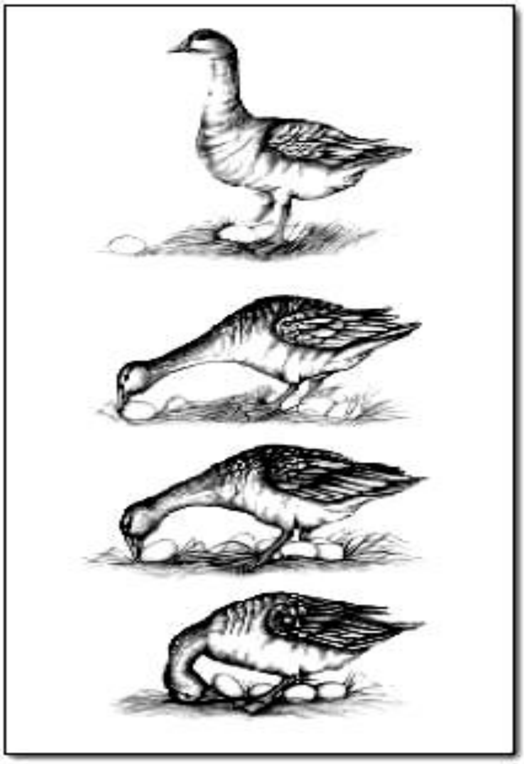


Fig. (2)

Other forms of FAP

1- Mating

2- Feeding patterns

3- Nest building (fig. 3, 4)

4- Parental care,

5- Vocalization

6- Songs of crickets, birds and whales.

7- Wing cleaning in insects.

8- Birds territory and aggression

9- Construction of web by spider

Fig. (3): The weaver bird

Fig. (4): The tailor bird

Learned Behaviors

Learned behaviors come from experience and are not present in an animal at its birth. Through trial and error, memories of past experiences and observations of others, animals learn to perform certain tasks. Generally speaking, learned behaviors are not inheritable and must be taught to or learned by each individual.

In general, learned behaviors will always be:

1- **Nonheritable** -- acquired only through observation or experience.

2- **Extrinsic** -- absent in animals raised in isolation from others

3- **Permutable** -- pattern or sequence may change over time

4- **Adaptable** -- capable of modification to suit changing conditions

5- **Progressive** -- subject to improvement or refinement through practice

Learned behavior can be of two types:

A- Flexible: accept further changes and experiences.

1- Habituation is learning to "ignore" stimuli that are unimportant, irrelevant, or repetitive.

For example, 1-a puff of air on the cerci of a cockroach (fig. 5) will cause the animal to scamper away. But repeating the same stimulus over and over will lead to a decrease in the response and eventually to no response at all.

2- Birds learn to ignore scare crow.

3-In squirrels: When one of them feels threatened, the others hear its signal and go to the nearest refuge. However, if the signal comes from an individual that has caused many false alarms, the other squirrels ignore the signal.

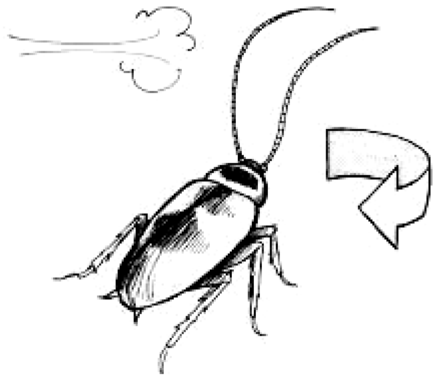


Fig. (5)

2- Associative Learning which takes two forms: classical conditioning and operant conditioning.

(Classical Conditioning) is learning to associate one stimulus with another, unrelated stimulus.

Honey bees, for example, learn to associate floral colors and fragrances with the presence of nectar. They can be "trained" to collect sugar water from colored dishes on a feeding table. If a blue dish with pure water sits next to a yellow dish with sugar water, worker bees will quickly learn to associate "yellow" with "food" (even if the dishes are moved around). When solutions in the two dishes are suddenly swapped (sugar to blue and water to yellow), the bees will ignore blue and continue to forage at yellow until they eventually "learn" (by trial and error) to look for the blue dish.

In another experiment (**Ivan Pavlov's experiments**) (fig. 6) every time a dog was given food, a bell was rung. This was repeated during several trials. After some time, the dog learned to associate the ringing of the bell with food and to respond by salivating.

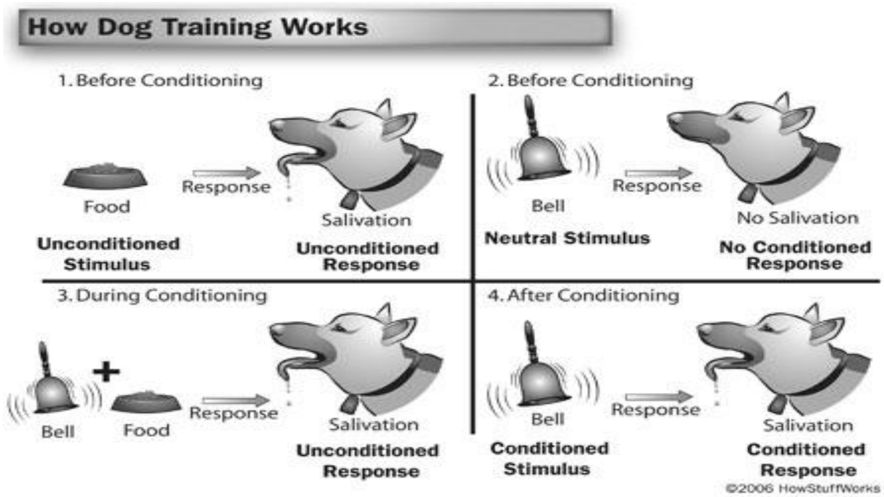


Fig. (6)

Also Classical Conditioning involves animals recognizing the relationship between certain stimuli and their positive or negative effects.

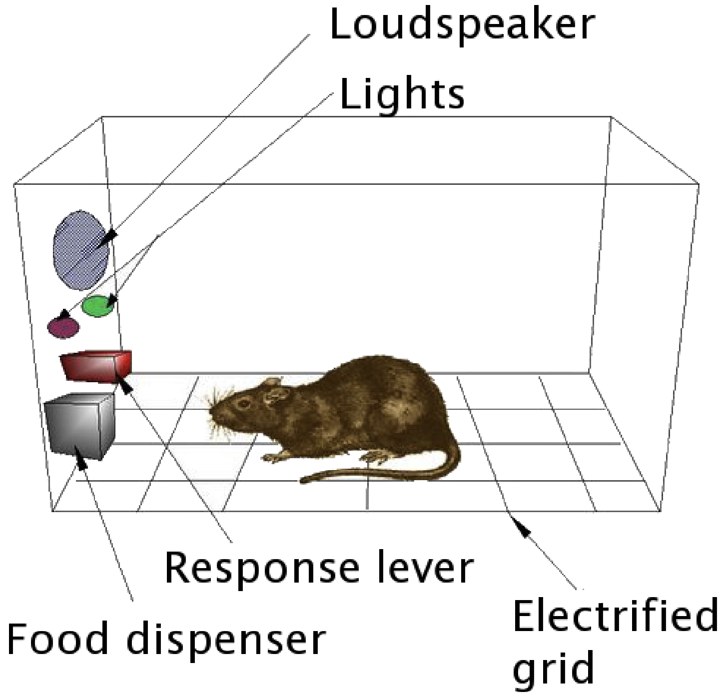
A bird that normally preys upon butterflies may capture and attempt to eat a brightly colored butterfly, such as a monarch, that is completely unpalatable. If this experience is strong enough, or is repeated enough times, the bird may learn to associate the bright colors of the monarch butterfly with its bad taste, and so will not prey on those butterflies anymore. Interestingly enough, this phenomenon may also bring a benefit to other butterflies that resemble the bad tasting monarch, as birds will also by pass them as prey items due to their physical appearance.

Operant conditioning

Operant conditioning is a bit different than classical conditioning in that it does not rely on an existing stimulus-response pair. Instead, whenever an organism performs a behavior—or an intermediate step on the way to the complete behavior—it is given a reward or a punishment. At first, the organism may perform the behavior—e.g., pressing a lever—purely by chance. Through reinforcement, the organism is induced to perform the behavior more or less frequently.

One prominent early investigator of operant conditioning was the psychologist **B. F. Skinner**, the inventor of the Skinner box, see image below. Skinner put rats in boxes containing a lever that would dispense food when pushed by the rat. The rat would initially push the lever a few times by accident, and would then begin to associate pushing the lever with getting the food. Over time, the rat would push the lever more and more frequently in order to obtain the food.

Operant conditioning (sometimes referred to as instrumental conditioning) is a method of learning that occurs through rewards and punishments for behavior. Through operant conditioning, an association is made between a behavior and a consequence for that behavior.



Not all of Skinner's experiments involved pleasant treats. The bottom of the box consisted of a metal grid that could deliver an electric shock to rats as a punishment. When the rat got an electric shock each time it performed a certain behavior, it quickly learned to stop performing the behavior. As these examples show, both positive and negative reinforcement can be used to shape an organism's behavior in operant conditioning. Ouch! Poor rats!

Operant conditioning is the basis of most animal training. For instance, you might give your dog a biscuit or a "Good dog!" every time it sits, rolls over, or refrains from barking. On the other hand, cows in a field surrounded by an electrified fence will quickly learn to avoid brushing up against the fence.

As these examples illustrate, operant conditioning through reinforcement can cause animals to engage in behaviors they would not have naturally performed or to avoid behaviors that are normally part of their repertoire.

3- Cognitive learning, perhaps the most complex type of learning.

Cognitive learning involves the ability of animals to not only receive and store information, but to also combine different sources of information and solve problems. Cognitive learning is also often associated with the presence of consciousness or self-awareness. As one example, consider a group of chimpanzees placed in a room. In the room, there are sticks on the floor, and food that is too high up to be reached by the chimps alone. In this scenario, the chimps eventually utilize the sticks to reach the food source. It isn't that sticks are directly associated with food in the chimpanzees' experience, but they are representative of a tool that, in this case, can be used to solve the problem of how to get to the food.

It is doubtful whether cognitive learning occurs in all or even most animals.

Cognitive learning seems to be more prevalent in certain groups of animals, such as the primates and dolphins.

4- Imitation is an advanced behaviour whereby an animal observes and exactly replicates the behaviour of another. Fig. (7)

The National Institutes of Health reported that capuchin monkeys preferred the company of researchers who imitated them to that of researchers who did not. The monkeys not only spent more time with their imitators but also preferred to engage in a simple task with them even when provided with the option of performing the same task with a non-imitator.

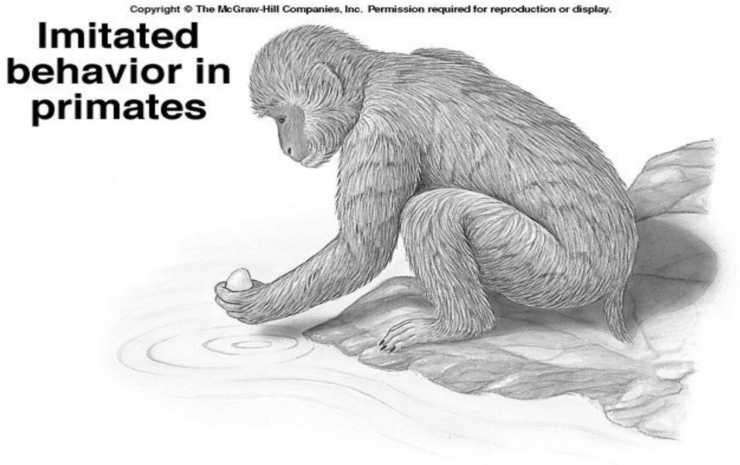


Fig. (7)

B- Restricted, it is only one type called imprinting.

Imprinting occurs in the young of some animals. Fig. (8)

Imprinting, which is very common in bird species, occurs when young of a species first recognize another organism as a parent figure. In most cases, the first other organism that newborn animals see is their parent. From that point, newborns quickly learn to associate their parent with food and protection. In some cases, however, offspring happen to see other organisms before their parents, and so 'imprint' on them, instead. This often happens, for instance, when humans raise ducks or geese from eggs. The first parent-figure that the newly hatched birds see, and which they associate with food and protection, is their human 'parent'. Because of this, chicks will follow around the person on which they imprinted, and even develop some of their behaviors.

Imprinting is also interesting because it is a time-sensitive phenomenon. In other words, organisms that imprint have a sensitive period during which they exhibit a strong tendency to imprint, and after which they are capable of imprinting much less, if at all.

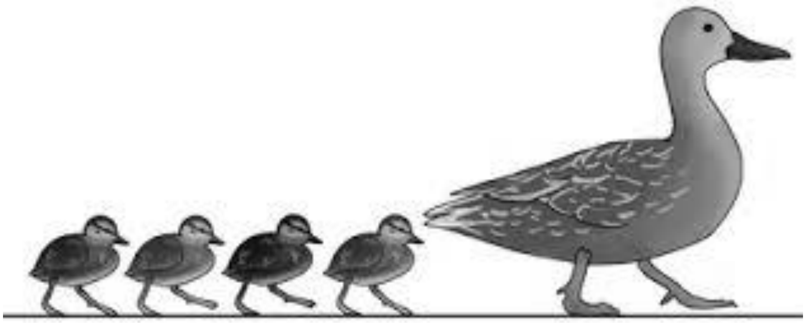


Fig. (8)

3-Complex Behavior

Behavior is actually more complicated than "innate" or "learned." Most behaviors are a mix of the two, neither completely innate nor entirely learned. For instance, some innate behaviors--such as flying in insects--can be perfected over time and through experience. Locusts know how to fly from birth, but they get better at it with practice, eventually learning to expend less energy to accomplish the same flight. The same is certainly true of foals, born with the knowledge of how to walk; it still takes time for the foal to learn how to operate its legs.

Social behavior and social organization

Social behavior is defined as interactions among individuals, normally within the same species, that are usually beneficial to one or more of the individuals. Social behavior serves many purposes and is exhibited by an extraordinary wide variety of animals, including invertebrates, fish, birds, and mammals. Thus, social behavior is not only displayed by animals possessing well-developed brains and nervous systems.

Types of Animal Groups

1- **Aggregation or association** = chance gathering produced by external factors or temporary union of individuals reacting in the same way to environmental stimuli.
   e.g.: insects gather around a source of light for mating.
   e.g.: earthworms collect under a rock for moisture or protection.
   e.g.: housefly collected around food source.
2- **True societies or organized societies** = permanent (sometimes temporary) union of individuals held together by mutual attraction of its members.

Eisenberg (1965) proposed four properties of organized societies:

1- **Communication**: all organized societies have some form of complex communication system. Members of a social group indicates messages by touch, change in coulor, vocalization, raise hair or complex messages like facial expression with vocalization in chimpanzees.
2- **Cohesion**: the individuals of a society tend to remain in close proximity to one another e.g. all the bees of a group

live in one hive, the individuals in a herd of deer or wolves remain in close in the home range.

3- **Division of labour**: individuals of different status (sexes or age group) have different function in remaining the society. Baboon and macaque young adult males often serve as front or rear guard for group as the group moves, they are the ones to face perdition. The old, adult, dominant males remain in a more central place decide the foraging and resting areas, the function of females is to bear and bring up infants and care for young. In bees colony there is one queen, few drones and workers (builders, soldiers and foragers).

4- **Permanence and impermeability**: individuals making up a society tend to be the same, there is little migration from or to the group.

Benefits of being Social

Social behavior seems to provide many benefits to those who practice it.

