JOLT MAGAZINE

Haverford's student-led STEM publication

ISSUE 4 — WINTER 2023

THE RESTING MIND

An Interdisciplinary Look Into Sleep, Rhythms, and Dreams

WHO'S DRIVING CLIMATE CHANGE?

An Analysis of Who or What Has the Biggest Effect on Our Climate

CROSSWORD PUZZLE

"Surfing in Your Sleep" (page 18)

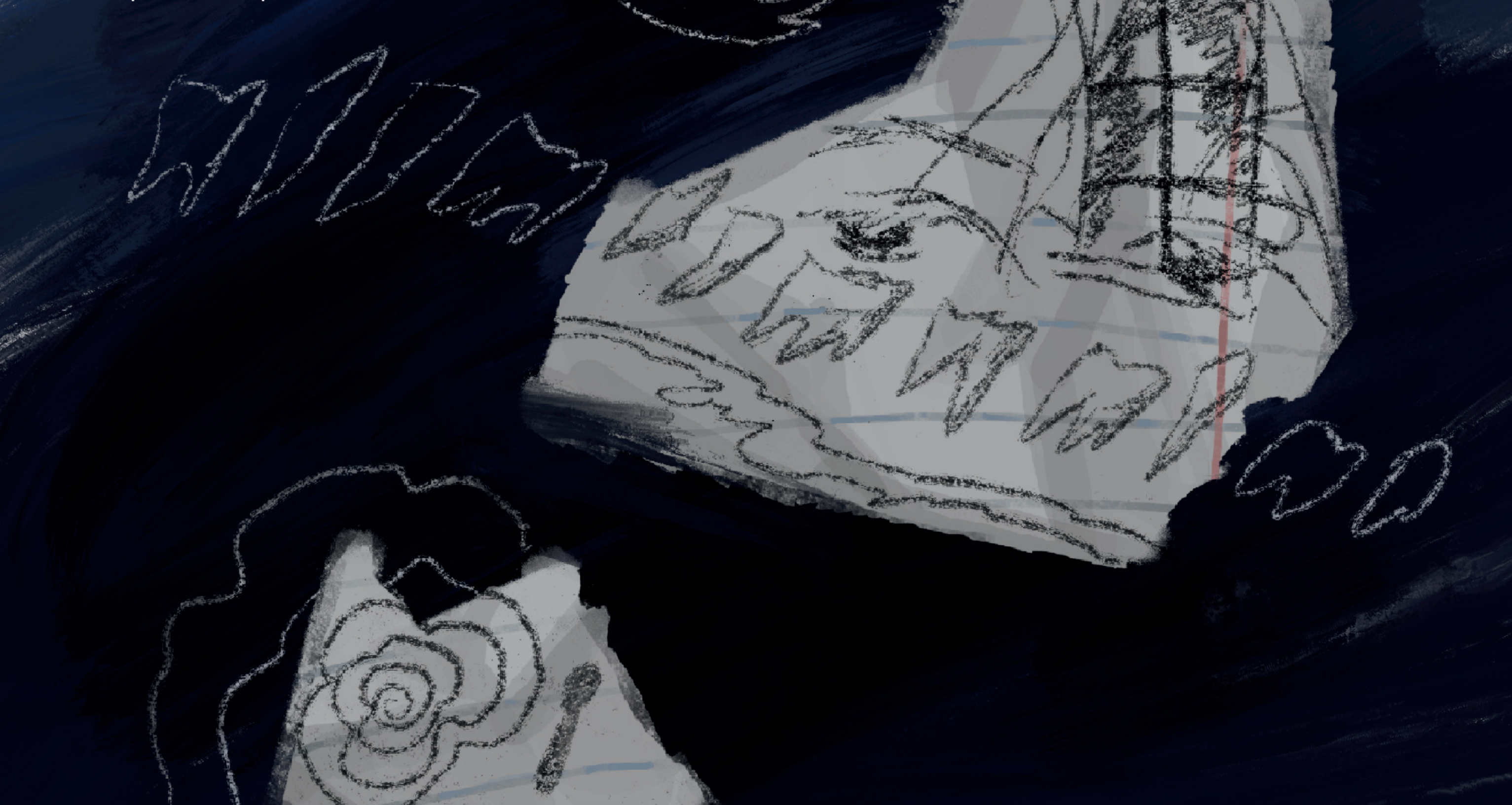
ON THE COVER:

Art and Description by Lulu Potter

I created the cover to depict the frantic scribbles one makes trying to capture a night of enigmatic dreams before it all fades. Familiar fears like the common nightmare of losing one's teeth mixed with feelings of déjà vu and cryptic symbols make you wonder—what does it all mean?

