

Introduction *Acaudaleyrodes rachipora* control Through Biological Studies: A Literature Review

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Abstract:

Research conducted on insects from a physiological perspective has helped explain the resistance of certain plant species to pests, especially when nutritional requirements are high. This research is also valuable in understanding how pesticides work and their impact on the nervous system. Studying the chemical composition of pesticides aids in the development of more effective pesticides that can penetrate the body through the cuticle. Additionally, it sheds light on results obtained from environmental and behavioral studies. This explanation provides crucial physiological information about the insects being studied. The study of sensory organs has demonstrated their utility in chemical and light traps. While research on insect hormones has led to the development of a new generation of pesticides known as (IGRs), along with identifying of their modes of action. New methods of resistance have emerged through the discovery of specific chemical reactions unique to insects. The discovery of pheromones has also played a role in insect resistance.

Keywords: nutritional requirements, physiological information, insect hormones, IGRS, sensory organs, chemical reactions

Introduction

*The body wall in insect's exoskeleton

The significance of the body wall in insects: The cuticle in insects is a defining characteristic of the insect class and is primarily responsible for their success in various environments. As insects are part of the invertebrate animal group, lacking a skeleton, they rely on robust body wall known as an exoskeleton for support during movement (Alcalá et al. 2020). This exoskeleton aids in the functioning of limbs such as legs and wings, which are connected to muscles that contract and expand using the body wall. The body wall services prevent water loss from insect's body, thereby maintaining internal water content. It acts as a protective barrier against predators and parasites, particularly with a hard body wall that deters feeding or eggs-chewing. Additionally, the body wall shields internal tissues from mechanical damage that may occur during movement (Baker et al. 2020). It also provides protection against toxic substances in the environment. The cuticle lines the digestive tracts, tracheae and contains sensory organs. The color of the body walls aids in environmental adaptation and mate selection in some species.

Comprising two main layers, the cuticle and the epidermis, the body wall is a vital component for insect survival (Ali et al. 2019).

Layers of the cuticle: The cuticle consists of two main layers. The first layer is the pro cuticle, which is thick, and the second layer is the epicuticle, which is thin. After molting, the outer third or half of the pro cuticle becomes harder and darker in color, Known as the exocuticle. Beneath the exocuticle is the endo cuticle, sometimes visible in some insects, and a very thin layer called the mesocuticle (Chen et al. 2019). The epicuticle consists of the following layers, from the outside to the inside: cement layer, wax layer, Cuticulin layer (Babendreier et al. (2019).

Chemical composition of the cuticle layer: Chitin: makes up about of the dry weight of the cuticle components and is concentrated in the endo cuticle. Chitin is a complex sugar that does not dissolve in water, alcohol or diluted acids and is not responsible for the hardness of the body wall (Amoabeng et al.2021). The structural unit of chitin is N-acetyl-glucosamine, linked to proteins in the cuticle. Proteins make up more than 50 of the dry weight of cuticle and include Arthropod in which is soluble in hot water and turns into Sclerotic protein in the outer cuticle layer (Dively et al. 2020).

Resilin, another protein is highly elastic and found in high concentrations in the inner cuticle layer, providing flexibility.

Lime, or calcium carbonate is found in the body wall of some aquatic insect larvae and dipterous insects. Other components found in small proportions include fats, inorganic components like Magnesium, Potassium, Sodium, Phosphate and Carbonate, Phenols, Enzymes, Pigments. Resin acids and fatty proteins (Colazza et al. (2023).

*Chemical composition of the surface cuticle layer: The cement layer: contains resin acids and hardened proteins from sebaceous glands. The wax layer is a mixture of paraffin's, esters, saturated and unsaturated fatty acids, sometimes sterols. The Cuticulin layer consists of fatty proteins originating from oenocytes (Fang et al. 2021).

*Epidermal layer: Consists of a single row of tightly packed cells that are very important in the process of exfoliation. Some of these cells have become specialized into sense organs, dermal glands, and Oenocytes, which are cells involved in the secretion of fatty proteins (Heong et al. 2021).

*The cycle of shedding and formation of new cuticle: The increased growth in size and weight of the insect during its development is not accompanied by an increase in the insect's cuticle because it is a non-cellular material. Therefore, when this growth occurs, the old cuticle is removed and replaced with a new one. This process is called molting or the molting cycle, which involves two main steps: The first is the separation of the old cuticle from the skin layer cells, called apolysis. The second is the removal of the remains of the old cuticle, a step known as ecdysis (Grez et al. 2021).

