Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Enduring understanding 2.E: Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.

Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.

a. In plants, physiological events involve interactions between environmental stimuli and internal molecular signals. [See also 2.C.2]

Evidence of student learning is a demonstrated understanding of each of the following:

1. Phototropism, or the response to the presence of light

2. Photoperiodism, or the response to change in length of the night, that results in flowering in long-day and short-day plants

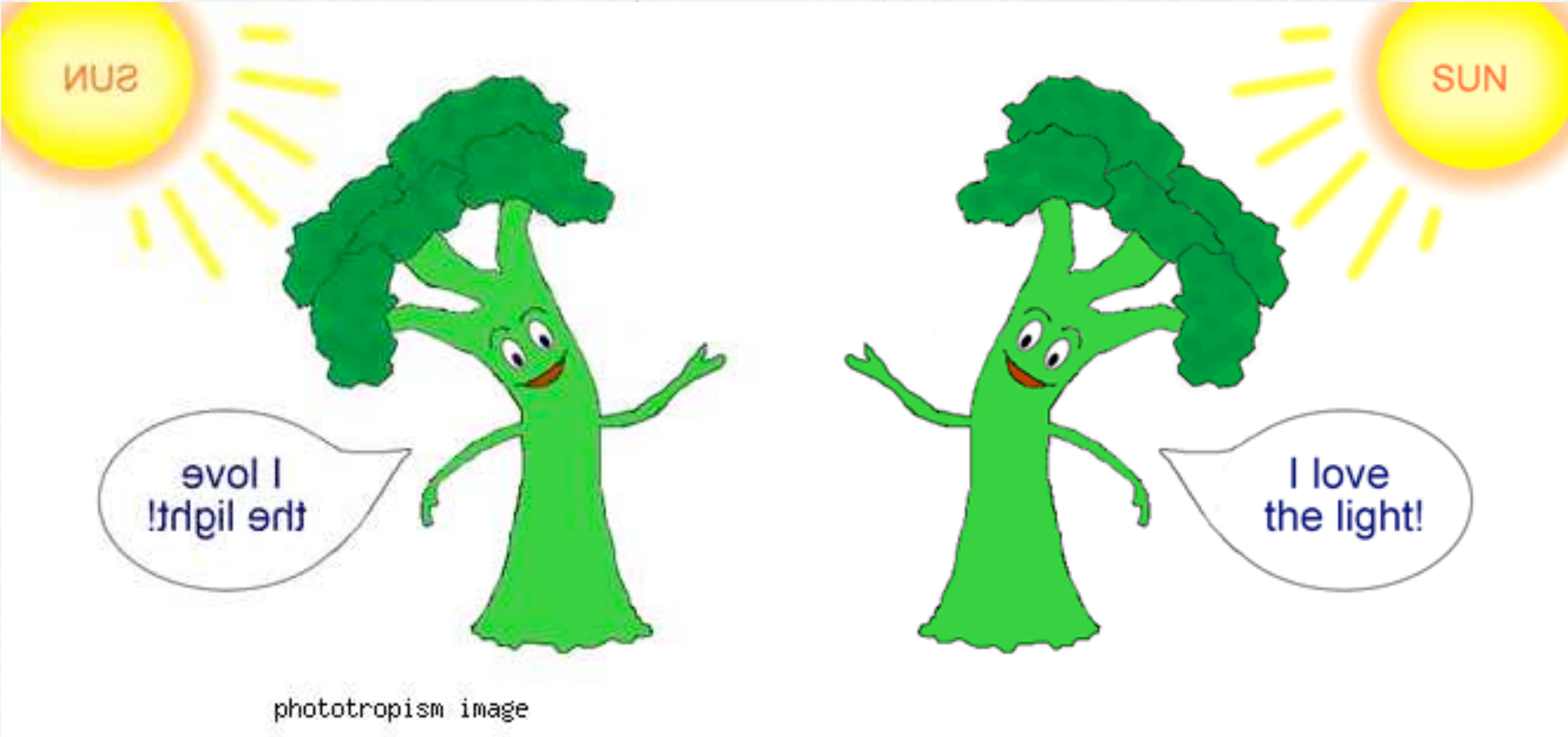
✘ Memorization of the names, molecular structures and specific effects of all plant hormones are beyond the scope of the course and the AP Exam.

Growth Responses in Plant

- Plants respond to a number of different stimuli.
- We will look at how plants will adjust their growth and development toward the following stimuli:
    - Light, Gravity, Mechanical Stress and Environmental Stress
    - Recall if plant growth results in a plant's organs bending to or away from a stimulus it is called a tropism.
    - Keep in mind not all plant responses involve tropisms.

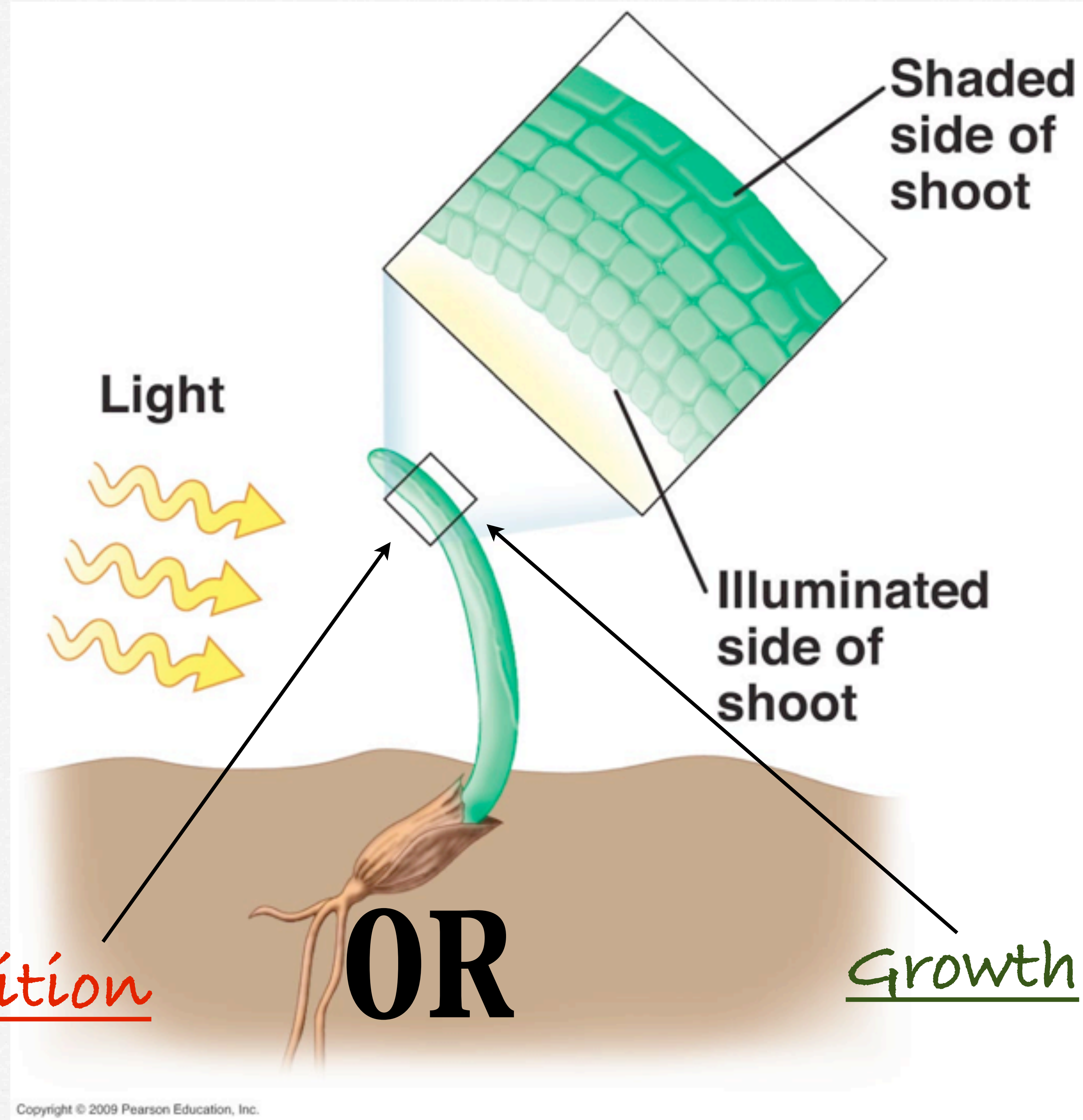
Phototropism

- Plants grow towards light.
- This results in straight upward growth unless the light source is not directly overhead in which case the plant may bend and grow towards the light. (tropism)