In the famous psychoanalytic case study of the "Wolf Man," Sigmund Freud describes and analyzes his patient's haunting nightmare the focused glare of a pack of white wolves outside his childhood bedroom (Freud Museum, London). Freud believed that dreams are often manifestations of unconscious desires and fears. By investigating our non-conscious life, we might better understand ourselves. The surrealist art movement was partly inspired by Freud's psychoanalytic theory to view the unconscious as a creative reservoir that could be used to create art that pulls unlikely symbols together into a meaningful whole (Reuben, 2017).

In turn, I was inspired by Wolf Man's famous dream and surrealism to create a cover that evoked a dreamy landscape open to interpretation.



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EDITOR'S NOTE

Dear Reader,

Thank you for reading this latest issue of *Jolt* Magazine!

This year, our writers took an interdisciplinary approach to analyze the science of sleeping and some surprising contributors to climate change. These articles draw on a wide range of disciplines including biology, chemistry, neuroscience, economics, psychoanalysis, mathematics, sociology, geology, and more!

Your curiosity also inspired us to launch our first-ever print edition of the Quirky Queries column, which is typically found on our website. We received many of your questions about sleep and dreaming, so turn to page 13 for our responses!

We'd like to thank our wonderful staff of writers, editors, graphic designers, and advisors who worked tirelessly to deliver the best magazine possible. We hope you enjoy this issue of *Jolt*!

CELESTE CUBBAGE
Co-Editor-in-Chief

SIMON THILL
Co-Editor-in-Chief

THE RESTING MIND:
AN INTERDISCIPLINARY LOOK INTO SLEEP, RHYTHMS, AND DREAMS

Flaming June
by Frederic Lord Leighton (1830-1896)

We spend a third of our lives unconscious. From an evolutionary standpoint, sleep is an intuitively disadvantageous behavior: we are completely vulnerable. So, how could it possibly be an adaptive behavior?

Sleep is not just a period of inactivity; it’s a complex and multifaceted behavior, vital for the health and wellbeing of virtually all animals… and scientists are still trying to figure out why. The need for sleep is conserved across all complex organisms, and circadian rhythms have existed since cyanobacteria ruled Earth. Yet, for all of its universality, the purpose of sleep remains a puzzle.

In this series of articles, we will dig into what we do and still don’t know about sleep. We’ll answer some of your questions; suggest how we as college students can improve our sleeping habits; and share the work of scientists at the frontier of knowledge in the field of sleep, circadian rhythms, and dreaming.

– Emi Krishnamurthy, 2024

SNOOZE TO SURVIVE

WHY SLEEP IS AN EVOLUTIONARILY CONSERVED BEHAVIOR

By Abby Ryan

Sleep is universal, but its evolutionary purpose remains unknown. It must be essential for our survival, or else it wouldn't be so widespread across species, but why? Though this question has no satisfactory answer, many hypotheses are circulating throughout the scientific community.

The mechanisms of sleep have been highly studied, providing foundational information on sleep's benefits. Critical to our sleep patterns, circadian rhythms maintain a 24-hour internal clock that regulates cycles of alertness and sleepiness in response to environmental light changes. However, through an evolutionary lens, circadian rhythms prove to be necessary for survival as they are observed in every organism. Humans are working toward understanding the mechanisms of sleep, but why it exists — and was evolutionarily conserved — still is unknown.

Many competing theories attempt to explain the function of sleep, yet most can be compiled into two main categories: restorative and adaptive theories.

Restorative Theories
encompass bodily repair, information consolidation, and dreaming.

The **brain plasticity theory** claims that sleep is needed for neural reorganization and brain growth, a process called neuroplasticity. Rest acts as a time when the brain isn't working at a high level and can instead take time to repair, reflect on gained information, and grow as a result (Freiberg). For example, the **synaptic homeostasis hypothesis** argues that while awake, there is a large need for energy, increased cellular stress, and use of synaptic pathways, subsequently causing impairment of brain functions as these stresses amount. Sleep makes up for the costs of being awake by refreshing synaptic strength, restoring supplies required for cellular function, and reducing plasticity (Tononi).

