Plant defense mechanism

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Wildlife disease (302.1)

Dr. Moitreyee Chakrabarty
Assistant Professor
PG Department of Conservation Biology
Durgapur Government College

In general, plants defend themselves against pathogens by a combination of weapons from two arsenals:

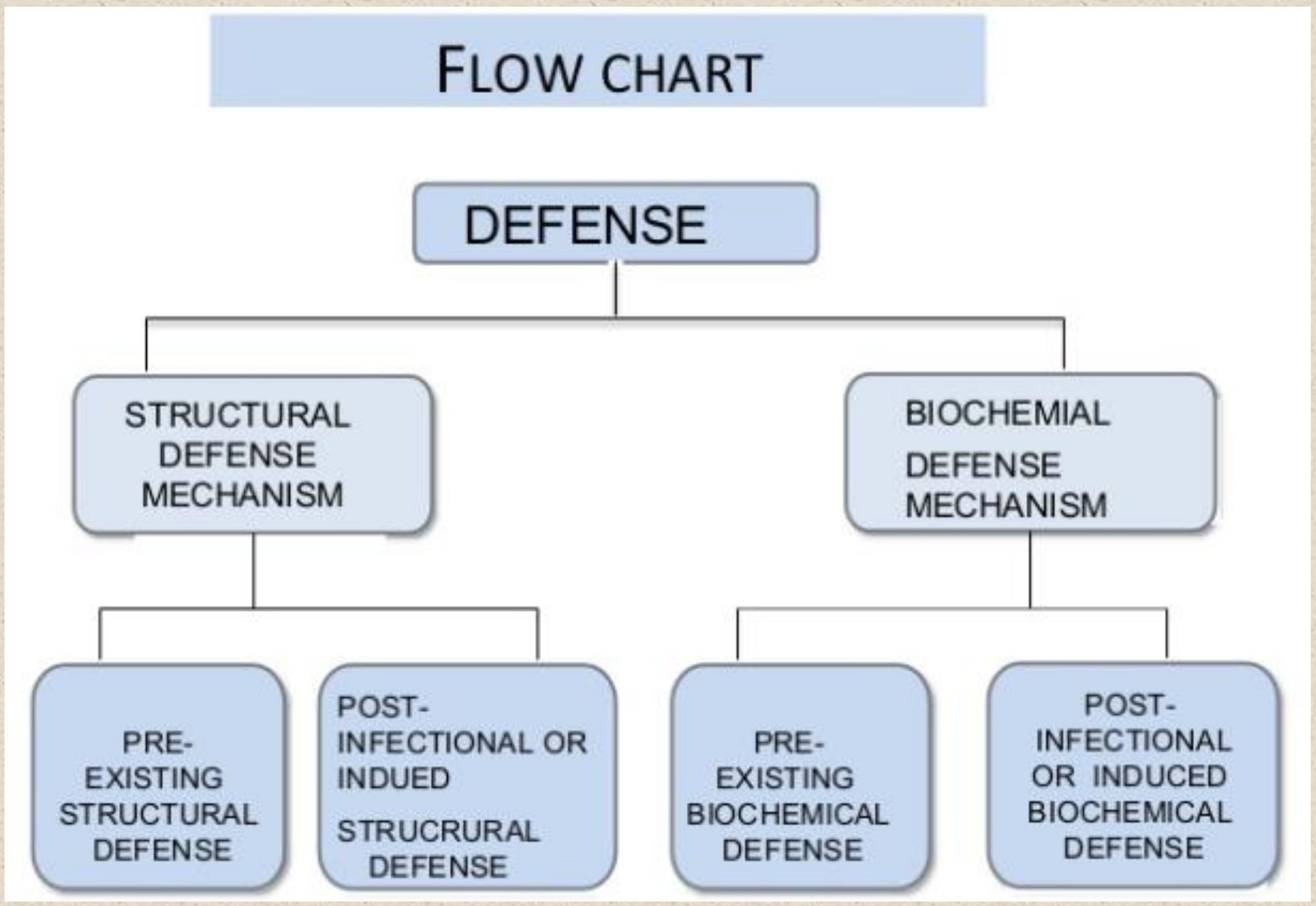
1) **Structural characteristics** that act as physical barriers and inhibit the pathogen from gaining entrance and spreading through the plant and

2) **Biochemical reactions** that take place in the cells and tissues of the plant and produce substances that are either toxic to the pathogen or create conditions that inhibit growth of the pathogen in the plant.

