1. (a) Define the following:
   - (i) Aphotic Zone
     - The aphotic zone is the portion of a lake or ocean where there is little or no sunlight. It is typically defined as the depths beyond which less than 1% of sunlight penetrates. This zone is characterized by darkness, cold temperatures, and high pressure.
   - (ii) Etiolation
     - Etiolation is a process in flowering plants grown in partial or complete absence of light. It is characterized by long, weak stems, smaller leaves, and a pale yellow color (chlorosis) due to the lack of chlorophyll synthesis. This adaptation helps the plant search for light.
   - (iii) Long day plant
     - A long-day plant is a plant that flowers only after being exposed to light periods longer than a critical minimum, or darkness periods shorter than a critical maximum. Examples include spinach, radish, and lettuce.
   - (iv) CO_2 compensation point
     - The CO_2 compensation point is the concentration of carbon dioxide at which the rate of photosynthesis exactly matches the rate of respiration. At this point, there is no net exchange of CO_2 between the plant and its environment.
   - (v) Serotonin
     - Serotonin is a monoamine neurotransmitter that plays a crucial role in various physiological processes, including mood regulation, sleep, appetite, digestion, learning, and

memory. It is primarily found in the gastrointestinal tract, platelets, and the central nervous system.

- (vi) Fovea
  - The fovea is a small, central pit in the macula of the human eye that contains a high concentration of cone photoreceptor cells. It is responsible for sharp, detailed central vision and is where visual acuity is highest.

(b) Expand the following:

- (i) RUBP
  - Ribulose-1,5-bisphosphate
- (ii) CAM
  - Crassulacean Acid Metabolism
- (iii) DVM
  - Diel Vertical Migration
- (iv) DLMO
  - Dim Light Melatonin Onset

(c) Give major contributions of the following scientists:

- (i) Hugo P. Kortschak
  - Hugo P. Kortschak, along with his colleagues at the Hawaiian Sugar Planters' Association Experiment Station, was instrumental in the discovery of the C4 photosynthetic pathway in sugarcane. They observed that in sugarcane, the first stable product of carbon fixation was a four-carbon compound (malate and aspartate) rather than the three-carbon compound (3-PGA) found in C3 plants.
- (ii) Robert Hill

- Robert Hill is best known for the "Hill reaction," which demonstrated that isolated chloroplasts can produce oxygen in the presence of a suitable electron acceptor and light, without the need for carbon dioxide. This experiment provided crucial evidence that the oxygen produced during photosynthesis comes from water.

- (iii) Shinobu Ishihara
  - Shinobu Ishihara was a Japanese ophthalmologist who developed the Ishihara color vision test. This test is a globally recognized and widely used method for detecting red-green color blindness and other color vision deficiencies.
- (iv) Paolo Panceri
  - Paolo Panceri was an Italian anatomist and zoologist. He is known for his work on bioluminescence in marine organisms, particularly in luminous invertebrates. His research contributed to the understanding of the mechanisms and functions of light production in these animals.
- (v) Pietro Angelo Secchi
  - Pietro Angelo Secchi was an Italian Jesuit priest and astronomer. He is credited with inventing the Secchi disk, a simple device used to measure water transparency or turbidity in lakes, rivers, and oceans. The Secchi disk is still widely used in limnology and oceanography.

2. Comment briefly (any five):
   - (i) Phosphoenolpyruvate carboxylase, unlike RuBisCO, only temporarily fixes carbon in C4 cycle.
     - In C4 plants, phosphoenolpyruvate carboxylase (PEP carboxylase) has a high affinity for CO_2 and efficiently

fixes it even at low concentrations in the mesophyll cells. It catalyzes the carboxylation of phosphoenolpyruvate (PEP) to form oxaloacetate, a four-carbon compound. This oxaloacetate is then converted to malate or aspartate, which is transported to the bundle sheath cells. In these bundle sheath cells, the malate or aspartate is decarboxylated, releasing CO_2. This released CO_2 is then refixed by RuBisCO in the Calvin cycle. Therefore, PEP carboxylase's role is to initially capture and concentrate CO_2, effectively acting as a "CO_2 pump" to deliver a high concentration of CO_2 to the bundle sheath cells where RuBisCO operates, thus temporarily fixing it before it enters the Calvin cycle.