1- Many animals are **more successful in finding food** if they search as a group. This is especially true if food resources are clumped together only in certain places. If more individuals are cooperating in the search, there is a greater chance one of them will find the clump of food. In some cases, foraging in a group makes it easier to capture a prey. Dolphins are known to surround a school of fish and to take turns darting into the center to eat the fish that are trapped in the middle. Many carnivores (wolves and lions) will band together when they try to capture large prey. When these animals are hunting much smaller prey, they will often hunt singly.

2- Many animals live in social groups for **protection**. Although one baboon might not be able to fight off a leopard, a troop of baboons often is able to do so. In addition, with more individuals cooperating together, some can serve as sentries looking for danger while the other group members are eating or sleeping like Prairie dogs.
Many prey species, such as schools of fish and flocks of shorebirds, travel in groups in which their rapidly movements are highly coordinated. This behavior creates confusion for the predator. However, if one individual is unable to keep up with the group, the predator will then be able to focus on it and usually will succeed in catching it.

3- Some animals form social groups to **make travel easier**. Canada geese and other bird species typically fly in a V formation. Just like bicyclists who ride behind one another in order to reduce wind resistance, the geese fly in formation to reduce the wind they must encounter.

4- Some animals congregate in close proximity to one another in cold weather in an effort **to stay warm**. Small birds are sometimes known to huddle so closely they form a single large ball of birds.

5- **Facilitation of reproduction**: group living improves reproductive success. In some animals it is difficult for them to find a mate in solitary but it may be easier in large social group.

Aggression and Dominance

Sociality requires cooperation at the same time animals tend to compete with one another because of limitations in the common resources that all require for life like food, water, sexual mates, or shelter when such requirements are limited in quantity and are therefore worth a fight.

Aggression may define as an offensive action, or threat, to force others to abandon something they own or might attain. Many behaviorists consider aggression part of a somewhat interaction called agonistic behavior, referring to any activity related to fighting, whether it be aggression, defense, submission, or retreat.

The winner of an aggressive competition is dominant to the loser, the subordinate. In a social species, dominance interactions often take the form of a **dominance hierarchy**. One animal at the top wins encounters with all other members in the social group; the second in rank wins all but those with the top-ranking individual.

Such a simple, ordered hierarchy was first observed in chickens by Schjelderup-Ebbe, who called the hierarchy a "peck-order." Once social ranking is established, actual pecking diminishes and is replaced by threats, bluffs, and bows.

Aggression and Territoriality

Territorial ownership is another facet of sociality in animal populations. A **territory** is a fixed area from which intruders *of the same species* are excluded. This exclusion involves defending the area from intruders and spending long periods of time being conspicuous on the site. Territorial defense has been observed in numerous animals: insects, crustaceans, fishes, amphibians, lizards, birds, and mammals, including humans.

Territoriality is generally an alternative to dominance behavior, although both systems may be observed operating in the same species. A territorial system may work well when the population is low, but it may break down with increasing population density and be replaced with dominance hierarchies in which all animals occupy the same space

Territory can be classified according to activities that take place inside it:

1- **Mating, nesting and feeding territory**: common among song birds and some mammals such as the muskrat. The males find a territory and defend it by fighting or by song in the case of birds.
2- **Mating and nesting territory**: common among some hawks.
3- **Mating territory** as in wood-cock and this area is not defended.
4- **Nesting territory**: some birds defend territories that large enough to build a nest.
5- **Feeding and resting territory**: common defended in winter.

Birds are conspicuously territorial. Most male songbirds establish territories in the early spring and defend these vigorously against all males of the same species during spring and summer when mating and nesting are at their height..

Territorial behavior is not as prominent with mammals as it is

with birds. Mammals are less mobile than birds, making it more difficult for them to patrol a territory for trespassers. Instead, many mammals have home ranges. **A home range** is the total area an individual traverses in its activities. It is not an exclusive, defended preserve but overlaps with the home ranges of other individuals of the same species.
For example, home ranges of baboon troops overlap extensively, although a small part of each range becomes the recognized territory of each troop for its exclusive use. Home ranges may shift considerably with the seasons. A baboon troop may have to shift to a new range during the dry season to obtain water and better grass.

Mating Systems

Sometimes social behavior is exhibited by groups of males or females during the breeding season. Animals display a diversity of mating systems. Behavioral ecologists generally classify mating systems by the degree to which males and females associate during mating.

1- **Monogamy** is an association between one male and one female at a time and both join to rear offspring. This type found in 90 % birds and less than 4 % mammals.

2- **Polygamy**: females and males may have more than one mate.

   a- **Polygyny** refers to a male that mate with more than one female. Male usually do not stay to help rearing young. This type most common among mammals. There are specific types of polygyny:

<u>Resource defense polygyny</u> occurs when males gain access to females indirectly by holding critical resources. For example, female bullfrogs prefer to mate with males who are larger and older. These males defend territories of higher quality than smaller males because their territories have better temperature regimes for tadpoles to grow or because they are free of predatory leeches.

<u>Female defense polygyny</u> occurs when females aggregate and, consequently, are defendable. Thus, when female elephant seals occupy a small island, dominant males can defend and gain access to them for mating relatively easily. This situation was previously known as a "harem."

<u>Male dominance polygyny</u> occurs when females select mates from aggregations of males. For example, some animals form leks. A lek is a communal display ground where males congregate to attract and court females. Females choose and mate with the male having the most attractive qualities. Leks characterize some birds, including prairie chickens and sage grouse. In these systems, sexual selection is often intense, resulting in evolution of bizarre courtship rituals and exaggerated morphological traits.

- **b- Polyandry** is a system in which a female mates with more than one male. It is the rarest and unusual mating system found in some birds.

3- **Promiscuity**: members of both sexes mate randomly (any male with any female in the group). The two sexes do not form long term bonds. It found in bears, wildebeests, and chimpanzees.

<u>Parental care</u>

Parental care is found in a broad range of taxonomic groups, including both ectothermic (invertebrates, fish, amphibians and reptiles), and endothermic (birds and mammals) species. Care can be provided at any stage of the offspring's life: pre-natal care including behaviours such as egg guarding, preparation of nest, brood carrying, incubation, and placental nourishment in mammals; and post-natal care including food provisioning and protection of offspring.

In Fishes

A number of **fishes** build nests made of bubbles that not only hold the eggs together but also provide the oxygen necessary for the developing embryos. **Other fishes,** particularly those that live in oxygen-poor waters, display elaborate fanning behaviour to keep the water moving around the eggs. **In some fishes**, the female incubates the egg in her mouth, thus providing protection against predators as well as constant aeration. The fry (young) of some of these mouthbreeders travel in a school near the parent. When danger approaches, they flee into the parent's mouth and later swim out after the danger passes.

In Birds

Birds have the problem of keeping the eggs at an optimum temperature for development of the embryo. With the onset of egg laying in many species, the feathers of the lower abdomen are lost, and the skin in that area becomes thickened and highly vascularized (filled with blood vessels), forming the so-called **brood patches**. The brood patches and "broodiness" are controlled by several hormones, combined with visual and tactile stimuli. Chief among these hormones is prolactin, which also controls the production of pigeon milk, a cheese-like substance produced only in the crops of adult doves and pigeons.

In mammals

Although there are some outstanding exceptions, most young **mammals** are completely helpless at birth. This helplessness is most striking in the marsupials (*e.g.*, opossums and kangaroos), in which the young are born at a very early stage of development; they crawl through the mother's hair to the brood pouch, where they attach themselves to a nipple and their development continues for many more months.

An early characteristic behaviour in **mammals** following birth is that of the mother licking the newborn. This serves at least two functions—one is general cleanliness to avoid infections or the attraction of parasites; the other would appear to be purely social. If a newborn mammal is removed from its mother and cleaned elsewhere before she can lick it, she usually will not accept it. Thus, licking behaviour also serves, in some manner, to establish a unique relationship between the mother and her offspring.

In some mammalian species, the females form social groups during the breeding season. In certain circumstances, females will look after one another's offspring while the other mother goes out to find food. In other species, such as lemurs, females may form social groups as a kind of defense. Males of some lemur species will try to kill the offspring of females that mated with another male. By banding together, the females are sometimes able to ward off the attacking male.

Animal Communication

Animal communication is "the transmission of a signal from one animal to another such that the sender benefits, on average, from the response of the recipient". Communication most often happens between members of a species, though it can also take place between different species. Animals may communicate by sounds, scents, touch, and movement.

1- Visual communication

It is done in various ways depending on the animal's physical structure and behavior. These includes:

a- changes in facial expressions. Dogs for example express anger through a snarling and showing their teeth. In alarm their ears will perk up. When fearful a dog will pull back their ears, expose teeth slightly and squint eyes.

b- changes in body shapes, when a cobra expands the skin on its neck as a sign of attack.

c- Change in color, some cephalopods, such as the octopus, have specialized skin cells that can change the apparent colour, rapid changes in skin colour are used while hunting and in courtship rituals.

d- Change in movements, honey bees use a dance to help other bees find flowers to collect food to the hive. Also courtship dancing in some birds. Fig. (9)

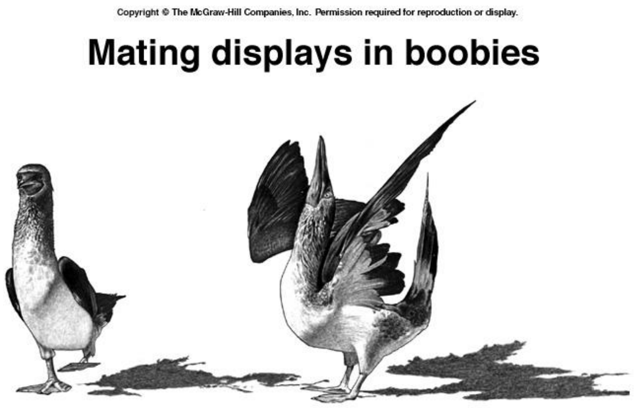


Fig. (9)

2- <u>Vocal communication</u>

Many animals communicate through vocalizations. Communication through vocalization is essential for many tasks including mating rituals, warning calls, conveying location of food sources, and social learning. Male mating calls are used to signal the female and to beat competitors in species such as hammer-headed bats, red deers, humpback whales and elephant seals. In birds, who use sounds to convey warnings, attract mates, defend territories, and coordinate group behaviors. Some birds also produce birdsong.

- Monkeys cry out a warning when a predator is near, giving the other members of the troop a chance to escape. Vervet monkeys even have different calls to indicate different predators.

- Bullfrogs croak to attract female frogs as mates. In some frog species, the sounds can be heard up to a mile away!
- Gibbons use calls to mark their territory, keeping potential competitors away. A paired male and female, and even their offspring, may make the calls together.

Water, like air, can carry sound waves, and marine animals also use sound to communicate. Dolphins, for instance, produce various noises—including whistles, chirps, and clicks—and arrange them in complex patterns. The idea that this might represent a form of language is intriguing but controversial.

3- Tactile communication

Tactile communication is the use of feel or touch to communicate. An example of tactile communication is when a cat rubs against your leg. Many species of primates groom each other using touch to both clean one another and to grow closer bonds.

4- Olfactory (or chemical) communication

Many mammals, in particular, have glands that generate distinctive and long-lasting smells, and have corresponding behaviours that leave these smells in places where they have been. Often the scented substance is introduced into urine or feces. Sometimes it is distributed through sweat, though this does not leave a semi-permanent mark as scents deposited on the ground do. Many animals such as **mountain lions** mark their territories by urinating on territory boundaries. **Bees** carry with them a pouch of material from the hive which they release as they reenter, the smell of which indicates that they are a part of the hive and grants their safe entry. **Ants** use pheromones to create scent trails to food as well as for alarm calls, mate attraction and to distinguish between colonies. Additionally, they have pheromones that are used to confuse an enemy and manipulate them into fighting with each other. A *pheromone* is a secreted chemical signal used to trigger a response in another individual of the same species. Pheromones are especially common among social insects, such as ants and bees. Pheromones may attract the opposite sex, raise an alarm, mark a food trail, or trigger other, more complex behaviors.

Dogs also communicate using pheromones. They sniff each other to collect this chemical information, and many of the chemicals are also released in their urine. By peeing on a bush or post, a dog leaves a mark of its identity that can be read by other passing dogs and may stake its claim to nearby territory

5- <u>Electro-communication</u>

Some fishes and animals are capable of releasing electricity in the water to use as electrocommunication (fig. 10).The Black Ghost Knife fish and Elephant Nose fish produce electric organ discharges (EOD) to communicate where they are, what gender they are and to help locate surrounding prey.

These fish produce these EODs in either a pulse or wave pattern depending on the fish.

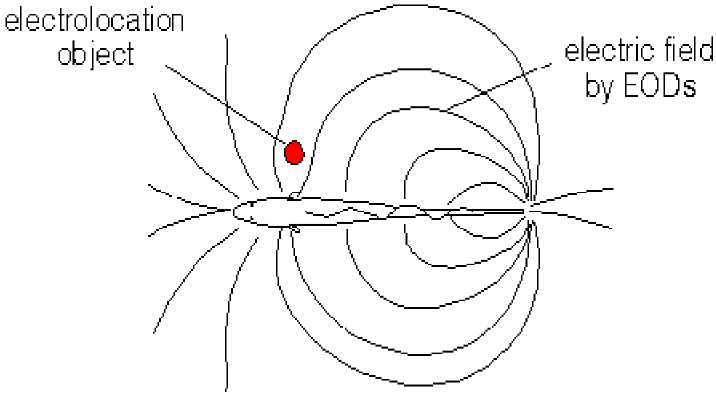
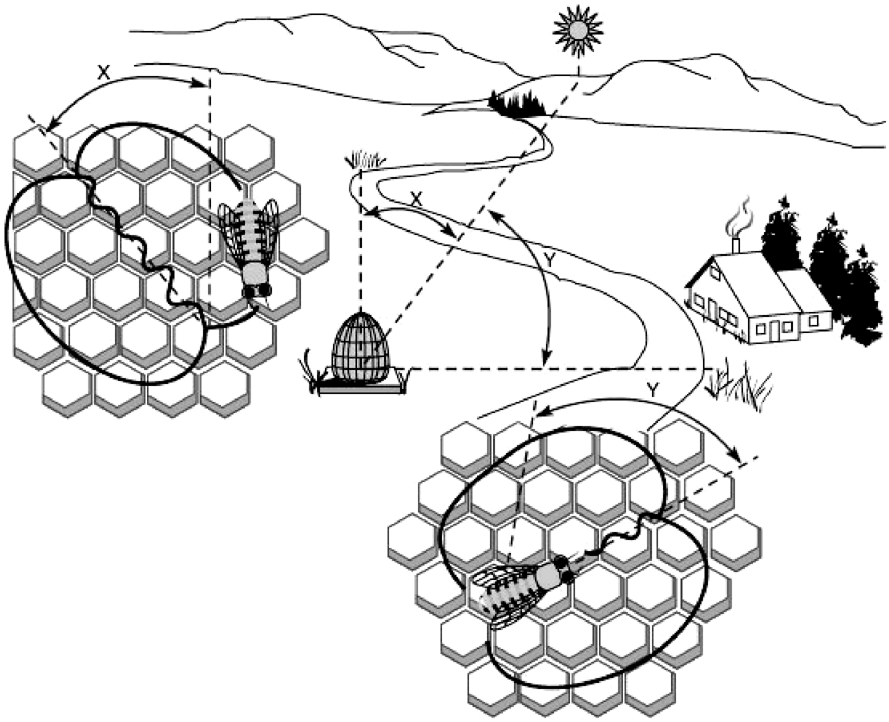


Fig. (10)

<u>Language of Honey Bees</u>

One of the most complexes of all nonhuman communication systems is the symbolic language of bees. Honey bees are able to communicate the location of food resources when these sources are too distant to be located easily by individual bees. They communicate by dances, (fig. 11) which are mainly of two forms. The form having the most informational richness is the **waggle dance**. Bees most commonly execute these dances when a forager has returned from a rich source, carrying either nectar in her stomach or pollen grains packed in basketlike spaces formed by hairs on her legs. The waggle dance is roughly in the pattern of a figure-eight made against the vertical surface on the comb inside the hive. One cycle of the dance consists of three components: (1) a circle with a diameter about three times the length of the bee, (2) a straight run while waggling the abdomen from side to side and emitting a pulsed, low frequency sound, and (3) another circle, turning in the opposite direction from the first. This dance is repeated many times with the circling alternating clockwise and counterclockwise.

