IMPACT OF LIGHT POLLUTION ON MENTAL HEALTH

Module 1: Foundations of Light and Health

Objectives:

- To establish a fundamental understanding of light as an environmental factor and its natural and artificial forms.
- To introduce the concept of light pollution and its primary sources.
- To explain the basic biological mechanisms through which light affects human physiology.

Learner Content:

- Introduction of light pollution: Review of the electromagnetic spectrum, with a focus on visible light and its characteristics (intensity, color temperature, spectral composition).
- Researches on impact of artificial light on human health
- Physiological Basics: Introduction to the eye's non-visual light detection system, focusing on ipRGCs (intrinsically photosensitive retinal ganglion cells) and the role of the hormone melatonin.

Learning Outcomes:

Upon completion, the learner will be able to:

- Define light pollution and identify its main types and sources.
- Explain the pathway through which non-visual light information travels from the eye to the brain's clock.
- Distinguish between natural light exposure and disruptive artificial light exposure.

Co-funded by the European Union

1.1. Introduction to Light Pollution

This section will define light pollution and its various forms, such as skyglow, light trespass, and glare. We'll explore the historical context of artificial lighting and the increasing prevalence of light pollution in urban environments.

Light pollution is the excessive, misdirected, or obtrusive use of artificial light. It's an unintended consequence of industrial civilization. It includes several distinct forms:

- **Skyglow:** The diffuse, bright haze over urban areas that's caused by the collective light from a city reflecting off atmospheric particles. It's why you can't see many stars from a city.
- **Light Trespass:** Light falling where it's not wanted, like a neighbor's security light shining into your bedroom window.
- **Glare:** Excessive brightness that causes visual discomfort, often from poorly shielded lights.
- **Clutter:** Excessive and confusing groups of bright lights, often seen along commercial strips.

Historically, humans relied on natural light sources like the sun, moon, and fire. The invention of the electric light bulb in the late 19th century fundamentally changed this, allowing for extended activity into the night. While this brought unprecedented productivity and safety benefits, it also marked the beginning of modern light pollution. The increasing prevalence of urban environments and the widespread adoption of powerful, often unshielded, lighting fixtures have exacerbated the issue. Today, the problem is not just about brightness but also about the **spectrum** of the light, with LED lights, rich in blue wavelengths, posing specific biological concerns. Light pollution is now recognized as a global environmental issue that affects not only astronomical observation but also human health and ecosystems.

Co-funded by
the European Union

1.2. Researches on the Impact of Artificial Light on Human Health

This part will cover the physiological effects of artificial light exposure. We'll examine the impact on **sight**, including issues like **eye strain and glare-related vision problems.** We'll also delve into the connection between light pollution and **"diseases of civilization,"** such as **obesity and cardiovascular disease**, and explore the mechanisms by which light at night can disrupt metabolic processes. The module will also address the growing body of research linking nighttime light exposure to increased **cancer risks**, particularly breast and prostate cancer, by discussing the role of **melatonin** as a tumor-suppressing hormone.

Impact on Sight and Vision

The most immediate and direct effect of artificial light is on the visual system. Prolonged exposure to poor-quality lighting can lead to **eye strain**, a common condition characterized by tired, aching, and itchy eyes, blurred vision, and headaches. This is often exacerbated by **glare**, which is excessive brightness that interferes with vision.

