Plant Propagation PLS 3221/5222

Guest Web Lecture

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CEAC
Controlled Environment Agriculture Center

The University of Arizona Controlled Environment Agriculture Program

College of Agriculture and Life Sciences

Department of Agricultural & Biosystems Engineering

With programs in

- **Education**
- **Extension - Outreach**
- **Research**
- **Design Analysis**
- **Business Development**

Greenhouse Systems for Plant Production

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Plant-Based Greenhouse System Design

- Given that greenhouse is a system of many systems and processes.

- Assume that the GH system consists of 3 fundamental aspects, each must be considered in combination, to assure effective design and successful operations

Three fundamental aspects:

- 1 Crop and Cultural Procedures
- 2 Nutrient Delivery System
- 3 Controlled Environment

3 Fundamental Aspects:

1. Crop Cultural Procedures

- the plant needs; based on crop[s] to be grown

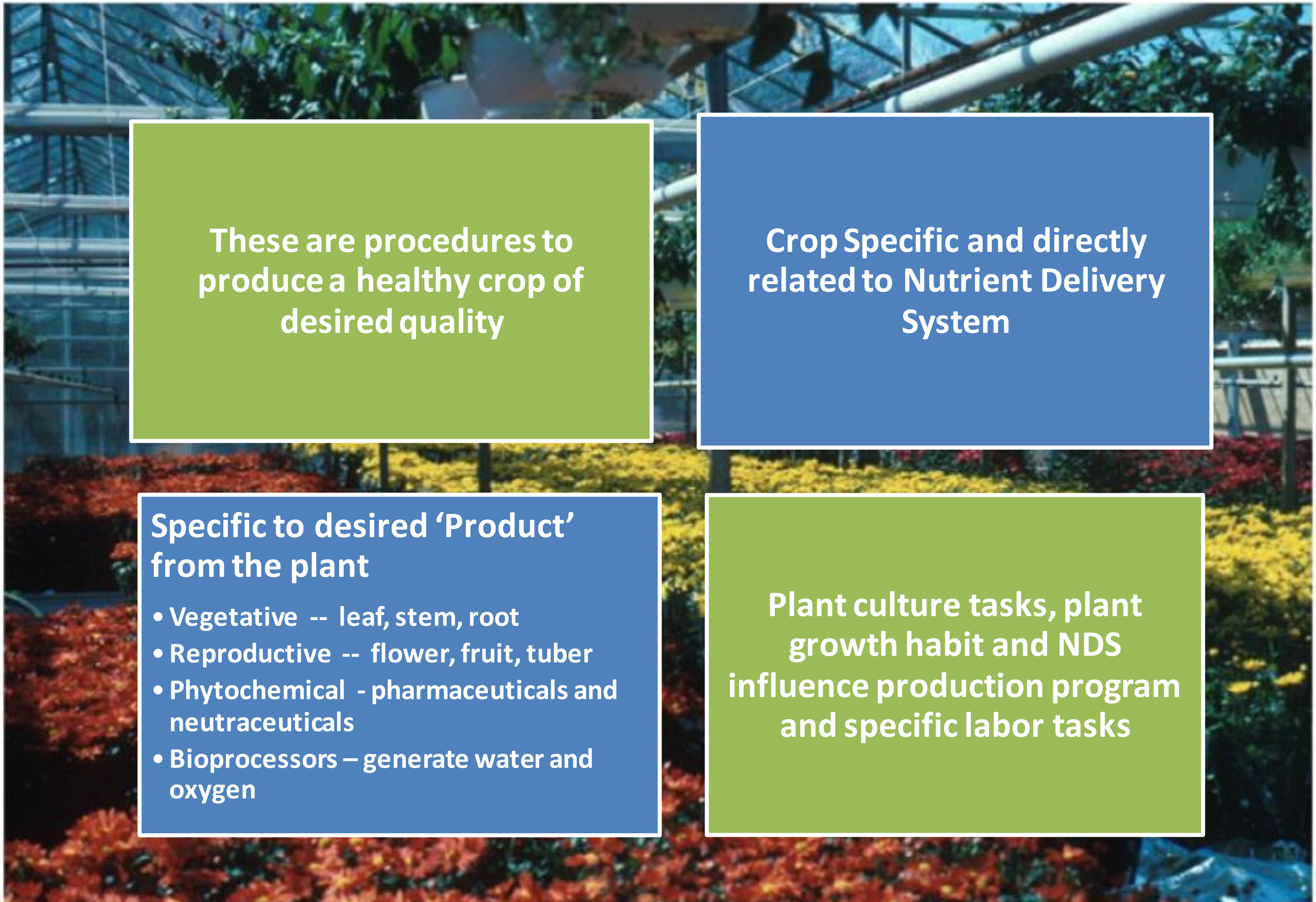
2. Nutrient Delivery System

- procedures for delivery of primarily water and fertilizer, but also CO_2, light, etc, to the crop

3. Environmental Control

- means to provide the plant environment, includes the structure and the environmental control systems [ventilation, cooling, heating, shading, lighting, computer, thermostats, etc]

Crop Cultural Technique



These are procedures to produce a healthy crop of desired quality

Crop Specific and directly related to Nutrient Delivery System

Specific to desired 'Product' from the plant

- Vegetative -- leaf, stem, root
- Reproductive -- flower, fruit, tuber
- Phytochemical - pharmaceuticals and neutraceuticals
- Bioprocessors – generate water and oxygen

Plant culture tasks, plant growth habit and NDS influence production program and specific labor tasks

Nutrient Delivery System [NDS]
Hardware to transport nutrients to plants

Nutrients

- Water, Fertilizer, [CO_2, Light]

Central location for nutrients

- Pre-mixed with storage
- Mixed on demand

Distribution

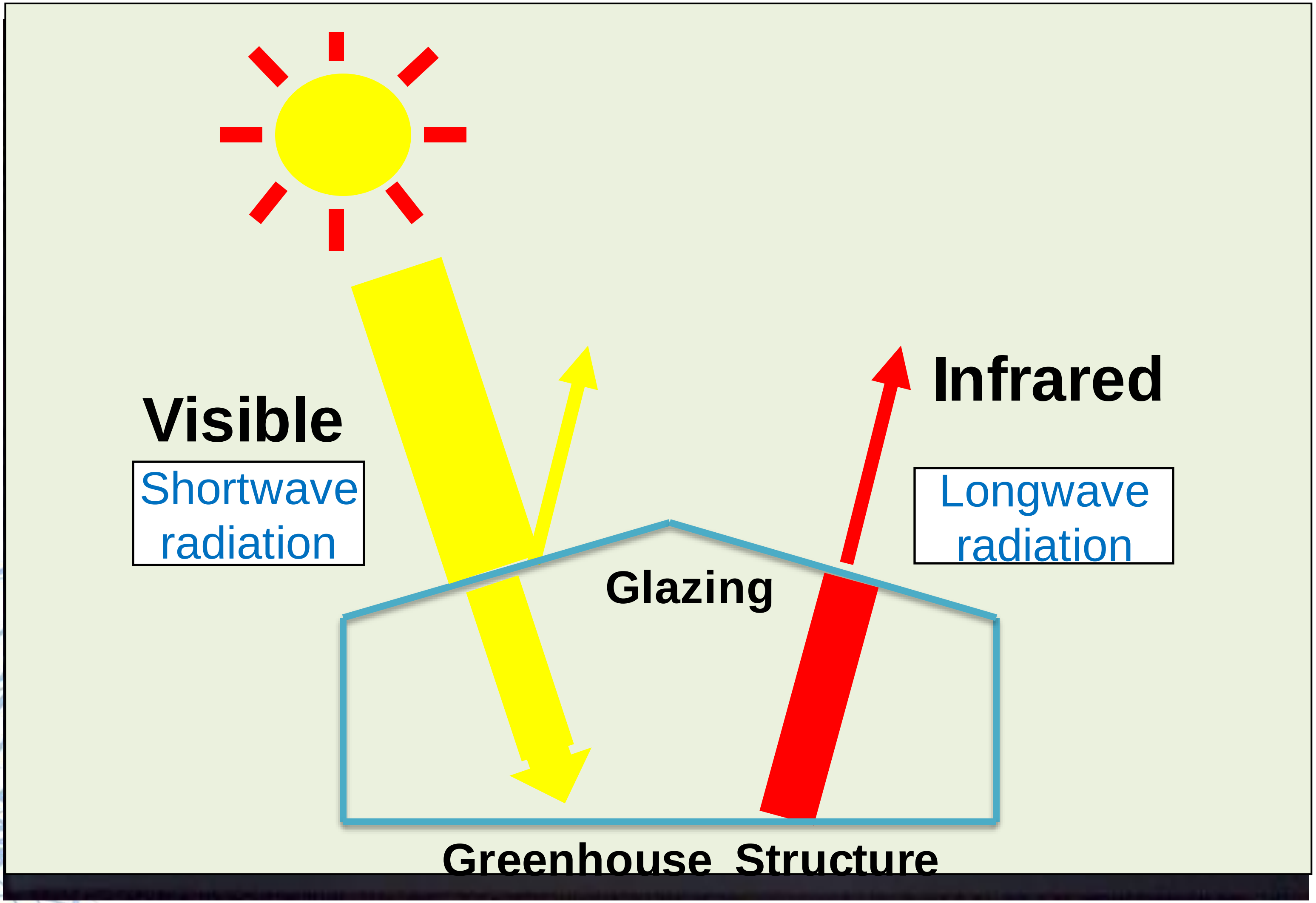
- to each plant by drippers
- to rows of plants by drippers & troughs
- to benches of plants by outlets & drains
- to floor of greenhouse crop by outlets & drains