The straight, waggle run is the important informational component of the dance. Waggle dances are performed almost always in clear weather, and the direction of the straight run is related to the position of the sun. If the forager has located food directly toward the sun, she will make her waggle run straight upward over the vertical surface of the comb. If food was located 60 degrees to the right of the sun, her waggle run is 60 degrees to the right of vertical. We see then that the waggle run points at the same angle relative to the vertical as the food is located relative to the sun.



Figure(11): Waggle dance of the honey bee used to communicate both the direction and distance of a food source. The straight run of the waggle dance indicates direction according to the position of the sun (angles X and Y).

Distance of the food source is also coded into bee dances. If the food is close to the hive (less than 50 m), the forager employs a simpler dance called the **round dance.** The forager simply turns a complete clockwise circle, then turns, and completes a counterclockwise circle, a performance that is repeated many times. Other workers cluster around the scout and become stimulated by the dance as well as by the odor of nectar and pollen grains from flowers she has visited.

The recruits then fly out and search in all directions but do not stray far. The round dance carries the message that food is to be found in the vicinity of the hive.

If the food source is farther away, round dances become waggle dances, which provide both distance and directional information. The tempo of the waggle dance is related inversely to the food’s distance. If the food is about 100 m away, each figure-eight cycle lasts about 1.25 seconds; if 1000 m away, it lasts about 3 seconds; and if about 8 km (5 miles) away, it lasts 8 seconds. When food is plentiful, the bees may not dance at all. But when food is scarce, the dancing becomes intense, and other workers cluster around the returning scouts and follow them through the dance patterns.

Functions of communication

While there are as many kinds of communication as there are kinds of social behaviour, a number of functions have been studied in particular detail. They include:

1-**Agonistic interaction**: everything to do with contests and aggression between individuals. Many species have distinctive threat displays that are made during competition over food, mates or territory; much bird song functions in this way. Often there is a matched submission display, which the threatened individual will make if it is acknowledging the social dominance of the threatener; this has the effect of terminating the aggressive episode and allowing the dominant animal unrestricted access to the resource in dispute.

2-**Mating rituals**: signals made by members of one sex to attract or maintain the attention of potential mate, or to cement a pair bond. These frequently involve the display of body parts, body postures or the emission of scents or calls, that are unique to the species, thus allowing the individuals to avoid mating with members of another species which would be infertile.

3-**Ownership/territorial**: signals used to claim or defend a territory, food, or a mate.

4-**Food-related signals**: many animals make "food calls" that attract a mate, or offspring, or members of a social group generally to a food source. When parents are feeding offspring, the offspring often have begging responses (particularly when there are many offspring in a clutch or litter - this is well known in altricial songbirds, for example). Perhaps the most elaborate food-related signal is the dance language of honeybees studied by Karl von Frisch.

5-**Alarm calls**: signals made in the presence of a threat from a predator, allowing all members of a social group (and often members of other species) to run for cover, become immobile, or gather into a group to reduce the risk of attack.

Communication between Humans and Other Animals

Human–animal communication is the communication observed between humans and other animals, from non-verbal cues and vocalizations through to, potentially, the use of a sophisticated language.

Scientists believe that to establish two-way communication between humans and other animals, the investigator must translate meanings into symbols that the animal can understand.

In the late 1960s Beatrix and Allen Gardner of the University of Nevada in Reno began using American Sign Language (ASL) to train a chimpanzee named Washoe to communicate with her hands the same way that deaf people do. By age five Washoe could sign 132 words, which she could put into strings forming sentences and phrases. She could answer questions, make suggestions, and convey moods. In one session, when asked what a swan was, Washoe answered “water bird.” Washoe also taught signs to other chimpanzees. At first, signs were used as play but soon the chimpanzees used them to make spontaneous requests to trainers such as

"drink," "tickle," and "hug." Similar work has been done with other primates including gorillas, orangutans, and pygmy chimpanzees.
Irene Pepperberg of the University of Arizona has worked for years with an African Grey parrot named Alex. Because parrots can vocalize like humans, Pepperberg was able to communicate with Alex using human vocal language. Over the years Alex learned a number of attributes including colors, shapes, and materials for more than 100 objects. Alex not only can identify objects by colors and shape, but can also distinguish the difference between two objects. Thus, if Alex is given two objects of the same color but one larger than the other, he could state that the difference between them was "size." Alex can also count and relate to the trainer how many objects of each particular category are present.

Human–animal communication is easily observed in everyday life. The interactions between pets and their owners, for example, reflect a form of spoken, while not necessarily verbal dialogue. A dog being scolded does not need to understand every word of its admonishment, but is able to grasp the message by interpreting cues such as the owner's stance, tone of voice, and body language. This communication is two-way, as owners can learn to discern the subtle differences between barks and meows, one hardly has to be a professional animal trainer to tell the difference between the bark of an angry dog defending its home and the happy bark of the same animal while playing.

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Zoology Department

Special Environments

(Soil Biology)

Theoretical Part

By/

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(Fourth Year Students)

Chemistry & Zoology

2022-2023

Soil Ecosystem

What is soil?

Soil is one of the world's most important natural resources. Together with air and water it is the basis for life on planet earth. It has many important functions which are essential for life. Not only does it play the major part in allowing us to feed the world's population, but it also plays a major role in the recycling of air, water, nutrients, and maintaining a number of natural cycles, thereby ensuring that there will be a basis for life in generations to come. Without soil, the world's population neither would nor could survive.

An ecosystem is all of the organisms in a given place in interaction with their nonliving environment.

Soil as an ecosystem

The soil is a thriving ecosystem of plants and animals which play an important role in the soil. The soil is the source of many different types of food for these creatures and is also the source of their nutrition and water. The soil can also offer a range of habitats, for instance the badger's sett, the rabbit warren, the earthworm channel, numerous pores where the small creatures can exist and develop.

Most of the soil life exists out of sight, beneath the surface of the soil. Billions of organisms inhabit the upper layers of the soil, where they break down dead organic matter, releasing the nutrients necessary for plant growth.

There is a very huge range of organisms in the soil varying in size from protozoa which require the strongest of microscopes to see them, up to large burrowing animals such as badgers and rabbits which live part of the time in the soil and part of it on the soil surface. Not only is there this large range of size but there is also wide variation in what they use the soil for.

Soil Composition

While a variety of substances may be found in soils, they are categorized into four basic components: **minerals**, **organic matter**, **air** and **water**. Most introductory soil textbooks describe the ideal soil (ideal for the growth of most plants) as being composed of 45% minerals, 25% water, 25% air, and 5% organic matter. In reality, these percentages of the four components vary tremendously.

1- **Soil minerals**

The mineral portion of soil is come from the rock deposits and sediments beneath them. This mixture gives the overall **texture** of the soil, namely whether the soil is mainly sandy, loamy or clayey. The mineral grains divided into three particle-size classes: **sand, silt, and clay**. (Note: Sand, silt, and clay are collectively referred to as the *fine earth fraction* of soil). They are <2 mm in diameter. Larger soil particles are referred to as rock fragments and have their own size classes. The particle size classes are defined as follows:

Particle Name	Particle Diameter
Clay	below 0.002 millimeters
Silt	0.002 to 0.05 mm
Very fine sand Fine sand Medium sand Coarse sand Very coarse sand	0.05 to 0.10 mm 0.10 to 0.25 mm 0.25 to 0.5 mm 0.5 to 1.0 mm 1.0 to 2.0 mm
Gravel	2.0 to 75.0 mm
Rock	greater than 75.0 mm

2- **Soil Organic Matter**

Soil organic matter (SOM) is a complex mixture of substances (mainly in the top 20 cm) that can be highly variable in its chemical content. It ranges from freshly deposited plant and animal parts to the residual humus —stable organic compounds that are relatively resistant to further rapid decomposition by the soil organisms.

An important physical property of SOM is its ability to absorb and hold large quantities of water. The mass and volume of water that can be absorbed by SOM often exceed the mass and volume of the SOM itself. Organic matter plays an important part in topsoil structures and is the major 'glue' holding particles together It can improve the workability of most soils whatever their texture.

3- **Soil air and water**

Soil air and water are found in the pore spaces between the solid soil particles.

Soil contains varying amounts of **water** depending on the climate (seasonally, weekly, and even daily) and the water holding capacity of the soil. Water is a very important component of soils and plays a huge part in the way soils behave and in the ease with which they can be worked for agriculture and other uses. Water is held in the soil around particles and the edges of pores. It is held in these positions with various degrees of strength. Sandy soils tend to hold little water whereas clayey soils can hold much water though some of it will be unavailable because it is held strongly in tiny pores. The drier the soil becomes, generally the stronger the soil will hold onto its water. Soil water is essential for the survival and growth of plants and for maintaining soil organisms.

The remaining important ingredient is **air**. The amounts of each of these components vary in time and across the landscape. This is a magical mixture of ingredients that allows the soil to perform many vital needs of living beings.

Some properties of the soil

Two of the most important physical properties of soils are their texture and structure. One of the most important chemical properties of a soil is its acidity or alkalinity, often stated as the pH of the soil.

<u>Soil texture</u>

Soil texture refers to the size of the particles that make up the soil (organic matter is excluded from the texture classification) and how this affects the way they feel and their cultivation.

The main components of soil texture are: sand, silt and clay particles. For example, soils that are dominantly composed of sand-sized particles (**sandy soils**) feel gritty; they contain lots of pores because of the way the grains stack together. This also means that rainwater entering the soil can easily drain away through the soil which leads to the soils being quite droughty. **Clayey soils** by comparison contain many smaller pores which mean that water does not pass through the soil as freely and means they can become waterlogged in wet periods and are sometimes difficult to cultivate. A **loamy soil** contains more or less equal amounts of clay, sand and silt. Soils with high silt content and those with high clay content have greater capacities for retaining water and available nutrients than sandy soils.

From the discussion of the soil particle sizes, it should be obvious that soil texture is important in:

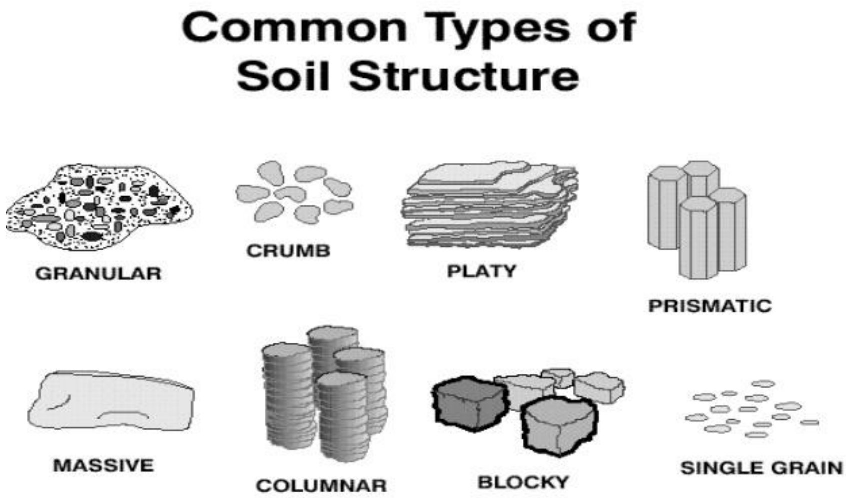
1- Determining the nutrient- holding abilities.
2- Water –holding capacity,
3- Water movement and
4- The amount and movement of soil air in a given soil.

Soil structure

The components of soil described above rarely occur as separate particles. There is, for example a strong bond between decomposed organic matter and the clay fraction of soils. In most soils, the particles are molded together into aggregates to form the architecture of the soil. Compare the architecture of a house - it is built with bricks and mortar and has entrances, rooms and corridors - a soil has the mineral particles, organic matter and these are used to build the architectural structure of the soil.

So, **the soil structure** describes the way these individual particles are assembled and bound into groups (aggregates) which separated by the pores (holes). Roots pass through these pores in search of water. Depending on the soil texture, amounts of organic matter and the way the soils are managed, the soil structure will vary with depth in the soil and from one soil type to another. The main types of soil structure are **crumb, granular, blocky, platy and prismatic**.

The best soil structures tend to be in the topsoils. This is mainly because there is usually organic matter present and this attracts huge numbers of organisms which work to decompose it. The organisms ingest the soil; create small structural units and numerous burrows in the soil. Crumb and granular structures formed in this way are ideal topsoil structures for farmers and gardeners because they contain plenty of pores through which air and water can circulate readily, and through which plant roots can readily move in search of air, water and nutrients.



Soil pH

An acid is a substance that dissolves in water to release hydrogen ions. pH is the measurement of the concentration of these hydrogen ions in a soil solution, i.e. a mixture of soil and pure water.

The pH of the soil ranges from about 3 to 8. Below 5.5 the soil is quite acidic. Above pH 7 the soil is alkaline. Soil with a pH in the range of 5.5 to 7 tends to be the most flexible and a wide range of plants can thrive within this pH range. Once the pH drops below 5.5, firmly into the acidic range, there is only a limited range of plants that like this level of acidity and can tolerate these acidic conditions. Once the pH is above 7.0, the soil tends to be colonized by a limited range of lime-loving plants.

Soils in wet climates and certainly those developed on acidic rocks, such as granite, will tend to be acidic. Soils in high rainfall areas tend to be acid because the rainfall leaches the soil of many of its nutrients which otherwise help to keep the pH higher. Acidic soils can be improved by adding lime to soil. This is a common agricultural practice where farm soils need to be maintained at a pH from 5.5 to 7 in order to grow a wide range of crops.

Soils formed in dry climates are often alkaline, i.e., with a pH above 7. Here there is a lack of rainfall to flush the nutrients out of the soil and they stay within the soil. In some dry conditions also evaporation may lead to deep-lying nutrients being brought to the surface. This can lead in some dry-climate soils to excessive amounts of salts being brought into the root zone. In extreme cases this can lead to salinization, in which the soils contain too many salts, which can prevent the growth of many crops.

The Soil Profile

Most soils have formed from rocks and sediments. Some have developed over many thousands of years by the gradual breakdown of rocks that occur beneath them and on which they lay.

Each soil consists of a series of layers, termed soil **horizons**. It is the type, nature and arrangement of these horizons that provide the clue to how soils have formed. The soil profile is the term used for the whole depth of soil including all the layers (horizons) of soil from the surface of the ground down as far as the rock or sediment some centimeters and even meters below the surface. Soil profiles are the basis for distinguishing one type of soil from another and form the basis for the names given to soils and the way we classify soils. Just as we give plants, such as daisies or bluebells, and animals such as badgers or moles, names, so we need to distinguish different types of soils and also give them names.

The soil profile is defined as a vertical section of the soil from the surface vertically down through the soil until the underlying rock or sediment is reached. If a person digs a hole in the ground and looks at the wall of that hole, he is looking at the soil's profile. The thickness varies with location, and under disturbed conditions: heavy agriculture, building sites or severe erosion for example, not all horizons will be present.

1. ***O horizon*** (organic layer).

It consists of three layers: the freshly fallen litter lying on the surface of the soil. The second layer is called **fermentation layer** where a partial decomposition occurred. The third layer (**humus layer**) is dark because of the completely decomposition of the organic matter that is occurring. The numerous organisms in this soil horizon are responsible for breaking down these additions of plants and animals and releasing the nutrients they contain to become available for the next generation of plants and animals. This O horizon is most prominent in forested areas, and often missing in cultivated soils.

