Light and Photosynthesis

Supplemental notes

Lab 4

Horticultural Therapy

Light

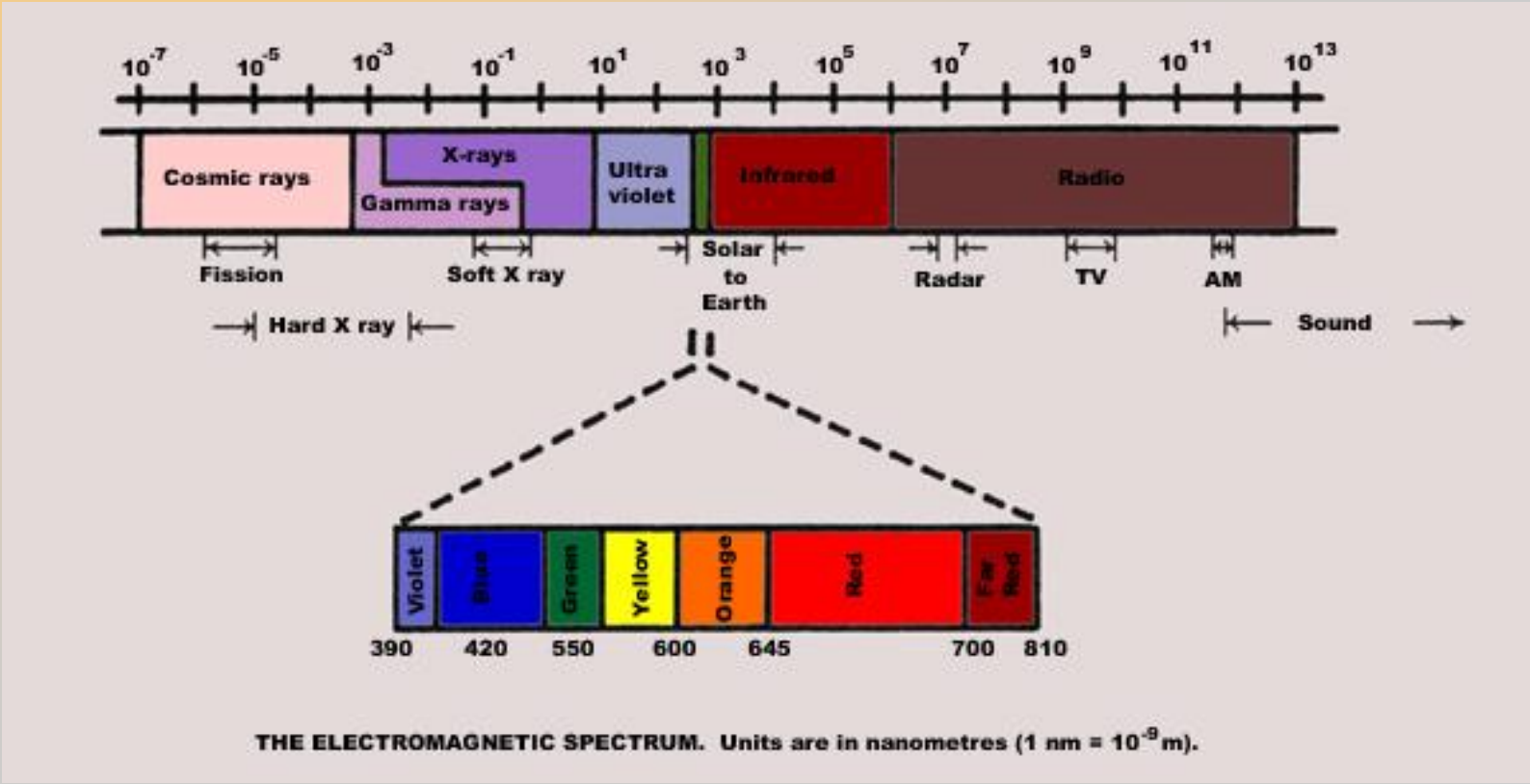
- The **Electromagnetic Spectrum** is a continuum of all electromagnetic waves arranged according to frequency and wavelength, the spectrum consists of gamma rays, visible light through to radio waves.

Light

- Wavelength is the linear distance between 2 similar points on adjacent electromagnetic waves;
- Is expressed as nanometres
  - (1 nm = 10^{-9} m).
- Wavelength is symbolized by the Greek letter lambda - λ.