*Steps of the molting process: Changes appear in the skin cells as a result of their normal division. They appear compacted and take the form of vertical cells, with an increase in size and a jagged surface. The old cuticle separates from the skin cells (apolysis) due to the changes in the skin cells mentioned in the previous step. The resulting space is filled with a liquid called molting fluid, released from the skin cells. When the Cuticulin layer is complete, the molting fluid begins to activate and digest the inner cuticle from the old body wall. The products of this enzymatic digestion are absorbed by the skin cells and used in the formation of new skin, and weak molting threads begin to form (ecdysis lines). The process of forming and depositing the first cuticle layer, the pro cuticle, begins. The process of removing the old cuticle (the outer cuticle layer) (ecdysis) begins, and shortly before that, the layer begins to form on the

surface of the new cuticle, called the shed cuticle. At this stage, and immediately after its completion, the cement layer forms above the waxy layer. The expansion phase of the new cuticle begins, which is flexible in its expansion. The wall of the new body hardens (sclerotisation) and the color darkens due to the deposition of pigments, especially melanin, a process called darkening. The deposition of the inner cuticle continues (Holland et al. 2020).

The process or step of ecdysis occurs when the old cuticle cracks along the line of molting as a result of the insect's muscular activity and also as a result of the insect ingesting water, as in the case of aquatic insects, which take in a large amount of air, increasing blood pressure to the outside, especially in the chest area. When the old cuticle cracks, the insect pulls itself out, starting with the head and chest area, then the limbs, and then the abdomen. The removal of the old cuticle is accompanied by the exit of the membranes lining the anterior and posterior digestive tracts (Intima) and the membrane lining the tracheae. After molting, the new cuticle remains tight and soft color. However, it helps movement somewhat and may reduce blood pressure, which remains high. This helps expand the new cuticle, and when this is complete, blood pressure returns to normal. Expansion occurs before the hardening process, which is called hardening or tanning, The proteins in the outer cuticle layer are transformed from light-colored soluble proteins called Arthropod to hard, brightly colored proteins called Scleroten, which give the insect's body wall its hardness with the help of the amino acid tyrosine (Irvin and Hoddle 2021).

The insect's digestive system: The digestive system of insects consists of the digestive tract and its appendages, including the esophagus and Malpighian tubules, directly connected to the digestive tract, as well as the salivary glands, indirectly connected. The length of the digestive tract varies depending on the type of insect and its diet. It may be equal in length to the body or much longer, causing it to coil inside the body, especially in insects that feed only on liquids. During embryonic development, the front and rear of the digestive tract are formed as an internal indentation in the body, resulting in the division of the tract into three main regions: The foregut (Stomodeum) – the foregut, the middle digestive tract (Mes enteron) – the midgut, the hind digestive tract (Proctodeum) – the hindgut. The anterior and posterior canals are lined with a layer of ectoderm; a continuation of the body wall called the Intima. The origin of the middle digestive canal (stomach) is from cells that form inside the embryo during its development. The anterior digestive tract is separated from the middle tract by the cardiac valve or cardiac valve. The middle tract is separated from the posterior tract by the pyloric valve or pyloric valve. The front part of the digestive tract is a tube-shaped part called the esophagus, followed by a large part called the crop, which narrows at the back to form a valve called the gizzard (proventriculus), the rear end of which connects to the middle canal or stomach at the cardiac valve of the stomach. The foregut connects to the pharynx in the head region, which turns into a pump to draw in fluid, as in the wings (Horgan et al. 2022).

Digestive Tract Appendages: Cecum: These are long, closed tubes that open into the anterior region of the stomach. Their number varies depending on the insect species (82 tubes). They provide a suitable environment for bacterial growth and play a role in digestion and absorption by increasing the surface area of the stomach. Malpighian tubules: Found in most insects as long, fine tubes that connect to the digestive tract. Their number varies among insects, ranging from 151 pairs. As their number increases, their length decreases. Their shape also varies among insects; they may be fine, branched, or have fine appendages. Salivary glands: Their shape varies depending on the insect species and they are located in the head and thorax. Types include: Lower lip glands: These glands secrete their contents near the lower

lip. This type of gland is found in most insects characterized by their clustered shape. They consist of two pairs of clustered lobes that empty into a common salivary duct that opens at the base of the lower lip, which in some insects may be sac-like or tubular in shape. Their function is to secrete saliva to moisten the mouth and food. They also contain enzymes; the type of enzyme present in the saliva depends on the type of food. Common enzymes include amylase and invertase, if the food is primarily composed of sugars, or protease. Lipase is present when food contains proteins and fats. In aphids, there is an enzyme called Pectinase to break down pectin found in cell walls, or saliva contains anticoagulant substances, as in insects that feed on animal blood. As for lepidopteran larvae, their salivary glands secrete a silken substance to build the cocoon. Digestive Enzymes in Insects (Jiang 2021).