2. ***A horizon***

It contains a mixture of organic and mineral components, commonly referred to as **topsoil**. As water moves down through the topsoil, many soluble minerals and nutrients dissolve. The dissolved materials leach downward into lower horizons (**leaching process**).

3. ***E horizon*** (E stands for eluviation)

It is stripped of much of its clay and sometimes staining agents, and is thus often lighter in color than the others. It is lower in organic matter than the A horizon.

4. ***B horizon***

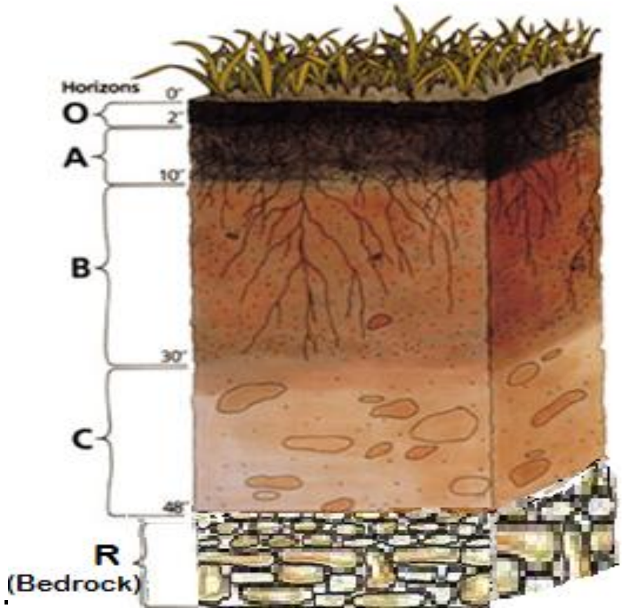
It is a zone of illuviation or accumulation (accumulated substances—clays, organic matter, iron and aluminum compounds) that have been leached from overlying horizons. It is low in organic matter.

5. ***C horizon***

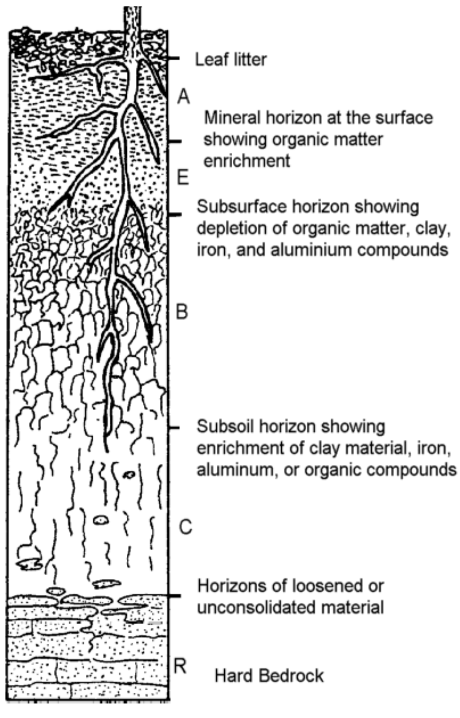
It is lightly weathered parent material. It is a transition area between soil and parent material. Partially disintegrated parent material and mineral particles may be found in this horizon. The C horizon contains fewer organisms than the horizons above and it contains very little organic matter, except where roots have penetrated the horizon.

6. **R) bedrock**

R horizons denote the layer of un-weathered bedrock at the base of the soil profile. Unlike the above layers, R horizons largely comprise continuous masses (as opposed to boulders) of hard rock that cannot be excavated by hand.



Soil Profile



How do soils form?

There are six main contributors that interact to produce soils: **parent material (rocks and sediments), climate, topography, vegetation and living creatures, time, and the effect of man**. Around the world the influence of these **soil forming factors** will be different from one country to another and this is why there are many different soils in the world.

1- **Parent material** is one of the most important influences on what type of soil develops. In some cases soils develop directly from the rock which lies beneath them. Gradually the rock will break down into smaller pieces under the effects of **weathering**, and these smaller pieces break down even further to produce soil. This fragmented rock forms the skeletal material of soils. If the rock is very hard, it can take hundreds of years just to form one centimeter of soil. If soils form on loose materials such as desert sand dunes or on more or less loose deposits left by the Ice Age, deeper soils can form quite quickly. The parent rock or sediment is the main factor responsible for the texture of the soil (i.e. whether the soil is sandy, loamy or clayey) and is also important in determining whether the soil is acid or basic and how rich it is in nutrients.

Weathering

There are three main types of weathering; physical, chemical and biological. ***Physical weathering*** is the influence of processes such as freezing and thawing, wetting and drying, and shrinking and swelling on rocks and other sediments, leading to their breakdown into finer and finer particles.

Chemical weathering is the decomposition of rocks through a series of chemical processes such as acidification, dissolution and oxidation. Some minerals, while stable within solid rock, become less stable on being more exposed to the atmosphere and so begin to alter in the rocks near the surface.

Biological weathering is the effect of living organisms on the breakdown of rock. This involves, for example, the effects of plant roots and soil organisms. Respiration of carbon dioxide by plant roots can lead to the formation of carbonic acid which can chemically attack rocks and sediments and help to turn them into soils.

2- **Climate** is the other most important soil forming influence, alongside parent material. It determines the rate of breakdown of parent rock and thus how quickly the soil will get deeper. The two main climatic influences are **temperature** and **moisture**. Higher temperature increase the rate at which breakdown of the underlying rock and thus also the release of nutrients into the soil. Rainfall and snow melt are also important in breaking down rock to form soil and in the distribution of nutrients in the soil. In hot, wet climates such as the tropics, soils tend to be deep, whereas in the cold Arctic areas, soils tend to be thin and poorly developed.

3- **Topography** is the hilliness, flatness, or amount of slope of the land. Topography generally affects the depth or thickness of soils. Steep slopes such as occur on the sides of hills and mountains generally have shallow soils because soil that does develop is regularly washed down the hillsides into the valleys below. The steep sides of mountains may lack soils altogether and be bare. By comparison flat land such as occurs in valley bottoms, flood plains of rivers or just low lying plains will have deeper soils. These flatter areas often receive sediments washed off the slopes above, which makes the flat land soils deeper.

4- **Vegetation** plays an important part in the formation of soils from solid rock. The acids released by the roots of some plants act to breakdown the rock on which the soil is forming. The vegetation on a soil is particularly important in supplying the soil with precious organic matter. There is often a close relationship between the vegetation and the soil, the vegetation supplying its dying remains to the soil and the soil converting them into nutrients so the vegetation can continue to survive and develop in years ahead. Different types of vegetation give rise to different forms of organic matter in soils.

Organisms, of which there are millions and millions in the soil, play vital parts in soil development and in enabling the soil to undertake its many roles. Organisms begin to set up their home in the soil from the moment soils begin to form. Their main role is to deal with the recycling of organic matter and releasing nutrients but they do other important things such as create pores and build the architecture of the soil. Earthworms, for example, make channels in the soil through which roots can move and water can flow to other parts of the soil.

5- It takes a long **time** for soils to develop from rock and from existing sediments. A few world soils, such as those on the old landscapes of South Africa, are millions of years old. Most world soils are, however, much younger because periods of geological turbulence such as mountain building, earthquakes and ice ages have meant that soil formation has to begin again. Most soils in the United Kingdom are just a few thousand years old, therefore, much, much younger than some of the really old world soils. It is a good thing that soils are always continuing to form and develop more every day.

6- **Human influences** can have far reaching effects on soils. Farmers have cultivated and tended their soils for centuries and farmed soils differ in many respects to those under natural vegetation, for example by having thicker topsoil due to ploughing and more nutrients because of added fertilizers. In most cases mankind has managed the soils well. In some parts of the world, though, soils have been damaged by human interference. For example, cutting down of parts of the tropical rainforest and cultivation of crops on steep slopes have led to soil erosion, which in some cases is irreversible. There is concern that with the pressures being put on our soils by human use, for example to produce more and more food, that we are damaging our soils. We must ensure this does not happen.

Soil Fauna Classification

Soil fauna have been classified by numerous authors including Kevan (1962), Schaller (1968) and Wallwork (1970). Five major groupings are widely accepted: classification based on body size; time spent in the soil; location or habitat preference; feeding strategies; and method of locomotion in the soil (Wallwork, 1970).

1- **Body size**

Body size ranges from 0.0002 cm to more than 20 cm and can be divided into microfauna, mesofauna and macrofauna.

a- **Microfauna** range in body size from 0.0002 to 0.002 cm and consist of protozoa and nematods.
b- **Mesofauna** range from slightly more than 0.002 to 1 cm and include mites, springtails, spiders, pseudoscorpions, pot-worms, insect larvae and the smaller millipedes and isopods.
c- **Macrofauna** are at least 1 cm or greater and include earthworms, the largest insects and arachnids, and the soil-dwelling vertebrates.

2- Presence (the amounts of time organisms spend in the soil)

1- Permanent

Some organisms of the soil fauna spend their entire lives in the soil and referred to as **geobionts** such as protozoans, nematodes, isopods, some annelid, collembola and mites.

2- Temporary

Other organisms (called **geophiles**) are temporarily associated with the soil community. This includes insects which seek for shelter, larva and pupae of insects.

3- Habitat preference

A distinction can be made between **aquatic fauna** living in water-filled spaces and surface films covering soil particles and the **terrestrial fauna**. To the former group belong the protozoans, copepods and certain nematods, while most of meso- and macro-fauna belong to the latter.

Another classification of soil fauna based on their location in the soil profile layers. Soil animals generally fit into one of three layers:

- **Epigeon**, or **Surface soil and litter species.** These species live in or near surface plant litter. They are typically adapted to the highly variable moisture and temperature conditions at the soil surface.
- **Hemiedaphon**, or **Upper soil species.** Some species move and live in the upper soil strata and feed primarily on soil and associated organic matter.
- **Euedaphon**, or mineral layers **or Deep-burrowing species**. Soils have numerous microhabitats and soil organisms can be classified according to their use of them.

4- Feeding strategies.

Feeding classifications include:

Carnivores, which feed on other fauna and includes: predators such as many mites, spiders, pseudoscorpions, scorpions, centipedes and some nematodes. Parasites such as parasitic insects and some nematodes.

Phytophages, which feed on green plant, root systems and woody material like nematode plant parasites and larvae of some insects.

Saprophages, which eat dead and decaying material such as isopods, millipeds, some mites, collembola and insects.

Microphytic-feeders, which feed on fungal hyphae and spores, algae, lichens and bacteria such as many mites and collembolan, ants, some nematodes and certain protozoans.

Miscellaneous feeders, which fit into two or more of the other categories (have a wide range of food materials) such as: mites, collembolan, nematodes and larvae of some insects.

5- **Locomotion.**

Distinctions are made between burrowing animals (burrow their way through the soil such as some insects and burrowing vertebrates) and those that move through the soil by making use of pore spaces, cavities or channels such as most small bodied-animals.

Role of Animals in the Soil Community

Vertebrates

Vertebrates (mice, moles, ground squirrels, etc.) are an example of soil macrofauna. They mix soil through their burrowing activity.

Annelids

Annelids (segmented worms) are another example of soil macrofauna. They are major decomposers (detritivores). The most important species of Annelida are earthworms. Earthworms are the original tillers of soil and can thus improve the rooting environment for plants and increase the amount of water that infiltrates the soil.

What do earthworms do?

Earthworms dramatically alter soil structure, water movement, nutrient dynamics, and plant growth. They are not essential to all healthy soil systems, but their presence is usually an indicator of a healthy system. Earthworms perform several beneficial functions.

Stimulate microbial activity. Although earthworms derive their nutrition from microorganisms, many more microorganisms are present in their feces or casts than in the organic matter that they consume. As organic matter passes through their intestines, it is fragmented and inoculated with microorganisms. Increased microbial activity facilitates the cycling of nutrients from organic matter and their conversion into forms readily taken up by plants.

Mix and aggregate soil. As they consume organic matter and mineral particles, earthworms excrete wastes in the form of casts, a type of soil aggregate. Charles Darwin calculated that earthworms can move large amounts of soil from the lower strata to the surface and also carry organic matter down into deeper soil layers. A large proportion of soil passes through the guts of earthworms, and they can turn over the top six inches (15 cm) of soil in ten to twenty years.

Increase infiltration. Earthworms enhance porosity as they move through the soil. Some species make permanent burrows deep into the soil. These burrows can persist long after the inhabitant has died, and can be a major conduit for soil drainage, particularly under heavy rainfall. At the same time, the burrows minimize surface water erosion. The horizontal burrowing of other species in the top several inches of soil increases overall porosity and drainage.

Improve water-holding capacity. By fragmenting organic matter, and increasing soil porosity and aggregation, earthworms can significantly increase the water-holding capacity of soils.

Provide channels for root growth. The channels made by deep-burrowing earthworms are lined with readily available nutrients and make it easier for roots to penetrate deep into the soil.

Bury and shred plant residue. Plant and crop residue are gradually buried by cast material deposited on the surface and as earthworms pull surface residue into their burrows.

Arthropods

Arthropods are fauna with a jointed exoskeleton and can belong to the macro or meso group. Arthropods range in size from microscopic to several inches in length. They include insects, such as springtails, beetles, and ants; crustaceans such as sowbugs; arachnids such as spiders and mites; myriapods, such as centipedes and millipedes; and scorpions.

Arthropods can be grouped as shredders, predators, herbivores, and fungal-feeders, based on their functions in soil. Most soil-dwelling arthropods eat fungi, worms, or other arthropods. Root-feeders and dead-plant shredders are less abundant. As they feed, arthropods aerate and mix the soil, regulate the population size of other soil organisms, and shred organic material.

WHAT DO ARTHROPODS DO?

Although the plant feeders can become pests, most arthropods perform beneficial functions in the soil-plant system.

Shred organic material. Arthropods increase the surface area accessible to microbial attack by shredding dead plant residue and burrowing into coarse woody debris. Without shredders, a bacterium in leaf litter would be like a person in a pantry without a can-opener – eating would be a very slow process. The shredders act like can-openers and greatly increase the rate of decomposition. Arthropods ingest decaying plant material to eat the bacteria and fungi on the surface of the organic material.

Stimulate microbial activity. As arthropods graze on bacteria and fungi, they stimulate the growth of mycorrhizae and other fungi, and the decomposition of organic matter. If grazer populations get too dense the opposite effect can occur – populations of bacteria and fungi will decline. Predatory arthropods are important to keep grazer populations under control and to prevent them from over-grazing microbes.

Mix microbes with their food. From a bacterium's point-of-view, just a fraction of a millimeter is infinitely far away.

Bacteria have limited mobility in soil and a competitor is likely to be closer to a nutrient treasure. Arthropods help out by distributing nutrients through the soil, and by carrying bacteria on their exoskeleton and through their digestive system. By more thoroughly mixing microbes with their food, arthropods enhance organic matter decomposition.

Mineralize plant nutrients. As they graze, arthropods mineralize some of the nutrients in bacteria and fungi, and excrete nutrients in plant-available forms.

Enhance soil aggregation. In most forested and grassland soils, every particle in the upper several inches of soil has been through the gut of numerous soil fauna. Each time soil passes through another arthropod or earthworm, it is thoroughly mixed with organic matter and mucus and deposited as fecal pellets. Fecal pellets are a highly concentrated nutrient resource, and are a mixture of the organic and inorganic substances required for growth of bacteria and fungi. In many soils, aggregates between 1/10,000 and 1/10 of an inch (0.0025mm and 2.5mm) are actually fecal pellets.

Burrow. Relatively few arthropod species burrow through the soil. Yet, within any soil community, burrowing arthropods and earthworms exert an enormous influence on the composition of the total fauna by shaping habitat. Burrowing changes the physical properties of soil, including porosity, water-infiltration rate, and bulk density.

