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3.2. Gall forming insects

3.2.1. Definition and features:

Galls are abnormal growths or swellings on plant tissues induced by various organisms, particularly insects, mites, fungi, and bacteria. These growths serve as protective shelters and nutrient sources for the organisms that induce them.

Definition of Galls (by Insects): Galls, induced by insects, are localized, abnormal outgrowths or deformities on various plant parts, including leaves, stems, branches, buds, flowers, fruits, and roots. They result from the interaction between the gall-inducing insect and the host plant, triggered by the insect's physical presence or the release of chemical signals. Galls provide a specialized microenvironment that benefits the gall-inducing insect by protecting it from predators, parasitoids, and environmental stressors, and by providing a source of nutrients.

Features of Galls Induced by Insects:

Abnormal Growth: Galls represent a deviation from the plant's normal growth pattern, causing localized swelling or distortion of plant tissues.

Distinctive Appearance: Galls can vary widely in appearance, depending on the host plant species and the specific gall-inducing insect. They can be spherical, conical, pouch-like, or have various other shapes and sizes.

Protection: Galls provide a protective environment for the gall-inducing insect and its offspring. They shield the insects from predators, harsh weather conditions, and other environmental stressors.

Nutrient Supply: Gall formation involves the redirection of nutrients from the host plant to the gall. This ensures a steady supply of resources, such as sugars and amino acids, for the gall-inducing insect.

Complex Structure: The internal structure of galls can be quite complex. Some galls feature multiple chambers, corridors, and specialized structures that facilitate the development and protection of the gall-inducing organism.

Specific Host-Inducer Relationships: Gall-inducing insects often have specific host plant species or genera that they interact with. They may induce galls on particular plant parts, such as leaves, stems, or roots.

Variable Ecological Roles: Galls serve as microhabitats for various other organisms, including parasitoids, inquilines, and mutualists. These organisms can inhabit or feed on the gall, making it a structured environment within plant tissues.

Chemical Manipulation: Gall-inducing insects often secrete chemicals into the plant tissues, including plant growth regulators and other compounds. These chemicals manipulate the plant's responses and promote gall formation.

Co-Evolution: The interaction between gall-inducing insects and host plants represents a fascinating example of co-evolution. The insects have evolved adaptations to exploit host plants, while the plants have developed strategies to resist or tolerate gall formation.

Biodiversity and Ecological Significance: Galls contribute to biodiversity and play important roles in ecosystem dynamics. They influence plant diversity, community interactions, and the abundance of associated organisms.

3.2.2. Formation of gall: Galls are abnormal growths on plants caused by various insects, mites, or microorganisms. Here are the basic steps in the formation of galls by insects:

Oviposition: The process begins when a female insect lays her eggs on or in a plant. Some insects have specialized structures, such as ovipositors, to insert their eggs into plant tissues.

Chemical secretion: As the eggs are laid, the insect often secretes chemicals that can manipulate the plant's growth and metabolism. These chemicals can stimulate the plant to create a protective structure around the eggs.

Plant response: The plant recognizes the presence of foreign substances, such as the insect's eggs or secretions. In response, it initiates a series of physiological and biochemical changes.

Gall formation: The plant's response leads to the formation of a gall, which is a unique structure that provides protection and nourishment for the developing insect larvae. Galls can vary in shape, size, and color depending on the species of insect and the type of plant involved.

Larval development: Inside the gall, the insect eggs hatch into larvae. These larvae feed on the gall tissue or the plant's nutrients provided by the gall.

Metamorphosis: The insect larvae undergo metamorphosis, transforming into pupae and then into adult insects.

Emergence: Once the insects complete their development, they emerge from the gall, often leaving exit holes through which they escape. The cycle may then repeat if the female insects lay their eggs on the same or other host plants.

Economic importance of gall

1. **Natural Dyes:** Some galls contain tannins, which can be used for dyeing fabrics and leather. The tannins in galls can produce various shades of brown and black, depending on the method of extraction and application. Historically, galls were used for dyeing textiles.

2. **Ink:** Iron gall ink, historically a common type of ink used for writing and drawing, is made from gallnuts. It is called "iron gall" because it contains iron salts, which react with the tannic acid in the galls to create a dark, indelible ink.

