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Course: PCP 101

Topic: Homeostasis

Basic concepts: Homeostasis, control, regulation, growth, nasty, tropism, photomorphogenesis, thigmotropism, osmoregulation, autopoiesis

Learning Objectives:

1. Understanding of the concept of homeostasis, regulation and control
2. Life as organisational homeostasis and its biological implications

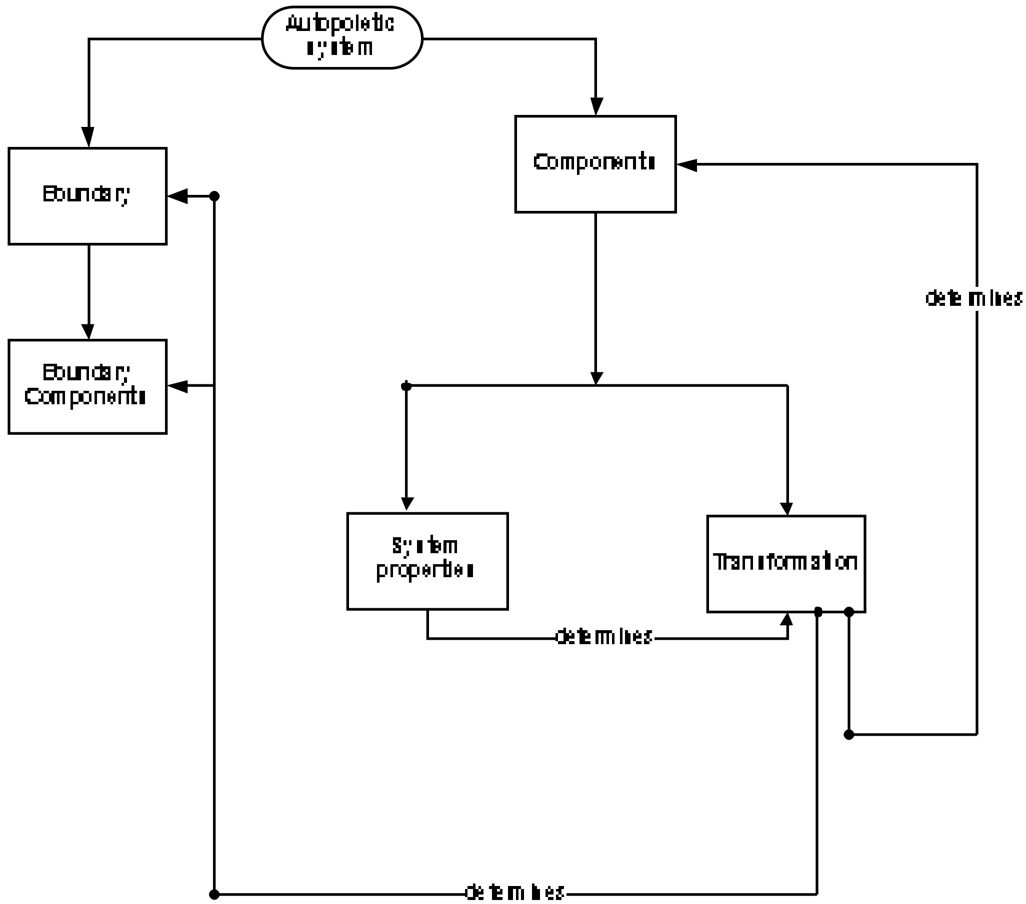
Theoretical Background:

The concept of **homeostasis** is pervasive in biological sciences. Conceptually it could be defined as **biological stability**. The basis for this biological stability could be ascribed to circularity observed in living systems. Present knowledge as proposed by Humberto Maturana indicated that the basis of life is **organisational invariance**, that is the organisational homeostasis observed in all living things. Though not generally accepted by the mainstream of biologist, it could serve as our working hypothesis in the definition of life as opposed to what is obtainable today, where a list of certain characteristics are given in profiling what could be regarded as life.

According to Humberto Maturana Life is an Autopoietic system that is semantically or operationally closed but thermodynamically opened. It is this closure that confers on the system organisational invariance, i.e organisational homeostasis.