Stimulate the succession of species. A dizzying array of natural bio-organic chemicals permeates the soil. Complete digestion of these chemicals requires a series of many types of bacteria, fungi, and other organisms with different enzymes. At any time, only a small subset of species is metabolically active – only those capable of using the resources currently available. Soil arthropods consume the dominant organisms and permit other species to move in and take their place, thus facilitating the progressive breakdown of soil organic matter.

Control pests. Some arthropods can be damaging to crop yields, but many others that are present in all soils eat or compete with various root- and foliage-feeders. Some (the specialists) feed on only a single type of prey species. Other arthropods (the generalists), such as many species of centipedes, spiders, ground-beetles, rove-beetles, and gamasid mites, feed on a broad range of prey. Where a healthy population of generalist predators is present, they will be available to deal with a variety of pest outbreaks. A population of predators can only be maintained between pest outbreaks if there is a constant source of non-pest prey to eat. That is, there must be a healthy and diverse food web.

A fundamental dilemma in pest control is that tillage and insecticide application have enormous effects on non- target species in the food web. Intense land use (especially monoculture, tillage, and pesticides) depletes soil diversity. As total soil diversity declines, predator populations drop sharply and the possibility for subsequent pest outbreaks increases.

Protozoa

Protozoa belong to soil microfauna. Protozoa are single-celled animals that feed primarily on bacteria, but also eat other protozoa, soluble organic matter, and sometimes fungi. As they eat bacteria, protozoa release excess nitrogen that can then be used by plants and other members of the food web.

WHAT DO PROTOZOA DO?

Protozoa play an important role in mineralizing nutrients, making them available for use by plants and other soil organisms. Protozoa (and nematodes) have a lower concentration of nitrogen in their cells than the bacteria they eat. (The ratio of carbon to nitrogen for protozoa is 10:1 or much more and 3:1 to 10:1 for bacteria.) Bacteria eaten by protozoa contain too much nitrogen for the amount of carbon protozoa need. They release the excess nitrogen in the form of ammonium (NH_4^+).

This usually occurs near the root system of a plant. Bacteria and other organisms rapidly take up most of the ammonium, but some is used by the plant.

Another role that protozoa play is in regulating bacteria populations. When they graze on bacteria, protozoa stimulate growth of the bacterial population (and, in turn, decomposition rates and soil aggregation.).

Protozoa are also an important food source for other soil organisms and help to suppress disease by competing with or feeding on pathogens.

Nematodes and protozoa

Protozoa and bacterial-feeding nematodes compete for their common food resource: bacteria. Some soils have high numbers of either nematodes or protozoa, but not both. The significance of this difference to plants is not known. Both groups consume bacteria and release NH_4^+.

Nematodes

Nematodes are non-segmented worms (commonly known as threadworms or roundworms) belong to soil microfauna. They are found in almost all soils in surprisingly large numbers. Those few species responsible for plant diseases have received a lot of attention, but far less is known about the majority of the nematode community that plays beneficial roles in soil.

Some are plant parasites that infest roots, some are predators that feed on other nematodes or bacteria, fungi, and protozoa. Like protozoa, nematodes have lower N requirements than many bacteria. Soil compaction generally reduces the populations of nematodes, which need adequate space between soil aggregates to move around.

An incredible variety of nematodes function at several trophic levels of the soil food web. Some feed on the plants and algae (first trophic level); others are grazers that feed on bacteria and fungi (second trophic level); and some feed on other nematodes (higher trophic levels).

WHAT DO NEMATODES DO?

Nutrient cycling. Like protozoa, nematodes are important in mineralizing, or releasing, nutrients in plant-available forms. When nematodes eat bacteria or fungi, ammonium (NH4+) is released because bacteria and fungi contain much more nitrogen than the nematodes require.

Grazing. At low nematode densities, feeding by nematodes stimulates the growth rate of prey populations. That is, bacterial-feeders stimulate bacterial growth, plant-feeders stimulate plant growth, and so on. At higher densities, nematodes will reduce the population of their prey. This may decrease plant productivity, may negatively impact mycorrhizal fungi, and can reduce decomposition and immobilization rates by bacteria and fungi. Predatory nematodes may regulate populations of bacterial-and fungal-feeding nematodes, thus preventing over-grazing by those groups. Nematode grazing may control the balance between bacteria and fungi, and the species composition of the microbial community.

Dispersal of microbes. Nematodes help distribute bacteria and fungi through the soil and along roots by carrying live and dormant microbes on their surfaces and in their digestive systems.

Food source. Nematodes are food for higher level predators, including predatory nematodes, soil microarthropods, and soil insects. They are also parasitized by bacteria and fungi.

Disease suppression and development. Some nematodes cause disease. Others consume disease-causing organisms, such as root-feeding nematodes, or prevent their access to roots. These may be potential biocontrol agents.

Nematodes and soil quality

Nematodes may be useful indicators of soil quality because of their tremendous diversity and their participation in many functions at different levels of the soil food web. Several researchers have proposed approaches to assessing the status of soil quality by counting the number of nematodes in different families or trophic groups.* In addition to their diversity, nematodes may be useful indicators because their populations are relatively stable in response to changes in moisture and temperature (in contrast to bacteria), yet nematode populations respond to land management changes in predictable ways. Because they are quite small and live in water films, changes in nematode populations reflect changes in soil microenvironments.

KEY TO ADULT SOIL AND LITTER INVERTEBRATES

1a. Body segmented.......................... 2

1b. Body not segmented, usually with a coiled shell. ....Gastropoda (snails)

2a. Appendages segmented...3

2b. Appendages (if present) not segmented. ....Annelida (segmented worms)

3a. Antennae present...7

3b. Antennae absent..4

4a. Three pairs of legs..Protura

4b. Four pairs of legs (pedipalps in front of legs & may appear leg-like). 5

5a. Pedipalps with pincher-like claws, abdomen segmented...Pseudoscorpionida (psuedoscorpions).

5b. Pedipalps without pincher-like claws, abdomen not segmented.........................6

6a. Cephalothorax & abdomen joined by a narrow connection. ....Araneae (spiders)

6b. Cephalothorax & abdomen joined by a broad connection. ....Acarina (mites)

7a. Three pairs of legs (Insects)..12

7b. More than three pairs of legs. 8

8a. Distinct head followed by a series of segments 9

8b. Distinct head absent ....Isopoda (pillbugs)

9a. 9-12 pairs of legs..10

9b. More than 12 pairs of legs 11

10a. Antennae branched......................................Pauropoda

10b. Antennae not branched...............................Symphyla

11a. Two pairs of legs on most body segments ....Diploda (millepedes)

11b. One pair of legs on each body segment ....Chilopoda (centipedes)

12a. Winged or with plate over thorax 16

12b. No wings and no plate over thorax 13

13a. Narrow-waisted, ant-like ....Hymenoptera (ants)

13b. Not narrow-waisted & ant-like 14

14a. Abdomen with 2-3 finger-like appendages on tail..............Thysanura (bristletails) **not** fork-like

14b. Abdomen without finger-like appendages 15

15a. Fork-like (2-part) jumping appendage on tail ....Collembola (springtails)

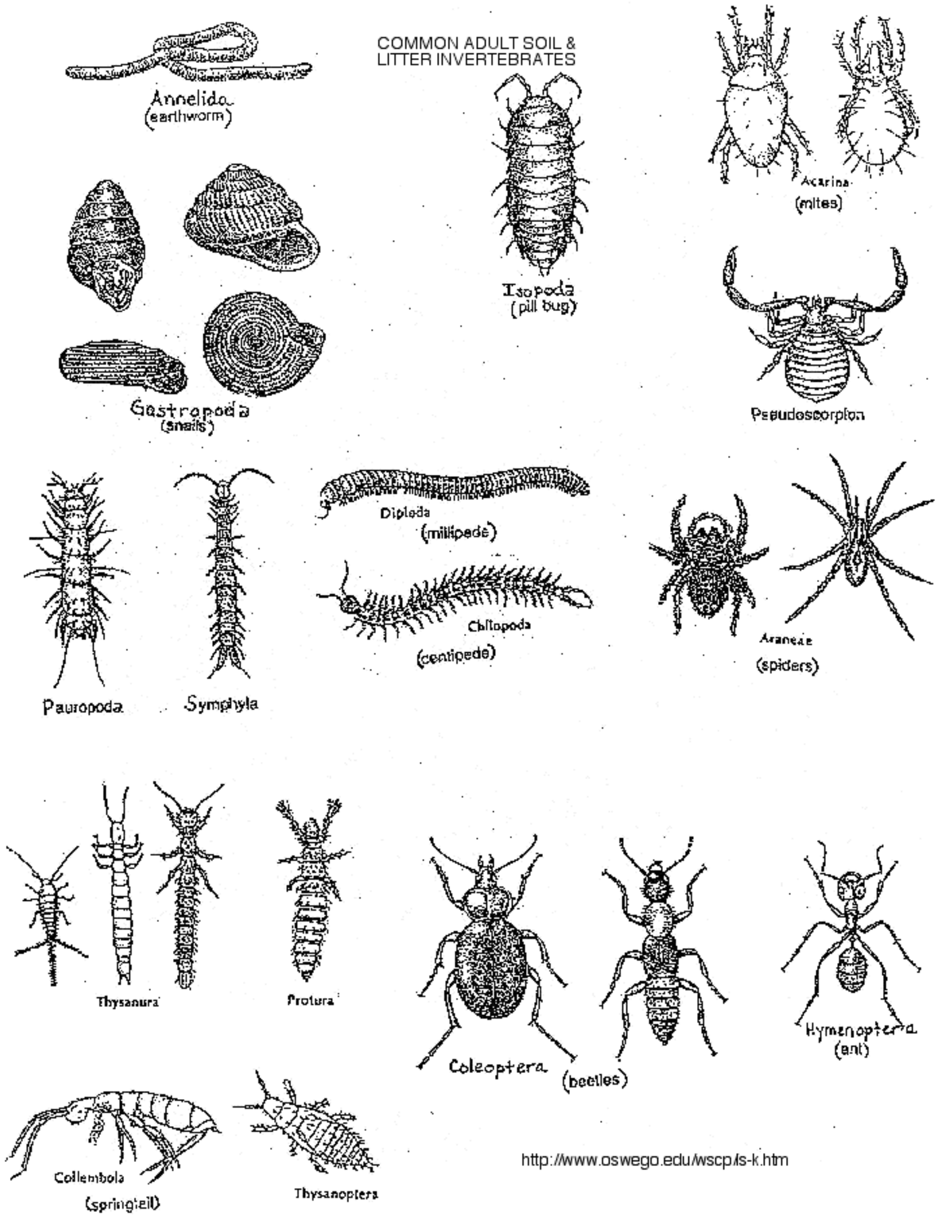
15b. No fork on tail..................................Thysanoptera (thrips)

16a. Front wings hard or leathery, covering hind wings................Coleoptera (beetles)

16b. Front wings not hard or leathery or not present..................................17

17a. Front wings thickened at base, membranous at tip, ...Hemiptera (bugs) sucking mouth parts

17b. Wings with veins, overlapping or held rooflike..............Orthoptera (grasshoppers)



Role of soil community and energy flow

Food Chains

The phrase 'food chain' is a way of indicating how energy moves through an ecosystem.

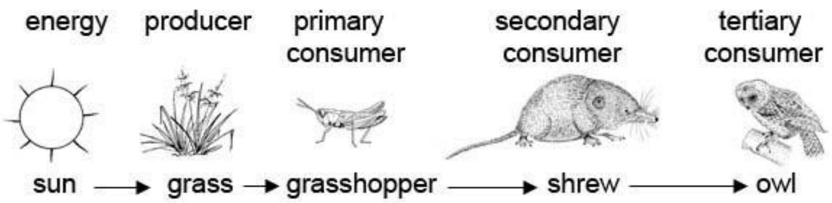
Components of a Food Chain:

- Plants or producers or **Autotrophs** - 'base' of the food chain.
- **Herbivores or primary consumers** - feed on plants; many are adapted to live on a diet high in cellulose.
- **Carnivores or secondary consumers**- feed on herbivores, omnivores & other carnivores
  - 1st level carnivore - feeds on herbivores
  - 2nd level carnivore - feeds on 1st level carnivores
  - 3rd level carnivore – feeds on 2nd level carnivores
- **Decomposers**
  - the 'final' consumer group
  - use energy available in dead plants and animals

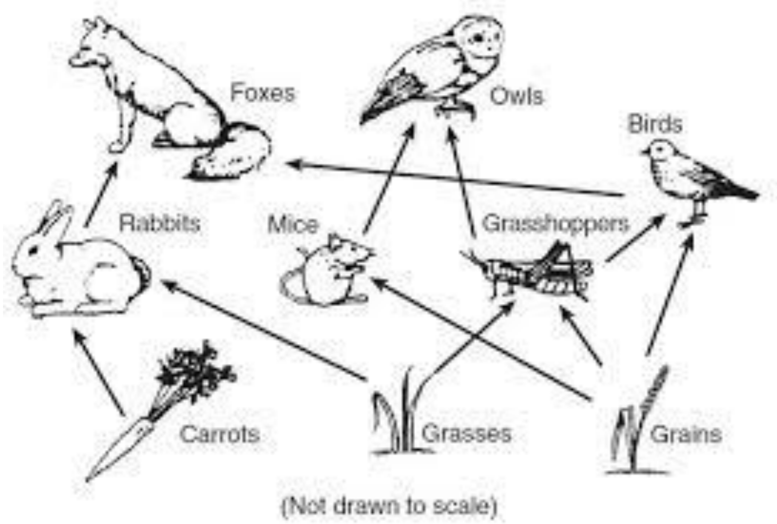
Types of Food Chains:

- **Grazing food chain** - The grazing food chain begins with the photosynthetic fixation of light, carbon dioxide, and water by plants (primary producers) Primary consumers or herbivores form the second link in the grazing food chain. They gain their energy by consuming primary producers. Secondary consumers or primary carnivores, the third link in the chain, gain their energy by consuming herbivores. Tertiary consumers or secondary carnivores are animals that receive their organic energy by consuming primary carnivores.
- **Detrital food chain**
  - The organisms making it up are generally smaller (like algae, bacteria, fungi, insects, & centipedes) and live in the soil.

- Decomposers process large amounts of organic matter, converting it back into its inorganic nutrient form.



- **Food webs** describe the transfer of energy between species in an ecosystem, consists of many overlapping food chains. While a food chain examines one, linear, energy pathway through an ecosystem, a food web is more complex and illustrates all of the potential pathways.



Significance of Food Chains and Food webs

1. They help in maintaining the ecological balance.
2. They help in understanding the feeding relations among organisms.
3. Energy flow and nutrient cycling take place through them.
4. It explains the concept of biomagnifications.

Energy Flow

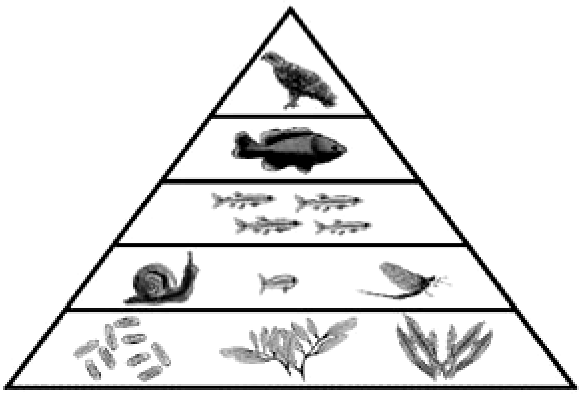
A general energy flow scenario follows:

- Solar energy is fixed by the green plants that produce sugars and other organic molecules. Once produced, these compounds can be used to create the various types of plant tissues. Primary consumers absorb most of the stored energy in the plant through digestion, and transform it into the form of energy they need, such as adenosine triphosphate (ATP), through respiration. A part of the energy received by herbivores, is converted to body heat (an effect of respiration), which is radiated away and lost from the system. The loss of energy through body heat is far greater in warm-blooded animals, which must eat much more frequently than those that are cold-blooded. Energy loss also occurs in the expulsion of undigested food by excretion .