Light

- Light and the Electromagnetic spectrum

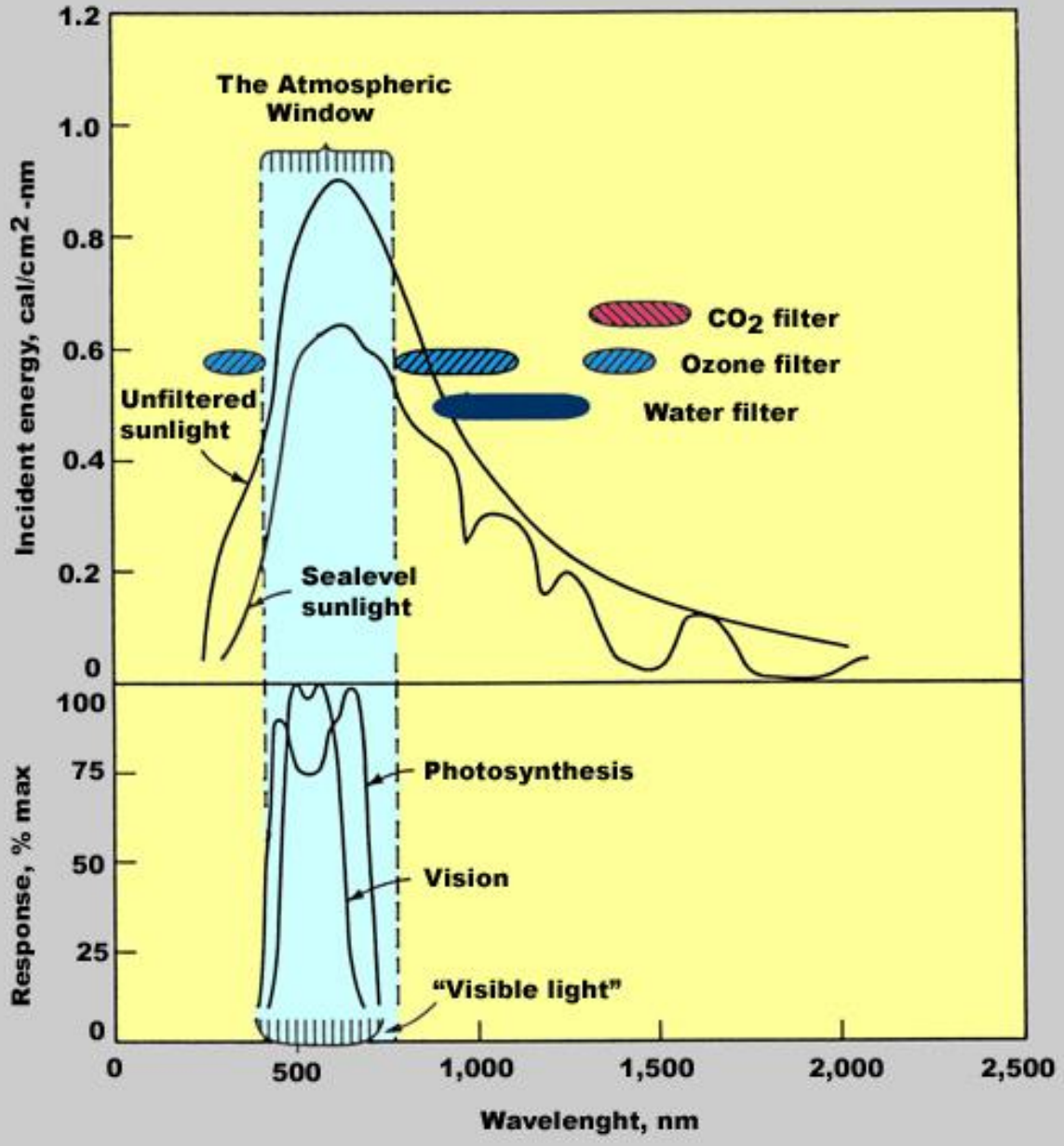


Light

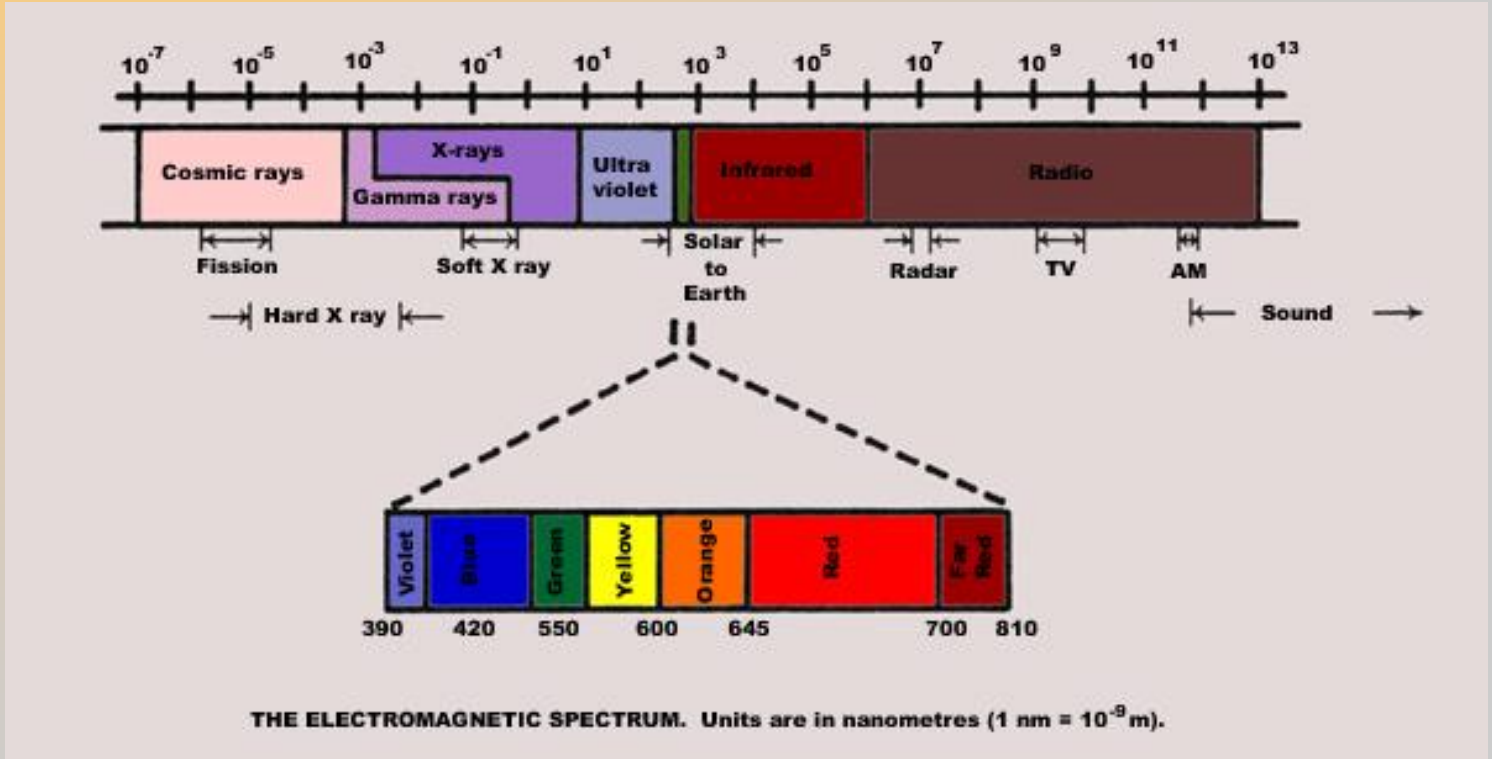
- The **Solar spectrum** is that portion of the electromagnetic spectrum that is being emitted by the sun.
- It is changed by passage through the atmosphere, so what is incident on the earth's surface at sea level is different than that outside the atmosphere.
- Visible light is that portion of the spectrum that can be ***seen*** by the human eye and is roughly the area 400 to 700 nm.

Light

- This band also approximates that portion of the spectrum that is used by plants for photosynthesis, and is referred to as **Photosynthetically Active Radiation - PAR**.
  - - is the energy source for photosynthesis.
- Light is required for the formation of the photosynthesis apparatus and its maintenance.
  - - for the development of chloroplast (plastid development) and the synthesis of chlorophyll.
- The far red is from 700 to 810 nm and it is this portion of spectrum that we sense or ***feel*** the energy as heat.


The Atmospheric Window
Incident energy, cal/cm2 -nm
1.2
1.0
0.8
0.6
0.4
0.2
0
CO2 filter
Ozone filter
Water filter
Unfiltered sunlight
Sealevel sunlight
Response, % max
100
75
50
25
0
Photosynthesis
Vision
"Visible light"
0
500
1,000
1,500
2,000
2,500
Wavelenght, nm

Light



THE ELECTROMAGNETIC SPECTRUM. Units are in nanometres (1 nm = 10^{-9} m).

Light

- There are 2 common irradiancy measurements that are used in relation to plant growth and development:

1. Radiant power or flux per unit area

- unit - W/m^2,
- when irradiancy in time is important the unit is Joule (J), or $W/m^2/s$.
- The instruments used to measure radiant power is the Radiometer or Spectroradiometer.
  - The latter can measure precisely the energy of a wavelength or a narrow wavelength band.

Light

2. **Quantum mechanics**

- This is the measure of the number of photons, or energy packets, being emitted by each wavelength. The shorter the wavelength the more energy.
- The unit is expressed as Einstein (E) or more commonly microEnstein (µE) - per m^2/s $[(\mu E \cdot M^{-2} \cdot s^{-1}]$.
  - The energy for PAR is measured in the bandwidth 400 - 700 nm.
  - One Einstein is defined as 1 mole of photons (1 mole - Avogadro's number - 6.02 x 1023 atoms; a µE is a millionth of an E.
- The instrument used is a Quantum Light Metre.