Both the defences are affected by:

1. Age of the plant.
2. Type of organ infected.
3. Nutritional status of the host.
4. Environmental conditions.

FLOW CHART


DEFENSE
STRUCTURAL DEFENSE MECHANISM
BIOCHEMIAL DEFENSE MECHANISM
PRE-EXISTING STRUCTURAL DEFENSE
POST-INFECTIONAL OR INDUED STRUCRURAL DEFENSE
PRE-EXISTING BIOCHEMICAL DEFENSE
POST-INFECTIONAL OR INDUCED BIOCHEMICAL DEFENSE

- **Pre-existing structural defense**
  - Wax
  - Thick cuticle
  - Thickness and toughness of the outer wall of epidermal cells
  - Stomata
  - Sclerenchyma cells
  - Lenticel

- **Induced structural defense**
- Cellular defense structure
  - Hyphal sheathing
- Histological defense structure
  - Formation of cork layer
  - Formation of abscission layer
  - Formation of tyloses
  - Deposition of gums

1. Structural defence mechanisms

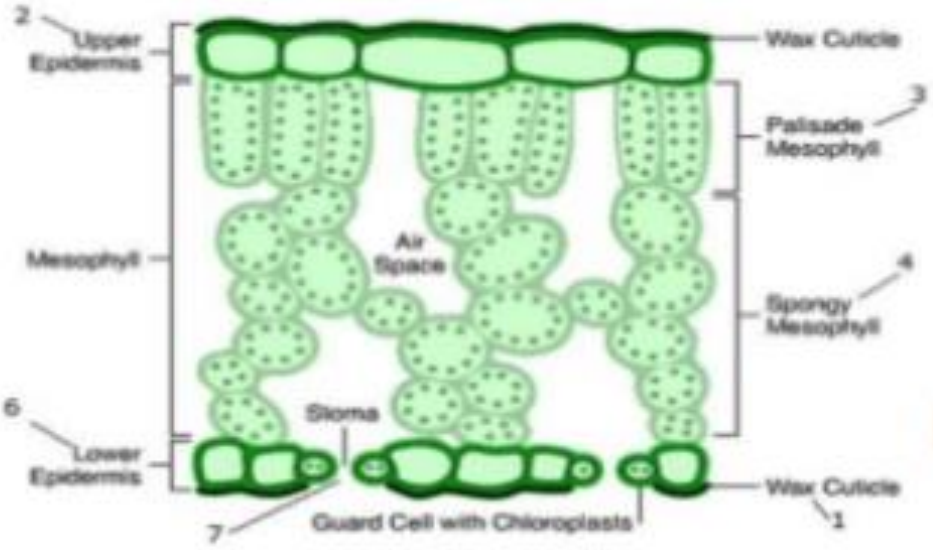
- **A. Pre formed or pre existing defense structures**

- The first line of defense of a plant against pathogens is its surface,which the pathogen must adhere to and penetrate if it is to cause infection.
- Some structural defense are present in the plant even before the pathogen comes in contact with the plant.
- Such structure include the amount and quality of wax and cuticle that cover the epidermal cells, the structure of the epidermal cell walls, the size, location and shapes of stomata and lenticels and
- The presence of tissues made of thick walled cells that hinder the advance of pathogen on the plant.
- A thick mat of hairs on a plant surface may also exert a similar water-repelling effect and may reduce infection.

