

P530/2
BIOLOGY
(Theory)
Paper 2
NOV. 2022
2½ Hours

UACE BIOLOGY CHAMPIONS

SUGGESTED SOLUTIONS

SECTION A (40 MARKS)

Question 1 is compulsory.

1. Ultraviolet-Visible (UV-Vis) spectroscopy was used to measure the spectra of phytochrome red (Pr) and phytochrome far red (Pfr), prepared from spinach chloroplasts. The absorbance of each phytochrome over a range of wavelengths was recorded on the same axes. The resultant absorbance spectrum is shown in figure 1.

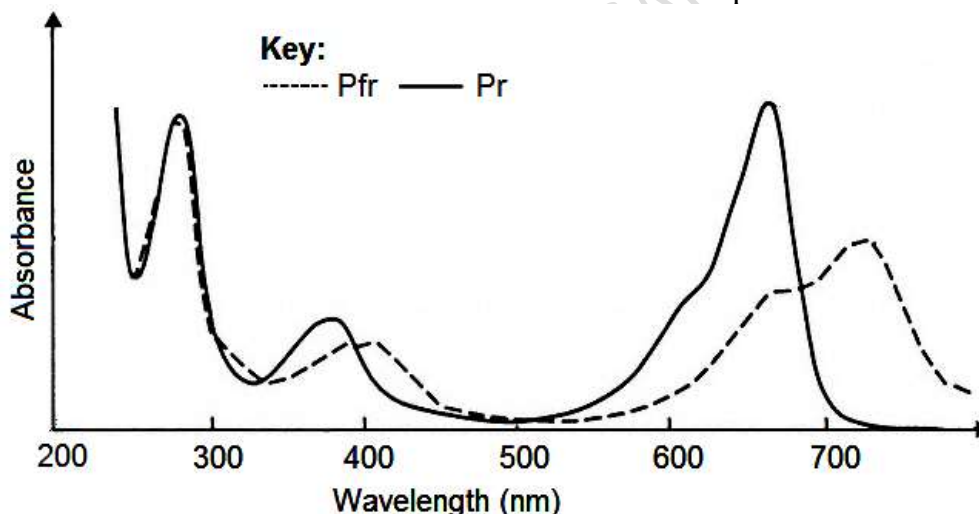


Fig. 1

- (a) Compare the absorbance of Pr and Pfr, with reference to figure 1. (06 marks)

Both Pr and Pfr:

- Have multiple peaks of absorbance;
- Mostly absorb/ highest absorbance in 250 nm – 300 nm and 650 nm – 750 nm wavelengths;
- Have lowest absorbance at 500 nm wavelength;
- Show the closely related patterns of absorbance;
- Pr absorbs mostly at 660 nm/ red light, while Pfr absorbs maximally at 730 nm/ far red light;
- Maximum absorbance for Pr is higher than Pfr;

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(b) Describe the molecular mechanisms underlying phytochrome-controlled changes in plants. (07 marks)

- The photoreceptor phytochromes monitor the red/far-red part of the electromagnetic spectrum;
- Phytochromes exist in the biologically active Pfr (far-red absorbing) or inactive Pr (red absorbing) forms;
- Phytochromes function as red/far-red light-regulated molecular switches to modulate plant growth and development;
- Exposure to red light (660 nm) converts the chromoprotein to the functional, active form (Pfr);
- While darkness or exposure to far-red light (730 nm) converts the chromophore to the inactive form (Pr);
- The activated phytochrome migrates into the nucleus in some light responses, where it interacts with gene regulatory proteins to alter gene transcription;

(c) Explain the role of the phytochrome system in plant growth and development.

