MICROBIAL PATHOGENICITY

Virulence is the measurement of the ability to cause diseases in the host. It describes the quantitative negative effect on the host. To cause disease, two factors are important: the nature of the pathogen and the nature of the host. Moreover, the genetic makeup of both pathogen and host is important for a disease to occur. The defense systems in hosts (e.g. immunity systems in an animal or phenolic compound in a plant) will alter the ability to contract a disease. However, high virulence may result in host mortality, and it affects negatively to host transmission, which leads to pathogen fitness.

Virulence factors are molecules produced by bacteria, viruses, fungi, and protozoa that add to their effectiveness and enable them to achieve the following:

- colonization of a niche in the host (this includes attachment to cells)
- immunoevasion, evasion of the host's immune response
- immunosuppression, inhibition of the host's immune response
- entry into and exit out of cells (if the pathogen is an intracellular one)
- obtain nutrition from the host

Specific pathogens possess a wide array of virulence factors. Some are chromosomally encoded and intrinsic to the bacteria (e.g. capsules and endotoxin), whereas others are obtained from mobile genetic elements like plasmids and bacteriophages (e.g. some exotoxins). Virulence factors encoded on mobile genetic elements spread through horizontal gene transfer, and can convert harmless bacteria into dangerous pathogens. Bacteria also gain the majority of their virulence from mobile genetic elements. Gram-negative bacteria secrete a variety of virulence factors at host-pathogen interface, via membrane vesicle trafficking as bacterial outer membrane vesicles for invasion, nutrition and other cell-cell communications. It has been found that many pathogens have converged on similar virulence factors to battle against eukaryotic host defenses. These obtained bacterial virulence factors have two different routes used to help them survive and grow:

- The factors are used to assist and promote colonization of the host. These factors include adhesins, invasins, and antiphagocytic factors.
- The factors, including toxins, hemolysins, and proteases, bring damage to the host.
    - Attachment, immunoinvasion, immunosupression
    - Bacteria produce various adhesins including lipoteichoic acid, trimeric autotransporter adhesins and a wide variety of other surface proteins to attach to host tissue.
    - Capsules, made of carbohydrate, form part of the outer structure of many bacterial cells. Capsules play important roles in immune evasion, as they inhibit phagocytosis, as well as protecting the bacteria while outside the host.

- Another group of virulence factors possessed by bacteria are immunoglobulin (Ig) proteases. Immunoglobulins are antibodies expressed and secreted by hosts in response to an infection. These immunoglobulins play a major role in destruction of the pathogen through mechanisms such as opsonization.
- Viruses also have notable virulence factors. Experimental research, for example, often focuses on creating environments that isolate and identify the role of "niche-specific virulence genes". These are genes that perform specific tasks within specific tissues/places at specific times.

DESTRUCTIVE ENZYMES

- Some bacteria, such produce a variety of enzymes which cause damage to host tissues. Enzymes include hyaluronidase, which breaks down the connective tissue component hyaluronic acid; a range of proteases and lipases; DNases, which break down DNA, and hemolysins which break down a variety of host cells, including red blood cells. Virulence Factors basically Include the Antigenic Structure and The Toxins produced by the organisms.

- A major group of virulence factors are proteins that can control the activation levels of GTPases.

TOXINS

- A major group of virulence factors are bacterial toxins. These are divided into two groups: endotoxins and exotoxins.

Endotoxins

- Endotoxin is a component (lipopolysaccharide (LPS)) of the cell wall of gram-negative bacteria. It is the lipid A part of this LPS which is toxic. Lipid A is an endotoxin. Endotoxins trigger intense inflammation. They bind to receptors on monocytes causing the release of inflammatory mediators which induce degranulation. As part of this immune response cytokines are released; these can cause the fever and other symptoms seen during disease. If a high amount of LPS is present then septic shock (or endotoxic shock) may result which, in severe cases, can lead to death. As glycolipids (as opposed to peptides), endotoxins are not bound by B or T-cell receptors and do not elicit an adaptive immune response.

Exotoxins

Exotoxins are actively secreted by some bacteria and have a wide range of effects including inhibition of certain biochemical pathways in the host.