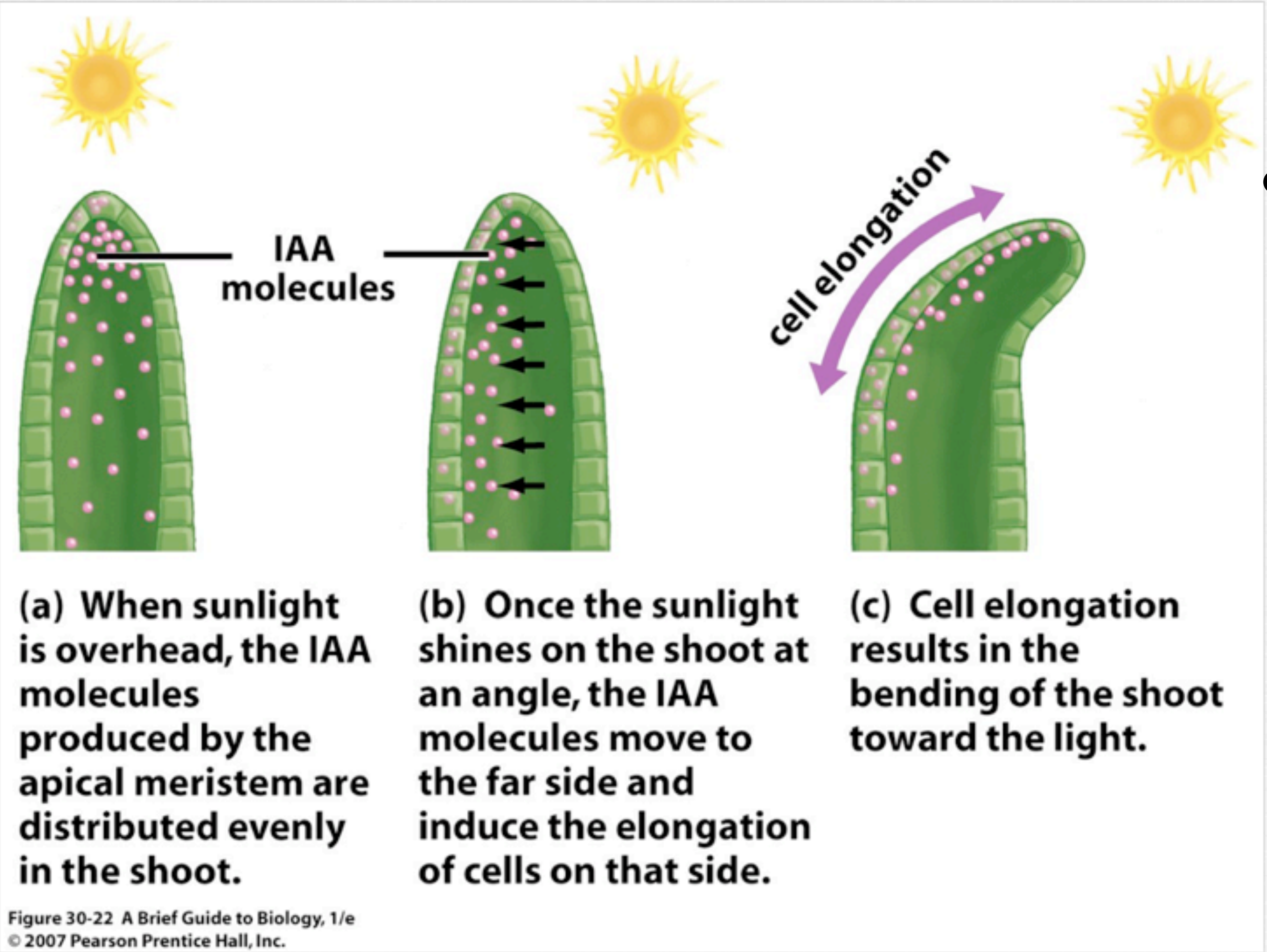
Phototropism

- Plants go grow in one direction by inhibiting certain cells from growing while allowing other cells to grow.



Growth Inhibition OR Growth

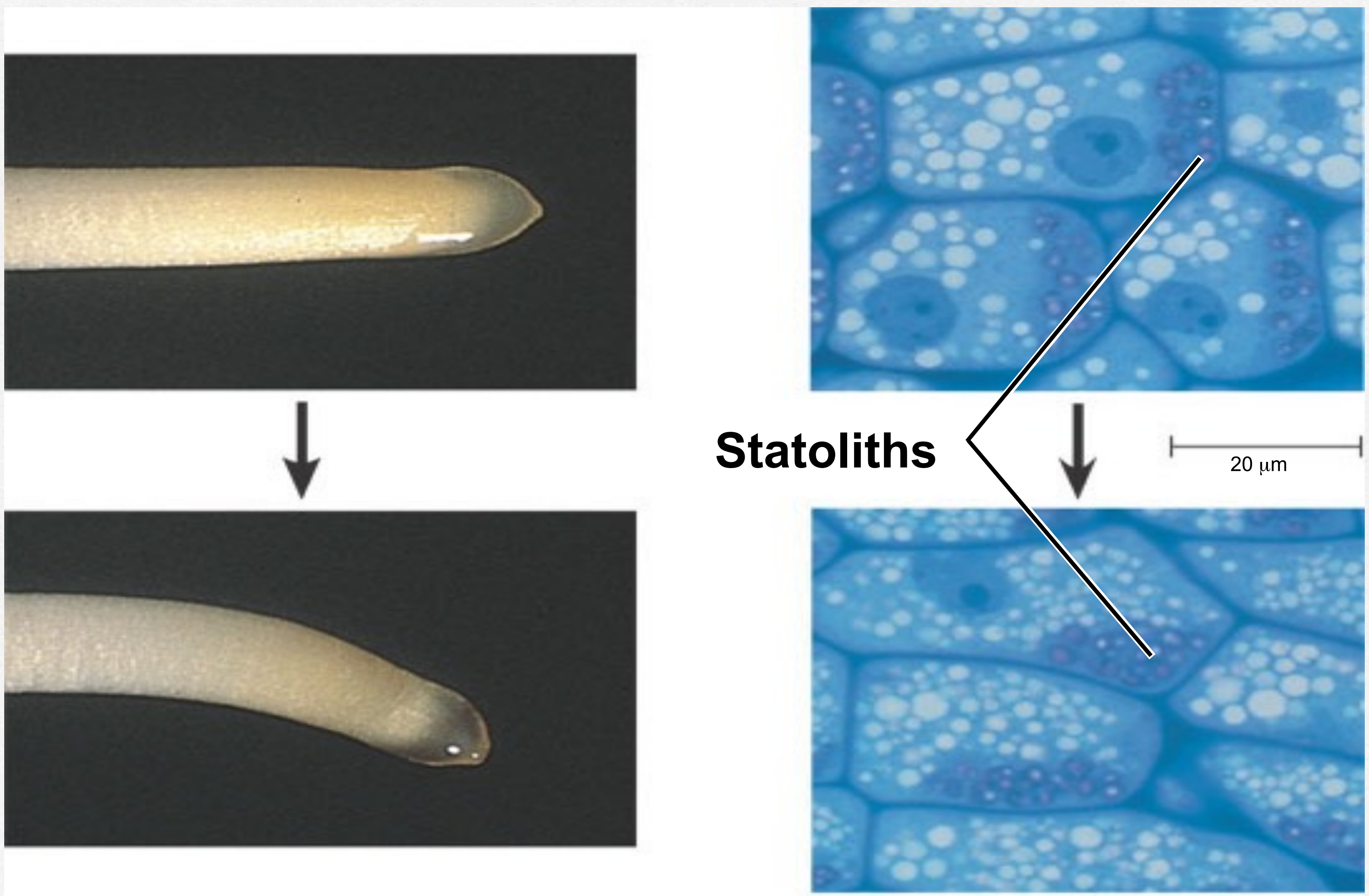
Phototropism



- Photoreceptors detect the direction of light
- The plant hormone auxin (IAA) moves away from light
- The plant hormone auxin triggers cell growth