The **recuperative theory** claims that sleep is a vital part of repairing and repleting cellular components used in necessary biological functions. This includes many components: muscle repair, tissue growth, protein synthesis, hormone release, enhanced immune responses, detoxification, and the ability to consolidate information (Freiberg).

Among these, the glymphatic system has been studied explicitly regarding the process of toxin removal. The state of unconsciousness causes a change in extracellular space, where specific brain cells, called glia, control the flow of fluid by shrinking in size. This allows a clear liquid – cerebrospinal fluid (CSF) – to rapidly flow through the brain, flushing out toxic molecules that cannot be reached when awake. This process only occurs when asleep (U.S. Department of Health and Human Services).

These theories face criticism, though, because not all organisms require these functions. If most of these theories don't pertain to the majority of species who sleep then there must be other reasons for the evolution of sleep.

Adaptive Theories

Perhaps the more widely supported hypothesis is adaptive theory. Adaptive theories argue the basis of sleep is due to evolutionary pressures.

The inactivity theory states that species adapted to become inactive at night due to a decreased risk of predation following a nighttime injury (Brinkman). In an evolutionary context, however, sleep leaves species most vulnerable and at a high risk of predation.

The energy conservation theory follows the idea that the body lessens metabolism at night, yet, it has been found that energy expenditure isn't significantly lower during sleep (Brinkman).

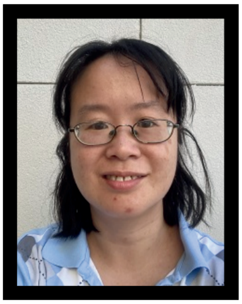
> “ why [sleep] exists — and was evolutionarily conserved — still is unknown.

Physiological Behavior Management Theory

One overarching hypothesis about sleep, containing both restorative and adaptive theories, accounts for a change in physiological behavior. Night and day are two different environments where organisms must utilize different functions and mechanisms to survive. This creates two competing niches, posing a problem of compromise — species are forced to develop different functions to work in both niches (Frieberg). Being awake both day and night would reduce an organism's ability to perform well in either environment, creating large selection pressures. This balance is further complicated because circadian rhythms are high-frequency cycles. Due to these pressures, sleep was introduced. It is as if species were given two options: pick day or night, optimize all functions and behaviors in that environment, and then avoid the other environment to avoid the risk of compromising performance.

This insight into the purpose of sleep gives a new perspective: sleep evolved to limit activity during the nighttime. It's as if sleep stops us from adapting to surviving during the night, yet this still doesn't fully explain why we turned to sleep as a way of escaping the dark. In this development, we can see how sleep would evolve to function restoratively since the body cannot interact with external stimuli.

There are still gaps between each theory and how they pertain to different species. Scientists have uncovered many functions of sleep, but it has been a challenge to connect all the pieces and solve the larger mystery that will further open the door to understanding biological processes.



SLEEP DEFINED BY A NEUROBIOLOGIST
AN INTERVIEW WITH **CYNTHIA HSU, PH.D.**

By Shir Toledo as told to Emi Krishnamurthy

Before we understand why we sleep, we must develop a neurobiological definition of what sleep is — what differentiates it from being comatose, anesthetized, or even dead? To answer these questions, we spoke to Dr. Cynthia Hsu, Assistant Professor at California State University, Fresno, and former Assistant Professor at Bryn Mawr College. Her research into neurobiological underpinnings of circadian rhythms in fruit flies may point to the mechanisms and properties underlying sleep.

Why is sleep such a neurobiological puzzle?

Dr. Hsu explains that sleep is fascinating as it is an evolutionary paradox: ”We spend such a huge fraction of our time asleep. So, why is this inactivity so important to brain development — and all of life?”

Sleep, often perceived as brain inactivity, is anything but simple. Hsu explains that sleep defines the typical model of neural activity comprising stimulus and response. “We typically think of neuronal communication as happening really fast. However, sleep is a neurological phenomenon that occurs on a very slow timescale.” Another property of sleep that interests Hsu is neural synchrony: “When an animal is awake, there are a whole bunch of neurons doing completely different things, but then when the animal is sleeping, all neurons start behaving in relative synchrony.”

Hsu's interest in sleep stems from these sleep-associated neural patterns: “Why does this occur? Is it just a symptom of something going on in the nervous system? Or is it functional from a biological perspective?”