Light

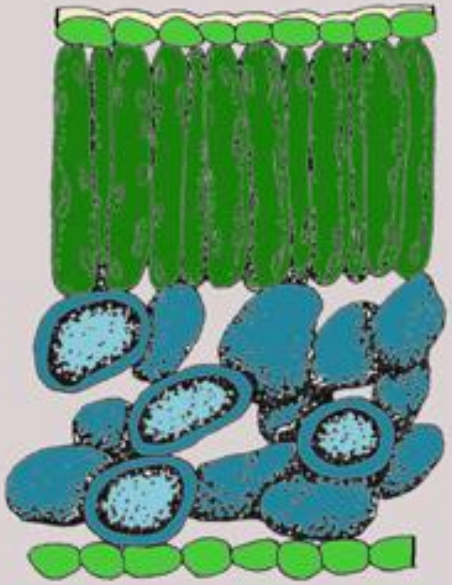
- Plants are affected by light though:
  - duration - photoperiod,
  - length of exposure,
  - quality - wavelength – λ or wavelength band,
  - and intensity.
- All three are important and interact to influence plant growth and development.

Light

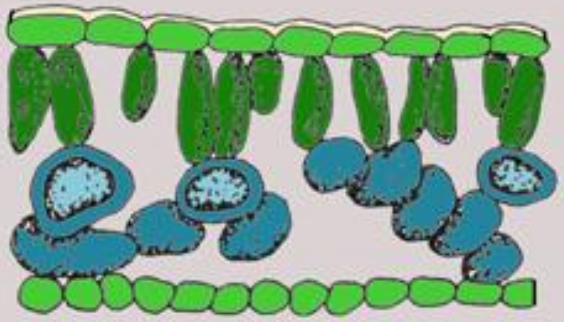
- **Light Regimes**
- Plants are adapted to different light environments, that is there are shade plants and full sun plants.
- There are some species that can only survive in full sun and others that can only survive in shade environment.
- Still other species may adapt to the particular light environment.
- Morphologically shade plants and full sun plants are different.

Light

Structure of sun and shade leaves.



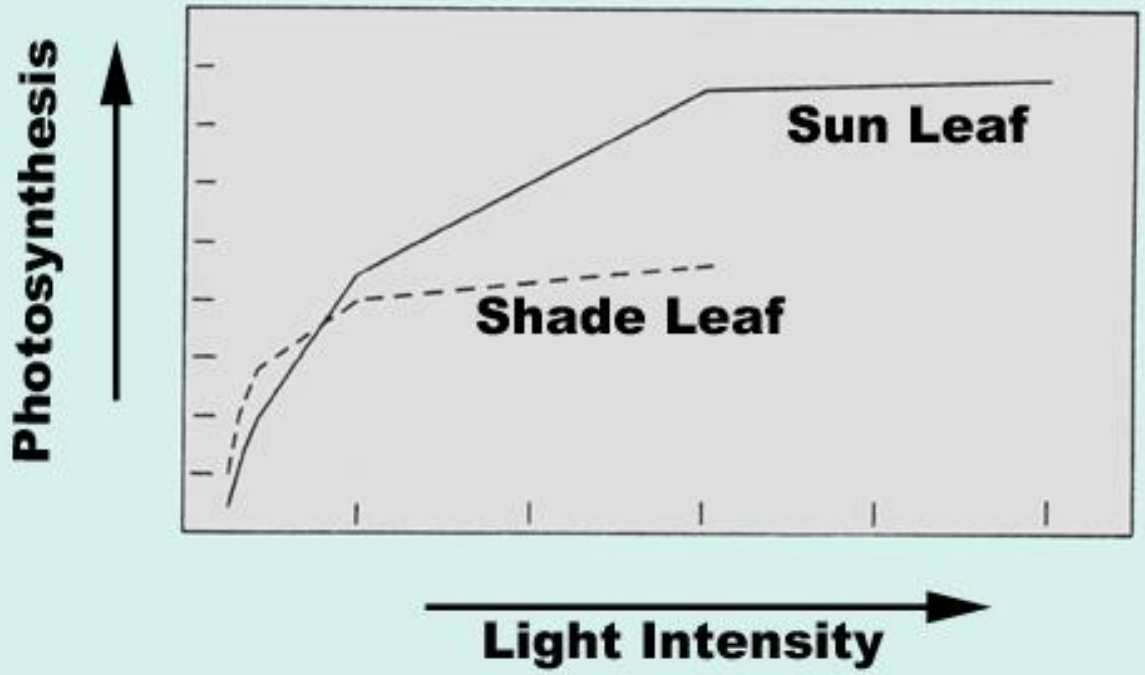
Sun Leaf



Shade Leaf

Light

Photosynthetic responses of sun and shade leaves.



Light

- The movement of a plant from one light regime to another usually requires time for metabolism to adjust to the new regime.
- The move should be a gradual to allow for light acclimation.
- The existing shade leaves will not change, but may become tolerant of the new light regime; new leaves have the form of full sun leaves.
- Moving a plant into full sun from shade too quickly can result in the bleaching (photochemical oxidation) of the chlorophyll.

