

Light-Driven Behaviors in Insects: Photo taxis and Photo Tactic-Based Strategies for Pest Management; A Comprehensive Review

Shah Alam Khan (Corresponding Author)

Dean Faculty of Crop Sciences, University of Agriculture Peshawar, Kp, Pakistan.

Email: profkhansa69@aup.edu.pk

Shafique Ahmed Memon

Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University

Tandojam, Pakistan Email: ahmedshafique89@yahoo.com

Amir Khan Korai

College of Plant Protection, Northwest A&F University, Yangling 712100, Shaanxi,

China Email: koraiamir.sau@gmail.com

Shah Mohammed

Directorate of Plant Protection Agriculture Research Institute Quetta

ABSTRACT

Various night-active insects show they are naturally attracted to artificial lights. Light traps are essential physical pest management instruments since scientists currently employ them to monitor insect pest numbers and implement population control measures. Light traps are crucial in integrated pest management (IPM) because they attract specific insect pests. The photo tactic activities of insects depend on their species, ambient light properties, and the overall health of the insects. Light produces multiple biological effects on insects, from biochemical to physiological, molecular and fitness effects. The study investigates photo taxis concepts of insects alongside crucial variables that affect their responses to light and the respective parallel wavelengths, as well as strategies to conserve beneficial insects during effective insect capture. Research data presents information regarding wavelength sensitivity that causes positive photo tactic responses in more than 70 species between insect pests and beneficial insects. Deploying contemporary light traps equipped with LEDs as light sources would increase physical pest control effectiveness for integrated pest management (IPM).

Key Words: Insect Behavior, Photo Taxis, Photo Tactic, Pest Management

Introduction

A growing number of insect pest outbreaks stem from global transformations involving modifications in both climate patterns and topography conditions that endanger agricultural production (Harvey et al., 2022). The extensive use of synthetic pesticides across multiple nations has led to four important issues affecting users and

pests, environmental degradation, and biodiversity damage. Organic farms face insect pest management as their primary concern, leading many researchers worldwide to find sustainable alternative methods such as electric traps, bait traps, and bio-pesticides (Mittal et al., 2020). Numerous insects, including nocturnal species, automatically move towards exterior artificial lights at night because of their natural positive photo taxis behavior. Scientifically known as negative photo taxis, the behavioral pattern describes how insects travel towards the darkness from artificial light. An insect displays photo tactic response behavior through light-dependent attributes of the source and outside elements including meteorological conditions and both chronological and biological factors influencing the insect's state. Insects use visual and temporal signals to perform orientation navigation and predator evasion and find hosts' prey and mating partners simultaneously (Suher et al., 2021).

Standard superposition compound eyes used by nocturnal moths possess approximately one thousand times more sensitivity than the opposition complex eyes of butterflies (Curra et al., 2023). Many insects detect light wavelengths across the UV and IR ranges in addition to the wavelength spectrum between 350 nm and 760 nm despite humans being unable to sense these wavebands. The compound eyes belong to insects and consist of three specific parts. The photoreceptor cells that detect ultraviolet, blue, and green wavelengths enable numerous insects to show strong behavioral responses to light (Sharkey et al., 2020). A specific population of sawflies from the Hymenoptera group holds four photoreceptors that function with a red-sensitive receptor. Researchers combine electrophysiological assessments with behavioral analyses to determine the wavelengths which cause insects to exhibit strong photo tactic responses (Cui et al., 2024). When compound eye retinal cells receive light stimulation, they create brain signals, leading insects to perform matching actions.

The electroretinogram (ERG) values from the compound eye retinal cells directly measure how sensitive the insect becomes to light exposure. The insect light wavelength sensitivity has been investigated through electroretinogram (ERG) measurements in insect compound eyes, which undergo testing with multiple light wavelengths (Alberto et al., 2022). The results from electroretinogram (ERG) experiments failed to match those obtained from behavioral studies during insect photo taxis investigations. Observable responses from the compound eyes of velvet worms (*Euperipatoides rowelli* and *Principapillatus hitoyensis*) led to maximum blue light (480 nm) detection, thus producing negative photo tactic responses from the animals under different wavelengths of light from UV to green spectrum (370-530 nm). Parasitoid fly (*Exorista japonica*) compound eyes responded best to UV light at 340 nm, while behavioral investigations demonstrated flies displayed stronger photo tactic reaction to the violet wavelength of 405 nm (Au et al., 2022). The ERG data reflects only one type of biological reaction in specific spectral areas from insect visual organs. Because the ERG level measures insect eye photosensitivity, it becomes difficult to understand light source-related behaviors solely through ERG data analysis. The behavioral characteristics of insects toward light serve agricultural pest control by appropriate placement in farming areas, greenhouses, forests and storage places based on pest management goals. However, light modification attracts beneficial insects and pest species, so pest control systems using light traps require

precise calibration (Preti et al., 2020). Scientists have investigated photo tactic behavioral reactions using different light sources to various insects before applying some findings to management methods.

Light traps equipped with optical sources for trapping aphids and whiteflies operate in greenhouses. However, mosquito light traps built from behavioral research on various wavelength responses serve to limit disease transmission from mosquitoes (Labbé et al., 2023). Developing light traps with LED lighting serves two purposes: biodiversity protection and reduced energy requirements. Proper physical pest management requires light traps as a fundamental component in integrated pest management (IPM).

To achieve practical use, insect wavelength sensitivities that produce positive photo tactic behavior according to species must be classified (Kirthika et al., 2022). As studied in this investigation, research on insect-positive photo taxis to specific wavelengths continues to advance. The review explores particular light wavelengths that trigger strong positive photo taxis across more than 70 species of insects so researchers can develop efficient, environmentally friendly, and cost-effective light traps and understand the root causes of photo taxis in insects (Auxillos et al., 2024). This research delivers practical knowledge for scientists who study insect photo taxis and light trap performance assessment in pest control.

Hypotheses on the photo tactic behavior of insects in response to light

Different insect behaviors to light result from their unique life patterns and natural body functions. Insects use their vision system to locate their mates and disperse while searching for food sources and defending against predators (Guzy et al., 2023). They also identify their food sources, hosts, and suitable places to rest and lay their eggs before winter. How an insect reacts to light relates to its light adaptations as it follows its circadian rhythm while responding to light conditions and photo toxicity. Nocturnal insects used to light during nighttime respond like day-active species by staying motionless and landing (Gencturk & Unal, 2024). Artificial darkness impacts the cycle of daily and nightly insect actions, including flight changes, movement patterns, feeding behaviors, relationship seeking, and mating. The length of light and dark cycles, known as photoperiodic, affects insect development only when insects reach specific periods of darkness to thrive (Wang & Lin, 2020). Different colored and natural white light affect insect conduct and growth patterns. Most scientists cannot explain why numerous insects strongly attract light sources.

Scientists across many years have worked to explain how insects react to light. Scientists study insect responses to light by testing different test methods. Particular explanations were developed from experimental results.

According to The Light Orientation Hypothesis, insects use moonlight and starlight to determine their direction when moving or flying. During nighttime flights, insects align their eyes to the light source at an ideal angle so they can mistake artificial lights for stars and the moon. Insects who wish to get too close to light lose directional control and move unpredictably through the air in terms of distance and circling paths. Although this hypothesis helps explain flying insect behavior toward the light, it does not explain why static insects follow the light source or how some species react negatively to light (Millard et al., 2021).