(07 marks)

- Activated phytochrome photoreceptors perceive, interpret, and transduce light signals, via distinct intracellular signaling pathways, to modulate photoresponsive nuclear gene expression, leading to adaptive changes at the cell and whole organism levels;
- Plants grow toward sunlight because the red light from the sun converts the chromoprotein into the active form (Pfr), which triggers plant growth;
- Plants in shade slow growth because the inactive form (Pr) is produced;
- If seeds in the dark sense light using the phytochrome system, they will germinate.
- Plants regulate photoperiodism by measuring the Pfr/Pr ratio at dawn; which then stimulates physiological processes such as

- (i) De-etiolation;
- (ii) Inhibition of leaf elongation;
- (iii) Regulation of flowering;
- (iv) Setting winter buds/ rhizomes;

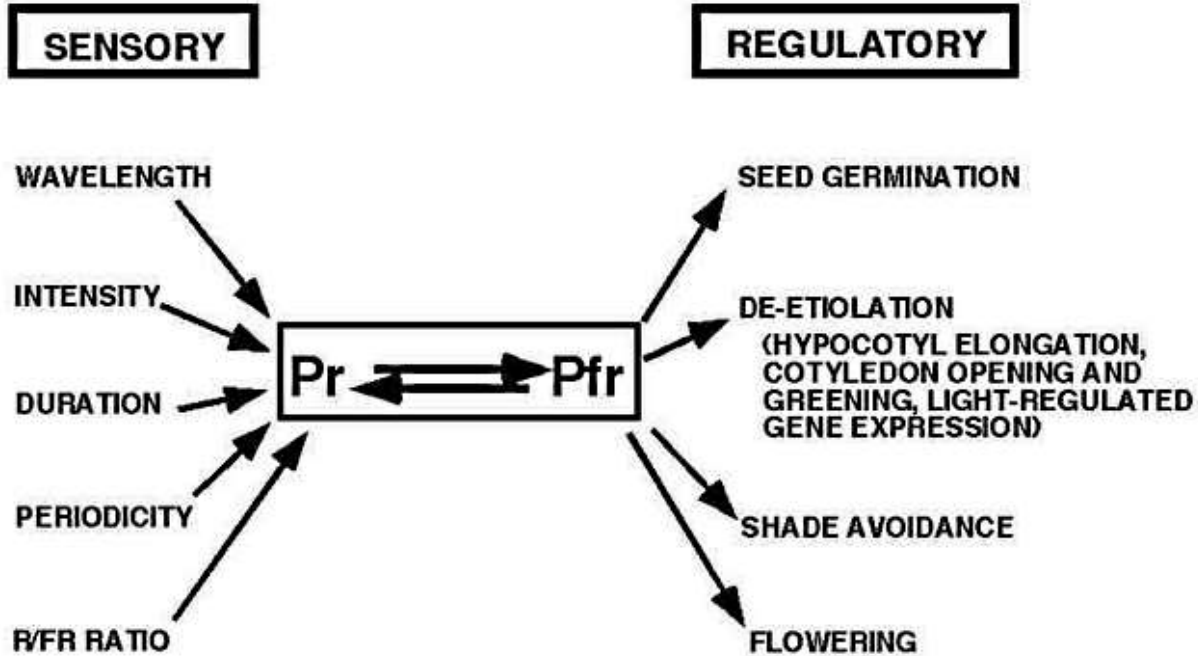


Figure 2 shows the absorption spectrum for **chlorophyll a** extracted from a plant and an action spectrum for the same living plant, at varying wavelengths of light. The action spectrum was determined as rate of photosynthesis, measured by release of oxygen.