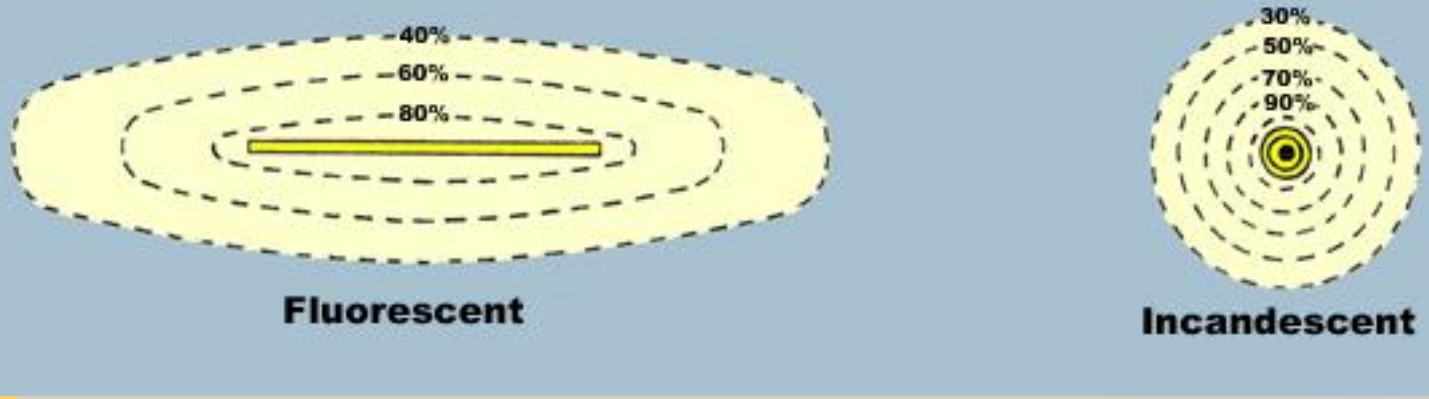
Light

- **Artificial Lights**

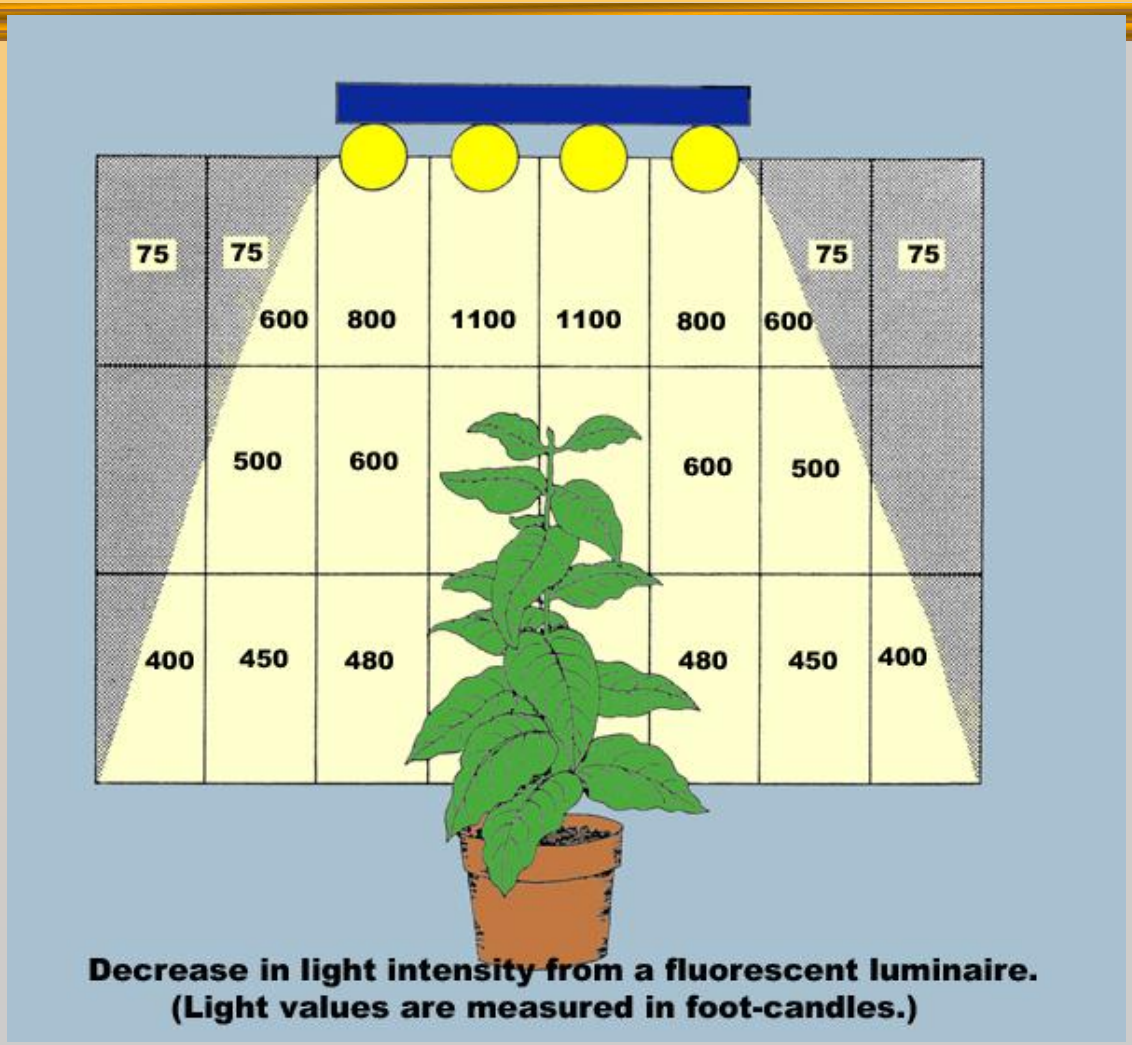
- Attention to light quality and intensity is important in the greenhouse environment and other areas where artificial lights are used.
- The intensity is controlled by the distance from the light fixture.
- The photoperiod is easily controlled by timers.
- It is important to know that the intensity decreases with distance from the fixture.

Light

Flux density distribution patterns from fluorescent and incandescent lamps.



Light



Decrease in light intensity from a fluorescent luminaire.
(Light values are measured in foot-candles.)

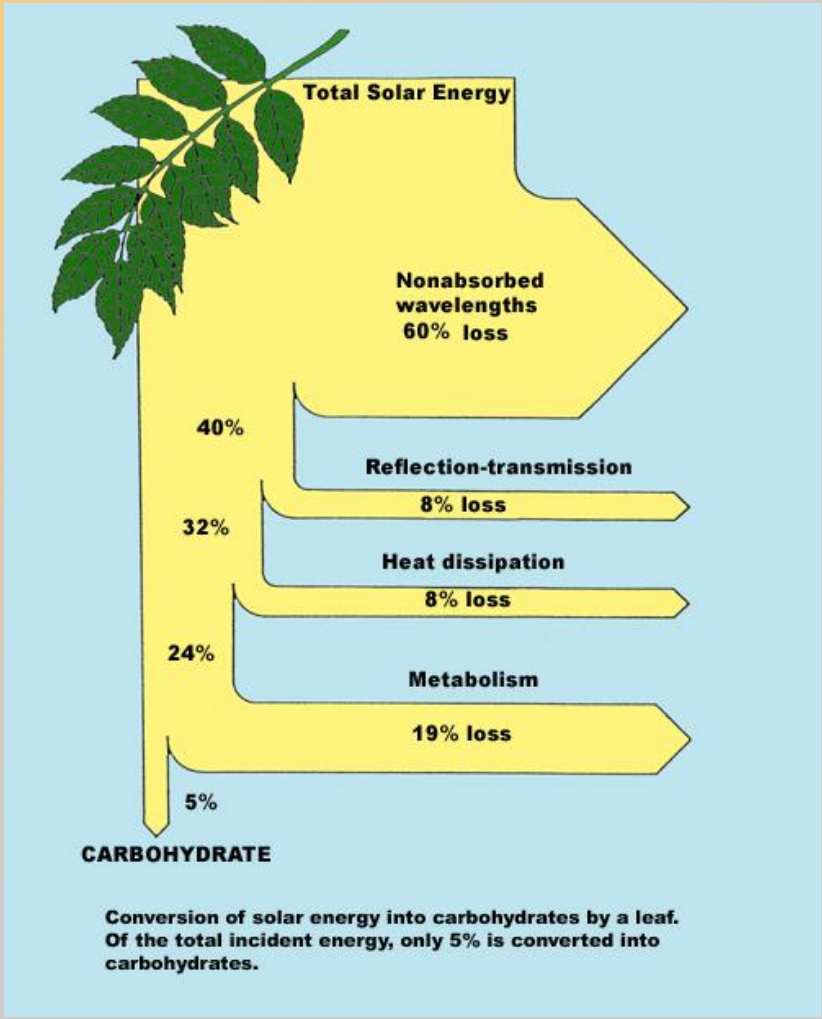
Light

- **Artificial Lights**
- Spectral quality is managed by the combination of fluorescent and incandescent bulbs, so as to approximate the solar spectrum.
- Bulbs are changed based on hours used, and before there is a change visible to the human eye
  - - important to record the number of hours the bulb has been in use and to change the bulb as required.
- The unit foot-candle is sometimes used to express light intensity; 1 foot-candle is equally to 5.01 µE/m2/s.
- Full sunlight at solar noon on a clear sunny day is 10,020 foot-candles or 2,000 µE/m2/s.