Controlled Environment

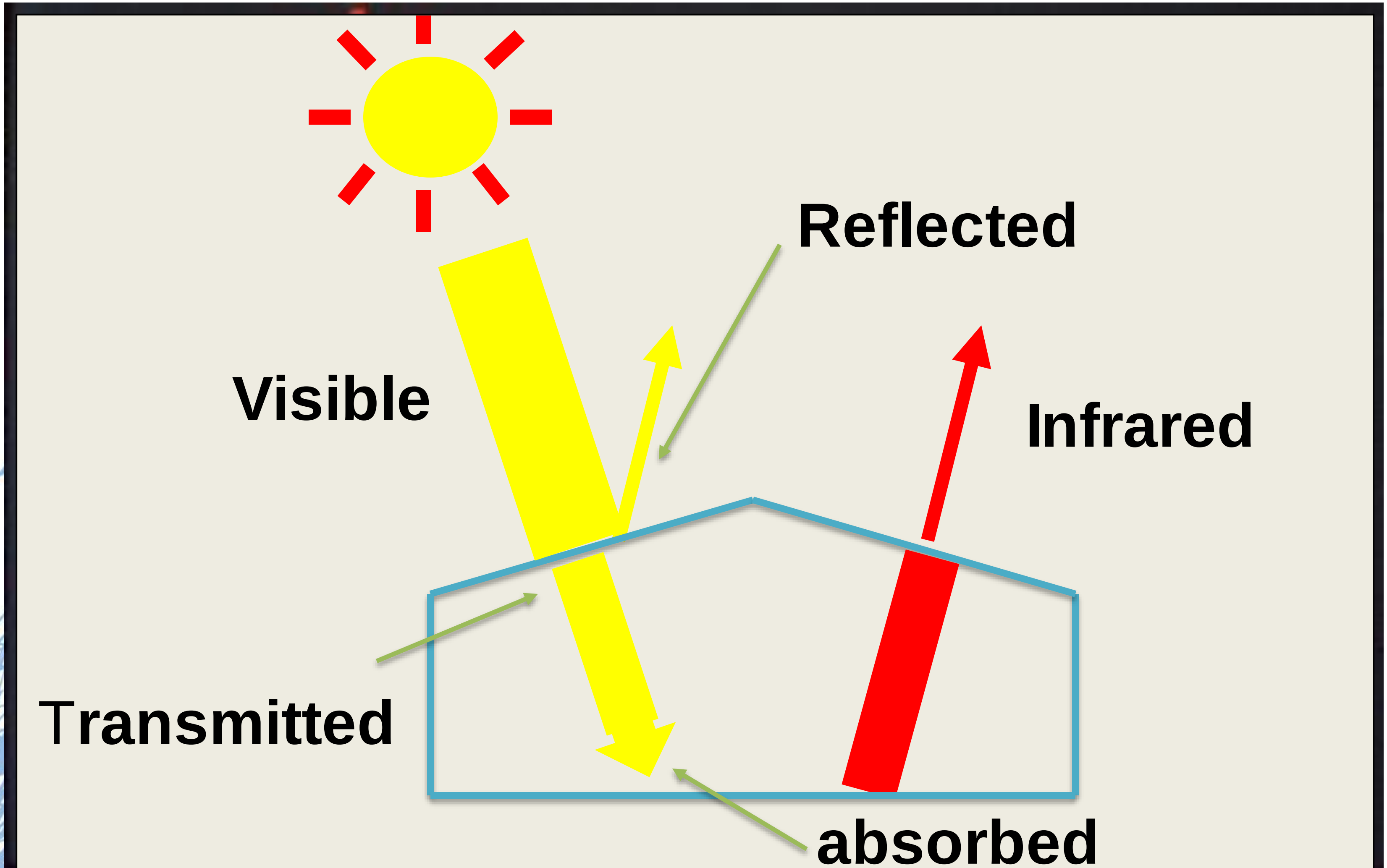
Greenhouse or other structure with environmental control systems

- Maintain desired climate
- Compatible with Nutrient Delivery System and Crop Culture Technique
- Unobtrusive and dependable for grower
- Based on the 'Greenhouse Effect'

Greenhouse Effect



Solar Energy enters and is trapped



Diffuse and Direct Radiation

Direct + Diffuse = Total Radiation

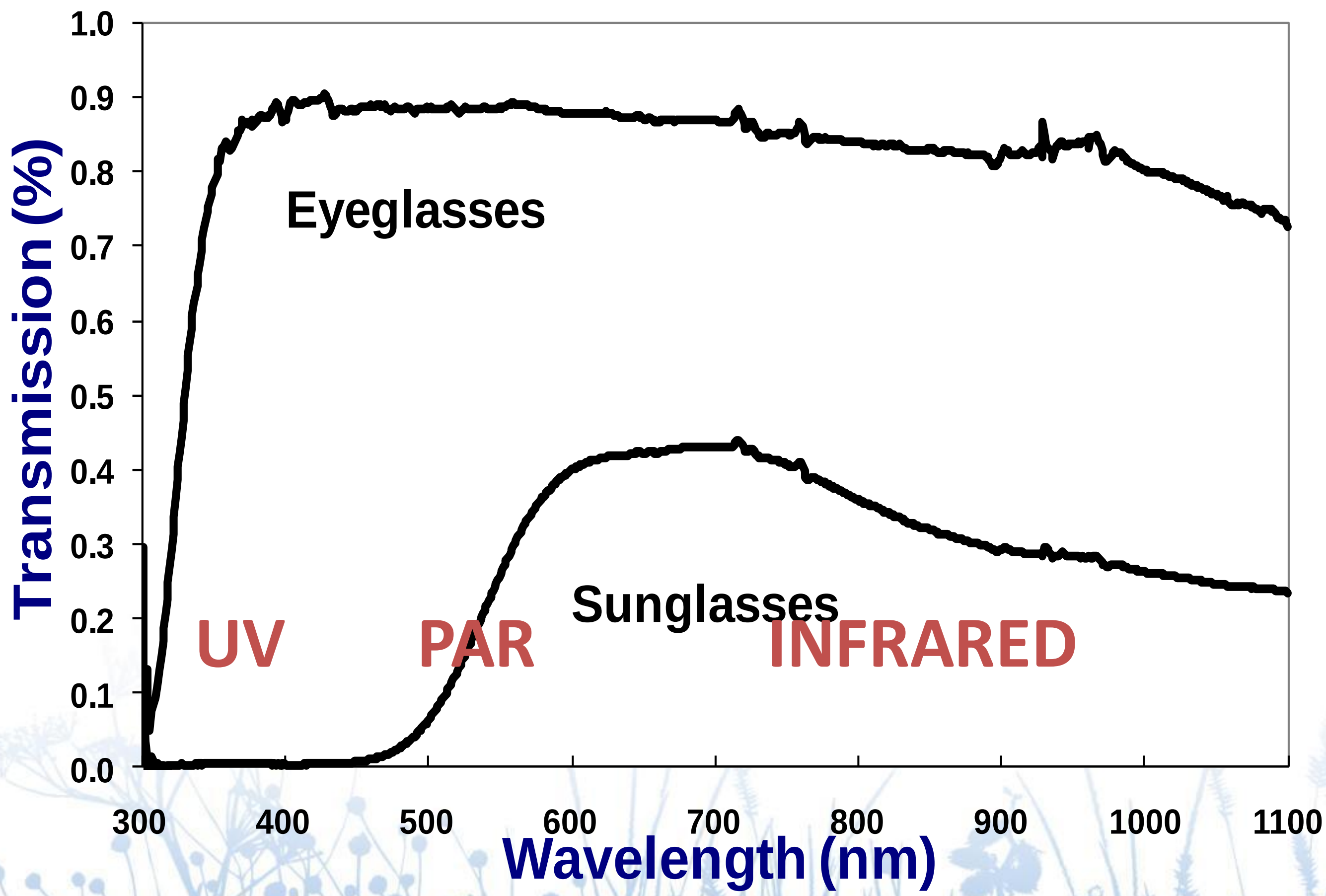
Diffuse Radiation

- radiation has been reflected by the atmosphere or glazing

Direct Radiation

- radiation received directly, without any reflection

Transmission of Spectacles



Note that sunglasses reduce the light intensity, and especially the UV compared to the typical eyeglasses

Radiation

Quantity

- **intensity or amount of energy within the waveband**

Quality

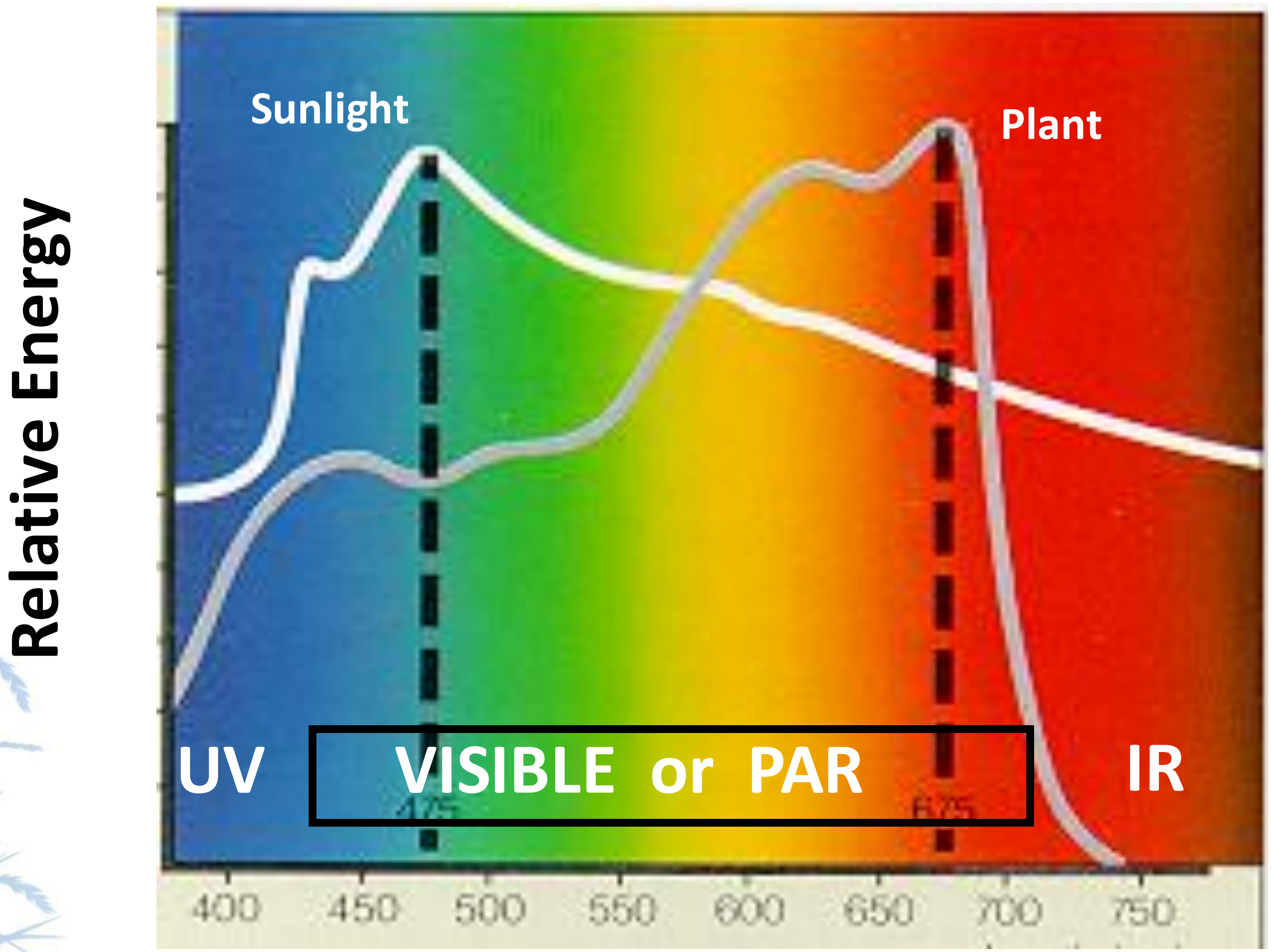
- **distribution and intensity of wavelengths within the waveband**