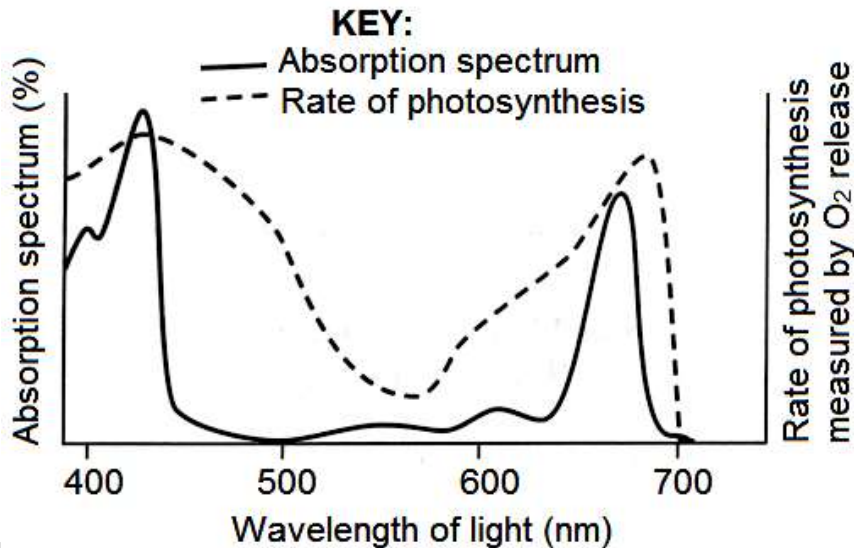


Fig. 2

(d) With reference to plants, distinguish between:

(i) Absorption spectrum and action spectrum.

(02 marks)

Absorption Spectrum shows the absorption of light of different wavelengths by a pigment; whereas Action Spectrum shows the relative effectiveness of these wavelengths in photosynthesis;

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(ii) **Chlorophyll a** and accessory pigments.

(02 marks)

Chlorophyll a is the primary pigment of photosynthesis that traps light energy and emits high-energy electrons into photosystems P680/ PSII and P700/ PSI while accessory pigments are light-absorbing compounds, found in photosynthetic organisms that trap light energy and pass the trapped energy into chlorophyll a e.g., chlorophyll b and carotenoids;

(e) Explain the pattern in rate of photosynthesis, with reference to **fig. 2**. (09 marks)

The action spectrum of photosynthesis corresponds closely to the absorption spectra of chlorophyll **a**; indicating that most of the wavelengths of light absorbed by chlorophyll **a** are used in photosynthesis;

The action spectrum is higher than observed absorption spectrum of chlorophyll a in the spectral range 450 nm – 500 nm; because at this wavelength, there is maximum absorption by accessory pigments/ carotenoids and chlorophyll b;

The wavelengths between 550 nm to 620 nm have the lowest absorption and action spectra; because the unabsorbed (reflected light) appears green, thus making chlorophyll, the chloroplasts and the leaves that contain it appear green to our eye;

The action spectrum peaks within the blue-violet and red regions of the light spectrum; indicating that maximum photosynthesis occurs in red part and blue-violet part of visible light;

(f) Describe how **chlorophyll a** is involved in photosynthesis.

(07 marks)

- Chlorophyll **a** molecule in PSII and PSI are excited by light of wavelength 680 nm and 700 nm respectively, causing the loss of electrons to a chain of electron carriers in a series of reduction-oxidation reactions; as follows:
- From PSI, some electrons may flow:
 - Cyclically to iron-protein complex, cytochromes b₆, plastoquinone, cytochrome-f, plastocyanin and back to P-700, during which electrons lose energy to form ATP from ADP and P_i;
 - Non-cyclically (Unidirectionally) to unknown molecule A, iron-protein complex, Ferredoxin, Flavin-Adenine Dinucleotide (FAD) which becomes reduced (FADH), finally to NADP to form reduced NADP (NADPH);
- From PSII to the unknown molecule Q, substance B, plastoquinone (PQ), cytochrome f, plastocyanin, (a copper enzyme), and finally to PSI, to replace the electrons earlier lost;
- During this flow, electrons lose energy to phosphorylate ADP to form ATP;
- The flow of electrons through carriers in the thylakoid membrane releases energy for active pumping of hydrogen ions (H⁺) from the stroma into the thylakoid space;

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- During chemiosmosis i.e., as the highly concentrated H^+ inside the thylakoid space diffuse along the steep electrochemical gradient from the thylakoid space via the stalked particles into the stroma, ATP and NADPH molecules are formed, which enter the Calvin cycle/ dark stage;

SECTION B (60 MARKS)

Answer **three** questions from this section.

Any additional question(s) answered will **not** be marked.

2. (a) How is the structure of carbohydrate molecules related to their functions in?

(i) Starch.