- (ii) Flowering plants require light for chlorophyll synthesis. Justify.
  - Flowering plants require light for chlorophyll synthesis because the final steps in the biosynthetic pathway of chlorophyll, specifically the conversion of protochlorophyllide to chlorophyllide, are light-dependent. The enzyme protochlorophyllide oxidoreductase, which catalyzes this reaction, requires light energy to function. In the absence of light, protochlorophyllide accumulates, and plants appear etiolated and yellowish, lacking the green pigment characteristic of chlorophyll. This is why plants grown in darkness are pale and elongated.
- (iii) Flowering in plants is impacted by the photoperiod.
  - Flowering in plants is indeed significantly impacted by the photoperiod, which is the relative length of day and night. Plants have evolved mechanisms to perceive the changes in photoperiod, primarily through photoreceptors like phytochromes. Based on their response to photoperiod, plants are categorized as long-day plants,

short-day plants, or day-neutral plants. Long-day plants flower when the day length exceeds a critical minimum, while short-day plants flower when the day length falls below a critical maximum (or more accurately, when the night period exceeds a critical minimum). Day-neutral plants flower regardless of the photoperiod. This photoperiodic control ensures that flowering occurs at an optimal time of year, maximizing reproductive success by synchronizing with favorable environmental conditions and the presence of pollinators.

- (iv) About 1 in 200 women are colorblind whereas 1 in 12 men are colorblind.
    - This disparity in color blindness prevalence between men and women is due to the X-linked recessive inheritance pattern of most common forms of color blindness, such as red-green color blindness. The genes for these color-sensing photoreceptors (cones) are located on the X chromosome.
        - Males have one X and one Y chromosome (XY). If their single X chromosome carries the defective gene for color vision, they will be colorblind because there is no second X chromosome to compensate.
        - Females have two X chromosomes (XX). For a female to be colorblind, both of her X chromosomes must carry the defective gene. If she inherits one defective X chromosome and one normal X chromosome, she will typically be a carrier but will have normal color vision due to the presence of the functional gene on her other X chromosome. The probability of inheriting two defective X chromosomes is much lower than inheriting one defective X chromosome.

- (v) Ultra-violet light exposure is both advantageous and disadvantageous to humans.
  - **Advantageous:**
    - UVB radiation is essential for the synthesis of Vitamin D in the skin. Vitamin D plays a crucial role in calcium absorption, bone health, immune function, and overall well-being.
    - UV light is used in phototherapy to treat certain skin conditions like psoriasis, eczema, and vitiligo.
  - **Disadvantageous:**
    - Excessive exposure to UVA and UVB radiation can cause DNA damage in skin cells, leading to sunburn, premature skin aging (wrinkles, age spots), and an increased risk of skin cancers, including melanoma, basal cell carcinoma, and squamous cell carcinoma.
    - UV exposure can damage the eyes, contributing to conditions like cataracts, pterygium, and photokeratitis (snow blindness).
    - It can suppress the immune system, making individuals more susceptible to infections.
- (vi) The hot and cold water extracts of light organ of Pyrophorus, give a luminescence when mixed together.
  - This phenomenon describes the separate components required for bioluminescence in the click beetle *Pyrophorus*. The "hot water extract" contains the enzyme luciferase, which is a protein and is denatured by heat. The "cold water extract" contains the substrate luciferin, which is a heat-stable molecule. When these two extracts are prepared and then mixed together, the native, active

luciferase from the "hot water extract" (which was initially denatured but can regain some activity if not fully destroyed) reacts with the luciferin from the "cold water extract" in the presence of oxygen and ATP (often present as trace amounts or added), resulting in the emission of light. This demonstrates the enzymatic nature of bioluminescence where an enzyme (luciferase) acts on a substrate (luciferin) to produce light.

3. (a) Describe the regeneration of the acceptor molecule in Calvin Cycle.