- Secondary consumers, carnivores, then consume the primary consumers, although omnivores also consume primary producers. Energy that had been used by the primary consumers for growth and storage is thus absorbed into the secondary consumers through the process of digestion. As with primary consumers, secondary consumers convert this energy into a more suitable form (ATP) during respiration. Again, some energy is lost from the system, since energy which the primary consumers had used for respiration and regulation of body temperature cannot be utilized by the secondary consumers.
- Tertiary consumers, which may or may not be apex predators, then consume the secondary consumers, with some energy passed on and some lost, as with the lower levels of the food chain.
- A final link in the food chain are decomposers which break down the organic matter of the tertiary consumers (or whichever consumer is at the top of the chain) and release nutrients into the soil. They also break down plants, herbivores and carnivores that were not eaten by organisms higher on the food chain, as well as the undigested food that is excreted by herbivores and carnivores. Saprotrophic bacteria and fungi are decomposers.

The energy is passed on from trophic level to trophic level and each time about 90% of the energy is lost, with some being lost as heat into the environment (an effect of respiration) and some being lost as incompletely digested food. Therefore, primary consumers get about 10% of the energy produced by autotrophs, while secondary consumers get 1% and tertiary consumers get 0.1%. This means the top consumer of a food chain receives the least energy, as a lot of the food chain's energy has been lost between trophic levels. This loss of energy at each level limits typical food chains to only four to six links.

What is an energy pyramid?



Energy pyramid

An energy pyramid is a graphical model of energy flow in a community. The different levels represent different groups of organisms that might compose a food chain. From the bottom-up, they are as follows:

- **Producers** — bring energy from nonliving sources into the community
- **Primary consumers** — eat the producers, which makes them herbivores
- **Secondary consumers** — eat the primary consumers, which makes them carnivores

-
- **Tertiary consumers** — eat the secondary consumers

Why are energy pyramids shaped the way they are?

An energy pyramid's shape shows how the amount of useful energy that enters each level — chemical energy in the form of food — decreases as it is used by the organisms in that level.

Methods of Collecting and Extraction of Soil Fauna

Soil zoology has tried for a long time to find a sampling method that allows collection of the greatest fraction of fauna as possible. However, there is now a growing general agreement that a method allowing a good sampling of one community of species may fail for other communities (Southwood & Henderson, 2000). Thus sampling protocols combining different methods must be established if maximal efficacy of sampling is to be achieved.

A-Field techniques

This section includes the methods used to collect in the field the target fauna or to collect the soil samples to be carried to the laboratory for extraction.

Direct sampling

This is the basic sampling method. The researcher will locate and capture the target fauna searching for the specimens in their habitat by eyeing the ground, turning stones, searching among litter, digging around plant bases, etc. This method usually allows the capture of macrofauna only. This method allows the sampling of the upper horizons of the ground.

<u>Collecting soil samples using an equipment</u>

To **sample the soils** you will need:

• Sampling ring or metal cube (with a height 5 cm)

• Trowel

• Flat surface large enough to cover surface of sampling ring (e.g. paint scraper)

• Plastic bags

How to collect…..

1- We recommend soil samples are taken first thing in the morning. The ground is cooler then, and soil fauna are likely to be nearer the surface.

2- Soil fauna abundance will vary throughout the year. Soil fauna biomass tends to be greatest in the top few centimeters of soil when the soil is moist. In dry summer months soil fauna abundance made be lower or you may find that the species that are present are very different to those present in winter.

3- When sampling soils, record the date, time, ambient temperature (approx) and weather conditions (sunny, raining, overcast).

4- Push the sampling ring or cube 5 cm into the ground. If the ground is hard you can tap the ring into the soil by placing a wooden board over top and hitting it lightly with a mallet.
5- Dig around one side of the ring with a trowel.
6- Slide the scraper straight underneath the ring. This stops losing soil when you lift the sample out.
7- Place the sample into a plastic bag (labeled with date and site).

B- Laboratory extraction methods

Sampling very small animals has the disadvantage that they cannot be separated in the field. In this case, carrying samples to undergo a laboratory extraction is obligatory. According to the nature of the methods, two kinds of extractions are to be distinguished: **mechanical or passive methods**, and **dynamical or active methods**. On the other hand, samples can be manually separated under the binocular.

1. Mechanical or passive methods

They are extracted active and non active organisms. The commonest are sieving (including dry and wet sieving) and flotation.

Separation protocols are very variable, since every research team tends to modify them in order to adjust them to their particular needs.

Sieving method

Sieving method is usually employed when the size of the animals under study is appreciably different from that of the soil particles. It is often possible to separate out several different size groupings of animals by using a number of sieves of differing descending mesh sizes assembled in a series. The nest of sieves loaded on to a mechanical shaker. Wet sieving is often more efficient than the dry method, particularly for medium and small sized litter dwelling animals other than arthropods. The leaf litter sample is washed with water over a set of sieves and ending in a paper filter or fine cloth for collecting animals.

Flotation

Is a widely used technique when the specific gravity of the fauna and of the soil grains is very different. Different liquids can be used as suspension media: solutions of 25% magnesium sulphate, of sodium chloride, of 75% of zinc chloride, of sucrose or directly heptanes (Southwood & Henderson, 2000).

The basic heptanes protocol is as follows: Put the sample in a cylinder with flat stopper and add 1 l of 50% ethyl alcohol and 10 ml of heptanes. Replace stopper and invert cylinder without shaking. Allow the heptanes to rise. Repeat inversion twice. Allow the cylinder to stand for 4 h. The sediment will settle. Decant the heptanes supernatant layer into a sieve. Rinse the sieve with 95% ethanol to remove the heptanes and wash the sample into a sorting dish.

Elutriation (soil washing)

This technique lies in separating the organisms by washing the sample in a constant current of water. Thus the specimens, floating more or less, are swept and later filtered, while the sediment, being heavier, is kept in the bottom of the device. It has been used to separate arthropods and springtails but is often used to separate soil nematodes in slightly modified devices (Southwood & Henderson, 2000). The **soil washing** technique uses a washing apparatus (Fig.) made of a stack of two sieves (a coarse one on top of a medium one) placed over a settling can. This can has a pivoted lateral drainage that allows floating animals to pass into the Ladell can, which has a 0.2 mm fine phosphor-bronze sieve in the bottom. Its lower opening is immersed in the drainage tank, so that the water level in the tank is always slightly above the sieve of the Ladell can. When water is poured over the sample placed in the upper sieve, specimens are filtered: large animals are caught in the coarse sieve, medium sized animals in the medium sieve and small animals (depending upon mesh size) are washed to the Ladell can sieve, where they can be recovered.

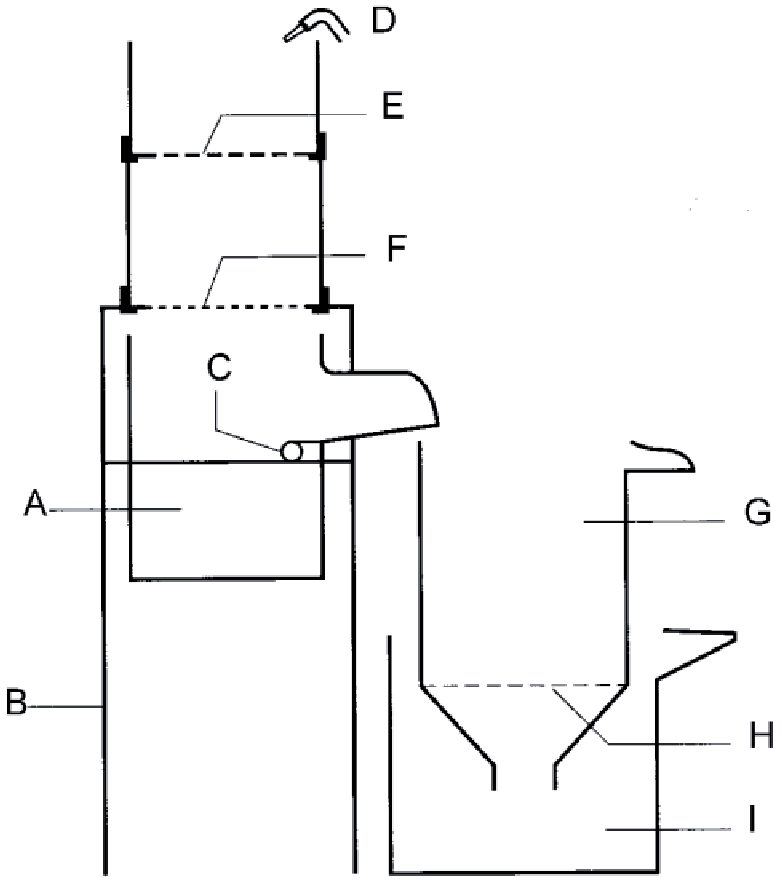


Fig.. Soil-washing apparatus, redrawn from Southwood & Henderson (2000). A = Settling can. B = Stand. C = Pivot. D = Nozzle of hose. E = Coarse sieve. F = Medium sieve. G = Ladell can. H = Fine phosphor-bronze gauze. I = Drainage tank.

One of the greatest disadvantages of the mechanical extraction techniques is the considerable amount of work involved and time consumed in separating them. Therefore, it is not surprising that many soil zoologists prefer to use behavioural techniques in which the animals do most of the work.

2- Dynamic or active methods (behavioural)

They are based on the migration of the sample organisms as a response to the alteration of the physicochemical conditions of their environment like heat, light and desiccation. The most common methods are the Berlese-Tullgren funnel and the Baermann funnel.

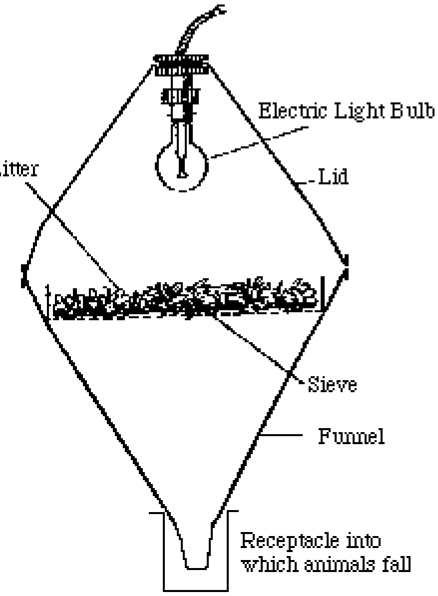
Berlese-Tullgren funnel

This technique was devised for dry samples. It was originally designed by Berlese (1905) with a hot water jacket to heat the sample and posteriorly modified by Tullgren (1918) by eliminating the jacket and adding a bulb on top. All of them are based in the negatively phototropic and positively geotropic behaviour of the soil fauna, which migrates downwards to fall in a collector container. Many small and medium-sized invertebrates (juvenile centipedes and millipedes, small insects and their larvae, mites and springtails or collembola) can be separated from soil and litter using this method. A functional Berlese funnel can be made from household items (a plastic soda bottle, cardboard, etc.). However different the shape, size, and material, every Berlese-Tullgren extractor consists of a funnel with smooth inner surface, a light source, a sieve fitting inside the funnel (mesh size 2 mm) and a container (into which the animals fall) with the appropriate killing-preserving liquid (usually 70% ethanol, added or not of up to 25% ethylene glycol; hypersaturated salt water can also be used).

A litter sample is placed on the screen (sieve) at the top of the funnel. The screen prevents soil and litter debris from falling into the collecting container. A small lamp with a low-power light bulb (10-40 Watts) heats and dries the soil from above. The light bulb should be positioned just above the litter, but not touching it, the collecting container is placed below and the top covering the sieve. As the soil dries out from the top down, the dryness stimulates the soil animals to move downward (this behavior is called positive geotaxis). This downward movement eventually causes the soil animals to fall through the sieve into a container with a preservative (usually 75% alcohol).

With the light bulb as a source of heat, the extraction can take 5-7 days, longer if a large amount of substrate is collected, or if the substrate is wet. If a power source for the light bulb is not available, for example in field conditions, the samples can be allowed to air-dry if the weather is dry and warm, although this will slow down the extraction. Air-drying will not work for wet substrates or in rainy weather.

Until ready to extract, the soil and litter containing invertebrates should be placed in plastic bags and kept in a cool, dark area. The Berlese-Tullgren extraction method gives a biased sample of soil fauna, because it is based on specific avoidance behaviour triggered by dryness and thus best captures animals that are mobile and do not desiccate easily. Immobile larvae, endophagous nymphs and some moisture-dependant invertebrates such as nematodes are not extracted by a Berlese funnel.



Berlese-Tullgren funnel

Baermann funnel

Baermann funnel is used for nematodes. The Baerman funnel is wet, however (while the Berlese funnel is dry) and does not depend on a light/heat gradient. Nematodes move out of the soil and to the bottom of the funnel because, as they move, they are denser than water and are unable to swim. The original model consisted of a glass funnel full of water, with a sieve at mid length, where the sample, wrapped in a gauze, is deposited. A later modification is the addition of a lamp heating the water, which accelerates the separation process.

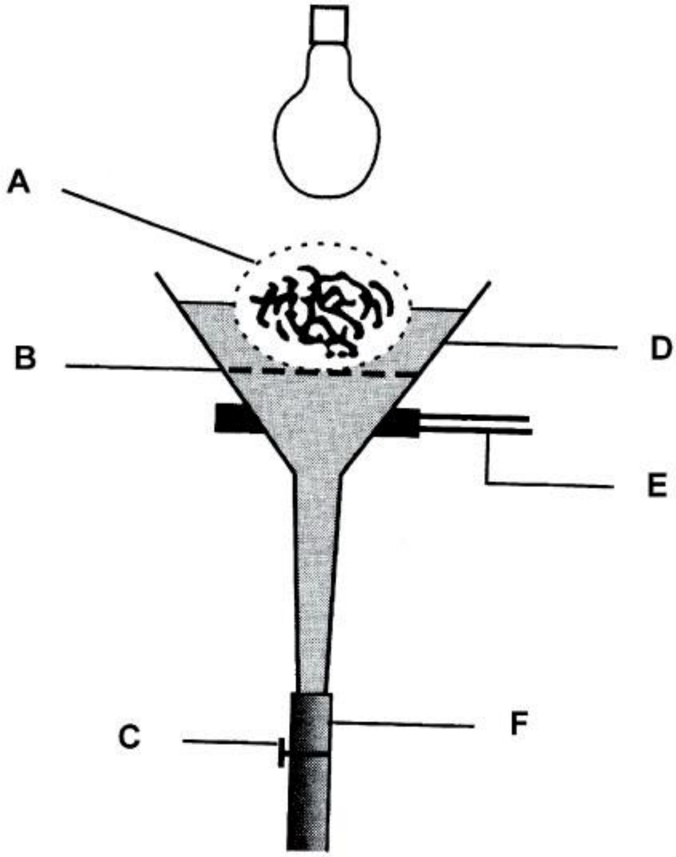


Fig. . Baermann funnel, redrawn from Southwood & Henderson (2000). A = muslin wrapped over sample. B = sieve. C = pinchcock. D = water. E = funnel stand. F = rubber tubing.

Determination of some Soil Ecological Factors

1- Soil moisture

After soil samples have been taken and returned to the lab, quick and careful procedures need to be taken. The following steps will help in drying the samples to determinate soil moisture:

1. Mix the samples in the plastic bags to ensure uniform distribution of the sample.
2. Weigh the paper plate before putting soil on the plate. This value will be needed for the calculation of soil moisture.
3. Place approximately 25 grams of wet/moist soil on the paper plate and record the weight of soil and plate.