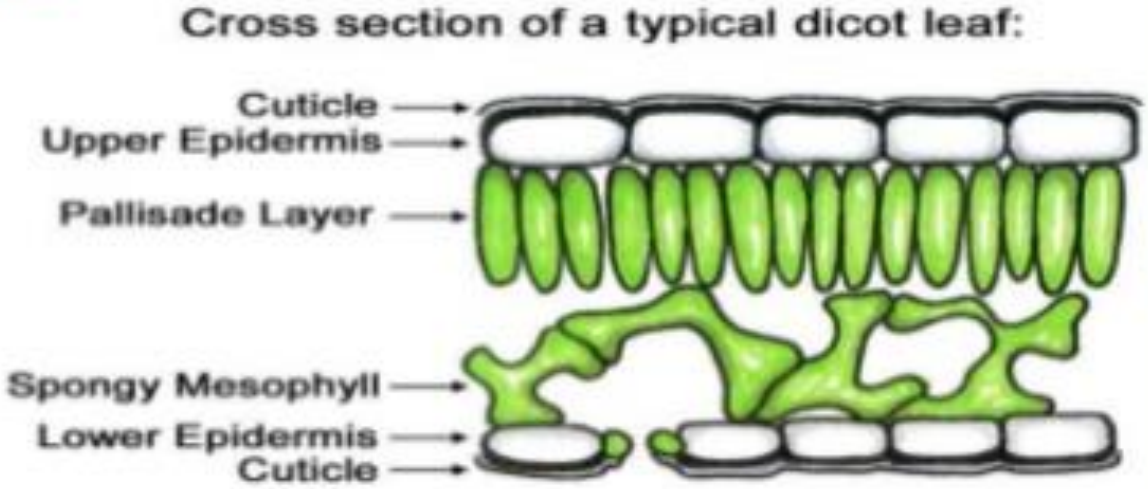
1-PRE-EXISTING STRUCTURAL DEFENSE

- It includes:
  - Amount and quality of wax and cuticle.
  - Shapes, size and locations of natural openings (stomata and lenticels).
  - Presence of thick walled cells in the tissues of the plant that hinder the advance of pathogen.

- **Wax-**
  - It is the mixture of long chain of apolar lipid.
  - It forming a protective coating on plant leaves and fruit.
  - Synthesized by epidermis.
  - Extremely hydrophobic.



- **Cuticle & Epidermal cell:-**



- **Ex:** Disease resistance in Barberry species infected with *Puccinia graminis tritici* has been attributed to the tough outer epidermal cells with a thick cuticle.
- In linseed, cuticle acts as a barrier against *Melampsora lini*.
- Silicification and lignifications of epidermal cells offers protection against *Pyricularia oryzae* and *Streptomyces scabies* in paddy and potato, respectively.

Sclerenchyma cells:-

- It composed of thickened walls of lignin.
- Sclerenchyma cells is present in stem and leaf veins.
- Brittle cells help in mechanical support of the plant.
- Effectively block the spread of some fungal and bacterial pathogens that cause **angular leaf spot.**

Structure of natural opening:-

A. Stomata:-

- Most of pathogen enter plants through natural opening.
- Some pathogen like stem rust of wheat (*Puccinia graminis* f.sp. *tritici*) can enters its host only when the stomata are open.
- Structure of stomata provides resistance to penetration by certain plant pathogenic bacteria.

B. Lenticels :-

- Lenticels are openings on fruit, stem and tubers that are filled with loosely connected cells that allow the passage of air.
- Shape and internal structure of lenticels can increase or decrease the incidence of fruit diseases.
- **Ex.** Small and suberised lenticels will offer resistance to potato scab pathogen, *Streptomyces scabies.*

B. Post infectional or induced defense structures

- Some of the defense structures formed involve the cytoplasm of the cells under attack, and the **cytoplasmic defense reaction**.
- Others invove the walls of invaded cells and are called **cell wall defense structures.**
- Still others involve tissues ahead of the pathogen (deeper into the plant) and are called **histological defense structures.**
- Finally, the death of the invaded cell may protect the plant from further invasion. This is **called necrotic or hypersensitive defense reaction.**

1. Cytoplasmic defense reaction

- The plant cell cytoplasm surrounds the clump of hyphae and the plant cell nucleus is stretched to the point where it breaks in two.
- In some cells, the cytoplasmic reaction is overcome and the protoplast dissappears while fungal growth increases.
- In some of the invaded cells, however the cytoplasm and nucleus enlarge. The cytoplasm becomes granular and dense, and various particles or structures appear in it.
- Finally, the mycelium of the pathogen disintegrates and the invasion stops.