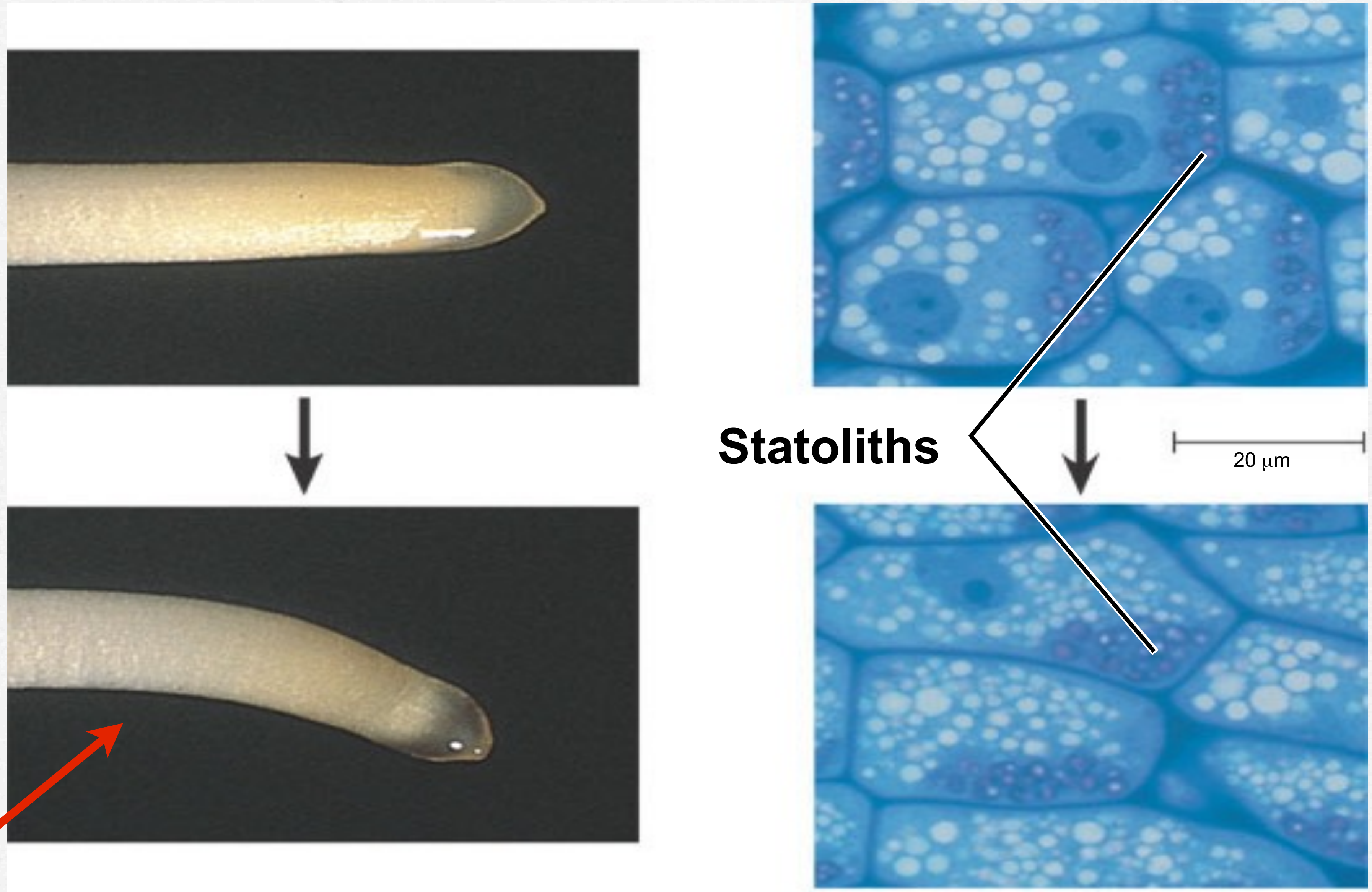
Gravitropism

- Plants may detect gravity by the settling of statoliths
  - Specialized plastids containing dense starch grains



Some evidence suggests that dense organelles or proteins may also contribute to this response

Differing rates of elongation by cells on opposite sides



Do you think this is a root or shoot?