The picture below indicated the basic mechanism underlying an autopoietic system, where the system is self-referential, autonomous without input and output.

Pic. 1 Autopoietic system



The dimensions of this biological stability are:

1. Physiological
2. Ecological

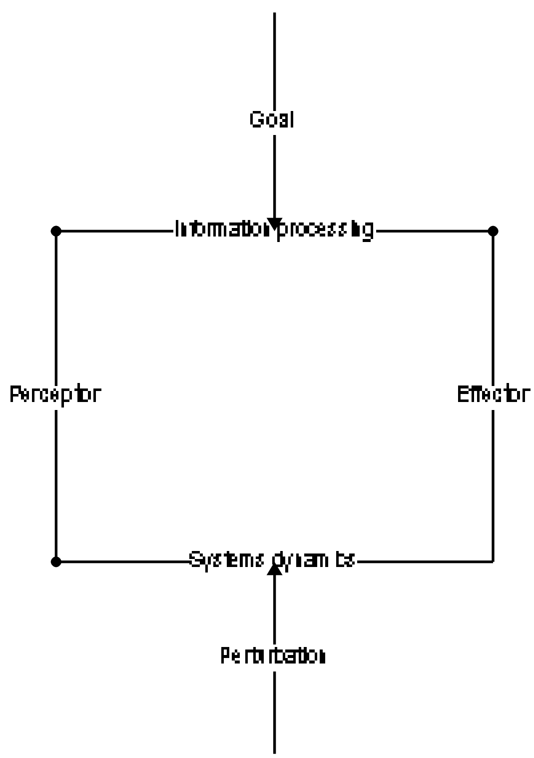
The basic axiom in any physiological process is that its level of activities is within certain limit for it to operate; all physiological processes operate within certain concentration of solutes, temperature and pH.

The ecological dimension of biological stability presupposes that there is a certain correspondence; functional and structural between the biological system and its environment. This is evident in the cycle of certain elements in nature, such as water, nitrogen, carbon, phosphorus cycles and the formation of different adaptive mechanisms to various ecological conditions. One vivid example is the formation of different ecotypes of plant depending on their adaptability to available water.

1. Mesophytes
2. Hydrophytes
3. Xerophytes
4. Halophytes

Conceptually, biological stability could be considered as a process of **coordination and control**, while control is a process of **regulation**. A graphical illustration is provided below depicting homeostasis in a living system.

Pic.2 Biological Homeostasis



The following elements are depicted in the illustration

1. Perturbation: Any environmental factor, capable of disrupting system's stability. These factors are Abiotic and biotic in nature
2. Sensor: element for detecting difference in status from the system goal. Within the context of a plant, there are different sensors; such as phytochrome, cryptochrome, phototropin and zeaxianthin.

3. Perceptor: plant organs
4. Model: The genetic composition of the plant
5. Goal: homeostasis
6. Information processing: signalling elements and signal transduction
7. Decision making: System survivability and senescence
8. Effector: Plant organ
9. Action: System's response, in plant they could take the following forms; growth, nasty, morphogenesis, tropism and thigmotropism.

Comparative plant and animal homeostasis matrix

		Organ/regulatory mechanism	
Scope of balance	Process nomenclature	Animal	Plant
Water	Osmoregulation	Kidney	Active accumulation of osmolyte independent of cellular volume change Uptake of compatible ions Ion extrusion, sequestration and
Nitrate		Kidney and Liver	Nitrogen cycle
Glucose		Pancreas and Liver	Glycolysis and glycogenesis
Temperature	Thermoregulation	Skin	Transpiration

Topic: OSMOREGULATION AND METHODS OF ELIMINATION OF WASTE MATERIALS IN PLANT

Basic concepts: Osmoregulation, transport, transporters, active and passive transport, primary and secondary transport, symport, antiport

Learning objectives:

1. Water balance in plants and strategies for acclimation and adaptation
2. Osmoregulation as a mechanism for maintaining water balance in plant
3. Methods of eliminating waste product in plants
4. Transport mechanism in plant

Theoretical background

Water is very vital towards increased agricultural productivity. Agricultural practise in the topics is greatly hampered by **Abiotic stressors**, namely; drought and heat shock. The presence of these stressors elicit water deficit leading to reduced growth and development in cultivated crop, eventually reducing agricultural productivity. **Salinity** due to inappropriate use of irrigation water or cultivation of crops in soils of high concentration of salt could lead to accumulation of toxic substances in plants. Water balance in plants has to be maintained. Different strategies were devised by plants in combating the adverse effects of osmotic stress towards the maintenance of water.