Co-funded by
the European Union

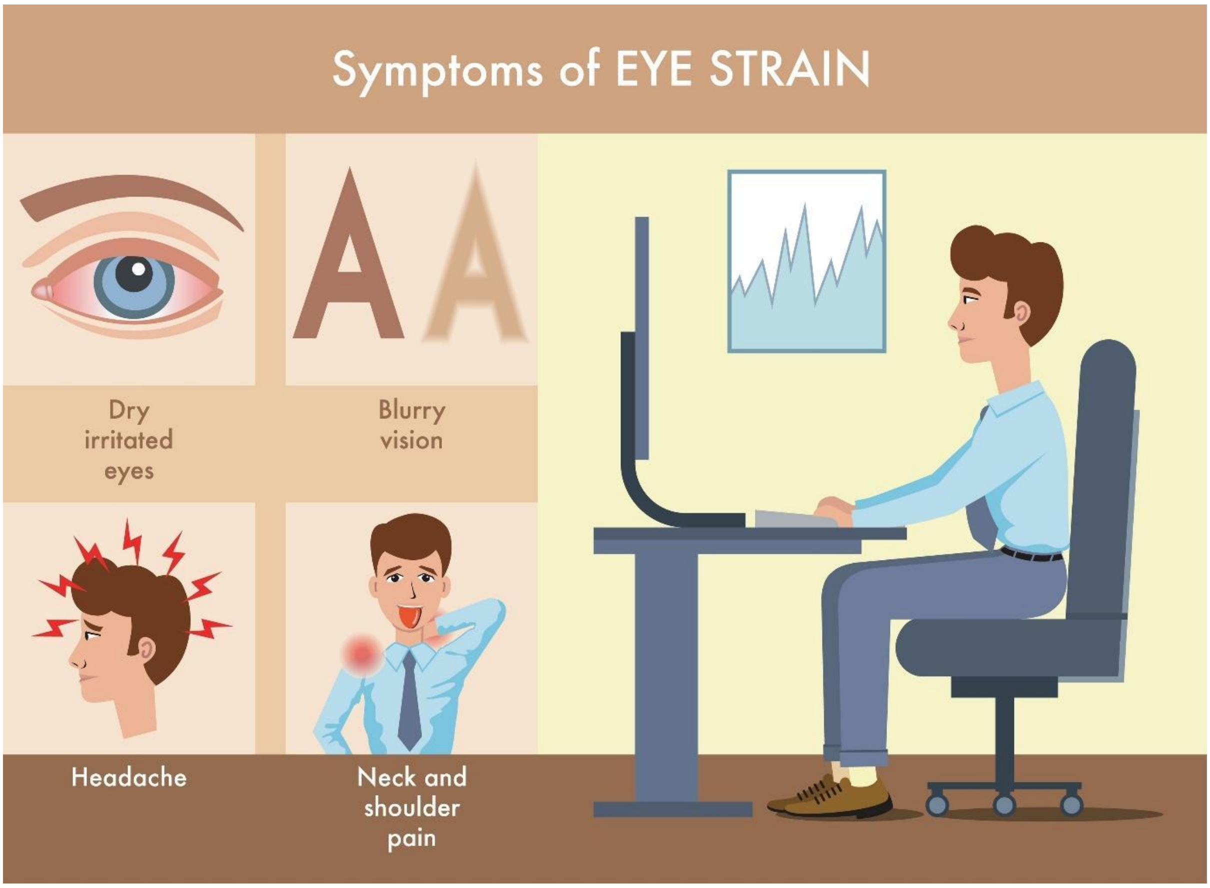

Fig. 1. Symptoms of Eye strain

Glare can be direct (from a light source) or reflected (from a shiny surface), and it significantly reduces visual performance and comfort. Modern **LED lighting**, particularly those with a strong **blue-light component**, can be a major source of glare and have been linked to an increased risk of long-term **retinal damage**.

Light Pollution and "Diseases of Civilization"

Beyond visual effects, **artificial light at night** (ALAN) is increasingly recognized as a contributing factor to various chronic conditions often referred to as "diseases of civilization," which are lifestyle-related illnesses prevalent in **developed countries**.

Co-funded by the European Union

- **Obesity and metabolic disruption:** Research has shown a strong correlation between exposure to light at night and a higher body mass index (BMI). The mechanism behind this is linked to the **disruption of metabolic processes**. ***The body's metabolism is synchronized with the circadian rhythm***; for example, the liver and pancreas operate on a 24-hour cycle. When ALAN suppresses melatonin and alters the circadian clock, it can lead to **insulin resistance**, **poor glucose control**, and **altered appetite hormones**, all of which promote weight gain and increase the risk of developing **Type 2 diabetes**.
- **Cardiovascular Disease:** The same disruption to the circadian rhythm can also negatively impact cardiovascular health. Studies have demonstrated a link between nighttime light exposure and increased blood pressure and heart rate. This is thought to be due to a chronic state of heightened sympathetic nervous system activity (the "fight-or-flight" response) that should normally decrease during rest.

Increased cancer risks and melatonin's role

A particularly alarming area of research concerns the link between nighttime light exposure and an elevated risk of certain cancers, most notably **breast and prostate cancer**. The central biological mechanism connecting these is the hormone **melatonin**.

Melatonin, often called the "**hormone of darkness**," is a powerful antioxidant and has oncostatic (tumor-suppressing) properties. It helps regulate cell growth, apoptosis (programmed cell death), and protects DNA from damage. Its production is directly tied to the light-dark cycle, with the pineal gland secreting melatonin only in the absence of light.

When we are exposed to artificial light at night, especially blue-rich light from screens and LED fixtures, the melatonin signal is suppressed. This chronic suppression leads to:

- **Reduced antioxidant пrotection:** The body loses some of its natural defense against DNA damage and oxidative stress.

Co-funded by
the European Union

- **Impaired immune surveillance:** Melatonin plays a role in regulating immune function, and its suppression may weaken the body's ability to detect and destroy cancerous cells.
- **Promotion of hormone-sensitive cancers:** For breast and prostate cancer, which are often hormone-sensitive, the disruption of melatonin (which can influence sex hormone levels) is believed to create a more favorable environment for tumor growth.

The growing body of research from both epidemiological studies and laboratory experiments strongly suggests that the widespread use of artificial lighting at night is an unaddressed environmental risk factor for these serious health conditions.

1.3. Human Circadian Rhythm, Sleep, and Melatonin Production

This is a core component. We will explain the concept of the **circadian rhythm**, the body's internal 24-hour clock that regulates various physiological processes. The role of the suprachiasmatic nucleus (SCN) in the hypothalamus as the master clock will be detailed. We will then focus on the critical relationship between light, the SCN, and the pineal gland's production of **melatonin**. We'll discuss how exposure to artificial light at night, especially blue light, suppresses melatonin secretion, thereby disrupting the sleep-wake cycle.

The **circadian rhythm** is our body's internal 24-hour biological clock. It orchestrates a vast array of physiological processes, from sleep-wake cycles and hormone release to body temperature and metabolism. This rhythm is synchronized primarily by external cues, with light being the most powerful.

- ***The Master Clock: The Suprachiasmatic Nucleus (SCN)***

At the heart of this system is the **suprachiasmatic nucleus (SCN)**, a tiny cluster of neurons located in the **hypothalamus** of the brain. The SCN is considered the body's **"master clock"** because it receives and processes light signals directly from the eyes. Specifically, specialized photoreceptors in the retina, called intrinsically photosensitive retinal ganglion cells (ipRGCs), detect light and transmit this information to the SCN.