Sources of Enzymes in Insects: Salivary glands, the midgut of the stomach, in some insects, microorganisms living in the digestive tract and in different locations contribute to digestion. The quantity and type of enzymes in insects vary depending on the type of food. If the diet is varied, as in the diet of cockroaches, the stomach secretes the enzymes protease, amylase, invertase, and lipase. However, in insects that feed on flower nectar, there is an enzyme... Invertase, parasites, and insect predators, or insects that feed on meat, secrete protease and lipase enzymes, primarily: The most important carbohydrate-degrading enzymes (Amylases): Carbohydrase enzymes break down disaccharides and polysaccharides into monosaccharides to facilitate their absorption by the epithelial cells of the stomach. The enzymes that break down disaccharides, while those that break down polysaccharides such as starch and glycogen, are called amylase. There are two types of amylases: The first is called exogenous amylase, which separates the disaccharide maltose from the end of the starch molecule. This results in a rapid increase in the concentration of maltose, which is then broken down into... Two glucose units by α -glucosidase. The second is called endo amylase, which attacks the internal bonds of the starch molecule. This leads to a slow increase in maltose. Initially, dextrin is formed, followed by maltose, which is then broken down in two glucose units by the enzyme α -glucosidase. It is called Maltase. As for insects that feed on cellulosic materials such as wood, only a few of them possess the enzyme Cellulase, which breaks down the complex sugar cellulose. As for other insects that feed on plants, they feed on the contents of plant cells without their walls or rely on microorganisms to digest cellulose. The enzyme Cellulase works to break down cellulose into the disaccharide Cellobiose (two units of a glucose unit), which is then broken down in turn by the enzyme Glucosidase- β . Insects that lack the enzyme Cellulase have microorganisms in their digestive tract that digest cellulose, as in the case of termites. These termites contain various types of flagellates (protozoa), found in large numbers in the hindgut of worker termites that feed on wood or cellulosic materials and convert the cellulose into glucose. Termites, after digesting cellulose into glucose, propel the sugar into the middle duct through contractions of the hindgut. In other species, the glucose remains within the flagellates, where anaerobic oxidation occurs, producing organic acids and CO₂ gas. These acids are then used... That was caused by the insect (Jiménez-Alfaro et al. 2020).

Proteinases: Primarily, proteins are digested in the middle duct, where this duct secretes the enzyme proteinase. This enzyme works to produce or break down protein molecules into smaller molecules called polypeptides. Poly peptidase enzymes, some of which are found in the lumen of the duct, but most of which are found in epithelial cells, then further break down these polypeptides. This indicates that most polypeptides... The byproducts of protein molecules are absorbed by these cells. Two types of these enzymes have been found: Carboxypolypeptidase, which attacks the peptide chain at its end containing

the carboxyl group (COOH). Amino Poly peptidase attacks the peptide chain at its end, which contains the amino group (NH₂). Then, another group of enzymes called dipeptide breaks down di-peptides into amino acids. As for insects that feed on animal proteins such as collagen and keratin (keratin is found in wool, hair, skin, and bird feathers), these insects have the ability to digest protein. This is because by secreting a special enzyme called Keratinase, while the larvae of the order Di ptera, which feed on animals, have the ability to secrete the enzyme Collagen, which breaks down collagen. To substances that are easily absorbed by the middle duct (Li et al. 2022).

Lipases: Most insects secrete the enzyme lipase to digest the fats in their food. This enzyme works to convert fats into fatty acids and cholesterol. This enzyme and another enzyme, esterase, are secreted from the middle duct and the salivary glands. The first enzyme works to break down long triglycerides, while the second enzyme works to break down long triglycerides. The second works to digest short triglycerides and esters of other fatty acids (the front, middle, back, and middle parts), or perhaps there is more than one part that absorbs them.

Protein Absorption: The main areas for the absorption of hydrolyzed proteins are the middle duct and the cecum. In some insects, such as grasshoppers and American cockroaches, the cecum also absorbs certain amino acids, such as glycine and serine. The posterior duct (rectal region) absorbs some amino acids that are excreted via the Malpighian tubules. In blood-feeding insects, the posterior part of the midgut has been found to absorb proteins without lysis, which are then broken down within the epithelial cells. The absorption mechanism for these lysed proteins is diffusion, although in other insects, active transport is used. **Absorption of Inorganic Substances:** The main absorption zones for inorganic substances such as ions or salts are the midgut. The rectum also works to retrieve or reabsorb these substances after they have been excreted by the Malpighian tubules. The absorption zone for these substances varies depending on the substance and the type of insect (anterior or midgut) (Khumairoh et al 2021).

Water absorption: The water absorption areas are the cercal tubes and the anterior part of the middle canal or its middle part. In many insects, the rectal glands contribute to the reabsorption of water excreted by the Malpighian tubes, such as in storehouse insects or insects that feed on dry matter. However, those that live on liquids do not require very little water, so water is not reabsorbed by the rectum. Therefore, no rectal papillae or glands are observed in these insects. The absorption mechanism is active diffusion or translocation. **Absorption of Food or Digestion Products.** The main absorption area is the middle duct, where most of the digestion products are absorbed. The posterior duct also contributes to the absorption of some substances. Absorption occurs using the mechanism of diffusion or active transport by the epithelial cells in the stomach (Muñoz et al. 2021).