Photosynthesis

- The energy from the sun incident on the earth's surface is used by plants to produce carbohydrates, but out of the total intercepted by plants only 5% of that energy is converted into carbohydrate

Photosynthesis



Conversion of solar energy into carbohydrates by a leaf. Of the total incident energy, only 5% is converted into carbohydrates.

Photosynthesis

- The chemical, physical and biological processes by which green plants manufacture carbohydrates from CO_2 in the presence of light (energy) is called **Photosynthesis**.
- It is arguably the most important chemical reaction on earth.

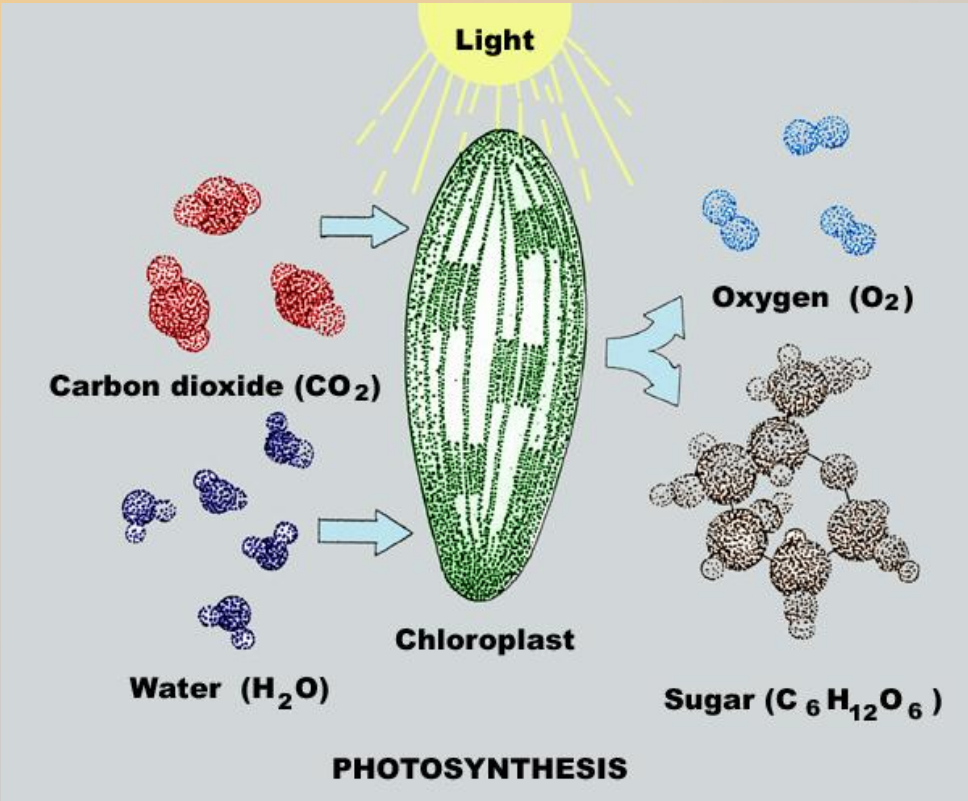
Photosynthesis

- Raw materials are **carbon dioxide** and **water**
- End products are **oxygen** and **sugar** (glucose).

- **$6\ CO_2 + 6\ H_20$ --*light*--> $C_6H_{12}O_6 + 6\ O_2$**

Photosynthesis

- This transformation of light energy into chemical energy occurs in the **chloroplast**.



Photosynthesis

- Photosynthesis **can only happen in light** and occurs in two steps.
- First **- light reaction**
  - results in the formation of high energy compounds.
- Second **- dark reaction**
  - the high energy compounds of step one are used to fix carbon dioxide into sugars.

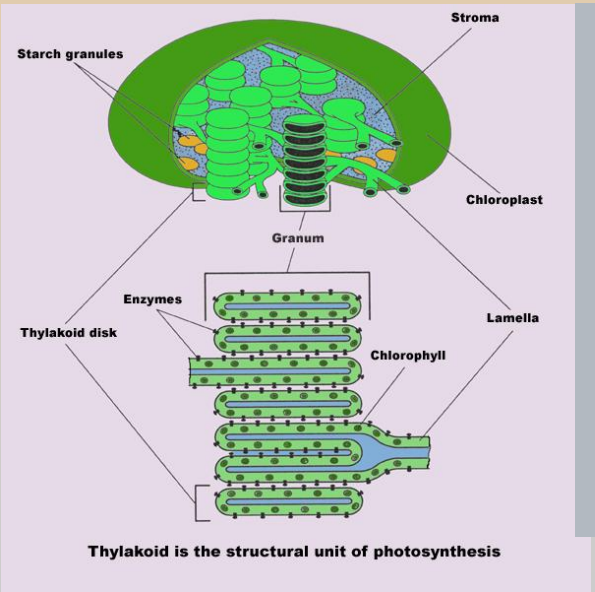
Photosynthesis

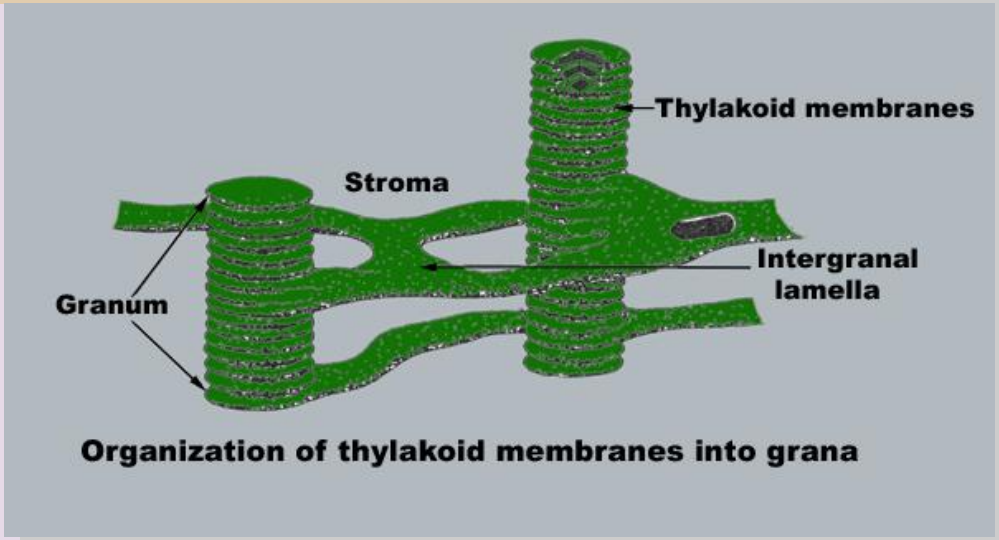
- **Chloroplast -** self replicating organelles found in all plant cells.
- Originate as plastids, small colourless bodies lacking mature structure are transmitted though the embryo from the mother plant as proplastids.
- On exposure to light the plastids develop into chloroplast, and become the site of photosynthesis.
- Consists of a photosynthetic membrane, the **thylakoid membrane** and **stroma**, a gel-like substance.
- Thylakoid membrane is made up of stack **granum** (grana - plural) and **intergranal** lamella.