> “ALL LIVING ORGANISMS, NOT JUST THE ONES WITH BRAINS, HAVE A MOLECULAR CLOCK.”

How do you define sleep in the laboratory? What differentiates it from being anesthetized or comatose?

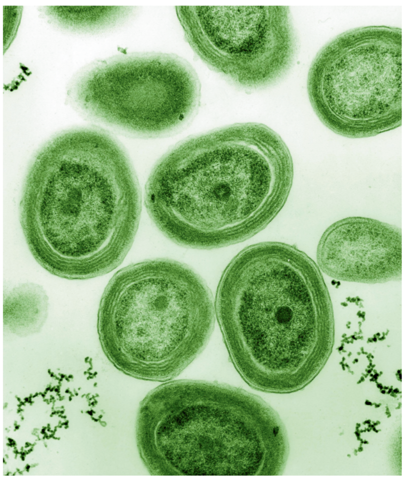
“On the molecular level, all living organisms, not just the ones with brains, have a molecular clock. This is believed to have been a way that cyanobacteria evolved so that they could anticipate changes in light and then increase their photosynthetic machinery before the light would appear. That's where the circadian clock is believed to arise from.

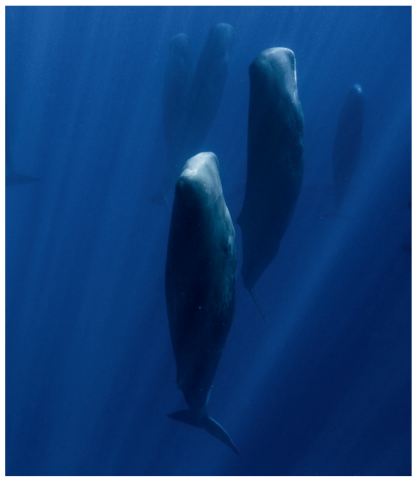
“There are a couple of different ways that we define sleep in humans. It's usually defined in terms of electroencephalogram (EEG) and electromyogram (EMG) — muscle and eye movements. People in the mouse field will use that too. In the insect literature, it's a little bit trickier because they're so small — we can't put EEGs on them. So we rely on behavioral definitions of sleep, like circadian-regulated periods of inactivity — flies are least active during the night. To distinguish sleep from general inactivity, though, there are a few other parameters that need to be true. The animal must have higher thresholds for sensory arousal — if an animal is awake, if you disturb it, it’ll respond in some way, but if it’s actually sleeping, you can disturb it and it might not wake up

“But you also want to be able to distinguish this higher threshold for arousal with an animal being comatose or dead. So there has to be some sort of a stimulus that's big enough that the animal will wake up, otherwise, it's probably comatose or anesthetized — not asleep.

“The most important part of the definition is that there has to be a homeostatic need — there has to be a buildup of ‘sleep need’ — such that if you deprive the animal of sleep, it needs to make up that sleep later. If it really is sleep, then it needs to be a biologically significant enough phenomenon that depriving the animal of it will compromise its function.”

Sleep — in its mechanisms and functions — remains a neurobiological puzzle, and researchers like Dr. Hsu are working toward solving it. By drawing parallels and comparisons between sleep mechanisms in humans and animal models like mice and fruit flies, researchers aim to elucidate this mystery and its implications in human health and well-being. This important research starts with an accurate definition of sleep, a challenge that Dr. Hsu and other researchers are addressing, bringing us one step closer to understanding the importance of sleep in our lives.





All living organisms have a molecular clock. (Left) Prochlorococcus marinus, a marine cyanobacterium that produces much of the world’s oxygen. Cyanobacteria are believed to be the organisms in which circadian rhythms arose. From Whitehead Institute, MIT. (Middle) Drosophila melanogaster (also known as the fruit fly), the model organism used by Dr. Hsu and many other geneticists due to its potential for genetic screening and manipulation. (Right) Sperm whales sleeping vertically in the Indian Ocean. Photo by Stephane Granzotto for National Geographic.