Carbohydrate Absorption: The digestive tract absorbs sugars after they have been broken down into simple or monosaccharide components. One of the most important absorption sites for monosaccharides is the cecum, as in desert locusts, or the anterior part of the stomach, as in mosquitoes. However, most insects, the stomach absorbs most products of sugar digestion. The process of sugar absorption depends on a specific mechanism. Absorption occurs when the blood's sugar concentration decreases, leading to absorption by the stomach, which contains a high concentration of complex sugar breakdown products. In the body, particularly in fatty tissues near the digestive tract, glucose is converted into the disaccharide trehalose to prevent further increases in blood glucose levels. The rate of glucose absorption decreases as blood glucose concentration rises. Trehalose in the blood may be converted to glycogen in muscles, fat cells, and stomach cells. Other monosaccharides, such as mannose and fructose, are absorbed at a

much lower rate than glucose because their conversion to trehalose is slower than the conversion of glucose to trehalose (Khumairoh et al 2021).

Fat Absorption: The main sites for absorbing the products of fat digestion are the cecum and the middle duct. The crop may absorb cholesterol in some other insect species, and the posterior duct may contribute to fat absorption, as in some adult beetles. Despite the presence of fat-digesting enzymes in the stomach, the stomach can still absorb fats. Fats are sometimes absorbed without being broken down, and in certain types of insects, specific parts of the midgut may be specialized in absorbing the breakdown products of fats, unlike other areas. Microorganisms and their relationship to digestion (Khumairoh et al 2021).

Symbiotic Digestion: The importance of microorganisms in the digestive system is evident in insects that feed on a limited diet, as well as in insects with a varied diet. In insects that feed on a limited diet, meaning a diet lacking certain types of essential nutrients or enzymes, microorganisms play a crucial role in digestion. The importance of these organisms in the growth and development of insects is evident in their presence in insects that feed on wood, dry grains, hides, wool, or similar materials. The role of these organisms in these insects is either to provide the necessary enzymes for digesting food or to supply essential nutrients such as vitamins or other important compounds involved in production cycles, energy or growth. A clear example of this is the symbiosis of certain types of flagellates (protozoa) in the hindgut of a termite. Their function is to break down cellulose, a complex sugar. This insect lacks the ability to break down this substance because it lacks the enzyme Cellulase, which breaks down cellulose into monosaccharides like glucose. Some types of flagellates break down and produce certain organic acids useful in energy production (Shields et al. 2019). This occurs in the hindgut. For substances to be absorbed by the middle gastrointestinal tract, contractions occur in the hindgut to propel these substances into the middle gastrointestinal tract, where they are then absorbed and utilized. Types of

Microorganisms and Their Location in the Body: Bacteria: There are many types, and they are the most common among microorganisms. They are found in most insects and live in the cecum. Flagellates:

There are different types, especially in termites and cockroaches. They live freely in the digestive tract.

Yeasts: There are different types of yeasts, belonging to the order Hemipterous and the order Coleoptera.

Yeasts live in special cavities located between the epithelial cells of the anterior part of the middle canal.

Excretion and Excretory Organs in Insects. Excretion is defined as the removal of waste products resulting from the process of metabolism, which are useless and harmful if left inside the body. It also involves regulating the balance between water content and salt concentration in the bloodstream to provide the appropriate chemical environment for the tissues within the insect's body to perform their functions properly. Functions of the excretory system in insects: Removal of unwanted substances that would be toxic if left inside the body, such as eliminating substances like ammonia and uric acid, either by excreting them from the body or storing them in specialized cells within the body (Paredes et al. 2021). Removing excess substances from the body, such as water, salt ions, amino acids, and sugars.

Maintaining the osmotic pressure of blood fluid by preserving water balance and salt concentration.

Excretory Organs: The typical excretory system in most insects consists of Malpighian tubes, intestines, and rectum. However, in insects that lack Malpighian tubes or whose Malpighian tubes are inefficient in removing unwanted materials, other excretory organs may be present. These organs may be present in certain insects but not in others. Examples of these organs include: The labial glands, also called the labial kidneys: In insects that lack Malpighian tubules, the labial glands, as in the order *Anal phis japonica* and *Anal phis tracheae*, isolate certain pigments resulting from the metabolic process from

the bloodstream and expel them through an opening at the base of the lower lip. In insects of the order Lepidoptera (family Saturniidae), there is a pair of glands that open at the lower lip. These glands secrete a potassium bicarbonate solution when the adult emerges from the pupa inside its cocoon. The benefits of this gland include: eliminating excess water from the bloodstream to reduce the insect's weight and enable it to fly. Eliminating... Excess potassium. Providing a suitable medium for the enzyme Coconase to digest the silk of the cocoon so that the adult can emerge (Sparta et al. 2021).