5. Drying the sample can be done in conventional drying oven. Place the sample in the oven at 105 degree centigrade for 24 hours.
6. Weigh the sample after drying and the difference between the two weights is the soil water content.

   Percentage= (water content ÷ weight of wet sample) × 100

2- Soil temperature.

A soil thermometer is the most accurate way to take your soil's temperature. Simply stick the probe into the soil and wait to see consistent readings.

3- Soil pH

To measure the concentration of hydrogen ions in soil, use a commercially available electronic pH meter, in which a rod is inserted into moistened soil.

4- Soil organic contents

(1)- Determine and record the mass of an empty, clean, and dry porcelain dish (MP).

(2)- Place a part of dried soil in the porcelain dish and determine and record the
mass of the dish and soil sample (MPDS).

(3)- Place the dish in microwave oven at 600 c. for 8 hours.

(4)- Remove carefully the porcelain dish using the tongs (the dish is very hot), and
allow it to cool at room temperature.

(5)- Determine and record the mass of the dish containing the ash (burned soil)
(MPA).

Data Analysis:

(1) Determine the mass of the dry soil.

$$MD = MPDS - MP$$

(2) Determine the mass of the ashed (burned) soil.

$$MA = MPA - MP$$

(3) Determine the mass of organic matter

$$MO = MD - MA$$

(4) Determine the organic matter (content).

$$OM = MO/MD \; x100$$

5- <u>Determination of root biomass</u>

Root biomass help bind the soil together by forming aggregates and granular structure.

This process improves the tilth as well as the erosion resistance of the soil.

1- Weight a part of the dried soil.
2- Roots are removed from the soil by hand rinsing soil from the roots through a sieve followed by drying the removed roots
3- Weight the dried roots and this is the root biomass.

6- <u>Soil particle size (Soil texture)</u>

The apparatus required to do this test:-
i) A set of fine Sieves of sizes – 2mm, 600µm, 425µm, 212µm and 75µm
ii) A set of coarse Sieves of sizes – 20mm, 10mm and 4.75mm
iii) Mechanical shaker

i) Soil sample should be dried in air or in the sun. Tree roots and pieces of bark should be removed from the sample.

ii) The big clods may be broken with the help of wooden mallet. Care should be taken not to break the individual soil particles.

iii) The different soil particles can be separated in the sieves (like the method of separating soil fauna).

Factors affecting soil fauna

Soil Fauna, just like higher plants depends entirely on soil for their nutrition, growth and activity. The major soil factors which influence the faunal population, distribution and their activity in the soil are:

1- **Soil moisture**

Soil moisture has often been reported to be the most important environmental variable affecting both the structure and function of the soil fauna community. Generally, it seems that the abundance of all faunal groups decreases with drought. For example, **soil mites**, one of the most abundant groups of mesofauna has been found to be positively related to soil moisture across many ecosystems.

Many soft-bodied animals such as **collembolans** are sensitive to desiccation during dry conditions. To avoid drought, 1- soil animals undertake vertical movements deeper into the soil or redistribute to moist patches (Verhoef & Van Selm 1983; Didden 1993).

2- They can also enter inactive stages, or survive as dormant eggs, which are reactivated by moisture (Hopkin 1997).

** The moisture content of the litter may affect the ability of juveniles to penetrate their substrates successfully (Norton 1994).

** Moisture changes may also affect the fungal community and, thereby, have indirect effects on the fungivorous fauna and the oviposition of oribatid mites (Hågvar 1998).

** Heavy rains or flooding may lead to waterlogged conditions that cause mortality among adult collembolans and require water-resistant eggs for the populations to persist (Mertens *et al.* 1983; Tamm 1984).

2- **Soil temperature**

Temperature also affects many aspects in the life of soil fauna. Seasonal temperature variations commonly induce vertical movements of soil animals in the soil profile (e.g., Luxton 1981; Didden 1993). The developmental rate of collembolans, mesostigmatid and oribatid mites are often temperature-dependent (e.g., Hopkin 1997; Walter & Proctor 1999; Bhattacharya *et al.* 1978). In some collembolans, fecundity and sex ratio in the populations may also be affected (Choudhuri 1961; Snider 1973).

3- Soil Structure and Texture

The structure and texture of soil affect the distribution of burrowing animals.

1- Compact soils **(Soil compaction** is the reduction of soil volume due to external factors) or very rocky soils may reduce the rate of burrowing by earthworms, for instance (Guild, 1955), or preclude burrowing altogether. Soils that are too fine may not be suitable for burrowing, except for those animals with special adaptations (Kuhnelt, 1976). These generalities hold not only for animals that spend all their lives in the soil, but also for vertebrates such as burrowing rodents that spend varying amounts of time underground.

2- Another aspect of soil structure, the size and number of spaces between soil particles, influences the species composition and vertical distribution of non-burrowing animals. A clear, positive correlation exists between the average size of pore space in soils and the animals that inhabit them (Kuhnelt, 1958). Furthermore, the size and number of spaces in soils affect soil moisture and carbon dioxide content.

4- Aeration (soil air)

Soil aeration is difficult to separate from soil moisture because they generally correlate inversely (Kevan, 1962). Under high soil moisture level / water logged conditions, gaseous exchange is hindered and the accumulation of Co2 occurs in soil air which is toxic to microbes. The resistance of soil organisms to high carbon dioxide levels is extremely variable, and little is known about aeration requirements of many soil animals. But some species such as nematodes (Wallace, 1956) apparently depend on specific levels of oxygen for successful emergence.

5- Soil pH

The pH of soils depends to a large extent upon the soil parent material, but the kind of vegetation on the surface and the level of aerobic and anaerobic decomposition processes also influence soil pH (Kevan, 1962; Wallwork, 1976). Soil organisms vary considerably in their preferences for soil pH, but most avoid very acid soils (Kevan, 1962).

6- Soil Organic Matter:

The organic matter in the soil being the chief source of energy and food for most of the soil organisms. Organic matter influence directly or indirectly on the population and activity of soil microorganisms. It influences the structure and texture of soil and thereby activity of the microorganisms.

Zoology Department

Special Environments

(Soil Biology)

Practical Part

By/

Dr. Heba M. Fangary

(Fourth Year Students)

(Chemistry & Zoology)

2022-2023

Methods of Collecting and Extraction of Soil Fauna

1- <u>Collecting soil samples from the field using an equipment</u>

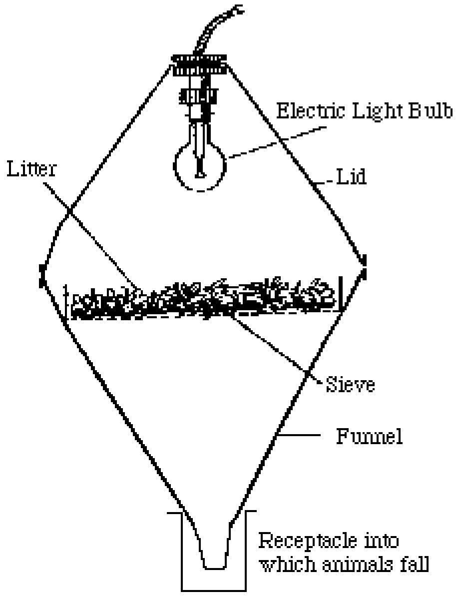
To **sample the soils** you will need:
• Sampling ring or metal cube (with a height 5 cm)
• Trowel
• Flat surface large enough to cover surface of sampling ring (e.g. paint scraper)
• Plastic bags

How to collect…..

1- We recommend soil samples are taken first thing in the morning. The ground is cooler then, and soil fauna are likely to be nearer the surface.
2- When sampling soils, record the date, time, ambient temperature (approx) and weather conditions (sunny, raining, overcast).
3- Push the sampling ring or cube 5 cm into the ground. If the ground is hard you can tap the ring into the soil by placing a wooden board over top and hitting it lightly with a mallet.
4- Dig around one side of the ring with a trowel.
5- Slide the scraper straight underneath the ring. This stops losing soil when you lift the sample out.
6- Place the sample into a plastic bag (labeled with date and site).
7- Until ready to extract, the soil and litter containing invertebrates should be placed in plastic bags and kept in a cool, dark area.

2- Laboratory extraction method (<u>Berlese-Tullgren funnel)</u>

This technique was devised for dry samples. It was originally designed by Berlese (1905) and posteriorly modified by Tullgren (1918). Many small and medium-sized invertebrates (juvenile centipedes and millipedes, small insects and their larvae, mites and springtails or collembola) can be separated from soil and litter using this method.



Berlese-Tullgren extractor consists of a funnel with smooth inner surface, a light source, a sieve fitting inside the funnel (mesh size 2 mm) and a container (into which the animals fall) with the appropriate killing-preserving liquid (usually 70% ethanol).

A soil sample is placed on the screen (sieve) at the top of the funnel. The screen prevents soil and litter debris from falling into the collecting container. A small lamp with a low-power light bulb (10-40 Watts) heats and dries the soil from above. The light bulb should be positioned just above the litter, but not touching it, the collecting container is placed below and the top covering the sieve. As the soil dries out from the top down, the dryness stimulates the soil animals to move downward (this behavior is called positive geotaxis). This downward movement eventually causes the soil animals to fall through the sieve into a container with a preservative. With the light bulb as a source of heat, the extraction can take 3-7 days.

Preserving and Preparing Specimens for light microscope

(a) Preserving: specimens preserved in 70-80% ethanol. In higher alcohol concentrations mites become brittle; at lower concentrations bacterial and fungal degradation can occur.
(b) Slide- mounting of specimens: using Hoyer·s mounting media. To make Hoyer·s, dissolve gum arabic in distilled water and let it sit over night. The next day, add the chloral hydrate and glycerine and then either filter the mixture through clean glass wool. Store Hoyer·s in a brown bottle to prevent degradation by light.

Hoyer·s Medium (Krantz 1978)

(a) Chloral hydrate	200 g
(b) Crystalline gum arabic	30 g
(c) Glycerol	20 ml
(d) Distilled water	50 ml

Simplified Key to Soil Invertebrates

1) The general shape of the organism.
   a) Shape is generally worm-like, without legs or with 6 or fewer leg-like appendages (See Figures 1, 3, 4, 5)………………………………….**Go to 2**
   b) Shape is bug-like with hard exoskeletion, with at least 6 leg-like appendages (Fig. 2, 6, 7) ……………………………………………………………………**Go to 4**


Figure 1

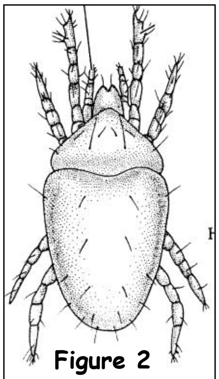


Figure 2

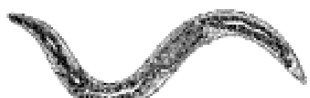


Figure 3

2) The presence or absence of appendages.

a) No recognizable appendages (Fig. 3, 4) ………………………………………………………… **Go to 3**

b) Possesses recognizable appendages, or head capsule (Fig. 1, 5) **Insect Larvae**

3) Identification of segmentation.

a) Lacks visible segmentation (Fig. 3) ……………………………………… **Unsegmented Worm**

b) Has visible segmentation (Fig. 4) ………………………………………… **Earthworm**

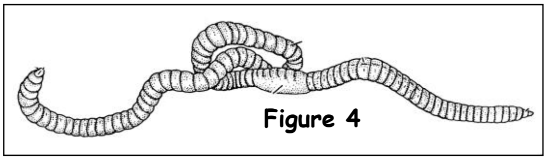


Figure 4

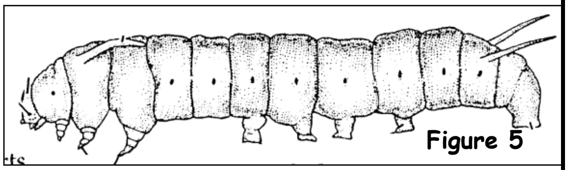


Figure 5

4) How many legs?

a) Six legs (Fig. 6)………………………………………**Go to 5**

b) More than six legs (Fig. 2, 7) ………… **Go to 6**

5) How many body and antennal segments?

a) Nine or fewer body segments behind the head; antenna with four segments; hinged tail appendage often visible (Fig 8)………………………… **Springtail**

b) Otherwise ……………………………………………...… **Other insect**

6) How many legs, again?

c) Eight legs (Fig. 2) ……………………………………… **Go to 7**

d) More than eight legs (Fig. 7) ……………… **Myriapod**

7) Considers thorax and abdomen.

a) Thorax and abdomen separated by constricted “waist” ………………………… **Spider**

b) Thorax and abdomen fused into one (Fig. 2) ……………………………………………… **Mite**

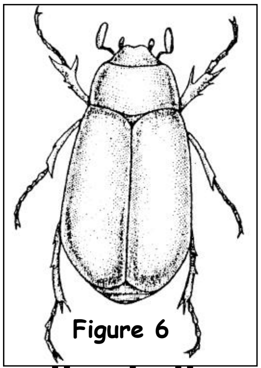


Figure 6

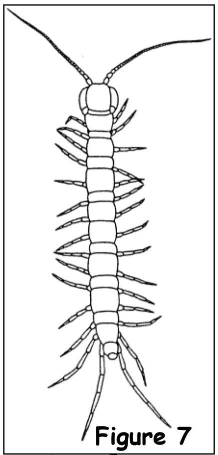


Figure 7

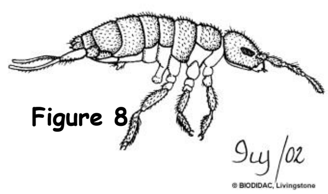


Figure 8

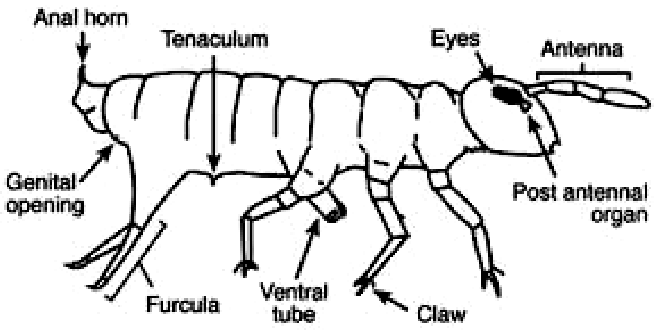
Soil collembolla

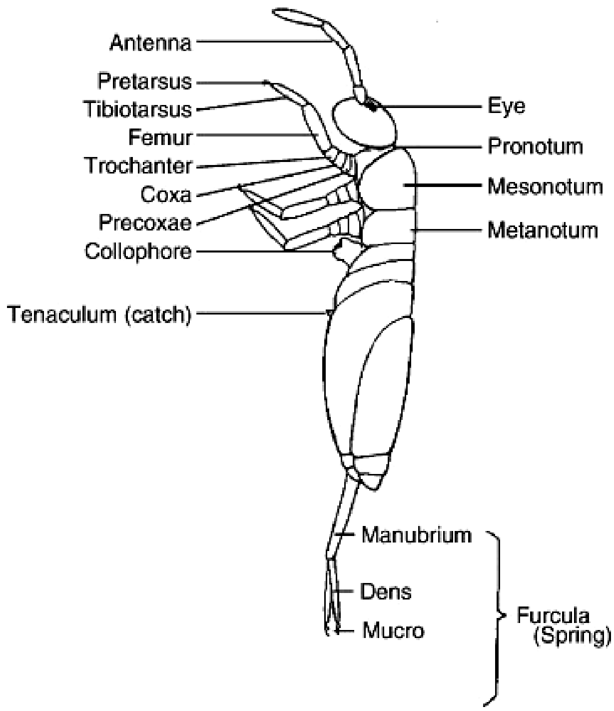
Collembola are small ([min. 0.12] 1-5 [max. 17] mm), wingless hexapods (insects) with antennae always present. Most but not all *Collembola* may be recognized by a posterior ventral forked abdominal appendage, the furca.