According to the Biological Antenna Hypothesis, insects possess antennae that function as receivers of pheromones similar to radio antennas. When seeking mates, insects use their antennae to detect pheromone waves because these waves belong to the far-infrared spectrum. Therefore, insects might respond to light beams that transmit far-infrared electromagnetic wavelengths. Scientists studied male *Spodoptera frugiperda*, *Heliothis zea* autumn armyworm, and maize earworm moths to determine their behavioral reactions towards 331 μm and 337 μm far-infrared wavelengths. The cabbage looped (*Trichoplusia*) moths showed no detectable behavioral reaction when exposed to far-infrared wavelengths of light. Researchers were unable to confirm this supposition. Examine the behavioral movement of moths in response to different wavelengths of light from UV to visible bands (Urquhart et al., 2024).

According to the light interference hypothesis, nocturnal insects have evolved to survive in darkness. Their visual system causes them to react quickly toward bright lights since they do not adapt well to changing brightness levels. Evidence demonstrates that light exposure of compound eyes adapted for low-light settings causes behavioral disturbances in nocturnal insects through visual stimulation. According to research findings, this perceptual phenomenon develops because unadapted insects try to avoid unfamiliar brightly lit surroundings until they become disoriented. However, this theory does not address why distanced insects move towards light even though they are far from it. Researchers face difficulties explaining how and why insects develop photo tactic behavior when situated far from the light source (Burte et al., 2023).

The Light Stress Hypothesis studies the environmental stress behavior of insects exposed to lighting. Over time, insects prefer darkness, which makes them struggle to handle bright light stress. When fleeing light of a specific color, insects appear to work towards reducing light stress. The new research showed that insects get stressed during this test. Several detoxification enzymes show more significant activity levels when exposed to UV light. At age 30, the drop in acetyl cholinesterase makes insects more excited and draws them to bright lights. This may cause them to lose flight control and end up dying near streetlights, as shown by dead insect bodies. Scientists find it hard to determine the starting point of positive photo tactic movement in insects since they tend to approach distant lights (Pimbert & Barry, 2021). Multiple studies still fail to uncover why insects move toward light sources properly.

Determinants influencing insect photo tactic behavior

Various conditions impact how bugs move toward artificial light, such as hourly light measures, lack of exposure, and weather information. Light and the surrounding environment are the primary factors determining how insects react to light (Susana, 2025). Photo tactic insects respond differently to light wavelengths depending on their exposure time and light strength. Most photo tactic bugs fly towards brighter light sources and exhibit strong movement towards weaker light of similar quality. The test produced thirty-two Mosquitoes, which flew towards the light until they located the source and turned back towards the darkened area (Marty, 2020). The bug needed 33 photons of light per unit surface area to cause *Nepotistic* cinctures to move toward the light. Under illumination with 480 nm light, photon emission reached 1.2 trillion photons per square meter per second. The highest number of *Mythomania* separate

moths showed attraction when treated with a green (520 nm) 200 Lux LED light for 40 minutes.

Many insects exhibit different behavior when they detect polarized light produced by human-made light sources. Through scientific research, investigators found that thirty-five different insect groups react more strongly to non-polarized light than other species (Leung et al., 2020). Several Chironomid midges show attraction to light polarized in direction. Weather affects how insects react to light. The number of plant hopper species *Sogatella furcera* and *Nilaparvata lugens* captured in LED light traps adjusted with meteorological aspects such as temperature, humidity, wind, and precipitation. The *M. separate* moths can fly their best at 27°C while their wings activate at 11°C and 32°C (Keesey et al., 2019). The insect angers total flight capacity when temperatures exceed 40 degrees Celsius or drop below 4 degrees Celsius.

The direction in which a flying insect moves depends on the type of light it detects and the shape of the light source. The types of insects captured and the number of captures from light traps depend on the type of light source running, including LED bulbs, compact fluorescent bulbs, and incandescent bulbs (Montgomery et al., 2021). Scientists have shown that how insects respond to light depends on their group classification. Canidae from Ephemeroptera show stronger attraction to LED light, whereas Geometridae from Lepidoptera prefer metal-halide and high-pressure sodium lights more than LED lights. Each trap produces different trapping results since its outer lighting design changes despite identical internal light sources (Bhartia et al., 2021). A test proved that traps using light-emitting diodes as a source captured best with the LED light-shaped like a cone because of its superior trapping performance above two other LED light types. Insects display different light-following behaviors that depend entirely on their body health status.

After birth, new insects show weak light responses that increase during life but fade over time. Winged pea aphids (*Acyrtosiphon pisum*) exhibit altered photo tactic behavior in response to light exposure, varying by developmental stage; wingless aphids demonstrate heightened sensitivity to red and green wavelengths, while one-day-old winged aphids show increased sensitivity to blue wavelengths (Sandhi & Reddy, 2020). Moreover, in the oriental fruit moth (*Grapholita molesta*) and *M. separate*, three-day-old specimens exhibit the most pronounced photo tactic response to green (520 nm) LED light compared to those aged one to five days. Photo tactic insect behavior changes depending on the unique biological differences between male and female specimens (Saiti & Theoharis, 2020). Research found that butterflies show male-female differences in their light wavelength sensitivity.

Numerous scientific studies demonstrate a clear difference between male and female moth reactions to light (Preti et al., 2020b). Expressions of male macro-Lepidoptera increased (over females) in each trapping session, but the preliminary difference varied by species. Insects from different sex groups show different photo behavior outcomes because their compound eyes vary with distinct facets and body dimensions. Before mating, males of certain insects display decisive light-seeking actions, but mated males react differently (Shevlin, 2020). Mothers show more assertive light attraction behavior than females who have not mated yet. Male Motley Dissotis beetles and mated women Moths in *M. separata* showed better photo taxis performance than all other test groups.

The light trap caught more male cotton leaf worm (*Spodoptera littoralis*) moths than female ones, even though most female moths got mated. Mated female moths gravitate toward light areas of the environment to lay eggs, which explains why they travel to these zones alongside male moths who wander there seeking female partners (Leving, 2019). When insects adapt to darkness, their photo response works differently. The light passing through nocturnal insect compound eyes depends on how their screening pigment granules respond to light. When insects have dark-adapted eyes, their screening pigments remain clustered, while they scatter when the insects have light-adapted eyes (Barichello et al., 2023). The photo tactic response of *G. molesta* moths to green light depends on how long they adapt to darkness before testing. After spending two hours in total darkness, the sample achieved its peak level of attraction for green LED lights, compared to related samples that acclimatized for one, three, or four hours.

The duration of dark adaptation may correlate with the time needed for the transition from light-adapted to dark-adapted vision, and the spectral sensitivity of insects with fully dark-adapted eyes surpasses that of others. Limited scientific data has been available to confirm the influence of these elements on the photo tactic behavior of insects; nevertheless, further research that incorporates these aspects may provide a precise and pragmatic foundation for the use of light in appropriate domains (Xiang et al., 2021).