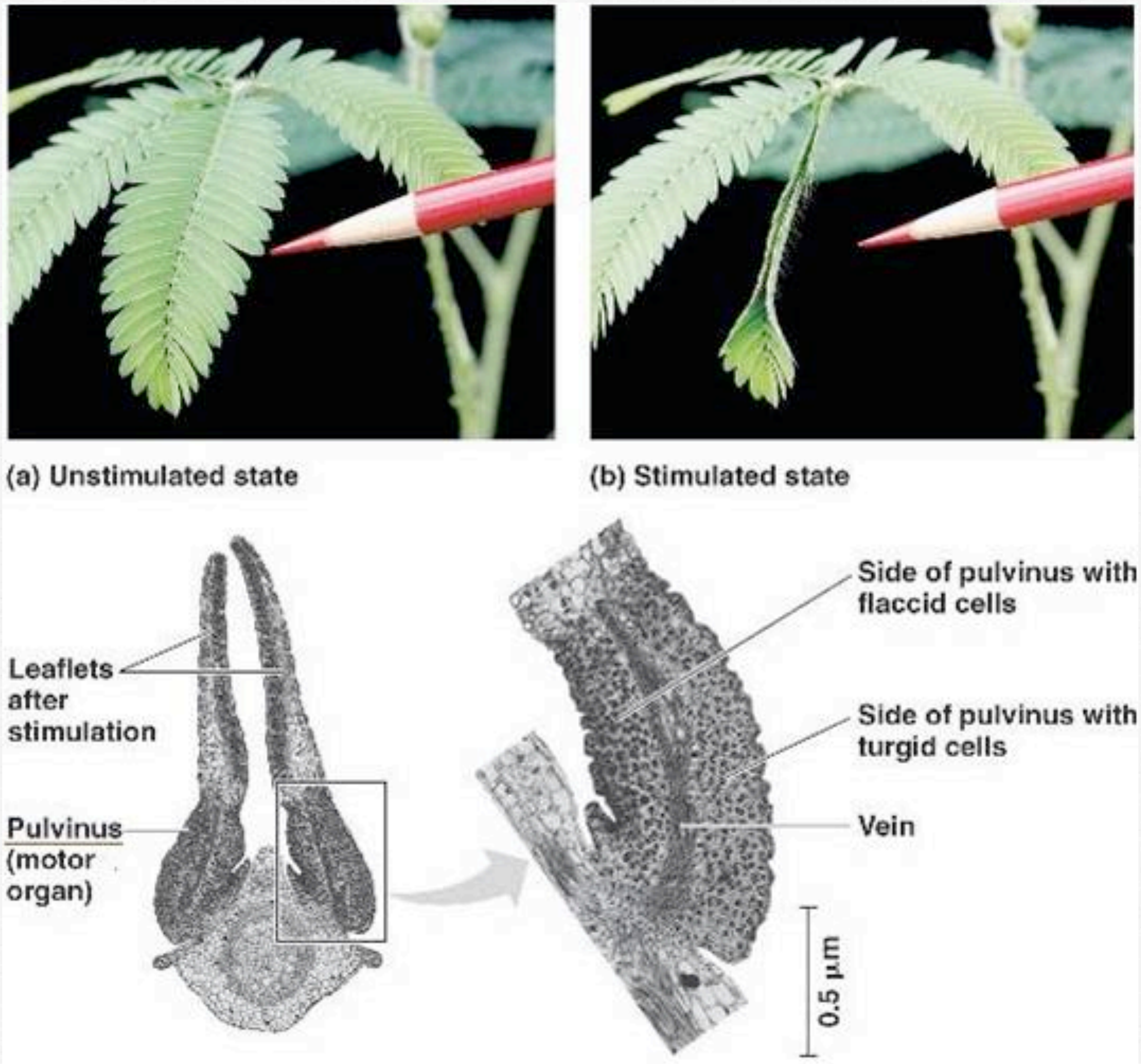
Thigmotropism

- Plants can grow directional from mechanical stimuli, touch.
  - Trees growing on a windy mountain ridge usually have shorter, stockier trunks compared similar trees in sheltered areas

WHY?

- Some plants have been become touch specialists.

- *Mimosa pudica*



(c) Cross section of a leaflet pair in the stimulated state (LM)

Potassium leaves motor cells

↓

Water follows

↓

Motor cells become flaccid

↓

Plant leaflets move!

WHY?

WHY?

Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.

b. In animals, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

-Circadian rhythms, or the physiological cycle of about 24 hours that is present in all eukaryotes and persists even in the absence of external cues