Co-funded by the European Union

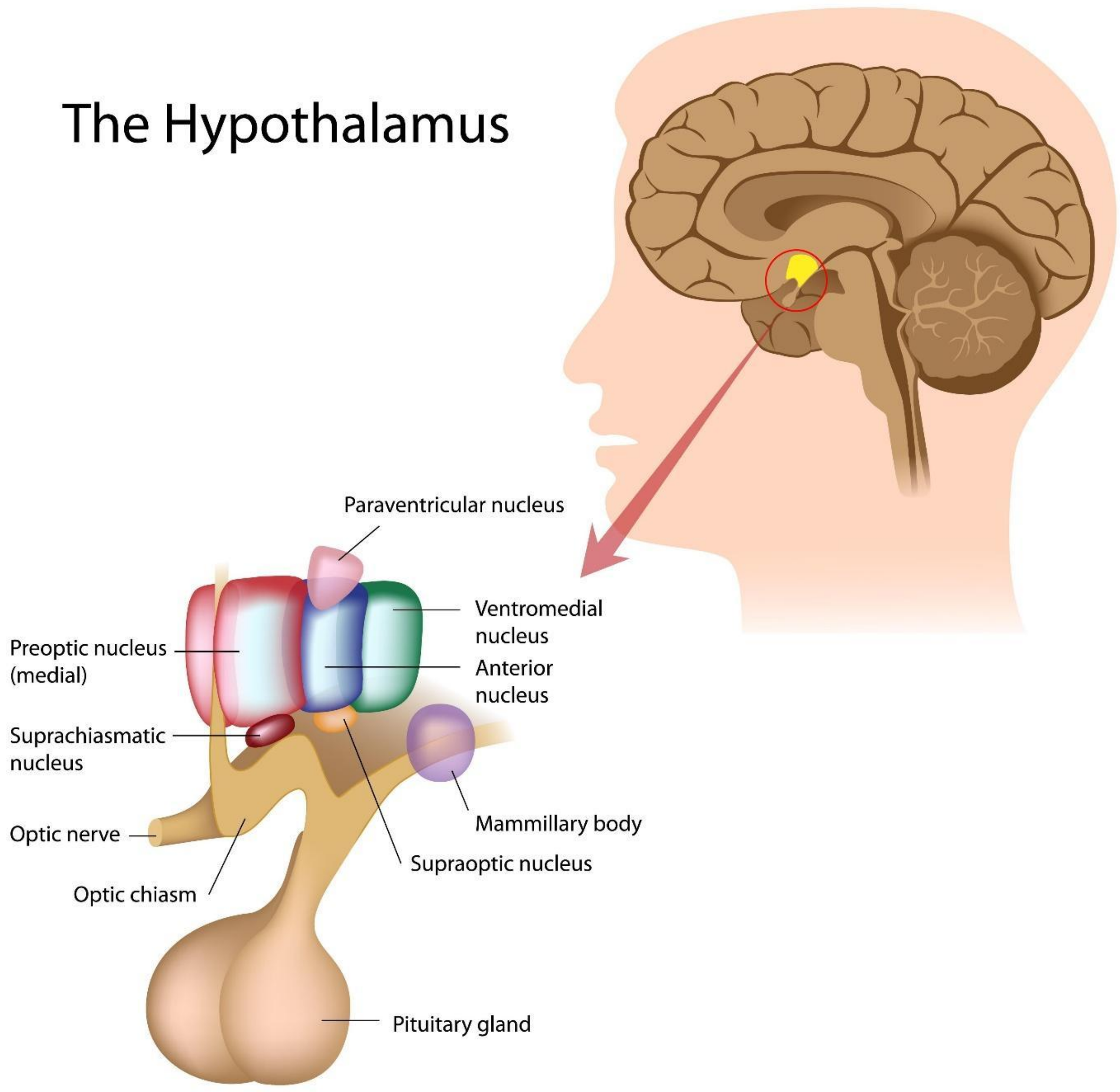

Fig. 2. The Master clock: SCN

This allows the SCN to align the body's internal clock with the external environment, ensuring that our biological processes occur at the appropriate time of day.

- ***The Light-SCN-Melatonin Pathway***

The relationship between light, the SCN, and the pineal gland is a critical feedback loop that governs our sleep-wake cycle. The **pineal gland** is a small endocrine gland located deep in the brain. Its primary function is to produce and secrete the hormone **melatonin**.

- **Darkness and melatonin production:** During periods of darkness, the SCN signals the pineal gland to increase melatonin production. Melatonin then circulates throughout the body, signaling that it is time to sleep and promoting a state of physiological rest.
- **Light and melatonin suppression:** When light hits the retina, the ipRGCs send a strong signal to the SCN. The SCN, in turn, inhibits the pineal gland's production of melatonin. This suppression of the "sleep hormone" is a key mechanism for waking us up and keeping us alert during the day.

The Role of Artificial Light and Blue Light

The advent of modern artificial lighting has profoundly disrupted this natural system. Exposure to artificial light at night (ALAN), particularly light rich in **blue wavelengths** (commonly emitted by smartphones, tablets, computers, and modern LED lighting), is highly effective at suppressing melatonin production. This is because the ipRGCs in the eye are most sensitive to blue light. Even a small amount of blue light exposure in the evening can trick the SCN into thinking it's daytime, leading to a significant and immediate drop in melatonin levels. This disruption delays the onset of sleep, compromises sleep quality, and can lead to a chronic misalignment between our internal biological clock and our actual sleep schedule, a condition known as **circadian rhythm disruption**.