Excretion via the digestive tract: Where nitrogenous waste is excreted, as in jumping-tail insects (which do not possess Malpighian tubules (where uric acid accumulates in the epithelial tissue of the midgut, and this tissue is shed several times to eliminate the uric acid). In insects that lack Malpighian tubules to remove uric acid, the intestines perform an excretory function, removing it from the blood and excreting it with the feces (Wan et al. 2019a).

Pericardial cells and renal cells Nephrocytes: In insects that cannot isolate or remove large molecules from their bloodstream, which the Malpighian tubules cannot remove, these insects possess cells distributed throughout the heart and aorta, and may also be found on the diaphragm or collateral muscles. These cells are called pericardial cells. As for the kidney cells (Nephrocytes), they are found in scattered areas of the body cavity or between fat cells. The cells (surrounding the heart and kidneys) filter out harmful substances with large molecular weights (some nitrogenous compounds and pigments) or any other substances that do not have Malpighian tubules for filtering, as these cells get rid of these substances from the bloodstream. This process, known as phagocytosis or pinocytosis, involves the formation of food vacuoles within the cell. Lysosomes contain enzymes that break down these molecules into their basic components, which are then excreted from the cell and eliminated from the body via Malbegi tubules (van Lenteren and Cock 2020).

Fat bodies and their role in storage: Adipose tissue, known as fat bodies, contain numerous cavities and are typically white but can also appear green, yellow, or orange. These fat bodies are organized in two layers within the body cavity: the parietal layer beneath the body wall and the visceral layer surrounding the digestive tract. One of their primary functions is to store excess fat and glycogen in cell cavities, releasing these substances as needed. Additionally, fat bodies play a crucial role in metabolizing nutrients and synthesizing essential compounds for an insect's life. Regarding excretion insects, lacking an efficient excretory system utilize urate cell to absorb and store uric acid crystals, which are later utilized in nucleic acids synthesis as a nitrogen source. Some insect, like those in the Pieridae family, store uric acid crystals and pteridines, from nitrogenous base breakdown in their wing scales. Insect with a typical excretory system, including Malpighian tubules, intestines, and rectum, manage waste elimination throughout their life cycle in coordinated manner. Malpighian tubules consist of a membrane derived from the bronchial terminals, containing muscle fibers that facilitate movement within the bloodstream to extract nutrients efficiently. The tubules basement membrane prevents the passage of high molecular weight substances, while epithelial cell folds enhance substance transport .The tubules extract ions .organic compounds ,sugars ,and amino acids from the blood fluid ,creating a distinct fluid composition compared to blood .The intestines aid in water absorption from tubal fluid and transport it to the rectum preventing the absorption of ions, and. Organic compounds .The rectum controls ion concentration ,water levels and reabsorbs beneficial organic compounds to maintain blood balance .Uric acid excretion involves its extraction into the bloodstream as urates ,which are precipitated in the rectum and excreted

as crystals with urine or feces. Insects regulate water and salt balance through various excretory structures, ensuring proper waste elimination and nutrient absorption for survival (Wan et al. 2019b).

Water balance and salt osmoregulation are crucial processes for the survival of insects. Firstly, terrestrial insects face the challenge of water loss through evaporation from the body wall, respiration through spiracles, and excretion. They obtain water by drinking consuming water-rich foods, metabolic water production, and absorbing water vapor from the atmosphere. A decrease in water content can lead to death in insects, highlighting the importance of maintaining water and salt balance.

Insects like the *Tenebrio* insect face challenge with water loss, especially those feeding on dry foods. However, insects consuming moist foods need to regulate excess water and salt ions in their blood. The digestive system absorbs salts from food, but continuous absorption is required. Most insects can regulate blood ionic content to prevent imbalances, with the excretory system playing a key role in maintaining this balance. In an aquatic insect, freshwater species have higher osmotic pressure in their blood, leading to water entering their bodies through different mechanisms like the body wall and gills. They balance intake with excretion to prevent salt loss. Saltwater insects lose water to their environment due to lower osmotic pressure, but they reabsorb lost water through the rectum. Salt balance is maintained through food intake and excretion. The ability of insect to regulate osmotic pressure is crucial for survival, with the rectum and Malpighian tubules playing key roles in maintaining balance. Osmoregulation is essential for preventing disruptions in blood osmotic pressure. Insects breathe through spiracles which connect to tracheae for gas exchange. Spiracles have a regulatory mechanism to control air entry, ensuring efficient respiration (Wan et al. 2018).