3. **Medicinal Uses:** In traditional medicine, galls have been used for various medicinal purposes. For example, they have been used to treat wounds, as astringents, or to stop bleeding due to their tannin content. However, the medical use of galls is largely outdated in modern medicine.

4. **Arts and Crafts:** Galls can be used in art and crafts, especially for making natural pigments or as a source of interesting shapes and textures for creative projects. They can be used for making natural jewelry, ornaments, and decorations.

5. **Gall-Wasp Products:** In some regions, galls formed by specific types of gall wasps can be collected and used for various purposes. For example, oak galls created by wasps have been used historically for making ink and dyes.

6. **Plant Health:** Galls are typically a sign of stress or damage to the plant. They can be caused by various factors, including insect infestations, fungi, bacteria, and other pathogens. These abnormal growths can weaken the plant and reduce its overall health, which can lead to reduced crop yields and quality**.**

7. **Crop Damage:** In agriculture, galls can affect a variety of crops, including fruits, vegetables, and grains. For example, crown gall, caused by the bacterium Agrobacterium tumefaciens, can lead to reduced yields in crops like grapes and stone fruits.

8. **Costs of Control:** Farmers often have to invest in pest management strategies to control the insects or pathogens responsible for gall formation. These control measures can include the use of pesticides, which can be costly and have their own environmental and health implications.

9. **Nuisance for Ornamental Plants:** Galls on ornamental plants can reduce their aesthetic appeal and market value. This can affect the horticulture industry, which relies on the sale of healthy, attractive plants.

10. **Impact on Forests:** Galls can also affect tree species in forests. For example, oak galls, caused by certain wasps, can harm oak trees. When galls become too prevalent, they can affect the overall health of forest ecosystems.

3.2.3 Common gall pests:

Gall pests, also known as gall-inducing organisms, are a diverse group of insects, mites, fungi, and bacteria that induce the formation of galls on various plant species. Here are some common gall pests and the types of galls they induce:

Gall Wasps (Cynipidae): Gall wasps are a large family of insects known for inducing a wide variety of galls on trees and shrubs. Examples of gall wasp-induced galls include oak apples, marble galls, and horned oak galls. These galls often form on oak trees and other hardwood species.

Aphids (Aphididae): Aphids are small insects that can induce galls on various plant parts, including leaves, stems, and roots. Aphid galls can take the form of pouch galls, bladder galls, or gall-like structures that provide shelter for the aphids.

Gall Midges (Cecidomyiidae): Gall midges are tiny flies that lay their eggs on or in plant tissues. The resulting larvae induce the formation of galls. Examples include the poplar flower gall and willow beaked gall.

Gall Mites (Eriophyidae): Gall mites are microscopic arachnids that can cause deformities in leaves, buds, and other plant structures. They are responsible for galls like the erineum galls found on many plant species.

Leafhoppers (Cicadellidae): Some leafhoppers induce galls by feeding on plant sap and secreting chemicals that stimulate gall formation. Examples include the grape leafhopper and its associated grape pouch galls.

Scale Insects (Coccoidea): Certain scale insects can induce galls on plant leaves and stems. These galls often serve as protective shelters for the scale insects. Examples include the felt or fluted scales.

Psyllids (Psyllidae): Psyllids, also known as jumping plant lice, can induce galls on plant tissues, including leaves and stems. An example is the pear psylla and its associated psyllid galls.

3.2.4. The extent of gall-making habits : The extent of gall-making habits in insects is quite significant and widespread in the insect world. Gall-inducing insects are found in multiple orders and families, and they have adapted to many different plant species across various ecosystems. Here are some key points regarding the extent of gall-making habits in insects:

Diverse Taxa: Gall-inducing behavior is observed in a diverse array of insect taxa, including gall wasps, gall midges, aphids, scale insects, thrips, beetles, and more. These insects belong to different orders and families, reflecting the widespread nature of this behavior.

Global Distribution: Gall-forming insects can be found in various ecosystems worldwide, including temperate, tropical, and arid regions. The behavior is not limited to a particular geographic area.