Picking the right instrument for behavioral testing helps we find which specific light color makes insects move towards light more strongly. Our method helps determine which environment and physical conditions make insects differentially react to distinct light wavelengths when following light sources (Samir et al., 2022). Scientists create specific instruments for bioassays using either behavioral or physical aspects of insects, plus study requirements. Scientists divide bioassays measuring insect photo tactic behavior into two groups: two-choice tests and multiple-choice procedures. A procedure checks which of two situations individuals choose by comparing light therapy with usual darkness or standard illumination settings (Kumar et al., 2022). The setup of the L-shaped bioassay chamber tested the direction in which *M. separata* moths moved toward their exposure to specific LED wavelengths.

A special chamber monitors the *Scleroderma guani* wasp's movement reaction to different light types through its straight passage. Laboratory test designs for the photo tactic behavior of live insects must handle insect size differences and light preference behaviors (Todaro et al., 2022). A multiple-choice behavioral assessment helps scientists detect how a subject picks one light source from among many lights displayed in a testing arena. To measure *E. japonica* photo taxis, the device tested six color LEDs with equal brightness but different wavelengths in a multiple-choice setup. When used for light source photo movement, the multiple-choice test helps measure insect response better than two-choice testing but needs a unique design for interfering light sources (Tsai et al., 2020).

Photo transduction

The majority of sensory receptors generate depolarization in cells after stimulus activation since this results in action potential generation and neurotransmitter release to associated neurons. Membrane potential in retinal photoreceptors changes in a

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

graded manner when activated by light yet does not produce action potentials because synapses experience a rate-dependent change in neurotransmitter discharge (Gallego et al., 2020). Gradient potential works as an effective signal processor in the retina since action potentials are not needed to pass information through brief neural pathways.

Subjecting photoreceptors to light results in membrane hyperpolarization regardless of their type (Figure 1). During dark conditions the receptor element exists in a depolarized state at -40 mV potential which spans all transmitter-secretory areas (Gire et al., 2019). The receptor membrane develops increasingly greater negative potential upon light intensity increases until reaching -65 mV of potential. The sensory recognition process requires no change other than a steady linkage between lighting intensity changes and neurotransmitter secretion frequency at photoreceptor synapses. The synaptic terminals of photoreceptors release transmitters through voltage-sensitive Ca^{2+} channels which operate the same way as nerve cells (Prigge et al., 2016). The synaptic terminals remain actively depolarized in darkness so their number of open Ca^{2+} channels stay high which causes more transmitters to release. The photoreceptors become hyperpolarized when exposed to light which decreases both open Ca^{2+} channels and transmitter release simultaneously (Sundar et al., 2019). Science has yet to uncover the explanation for this distinctive arrangement of sensory receptor cells which separates them from other receptor cells.

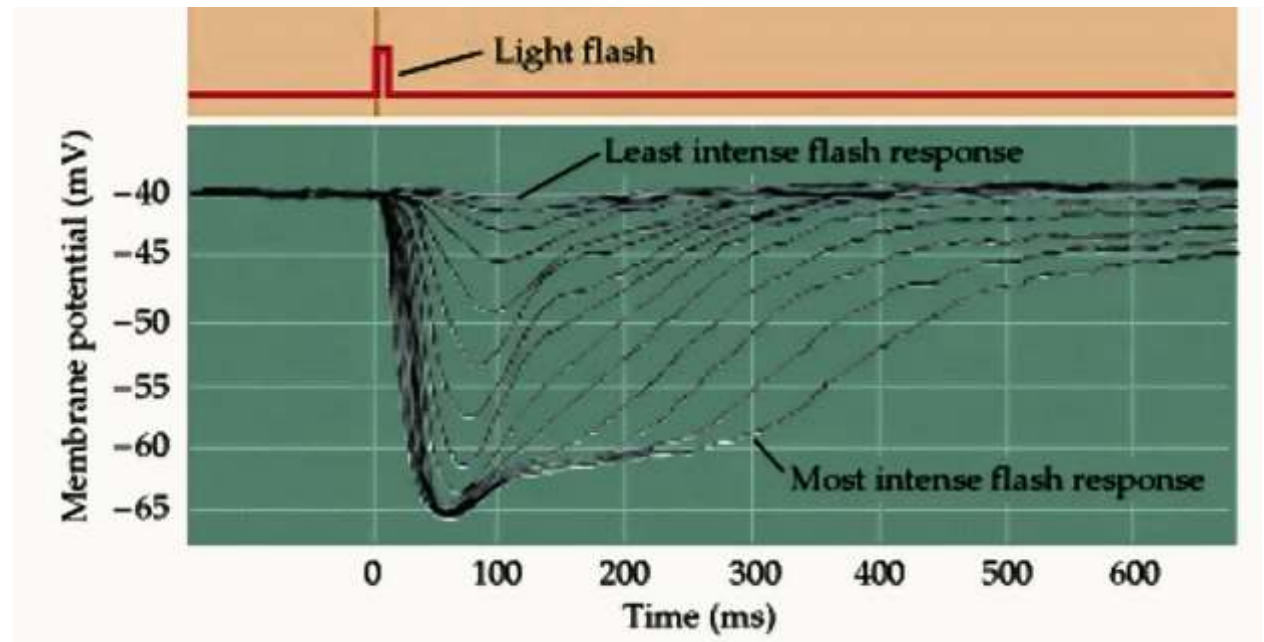


Figure 1: Insect response to least intense flash

The dark state of photoreceptors depends on ion channels located on outer segment membranes which enable Na^{+} along with Ca^{2+} ions to enter cells thus lowering internal negativity (Figure 2). The probability of these channels in outer segments to be open or closed depends on cyclic guanosine monophosphate (cGMP) concentration levels in a manner similar to other second messenger systems (Hospital et al., 2022).

Outer segment cGMP builds up when there is no light present which keeps the channels open. The membrane of the outer segment becomes hyperpolarized when cGMP levels decrease because some channels close after light exposure thus reducing transmitter release at the photoreceptor synapse.