2. Cell wall defense structures

- The outer layer of cell wall of parenchyma cells coming in contact with incompatible bacteria swells and produces an amorphous, fimbrillar material that surrounds and traps the bacteria and prevents them from multiplying.
- Cells walls thicken in response to several pathogens by producing what appears to be a cellulosic materials. This material, however, is often infused with phenoloic substances that are cross-linked and further increase its resistance to penetration.
- Callose papillae are deposited on the inner side of cell walls in response to invasion by fungal pathogens.

3. Histological defense structures

Cork layer :-

- Infection by fungi, bacteria, some viruses and nematodes induce plants to form several layers of cork cells beyond the point of infection.
- These cork cells inhibits the further invasion by the pathogen beyond the initial lesion and also blocks the spread of toxin substances secreted by the pathogen.
- It also stop the flow of nutrients and water from the healthy to the infected area and deprive the pathogen of nourishment.

ABSCISSION LAYERS

- An abscission layer consists of a gap formed between infected and healthy cells of leaf surrounding the locus of infection.
- Due to the disintegration of middle lamella of parenchymatous tissue.
- Gradually, infected area shrivels, dies, and sloughs off, carrying with it the pathogen.
- Abscission layers are formed on young active leaves of stone fruits infected by fungi, bacteria or viruses.

TYLOSES

- Tyloses are the overgrowths of **the protoplast of adjacent living parenchymatous cells,** which protrude into xylem vessels through pits.
- Tyloses have cellulosic walls.
- It formed quickly ahead of the pathogen and may clog the xylem vessels completely blocking the further advance of the pathogen in resistant varieties.

❖ GUM DEPOSITION-

- Various types of gums are produced by many plants around lesions after infection by pathogen or injury.
- Gums secretion is most common in stone fruit trees but occurs in most plants.
- Generally these gums are exudated by plant under stressed condition.
- Gummosis is the process in which gum produced by the plants and trees.

BIOCHEMICAL DEFENSE MECHANISM

- **Pre-existing chemical defense**
  - **1. Inhibitors**
    - Released by plant in it's environment
    - Present in plant cells before infection
  - **2. Phenolics**
    - Tannins
    - Glucanases
    - Dienes
    - Chitinase

- **Induced chemical defense**
  - Hypersensitivity response (HR)
  - Production of Antimicrobial substances
    - Phytoalexins
    - Plantibodies

❖ PRE-EXISTING CHEMICAL DEFENSE

- Although structural characteristics may provide a plant with various degree of defense against attacking pathogens.

- It is clear that the resistance of a plant against pathogen attack depends not so much on its structural barriers as on the substances produced in its cell before or after infection.

- Before infection or penetration of pathogens, host released some chemicals to defend themselves.

❖ INHIBITORS RELEASED BY THE PLANT IN IT'S ENVIRONMENT

- Plants exude a variety of substances through the surface of their aboveground parts as well as through the surface of their roots.
- Inhibitory substances directly affect micro-organisms or encourage certain groups to dominate the environment which may act as antagonists to pathogens.

  - **Ex 1:** Root exudates of marigold contain α-terthinyl which is inhibitory to nematodes.
  - **Ex 2:** In *Cicer arietinum* (chickpea), the *Ascochyta* blight resistant varieties have more glandular hairs which have **maleic acid** which inhibit spore germination.

Red scales of red onion contains phenolic compounds protocatechuic acid and catechol

❖ INHIBITORS PRESENT IN PLANT CELLS BEFORE INFECTION

- It is becoming increasingly apparent that some plants are resistant to disease caused by certain pathogens of an inhibitory compound present in the cell before infection.
- It stored in vacuoles of plant cells.
- **Phenolics** – onion (catechol and protocatechuic acid).
- **Tannins**, and some fatty acid-like compound such as **dienes**,which are present in high concentrations in cells of young fruits, leaves or seeds.
  - ✓ These compounds are potent inhibitors of many hydrolytic enzymes.
  - ✓ **Ex**: Chlorogenic acid in potato inhibits common scab bacteria, *Streptomyces scabies*,and to wilt pathogen, *Verticillium alboatrum*

❖ Saponins:-

- It have antifungal membranolytic activity.
  - **Ex: Tomatine** in tomato and **Avenacin** in oats.

❖ Lactins:-

- They are protiens.
- Bind specifically to certain sugars and occur in large concentrations in many types of seeds, cause "lysis" and growth inhibition of many fungi.