-Diurnal/nocturnal and sleep/awake cycles

-Jet lag in humans

-Seasonal responses, such as hibernation, estivation and migration

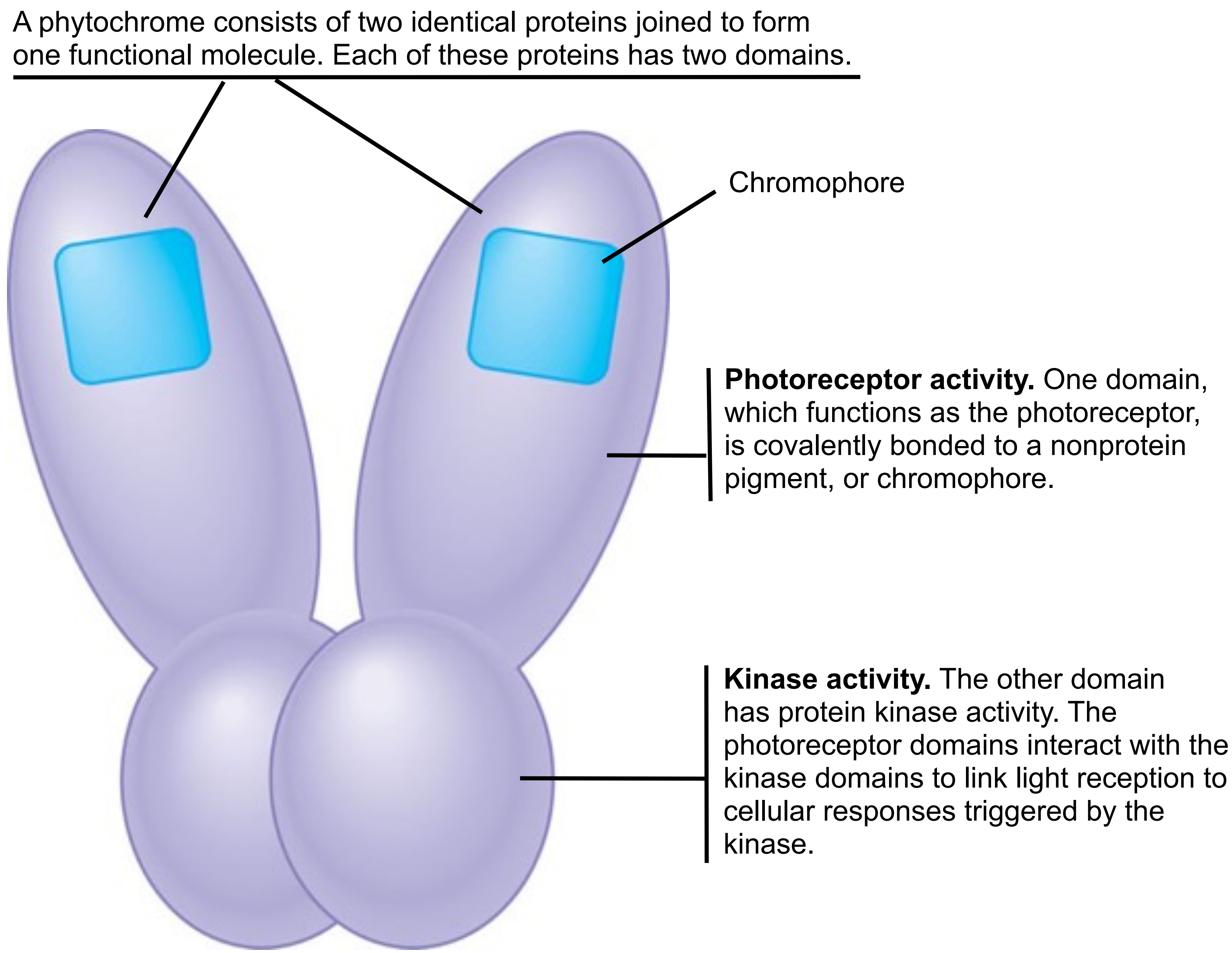
-Release and reaction to pheromones

-Visual displays in the reproductive cycle

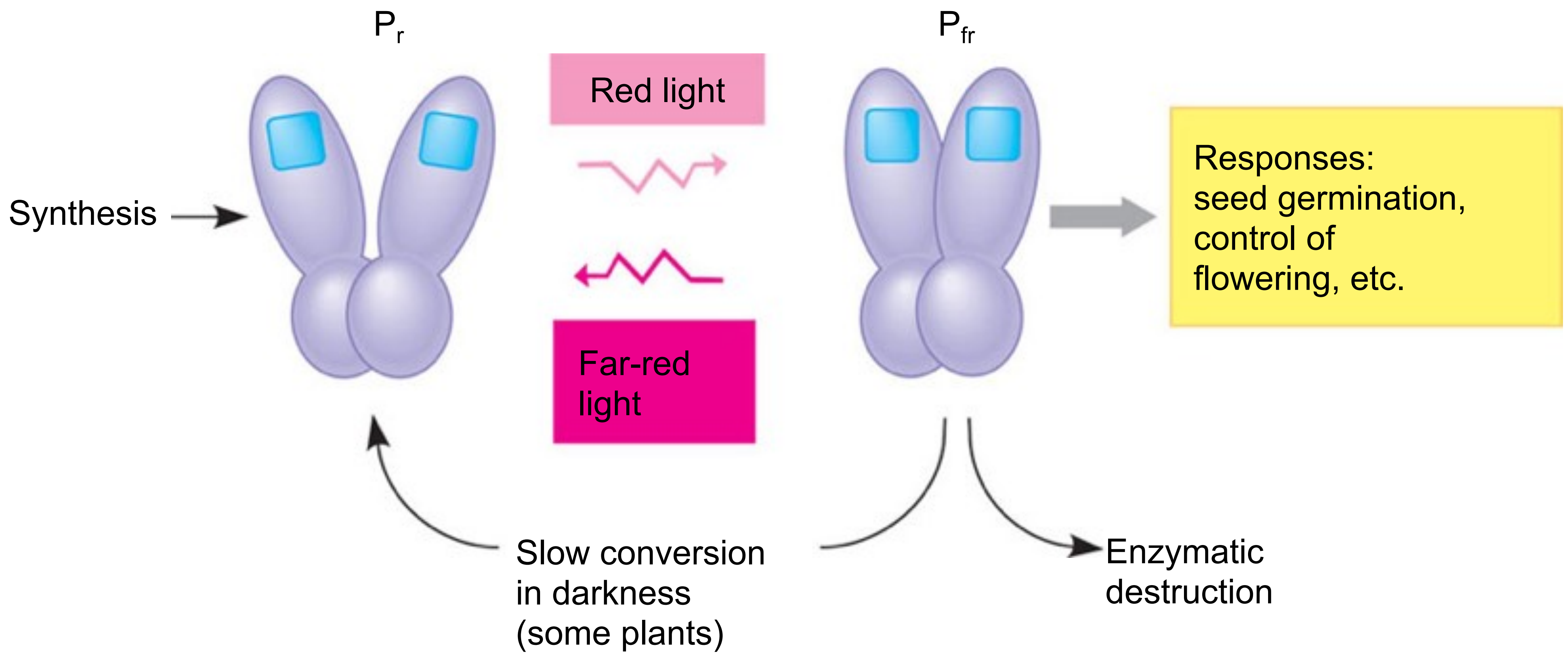
Phytochromes as Photoreceptors

- Phytochromes
  - Regulate many of a plant's responses to light throughout its life

- A phytochrome
  - Is the photoreceptor responsible for the opposing effects of red and far-red light



- Phytochromes exist in two photoreversible states
  - With conversion of P_r to P_{fr} triggering many developmental responses



Phytochromes and Shade Avoidance

- The phytochrome system
  - Also provides the plant with information about the quality of light
- In the "shade avoidance" response of a tree
  - The phytochrome ratio shifts in favor of P_r when a tree is shaded

Biological Clocks and Circadian Rhythms

- Many plant processes
  - Oscillate during the day
- Many legumes
- Lower their leaves in the evening and raise them in the morning

Noon

Midnight

- Cyclical responses to environmental stimuli are called circadian rhythms
  - And are approximately 24 hours long
  - Can be entrained to exactly 24 hours by the day/night cycle

The Effect of Light on the Biological Clock

- Phytochrome conversion marks sunrise and sunset
  - Providing the biological clock with environmental cues

Photoperiodism and Responses to Seasons

- Photoperiod, the relative lengths of night and day
  - Is the environmental stimulus plants use most often to detect the time of year
- Photoperiodism
  - Is a physiological response to photoperiod

Photoperiodism and Control of Flowering

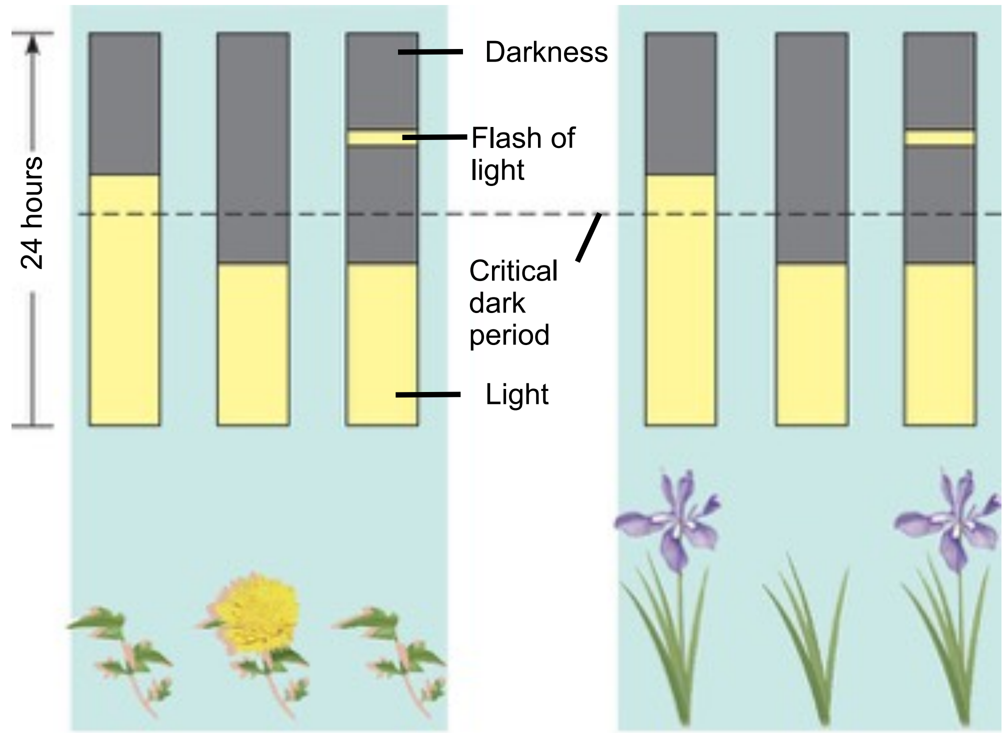
- Some developmental processes, including flowering in many species
  - Requires a certain photoperiod

Critical Night Length

- In the 1940s, researchers discovered that flowering and other responses to photoperiod
  - Are actually controlled by night length, not day length

EXPERIMENT During the 1940s, researchers conducted experiments in which periods of darkness were interrupted with brief exposure to light to test how the light and dark portions of a photoperiod affected flowering in “short-day” and “long-day” plants.

RESULTS



(a) “Short-day” plants flowered only if a period of continuous darkness was *longer* than a critical dark period for that particular species (13 hours in this example). A period of darkness can be ended by a brief exposure to light.

(b) “Long-day” plants flowered only if a period of continuous darkness was *shorter* than a critical dark period for that particular species (13 hours in this example).

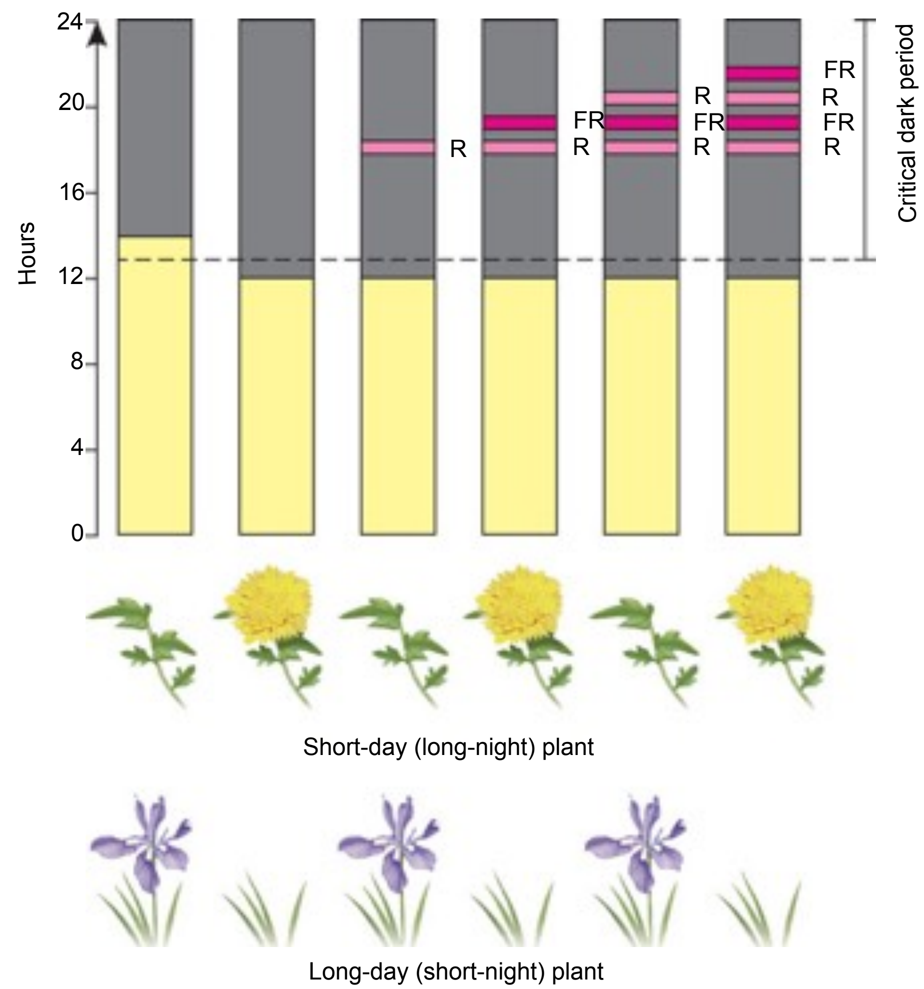
CONCLUSION The experiments indicated that flowering of each species was determined by a critical period of *darkness* (“critical night length”) for that species, *not* by a specific period of light. Therefore, “short-day” plants are more properly called “long-night” plants, and “long-day” plants are really “short-night” plants.