Measured as Energy [W m^{-2}] Watts per sq. meter, or as Number of Photons [μMol $m^{-2}s^{-1}$] micro Mol per sq. meter per sec, within a waveband

Wavebands of Solar Radiation

	waveband
Ultra-Violet or UV	• 100-400 nm
Visible or white "light"	• 380-760 nm
PAR	• 400-700 nm
Infrared or IR	• 750 - 1,000,000 nm

Wavebands of Solar Radiation



(from PootLichtenergie BV.)

Sunlight - relative amount of energy for each wavelength from the sun
Plant – relative amount of energy at each wavelength absorbed by leaf

The "colors" of the radiation visible to humans can be divided into the following wavebands:

Violet
- 380-436 nm
- may support effect of blue light

Blue
- 436-495 nm
- some need, prevents tall plants

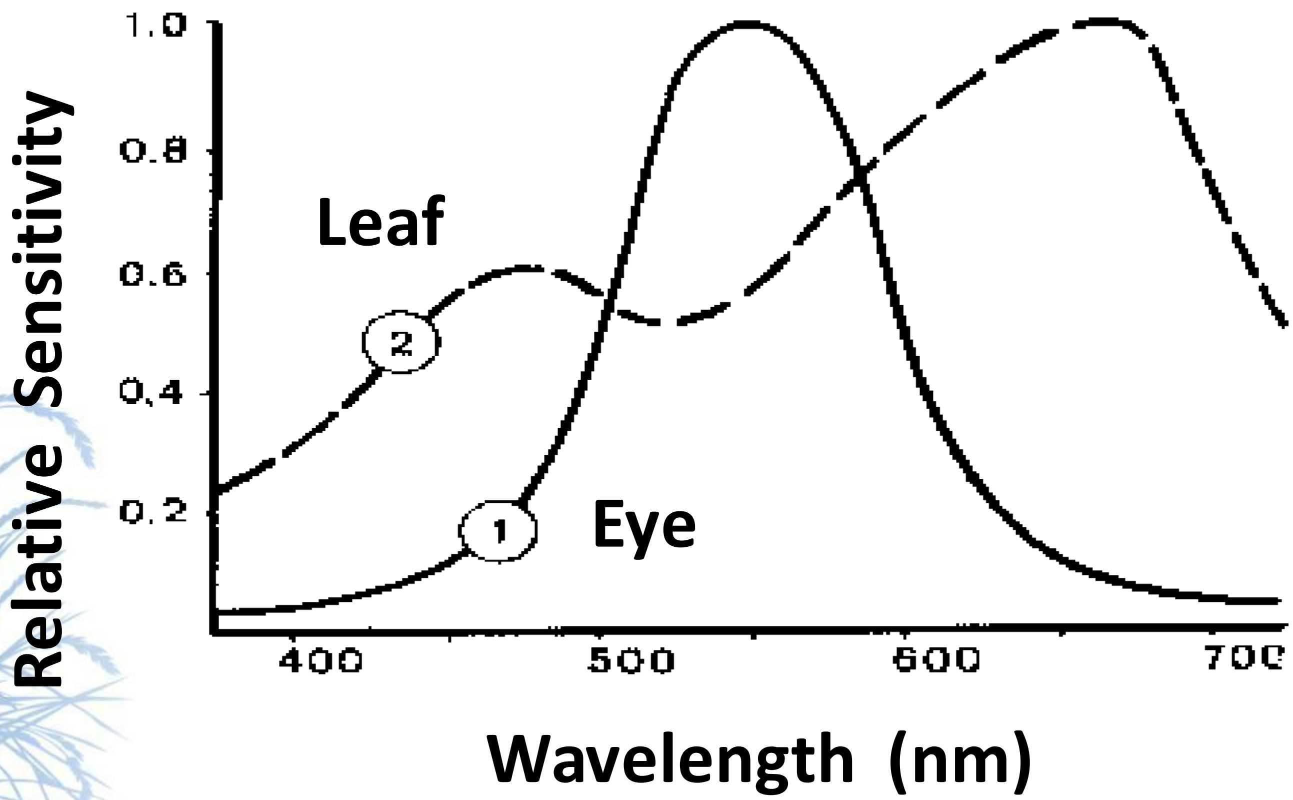
Green
- 495-566 nm
- contributes to photosynthesis

Yellow
- 566-589 nm
- contributes to photosynthesis

Orange
- 589-627 nm
- maximum photosynthesis

Red
- 627-780 nm
- maximum photosynthesis; enhance flowering, stem length;
- Red/Far-red ratio is important

Comparison of what the human eye "sees" relative to what the plant utilizes



(from PootLichtenergie BV.)

What's A Photon?

Photon is a unit of light

It has a <u>Wavelength</u> (or Frequency) and <u>Energy</u>

Wavelength measured in nanometers (nm)
Frequency measured in cycles per second

$$\text{Energy} = \frac{h * c}{\text{wavelength}}$$

Thus the energy, 'E', of a photon is equal to 'h', a constant, multiplied by 'c', speed of light, and divided by 'wavelength' of the light

What's A Photon?

As Wavelength <u>increases</u>, the Energy <u>decreases</u>

As Wavelength <u>decreases</u>, the Energy <u>increases</u>

Therefore,
the longwave [Red] has _ _ _ _ energy than
the shortwave [Blue]?

What's A Photon?

As Wavelength <u>increases</u>, the Energy <u>decreases</u>

As Wavelength decreases, the Energy increases

Therefore,
the longwave [Red] has <u>L</u> <u>E</u> <u>S</u> <u>S</u> energy than
the shortwave [Blue].
Because Red light has a longer wavelength than blue!

Sensors

Pyranometer sensor

- measures solar radiation from 280-2800 nm. 97% of the sun's spectral distribution "total solar" radiation. Units are $W\ m^{-2}$

Quantum sensor

- is PAR waveband (400-700 nm) measured as $\mu Mol\ m^{-2}\ s^{-1}$ or $W\ m^{-2}$

Net Radiometer

- determines the difference of the radiation measured above to that being reflected from below a surface

Spectroradiometer

- splits incoming radiation into individual wavelengths or prescribed wavebands, then measures the irradiance (energy) of the photons.
- measures spectral irradiance as $\mu Mol\ m^{-2}\ s^{-1}\ nm^{-1}$ or $W\ m^{-2}\ nm^{-1}$

GREENHOUSE DESIGN and CONSTRUCTION, SPACE UTILIZATION, FACILITIES MANAGEMENT

Decisions on design of greenhouse structure will affect:

- Labor Management
- Materials Flow
- Space Utilization
- Automation & Labor Savers
- Utilities Distribution
- Height of Greenhouse
- Energy Costs
- Total Light and Light Distribution

The Choice of Greenhouse should be the LAST Decision

- **Since the structure affects EVERYTHING**

YES! All crops, growing procedures, and management preferences should be decided first!

High Tunnel Greenhouses

Polyethylene film covered, pipe-framed quonset or ground-to-ground greenhouse
Natural ventilated, with roll-up sidewalls