The tracheae (or tracheoles): are flexible, silvery-white, air-filled tubes that branch out into numerous smaller branches, which then spread throughout all the body's systems and organs. The air sacs: sometimes dilate in certain parts to create thin-walled, sac-like swellings. Air sacs are found in most winged insects but not in wingless insects, and they serve as an air reservoir to nourish muscles that require large amounts of air. Insects are classified into two categories based on the number of spiracles present and the number of functional and closed spiracles: Insects that have lost one or more pairs of spiracles are called hyponastic insects, such as some types of scale insects. Insects that have ten pairs of spiracles are classified according to the number of functioning stomata and their distribution: Holopneustic insects, which have a complete respiratory system with ten pairs of stomata, all of which are functional and are found in most insects. Hemipneustic insects have one or two pairs of stomata. Apneustic insects have a closed respiratory system and breathe through the body wall or gills, as in aquatic insects (Wang et al. 2019).

Mechanism of Respiration: Respiration occurs through the exchange of gases between the incoming air and the cell walls of the tissues (oxygen is taken in and carbon dioxide and water vapor are released). This exchange depends on the process of diffusion. At rest, the respiratory sacs are closed and the bronchioles are filled with air, except for the bronchioles whose ends are located between tissue cells, which are filled with bronchial fluid. When flying, exerting oneself, or increasing metabolism, increased muscle activity and lactic acid formation in tissues cause an increase in osmotic pressure within the tissues. This movement causes the bronchial fluid at the ends of the bronchioles to enter the tissues. The air in the bronchioles is then forced out, displacing the fluid. This allows oxygen-rich air to reach the body tissues, facilitating gas exchange where oxygen is released from the air and tissues produce carbon dioxide. When an insect's activity decreases and its muscles relax, lactic acid production decreases, and

the osmotic pressure within the tissues drops, causing bronchial fluid to flow back into the bronchi. Expiration occurs when the insect's body contracts due to muscle contraction, causing increased pressure on the bronchi and a decrease in their capacity. The air pressure inside the bronchial system then exceeds atmospheric pressure, causing the stomata to swell and expel air (Tania and Muñoz ,2023). Inspiration occurs when the body relaxes, reducing the internal blood pressure on the bronchi, increasing their capacity, and lowering the air pressure inside them be low atmospheric pressure, forcing outside air through the stoma and filling the bronchi. The respiratory stoma closes when the internal and external air pressures are equal. Carbon dioxide is released after the gas exchange process and diffuses into the body cavity, then exits either through the respiratory openings, the cuticle (in insects with thin cuticles), or between the segments. In aquatic insects, respiration occurs either through the body wall by diffusion of water-soluble oxygen through the body wall, or through gills containing blood and covered by a thin wall, where gas exchange also occurs by diffusion. Circulatory System: Insects possess an open circulatory system where blood occupies the general body cavity known as the hemocoel. The movement and circulation of blood depend primarily on the activity of the dorsal blood vessel located in the pericardial sinus, a cavity insulated by the dorsal diaphragm. The diaphragm separates the per visceral sinus from the visceral cavity. Sometimes, the ventral diaphragm, located above the nerve cord, isolates the per neural sinus from the visceral cavity. The nerve cord is smaller than the per neural sinus (Zhu et al. 2017a).

The per neural sinus is smaller than the visceral sinus. The Dorsal Vessel: divides into two main parts: the posterior part is the heart, and the anterior part is called the aorta. In most insects the heart is located in the abdominal region and may extend to the thoracic region, as seen in Dictyoptera insects. The heart contains openings resembling slits on either side of the heart wall, numbering nine pairs in the abdomen and three in the thorax, as in the aforementioned order. However, in flies of the genus *Musca*, there are three pairs of anterior and posterior slits. These openings protrude into the heart allowing blood to flow in during diastole and preventing its exit during systole. There are also openings of another type called excurrent Ostia, as seen in some insects of the order Orthoptera. A pair of ventricular collateral slits in the heart wall, but without internally located valves. The number of these slits varies depending on the insect. Externally, each slit is surrounded by a group of spongy cells acting as a valve. These slits widen when the heart contracts, allowing blood to flow out. When the heart relaxes, these slits close to prevent blood from entering. In most Dictyoptera insects, there are no excurrent Ostia inside the heart, but they contain segmental vessels through which blood exits the ventricles. In Blatt aria, there are two in the thoracic region and four in the abdominal region. In other insects, only the ventral Ostia are present, as in dragonflies. These tubes pass between the alar muscles and then branch into fine branches inside the heart. At the origin of these vessels, there is a group of cells that close these tubes to prevent blood from entering the heart, Known as Incurrent Ostia. The Aorta a t the front of the heart, continues as a simple tube that does not contain Ostia but has an opening that opens in the head or anterior chest region. In some orders such as Strep siptera, Embioptera, Phasmatodea and Orthoptera, there may be an extension of the aorta from the dorsal side called the incurrent Ostia. This extension is associated with the accessory pulsating organs that help with Diverticulum (Blood Circulation Within the Wings) (Zhu et al. 2017b). Alary Muscles and Dorsal Diaphragm: The pterygoid muscles, which extend from one side of the body to the other directly below the heart, are closely connected to the heart. They appear as a layer at their origin on the tarsals and then expand beyond the midline of the heart. The muscles near the tarsals are