GENETICS UNDERLYING CIRCADIAN RHYTHMS

By Isabel Thornberry

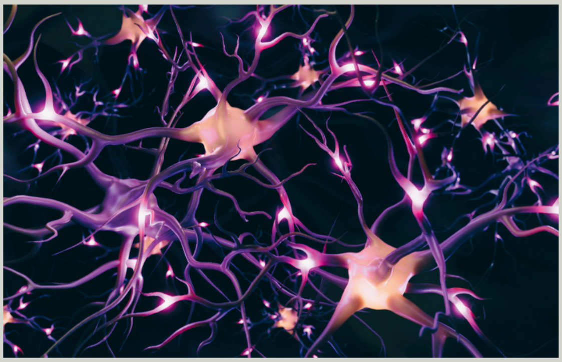
Circadian rhythms are the 24 hour biological clock that drive our sleep patterns as well as other regular changes in behavior, metabolism, and physiological processes over the course of a day. This rhythm responds to environmental stimuli such as temperature or light, and, while these oscillations certainly affect our brains, they also effect change at the cellular level in many other tissues.

So, how does our body understand these environmental cues, and what do circadian rhythms look like within cells?

The answer lies with a type of molecular cycle called transcription-translation feedback loops. These feedback loops were initially discovered in the 1990s, but the complexity in the interactions and number of players involved in these loops mean that research to tease out these mechanisms is ongoing (Benito et al., 2007).

By the central dogma of molecular biology, which describes how genetic information is processed in cells, DNA sequences are a stable way to maintain encoded information in the cell. However, to make proteins that are active in cell function and work, this genetic information undergoes two processes. Transcription copies DNA sequences that are stored in the nucleus into mRNA transcripts, which are less stable but are able to leave the nucleus. Translation uses these mRNA to synthesize amino acid sequences that then fold into proteins. Other proteins can play a role in controlling which genes in DNA are transcribed and thus translated by binding near a gene to promote (increase) or repress (decrease) transcription. Modifications to proteins can also be made after translation to control activity by adding chemical groups.

Self-sustaining circadian rhythms are observed in nearly every organism, and researchers have used Drosophila melanogaster, the fruit fly, to explore their molecular control mechanisms (Benito et al., 2007). Such mechanisms are of interest to Dr. Cynthia Hsu at California State University, Fresno, who explains that circadian oscillations in cells are controlled by numerous proteins, which interact to regulate the transcription and translation of other proteins as well as of themselves.



The proteins CLOCK and CYCLE are most abundant in cells around midday, and they bind to one another and then to specific DNA regions to activate the transcription of two other genes, per and tim, short for period and timeless (see Figure 1, 1). Transcription of per and tim genes then increases such that the accumulation of mRNA transcripts peaks at dusk (2). These mRNA transcripts are translated into PER and TIM proteins; however, protein activity is delayed until midnight as they are post-translationally modified (3, 4).

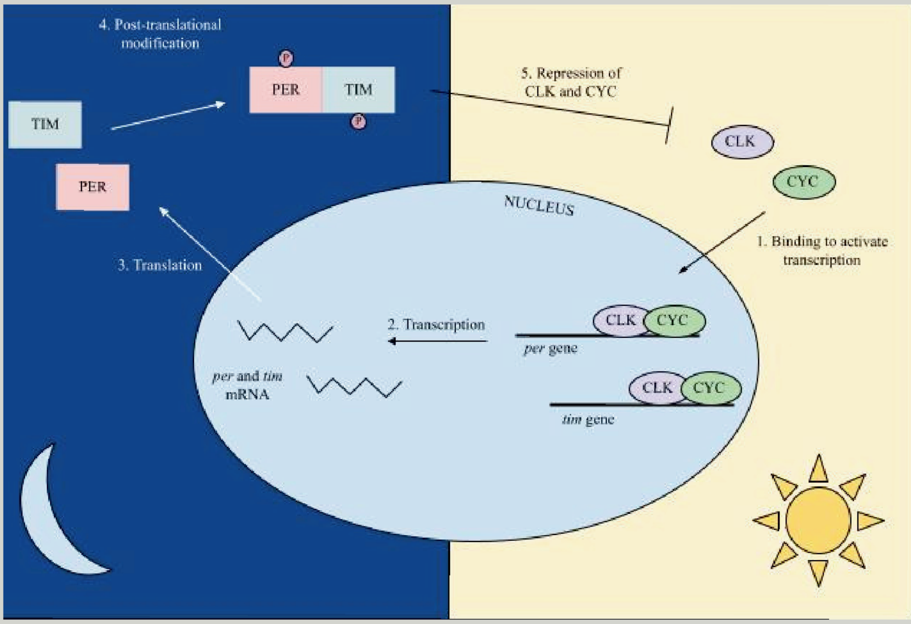


Fig 1. Simplified conceptual diagram of the per/tim negative transcription-translation feedback loop.