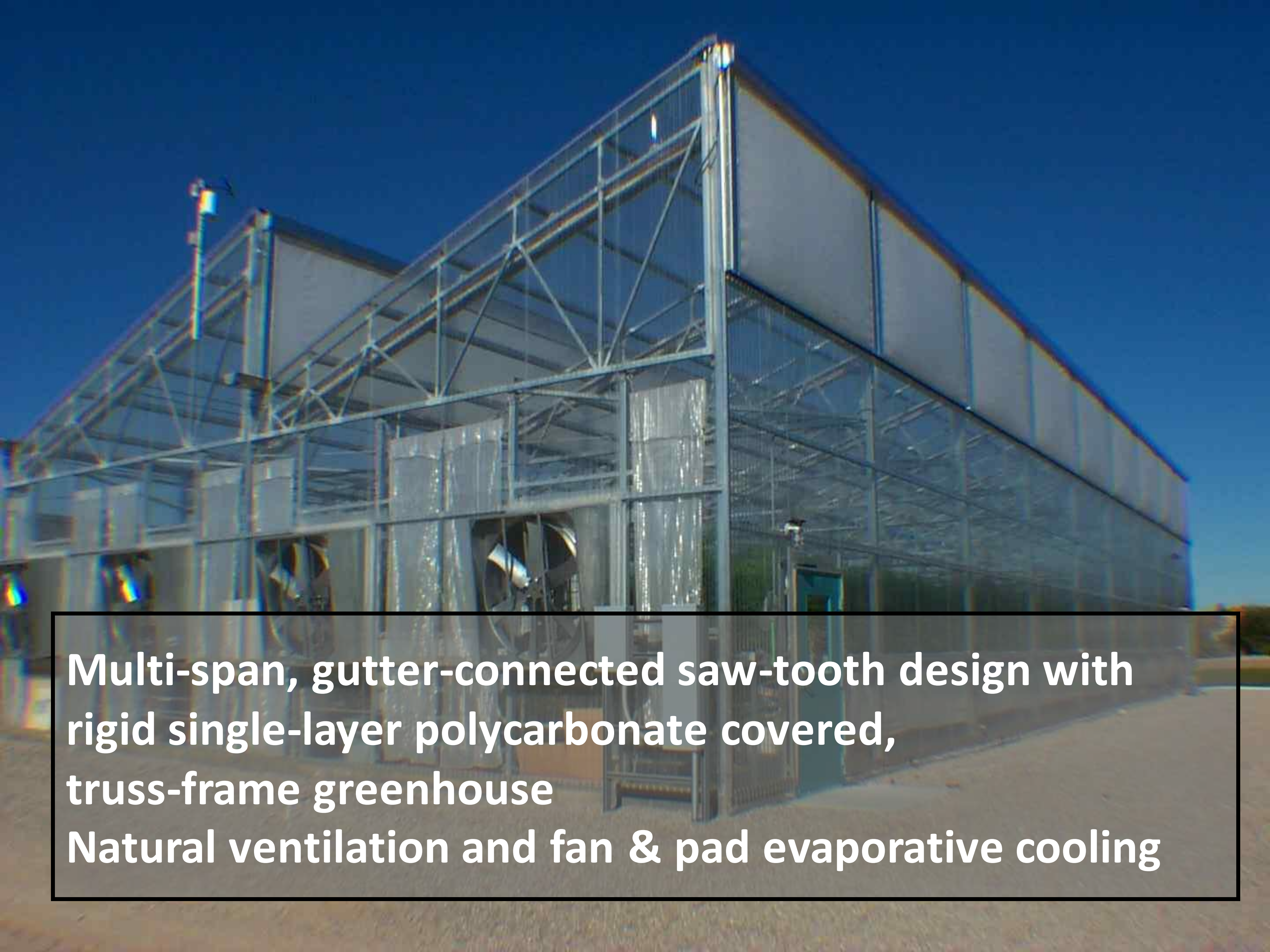
Dr. Otho Wells, UNH, 2002.

Pipe-Framed Ground-to-Ground Greenhouse

Inexpensive greenhouse Framed by bent pipes covered with film glazing

Dr. Otho Wells, University of New Hampshire

Fan ventilated and heated
20 by 96 foot polyethylene film covered, pipe-framed quonset or ground-to-ground greenhouse

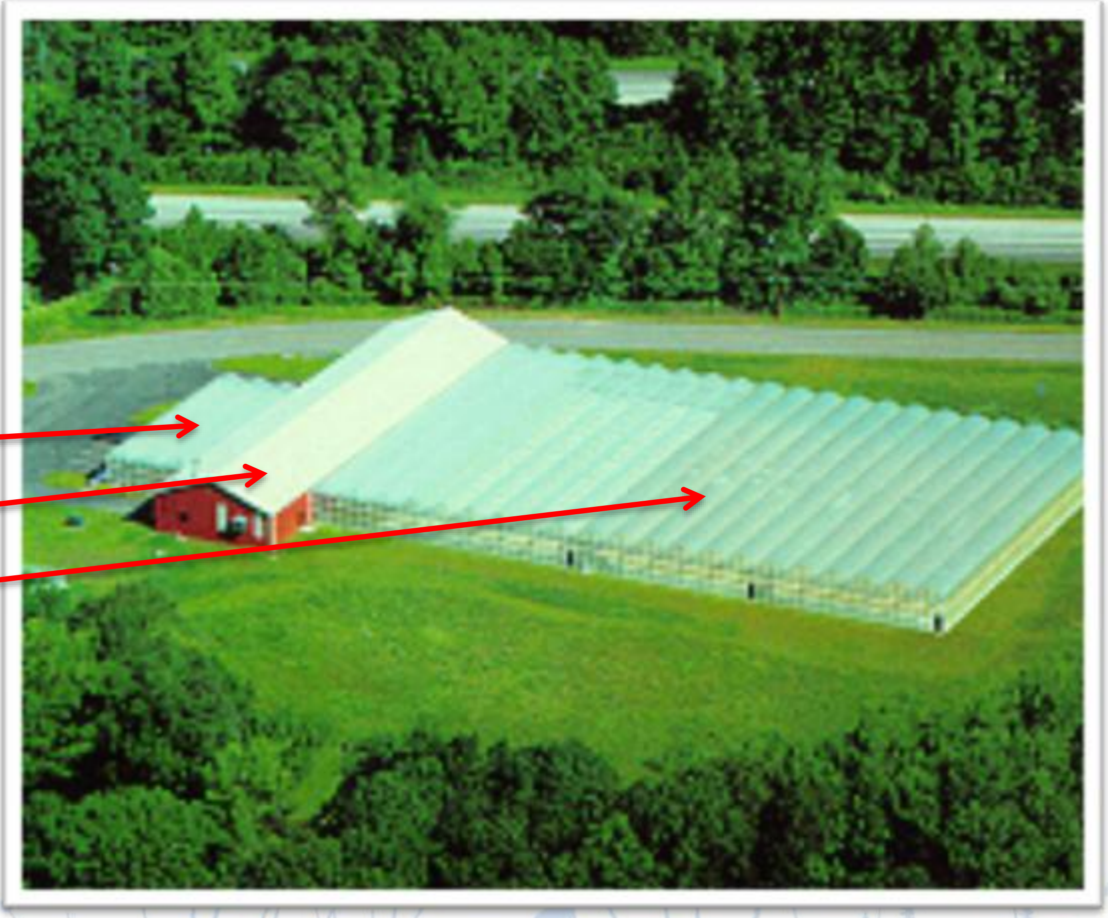


Multi-span, gutter-connected saw-tooth design with rigid single-layer polycarbonate covered, truss-frame greenhouse

Natural ventilation and fan & pad evaporative cooling

Controlled Environment Plant Production System

Gutter-connected,
multi-span,
or ridge & furrow greenhouse
with separated
seedling,
headhouse and
production area



Burlington County Eco-Complex, NJ

OBJECTIVES of Facilities Planning

- Grow the maximum plants per unit area per unit time
- Improve crop quality
- Organize/Simplify operations
- Improve management
- Improve labor efficiency
- Improve equipment utilization
- Reduce energy & water costs (per plant)

In General,

- Capitalize on Expertise of Grower\Manager
- Consider Future Expectations
- Design for Basic Production Necessities
- Design for Future Expansion and Upgrades
- Do Not Block Future Moves
- Select Systems With Immediate Need
- Create “Workable”, Not “Optimal” System

GREENHOUSE PLAN

There are 3 general "locations" within all greenhouses.

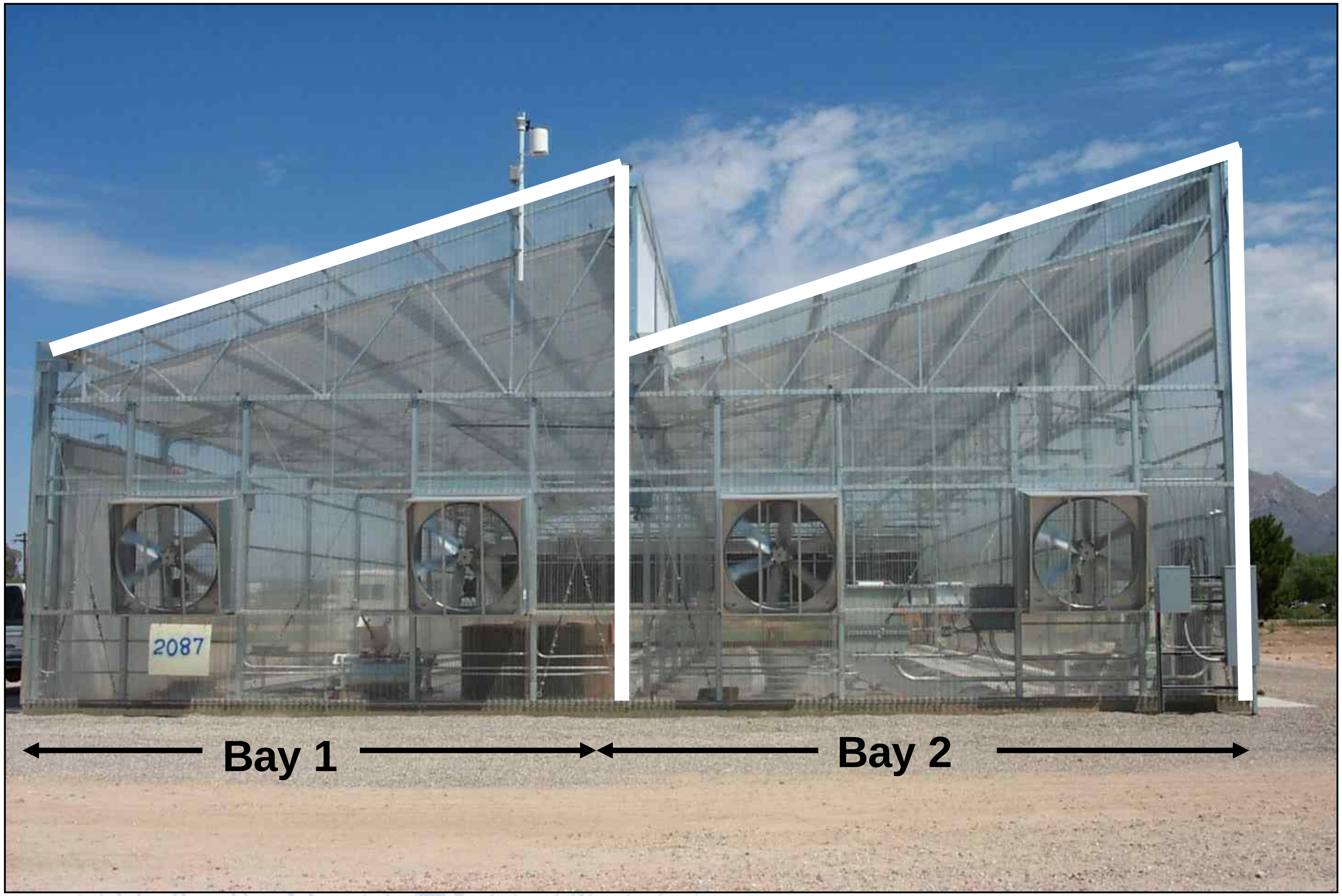
- **They can be arranged in various ways.**
- **They can exist in a number of forms.**