Host Plant Range: Gall-inducing insects can be highly host-specific or more generalist, depending on the species. Some insects may be specific to a single plant species or genus, while others can induce galls on a broad range of host plants.

Complex Relationships: The interactions between gall-inducing insects and their host plants are often complex and involve co-evolution. These insects have evolved specific adaptations to exploit host plants, and plants have developed strategies to resist or tolerate gall formation.

Economic Impact: In agriculture and forestry, certain gall-inducing insects can have economic significance. For example, the grape phylloxera (a type of aphid) is a major pest of grapevines, and the oak gall wasp can affect oak tree health.

Ecological Roles: Galls serve as microhabitats for various other organisms, such as parasitoids, inquilines, and mutualists. These galls can provide a structured and protected environment within plant tissues.

Niche Exploitation: Gall-making behavior allows insects to exploit a unique ecological niche. By manipulating plant tissues, gall-inducing insects create a sheltered space and nutrient source for their offspring, reducing competition with other herbivores.

Biodiversity: Gall-inducing insects contribute to the biodiversity of ecosystems, and their interactions with host plants influence plant diversity and community dynamics.

Scientific Study: Gall formation is an area of active research in entomology and botany. Scientists study these interactions to better understand co-evolution, ecological relationships, and plant defenses.

3,2.5.Gall as dwelling place, the position of gall:

Galls can serve as dwelling places for various organisms, including the gall-inducing insects or mites themselves, as well as other species that inhabit or parasitize the gall structure. The position of the gall on a host plant can vary depending on the gall-inducing organism and the specific host plant. Here are some common positions and types of galls as dwelling places:

1. **Leaf Galls:** Galls that form on leaves can be found on the upper or lower surfaces, along the leaf margins, or even within the leaf tissue. In the case of leaf galls, the gall-inducing organism and its offspring often live inside the gall structure. For example, pouch galls, blister galls, and spindle galls are common types of leaf galls.

2. **Stem or Twig Galls**: Galls that form on stems, twigs, or branches are typically found attached to the plant's woody structure. These galls can be located at various positions along the stem, including near the tips, in the middle, or closer to the base. The insect larvae or mites responsible for these galls often inhabit the inner chambers of the gall.

3. **Root Galls:** Root galls form on or within the roots of plants. They can vary in position, with some being located close to the soil surface and others deeper in the root system. Root-knot nematodes, for example, induce root galls, and the nematodes reside within these structures.
4. **Bud Galls:** Galls can also develop within plant buds, causing the buds to swell and take on unusual shapes. The gall-inducing organism and its larvae often inhabit these gall structures. Examples include bud galls induced by gall midges or aphids.
5. **Flower Galls:** Galls that form on flowers can be located on various floral parts, such as petals, sepals, or the reproductive organs. The gall-inducing insects may feed on the gall or reside within it.
6. **Fruit Galls:** Some galls develop on the fruits of plants, either on the surface or within the fruit tissue. These galls can house the gall-inducing insect or mite and protect it from external threats.
7. Trunk Galls: On larger woody plants, galls may form on the main trunk or branches. These galls can be extensive and may serve as dwelling places for the gall-inducing organism and other organisms.

The specific position of a gall often depends on the gall-inducing organism's behavior, the way it interacts with the host plant, and the plant's response to the stimulus. Galls provide a microhabitat that can protect the inhabitants from environmental factors, predators, and parasitoids, making them a suitable dwelling place for the gall-inducing organism and associated organisms

3.2.6.Classification of galls by Orders:

Galls induced by insects are quite diverse, and they can be classified into different orders of insects based on the types of insects that cause them. Here are some common orders of insects that induce galls:

1. **Hymenoptera (Ants, Bees, and Wasps):**
    - **Cynipidae (Gall Wasps):** These wasps are known for inducing various galls on trees and shrubs, such as oak apples, marble galls, and horned oak galls.
    - **Chalcidoidea:** Certain parasitic wasps in this superfamily induce galls on plants. Examples include fig wasps (Agaonidae) and cynipoid wasps (Figitidae).
2. **Diptera (Flies):**
    - **Cecidomyiidae (Gall Midges):** These tiny flies are significant gall inducers, often forming galls on various plant parts, including leaves, stems, and flowers.
3. **Hemiptera (True Bugs):**
    - **Aphididae (Aphids):** Aphids are known to induce a variety of galls, including pouch galls, bladder galls, and other deformities on leaves, stems, and roots.
    - **Cicadellidae (Leafhoppers):** Some leafhoppers can stimulate gall formation by feeding on plant sap and secreting chemicals. They induce galls on leaves, stems, and other plant parts.
4. **Arachnida (Mites):**
    - **Eriophyidae (Gall Mites):** Gall mites are microscopic arachnids responsible for causing deformities in leaves, buds, and other plant structures.
5. **Coleoptera (Beetles):**

- **Curculionidae (Weevils):** Some weevils induce galls by depositing their eggs in plant tissues. Larval feeding often results in gall formation, such as acorn weevil galls on oak trees.

6. **Psocoptera (Barklice):**
    - **Psocidae:** Certain barklice species induce galls on plant stems and branches.
7. **Lepidoptera (Butterflies and Moths):**
    - **Tineidae:** Some species of Tineid moths can cause leaf galls, especially on oaks.
    - **Gelechiidae:** Certain Gelechiid moths induce galls on plant tissues.
8. **Thysanoptera (Thrips):**
    - **Phlaeothripidae:** Some thrips species can cause galls on leaves and flower buds.

3.2.7.Adaptation for the gall making habits:

Insects that engage in gall-making behavior have evolved various adaptations that help them thrive in this unique ecological niche. These adaptations often benefit both the gall-inducing insect and, in some cases, the associated symbiotic organisms. Here are some common adaptations for gall-making habits in insects:

Chemical Manipulation: Gall-inducing insects often secrete chemicals into plant tissues to stimulate the formation of galls. These chemicals can include plant growth regulators, enzymes, and other compounds that interfere with normal plant development. This manipulation ensures a controlled and protective environment for the insect and its offspring.

Protection: Galls provide a protective structure that shields the developing insect and its eggs or larvae from predators, parasitoids, and environmental stressors. The gall's structure and chemistry can deter potential threats.

Nutrient Extraction: Gall-forming insects can alter the plant's nutrient transport systems, redirecting essential nutrients to the gall to support their development and the growth of their offspring.

Oviposition Behavior: Many gall-inducing insects have specialized ovipositors (egg-laying structures) that enable them to lay their eggs within plant tissues, often at precise locations. This ensures that the developing larvae are in close proximity to a reliable food source.

Synchronized Life Cycles: The timing of gall formation and the development of the gall-inducing insect's offspring are often synchronized with the plant's growth and development. This ensures a continuous supply of nutrients and a suitable environment for the insect throughout its life cycle.

Gall Structure: The physical structure of the gall can be adapted to meet the needs of the gall-inducing insect. For example, galls may have specialized chambers for larval development or offer protection from environmental extremes.

Associations with Symbionts: Some gall-inducing insects form mutualistic relationships with bacteria or fungi that live within the gall. These symbiotic microorganisms can help with nutrient processing and detoxification, making the gall an even more hospitable environment for the insect.

Selection of Suitable Host Plants: Gall-inducing insects have adapted to select specific host plant species or even particular parts of a plant that are most suitable for gall formation. This selective behavior helps ensure the success of gall formation and the survival of their offspring.

Reduced Mobility: Many gall-inducing insects have relatively limited mobility, often staying near the gall and not wandering far from their place of oviposition. This is because the gall itself provides a stable food source and protection.

Cooperation with Other Gall-Formers: In some cases, multiple species of gall-forming insects can coexist within the same gall. They may cooperate or partition resources within the gall to reduce competition and maximize the use of the gall structure.

3.2.8 Origin and types of galls (open & closed):

Galls are abnormal growths or swellings on plant tissues induced by various organisms, such as insects, mites, fungi, and bacteria. They serve as protective shelters and nutrient sources for the organisms that induce them. Galls can be broadly categorized into two main types: open galls and closed galls. Here's an overview of the origin and types of galls:

Origin of Galls:

The formation of galls is typically a response by the host plant to an external stimulus or injury. The gall-inducing organisms, which can be insects, mites, fungi, or bacteria, introduce chemical signals or physically damage the plant, leading to the development of galls. These galls provide a specialized microenvironment that benefits the gall-inducers by protecting them from predators and providing them with a source of nourishment.