PER and TIM then act to repress the transcription of the clock gene, reducing their own activator (5). Because CLOCK proteins are no longer abundant to activate new per and tim transcription, existing PER and TIM proteins are naturally degraded through early morning. The degradation and thus removal of PER and TIM means that the clock gene is no longer repressed, thus increasing its transcription and translation again to peak at midday and repeat the cycle. Thus, CLOCK and CYCLE protein oscillate in opposition to PER and TIM proteins. As summarized by Dr. Cynthia Hsu, "transcriptional activators CLOCK and CYCLE will increase the transcription of their own repressors, per and tim, and so eventually PER and TIM will build up, will block clock and cycle."

In adult flies, these feedback loops occur within cells of the brain, in neurons throughout the body, and in other tissues in the legs or wings, for example. While these negative feedback cycles are self-sustaining, they also remain closely linked to environmental cues in fruit flies by light-dependent degradation of TIM proteins such that translated protein concentrations are always highest at night in the dark (Lin et al., 2001). However, the effects of these cycles are not restricted within a single cell. The same feedback loops that generate circadian rhythms control the timing of hormone release and thus key activities like body temperature regulation and locomotion activity.

QUIRKY QUERIES

Quirky Queries is the column where we answer your random science questions. If you have a question, let us know: DM us on Instagram! @haverfordjolt

DO ANIMALS DREAM? HOW WOULD WE KNOW?

We all know that animals sleep, just like humans. But do they dream as well? This is an interesting question that requires us to define dreaming. Sleep experts agree that it is best understood as a reset of the neural connections that prepares our nervous system for the coming day through memory consolidation and cognition optimization (Handwerk, 2022). During REM sleep stages, our brain remembers daily events and replays or integrates them with other experiences. This process is critical for learning and transfer from short to long-term memory.

How do we know animals do this, too? Studies have shown that mammals follow similar sleep stages, and researchers, by measuring neuronal firing patterns, have concluded that other mammals dream. Rats were trained to run a course for a food reward. Researchers recorded the brain's distinct neuron firing patterns while rats navigated a maze to earn a food reward. During sleep, they found that around half of the rats' brain activity was nearly identical to when they were in the maze (MIT News, 2001). This indicates that the brain is replaying daily events through dreaming in order to process them. Another study looked at the sleeping behaviors of chimpanzees trained in sign language. Through camera footage, researchers found that they signed complex sentences in their sleep. One chimpanzee even signed a request for coffee (Peña Guzmán, 2022). Social interactions are replayed during sleep, indicating high dream complexity.

While research suggests that invertebrates such as spiders also undergo REM sleep and have visual dreams, more evidence still needs to be made to make a firm conclusion (National Geographic, 2022). We know mammals understand and process their life through dreams, just like humans. Significant events, habits, and skills are replayed and analyzed, which helps build memory storage. So, the next time you see your pet sleeping, remember they are probably dreaming about you!

WHAT IS "SLEEP HYGIENE"?

When you think of the word "hygiene," sleep is probably not the first thing that comes to mind. You're probably thinking of dental hygiene — brushing your teeth, flossing, etc. Or maybe you're thinking about body hygiene, like showering or grooming. However, with the growing amount of research into sleep, you might want to reconsider the importance of sleep hygiene.

Sleep hygiene refers to the set of behaviors that can impact your ability to fall asleep and stay asleep (Stepanski and Wyatt, 2003). Why is this important? While we're not yet sure why we sleep, what we do know is that there are severe consequences for not sleeping enough (Stoica, 2019). Research has shown that sleep deprivation increases the risk of developing several chronic conditions, such as obesity, diabetes, and heart disease, in addition to cognitive effects like mood swings, difficulties concentrating, or impaired judgment (Harvard Health, 2023).

But even if you do recognize the significance of sleep, it can be difficult to devise and implement healthy sleep habits. Here's a sleep hygiene checklist from Harvard's Stress and Development Lab to help you get started:

- ☐ **AVOID ELECTRONICS 30 MINUTES BEFORE BED**
  Bright light from screens can disrupt your body's natural sleep-wake cycle.

- ☐ **REMOVE (OR LIMIT) NAPS**
  Regular naps can deter nighttime sleep. If you need one, do it before 3pm and keep it under an hour.