1. Growing Area

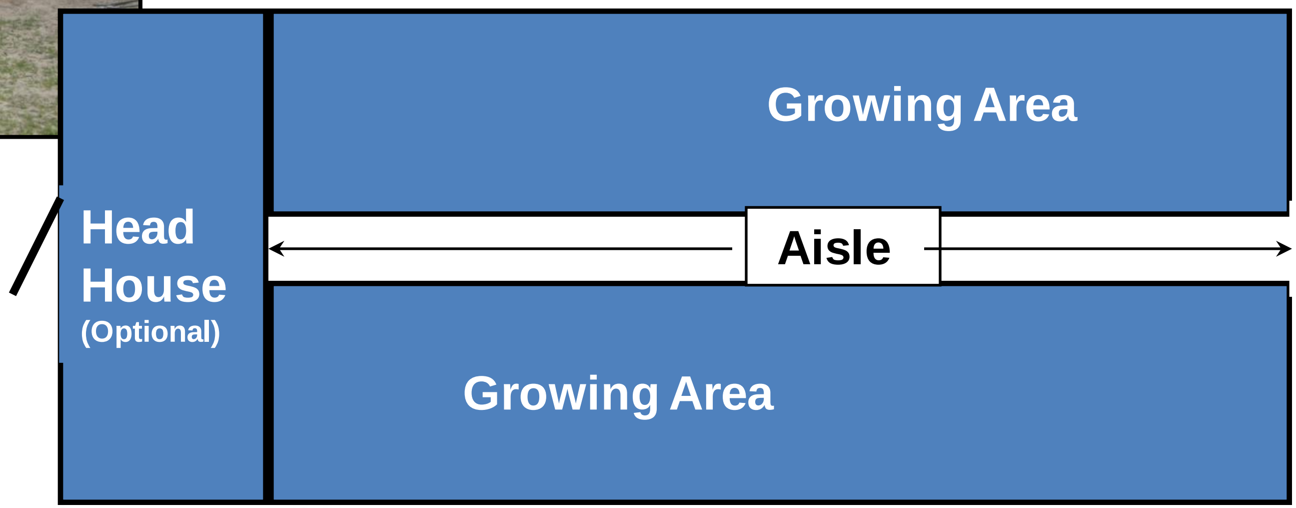
2. Work Area

3. Connecting Pathways

Multi-Bay, Gutter-Connected

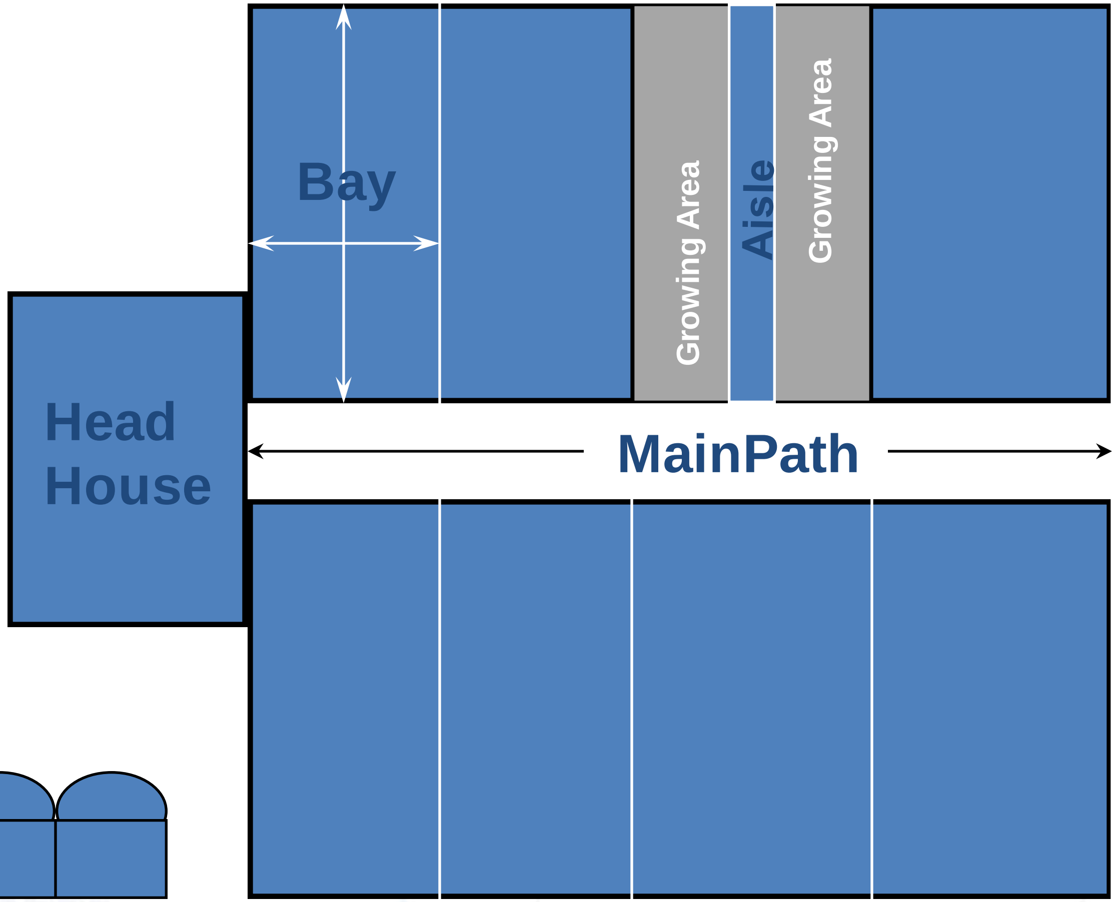


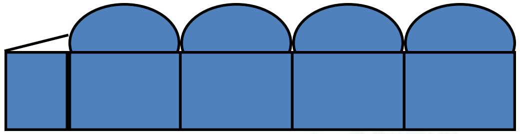
Locations in Greenhouse Plan



single bay, ground-to-ground greenhouse

Locations in Greenhouse Plan





gutter-connected greenhouse

gutter-connected greenhouse

Eurofresh Farms, Willcox, AZ

Labor Management, Materials Handling and Economy of Scale is better with Gutter-Connected than with Ground-to-Ground Greenhouses

For "Large" Greenhouse Business, Select a Gutter Connected Structure

Other Structures

Fixed shade structure

Movable screen structure

Opening roof structure

Semi-Closed Structure

Light Affects Plant Growth and Depends on:

Location of the Greenhouse

Time of the year

Glazing or cover on the Greenhouse

Greenhouse structure

Orientation of the greenhouse

North-South, or East-West

Light Availability to Plants

Greenhouse Orientation Compass Direction of Gutters/ Ridge (East-West) or (North-South)