Photosynthesis

•Consists of a photosynthetic membrane, the **thylakoid membrane** and **stroma**, a gel-like substance.

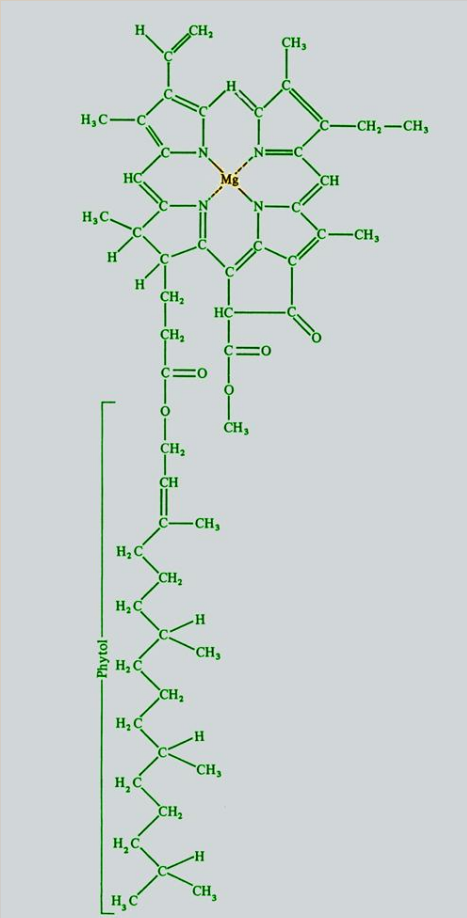
•Thylakoid membrane is made up of stack **granum** (grana - plural) and **intergranal** lamella.





Photosynthesis

- There are pigments on thylakoid membrane which are chemicals capable of absorbing radiation.
- The most abundant pigment in the chloroplast are the **chlorophylls**, they are responsible for the green colour.



Structure of chlorophyll a

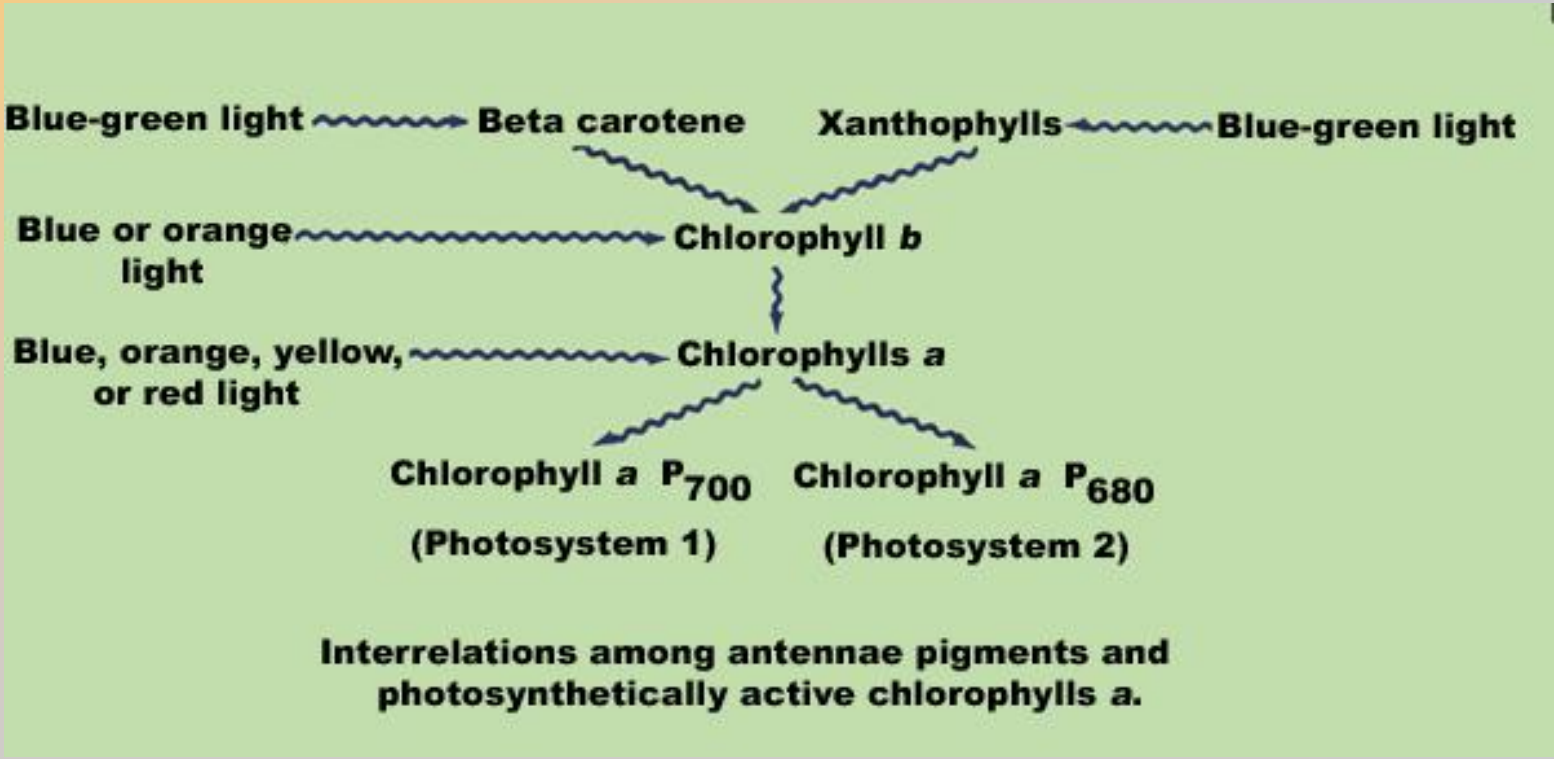
Photosynthesis

- There are other secondary pigments found in or on the thylakoid, including the carotenes, in higher plants beta-carotene dominates and it is responsible for the bright orange and reds;
- carotenoids (yellows); xanthopylls;
- and other colours such as anthocyanins - deep red and tannins - browns.

Photosynthesis

- The role of the secondary pigments is that of antennae pigments and they collect light energy and transfer this energy to Chlorophyll a.
- They also play a role in preventing the destruction of chlorophylls by high intensities of visible and near visible light.