• Action spectra and photoreversibility experiments

– Show that phytochrome is the pigment that receives red light, which can interrupt the nighttime portion of the photoperiod

EXPERIMENT A unique characteristic of phytochrome is reversibility in response to red and far-red light. To test whether phytochrome is the pigment measuring interruption of dark periods, researchers observed how flashes of red light and far-red light affected flowering in "short-day" and "long-day" plants.

RESULTS



CONCLUSION A flash of red light shortened the dark period. A subsequent flash of far-red light canceled the red light's effect. If a red flash followed a far-red flash, the effect of the far-red light was canceled. This reversibility indicated that it is phytochrome that measures the interruption of dark periods.

Circadian Rhythms in Animals

- The hypothalamus also regulates circadian rhythms
  - Such as the sleep/wake cycle
- Animals usually have a biological clock
  - Which is a pair of suprachiasmatic nuclei (SCN) found in the hypothalamus

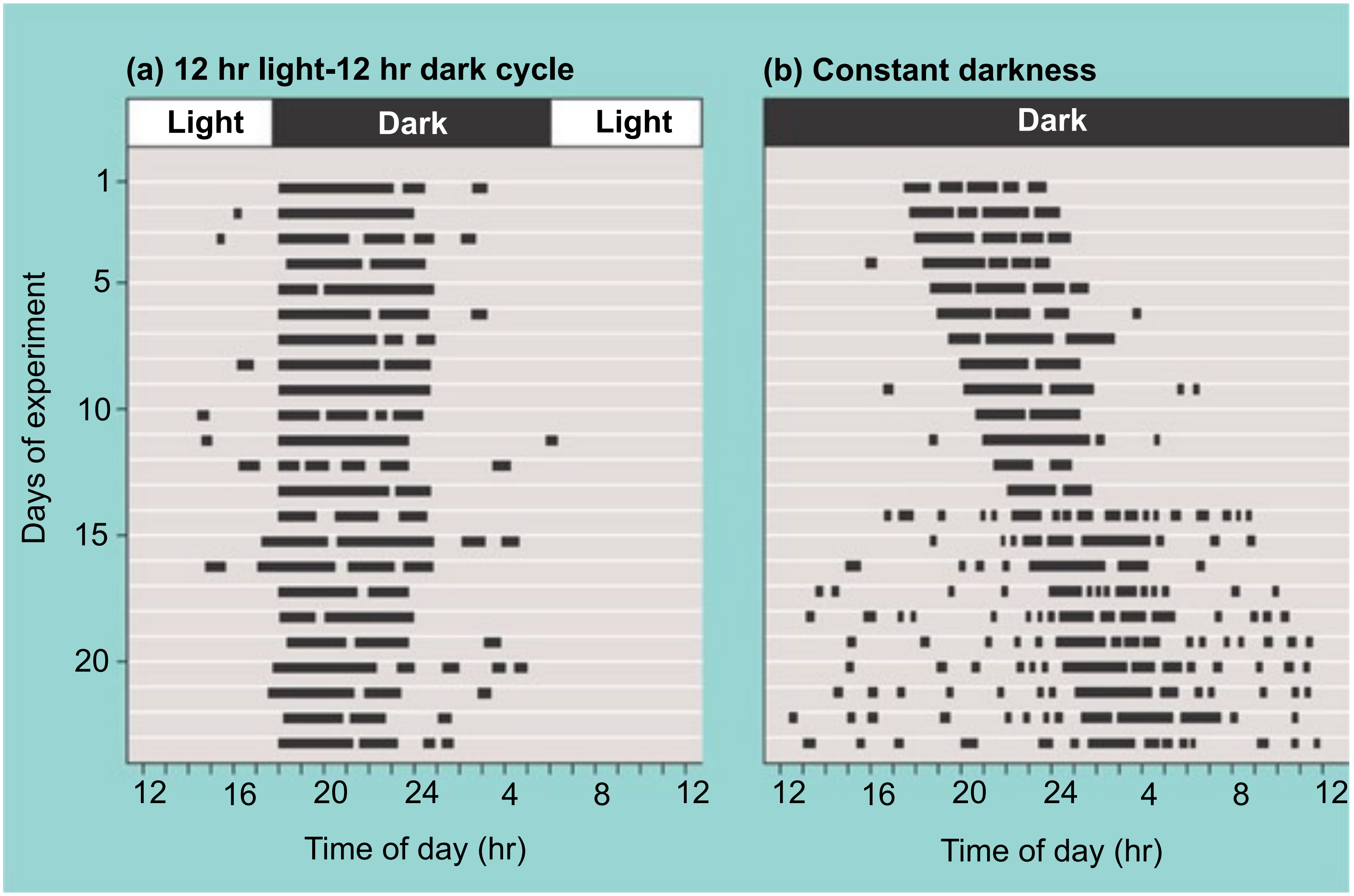
• Biological clocks usually require external cues

– To remain synchronized with environmental cycles

In the northern flying squirrel (*Glaucomys sabrinus*), activity normally begins with the onset of darkness and ends at dawn, which suggests that light is an important external cue for the squirrel.

EXPERIMENT

To test this idea, researchers monitored the activity of captive squirrels for 23 days under two sets of conditions: (a) a regular cycle of 12 hours of light and 12 hours of darkness and (b) constant darkness.The squirrels were given free access to an exercise wheel and a rest cage. A recorder automatically noted when the wheel was rotating andwhen it was still.