↓

Most Total Light per Year

N-S

↓

Most "Winter" Light

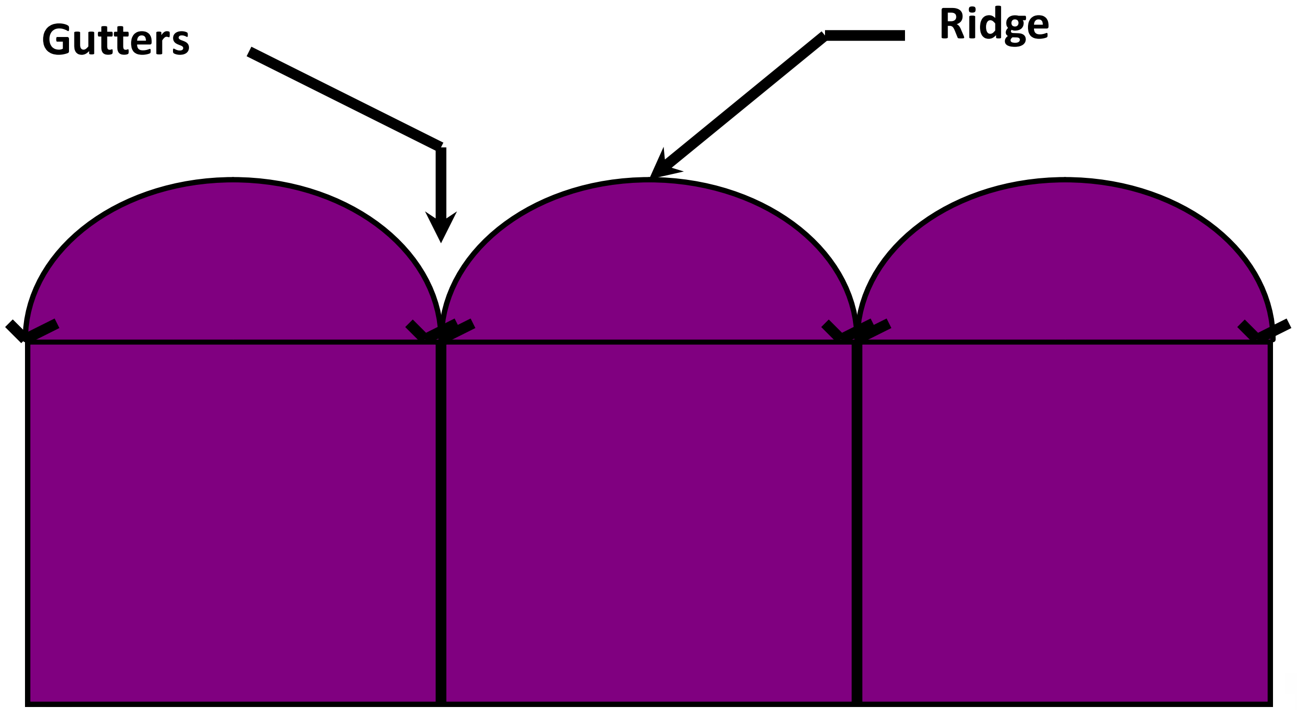
E-W

↓

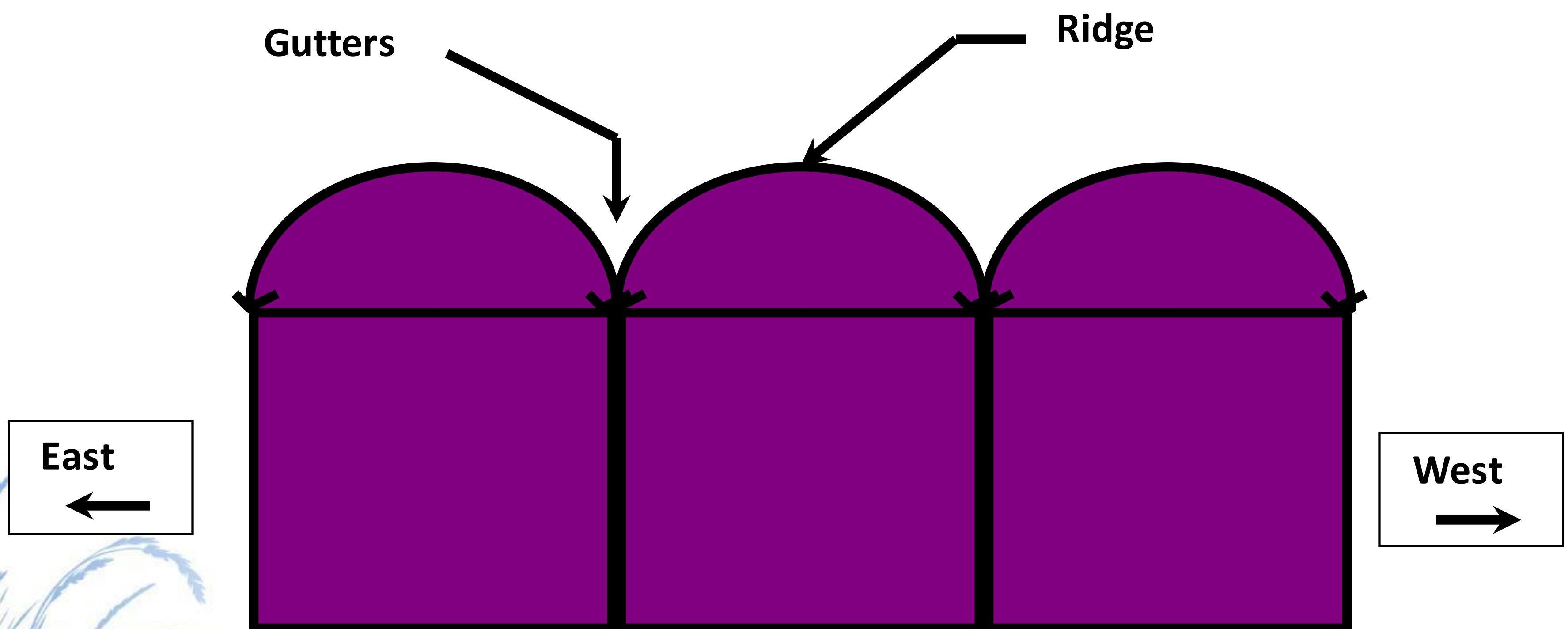
Most Uniform Light Distribution

N-S

Gutter - Connected Greenhouse

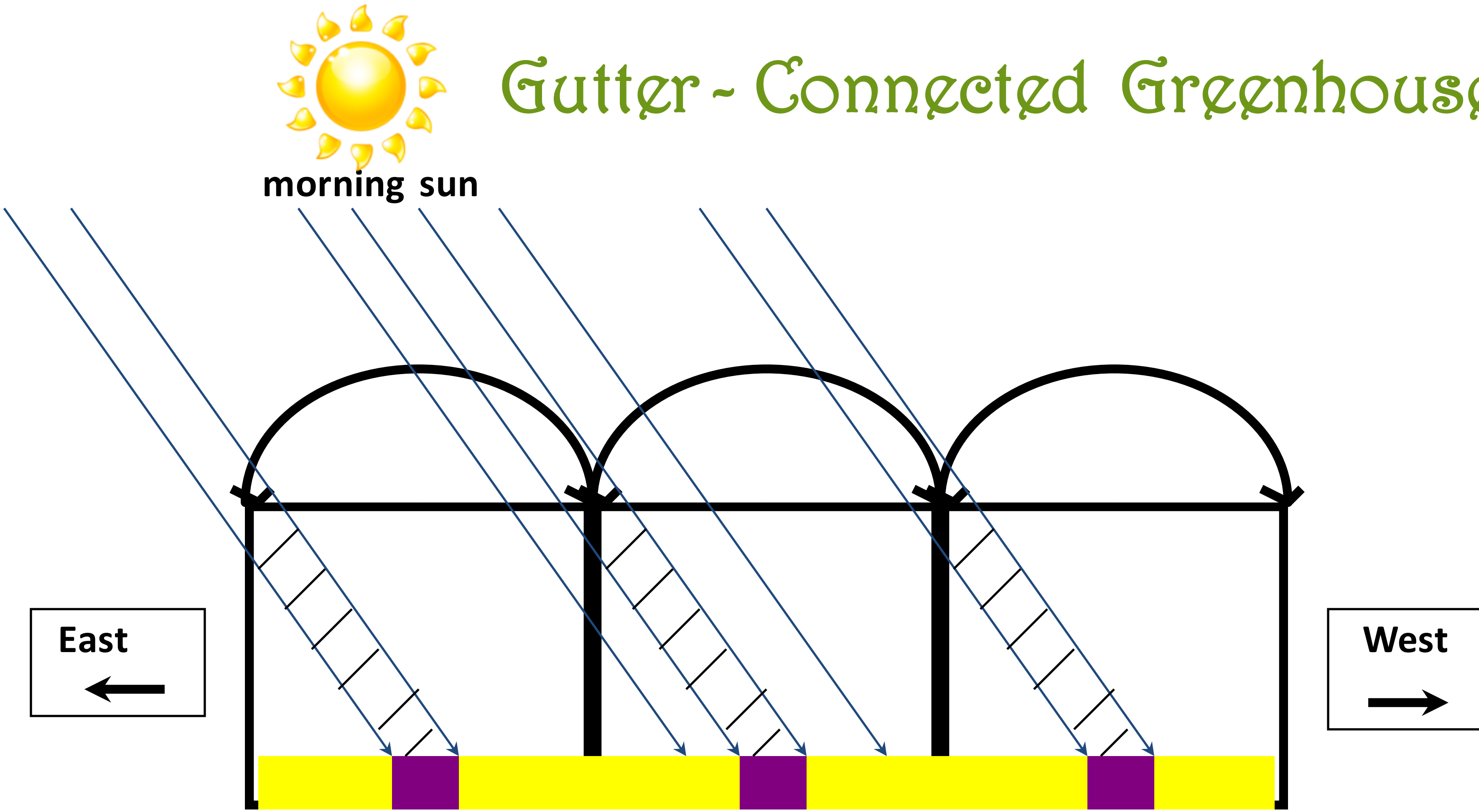


Gutter - Connected Greenhouse



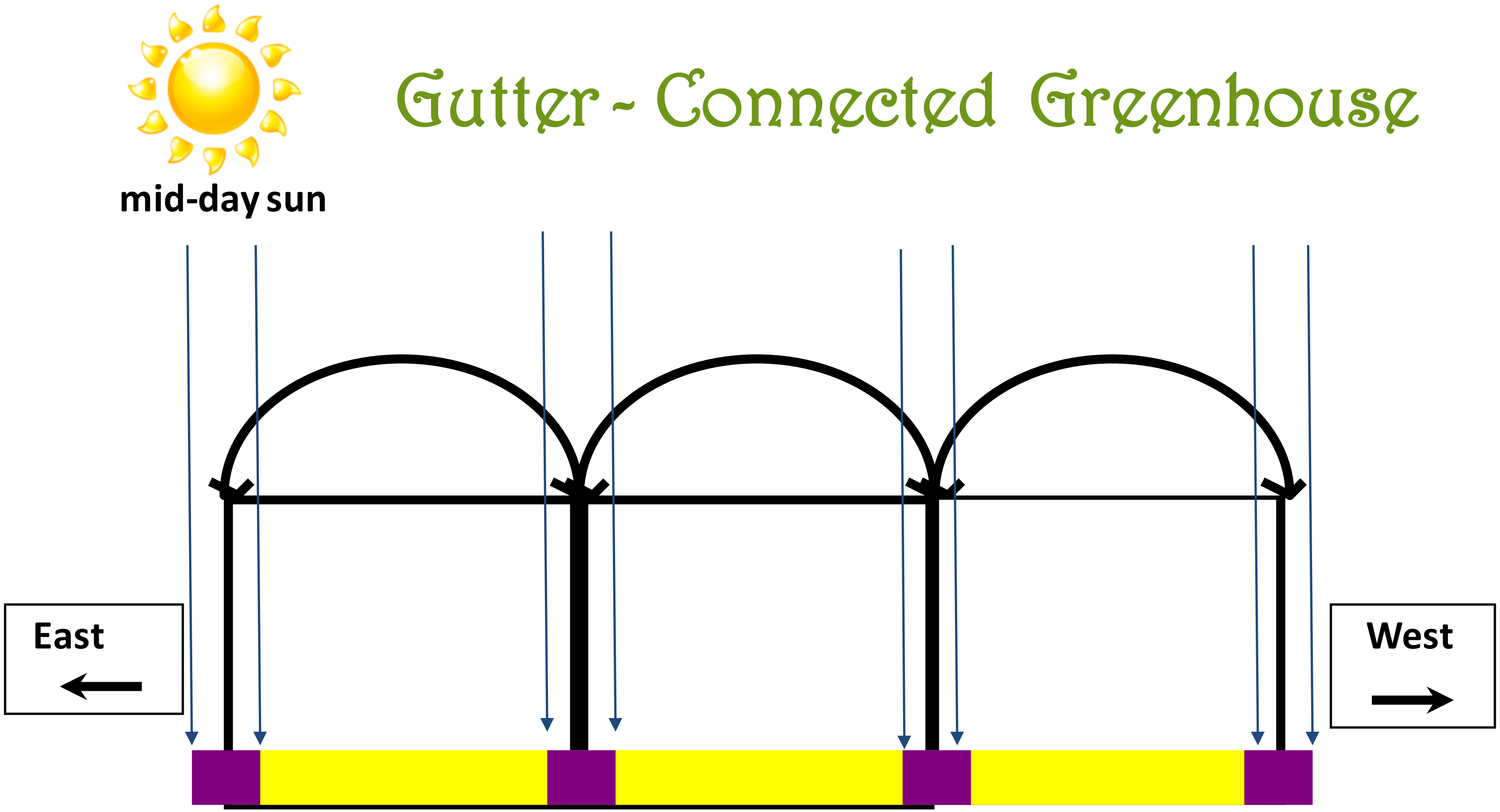
North–South ridge & gutter