(06 marks)

- Starch is the storage polysaccharide of plants;
- **Starch molecules:**
 - Comprise straight-chained Amylose and branch chained amylopectin that enable starch molecules to coil into a compact shape and store lots of energy in a small space during storage;
 - Are large hence can't leave the cell by diffusion;
 - Contain Amylopectin (70 - 90% of starch) branches resulting in many terminal glucose molecules that can be easily hydrolysed for use during cellular respiration or stored;
 - Contain Amylose (10 - 30% of starch) forming a helix shape, enabling it to be more compact and thus it is more resistant to digestion during storage;
 - Contain Amylopectin that forms a straight component, making the molecules suitable to construct cellular structures e.g., cellulose;
 - Contain amylopectin the branch chained part that is insoluble, hence doesn't affect the water potential when stored;

(ii) Cellulose.

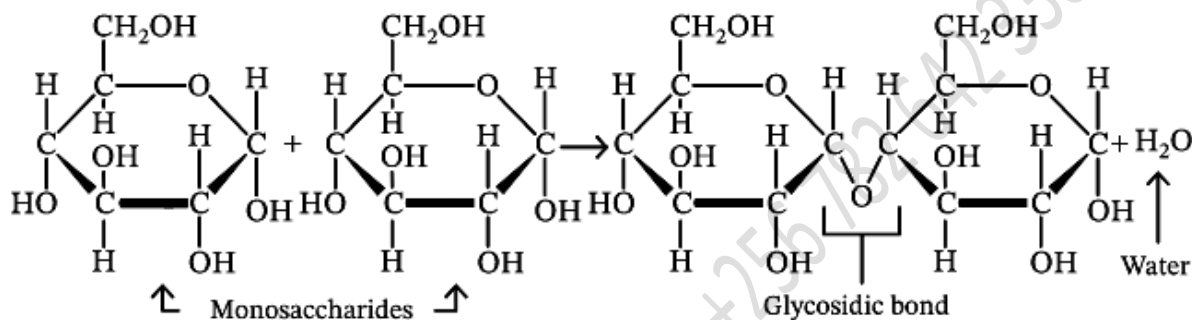
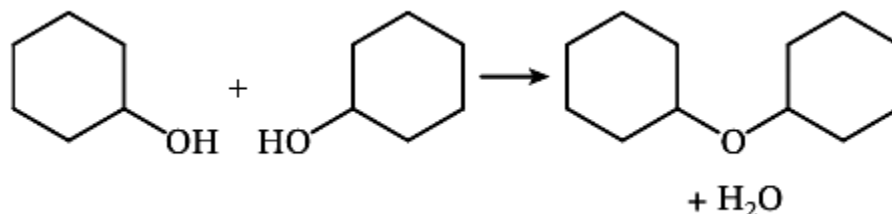
(05 marks)

- Cellulose is the main structural component of cell walls;
- Due to the inversion of the β -glucose molecules, many hydrogen bonds form between the long chains giving cellulose its high tensile strength; allowing stretching without breaking; hence making it possible for cell walls to withstand turgor pressure;
- The cellulose fibres in combination with other molecules (e.g., lignin) found in the cell wall form a matrix which increases the strength of the cell walls;

(b) Describe the formation of a disaccharide molecule from its component molecules.

(09 marks)

Two monosaccharides bond together during a chemical reaction called a **condensation** reaction; involving release of one water molecule; This occurs when one hydroxyl group from each of the two monosaccharides rearrange and join in what is called a "**glycosidic bond**"



3. The inability to digest starch in some mammalian species is a genetic disorder with equal frequency in males and females, and neither parent of affected offspring suffers from this condition in most cases.

(a) Describe the most probable pattern of inheritance for this condition.

(12 marks)

(CREDIT usage of Punnett Square illustrating monohybrid cross to determine the probable pattern of inheritance for this condition)

- Most probable pattern of inheritance is autosomal recessive; a person with the condition bears two recessive alleles, one from each parent;
- Since both parents are carriers, they transmit the gene to their offspring, resulting in full expression of the gene;
- A carrier parent mating with dominant parent produce normal offspring that may inherit the allele;

Let S represent the allele for normal starch digestion (dominant allele), s represent allele for inability to digest starch (recessive allele);

- Mating two heterozygous parents shows the following possibility:
 - Fully dominant (25%), carrier (50%), or recessive (25%);
- Three of those four offspring will be able to digest starch, the fourth offspring receives two recessive alleles hence unable to digest starch;

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(b) Explain how this inability to digest starch could result from mutation.