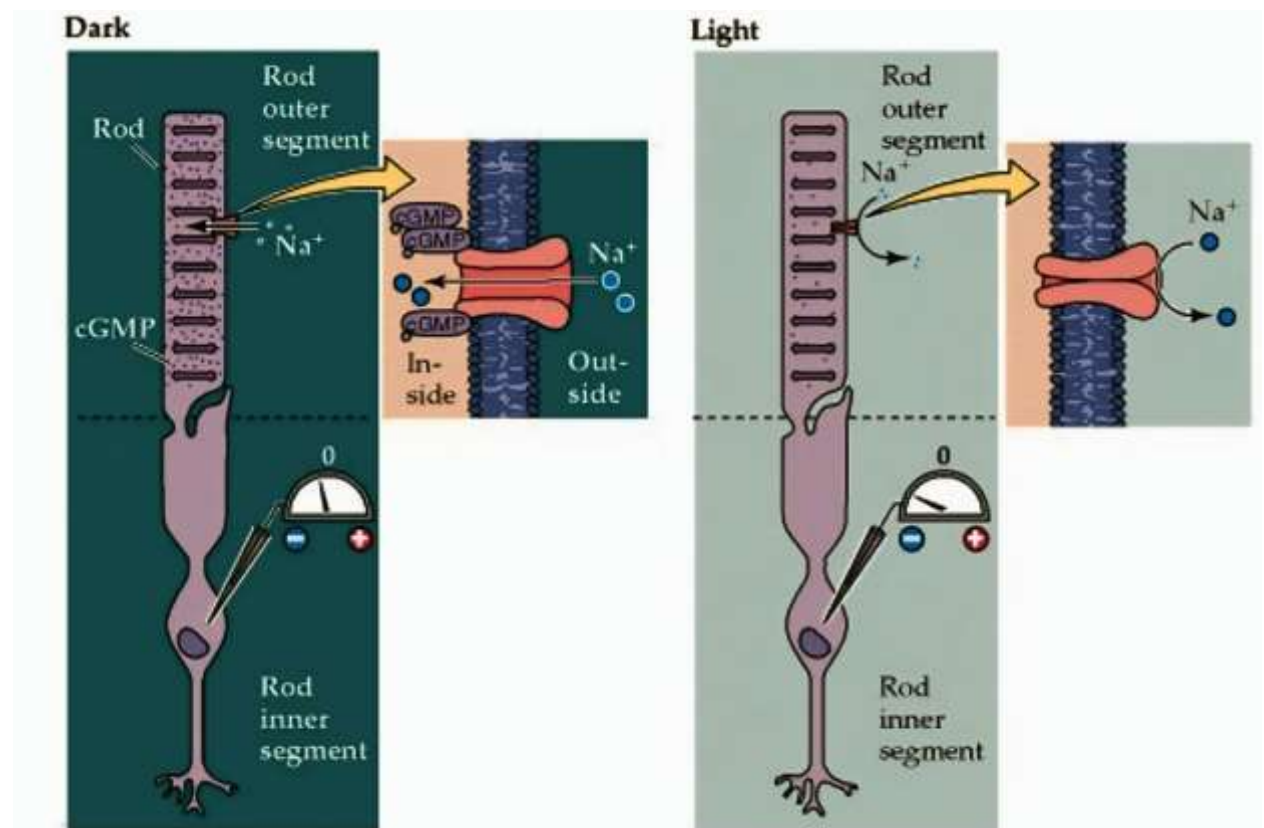


Figure 2: Insect response to light and dark

The cascade which lowers cGMP begins after receptors capture photons that strike their photo pigments within the disk structure. The photo pigment contains the light-absorbing retinal aldehyde of vitamin A that links with multiple opsin proteins to determine specific wavelength absorption (Ankel-Simons, 2024). Rods and cones maintain separate protein elements of their photo pigment molecules which create their functional differences as detector types. Research on rods provided most of the understanding regarding photo transduction mechanisms because their photo pigment is rhodopsin (Figure 3 A). Photon absorption by the retinal moiety in the rhodopsin molecule triggers its 11-cis isomer to all-trans retinal transformation that sets off protein alterations throughout the molecular structure (Figure 3 B). After these alterations take place transducing becomes activated then triggers a phosphodiesterase to break down cGMP (Derrickson, 2024). All activities responsible for signal transmission take place within the boundaries of the disk membrane. Hydrolysis by phosphodiesterase occurring at the disk membrane reduces cGMP presence in the outer segment which lowers cGMP availability to reach outer segment membrane channels thus blocking the channel activity.

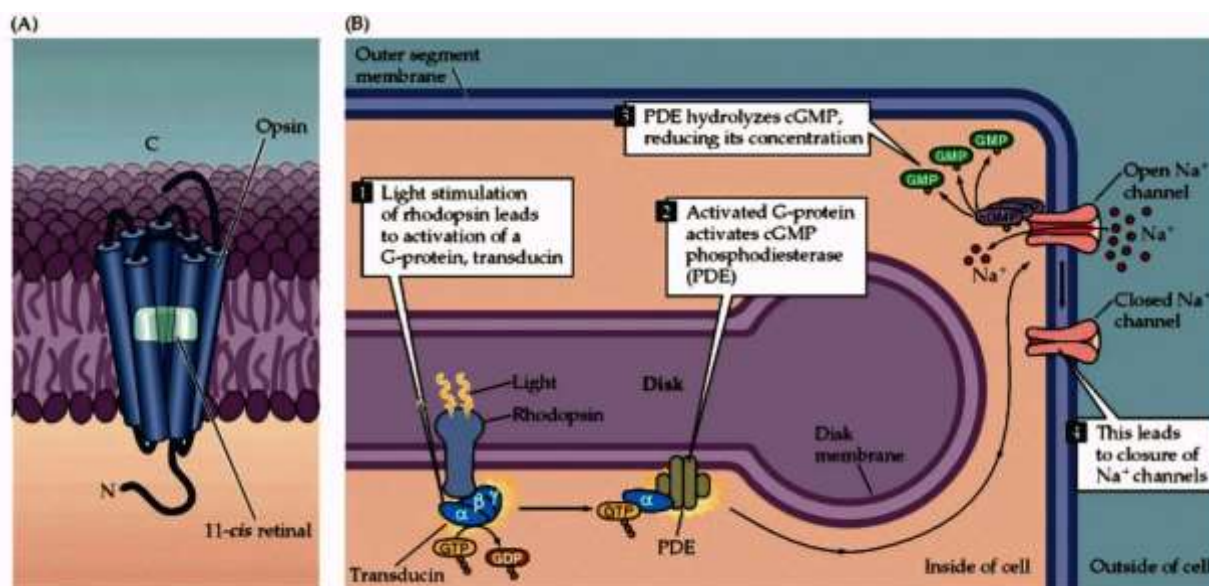


Figure 3: Insects response to light due to photo-pigments

The intricate metabolic cascade of photo detection amplifies signals to a considerable extent following the capture of photons. The activation of 800 transducing molecules happens because of a single light-activated rhodopsin molecule in relation to the eight percent covering of the disk surface. The transducing molecules activate phosphodiesterase molecules and it takes six cGMP molecules to be degraded by a single activated phosphodiesterase molecule (Acquarone et al., 2019). Upon absorbing one photon a rhodopsin molecule triggers the closure of two hundred ion channels which represents a fraction of the channel openings found in each rod in dark conditions. The membrane potential changes by approximately 1 mV as a result of the blocking of 200 ion channels.

Light adaptation controls how much the amplification will extend when measured versus existing ambient light conditions. The sensitivity of photoreceptors reaches its peak at low levels of surrounding light. The increase in illumination intensity leads to decreased sensitivity which prevents receptor saturation while extending the photoreceptors operational intensity range (Broser et al., 2020). The quantity of calcium ions present in the photoreceptor outer segment plays a fundamental role in maintaining light-based sensitivity control. Through the cGMP-gated channels in the outer segment Na^+ and Ca^{2+} can pass but their closure during light exposure leads to decreased Ca^{2+} inside the photoreceptor. Many photo transduction cascade transformations start after the reduction occurs which causes generally decreased light sensitivity of the receptor. Cellular Ca^{2+} decrease activates guanylate cyclase enzymes that produce cGMP so cGMP concentrations rise. The decreasing Ca^{2+} concentration in the cilium elevates the cGMP affinity of cGMP-gated channels thus making the cGMP levels less sensitive to light reduction (Stefanov et al., 2019). The photo transduction cascade regulation by Ca^{2+} represents one part of the network which modifies retinal lighting sensitivity but horizontal cells linking with photoreceptor endings contribute another essential aspect.