Co-funded by
the European Union

Module 2: The Circadian Rhythm and Mental Health

Objectives:

- To detail the **central role of the circadian rhythm** in regulating human physiological processes.
- To analyze the **specific negative impacts** of light pollution on sleep, mood, and cognitive function.
- To connect **circadian disruption** directly to various mental and physical health issues.

Learner Content:

- **The Master Clock:** Deep dive into the **Suprachiasmatic Nucleus (SCN)** and its role as the central pacemaker, regulated by the light-dark cycle.
- **Impact on sleep:** Examination of how **exposure to blue-rich artificial light** at night suppresses melatonin, leading to sleep onset insomnia, reduced REM sleep, and poor sleep quality.
- **Mental health implications:** Exploration of the link between chronic circadian misalignment (due to light pollution) and increased risk for **depression, anxiety, mood disorders**, and **impaired cognitive performance** (e.g., memory and attention).

Learning Outcomes:

Upon completion, the learner will be able to:

- **Describe** the function of the SCN and how light timing *entrains* the human body clock.
- **Articulate** how nocturnal light exposure negatively affects sleep quality and quantity.
- **Summarize** the evidence linking circadian rhythm disruption from light pollution to common mental health conditions.

Co-funded by
the European Union

2.1. Researches on Circadian Rhythm – Nobel Prize in Medicine 2017

This segment will be an in-depth look at the groundbreaking research that earned Jeffrey C. Hall, Michael Rosbash, and Michael W. Young the 2017 Nobel Prize. We will explore their discovery of the molecular mechanisms that control the circadian rhythm, specifically the ***period* gene** and the proteins it produces. This will provide a solid scientific basis for understanding why rhythm disruption is so impactful.

The 2017 Nobel Prize in Physiology or Medicine was awarded to Jeffrey C. Hall, Michael Rosbash, and Michael W. Young for their groundbreaking discoveries of the molecular mechanisms controlling the circadian rhythm. Their work, primarily conducted using the fruit fly, *Drosophila melanogaster*, provided a definitive answer to a question that had long fascinated biologists: how do organisms internally synchronize their biology with the regular ebb and flow of a 24-hour day?

Their research revealed that the internal biological clock is governed by a self-sustaining feedback loop involving specific genes and the proteins they produce. The journey began in the 1980s when Hall and Rosbash, working together at Brandeis University, successfully isolated a gene they called the **period gene**. They were able to show that this gene played a crucial role in **controlling the fly's circadian rhythm.** A few years later, Michael W. Young, working independently at Rockefeller University, also made significant contributions by isolating and characterizing another key gene, the timeless gene.

The central discovery of the three laureates was the elegant, yet complex, molecular mechanism that makes the clock "tick." The period gene (per)

Co-funded by
the European Union

contains the instructions for making a protein known as PER. Similarly, the timeless gene (tim) provides the blueprint for the TIM protein. Throughout the day, as a new cycle begins, the per gene is actively expressed, leading to the gradual accumulation of PER protein within the cell. However, a twist in the tale was needed to explain how this process could be cyclical.

The key to the oscillation lies in the interaction between the PER and TIM proteins. The two proteins are able to bind together and form a complex. As the concentration of this PER-TIM complex reaches a certain threshold, a critical event occurs: the complex is able to enter the cell's nucleus. Once inside the nucleus, the complex acts as a negative regulator, effectively shutting down the very gene that created it—the per gene. This negative feedback loop means that as PER levels rise, they eventually inhibit their own production, causing the levels to fall again.

As the PER-TIM complex is gradually degraded by the cell, its inhibiting effect on the per gene diminishes. This allows the per gene to become active once more, starting the entire cycle over again. This intricate, self-regulating mechanism explains how the circadian rhythm is generated internally and maintained with remarkable precision. The process takes approximately 24 hours to complete, perfectly aligning with Earth’s rotation.

The profound impact of this research cannot be overstated. By revealing the fundamental molecular basis of the biological clock, Hall, Rosbash, and Young provided a scientific foundation for understanding how this rhythm influences virtually every aspect of our physiology. Disruptions to this highly synchronized system, whether from shift work, jet lag, or modern lifestyles, are no longer seen as mere inconveniences. We can now understand at a molecular level how such disruptions affect metabolic processes, cognitive function, and, as explored in other parts of this module, significantly impact mental health by disrupting the delicate balance of neurological and hormonal systems controlled by the body's internal clock.

Co-funded by
the European Union

2.2. Impact of Circadian Rhythm Disorder on Insomnia and Mental Health

Building on the previous module, this section will directly link circadian disruption to **insomnia**. We will discuss how chronic sleep deprivation and poor sleep quality contribute to a range of mental health issues. A primary focus will be on the strong correlation between circadian rhythm disorders and the increased risk of developing conditions such as **depression, anxiety, bipolar disorder, and seasonal affective disorder (SAD)**. We will explore the neural pathways and neurotransmitter systems (e.g., serotonin) that are affected by disrupted sleep and rhythm.

Building on the foundation laid by the Nobel-winning research, we can now directly link circadian disruption to one of its most prevalent manifestations: insomnia. Circadian rhythm disorder, a condition where the body's internal clock is out of sync with external cues, is a primary driver of chronic insomnia. The misaligned rhythm sends conflicting signals to the brain regarding wakefulness and sleep, making it difficult to fall asleep, stay asleep, or achieve restorative sleep. This chronic sleep deprivation and poor sleep quality are not merely physical ailments; they contribute significantly to a wide range of mental health issues.