(08 marks)

- A mutation could be a frameshift deletion;
- The DNA sequence that is the phenotype for the ability to digest starch is deleted;
- Altering the frame and removing the enzyme that allows this process, causing for the inability to eat starch;
- There could also be a point mutation;
- Which could cause a premature stop codon;
- Before the protein for digesting starch is created;
- Or there could be a wrong amino acid for digesting starch;

4. (a) Describe the movement of energy and nutrients in an ecosystem. (10 marks)

- Ecosystem is a community and its abiotic environment;
- Solar energy collected by autotrophs/plants (via photosynthesis);
- Moves through trophic levels via food;
- Only 5 to 20 % transferred from one trophic level to next / never 100 % efficient;
- Lost as metabolic heat/organic waste;
- Energy flow can be illustrated by pyramid shape;
- Organisms absorb nutrients from food/environment;
- Nutrients occur as complex organic matter in living organisms;
- After death, saprotrophic bacteria and fungi (decomposers) breakdown complex organic matter;
- Breakdown products are simpler substances;
- Absorbed into plants for resynthesis into complex organic matter/recycled;

(b) What are the effects of global temperature rise on ecosystems? (10 marks)

- Increasing rates of decomposition of detritus;
- Expansion of the range of habitats available to temperate species;
- Loss of habitats;
- Changes in water salinity;
- Changes in distribution of prey species affecting higher trophic levels;
- Increased success of pest species;
- Loss of ice increases absorption of solar radiation increasing warming of atmosphere;
- Extinction of species adapted to arctic/cold conditions;

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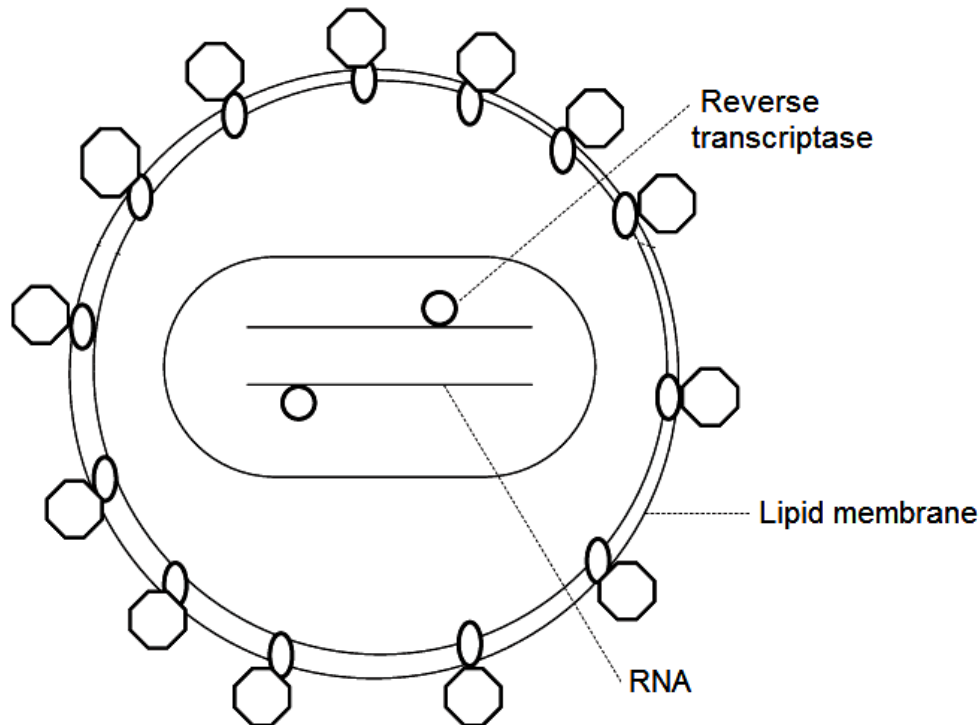
5. (a) What are the distinguishing features of viruses? (06 marks)
- All viruses are obligate parasites;
 - They multiply only within their living hosts cells and remain metabolically inert outside the host cell;
 - They are ultramicroscopic and can only be viewed with electron microscope (the smallest known virus is merely 0.002 μm in diameter, while the largest ones are typically about 0.8 μm in diameter);
 - Viruses are, actually, nucleoproteins;
 - The viral genetic material, the nucleic acid, may be either DNA or RNA; The two nucleic acids are never present in a given virus,
 - These are the nucleic acids of the viruses which are infectious, and not the protein coat;
 - Viruses are usually so minute that they can easily pass through a filter, which can hold back even the smallest bacteria;
 - Viruses are easily transmitted from infected host to the healthy ones through various agencies;
 - Viruses can easily be crystallized;
 - Viruses are considered to be host-specific and represent obligate parasitism even at genetic level; and
 - Since the viruses have no metabolic activities of their own and utilize the metabolism of host cells, antibiotics have no effect on them;