The initiation phase has supplementary processes that both shorten this amplification

cascade length and convert the active components into resting forms. Arrestin blocks the activation of transducing by active rhodopsin while simultaneously leading to the breakdown of rhodopsin in its activated state. Fluid through the cytoplasmic space of the outer segment, the all-trans retinal separates from opsin before reaching pigment epithelium cells where specific enzymes transition it into 11-cis retinal (Du et al., 2024). The 11-cis retinal enters the outer segment where it assembles with opsin inside the presynaptic membrane receptor disks. For photoreceptors to maintain their light sensitivity the recycling process of rhodopsin plays a crucial role. Regardless of strong light exposure the pigment molecules stay sufficiently abundant through their regeneration process.

Insect behavioral reactions to various light wavelengths

Insects will respond to artificial light but only when the light source uses specific types of light energy. Research teams sought to find out which colors of artificial lights most strongly attract specific insect pests since these pests react strongly to light (Coleman et al., 2023). From behavioral experiments that show positive photo taxis to light wavelengths, researchers determined the wavelength sensitivities of different insect pests. Many types of insects have this feature.

The insects behave in response to specific light types because they react to ultraviolet, blue and green light wavelengths. Many insect species react strongly to the light bands between UV and green wavelengths because their photoreceptors are specialized for these frequencies. Scientific research proved that in tobacco hornworm (*Manduca sexta*) photoreceptor cells, green light triggers a response in 75% of them, with the other 25% responding most strongly to blue and UV light (Deppisch et al., 2023). Nocturnal moths process green light better than UV and blue through their combined eyes. When exposed to green light, these moths react better than they do to the visible spectrum colostrum. How well insects seek out artificial night lights depends on the choices of light and the types of insects.

The light traps experiment showed that different insect orders reacted differently to specific light wavelengths between 320 and 390 nm. UV brought in the most insects, which Hemiptera and Orthoptera liked best. Green (500-560 nm) attracted Lepidoptera, blue (350-490 nm) attracted Coleoptera, and finally, yellow (555-610 nm), which Diptera favored (Cowan, 2009). Lepidoptera favors receiving light at UV and green bands, Hemiptera picks blue and green frequencies, and Coleoptera chooses UV and violet light. Diptera bugs react best to the specific colors of green light, while Hymenoptera bugs are more attracted to mixed blues and greens. People's choices about light match their specific evolutionary changes in eye structures and functions. The test must evaluate the target insect light response under real-life situations alongside its behavior and health status (Dhanaraju et al., 2022). Special wavelength light traps that effectively lure target insect pests must be deployed to guard against harmful pests while sparing harmless species.

The impact of light on the physiological reactions of insects

The light wavelengths that drive insect movement in the direction of light deserve study to uncover how the biological system produces this behavior. Scientists studied insect light reactions through biochemical and fitness testing because these tests help

explain how insects move toward light. A single light source with a defined wavelength can create photic stress in insects that hurt their fragile organs, especially retinas (Drozdova et al., 2021). The stress response emerges either within certain species or just for selected light wavelengths. Continuous exposure to UV light may raise reactive oxygen species levels in insects, and the resulting cell harm can end their life cycle. A selected light beam allows specific insects living here to develop faster and live longer.

Insects exposed to light adjust their antioxidant enzymes based on how long and at what wavelength they are exposed to light. Numerous insect species move toward UV light panels (320 to 380 nm), further examining this light spectrum. Upon UV irradiation, *H. armigera* moths made their antioxidant enzymes superoxide dismutase, catalase, peroxidase, and glutathione-S-transferase work differently while adjusting their total antioxidant capacity and protein concentrations (Bariami, 2013). The carboxyl content increased significantly after more time spent under UV light. When UV light impacted bug moths, their enzymes for detoxification showed decreased activities such as carboxyl esterase and acetyl cholinesterase. The results show that exposure to UV light can harm DNA, proteins, and lipids while stressed insects move toward light and extended light stress causes illness and death.

The number of insects caught in traps depends on the level of oxidative stress that light produces. Scientists studied how various light sources, compared to their trapping effectiveness for pests underground, and also affected pest oxidative stress. Their research showed that pests prefer traps using low-stress light sources. The laboratory tests found that *M. separate* moths developed only mild oxidative stress when illuminated by 520 nm light, yet their stress level increased markedly under UV rays (Bachmann, 2023). The green light attracts *M. separate* moths with more substantial results than other light wavelengths. Only trials that produce results of the insect's total responses to light will confirm if their activity occurs when they are burdened by light pressure.

Light energy in a proper spectral band triggers certain insect genes to turn on. When *H. armigera* adults were exposed to UV-A light 320-400nm, they showed 1,200 protein locations, with 12 up regulated spots and 21 down regulated spots. Following 30 to 90 minutes of UV-An exposure, both male and female moths showed higher activity in the antioxidant enzyme genes Cu/ZnSOD CAT and GPX, yet uninterrupted light exposure failed to increase their gene expression (Oonincx & Finke, 2020).

Light entering insects' compound eyes causes the production of opsin genes. Several studies demonstrate that the opsin gene impacts beetroot armyworms' movement toward light. The beetroot armyworm's (*Spodoptera exigua*) three opsin genes, Se-uv, Se-bl, and Se-lw, showed higher levels during daytime than nighttime (Neath, 2019). Insect moths demonstrated decreased green light sensitivity when their Se-lw photoreceptors were reduced, and their photo tactic behaviors were impaired. After 6 hours of UV blue and green light exposure, *H. armigera* males displayed higher expression rates of eight UV opsin genes than the females. Through UV light, Fasting reduced these opsin gene expression levels in *S. exigua* and *H. armigera* plant-eating moths. Different exposure to light adjusted how *M. separate* moths regulated their photo transduction system in fruit flies, clock rhythms, and taste and olfactory reception processes. *T. castaneum* responded to UV light by producing higher stress-

related genes, including cytochrome P450 members and Hsp proteins (Schoville et al., 2018). The UV exposure caused substantial increases in the activity level of eleven heat shock protein genes in *Drosophila melanogaster*. Research into molecules will give us better insights into how insects respond to light movement.

Insects need light to survive normal photoperiod conditions, which help them progress in their life cycle. The development of night artificial lights allows scientists to extend photo hours in an insect's natural environment. Artificial light outside daylight hours directly relates to insects' light-dark cycle, but specific light wavelengths affect both their daily survival and life span (Greeter, 2019). Research shows that night light exposure with specific wavelengths affects insect development, while different biological measures depend on light wavelength and time duration. For 24 hours, LED light affected all life stages of *M. separate* and harmed their physical development while changing light settings. White light did not affect the regular hatching and emerging rates or stage development times but lowered larval survival, pupation, and adult survival rates below control levels.