Exotoxins are also produced by some fungi as a competitive resource. The toxins, named mycotoxins, deter other organisms from consuming the food colonised by the fungi

Strategies to target virulence factors and the genes encoding them have been proposed. Small molecules being investigated for their ability to inhibit virulence factors and virulence factor expression include alkaloids, flavonoids, and peptides. Experimental studies are done to characterize specific bacterial pathogens and to identify their specific virulence factors.

VIRULENCE FACTOR IN VIRUSES

More than one thousand viruses are currently known to be potentially capable of infecting plants. Despite the large number of possible combinations, the development of disease is an exception rather than a common outcome and thus, in most cases, plants are capable of counteracting the harmful effects of viruses. This resistance is owed to the absence of essential host susceptibility factors (passive resistance) or to the existence of several defence layers that the virus has to overcome. First, the virus needs to overcome a series of pre-existing physical and chemical barriers in plants. If a pathogenic virus succeeds in overcoming this first line of defence, it would have to face the non-specific defensive reactions with which the plant responds to some molecular patterns that are common to different pathogens. If a virus has evolved to acquire virulence factors to counteract this basal defence it is in a position to be able to trigger infection. In many cases, however, plants are able to recognize these virulence factors and create a new, more specific resistance layer that is only induced when faced with viruses expressing this virulence factor . A virus can cause productive infection only in those plants that have not developed specific defensive responses to its virulence factors.

Also, viral RNA induces specific plant defence responses in which a large number of plant proteins participate. This antiviral response, which is one of the manifestations of a complex set of cellular processes known as RNA silencing, is apparently universal; so for the virus to be successful it has to escape it. These suppressors not only affect antiviral defence, but also interfere with plant physiological processes that depend on RNA silencing, and this interference may contribute significantly to the pathogenesis of different viruses.

A virus not only needs to escape the defences that plants erect, but must also tackle different processes to complete its productive cycle. The initiation of this cycle depends on the nature of the genetic material of the virus. Positive-polarity RNA viruses are the most abundant in the plant kingdom.

1. For these viruses, genomic RNA must be uncoated and translated after viral particles have entered the plant cell, and both processes are highly coordinated. There also seems to be some kind of coupling between the synthesis of viral proteins and the assembly of some of these proteins with genomic RNA and host factors to form replication complexes. The next stage of the virus cycle entails its movement to neighbouring cells and its dissemination throughout the plant. Interactions of viral and cellular factors may not only contribute to facilitate these viral infection steps and help to establish optimum infection susceptibility conditions but may also indirectly affect host physiological processes.

Although many viral infections progress efficiently without symptom development, induction of plant defence mechanisms, their suppression by counteracting viral strategies and the co-option of host factors required for virus replication and movement can confer a pathological character upon the viral infection.

2. Traditionally, it has been accepted that viral disease symptoms could be caused by a toxic effect of some virus components.

The hypersensitive reaction (HR) is one of the most common plant reactions to any type of pathogenic organism, including viruses. In general, the HR has been associated with a defence response perceived by receptors known as *R* genes, which confine the pathogen to the inoculated area, and thus its potential propagation through the whole plant is impeded. Several virus-specific *R* genes have been identified. Leaves do not hinder the virus from propagating throughout the plant, but occasionally give way to systemic necrotic symptoms that might prove lethal.

Viruses express their genes through an RNA intermediate. Because viruses lack ribosomes, translation of viral proteins from genomic RNA, subgenomic RNA, or mRNA is dependent on the cellular translation machinery.

While plant DNA viruses form minichromosomes in the nucleus of infected cells that are replicated by cellular DNA-dependent DNA polymerases, RNA viruses induce the formation of specialized organelle-like replication vesicles bound to cellular membranes. These vesicles contain viral genomic RNA, viral RNA-dependent RNA polymerases, host factors and are the sites of virus replication . The most detailed information about virus replication complex formation and activity is for positive-single-strand RNA brome mosaic virus (BMV), tomato bushy stunt virus (TBSV), and turnip mosaic virus (TuMV). In addition to cellular membranes, cellular proteins participate in the formation and are essential components of viral RNA replication compartments. Other host factors modulate the accumulation or activity of virus replication proteins

3. The RNA silencing machinery cleaves viral dsRNA structures, giving rise to small interfering RNAs (siRNA) that lead RISC complexes to degrade viral ssRNA and/or to inhibit its translation. mRNAs of some host genes can also be the target of RISC loaded with viral siRNAs, and it has been postulated that downregulation of these genes can contribute to suppressing antiviral defences and/or eliciting disease symptoms .