The connection between disrupted circadian rhythms and mental health is supported by a strong body of research showing a significant correlation between circadian rhythm disorders and an increased risk of developing conditions such as depression, anxiety, bipolar disorder, and seasonal affective disorder (SAD). The neural pathways and neurotransmitter systems that regulate mood and cognition are highly sensitive to disruptions in the sleep-wake cycle. For example, the synthesis and regulation of key neurotransmitters like serotonin, often referred to as a "feel-good" chemical, are heavily influenced by the circadian rhythm. When the rhythm is disrupted, serotonin levels can fluctuate erratically, leading to mood instability and an increased vulnerability to depressive episodes.

Furthermore, a disrupted circadian rhythm can also impact the production of other hormones, such as melatonin, which signals to the body that it is time to sleep. In addition to regulating sleep, melatonin has been shown to have neuroprotective effects, and its dysregulation is implicated in mood disorders.

Co-funded by
the European Union

The stress hormone cortisol, which should naturally be low at night, may also be released at inappropriate times, further disrupting sleep and causing heightened anxiety and stress responses. Ultimately, the intricate biological mechanisms of the circadian rhythm are deeply intertwined with the brain's delicate neurochemical balance, and any sustained disruption can have profound and lasting consequences for an individual's mental and emotional well-being.

1. Depression (Major depressive disorder)

Aspect	**Detail**
Mechanism	The primary link is the dysregulation of **neurotransmitter systems** (like serotonin, dopamine, and norepinephrine) and **hormone rhythms** (like melatonin and cortisol) which are under circadian control. **Melatonin suppression** by light pollution is a key factor, as low or mistimed melatonin signals are associated with increased depressive symptoms. Chronic misalignment can also lead to **neuroinflammation**, which is implicated in the pathophysiology of depression.
Impact	Studies show that individuals living in areas with higher levels of outdoor ALAN have an **increased prevalence of depressive symptoms** and, in some cases, suicidal behaviors. Symptoms often include:
	- **Sleep abnormalities:** Insomnia or hypersomnia, a hallmark of MDD.
	- **Diurnal variation:** Symptoms (especially mood) often exhibit a pattern, being worse in the morning or evening, reflecting the misalignment of the body clock.
	- **Severity correlation:** The degree of misalignment is often correlated with the **severity of depressive symptoms**.

Co-funded by the European Union

Aspect	Detail
Evidence	Chronotherapies like **bright light therapy** (timed to *reset* the clock, often in the morning) are effective treatments for some types of depression, further supporting the central role of the circadian system.

2. Anxiety and mood disorders (including Bipolar Disorder)

Aspect	Detail
Mechanism	Similar to depression, anxiety and other mood disorders are affected by the breakdown of rhythmic physiological control. Circadian disruption leads to an **altered stress response**, specifically the dysregulation of the **Hypothalamic-Pituitary-Adrenal (HPA) axis** and **cortisol rhythm**. Normally, cortisol peaks in the morning and drops at night; misalignment can flatten or mistime this rhythm, increasing vulnerability to stress and anxiety.
Anxiety Impact	Increased ALAN exposure is associated with a **higher risk of anxiety symptoms**. This is often mediated by the resulting sleep problems, as chronic poor sleep is a major risk factor for anxiety disorders.
Mood Disorders Impact	In **Bipolar Disorder (BD)**, circadian disruption is considered a core feature. ALAN and sleep disruption are often triggers for **manic or hypomanic episodes** or shifts in mood cycling. The misalignment may exacerbate the genetic vulnerability to these disorders by destabilizing the brain's internal rhythmicity. Alterations in the **core clock genes** (like *CLOCK* and *BMAL1*) have been observed in individuals with mood disorders.

Co-funded by
the European Union

3. Impaired cognitive performance (memory and attention)

Aspect	Detail
Mechanism	Cognitive functions—like memory consolidation, sustained attention, and executive function—are not static; they exhibit **strong circadian rhythms**, with peak performance typically during the day. Chronic misalignment forces the brain to perform complex tasks during its **"biological night,"** a period when it's naturally programmed for rest and maintenance.
Attention & Alertness	Performance on tasks requiring **sustained attention** and **vigilance** is significantly impaired. Misalignment leads to increased **subjective sleepiness** and decreased overall alertness, resulting in slower reaction times and more errors, particularly in the early morning hours (the nadir of the body clock).
Memory	The process of **memory consolidation**—moving new information into long-term storage—largely occurs during sleep. Circadian misalignment, by causing fragmented and non-restorative sleep, disrupts the necessary neural activity (e.g., slow-wave sleep) for this consolidation. Chronic disruption can lead to **impaired learning** and difficulties in **working memory**.
Evidence	Studies simulating chronic circadian misalignment (e.g., in shift workers) consistently demonstrate significant decreases in cognitive throughput, information processing speed, and overall efficiency, which have serious implications for occupational safety and academic performance.

Co-funded by
the European Union

Module 3: Impact and mitigation strategies

Objectives:

- To explore the broader public health and environmental consequences of light pollution.
- To examine practical, interdisciplinary solutions to mitigate light pollution and its health effects.
- To review current research trends and areas for future study in chronobiology and environmental health.