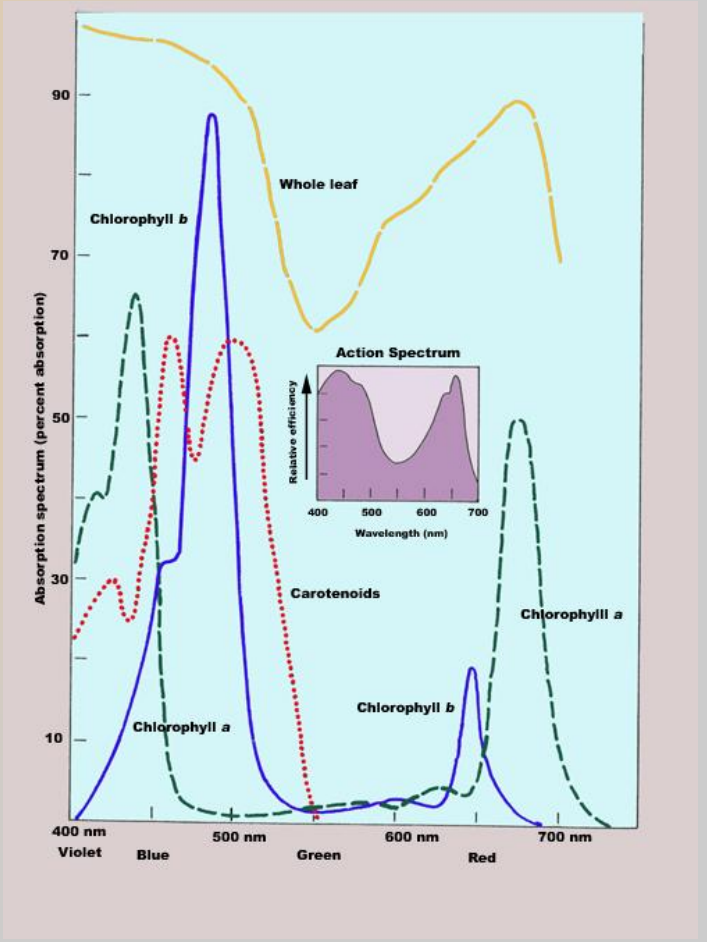
Photosynthesis



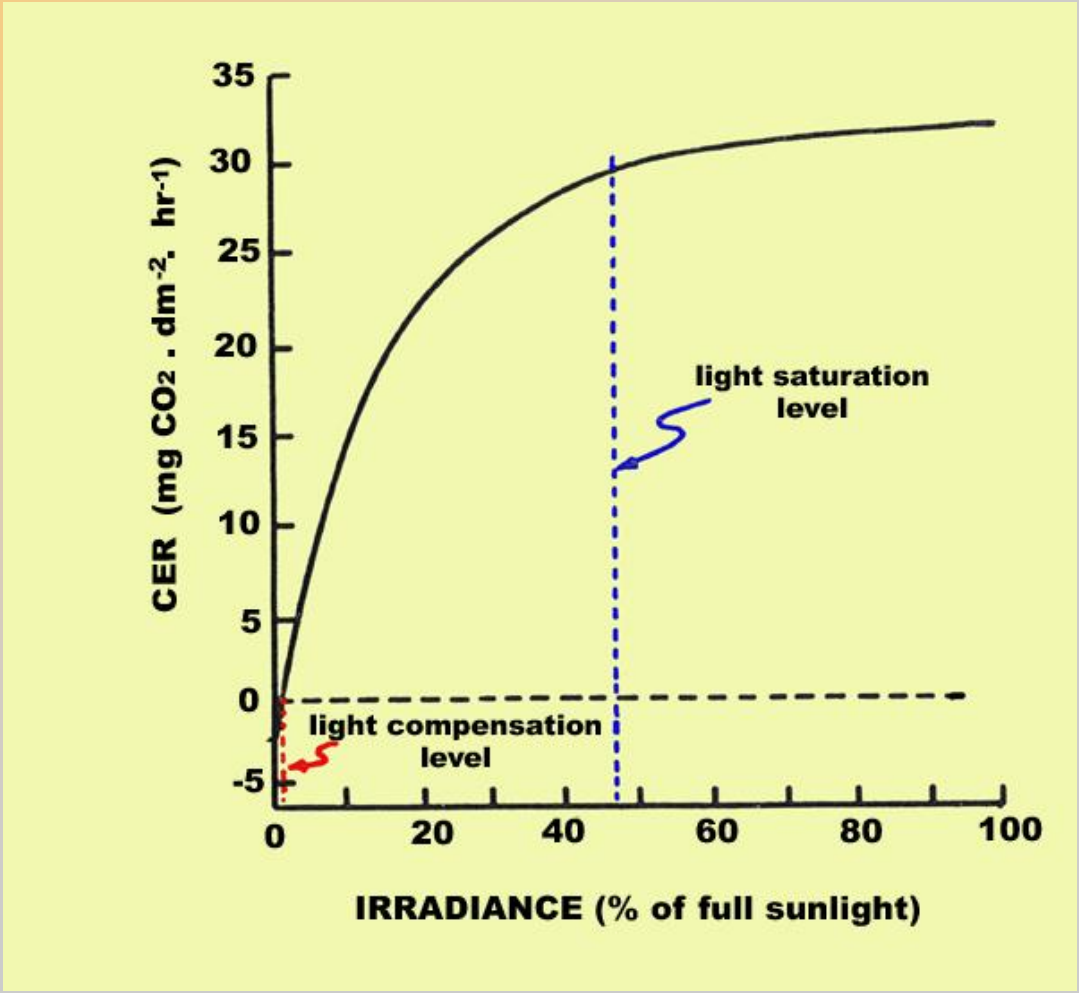
Interrelations among antennae pigments and photosynthetically active chlorophylls *a*.

Photosynthesis

- The pigments are absorbed at different wavelengths along the spectrum.
- The area of the electromagnetic spectrum that provides the energy for photosynthesis is referred to as the **Action Spectrum**