When *M. separata* and *H. armigera* insects were exposed to UV light (365 nm), they exhibited reduced hatch rate and duration, declined larval survival, and slowed growth. At the same time, cocoon transformation and adult life span were also impaired. Prolonged exposure to UV light increases these detrimental effects. The initial insect pests' eggs received damage in F1 generation, but no harm struck later life stages (Dadlani & Yadava, 2023). House and oriental latrine flies (*Chrysomya megacephala*) hatched weakly when exposed to lights emitting at 435 nm wavelength. Light with specific wavelengths affects the reproductive capacity and life span of things exposed.

The reproductive success and lifespan of *G. molesta* female moths declined when raised under green light at night compared to a control group. The winter moth *Operophtera brumata* experiences sexual challenges during its mating due to various artificial lights, mainly when it receives green or red-light sources (Ramakers, 2019). How light affects how often females reproduce affects how long adults live. More offspring from female light exposure could shorten their natural lifespan. UV light exposure of 365 nm for one hour daily raised *M. separate* moth fertility and egg-laying while decreasing lifespan. *H. amigera* females under 5 hours daily UV (365 nm) exposure produced more eggs and laid them more frequently, yet their lifespan was reduced for both genders. Certain wavelengths of night light alter insect biology by affecting juvenile hormones. This h (JH) is insect development and other life processes. The JH concentrations in *H. amigera* decreased steadily with increasing exposure to UV light because UV radiation affected how these insects develop. Developed scientists believe excessive light stress from UV radiation modifies the natural development of moths under UV lighting (Bi et al., 2021). Researchers need to find better proof about why individual lights affect insect biology so strongly.

Conclusions and Prospective Outlook

For centuries, scientists have recognized the phototactic actions of insects as people traditionally used flames to capture bug pests. In recent decades, research on insect phototactic mechanisms has enabled scientists to establish practical pest traps with specific light sources. Despite recent research, the underlying reason for insect

phototactic behavior remains unclear because practical pest management requires effective and practical light traps. The development of efficient light traps becomes feasible by utilizing LED lights. Current technological development allows the fabrication of traps with various wavelength-emitting LED lights, which are now commonly used for physical pest control within Integrated Pest Management (IPM) worldwide. Research into insect-light resource relationships in biology should target a full explanation of why insects respond to light to produce better environmentally friendly and budget-friendly light traps.

References

- Acquarone, E., Argyrousi, E. K., Van Den Berg, M., Gulisano, W., Fà, M., Staniszewski, A., Calcagno, E., Zuccarello, E., D'Adamio, L., Deng, S., Puzzo, D., Arancio, O., & Fiorito, J. (2019). Synaptic and memory dysfunction induced by tau oligomers is rescued by up-regulation of the nitric oxide cascade. *Molecular Neurodegeneration*, 14(1), 26. <https://doi.org/10.1186/s13024-019-0326-4>
- Alberto, D. a. S., Rusch, C., Zhan, Y., Straw, A. D., Montell, C., & Riffell, J. A. (2022). The olfactory gating of visual preferences to human skin and visible spectra in mosquitoes. *Nature Communications*, 13(1), 555. <https://doi.org/10.1038/s41467-022-28195-x>
- Ankel-Simons, F. (2024). *Primate anatomy: Introduction to Extant Primates*. Elsevier.
- Au, D. D., Liu, J. C., Nguyen, T. H., Foden, A. J., Park, S. J., Dimalanta, M., Yu, Z., & Holmes, T. C. (2022). Nocturnal mosquito Cryptochrome 1 mediates greater electrophysiological and behavioral responses to blue light relative to diurnal mosquito Cryptochrome 1. *Frontiers in Neuroscience*, 16, 1042508. <https://doi.org/10.3389/fnins.2022.1042508>
- Auxillos, J., Crouigneau, R., Li, Y., Dai, Y., Stigliani, A., Tavernaro, I., Resch-Genger, U., Sandelin, A., Marie, R., & Pedersen, S. F. (2024). Spatially resolved analysis of microenvironmental gradient impact on cancer cell phenotypes. *Science Advances*, 10(18), eadn3448. <https://doi.org/10.1126/sciadv.adn3448>
- Bachmann, J. (2023). Mechanistic investigations of on-demand light degradable polymeric materials. <https://doi.org/10.5204/thesis.eprints.239044>
- Bariami, V. (2013). Unraveling the molecular basis of pyrethroid resistance in dengue vector aedes aegypti. <https://doi.org/10.12681/eadd/30040>
- Barichello, J., Mariani, P., Vesce, L., Spadaro, D., Citro, I., Matteocci, F., Bartolotta, A., Di Carlo, A., & Calogero, G. (2023). Bifacial dye-sensitized solar cells for indoor and outdoor renewable energy-based application. *Journal of Materials Chemistry C*, 12(7), 2317–2349. <https://doi.org/10.1039/d3tc03220e>
- Bhartia, R., Beegle, L. W., DeFlores, L., Abbey, W., Hollis, J. R., Uckert, K., Monacelli, B., Edgett, K. S., Kennedy, M. R., Sylvia, M., Aldrich, D., Anderson, M., Asher, S. A., Bailey, Z., Boyd, K., Burton, A. S., Caffrey, M., Calaway, M. J., Calvet, R., . . . Zan, J. (2021). Perseverance's Scanning Habitable Environments with Raman and Luminescence for Organics and Chemicals (SHERLOC) Investigation. *Space Science Reviews*, 217(4). <https://doi.org/10.1007/s11214-021-00812-z>