the ones that contract and relax. These muscles are also attached to connective tissues and may attach directly to the heart wall, as in Diptera insects, instead of the junction below the heart. The number of these muscles also varies, and may reach up to ten pairs in the abdominal region and two pairs in the thoracic region, as in the order Orthoptera. The pterygoid muscles form a lateral, incompletely formed membranous connective tissue. Therefore, the dorsal cavity connects laterally to the visceral cavity. The ventral diaphragm is a horizontal septum located directly above the nerve cord, separating the visceral and neural cavities. It is present in many adult larvae of the orders Raphidioptera, Neuroptera Orthoptera, and Strepsiptera, as well as in Diptera, and is absent in the remaining orders. Laterally, it connects to the sternites at a single point for each segment, except in the order Lepidoptera. There are several points of connection, hence there are lateral openings connecting the visceral and neural cavities. This diaphragm is found in most orders only in the abdominal region, but it extends to the thoracic region, as in the order Orthoptera. The movement of this membrane is muscular, while the neural action is a cycle of reducing the number of contractions. The structure of this diaphragm is a thin membrane containing muscle fibers, especially in the abdominal region (Zhu et al. 2017b).

Accessory Pulsating Organs: The diaphragm is considered an accessory pulsating organ because it functions through the contraction and relaxation of its muscle fibers. As a result, it moves in a cyclical motion from front to back, causing blood to move within the neural cavity towards the rear of the insect. During this movement, the blood ascends into the visceral cavity and then... The dorsal diaphragm, through the lateral openings located on either side of the ventricular and dorsal diaphragms, allows blood to enter the blood vessel, which is a major pulsating organ that moves blood in the body cavity. There are other pulsating organs located within the blood cavity that help maintain blood pumping and circulation in the insect's limbs. In the mid-thorax, and sometimes in the posterior thorax, there is a pulsating organ responsible for blood circulation in the wings, called thoracic pulsating organs. These are usually found in the thorax of fast-flying insects. Each pulsating organ pushes the incoming blood from the aorta to the... The wings then draw it back into the aorta. An example of some auxiliary pulsating organs in the tremors is the thoracic pulsating organ, which consists of a blood-filled space that opens via a terminal opening (Ostia) located at the top of a sac-like space (ampulla) at the end of the pulsating organ, which crosses the aorta. When the pulsating organ relaxes, the terminal opening opens, and thus blood is drawn from the space. The blood found below the vents, and indirectly, the blood present in the wings is withdrawn (Zhu et al. 2018).

Insect Hemolymph: Insect blood consists of plasma fluid and blood cells (hemocytes).

Hemocytes: There are many types of blood cells in insects that will be identified in the practical lesson. Another observation about blood cells in insects is that the number of blood cells The number of blood cells present in the bloodstream changes constantly and over short periods. Generally, the number of these cells is high before molting and decreases after molting. Examples of blood cell counts in larvae before molting and immediately before pupation, and in the pupa after its formation, are as follows: 8000/mm³ Sarcophagidae larvae; larvae before pupation; 34000/mm³ newly formed pupa; 12000/mm³. Other blood cells are present in the bloodstream either as suspended cells (free cells) or as cells attached to the surface of various internal tissues (Colazza et al. 2023).

Blood Plasma or Plasma Fluid

Chemical Composition of Blood Plasma in Insects: Water constitutes 92-42 of the total body weight and approximately 90 of the total body weight. **Proteins:** Their percentage varies among insects, ranging from 1.6 to 6.6 in plasma fluid. In most insects, they are around 5. The percentage also varies among different species. The protein content in the blood varies according to the insect's developmental stages. Its composition increases before pupation and decreases during the pupa stage. There are also differences in the type and quantity of protein between males and females (for example, female blood contains the female protein Vitellogenin). Furthermore, many types of proteins are bound to either sugars or fats (Wan et al. 2018).

Enzymes: Various enzymes are found in the blood, such as. glucosidase enzymes, trehalose enzymes, esterase (JH enzymes), and dehydrogenases, that participate in the oxidation of sugars. Phenolases such as tyrosinase, responsible for the darkening or blackening of insect blood upon exposure to air, are also present (Wan et al. 2018).

Amino Acids: Insect blood is characterized by its high concentration of amino acids, sourced from nutrition or biological activities within body tissues. The percentage of amino acids in insect blood ranges between 65 and 35 of the total non-protein nitrogenous compounds. There are also 15 free amino acids present in blood plasma, which, along with fatty acids and proteins are important in classifying insects to the species level. The percentage of amino acids varies according to stages of development, for example, Tyrosine (van Lenteren and Cock 2020).