(b) With reference to viruses in plants, describe:

(i) The structural organisation of the particle. (06 marks)

Simpler viruses/ virions consist of 1 molecule of nucleic acid (DNA/ RNA) surrounded by protein coat/ capsid;
Capsid and its enclosed nucleic acid together form the nucleocapsid;
Complex viruses comprise the capsid surrounding protein core;
In other viruses the capsid is surrounded by a lipoprotein envelope;
The capsid is composed of morphological units called capsomers; held together by noncovalent bonds;
Individual capsomers, consist of 1/ more polypeptide molecules;
In helical nucleocapsids, the viral nucleic acid is folded throughout its length in a specific relationship with the capsomers;

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Simple illustration of the basic structure of HIV-1



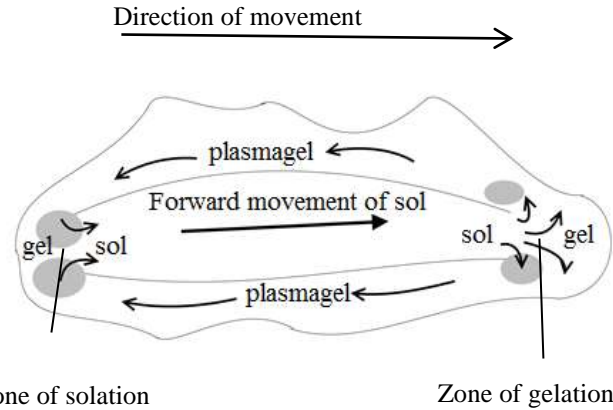
(ii) The means of transmission and prevention. (08 marks)

- Rubbing of leaves together; prevent infection by removing infected plants;
- Exchange saps through wounds; remove infected plants/ spray;
- In laboratories; sanitize working environment;
- Seeds - Viruses may be present on external surfaces of the seeds, may be present internally in testa, endosperm or embryo of infected seeds;
- Vegetative propagation/ grafting; prevent this infection by disinfecting with suitable disinfectants;
- Fungi; prevent this infection by spraying with suitable fungicides;
- Dodder/ parasitic plant; prevent this infection by weeding out this parasitic plant;
- Pollen; spray to disinfect;
- Soil contact; spray to disinfect;
- Nematodes; spray to kill nematodes;
- Insect feeders; prevent this infection by spraying with suitable insecticides;

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6. (a) Describe how non-muscular movement occurs in organisms. (10 marks)

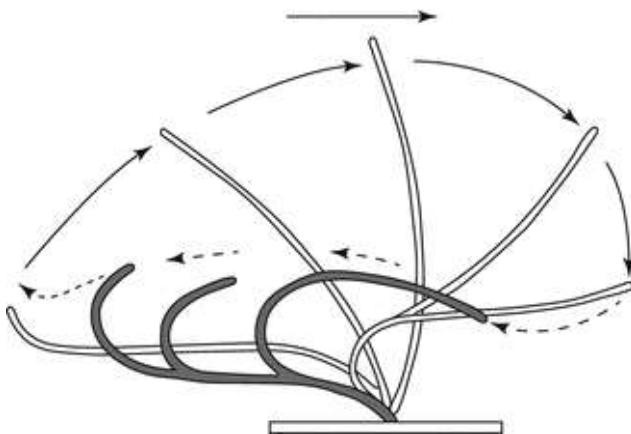
Non-muscular movements include; Amoeboid, Ciliary and Flagellar movement;