Gutter - Connected Greenhouse



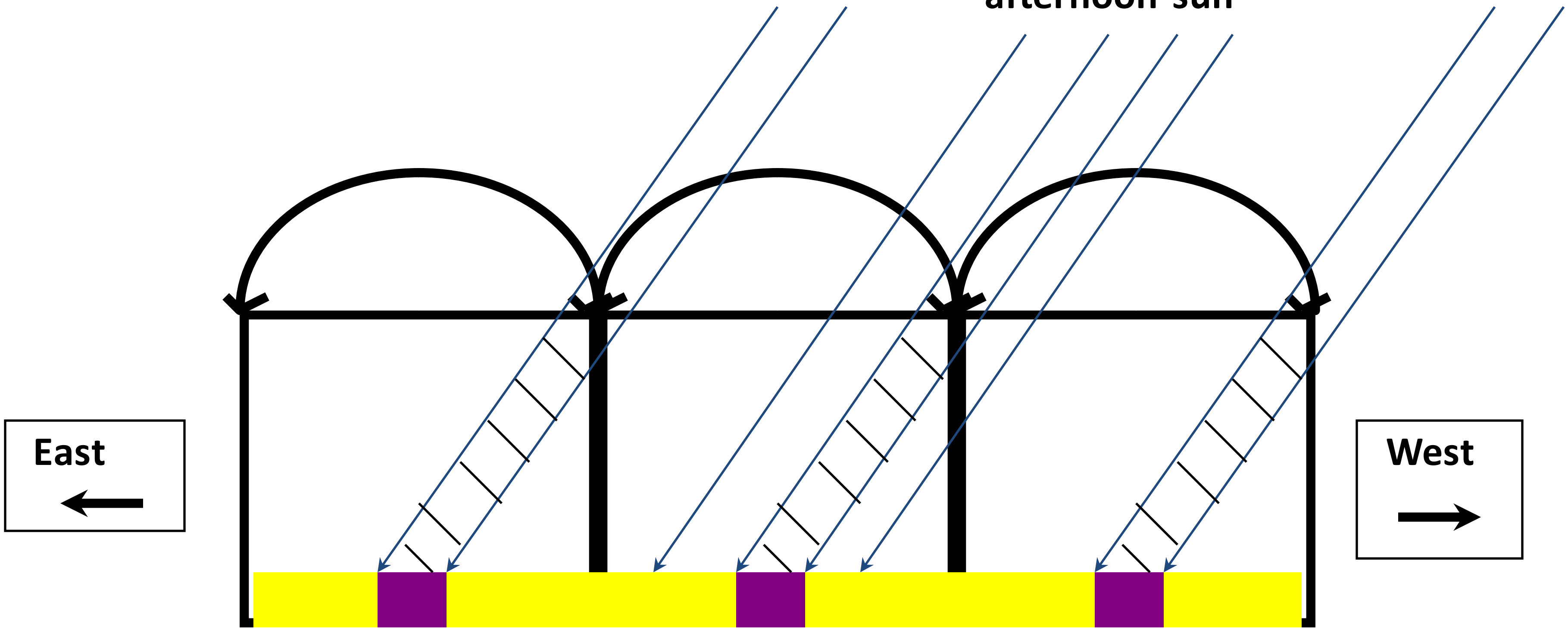
North–South ridge & gutter

Gutter - Connected Greenhouse



North - South ridge & gutter

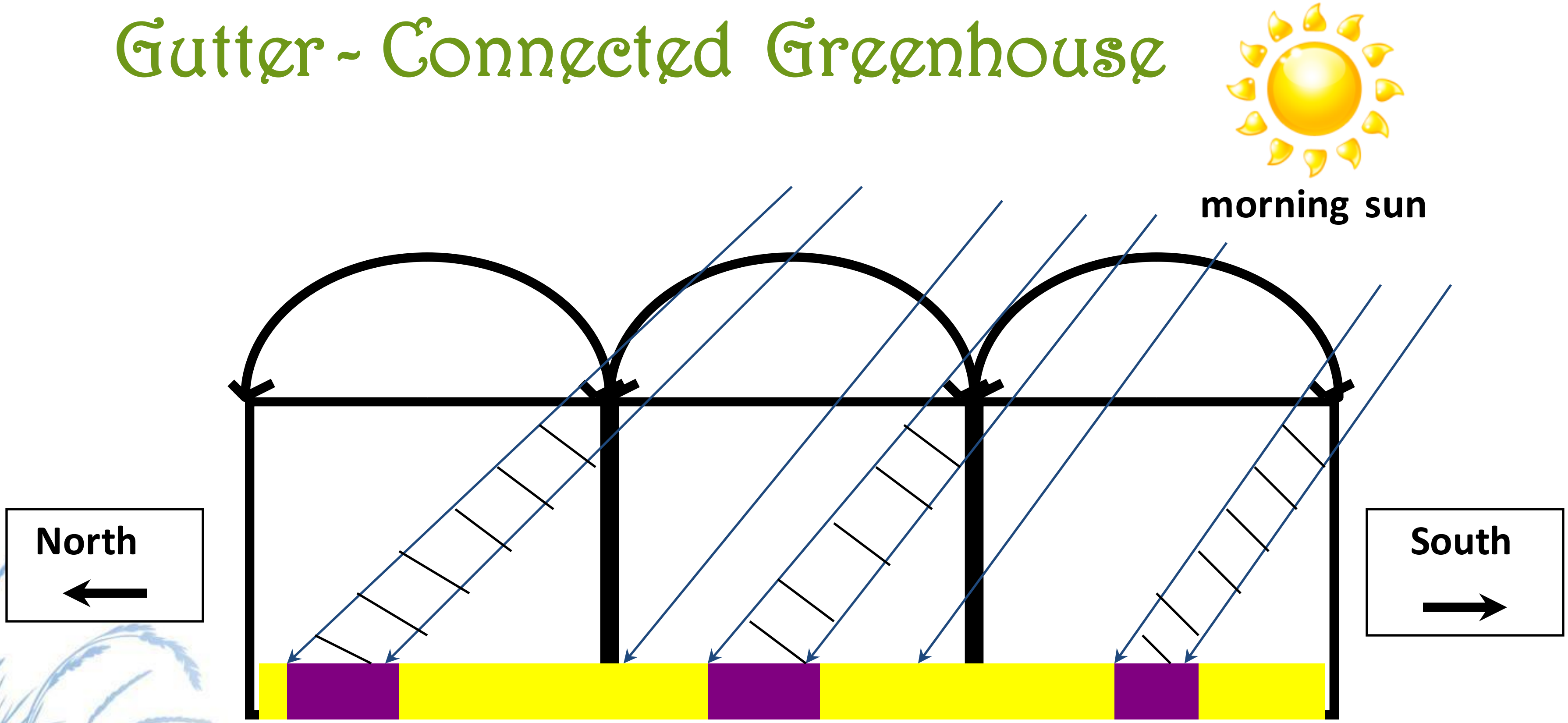
Gutter - Connected Greenhouse



North - South ridge & gutter

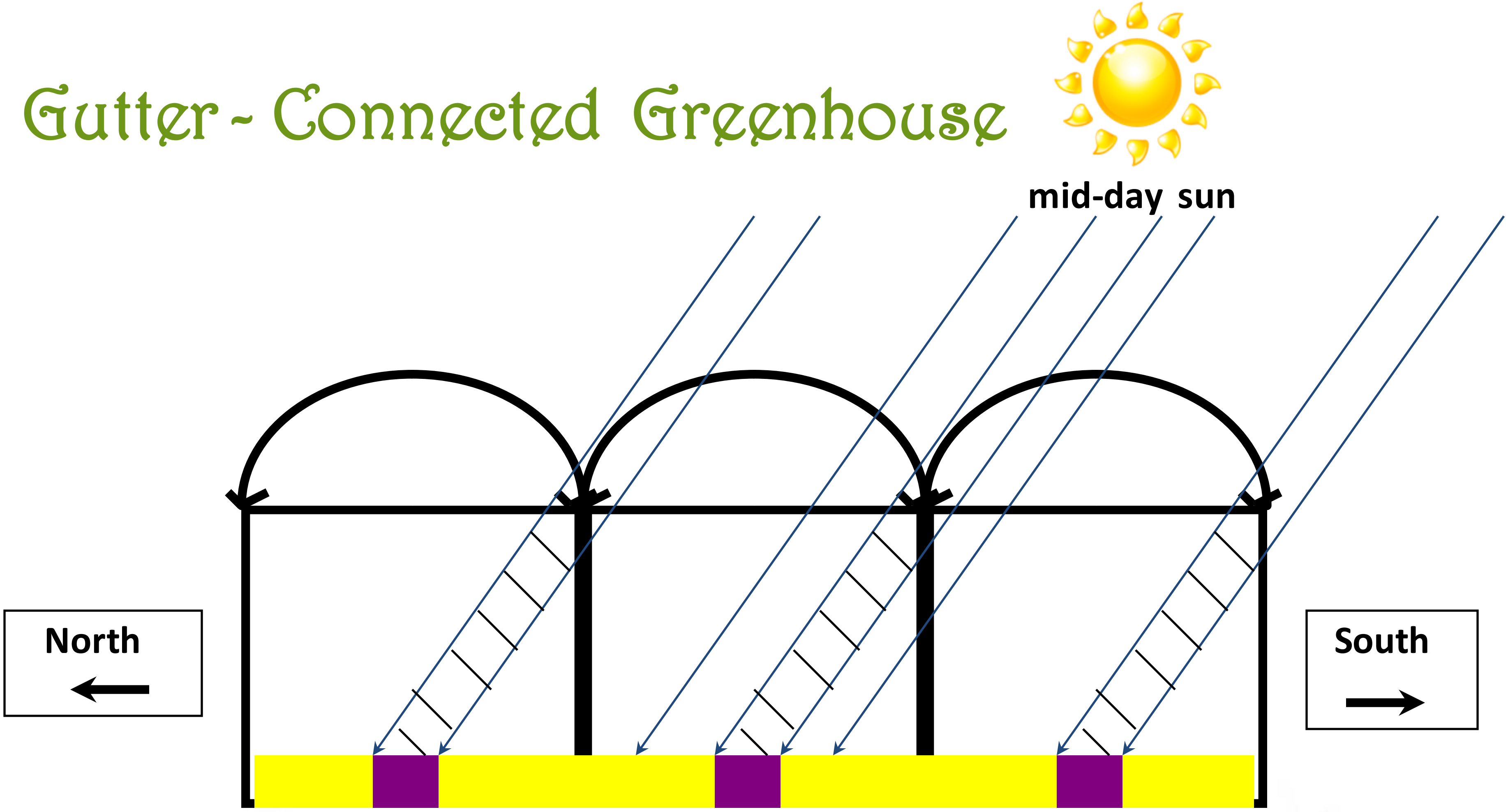
Note that the shadow, and thus the direct light to plants moves during the day