   - In the Calvin cycle, the primary CO_2 acceptor molecule is ribulose-1,5-bisphosphate (RuBP), a five-carbon sugar. The regeneration of RuBP is a crucial step that ensures the continuous operation of the cycle. This process involves a series of complex enzymatic reactions that convert 10 molecules of 3-phosphoglycerate (3-PGA) into 6 molecules of glyceraldehyde-3-phosphate (GAP), and then further rearrange these to regenerate 6 molecules of RuBP.
   - The regeneration phase consumes ATP, which is produced during the light-dependent reactions of photosynthesis. For every six molecules of triose phosphate (glyceraldehyde-3-phosphate) formed, five are used to regenerate three molecules of RuBP. This involves several steps including isomerization, phosphorylation, and rearrangement reactions catalyzed by enzymes such as triose phosphate isomerase, aldolase, transketolase, and ribulose-5-phosphate kinase. Specifically, 6 molecules of ATP are used to convert 6 molecules of ribulose-5-phosphate into 6 molecules of RuBP, thus preparing the acceptor molecule for another round of CO_2 fixation.

   (b) Write a note on the structural differences and role of rods and cones in vision.

- **Rods and Cones: Structural Differences and Roles in Vision**
  - The human retina contains two main types of photoreceptor cells: rods and cones. While both are responsible for converting light into electrical signals, they differ significantly in their structure, distribution, and functional roles.
  - **Structural Differences:**
    - **Shape:** Rods are elongated, cylindrical cells, whereas cones have a conical shape at their outer segment.
    - **Outer Segment:** The outer segment of both rods and cones contains stacks of membranous disks where photopigments are located. In rods, these disks are detached from the outer membrane and float freely within the cytoplasm. In cones, the disks are continuous with the outer membrane.
    - **Photopigment:** Rods contain a single type of photopigment called rhodopsin. Cones, however, contain one of three different types of photopigments (photopsins), each sensitive to different wavelengths of light (red, green, or blue).
    - **Mitochondria:** Cones generally have more mitochondria than rods, reflecting their higher metabolic activity, especially during daylight vision.
    - **Synaptic Terminals:** The synaptic terminals where photoreceptors communicate with bipolar cells also show structural differences, though less distinct.
  - **Roles in Vision:**
    - **Rods:**

- **Scotopic (Night) Vision:** Rods are highly sensitive to light and are responsible for vision in dim light conditions (scotopic vision). They allow us to see in low light, but they do not detect color.
- **Peripheral Vision:** Rods are much more numerous than cones (approximately 120 million rods vs. 6 million cones) and are predominantly found in the peripheral retina. This contributes to our ability to detect movement and perceive shapes in our peripheral vision.
- **Low Acuity:** Due to their convergence onto ganglion cells (multiple rods synapse with a single ganglion cell), rods provide low visual acuity, meaning they are not good for detailed vision.

- **Cones:**
  - **Photopic (Day) Vision:** Cones require brighter light to function and are responsible for vision in bright light conditions (photopic vision).
  - **Color Vision:** The presence of three types of cones, each sensitive to different wavelengths of light, enables us to perceive color. This is the basis of trichromatic color vision.
  - **Central Vision and High Acuity:** Cones are concentrated in the fovea, the central part of the retina, and are directly linked to individual ganglion cells (low convergence). This allows for high visual acuity and the perception of

fine details, which is crucial for tasks like reading and recognizing faces.

4. (a) Define a circadian rhythm and graphically represent it. Discuss the important characteristics of a circadian rhythm.

   - **Definition of a Circadian Rhythm:**
     - A circadian rhythm is a natural, internal process that regulates the sleep-wake cycle and other physiological processes over a roughly 24-hour period. It is an endogenous (internal) biological rhythm that persists even in the absence of external cues, though it is entrained (synchronized) by environmental signals, primarily light-dark cycles. The term "circadian" comes from the Latin words "circa" (about) and "dies" (day), meaning "about a day."

   - **Graphical Representation:**
     - A graphical representation of a circadian rhythm typically plots a physiological variable (e.g., body temperature, melatonin levels, activity levels) on the y-axis against time (over several days) on the x-axis. The graph would show a cyclical pattern with a period of approximately 24 hours, even when the organism is kept in constant conditions (e.g., constant darkness for a nocturnal animal, constant light for a diurnal animal), demonstrating its endogenous nature. The peak and trough of the rhythm would occur at roughly the same time each "day."
     - (Imagine a sine wave or a similar oscillating pattern with a period of approximately 24 hours, repeating over multiple days.)