Learner Content:

- Wider Impacts: Brief overview of light pollution's effect on wildlife (eco-chronobiology) and energy waste.
- Mitigation Strategies (Design & Policy): Review of effective lighting practices (e.g., warm color temperature, full shielding, lower intensity, strategic timing) and the role of public policy (e.g., Dark Sky initiatives, urban planning).
- Personal Health Strategies: Practical tips for learners on reducing personal light exposure (e.g., amber glasses, screen filters, optimizing bedroom darkness) and behavioral changes.
- Future Research: Discussion of ongoing studies into light's effect on metabolism, chronic disease (e.g., diabetes, cardiovascular health), and long-term neurocognitive effects.

Learning Outcomes:

Upon completion, the learner will be able to:

- Propose and justify effective lighting design principles (The 4 principles: Fully Shielded, Correct Spectrum, Appropriate Intensity, Only When Needed) for reducing light pollution.
- Identify at least three personal and three policy-level actions that can mitigate the negative health effects of artificial light at night.

Co-funded by
the European Union

- Connect the impact of light pollution on human health to its broader environmental and public health context.

3.1. Wider impacts

This module will address the legal dimension of the problem. We will examine existing and potential **legal frameworks** for regulating light pollution, including zoning ordinances, public nuisance laws, and international guidelines. This part will consider the rights of individuals to a healthy environment and the section for the law audience, connecting the scientific findings to practical legal applications.

Existing and Potential Legal Frameworks

Legal responses to light pollution typically operate at local, national, and international levels, utilizing a blend of specific regulations and general environmental and nuisance laws.

Zoning Ordinances

Zoning ordinances are local municipal laws that dictate land use and development standards. They are a primary tool for regulating light pollution by setting requirements for the **placement, type, and intensity of outdoor lighting** within specific geographical zones (e.g., residential, commercial, industrial). These ordinances often specify **"Dark-Sky Friendly"** requirements, such as mandating the use of **fully shielded fixtures** (directing light only downward) and limiting the color temperature of lights (e.g., warm white light below 3000K).

Building Codes

Building codes are regulations governing the design, construction, and alteration of structures. While generally focused on safety and structural integrity, modern codes are increasingly incorporating lighting efficiency and pollution standards. Their key focus is mandating the use of specific hardware,

Co-funded by
the European Union

such as **full cut-off fixtures**, or placing limits on the **total wattage or lumen output per area** for new construction and major renovations to prevent excessive light output.

Public Nuisance Laws

Public nuisance laws are civil and criminal statutes addressing acts that interfere with the public's enjoyment of community resources or quality of life. These laws address the specific problem of **light trespass** or excessive glare. Individuals can use these frameworks to legally challenge or litigate instances where misdirected artificial light unreasonably interferes with their property rights or public health.

Environmental protection acts

Environmental Protection Acts are national or state/provincial laws aimed at protecting the natural environment. The key focus here is incorporating light pollution as a form of **environmental degradation or pollution** that must be minimized. Although historically focused on air or water quality, these acts can be used to address the impact of artificial light on wildlife, such as migratory birds, insects, and nocturnal animals, thus framing the issue in a broader ecological context.

International guidelines

International guidelines are non-binding treaties, recommendations, or best-practice documents typically issued by bodies like the United Nations or the **International Dark-Sky Association (IDA)**. They serve to promote global cooperation and provide **models for national legislation**. These guidelines are particularly important for establishing areas of high protection, such as astronomical reserves, or addressing transboundary impacts of light pollution.

The Right to a Healthy Environment

A foundational concept in regulating light pollution is the recognition of an individual's or community's **right to a healthy environment**.

Co-funded by the European Union

In many jurisdictions, this right is explicitly guaranteed in the constitution, which can provide a strong legal basis for citizens to challenge government inaction or to support stringent light pollution controls.

The "Right to Starlight": While not universally recognized as a formal legal right, the concept represents the right to an environment free from disruptive artificial light, allowing for natural darkness and the visibility of the night sky. Legal arguments can frame light pollution as an infringement on aesthetic, cultural, and environmental interests.

Legal arguments increasingly link light pollution to documented health effects (disrupted circadian rhythms), positioning regulations as necessary public health measures, not just environmental protection.

Light pollution is an interdisciplinary challenge affecting more than just the human circadian system.

- **Ecological impact (Eco-Chronobiology)**

Light pollution acts as a powerful ecological stressor, disrupting the natural dark cycle that many organisms rely on.

- **Wildlife disruption**: ALAN affects key life cycle events regulated by natural light-dark cycles, including migration, reproduction, and foraging.
  - **Insects**: Moths and other nocturnal insects are drawn to bright lights, leading to exhaustion, predation, and local population declines. This disrupts the food web for insectivorous animals.
  - **Birds**: Migratory birds, which navigate using the stars and the Earth's magnetic field, can become disoriented by city lights, leading to fatal collisions with buildings.
  - **Sea Turtles**: Hatchlings on beaches instinctively crawl toward the brightest horizon (naturally the moon/ocean), but artificial beachfront lighting draws them inland, leading to death by dehydration or predators.

Co-funded by
the European Union

- **Plant life**: ALAN can disrupt the timing of budding and leaf shedding in some plant species, altering the seasonal behavior of entire ecosystems.

 Energy Waste and Economic Cost

Light pollution represents a massive waste of energy. Light that is directed upward or sideways (sky glow or light trespass) is not illuminating anything useful and is a direct loss of electricity.

- Lost energy: Estimates suggest that a significant portion of outdoor lighting energy is wasted due to inefficient fixtures and improper installation, contributing unnecessarily to greenhouse gas emissions and climate change.
- Economic burden: This wasted energy translates to billions of dollars in unnecessary electricity costs globally each year.