❖ Hydrolytic enzymes:-

- ✓ "Glucanases" and "chitinases" enzymes.
- ✓ It may cause breakdown of pathogen cellwall.

❖ INDUCED CHEMICAL DEFENSE

❑ Phytoalexins:- (Phyton = plant; alexin = to ward off)

- **Muller** and **Borger** (1940) first used the term phytoalexins for fungistatic compounds produced by plants in response to injury (mechanical or chemical) or infection.
- Phytoalexens are toxic antimicrobial substances.
- It produced in appreciable amounts in plants only after stimulation by phytopathogenic micro-organisms or by chemical or mechanical injury.
- Phytoalexins are not produced during compatable reaction.

Characteristics of phytoalexins:-

- Fungitoxic and bacteriostatic at low concentrations.
- Produced in host plants in response to stimulus (elicitors) and metabolic products.
- Absent in healthy plants.
- Remain close to the site of infection.
- Produced in quantities proportionate to the size of inoculum.
- Produced in response to the weak or nonpathogens than pathogens.
- Produced within 12-14 hours reaching peak around 24 hours after inoculation.
- Host specific rather than pathogen specific.

S.No	Phytoalexin	Host	Pathogen
1	Pisatin	Pea	*Monilinia fructicola*
2	Phaseolin	French bean	*Sclerotenia fructigena*
3	Rishitin	Potato	*Phytopthora infestans*
4	Gossipol	Cotton	*Verticillum alboratum*
5	Cicerin	Bengal gram	*Ascochyta blight*
6	Ipomeamarone	Sweet potato	*Ceratocystis fimbriata*
7	Capsidol	Pepper	*Colletotrichum capsici*

Hypersensitive response (HR):-

- The term hypersensitivity was first used by **Stakman** (1915) in wheat infected by rust fungus, *Puccinia graminis*.
- The HR is a **localized induced cell death** in the host plant at the site of infection by a pathogen, thus limiting the growth of pathogen.
- HR occurs only in **incompatible** host-pathogen combinations.
- HR is initiated by the recognition of specific pathogen-produced signal molecules, known as **elicitors**.

Plantibodies:-

- It is generally antibodies.
- It is encoded by animal genes, but produced in and by the plants.
- So that it is called as plantibodies.
- Transgenic plants have been produced which are genetically engineered to incorporate into their genome, and to express foreign genes.
- Mouse genes that produce antibodies against certain plant pathogens.
- It shown in transgenic plant.

- Eg. 1. Plantibodies to *tobacco mosaic virus* in tobacco decreased infectivity of the virus by 90%

- Eg. 2. Plantibodies to *beet necrotic yellow vein virus*, also in tobacco, provides *a* partial protection against the virus in the early stages of infection and against development of symptoms later on;

Pathogenesis-Related Proteins

- Pathogenesis-related proteins, often called PR proteins, are a structurally diverse group of plant proteins that are toxic to invading fungal pathogens.
- They are widely distributed in plants in trace amounts, but are produced in much greater concentration following pathogen attack or stress.
- PR proteins exist in plant cells intracellularly and also in the intercellular spaces, particularly in the cell walls of different tissues.

5) Disruption of host cell membrane:

- Some structural and permeability changes in host cell membrane play a role in defense.

Most common are -

- Release of molecules in signal transduction around cell and systemically.
- Release and accumulation of reactive oxygen 'radicals' and lipoxygenase enzyme.
- Activation of phenol oxidases and oxidation of phenolic due to loss of comport meutalisation.

6) Oxidative burst and release of Nitric oxide (NO):

- Rapid generation of activated oxygen radicals, superoxide (O2-),
- Hydrogen peroxide (H2O2), Hydroxylradical (OH) released by multisubunit NADPH enzymes complex of cell membrane.
- Hydroperoxidation of membrane phospholipids to lipid hydroperoxides.
- Disrupt cell membrane and induce cell colapse and death.

CONCLUSION

- Both the host and pathogen evolve in nature side by side.
- Disease development depends upon successful host-pathogen interaction.
- Susceptibility and resistance of a host against various pathogens is predominantly decided by the gene.
- Different types of chemical and structural defense mechanism provide plant defenses response to the pathogens.
- Defense mechanism will not work ,when compatible reaction occurs between host and pathogen.