   - **Important Characteristics of a Circadian Rhythm:**

- **Endogenous (Self-Sustained):** Circadian rhythms are generated internally by an organism's biological clock, meaning they can persist even in the absence of external time cues (zeitgebers) like light. While not precisely 24 hours in constant conditions (often slightly longer or shorter), they remain rhythmic.
- **Entrainable:** Although endogenous, circadian rhythms can be synchronized or "reset" by external environmental cues, with the light-dark cycle being the most potent zeitgeber. This process, called entrainment, ensures that the internal clock is aligned with the external 24-hour day.
- **Temperature Compensation:** Circadian rhythms are relatively insensitive to changes in ambient temperature within a physiological range. This ensures that the clock remains accurate despite daily temperature fluctuations, which would otherwise speed up or slow down biochemical reactions.
- **Heritable:** The genetic basis of circadian rhythms has been well-established across various organisms, indicating that the molecular components of the clock are inherited.
- **Ubiquitous:** Circadian rhythms are found in almost all forms of life, from single-celled organisms to complex multicellular organisms like plants, animals, and fungi, indicating their fundamental importance for survival.
- **Physiological Relevance:** Circadian rhythms regulate a wide array of physiological and behavioral processes, including sleep-wake cycles, hormone secretion, body temperature regulation, metabolism, cell division, and immune function, optimizing these processes for specific times of the day.

(b) How does the autocatalytic property of PCR cycle increase the amount of the primary acceptor molecule?

- The question seems to have a misunderstanding. PCR (Polymerase Chain Reaction) is a molecular biology technique used to amplify specific DNA sequences, not to increase the amount of a "primary acceptor molecule" in a biological pathway like the Calvin Cycle (which uses RuBP as its primary acceptor molecule). The term "autocatalytic" refers to a reaction where the product of the reaction acts as a catalyst for the same reaction, leading to an accelerating rate.
- **In the context of PCR, the "autocatalytic" nature refers to the exponential amplification of DNA:**
    - **Initial Setup:** PCR starts with a template DNA molecule, primers (short DNA sequences complementary to the ends of the target DNA), DNA polymerase, deoxynucleotides (dNTPs), and a buffer.
    - **Cycle 1:**
        - **Denaturation:** The DNA is heated to separate the double strands.
        - **Annealing:** Primers bind to their complementary sequences on the separated strands.
        - **Extension:** DNA polymerase synthesizes new DNA strands using the primers as starting points and the template as a guide.
        - At the end of the first cycle, you have two new DNA molecules synthesized from each original template molecule, resulting in a total of 2 copies (if starting with 1 template).
    - **Subsequent Cycles:**

- Crucially, in each subsequent cycle, *both* the original template DNA strands *and* the newly synthesized DNA strands from the previous cycle serve as templates for further amplification.
- This means the number of DNA copies doubles with each cycle (theoretically 2n copies after 'n' cycles). This exponential increase is what makes the PCR reaction appear "autocatalytic" – the product (newly synthesized DNA) acts as a template for further product formation, rapidly accelerating the amount of target DNA.

- Therefore, PCR doesn't increase a "primary acceptor molecule" like RuBP; instead, its autocatalytic-like property allows for the rapid, exponential amplification of a specific DNA sequence, where the products of one round become the templates for the next.

5. (a) Why do C4 plants not experience photorespiratory losses.

- C4 plants have evolved a specialized anatomical and biochemical mechanism, known as the C4 pathway, that largely eliminates photorespiration, a wasteful process that occurs in C3 plants. Here's why C4 plants avoid photorespiratory losses:
  - **Spatial Separation of Carbon Fixation:** C4 plants exhibit Kranz anatomy, where the photosynthetic process is spatially separated into two distinct cell types: mesophyll cells and bundle sheath cells.
  - **Initial CO_2 Fixation by PEP Carboxylase:** In the mesophyll cells, CO_2 is initially fixed by the enzyme phosphoenolpyruvate carboxylase (PEP carboxylase). This enzyme has a very high affinity for CO_2 and, unlike RuBisCO, does *not* have an affinity for oxygen. This means it can efficiently fix CO_2 even at low atmospheric

concentrations and is not inhibited by high oxygen levels. This reaction forms a four-carbon compound (e.g., oxaloacetate).