3.2. Mitigation strategies: Design and solutions

Effective mitigation requires a practical, interdisciplinary approach that combines responsible design with supportive public policy.

The 4 Principles are effective design lighting principles that allow us to reduce the negative impact of the ALAN. Lighting professionals and dark-sky advocates use these four principles to guide responsible outdoor lighting:

1. **Fully Shielded**

Use fixtures that emit no light above the horizontal plane (full cut-off). Eliminates glare and light trespass onto neighboring properties, and prevents sky glow.

2. **Correct spectrum (Warm Color Temperature)**

Limit the use of blue-rich light at night. The recommended spectrum is warm white or amber light (ideally 3000K or lower). This minimizes the suppression

Co-funded by
the European Union

of human melatonin and reduces the disruptive effect on wildlife and the SCN (the biological clock).

3. Appropriate intensity (Lower light levels)

Use the lowest light level necessary to safely complete a task (i.e., illuminate only to code or need). This reduces energy consumption and minimizes the biological and ecological impact of excessive brightness.

4. Only when needed (Strategic timing)

Use timers, motion sensors, or dimmers to ensure lights are on only when and where they are required. This saves energy, preserves darkness during peak biological sleep/activity hours, and enhances safety by drawing attention to movement.

Fig. 3. The 4 Principles for effective design lighting

Co-funded by
the European Union

Personal health strategies and behavioral changes

Strategy	Action	Rationale
Optimize Bedroom Darkness	Use **blackout curtains** and eliminate all sources of light (LED indicators, charger lights).	Even dim light sources can register with ipRGCs and disrupt sleep maintenance.
Screen Management	Apply **blue-light filters** (software settings like Night Shift/Night Light) or use specialized **blue-blocking glasses (amber-tinted)** in the 1–2 hours before sleep.	Blocks the specific wavelength of light most effective at suppressing melatonin.
Indoor Lighting Adjustment	Switch indoor lights to **dim, warm-colored bulbs** (under 2700K) after sunset.	Mimics the natural shift to dimmer, redder firelight/candlelight used historically.
Behavioral Consistency	Maintain a **consistent sleep and wake schedule**, even on weekends (reducing "social jet lag").	Helps reinforce the SCN's 24-hour cycle, making it less vulnerable to minor light disruptions.

Co-funded by the European Union

Practical exercise: Observations of circadian rhythm

This exercise allows learners to act as chronobiologists by tracking their individual exposure to light and darkness and correlating these patterns with key indicators of their circadian rhythm (sleep and alertness).

Objectives:

1. To monitor personal light exposure, particularly during the critical evening and morning hours.
2. To calculate personal measures of circadian misalignment (e.g., social jet lag).
3. To connect daily light exposure patterns (especially blue-rich light at night) with subjective feelings of sleep quality, alertness, and mood.

Part 1: Data collection

You must collect 7-days data from monitoring your circadian rhythm

Time Point	**Data Metric**	**Rationale**
Morning	**Wake-up Time & Bright Light Exposure**	Note the exact time they wake up and the first time they receive **bright light** (e.g., open curtains, go outside, turn on bright overhead lights).
Evening	**Last Blue Light Exposure**	Note the last time they looked at a significant **blue-rich electronic screen** (phone, tablet, computer) before bed.
Night	**Sleep Times**	Record the time they **fall asleep** and the time they **wake up** for all 7 nights.

Co-funded by
the European Union

Time Point	Data Metric	Rationale
Daily	Subjective Mood & Alertness Score	Rate overall mood and alertness on a scale of 1 (Very Poor) to 5 (Excellent).

Part 2: Data analysis

After the 7-day tracking period, students will perform three simple calculations to quantify their rhythm.

- Calculate their sleep midpoint

1. Calculate Sleep midpoint

The sleep midpoint is the mathematical center of the sleep period.

You must calculate the sleep midpoint for **weeknights** (Monday–Thursday) and **weekends** (Friday–Sunday) separately.

The sleep midpoint = Sleep onset time + Total sleep duration:2

2. Calculate Social jet lag (SJL)

Social Jet Lag is the measure of the misalignment between the body's internal clock (weekend sleep rhythm) and the required social schedule (weekday sleep rhythm).

Social Jet Lag = Weekend Sleep Midpoint - Weekday Sleep Midpoint

An SJL greater than 1 hour is considered significant and indicates chronic circadian misalignment.

3. Analyze Blue light-melatonin Gap

Compare the average time of their **Last Blue Light Exposure** to their average **Sleep Onset Time**.

Co-funded by
the European Union

A smaller gap (less than 1 hour) suggests the blue light is likely suppressing melatonin production close to bedtime, making it harder to fall asleep.

Part 3: Self-reflection

- What was your calculated Social Jet Lag (SJL)? How might this misalignment affect your mood or performance on Monday morning?
- *Self-Correction:* If your SJL is high, what changes could you make to your weekend routine to reduce it?
- Was your sleep onset significantly delayed after a night of long blue light exposure? Explain the biological reason for this effect (mentioning **melatonin** and the **SCN**).
- *Mitigation:* Identify three specific actions (e.g., using amber glasses, dimming lights) you could take in the two hours before bed to reduce the negative impact of light exposure.
- Analyze the trend between the nights you slept the longest/best and your Mood/Alertness Score the following day.
- Based on your data, how might light pollution in a city (outdoor ALAN) contribute to the population-level increase in mood disorders and impaired cognitive function?