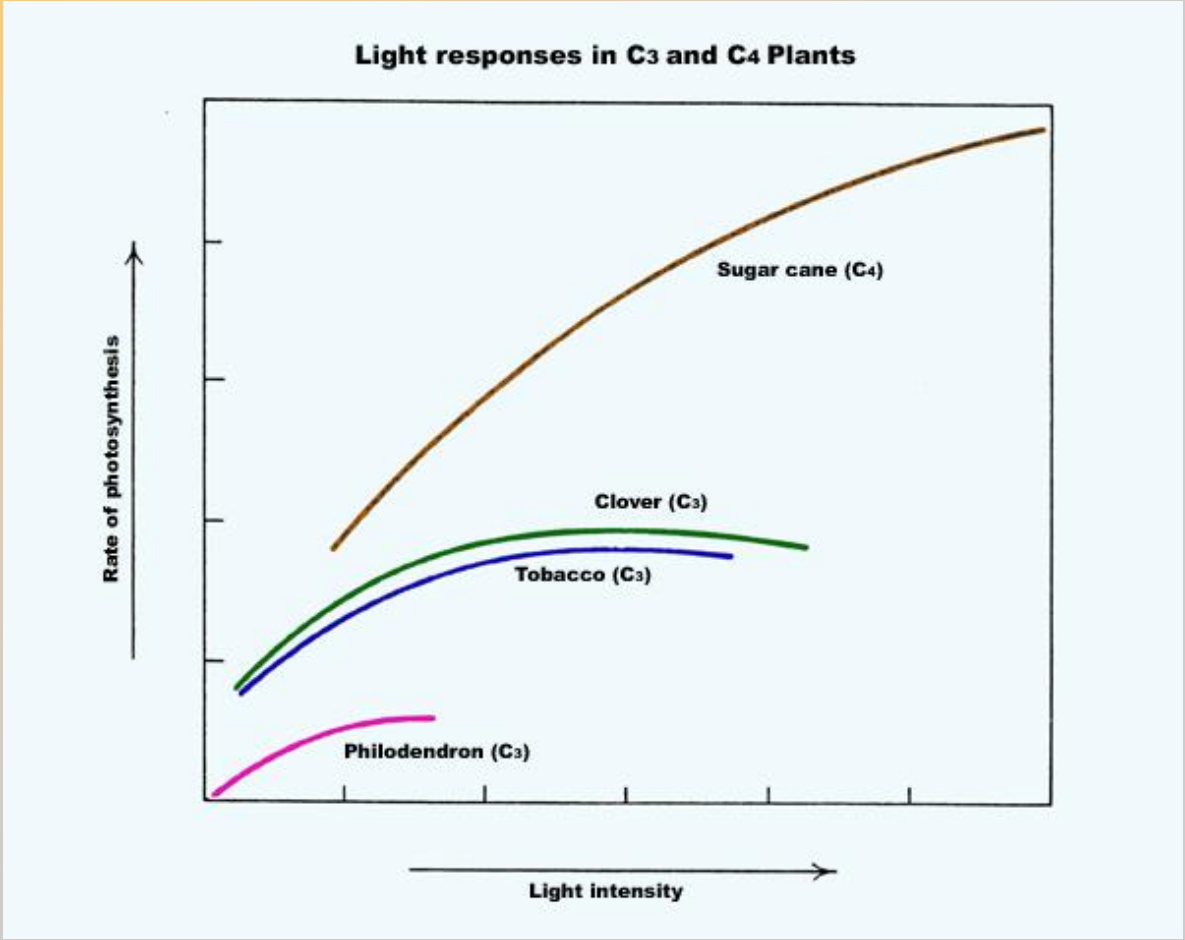
Photosynthesis



Photosynthesis

- The rate of photosynthesis is affected by several environmental factors, previously considered was the effect of water stress on stomatal closure.
- Any event that will result in stomatal closure will also have the effect of stopping photosynthesis, as the raw material CO_2 enters the substomatal cavity via the stoma.
- The rate of photosynthesis is affected by light intensity and with the maximum rate of photosynthesis for C4 plants close to double that of C3 plants.
- There is a difference among species within C3 plants, with the light saturation point being different not only between full sun and shade plants, but also within each category.

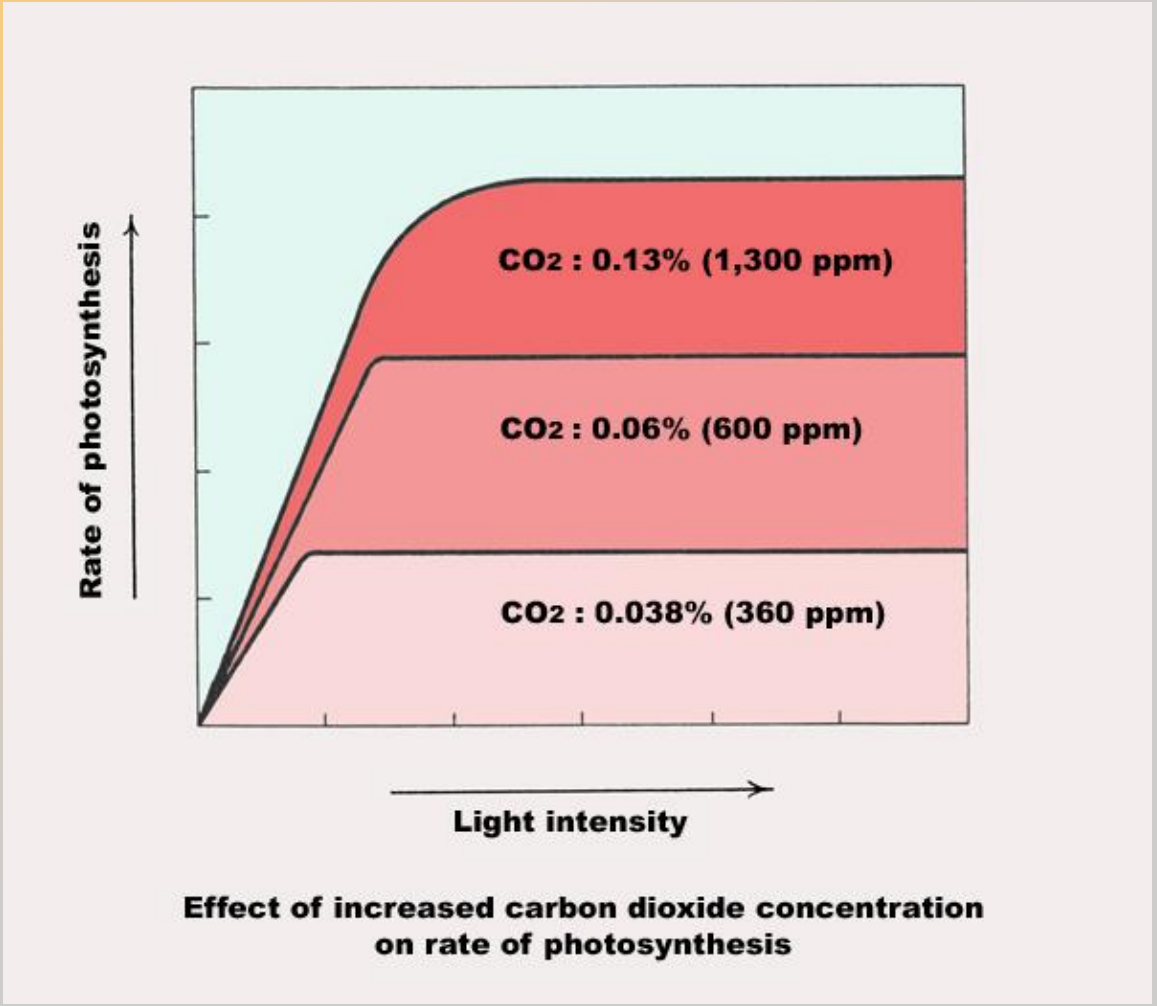
Photosynthesis



Photosynthesis

- Carbon dioxide levels also influence the rate of photosynthesis, and at higher concentrations of atmospheric CO_2 the greater the rate of photosynthesis and the higher the light saturation point.
- This has been applied in the greenhouse with the addition of CO_2 to increase the rate of growth and development of several species.
- There is a significant effect up to approximately 1000 ppm, but beyond that there is a negligible effect.

Photosynthesis



Effect of increased carbon dioxide concentration on rate of photosynthesis

Photosynthesis

Characteristics of Photosynthesis

- It occurs in cells containing chlorophyll.
- It proceeds only in the light.
- Carbon dioxide and water are the raw materials.
- Sugars, oxygen, and water are end products.
- Energy is stored.