- **CO_2 Concentration Mechanism:** The four-carbon compound (e.g., malate or aspartate) is then transported from the mesophyll cells to the bundle sheath cells. In the bundle sheath cells, these C4 acids are decarboxylated, releasing CO_2.
- **High CO_2 Concentration at RuBisCO Site:** This decarboxylation creates a very high local concentration of CO_2 around RuBisCO within the bundle sheath cells.
- **Suppression of Photorespiration:** By maintaining a high CO_2:O_2 ratio in the bundle sheath cells where the Calvin cycle (and thus RuBisCO) operates, RuBisCO is preferentially driven to catalyze the carboxylation reaction (adding CO_2 to RuBP) rather than the oxygenation reaction (adding O_2 to RuBP), which initiates photorespiration. This effectively suppresses photorespiration.

- In summary, the C4 pathway acts as a "CO_2 pump" that actively concentrates carbon dioxide at the site of RuBisCO activity, thus minimizing the opportunity for photorespiration and enhancing photosynthetic efficiency, especially in hot, dry environments.

(b) Discuss the various ways in which bioluminescence is used in offence and defense by organisms.

- Bioluminescence, the production of light by living organisms, is a fascinating adaptation used by a diverse range of creatures, primarily for survival through both offensive and defensive strategies.
- **Offensive Uses:**

- **Lure/Attraction of Prey:** Many predators use bioluminescence as a bait to attract prey. The classic example is the anglerfish, which possesses a bioluminescent lure (esca) at the end of a modified dorsal fin ray (illicium) that it dangles in front of its mouth to attract smaller fish. Similarly, some deep-sea squid and jellyfish use flashing lights to draw in unsuspecting victims.
- **Stunning or Disorienting Prey:** Some organisms emit sudden flashes of light to temporarily blind or disorient prey, making them easier to capture. Certain deep-sea shrimp, for instance, can eject a cloud of bioluminescent fluid that acts like a "smoke screen" to confuse predators, but it can also disorient prey.
- **Illumination to Locate Prey:** While less common, some deep-sea predators might use dim bioluminescence to illuminate their immediate surroundings, helping them to spot prey in the perpetual darkness of the deep ocean. The "headlights" of certain dragonfish are an example, emitting red light that most deep-sea organisms cannot see, thus allowing the fish to see its prey without being detected.

- **Defensive Uses:**
  - **Startle Response (Flashlight Effect):** A sudden burst of light can startle or temporarily blind a predator, giving the prey a chance to escape. Many squids, jellyfish, and deep-sea worms exhibit this "flash and dash" strategy.
  - **Burglar Alarm Effect:** Some prey organisms emit light when attacked by a predator. This attracts secondary, larger predators that are likely to prey on the initial attacker, thus saving the original prey. Dinoflagellates, for

example, light up when disturbed by grazing zooplankton, attracting larger fish that consume the zooplankton.

- **Counter-illumination (Camouflage):** Many marine organisms, particularly in the mesopelagic zone, use ventral (underside) bioluminescence to camouflage themselves against the dim downwelling light from the surface. By adjusting the intensity of their light to match the background light, they eliminate their silhouette, making them virtually invisible to predators looking up from below. Examples include many species of fish, squid, and crustaceans.
- **Aposematic Signaling (Warning):** While not as widespread as in terrestrial systems, some toxic or unpalatable organisms may use bioluminescence as a warning signal to predators. The glow serves to alert predators of their unpleasant nature, encouraging them to avoid future encounters.
- **Sacrificial Tag:** Some organisms can detach a glowing body part when threatened, distracting the predator while the main body escapes. Certain brittle stars and worms employ this strategy.
- **False Target/Decoy:** Similar to ink clouds, some organisms release a cloud of bioluminescent fluid as a decoy, creating a glowing distraction that the predator attacks while the organism escapes in the opposite direction. This is observed in some squid and deep-sea shrimp.

6. Write short notes on any three:
    - (i) Plant Pigments
        - Plant pigments are natural colorants produced by plants that play crucial roles in various physiological processes,

most notably photosynthesis and photoprotection. These pigments absorb specific wavelengths of light, reflecting others, which gives plants their characteristic colors. The major classes of plant pigments include:

- **Chlorophylls:** These are the primary photosynthetic pigments (e.g., chlorophyll a and chlorophyll b) responsible for capturing light energy for photosynthesis. They absorb light most strongly in the blue and red portions of the electromagnetic spectrum and reflect green light, which is why plants appear green.
- **Carotenoids:** These yellow, orange, and red pigments (e.g., beta-carotene, lutein, zeaxanthin) are accessory pigments in photosynthesis, absorbing light in wavelengths not absorbed by chlorophylls and transferring this energy to chlorophyll. They also play a vital photoprotective role by dissipating excess light energy as heat, preventing damage to the photosynthetic apparatus. They become visible in autumn leaves when chlorophyll breaks down.
- **Anthocyanins:** These water-soluble pigments produce red, purple, and blue colors in flowers, fruits, and leaves. Their production is often influenced by factors like light intensity, temperature, and pH. They are thought to protect against UV radiation, attract pollinators and seed dispersers, and may have antioxidant properties.
- **Phycobilins:** Found in cyanobacteria and red algae, these pigments (phycoerythrin, phycocyanin, allophycocyanin) allow these organisms to capture

light at wavelengths that chlorophylls do not absorb efficiently, especially in deeper waters.

- Beyond their roles in photosynthesis and protection, pigments are involved in phototropism (growth towards light), photoperiodism (response to day length), and plant-animal interactions (e.g., attracting pollinators).

- (ii) Circadian rhythms in plants
  - Circadian rhythms in plants are endogenous, self-sustaining biological cycles that oscillate with a period of approximately 24 hours, regulating a wide array of physiological and developmental processes. These rhythms allow plants to anticipate daily environmental changes, such as the light-dark cycle and temperature fluctuations, optimizing their growth and survival. Key characteristics include:
    - **Leaf Movements (Nyctinasty):** One of the most observable circadian rhythms in plants is the rhythmic opening and closing of leaves (e.g., "sleep movements" in legumes), where leaves are horizontal during the day and fold vertically at night.
    - **Photosynthesis and Respiration:** The rates of photosynthesis and respiration often follow a circadian rhythm, allowing plants to optimize energy capture during the day and metabolic processes during the night.
    - **Stomatal Opening and Closing:** Stomata, the pores on leaves that regulate gas exchange, typically open during the day to allow CO_2 uptake for photosynthesis and close at night to conserve water, a pattern often under circadian control.

        - **Flowering Time:** The timing of flowering in many plants is regulated by circadian clocks in conjunction with photoperiodic signals, ensuring reproduction occurs at the most favorable time of year for pollination and seed dispersal.
        - **Gene Expression:** A significant proportion of a plant's genome exhibits circadian regulation, with genes involved in various metabolic pathways, hormone synthesis, and stress responses showing rhythmic expression.
        - **Entrainment by Light:** Similar to animals, light is the primary zeitgeber (time cue) that entrains plant circadian rhythms, synchronizing their internal clocks with the external 24-hour cycle. Phytochromes and cryptochromes are key photoreceptors involved in this process.
    - The plant circadian clock confers a significant adaptive advantage by allowing plants to predict and prepare for daily environmental changes, thereby optimizing resource allocation, growth, and fitness.
- (iii) Physiological Color Change
    - Physiological color change refers to rapid, reversible changes in an animal's skin coloration due to the movement or dispersion of pigment within specialized cells called chromatophores. Unlike morphological color change, which involves altering the amount of pigment or the number of chromatophores over longer periods (days to weeks), physiological color change occurs within seconds to minutes. This rapid response is typically mediated by the nervous system and/or hormones.
    - **Mechanisms:**

- The most common mechanism involves the aggregation or dispersion of pigment granules within chromatophores (e.g., melanophores containing melanin, erythrophores containing red pigments, xanthophores containing yellow pigments, iridophores containing reflective guanine crystals).
- When pigment granules aggregate towards the center of the cell, the skin appears lighter as less pigment is exposed. When they disperse throughout the cell's processes, the skin appears darker or more vibrant as more pigment is presented to incident light.

- **Examples and Functions:**
  - **Camouflage:** Many animals, such as chameleons, cuttlefish, octopuses, and some fish and amphibians, use physiological color change to blend seamlessly with their surroundings. This allows them to avoid predators or ambush prey. Cuttlefish are masters of this, rapidly changing complex patterns and textures on their skin to match diverse backgrounds.
  - **Signaling:** Color changes can be used for communication within a species, such as for courtship displays, territorial defense, or indicating mood (e.g., anger, submission). For instance, some lizards display bright colors during mating rituals.
  - **Thermoregulation:** In some animals (e.g., certain lizards, frogs), physiological color change can help regulate body temperature. Darkening the skin increases heat absorption, while lightening it

reduces absorption, allowing them to warm up or cool down more effectively.