Types of Galls:Open Galls:

Simple Open Galls: These are relatively simple and unbranched structures formed by localized cell proliferation and swelling in response to the gall-inducing organism. They typically have an opening or pore through which the gall-inducer has access to the outside environment. Examples include the woolly apple aphid gall.

Complex Open Galls: These galls are more complex in structure, often featuring multiple chambers, cavities, and projections. They may have complex arrangements of plant tissues and can be induced by various organisms. Examples include the oak apple gall induced by gall wasps and the cedar-apple rust gall.

Closed Galls:

Bladder Galls: Bladder galls are a type of closed gall that is typically round or oval in shape and filled with liquid. The gall-inducing organisms secrete fluids into the gall, which provides both protection and a source of nutrients.

Pouch Galls: Pouch galls are shaped like small pouches or bags and are often formed in plant parts such as leaves or stems. They are enclosed structures that offer protection to the gall-inducer. Some aphids induce pouch galls.

Hard or Woody Galls: These galls are solid and woody in nature, often taking the form of knobby or irregular growths. They can be quite durable and provide long-term protection for the gall-inducing organisms. Examples include the oak marble gall.

Gall Apples: Gall apples are closed galls found on various types of plants, including oak trees. They are often induced by gall wasps and are characterized by a tough, woody structure.

3.2.9 Physiology of gall formation: The physiology of gall formation is a complex process involving the interaction between a gall-inducing organism (insect, mite, fungus, bacterium) and the host plant. This interaction triggers a series of physiological and biochemical changes in the plant tissues, resulting in the formation of a gall. Here is an overview of the key physiological processes involved in gall formation:

1. **Recognition and Contact:** The gall-inducing organism comes into contact with the host plant, typically through feeding, oviposition (egg-laying), or physical contact.
2. **Chemical Signals:** The gall-inducing organism releases a variety of chemical signals, which can include plant growth regulators, enzymes, and other compounds, into the plant tissues. These chemical signals are often specific to the organism and play a crucial role in manipulating plant responses.
3. **Plant Response:** The plant recognizes the presence of the gall-inducing organism and perceives the chemical signals as a threat or disturbance. This triggers a cascade of physiological responses, including changes in gene expression and hormone levels.
4. **Cell Division:** One of the primary responses is the rapid and localized cell division at the site of the stimulus. This leads to the development of a cluster of rapidly dividing cells that will form the initial structure of the gall.
5. **Cell Enlargement (Hypertrophy):** The newly formed cells within the gall undergo hypertrophy, which means they increase in size significantly. This is a key feature of gall formation, as it leads to the characteristic swelling or bulging in the plant tissue.
6. **Nutrient Redirection:** The gall-inducing organism often manipulates the plant's nutrient transport systems. This redirection of nutrients ensures a steady supply of resources, such as sugars and amino acids, to the growing gall.
7. **Gall Development:** Over time, the mass of enlarged and hypertrophied plant cells forms the characteristic structure of the gall. The specific appearance of the gall can vary widely depending on the host plant and the gall-inducing organism.
8. **Hormonal Regulation:** Hormones, such as auxins, cytokinins, and gibberellins, play a critical role in gall formation. They regulate cell division, cell expansion, and tissue differentiation within the gall.
9. **Protection and Maintenance:** The gall structure provides a protective environment for the gall-inducing organism, shielding it from predators, harsh environmental conditions, and competition with other organisms. The plant continues to supply nutrients to the gall to support the gall-inducing organism.
10. **Gall Maturation:** As the gall-inducing organism completes its life cycle within the gall, the gall may mature, change in color, or develop specialized structures for the protection and nourishment of the gall-inducing organism.
11. **Release of Gall-Inducers:** Once the gall-inducing organism's life cycle is complete, it may exit the gall, often leaving behind an empty or senescent structure. Some galls may persist on the plant for an extended period, while others eventually break down and decompose.