Gutter - Connected Greenhouse



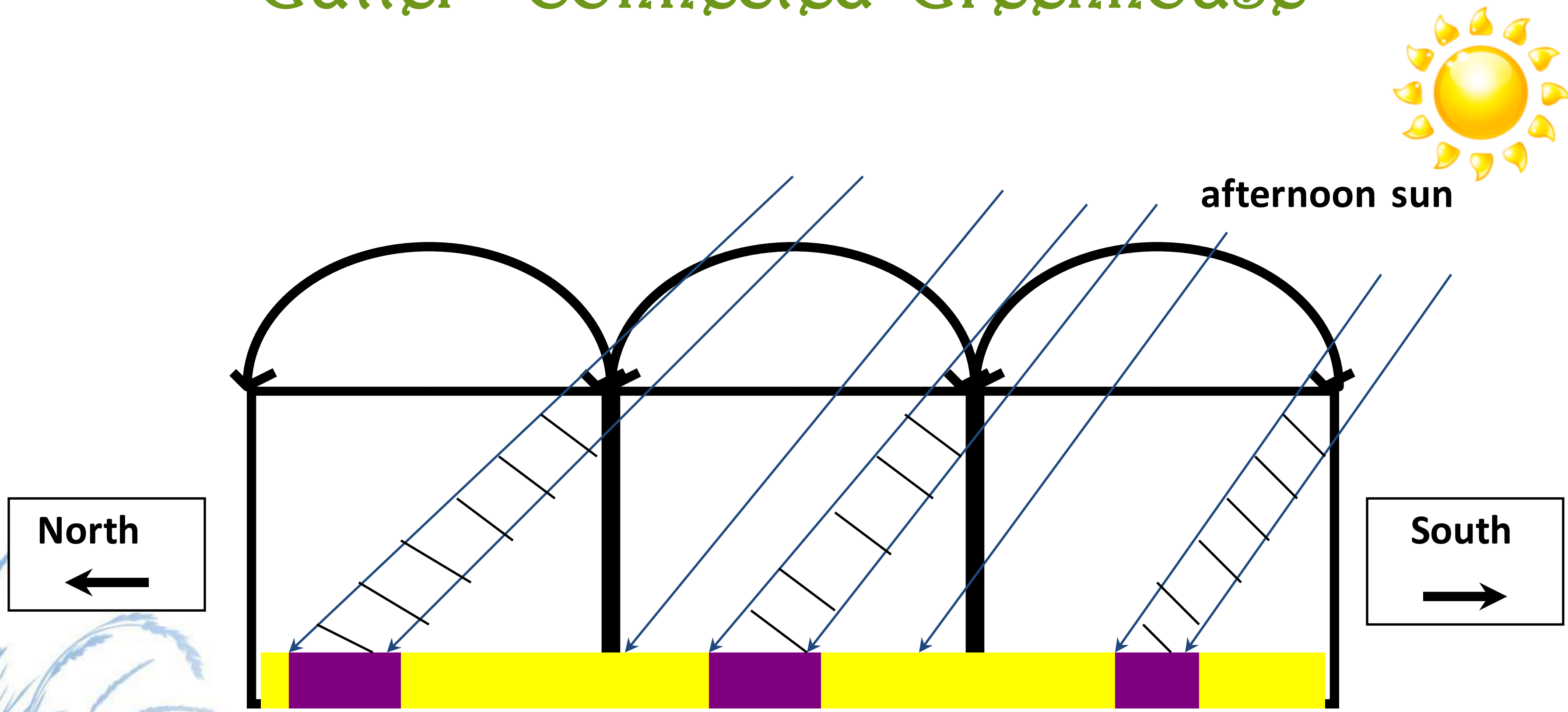
East - West ridge & gutter

Gutter - Connected Greenhouse



East - West ridge & gutter

Gutter - Connected Greenhouse



East - West ridge & gutter

Note that the shadow moves a little, but grows larger or smaller during the day

Can you see the shadows caused by the greenhouse structure?

Pathway of Solar Radiation

- pass through atmosphere
- reach the greenhouse
- pass through glazing
- framework and overhead
- then to the plant canopy

Therefore it is important to consider

- southerly exposure
- free from nearby buildings, groves of trees and other obstructions
- obstruction-free northern exposure [on cloudy, diffuse days, much light enters from the north]
- greenhouse structure

Freestanding, single-bay greenhouse

ground to ground, or Quonset-style provides more light than a gutter-connected, multi-bay greenhouse

Why?

- **less overhead structure,**
- **relatively narrow span**
- **gives more glazing area for light reception**

Greenhouse compass orientation

Affects total light and distribution within the greenhouse

East-west oriented ridge

[large south-facing wall and roof area]

- **good for low sun angle winter sunlight**
- **provides most total daily light during the winter season**
- **however, distribution not uniform within greenhouse**
- **causes variable plant growth especially for tall crops, if rows aligned with east-west ridge**

For Best Winter Light

- freestanding east-west greenhouse
- long, narrow [less than 25 feet wide]
- for short crops like bedding and potted plants, or hydroponic lettuce

Greenhouse compass orientation affects total light and distribution within the greenhouse

North - South Oriented Ridge

- For tall crop, grown in gutter-connected, multi-bay greenhouse, orient gutters [or ridges] in north-south direction.
- The reduction in total light entering the greenhouse in the winter is offset by improved daily light uniformity throughout the growing area.
- The “movement” of the shadows from the overhead structures as the day progresses from an eastern to western sun location, increases daily light uniformity.

GLAZING

Greenhouse coverings dominated by plastics

Traditional glass to the polymer plastics, thin films or multi-layer rigid plastic panels

Enhancements include:

- **ultra-violet radiation (UV) inhibitors**
- **infrared radiation (IR) absorbency**
- **anti-condensation drip surfaces**
- **selective radiation transmission properties.**

Decision is influenced by greenhouse structure and crop production system.

Three categories of coverings used for commercial greenhouses

1. glass
2. plastic films
3. rigid plastic

Modern Plastics Alternatives

Rigid plastic structured panels

- fiberglass reinforced polyester (FRP), polycarbonate (PC),
- acrylic (PMMA, polymethylmethacrylate)
- polyvinyl chloride (PVC)

Thin films

- low-density polyethylene (LDPE)
- polyvinylchloride (PVC),
- ethylene vinyl acetate copolymer (EVA)
- ethylene tetrafluoroethylene (ETFE)

Manufactured in single, double and triple layers

Rigid Plastic Structured Panels

Initially more expensive than polyethylene film

Less maintenance and provide a longer useful life

New construction or glasshouse renovations or end walls

Acrylic and polycarbonate panels use fewer, stronger supports spaced wider for reduced shading

Strength from double-walled cross section and depths up to 0.63 inch.

Plastic panels require more elaborate aluminum extrusions for attachment to greenhouse

Rigid Plastic Structured Panels

FRP (fiberglass)

- resistance to hail damage,
- degrade on surface, exposes fibers, becomes dirty
- treatment with Tedlar coating

Acrylic and Polycarbonate

- double-walled channel cross section
- light weight, structural strength, and heat savings
- widths of 4 ft, lengths up to 16 ft [Acrylic], or 32 feet [PC]
- PC thinner cross sections bend into arch roof shape
- UV radiation will discolor PC, if not protected
- co-extrude with acrylic or acrylic coated for UV protection
- corrugated, single-layer cross section
- condensation and algae inside double-walls

Double wall, acrylic-coated polycarbonate

Single wall, corrugated polycarbonate sheets

Plastic Thin Films

Minimum useful life of 24 months

Three and four year films available

Manufacturing

- co-extruding and multi-layering

Additives

- ethyl vinyl acetate [EVA]
- cracking resistance in cold temperatures
- tear strength (at folds)
- ultra-violet radiation [UV] inhibitors
- infrared [IR] barrier
- condensate control
- wavelength selective transmission [“filter”]

Plastic Thin Films

Polyethylene film

- most common
- Reliable, low initial cost
- Low air-infiltration rates
- continuous film offers energy savings
- High greenhouse air humidity
- Moisture condensation/dripping – avoid flattened arch-shaped roofs

Traditionally, fan ventilation for cooling, no ridge vent openings

Currently, natural ventilated film-covered structures and opening roof greenhouse

Potential Film Problems

- Ultra violet radiation promotes degradation
- Temperature extremes and their duration
- Film contact on greenhouse structure
- Air pollutants reduce radiation transmission
- Chemicals for pest control
- Over-inflation