The body of *Collembola* basically comprises three parts: a head capsule, a thorax and an abdomen.

- **The head** bears two antennae (often 4 segments), two postantennal organs, two clusters of simple eyes (each with 8 ommatidia) and the mouthparts.
- **The thorax** with three segments, each segment bears ventrally a pair of walking limbs.
- **The abdomen** with 6 segments. The first bears a ventral tube (collophore) having two eversible vesicles. The third abdominal segment ventrally bears the tenaculum. The fourth abdominal segment ventrally bears the furca. The genital orifice opens at the ventral side of the fifth abdominal segment. The anus opens terminally at the six abdominal segment (periproct).

- The ventral tube or collophore may be helps maintain water balance in the body by absorbing moisture from the environment, also attaching the animal to the substratum.
- The furca composed of a basal manubrium, bearing two arms, each of them comprising a dens and a mucro. It is folded beneath the body to be used for jumping.
- The tenaculum held on the furca, and when released causes the furca snap down against substrate.





General structure of collembola

Class: Insecta

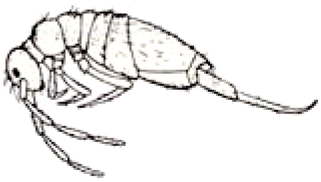
Subclass: Apterygota

Order: Collembolla

Suborder

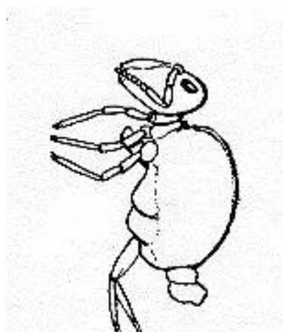
Arthropleona

Abdomen is elongate.
Abdomen segments distinct.



Symphypleona

Abdomen is subglobular.
Abdomen segments indistinct.



Suborder: Arthropleona

Section

Poduromorpha

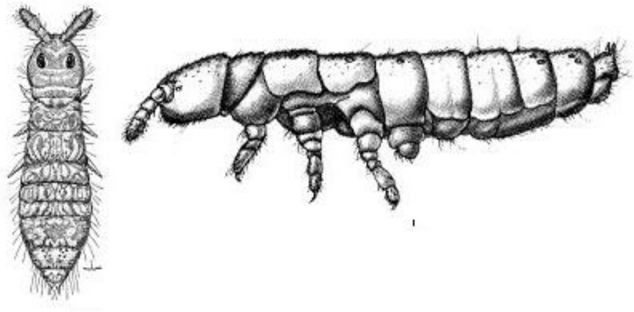
(Prothoracic tergum distinct)

Family: Neanuridae

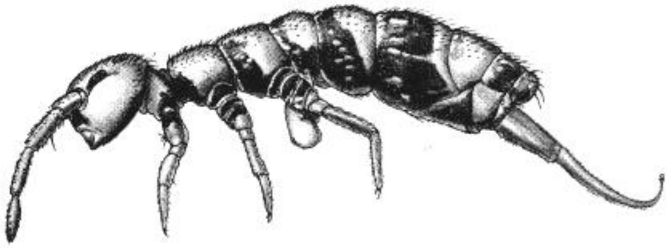
Prothorax with setae.
Dents of furca absent or vestigial or when present relatively short.

Entomobrymorpha

(Prothoracic tergum indistinct)



General form of Poduromorpha



General form of Entomobrymorpha

Family: Neanuridae

Subfamily: Frieseinae

e.g.: *Friesea*

Comment:

1- Head: Antennae with 4 segments. Presence of 8 simple eyes (4 on each side).
2- Thorax: the three segments (pro-, meso and metathorax) are equal, each with a pair of legs. Prothorax with setae.

3- Abodomen: elongate with six segments. The first bears short ventral tube. The fourth bears short furca. The last one is big and bears 3 anal spines.

4- The colour of the body is dark in upper part and light in lower part.

Entomobrymorpha

Family: Isotomidae

Body without scales. Body setae simple or at most sparsely ciliate. Post antennal organ present. The 4th and 3rd abdominal segments are equal.

Entomobryidae

Body with scales. Body setae long and densely ciliated. Post antennal organ absent. 4 th abdominal segment often much longer than third.

Family: Isotomidae

e.g. : *Isotomina*

Comment:

1- Head: Antennae with 4 segments. Presence of 8 simple eyes (4 on each side).

2- Thorax: the three segments (pro-, meso and metathorax), each with a pair of legs. The prothorax redused from dorsal side, but present from ventral side.

3- Abodomen: elongate with six equal segments. The first bears short ventral tube. The fourth bears forked furca.

4- The color of body is light due to absence of scales.

Family: Entomobryidae

e.g.: *Seira*

Comment:

1- Head: Antennae with 4 segments. Presence of 8 simple eyes (4 on each side).
2- Thorax: the three segments (pro-, meso and metathorax), each with a pair of legs. The prothorax is very small.
3- Abodomen: elongate with six segments. The 4th segment equals twotimes the 3rd segment. The first bears short ventral tube. The fourth bears long forked furca.
4- The color of body is dark due to presence of scales.

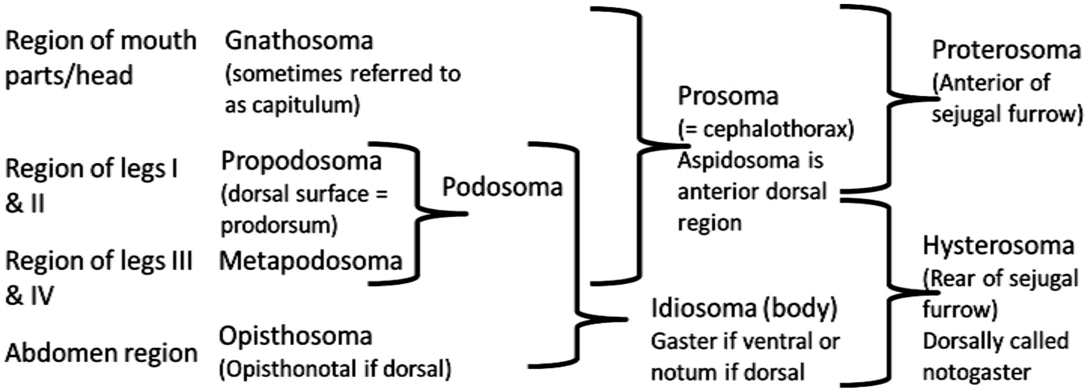
Class: Arachnida

Order: Acarina (mites)

The basic division of the acarine body is into two sections: the gnathosoma (head) and the idiosoma (main body).

- The gnathosoma bears mouthparts comprising a pair of chelicerae (often pincer like) and paired palps (or pedipalps) which are leg-like appendages.
- The idiosoma bears four pairs of legs consists of a number of segments (Tarsus – Tibia – Genu – Femur – Trochanter – Coxa).

The simple body division into gnathosoma and idiosoma is most easily seen in ticks and Mesostigmata, but can be subject to fusion and subdivision in other groups. For this reason mites in different groups often have different names for different parts of the body.



<u>Body divisions in mites.</u>

Many mites breathe through holes in their exoskeleton called stigmata (singular is stigma) which is often associated with a channel called a peritreme. These peritremes can be located on the sides of the animal (Mesostigmata), or around the mouthparts (Prostigmata), or may not be visible at all (Oribatida).

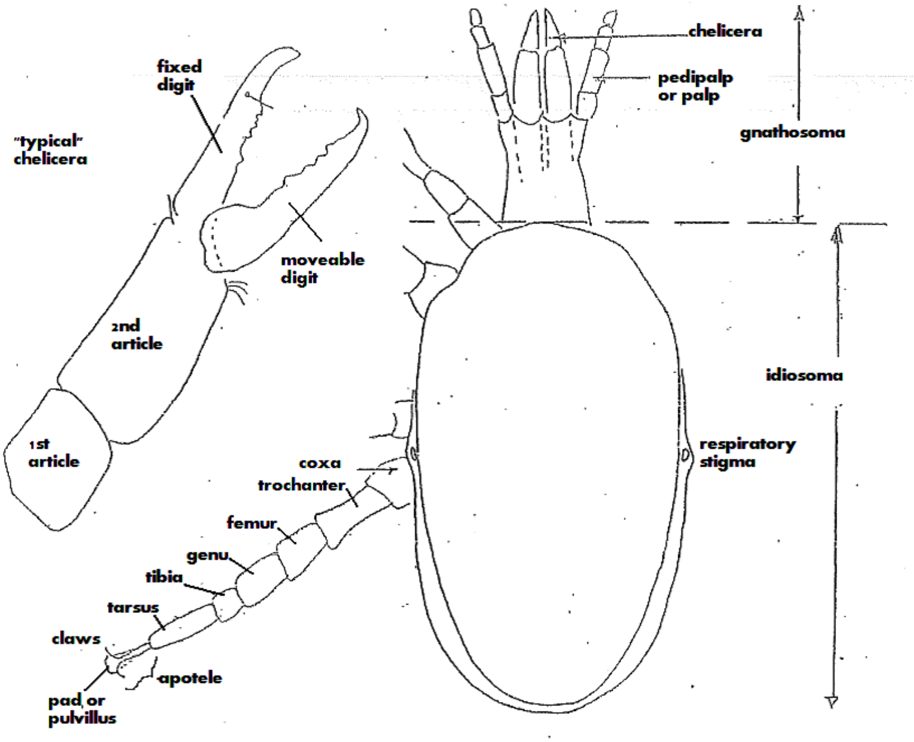
Order: Acarina

Suborder **Mesostigmata** **Sarcoptiformes**

Mesostigmata

1- The body divided into gnathosoma and idiosoma.
2- Eyes absent.
3- Have a pair of lateral stigmatal openings usually around the level of coxae II-IV, often associated with elongated peritremes.
4- Legs with 6 segments (coxa free, not fused with the ventral side).
5- First pair of legs forward facing.

6- The genital opening with undivided plates, while the anal opening with divided plates.



General form of Mesostigmata

Group: Uropodina

e.g.: *Uropodina*

Comment:

- The body is roundish-disc shaped.
- The gnathosoma bears two chelicerae and two pedipalps. And it is not observable from the dorsal side due to extending of the dorsal shield.
- The idiosoma bears 4 legs, each leg can be withdrawn into a hollow beside it (pedifossae) found on the ventral surface.

- The stigmata between the 3-4 legs.
- The peritremes is connected.
- The genital plate with genital opening.
- The anal plate with anal plate.

Group: Gamasina

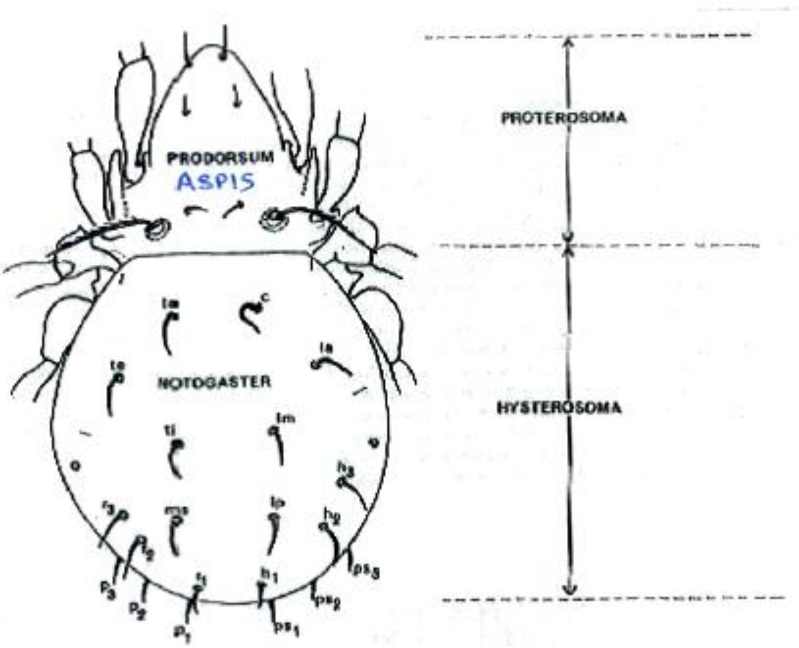
Family: Laelaptidae

e.g.: *Pachylae laptidae*

- The Gnathosoma with 2 chelicerae and 2 pedipalps, and it observable anteriorly.
- The Idiosoma: the first pair of legs forward facing.
- The peritreme is separated.

Sarcoptiformes (Oribatida)

1- The idiosoma split into at least two sections when viewed from above (dorsal), the proterosoma and the hysterosoma. A dorsal shield called prodorsum covering the front of the proterosoma often extending far forward covering the "head". Another shield "notogaster", covering the hysterosome.
2- The gnathosoma of these mites is often hidden under the projecting front part of the proterosome called a camerostome ("chamber-hole"). The chelicerae are often hard to see, tucked deep within the camerostome.
3- Eyes and stigmata absent.
4- Legs are 5-segmented, coxa fused to the ventral side.
5- Genital and anal plates are divided.



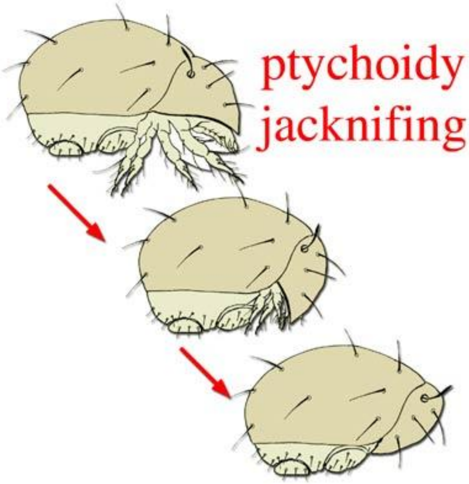
General structure of Oribatida

Group: Oribatei inferiors (lower oribatids)

Family: Phthiracaridae

e.g.: ***Rhysotritia***

- The body is generally laterally compressed (Blade of knife) and divided into the proterosoma and the hysterosoma.
- The body with a ptychoid form, which allow them to retract into a ball to protect their sort parts from predators.
- The gnathosoma is often hidden under the projecting front part of the proterosoma which called a camerostome.
- The genital and anal plates connected in one structure.



Family: Lohmannidae

e.g.: *Lohmania*

- The genital and anal plates found in one structure.

Family: Epilohmannidae

e.g.: *Epilohmania*

- The colour is light.
- There is a region (neck-like) between proterosima and hysterosoma.

Group: Oribatei superiors (higher oribatids)

Family: Oribatelloidae

e.g.: *Setobates*

- Hard-bodied, dark oribatids with projections of the dorsal shield (Pteromorphs) that protect the base of the legs.
- The pteromorphs or wings are very small.

- The prodorsum shield with projecting lamellae but not connected medially with each others.
- The genital and anal plates with clearly defined space between them, and the genital plate not connected with the lamellae.
- Tibia in the leg is large.

e.g.: *Lamellobates*

- Lamellae are larger than in Setobates and connected medially with each other and with the genital plate.
- The pteromorphs are larger than in Setobates.

Family: Galumnidae

e.g.: *Galumna*

- Lamellae are absent or very small.
- The pteromorphs are large and auriculate.

Family: Passalozetidae

e.g.: *Passalozetes*

- Hard-bodied, dark oribatids without pteromorphs.
- The body outer edges are darker in colour.
- The genital and anal plates with clearly defined space between them.

Family: Oppiidae

e.g.: *Oppia*

- Hard-bodied, dark oribatids without pteromorphs.
- There are two dark spots in the sides of the body.
- The genital and anal plates with clearly defined space between them.