At the molecular level were observed the following osmoregulatory strategies:

- Synthesis and accumulation of **osmolytes** and **osmoprotectants**
  - Organic nitrogen-containing
  - Organic non-nitrogen containing
- Uptake of compatible ions
- Extrusion, sequestration and compartmentalisation of incompatible ions

The advent of osmotic stress in most crop leads to synthesis and accumulation of osmolytes and osmoprotecting substances.

Among the compatible organic solutes are nitrogen containing:

- o Amino acids e.g. proline, glycine betaine
- o Amino acids derivates
- o Quaternary amino acids

Non-nitrogen containing:

- o Sugars
- o Cyclic and acyclic polyols; mannitol, sorbitol
- o Fructans
- o Sulfonium compounds

Accumulation of these substances in the cell *will not lead* to the disruption of normal metabolic activities, hence the name compatible solute. The mechanism of their action is in the reduction of cellular water potential, thus facilitating movement of water into the cell. Apart from that they have been reported to play a vital role in **osmoprotective** functions such as the protection of the protein stability, scavenging **reactive oxygen radical**, adjustment of cellular **redox state** and **membrane stabilisation**.

In other to lower the water potential of plants with the commencement of osmotic stress, inorganic ions like K^+ are passively absorbed by plant down concentration gradient.
Extrusion, sequestration and compartmentalisation facilitate the removal of toxic ions from the cell or compartmentalisation in another organ where like the vacuole, Golgi bodies or endoplasmic reticulum, where their toxic effect could be greatly ameliorated. The process is mediated actively via the actions of certain transporters like;

1. Channels
   a. Selective (Potassium Inward Regulated Channel, KIRC; Potassium Outward Regulated Channel, KORC, Aquaporin)
   b. Non-Selective
2. Carriers; High and low affinity carriers
3. Pumps
   a. Electrogenic (H^+/ ATP-ase, H^+/PP)
   b. Electroneutral

Primary active transport process coupled with the hydrolysis of ATP will lead to the generation of **proton motive force** that will facilitate secondary influx of proton into the cytoplasm or vacuole with other ions transported symportically or antiportically. Apart from regulation of the osmotic status of the cell and water balance, this chemiosmotic regulation could lead to the regulation of nutrient uptake, water balance pH level in the plant and the excretion of toxic waste product of metabolism.

Excretion in plant is the removal from the body toxic waste product of metabolism. Compared to animals, plants do not have as such a specialised organ of excretion. Leaf in most cases act as organ of excretion. Toxic waste product of metabolism like water vapour, carbon dioxide and certain salt are removed from the leaf of the plant.

Topic: PLANT HORMONES

Basic concepts: growth, development, phytohormones, physiologically active substances, growth promoters, growth inhibitors, cell division, elongation and differentiation

Learning objectives:

1. Understanding of the concept of growth in plant
2. Understanding the concept phytohormones and their roles in growth of plant
3. Classification of phytohormones and their roles in cell division, elongation and differentiation

Theoretical background:

Growth could be defined as a process of **irreversible, quantitative change** in plant. There are various dimensions of these changes; namely **weight, form, volume and size**. Development on the other hand is a qualitative change. The cellular processes underlying growth are:

1. Cell division
2. Cell elongation
3. Cell differentiation

Please find in table 1 a comparative analysis of the cellular basis of growth phase, using certain cytological and kinetic parameters.