- This rapid control over appearance provides a flexible and dynamic means for animals to interact with their environment and other organisms.

- (iv) Jet Lag
    - Jet lag, also known as desynchronosis or circadian dysrhythmia, is a temporary sleep disorder and physiological disruption that occurs when a person travels rapidly across multiple time zones. It results from a mismatch between the body's internal circadian clock (which is still set to the departure time zone) and the new time zone's light-dark cycle and social cues.
    - **Causes:** The primary cause is the rapid shift in external time cues (light, meal times, social activity) that the body's internal clock cannot immediately adjust to. The suprachiasmatic nucleus (SCN) in the hypothalamus, the master pacemaker of the circadian system, takes time to re-entrain to the new schedule. Traveling eastward is generally worse than westward travel because it requires shortening the day, which is harder for the body's natural clock to adjust to than lengthening it.
    - **Symptoms:** Common symptoms include:
        - Sleep disturbances (insomnia at night, excessive sleepiness during the day)
        - Fatigue and lethargy
        - Difficulty concentrating and impaired cognitive performance
        - Irritability and mood changes

        - Headaches
        - Digestive problems (e.g., nausea, appetite changes)
        - General malaise
    - **Management and Prevention:** Strategies to mitigate jet lag include gradually adjusting sleep schedules before travel, maximizing light exposure during the day and avoiding it at night in the new time zone, staying hydrated, eating light meals, avoiding alcohol and excessive caffeine, and considering melatonin supplements. Recovery typically takes about one day per time zone crossed.
- (v) Behavioural adaptations of animals to extreme light conditions.
    - Animals exhibit a remarkable array of behavioral adaptations to cope with extreme light conditions, ranging from constant darkness (e.g., deep sea, caves) to intense sunlight (e.g., deserts, high altitudes), or even the prolonged light and darkness of polar regions. These adaptations help regulate body temperature, conserve energy, avoid predators, and find food.
    - **Adaptations to Extreme Darkness (e.g., Deep Sea, Caves):**
        - **Reduced Activity Cycles:** Many cave-dwelling animals (troglobites) exhibit reduced or absent circadian rhythms as there are no external light cues to entrain them.
        - **Reliance on Other Senses:** Behavioral reliance shifts from vision to other senses, such as chemoreception (smell/taste), mechanoreception (touch, vibration, lateral line system in fish), and

echolocation (bats, some deep-sea whales) for navigation, foraging, and predator avoidance.

- **Slow Metabolism and Energy Conservation:** Many deep-sea animals exhibit reduced metabolic rates and sluggish movements to conserve energy in a resource-scarce environment.
- **Bioluminescence:** As discussed, bioluminescence is extensively used for offense (luring prey, illumination) and defense (startle, burglar alarm, counter-illumination) in the perpetually dark deep-sea.

- **Adaptations to Extreme Brightness/Heat (e.g., Deserts, Tropics):**
  - **Nocturnal Activity:** Many desert animals (e.g., rodents, reptiles, insects) are nocturnal, meaning they are active primarily during the cooler night hours to avoid the searing daytime heat and intense solar radiation. They retreat into burrows or shade during the day.
  - **Crepuscular Activity:** Some animals are most active during dawn and dusk (crepuscular) when light levels are lower and temperatures are more moderate.
  - **Burrowing Behavior:** Digging burrows allows animals to escape extreme surface temperatures and UV radiation, maintaining a more stable microclimate underground.
  - **Shade Seeking:** Animals will actively seek out shade provided by rocks, vegetation, or their own bodies (e.g., birds perching in trees during midday).

- **Orientation and Posture:** Some animals orient their bodies to minimize direct sun exposure (e.g., dragonflies orienting their bodies away from the sun).

- **Adaptations to Prolonged Light/Darkness (e.g., Polar Regions):**
  - **Seasonal Hibernation/Estivation/Migration:** Animals in polar regions often undergo seasonal behavioral changes to cope with extreme light conditions, such as hibernation during prolonged dark winters or migration to areas with more favorable light and food availability.
  - **Adjustment of Circadian Rhythms:** Some arctic animals may exhibit a "free-running" circadian rhythm or even a breakdown of the typical 24-hour cycle during periods of continuous daylight or darkness, as the strong light-dark cues are absent.

- These behavioral strategies are crucial for survival in diverse and challenging light environments across the globe.