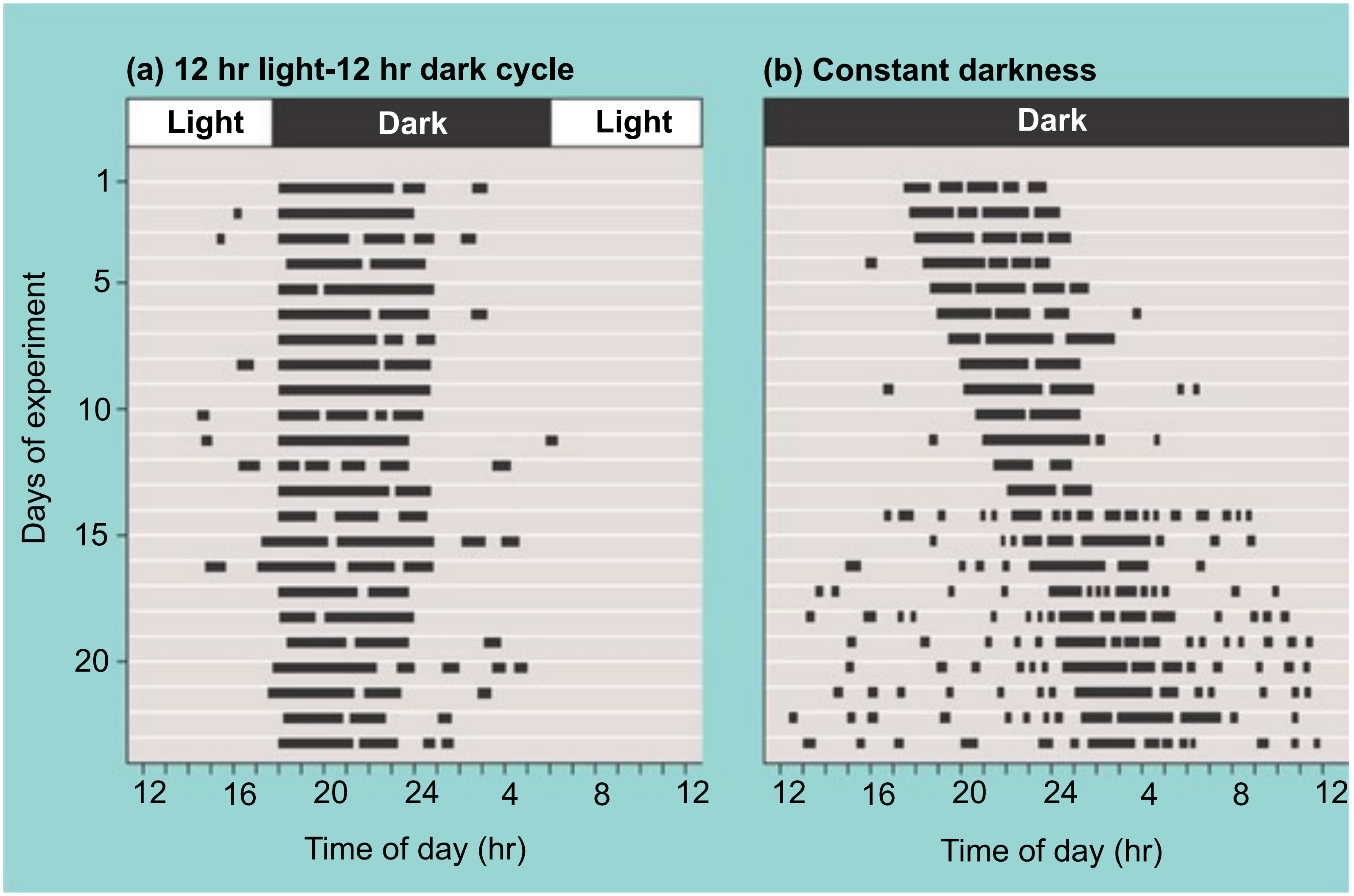


Biological clocks usually require external cues

- To remain synchronized with environmental cycles

When the squirrels were exposed to a regular light/dark cycle, their wheel-turning activity (indicated by the dark bars) occurred at roughly the same time every day. However, when they were kept in constant darkness, their activity phase began about 21 minutes later each day.

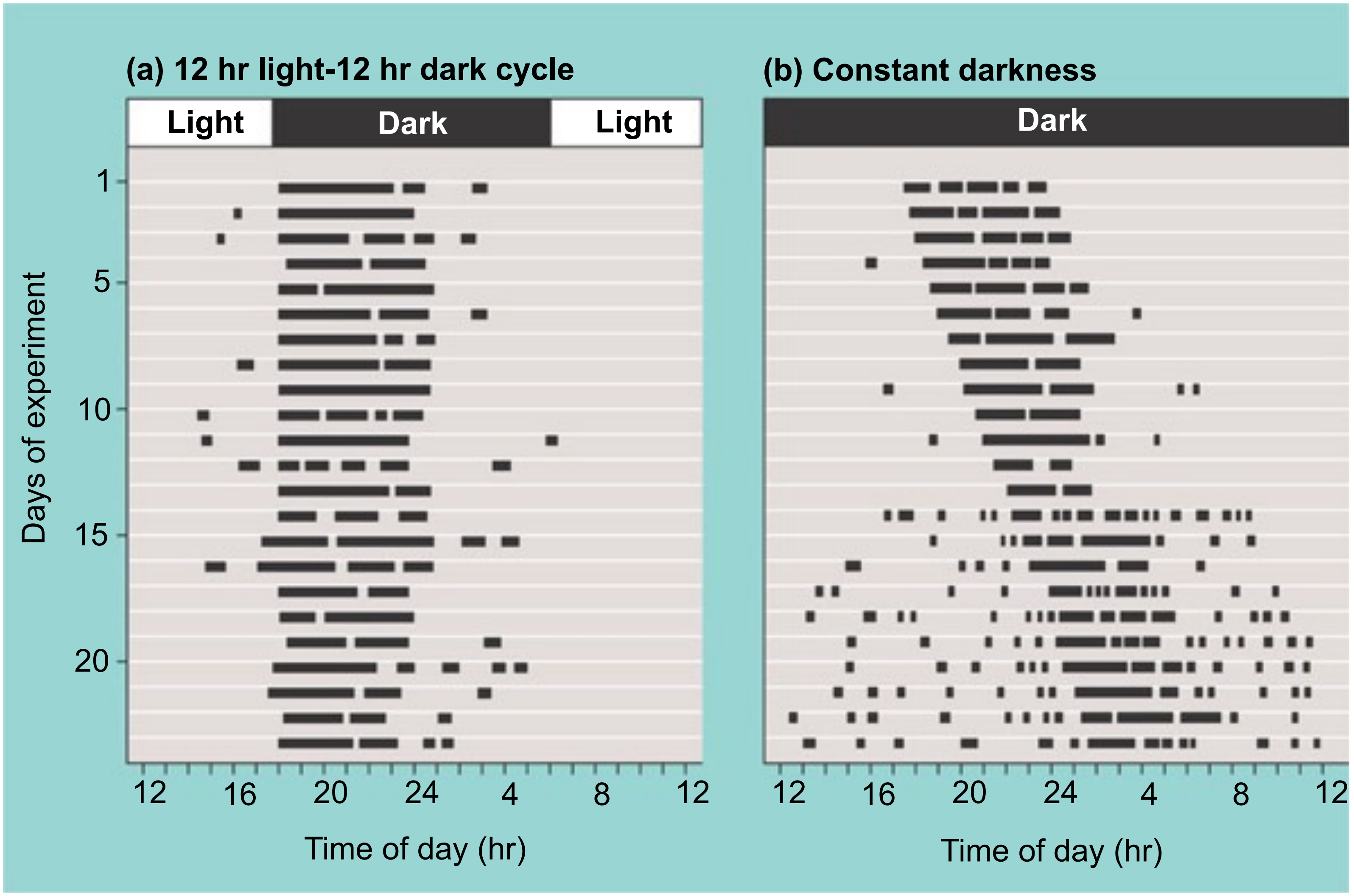
RESULTS



- Biological clocks usually require external cues
  - To remain synchronized with environmental cycles

CONCLUSION

The northern flying squirrel's internal clock can run in constant darkness, but it does so on its own cycle, which lasts about 24 hours and 21 minutes. External (light) cues keep the clock running on a 24-hour cycle.



Essential knowledge 2.E.2: Timing and coordination of physiological events are regulated by multiple mechanisms.

c. In fungi, protists and bacteria, internal and external signals regulate a variety of physiological responses that synchronize with environmental cycles and cues.