Phytohormones are physiologically active substances that affect plant growth and development in conjunction with other environmental factors. They are required in small quantity, transported from the site of synthesis to mediate physiological response in other parts of the plant. See table 3 for a comparative analysis of different phytohormones

Tab. 1 Comparative analysis of growth phases

Growth phases	Parameters for comparison				
	Cytological parameters				Kinetic parameters
	Cell wall	Protoplasm	Vacuole	Nucleus	Growth rate
Division	Thin/isodiametric	Most dense	Smallest	Largest	Slowly
Elongation	Thicker	Medium	Bigger	Medium	Rapid
Differentiation	Thickest	Least dense	Biggest	Smallest	Steady

Tab. 2 Dimensions of Physiologically Active Substances

Parameters for comparison	**Dimensions of physiologically active substances**		
	Phytohormones	**Elicitor Molecule**	**Growth Substances**
Nature	Endogenous or naturally occurring	Naturally occurring or synthetic	Naturally occurring or synthetic
Quantity produced	Small	Small	Small
Plant response mode	o Physiological changes o Changes in growth and development o Signalling element	Initiation or improvement of specific compound with hormone-like activities	o Induction of physiological processes o Changes pattern of growth and development
Type of physiologically active substance	o Auxin o Gibberellin o Cytokinin o Abscissic Acid o Ethylene	Brassinosteroids Jasmonic Acid Salicylic Acid Polyamines	

Topic: Respiration

Basic concepts: Respiration, Redox reaction, glycolysis, glycogenesis, biological polymer, electron transport system, phosphorylation types (photophosphorylation, oxidative phosphorylation, transphosphorylation)

Learning Objectives:

1. Understanding of the basic principle of respiration
2. Understanding of the mechanism of respiration
3. Comparative analysis of aerobic and anaerobic (Fermentation) respiration
4. Factors affecting respiration
5. Importance of respiration in agricultural process

Theoretical background:

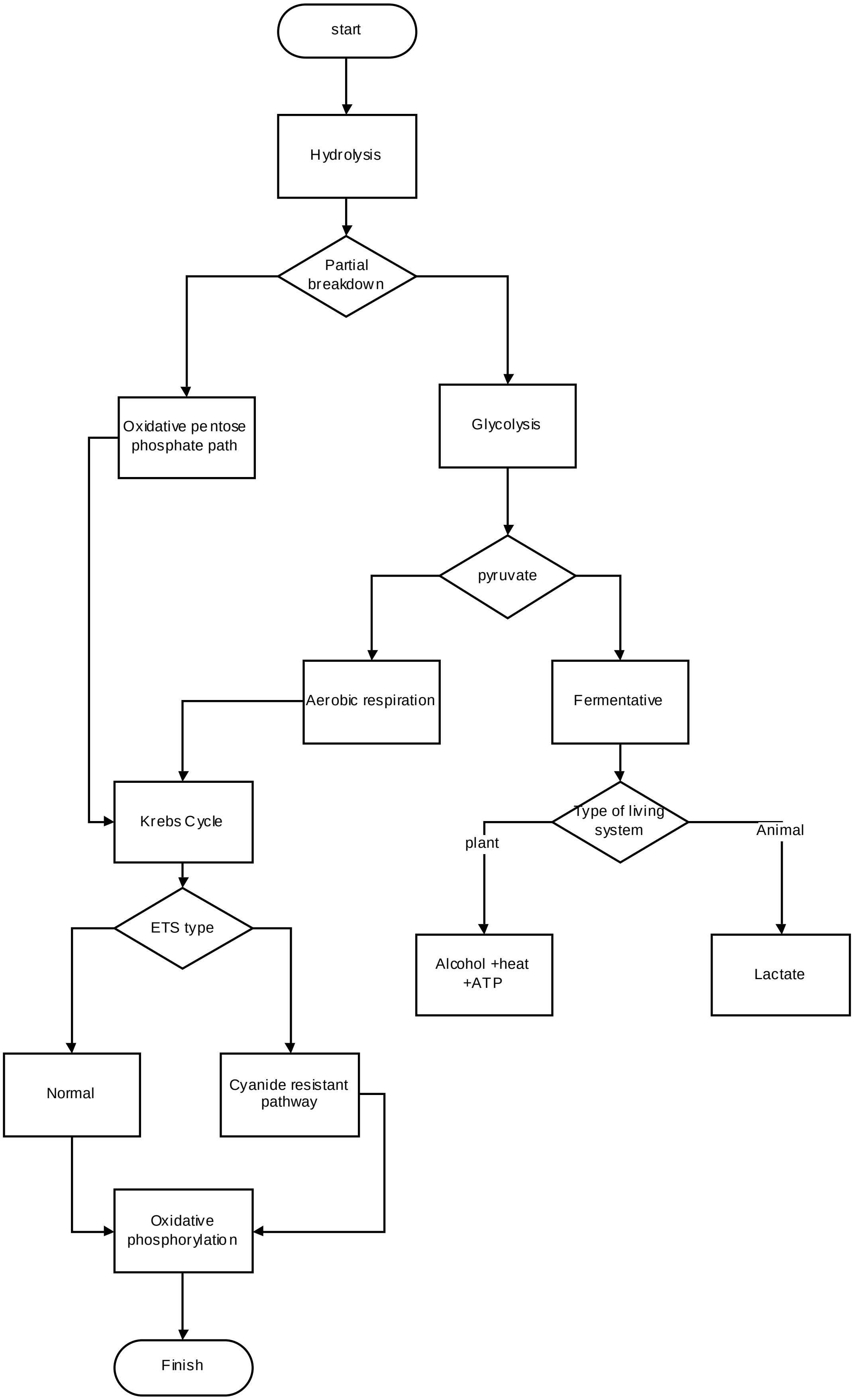
Plants are living system, thermodynamically opened to the exchange of energy and matter with the environment. Among the basic characteristics of any living system is the process of transformation of energy or metabolic process. Conceptually, this process could be classified into two catabolic and anabolic processes. Anabolic process is the transformation of energy and matter towards the building of complex biological polymer. An example of such a process is photosynthesis. Catabolic process on the other hand involves breakdown of such biological polymer and the consequent release of energy and other products of metabolism. Respiration is an example of a catabolic process.