- Bi, W., Li, H., Hui, D., Gaff, M., Lorenzo, R., Corbi, I., Corbi, O., & Ashraf, M. (2021). Effects of chemical modification and nanotechnology on wood properties. *Nanotechnology Reviews*, 10(1), 978–1008. <https://doi.org/10.1515/ntrev-2021-0065>
- Broser, M., Spreen, A., Konold, P. E., Schiewer, E., Adam, S., Borin, V., Schapiro, I., Seifert, R., Kennis, J. T. M., Sierra, Y. a. B., & Hegemann, P. (2020). NeoR, a near-infrared absorbing rhodopsin. *Nature Communications*, 11(1), 5682. <https://doi.org/10.1038/s41467-020-19375-8>
- Burte, V., Cointe, M., Perez, G., Mailleret, L., & Calcagno, V. (2023). When complex movement yields simple dispersal: behavioural heterogeneity, spatial spread and parasitism in groups of micro-wasps. *Movement Ecology*, 11(1), 13. <https://doi.org/10.1186/s40462-023-00371-8>
- Coleman, J. L., Lum, D. W. H., & Yao, X. (2023). From sodium-vapour to LEDs: how an outdoor lighting retrofit affects insects in Singapore. *Journal of Urban Ecology*, 9(1). <https://doi.org/10.1093/jue/juad009>
- Cowan, T. (2009). Light attraction of the Indian meal moth, *Plodia interpunctella* (Hübner) (Lepidoptera pyralidae), and regional spectral sensitivity of its compound eye.
- Cui, L., Li, S., Wang, S., Wu, X., Liu, Y., Yu, W., Wang, Y., Tang, Y., Xia, M., & Li, B. (2024). Major depressive disorder: hypothesis, mechanism, prevention and treatment. *Signal Transduction and Targeted Therapy*, 9(1), 30. <https://doi.org/10.1038/s41392-024-01738-y>
- Currea, J. P., Sondhi, Y., Kawahara, A. Y., & Theobald, J. (2023). Measuring compound eye optics with microscope and microCT images. *Communications Biology*, 6(1), 246. <https://doi.org/10.1038/s42003-023-04575-x>
- Dadlani, M., & Yadava, D. K. (2023). Seed science and technology. <https://doi.org/10.1007/978-981-19-5888-5>
- Deppisch, P., Kirsch, V., Helfrich-Förster, C., & Senthilan, P. R. (2023). Contribution of cryptochromes and photolyases for insect life under sunlight. *Journal of Comparative Physiology A*, 209(3), 373–389. <https://doi.org/10.1007/s00359-022-01607-5>
- Derrickson, B. H. (2024). *Human physiology*. John Wiley & Sons.
- Dhanaraju, M., Chenniappan, P., Ramalingam, K., Pazhanivelan, S., & Kaliaperumal, R. (2022). Smart Farming: Internet of Things (IoT)-Based Sustainable agriculture. *Agriculture*, 12(10), 1745. <https://doi.org/10.3390/agriculture12101745>
- Drozdova, P., Kizenko, A., Saranchina, A., Gurkov, A., Firulyova, M., Govorukhina, E., & Timofeyev, M. (2021). The diversity of opsins in Lake Baikal amphipods (Amphipoda: Gammaridae). *BMC Ecology and Evolution*, 21(1), 81. <https://doi.org/10.1186/s12862-021-01806-9>
- Du, X., Butler, A. G., & Chen, H. Y. (2024). Cell-cell interaction in the pathogenesis of inherited retinal diseases. *Frontiers in Cell and Developmental Biology*, 12, 1332944. <https://doi.org/10.3389/fcell.2024.1332944>
- Gallego, G., Delbruck, T., Orchard, G., Bartolozzi, C., Taba, B., Censi, A., Leutenegger, S., Davison, A. J., Conradt, J., Daniilidis, K., & Scaramuzza, D. (2020). Event-Based Vision: a survey. *IEEE Transactions on Pattern Analysis*

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

- and Machine Intelligence, 44(1), 154–180.
<https://doi.org/10.1109/tpami.2020.3008413>
- Gencturk, S., & Unal, G. (2024). Rodent tests of depression and anxiety: Construct validity and translational relevance. *Cognitive Affective & Behavioral Neuroscience*, 24(2), 191–224. <https://doi.org/10.3758/s13415-024-01171-2>
- Gire, D. H., Zak, J. D., Bourne, J. N., Goodson, N. B., & Schoppa, N. E. (2019). Balancing Extrasynaptic Excitation and Synaptic Inhibition within Olfactory Bulb Glomeruli. *eNeuro*, 6(4), ENEURO.0247-19.2019. <https://doi.org/10.1523/eneuro.0247-19.2019>
- Greeter, J. (2019). Damping at Every Turn: Maneuvers and Stability in the Free Flight of Hawkmoth *Manduca sexta*. Carolina Digital Repository (University of North Carolina at Chapel Hill). <https://doi.org/10.17615/cex8-rp49>
- Guzy, J. C., Falk, B. G., Smith, B. J., Willson, J. D., Reed, R. N., Aumen, N. G., Avery, M. L., Bartoszek, I. A., Campbell, E., Cherkiss, M. S., Claunch, N. M., Currylow, A. F., Dean, T., Dixon, J., Engeman, R., Funck, S., Gibble, R., Hengstebeck, K. C., Humphrey, J. S., . . . Hart, K. M. (2023). Burmese pythons in Florida: A synthesis of biology, impacts, and management tools. *NeoBiota*, 80, 1–119. <https://doi.org/10.3897/neobiota.80.90439>
- Harvey, J. A., Tougeron, K., Gols, R., Heinen, R., Abarca, M., Abram, P. K., Basset, Y., Berg, M., Boggs, C., Brodeur, J., Cardoso, P., De Boer, J. G., De Snoo, G. R., Deacon, C., Dell, J. E., Desneux, N., Dillon, M. E., Duffy, G. A., Dyer, L. A., . . . Chown, S. L. (2022). Scientists' warning on climate change and insects. *Ecological Monographs*, 93(1). <https://doi.org/10.1002/ecm.1553>
- Hospital, M. E., London, Kingdom, U., London, U. C., London, Kingdom, U., London, K. C., London, & Kingdom, U. (2022). Abstracts of the 59th Symposium of the International Society for Clinical Electrophysiology of Vision (ISCEV): Liverpool, 3–6 August, 2022. *Documenta Ophthalmologica*, 145(S1), 3–36. <https://doi.org/10.1007/s10633-022-09886-8>
- Keesey, I. W., Grabe, V., Gruber, L., Koerte, S., Obiero, G. F., Bolton, G., Khallaf, M. A., Kunert, G., Lavista-Llanos, S., Valenzano, D. R., Rybak, J., Barrett, B. A., Knaden, M., & Hansson, B. S. (2019). Inverse resource allocation between vision and olfaction across the genus *Drosophila*. *Nature Communications*, 10(1), 1162. <https://doi.org/10.1038/s41467-019-09087-z>
- Kirthika, S., Goel, G., Matthews, A., & Goel, S. (2022). Review of the untapped potentials of antimicrobial materials in the construction sector. *Progress in Materials Science*, 133, 101065. <https://doi.org/10.1016/j.pmatsci.2022.101065>
- Kumar, Y., Koul, A., Singla, R., & Ijaz, M. F. (2022). Artificial intelligence in disease diagnosis: a systematic literature review, synthesizing framework and future research agenda. *Journal of Ambient Intelligence and Humanized Computing*, 14(7), 8459–8486. <https://doi.org/10.1007/s12652-021-03612-z>
- Labbé, F., Abdeladhim, M., Abrudan, J., Araki, A. S., Araujo, R. N., Arensburger, P., Benoit, J. B., Brazil, R. P., Bruno, R. V., Da Silva Rivas, G. B., De Abreu, V. C., Charamis, J., Coutinho-Abreu, I. V., Da Costa-Latgé, S. G., Darby, A., Dillon, V. M., Emrich, S. J., Fernandez-Medina, D., Gontijo, N. F., . . . McDowell, M. A. (2023). Genomic analysis of two phlebotomine sand fly