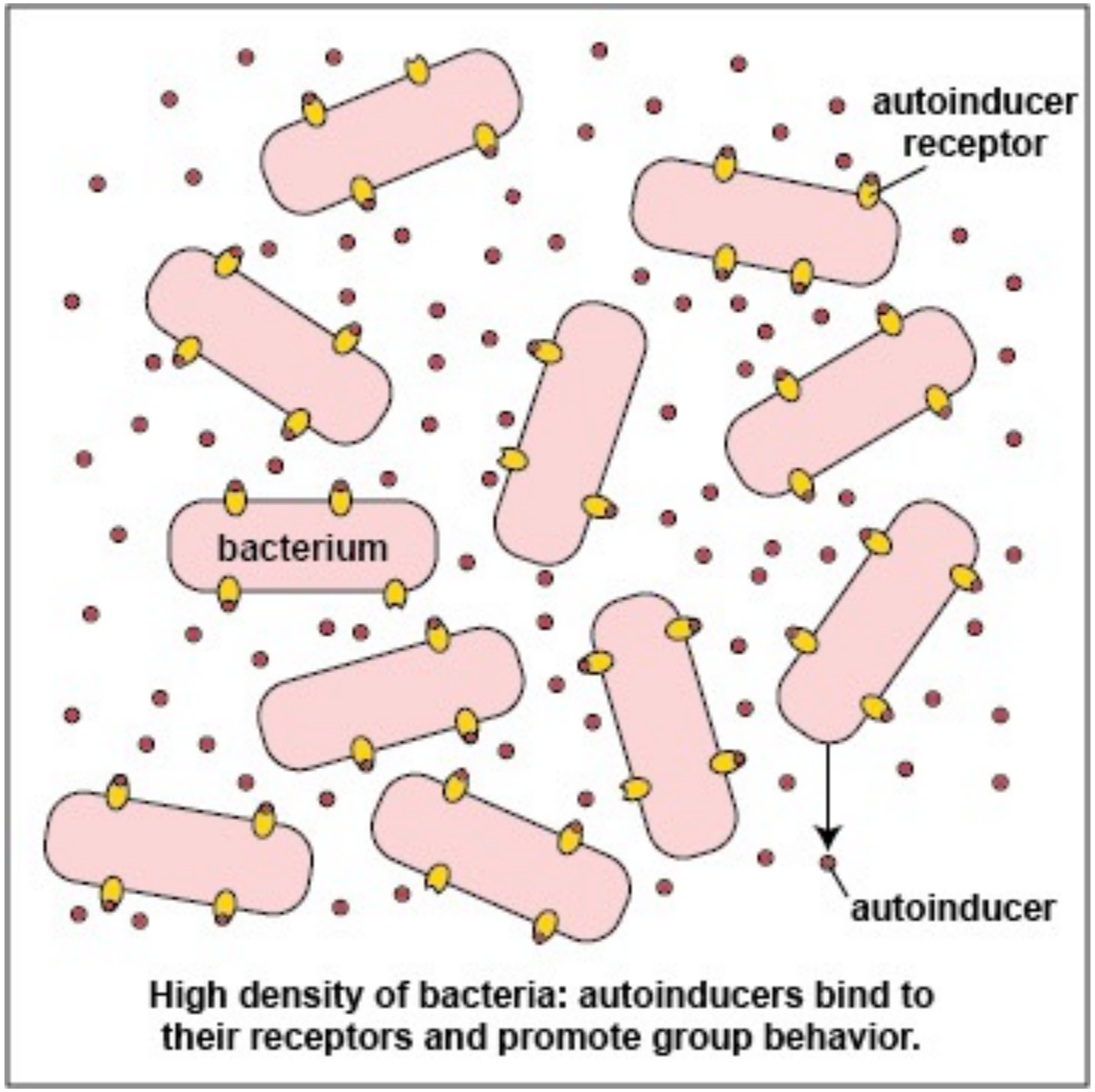
To foster student understanding of this concept, instructors can choose an illustrative example such as:

-Fruiting body formation in fungi, slime molds and certain types of bacteria

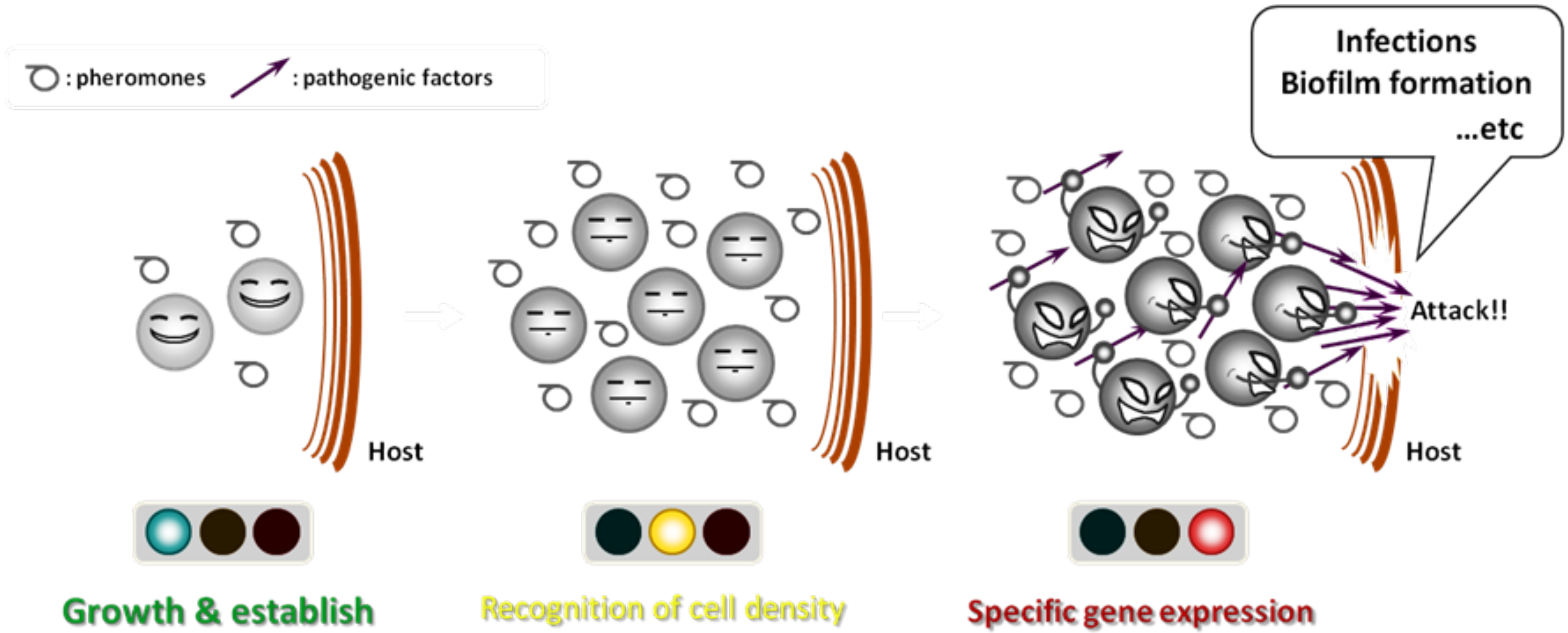
-Quorum sensing in bacteria

✘ Memorization of the names, molecular structures and specific effects of hormones or features of the brain responsible for these physiological phenomena is beyond the scope of the course and the AP Exam.

Quorum sensing is a system of stimuli and response correlated to population density. Many species of bacteria use quorum sensing to coordinate gene expression according to the density of their local population.



Some of the best-known examples of quorum sensing come from studies of bacteria. Bacteria use quorum sensing to coordinate certain behaviors such as biofilm formation, virulence, and antibiotic resistance, based on the local density of the bacterial population.



Cell density dependent gene expression in quorum sensing
(e.g. virulence expression)

Quorum Sensing

Quorum sensing can occur within a single bacterial species as well as between diverse species, and can regulate a host of different processes, in essence, serving as a simple indicator of population density or the diffusion rate of the cell's immediate environment.

A variety of different molecules can be used as signals.

In similar fashion, some social insects use quorum sensing to determine where to nest. In addition to its function in biological systems, quorum sensing has several useful applications for computing and robotics.

Learning Objectives:

LO 2.35 The student is able to design a plan for collecting data to support the scientific claim that the timing and coordination of physiological events involve regulation. [See SP 4.2]

LO 2.36 The student is able to justify scientific claims with evidence to show how timing and coordination of physiological events involve regulation. [See SP 6.1]

LO 2.37 The student is able to connect concepts that describe mechanisms that regulate the timing and coordination of physiological events. [See SP 7.2]