Description of amoeboid movement according to the sol-gel-sol theory

- The plasmalemma attaches to the substratum
- Stimulation of the ectoplasm (plasmagel) at a certain point causes its conversion to plasmasol, and flowing of the pressured plasmasol (endoplasm) into the weakened area, forming first a bulge and then a tube.
- The movement is sustained by contraction of the outer gel layer which squeezes inwards, causing cytoplasmic streaming towards the tip of the pseudopodium.
- Within the advancing tip at the **fountain zone**, plasmasol is converted to plasmagel which is then deposited on the sides of the pseudopodium. At the temporary posterior (rear/hind) end of the cell the plasma gel is converted to plasmasol, which then flows forwards into the newly formed pseudopodium so much so that the whole of body cytoplasm comes into it.
- Now the plasmagel tube contracts and the body moves forwards. Soon after this a new pseudopodium is again formed in this direction.

Ciliary movement illustration



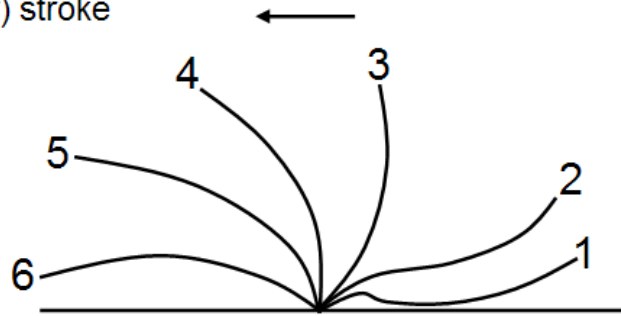
- A ciliary beat cycle consists of an **effective (power) stroke phase** and a **passive recovery stroke phase**.

- During the **effective stroke phase** the fully extended cilium makes an oar-like movement towards one side exerting maximum force on the surrounding fluid. The cilia beat in reverse when the power stroke is directed toward the anterior end of the organism so as to propel it backwards while beating towards the posterior end causes the cell or organism to swim forward.

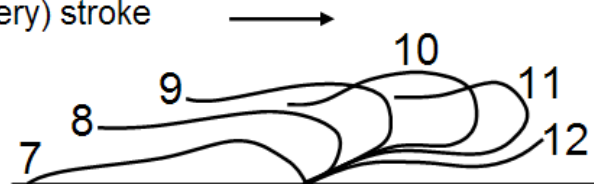
- In the **passive recovery stroke phase** which follows the effective stroke, the cilium moves back by propagating a bend from base to tip in an unrolling motion to reduce drag.

- The cycles of adjacent cilia are slightly out of phase so that they do not bend at exactly the same moment, resulting in **metachronal rhythm** in which waves of ciliary activity pass along the organism from front to rear.

Forward (power) stroke



Backward (recovery) stroke



(b) Compare jumping movements in a grasshopper and toad. (10 marks)

▪ For jumping movements in both the toad and grasshopper:

- At rest, the hind legs are folded up in the shape of letter Z;
- Fore-limbs land first, hence absorbing shock on landing;
- Fore-limbs prop-up to support the front end of the body when the animal is at rest;
- Hopping/ leaping/ jumping is by means of their hind limbs that quickly straighten out, lifting the animal off the ground;
- Extensor tibiae muscles contract to extend the rear/back leg when jumping;
- Flexor tibiae muscles contract to flex/ fold the legs at rest at rest;
- Before jumping, the hind leg muscles shorten, then propel the animal up and away;

- Grasshopper jumps to a longer distance while toad leaps a shorter distance;
- Grasshopper jumps to a higher height while toad leaps lower height;
- Grasshopper's flexor and extensor muscles insert on apodemes of exoskeleton while toad's flexor and extensor muscles insert on tendons of endoskeleton;

▪

END.