EFFECT OF PATHOGENS ON HOST PHYSIOLOGICAL PROCESSES

1. PHOTOSYNTHESIS

Photosynthesis, the only process of food synthesis using light energy on the earth, is the distinctive physiological activity of green plants. In spite of its fundamental significance, comparatively little is known about the effects of pathogens on

photosynthesis. Main attention has been paid to the effect of the pathogen on the overall rate of photosynthesis by plants because the chloroplast, the photosynthetic apparatus, is destroyed or disturbed by pathogens.

However, the effects of pathogens on the process of photosynthesis can be discussed under the following heads:

1. Reduction in Photosynthetic Area
2. Reduction in Chlorophyll Content

$$\text{Chlorophyll} \xrightarrow{\text{chlorophyllase}} \text{Chlorophyllide} + \text{Phytol}$$

Chlorophyllase enzyme located in the chloroplast is involved in what is probably the first step in the destruction of chlorophyll in the infected host. Chlorophyll is removed from the lamellae of the chloroplast and chlorophyllide crystallizes within the cell.

3. Alteration in Chloroplast Number and Structure

4. Effect of Toxins
5. Reduction in the Activity of Calvin Cycle Enzymes
6. Alteration in Starch and Sugar Contents

A. In Bacterial Infection

- Decrease in chloroplast
- Suppress CO2 fixation

B. Effect of virus

- Reduce chloroplast amount
- Reduce chlorophyll and sucrose amount
- Cause chloroplast abnormalities.

C. Effect of fungi

- Reduce chloroplast content
- Loss of chlorophyll
- Reduce photophosphorylation coupling mechanism
- Suppress CO2 fixation

2. RESPIRATION

Attack by pathogens in plants can lead to considerable changes in both dark respiration and photorespiration. A common and prominent feature of fungal infection of plants is a

substantial increase in respiration. Such increases can be observed in plants infected with biotrophic and necrotrophic pathogens. Infections can result in increased respiration rates in damaged leaves. Rubisco can catalyse the oxygenation of ribulose bisphosphate (RuBP). This leads to the formation of glycolate 2-phosphate, which is then metabolised via the glycolate pathway.

A. In Bacterial Infection

4. Respiration is increased during pathogen attack
5. Respiration rate rises continuously during multiplication and sporulation of the pathogen
6. Respiration rate may decline to normal or below the normal level
7. Increased respiration cause depletes plant reserve
8. Metabolic changes are observed
9. In resistant plant tissue, there is an immediate increase in oxygen consumption

B. Effect of virus

1. Slightly increase in respiration rate in in leaves

C. Effect of fungi

1. Respiration rate is usually increased in diseased plants.

2. In the early stage of disease synthetic process-induced high rate of respiration

3. In late stage, injury and decomposition leads to increased respiration

3. MECHANISM OF PERMEABILITY

Pathogen change the permeability by

1. Mechanical injury

2. Enzymatic degradation

3. Toxins

4. Cause leakage of electrolytes

4. TRANSLOCATION OF WATER AND NUTRIENTS

1. Affect the function of root
2. Roots absorb less water
3. Interfere with water economy of plant by causing excessive transpiration.

A. In Bacterial Infection

Enter the vascular system in both xylem and phloem through the wound

B. Effect of virus

- Death of phloem
- Inhibit enzymes that break down starch into smaller into translatable molecules.

C. Effect of fungi

- Decrease water absorption
- Vascular Wilt disease
- Decrease water flow

5. PLANT GROWTH AND REPRODUCTION

- Expression of genes
- Cause a drastic unfavorable change in the structure and function of affected cells.
- Change in composition, structure or function of chromatin associated with cell DNA
- Infection causes increase in the activity of enzymes that breakdown RNA
- Energy requirement increases to perform metabolic activity
- Production of phenolics increases
- Resistant plants show increased rate of protein synthesis in the first few minutes of infection