Lipids: Various types of lipids are found in insect blood plasma, including neutral lipids, sterols, phospholipids, and protein-bound lipids. The amount of lipids in the blood increases either as a result of the breakdown of fat bodies during a stage of development or when the insect consumes a high-fat meal. The amount of lipids in the blood decreases when the insect is hungry. **Carbohydrates:** Insect blood contains trehalose, a sugar broken down by the enzyme trehalase within the tissues into two glucose molecules, used for energy production energy. Blood plasma also contains other types of monosaccharides and disaccharides. Large quantities of sugars a long with protein, are found in insect blood, forming glycoproteins. **Inorganic substances:** **Negative ions:** like chloride, are common in insect blood, with high concentrations most i insects, except fully formed insects, B. **Positive ions** like Sodium and potassium, are also present sodium being the most common positive ion. These ions help maintain the ionic balance necessary for tissue activity and effectiveness (Sparta et al. 2021). **Pigments:** Insect blood can be colorless, green, or yellowish, depending on the insect species plant pigments like carotene and xanthophyll. Contribute to these colors, while hemoglobin in some insects gives the blood a light red color. **Functions of Blood plasma:** transports various substances throughout the body, including digestion products, metabolic byproducts, and hormones. It also acts as a storage reservoir for substances like trehalose and amino acids. Additionally, tearing, and wing unfurling. The hydraulic pressure in blood plasma results from muscle relaxation and contraction in the body (van Lenteren and Cock 2020).

Blood Circulation: Proper blood circulation within an insect's body is crucial for the functions mentioned above. The process of blood circulation within an insect's body unfolds as follows: The heart draws blood from the abdomen and pumps it forward, then to the aorta, which releases the blood into the cerebrospinal fluid. The heart functions in the following manner: When the dorsal cavity is filled or when the blood surrounding the heart expands (diastole), the heart chambers open, and all the atrial and ventricular valves open. This action reduces the pressure inside the heart compared to the outside,

allowing blood to flow from the cavity mentioned earlier and fill the heart chambers through the atrial openings. The heart initiates the contraction process (Systole) starting from the posterior chambers compressing the blood inside and closing the atrial valves (Eustachian foramina) forcing the blood to rush towards the next chamber from the front, passing through the ventricular foramina via the ventricular valve. After the blood enters this final chamber, it begins to contract in turn, as the Ostia and the associated ventral stenosis close posteriorly, propelling the blood to the next chamber anteriorly, passing through the ventral stenosis, located at the front of this contracting chamber (Wan et al. 2018). This process continues until the blood reaches the aorta and then flows to the cranial cavity, or through the posterior vessels, entering the visceral cavity. Due to the difference in blood pressure, which is lower in this cavity, blood flows from there into the neural or abdominal cavity. Through the wave-like movement of the ventral diaphragm from front to back, blood moves backward in this cavity. The dorsal diaphragm, which is normally convex or when the muscles are relaxed... The pterygoid chambers, when contracted, become flattened. This flattening results in an increase in the volume of the pericardial cavity and a decrease in the volume of the visceral cavity. As a result of the pressure difference between the two chambers—higher in the visceral cavity than in the dorsal cavity—blood enters at the moment the heart chambers relax, continuing the circulation process within the body (Pingyang et al. 2022).

The Male Reproductive System: The male reproductive system consists of a pair of testes located above or below the digestive tract. Each testis contains a number of tubes called testis tubes (or follicles), which vary widely in number and arrangement among different insects. Most testes are connected to a pair of seminal vesicles, where they meet through the ejaculatory duct, lined internally with a layer of cuticle equipped with strong muscles. Among the male reproductive systems appendages are several accessory glands, the number of which varies among species or is absent in some insects. These glands function to secrete their fluids into the ejaculatory duct to mix with the sperm in the seminal fluid, forming structures. The sperm cells are concentrated in structures called spermatophores, where the sperm heads are enclosed within a gelatinous sheath (Li et al. 2022).

Spermatogenesis: This process occurs in the testes, each containing several regions: The germinal region which houses germ cells that produce sperm Spermatogonia: which also contains large nourishing cells called apical cells that feed the sperm during early development. The Zone of Growth also known as the zone of spermatocytes, where Spermatogonia undergoes divisions, resulting in 64 to 256 spermatocytes enclosed by a membrane, expanding into a sac called a cyst containing multiple cells. The Zone of Maturation, where each spermatocyte undergoes meiosis to form two tailless spermatids and then mitosis to form four tailless spermatids. The Zone of Transformation: where the spermatids develop into spermatozoa, or tailless sperm, released from the sacs in this region, propelled by the movement of their tails into the vas deferens and stored in the seminal vesicles. These transformation spermatids into spermatozoa are known as spermatogenesis until mating (Holland et al. 2020).

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