- vectors of *Leishmania* from the New and Old World. *PLoS Neglected Tropical Diseases*, 17(4), e0010862. <https://doi.org/10.1371/journal.pntd.0010862>
- Leung, D. Y. M., Akdis, C. A., Bacharier, L. B., Cunningham-Rundles, C., Sicherer, S. H., & Sampson, H. A. (2020). *Pediatric Allergy, E-Book: Principles and Practice*. Elsevier Health Sciences.
- Leving, Y. (2019). Chapter three. *STRUCTURE*. In Academic Studies Press eBooks (pp. 125–242). <https://doi.org/10.1515/9781618117045-008>
- Marty, B. (2020). Origins and early evolution of the atmosphere and the oceans. *Geochemical Perspectives*, 9(2), 135–313. <https://doi.org/10.7185/geochempersp.9.2>
- Millard, J., Outhwaite, C. L., Kinnersley, R., Freeman, R., Gregory, R. D., Adedaja, O., Gavini, S., Kioko, E., Kuhlmann, M., Ollerton, J., Ren, Z., & Newbold, T. (2021). Global effects of land-use intensity on local pollinator biodiversity. *Nature Communications*, 12(1), 2902. <https://doi.org/10.1038/s41467-021-23228-3>
- Mittal, D., Kaur, G., Singh, P., Yadav, K., & Ali, S. A. (2020). Nanoparticle-Based Sustainable Agriculture and Food Science: Recent advances and Future Outlook. *Frontiers in Nanotechnology*, 2. <https://doi.org/10.3389/fnano.2020.579954>
- Montgomery, G. A., Belitz, M. W., Guralnick, R. P., & Tingley, M. W. (2021). Standards and Best practices for monitoring and Benchmarking Insects. *Frontiers in Ecology and Evolution*, 8. <https://doi.org/10.3389/fevo.2020.579193>
- Neath, D. O. (2019). Preliminary investigations into the genetic variation of three armyworm species, *Spodoptera exigua*, *Spodoptera latifascia* and *Spodoptera frugiperda* in Jamaica.
- Oonincx, D., & Finke, M. (2020). Nutritional value of insects and ways to manipulate their composition. *Journal of Insects as Food and Feed*, 7(5), 639–659. <https://doi.org/10.3920/jiff2020.0050>
- Pimbert, M. P., & Barry, B. (2021). Let the people decide: citizen deliberation on the role of GMOs in Mali's agriculture. *Agriculture and Human Values*, 38(4), 1097–1122. <https://doi.org/10.1007/s10460-021-10221-1>
- Preti, M., Verheggen, F., & Angeli, S. (2020a). Insect pest monitoring with camera-equipped traps: strengths and limitations. *Journal of Pest Science*, 94(2), 203–217. <https://doi.org/10.1007/s10340-020-01309-4>
- Preti, M., Verheggen, F., & Angeli, S. (2020b). Insect pest monitoring with camera-equipped traps: strengths and limitations. *Journal of Pest Science*, 94(2), 203–217. <https://doi.org/10.1007/s10340-020-01309-4>
- Prigge, C. L., Yeh, P., Liou, N., Lee, C., You, S., Liu, L., McNeill, D. S., Chew, K. S., Hattar, S., Chen, S., & Zhang, D. (2016). M1 ipRGCs Influence Visual Function through Retrograde Signaling in the Retina. *Journal of Neuroscience*, 36(27), 7184–7197. <https://doi.org/10.1523/jneurosci.3500-15.2016>
- Ramakers, J. J. C. (2019). Quantifying evolution in wild populations. <https://doi.org/10.18174/472942>
- Saiti, E., & Theoharis, T. (2020). An application independent review of multimodal 3D registration methods. *Computers & Graphics*, 91, 153–178.

- <https://doi.org/10.1016/j.cag.2020.07.012>
- Samir, A., Ashour, F. H., Hakim, A. a. A., & Bassyouni, M. (2022). Recent advances in biodegradable polymers for sustainable applications. *Npj Materials Degradation*, 6(1). <https://doi.org/10.1038/s41529-022-00277-7>
- Sandhi, R. K., & Reddy, G. V. P. (2020). Biology, ecology, and management strategies for pea aphid (Hemiptera: aphididae) in pulse crops. *Journal of Integrated Pest Management*, 11(1). <https://doi.org/10.1093/jipm/pmaa016>
- Schoville, S. D., Chen, Y. H., Andersson, M. N., Benoit, J. B., Bhandari, A., Bowsher, J. H., Brevik, K., Cappelle, K., Chen, M. M., Childers, A. K., Childers, C., Christiaens, O., Clements, J., Didion, E. M., Elpidina, E. N., Engsontia, P., Friedrich, M., García-Robles, I., Gibbs, R. A., . . . Richards, S. (2018). A model species for agricultural pest genomics: the genome of the Colorado potato beetle, *Leptinotarsa decemlineata* (Coleoptera: Chrysomelidae). *Scientific Reports*, 8(1), 1931. <https://doi.org/10.1038/s41598-018-20154-1>
- Sharkey, C. R., Blanco, J., Leibowitz, M. M., Pinto-Benito, D., & Wardill, T. J. (2020). The spectral sensitivity of *Drosophila* photoreceptors. *Scientific Reports*, 10(1), 18242. <https://doi.org/10.1038/s41598-020-74742-1>
- Shevlin, H. (2020). Rethinking creative intelligence: comparative psychology and the concept of creativity. *European Journal for Philosophy of Science*, 11(1). <https://doi.org/10.1007/s13194-020-00323-8>
- Stefanov, A., Novelli, E., & Stretto, E. (2019). Bipolar cells in Retinitis Pigmentosa - Influence of the age of onset on the nature and severity of remodeling. *Florence Research (University of Florence)*. <http://hdl.handle.net/2158/1151614>
- Suher, J., Szocs, C., & Van Ittersum, K. (2021). When imperfect is preferred: the differential effect of aesthetic imperfections on choice of processed and unprocessed foods. *Journal of the Academy of Marketing Science*, 49(5), 903–924. <https://doi.org/10.1007/s11747-021-00783-1>
- Sundar, J. C., Munezero, D., Bryan-Haring, C., Saravanan, T., Jacques, A., & Ramamurthy, V. (2019). Rhodopsin signaling mediates light-induced photoreceptor cell death in rd10 mice through a transducin-independent mechanism. *Human Molecular Genetics*, 29(3), 394–406. <https://doi.org/10.1093/hmg/ddz299>
- Susana, R. R. (2025). Expressing surprise at the crossroads. <https://doi.org/10.1515/9783111386683>
- Todaro, L., Galbiati, A., Lo Giudice, V., & Turkulin, H. (2022). Wood in sport equipment - heritage, present, perspective. In *DISAFA, University of Torino, Italy eBooks*. <https://doi.org/10.22382/book-2022-01>
- Tsai, C., Childers, R. A., Shi, N. N., Ren, C., Pelaez, J. N., Bernard, G. D., Pierce, N. E., & Yu, N. (2020). Physical and behavioral adaptations to prevent overheating of the living wings of butterflies. *Nature Communications*, 11(1), 551. <https://doi.org/10.1038/s41467-020-14408-8>
- Urquhart, A. S., Gluck-Thaler, E., & Vogan, A. A. (2024). Gene acquisition by giant transposons primes eukaryotes for rapid evolution via horizontal gene transfer. *Science Advances*, 10(49), eadp8738. <https://doi.org/10.1126/sciadv.adp8738>

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

- Wang, Q., & Lin, C. (2020). Mechanisms of Cryptochrome-Mediated photoresponses in plants. *Annual Review of Plant Biology*, 71(1), 103–129. <https://doi.org/10.1146/annurev-arplant-050718-100300>
- Xiang, H., Xing, Y., Dai, F., Wang, H., Su, L., Miao, L., Zhang, G., Wang, Y., Qi, X., Yao, L., Wang, H., Zhao, B., Li, J., & Zhou, Y. (2021). High-entropy ceramics: Present status, challenges, and a look forward. *Journal of Advanced Ceramics*, 10(3), 385–441. <https://doi.org/10.1007/s40145-021-0477-y>