Respiration is a bio- oxidative process; involving loss of electron, proton and the addition of oxygen. Oxidative process is coupled with reduction, hence the process is better characterised as a redox reaction with the formation of energy in the form of ATP, the energy currency of living system. Table 4 provides a conceptual framework of respiration. Respiration in plant is mediated via passive diffusion of gases, with no specialised organ and carrier as obtainable in animals.

Tab. 4 Dimensions of respiration

Questions dimensions	
What	Biooxidative-reductive process
Why	1. Energy is released which is consumed in various metabolic processes essential for plant and activates cell division 2. It brings about the formation of other necessary compounds participating as important cell constituents 3. It converts insoluble food into soluble form 4. It liberates carbon dioxide and plays a part actively in maintaining the balance of carbon cycle in nature 5. It converts stored energy (potential energy) into usable form (Kinetic energy)
How	**Initial degradation** (hydrolysis)-**Partial degradation** (glycolysis/EMP/oxidative pentose phosphate pathway/Enter-Doudoroff pathway)-**Total degradation** (Krebs cycle and electronic transport system) $\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \longrightarrow \underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{energy}$
Where	• Cytosol • Mitochodria
When	Throughout the life of the plant

Find below a flow chart depicting the mechanism of respiration in plants


start
Hydrolysis
Partial breakdown
Oxidative pentose phosphate path
Glycolysis
pyruvate
Aerobic respiration
Fermentative
Krebs Cycle
Type of living system
plant
Animal
ETS type
Alcohol +heat +ATP
Lactate
Normal
Cyanide resistant pathway
Oxidative phosphorylation
Finish

Tab. 5 Distinction between aerobic and anaerobic respiration

S/N	Aerobic respiration	Anaerobic respiration
1	It is common to all plants	It is a rare occurrence
2	It goes on throughout the life	It occurs for a temporary phase of life
3	Energy is liberated in larger quantity. In total, 38 ATP molecules are formed	Energy is liberated in lesser quantity. Only 2 ATP molecules are formed
4	The process is not toxic to plants	It is toxic to plants
5	Oxygen is utilised during the process	It occurs in the absence of oxygen
6	The carbohydrates are oxidised completely and are broken down into CO_2 and H_2O	The carbohydrates are oxidised incompletely and ethyl alcohol and carbon dioxide are formed
7	The end-products are CO_2 and H_2O	The end-products are ethyl alcohol and carbon dioxide
8	The process takes place partly in cytosol (glycolysis) and partly inside mitochondria (Krebs cycle)	The process occurs only in the cytosol