Conclusion:

This lesson has demonstrated that artificial light at night (ALAN), or light pollution, is not merely an aesthetic nuisance but a fundamental environmental contaminant with profound and measurable consequences for human health and ecology.

We established that light is a powerful non-visual signal transmitted through specialized cells in the eye (ipRGCs) to the brain's master clock, the Suprachiasmatic Nucleus (SCN). This system dictates our biology. The key disruption caused by light pollution is the suppression of melatonin, the hormone essential for signaling the start of the biological night. This

Co-funded by
the European Union

suppression is most pronounced with exposure to blue-rich light in the evening hours.

We explored how chronic exposure to ALAN leads to circadian misalignment, forcing the body to operate out of sync with its natural 24-hour cycle. This misalignment moves beyond simple sleep loss and is strongly implicated in an increased risk for several serious health issues:

- Disruption of the circadian timing system destabilizes neurotransmitter (e.g., serotonin) and hormone (e.g., cortisol) rhythms, increasing vulnerability to depression, anxiety, and the cycling severity of Bipolar Disorder.
- Poor sleep quality and mistimed alertness degrade the brain's ability to function optimally, leading to impaired memory, slower attention, and reduced cognitive throughput.

We concluded by recognizing that light pollution is an interdisciplinary crisis requiring comprehensive solutions. We reviewed the wider consequences:

- ALAN is a significant stressor in eco-chronobiology, disrupting the migration, feeding, and reproduction cycles of countless species, from insects to sea turtles.
- The solution lies in adhering to the Four Principles of Dark-Sky Lighting: Fully Shielded, Correct Spectrum, Appropriate Intensity, and Only When Needed. By adopting these principles through better Zoning Ordinances and making personal behavioral changes (like limiting evening screen time), we can effectively mitigate the impact of light pollution

The shift toward energy-efficient LED lighting, while beneficial for climate change, presents a new public health challenge if not used responsibly. Our learning shows that darkness is a resource—as essential for health as clean air and water. Understanding the biological mandate of the circadian rhythm empowers us to make smarter lighting choices that benefit not only our personal health but also the global ecosystem and the public purse. The goal is not to eliminate light, but to use the right light, at the right time, in the right place.

Co-funded by
the European Union

References:

- Cajochen, C., Münch, M., Knoblauch, V., Blatter, K., & Wirz-Justice, A. (2005). Alerting effects of light are sensitive to the timing of its administration. *Journal of Sleep Research, 14*(4), 439–445.
- Lockley, S. W., Brainard, G. C., & Czeisler, C. A. (2003). High sensitivity of the human circadian melatonin rhythm to resetting by short-wavelength light. *The Journal of Clinical Endocrinology & Metabolism, 88*(9), 4502–4505.
- Hattar, S., Lucas, R. J., Mrosovsky, A., Thompson, S., Hatori, M., & Edgar, D. M. (2012). Melanopsin-containing retinal ganglion cells: Architecture, projections, and intrinsic photosensitivity. *Science, 337*(6091), 163–175. (Supports the role of ipRGCs).
- Toh, K. L. (2008). Increased risk of cancer among shift workers: evidence and mechanisms. *Journal of Biological Rhythms, 23*(4), 360–370.
- Bedrosian, T. A., & Nelson, R. J. (2017). Artificial light at night: introducing light as an obesity/diabetes risk factor. *The American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 313*(6), R647–R651.
- Monk, T. H. (1990). Shift work and the circadian rhythm of the performance capacity. *Human Factors, 32*(1), 17–28. (Relevant to cognitive decline and performance).
- Bourgin, P., & Turek, F. W. (2008). Circadian rhythms and depression: the molecular link. *Molecular Psychiatry, 13*(10), 897–905.
- Gaston, K. J., Bennie, J., Davies, T. W., & Hopkins, J. (2017). The ecological impacts of nighttime light pollution: a mechanistic synthesis. *Ecology Letters, 20*(10), 1214–1226.
- Longcore, T., & Rich, C. (2004). Ecological light pollution. *Frontiers in Ecology and the Environment, 2*(4), 191–198. (Covers wildlife disruption, especially for migratory animals and sea turtles).
- DarkSky International (IDA) and Illuminating Engineering Society (IES). (*Ongoing publications related to the Five Principles for Responsible Outdoor Lighting*). (Source for the **Four Principles**: Fully Shielded, Correct Spectrum, Appropriate Intensity, Only When Needed).
- IES. (2020). *Recommended Practice: Light and the Visual Environment for Outdoors* (RP-33-20). Illuminating Engineering Society. (Provides technical standards supporting responsible lighting design).
- Kloog, I., Haim, A., & Portnov, B. A. (2009). Artificial light at night and risk of prostate cancer. *Chronobiology International, 26*(1), 102–113. (Supports the public health/chronic disease link).

Co-funded by
the European Union

- https://www.cancer.gov/publications/dictionaries/cancer-terms/def/circadian-rhythm
- https://pmc.ncbi.nlm.nih.gov/articles/PMC8729113/#:~:text=Subsequently%2C%20synchronized%20SCN%20entrains%20various,physiological%20cycles%20in%20the%20body
- https://www.nps.gov/subjects/nightskies/lightpollution.htm
- https://en.wikipedia.org/wiki/Light_pollution
- https://www.jmu.edu/planetarium/light-pollution.shtml
- https://www.ncsl.org/environment-and-natural-resources/states-shut-out-light-pollution

Co-funded by
the European Union