- ☐ **AVOID CAFFEINE AND ALCOHOL 4-6 HOURS BEFORE BED**
  Stimulants, like caffeine, activate systems that maintain wakefulness. Alcohol metabolization interferes with sleep cycles.

- ☐ **DO RELAXING ACTIVITIES BEFORE GOING TO BED**
  Some ideas include stretching, listening to calm music, or taking a shower (Harvard Stress and Development Lab, 2023).

IS MY NAP REALLY HELPING ME?

To the average college student, that post-class, post-practice, midday nap is both a ritual and a necessity. Approximately half of college-aged students nap at least once per week, a habit attributed to inconsistent dorm room sleep (Rea et al, 2022). Here at Haverford, students nap mainly to curb physical exhaustion or mental tiredness, according to recent Jolt survey. But are our “power naps'' really making up for lost sleep and improving our daily performance?

SCIENCE SAYS: IT DEPENDS.

Dr. Cynthia Hsu, Assistant Professor at California State University, Fresno, studies sleep, using Drosophila flies as a model for circadian patterns applicable to human systems. Dr. Hsu attributes similar afternoon napping tendencies in both flies in humans to commonalities in their early evolutionary environments.

“Drosophila evolved in the African deserts, so maybe the nap was an evolutionary way for them to avoid expending too much energy in the hottest part of the day,” Dr. Hsu explains. “Even humans, to some extent — we also initially evolved in warmer climates, and even though it's not necessarily true that we all nap, it's definitely known that one of our circadian ‘slumps’ is at four o'clock in the afternoon — similar to Drosophila. This ‘slump’ is not as bad as it is in the middle of the night, but there is a trough in our activity which reflects this tendency to nap.”

This biological propensity for midday napping, Dr. Hsu highlights in her interview with Jolt, is driven by neurons distinct from nighttime sleep-inducing neurons. “I figured if they're sleep-promoting neurons,” Dr. Hsu commented, “then they should be turned on at night. But it turns out in the particular population of neurons that I studied are turned on in the middle of the day. They're apparently nap-promoting neurons.”

Dr. Hsu describes these “nap-promoting neurons” as uninvolved in nightly sleep, pointing to the distinct neuronal mechanics of midday versus nighttime rest. Dr. Hsu along with other researchers agree that naps cannot compensate for inadequate nightly rest (Dutheil et al, 2021). “If you were to lose one versus the other,” says Dr. Hsu, “losing sleep at night is more detrimental than losing sleep during the day.”

Prioritize a good night’s rest, but if naps are your norm, nap right. The optimal nap duration is between 30 to 120 minutes, tied to acute improvements to alertness and knowledge retention (Cousins et al, 2019; Dutheil et al, 2021). Beyond this, however, napping has not been implicated in long-term increased cognitive function, including memory or overall productivity (Cousins et al, 2019). Additionally, naps that are too long could be detrimental to daily function, causing increased lethargy and inconsistent nightly rest (Oriyama, 2023; Rea et al, 2022). So next time you take a midday snooze, sleep soundly knowing your nap could help you… if done right!

WHY DO WE REMEMBER SOME DREAMS BUT FORGET OTHERS?

Scientists have an incomplete understanding of why this happens. One popular theory suggests that the amount of time spent in REM sleep and the number of transitions between REM and NREM sleep influence our ability to recall dreams. Dreams can occur in any stage of sleep, the most vivid ones typically occur during REM sleep.

Electroencephalogram (EEG) studies can provide insight. Human sleep studies often use EEG, which records electrical activity on the surface of the brain — researchers can parse out specific brain wave patterns from these recordings. Different sleep stages are associated with different patterns, categorized by signal frequency (Hz) and sequence: for example, alpha and beta waves occur during wakefulness, theta waves in stage 1, sleep spindles and k-complexes in stage 2, delta waves in deep sleep, and a mix of theta and beta waves in REM sleep.

A 2011 study from the University of Rome found a correlation between specific electrical activity patterns and dream recall. Particularly, higher frontal theta activity upon awakening from REM sleep was associated with successful dream recall. Additionally, dream recall after awakening from stage 2 NREM sleep is related to lower alpha wave activity in the right hemisphere. This mirrors the frontal theta activity observed during the encoding of episodic memories in wakefulness (Marzano et al.), suggesting that the way we remember dreams is similar to how we remember everyday events, regardless of whether we are asleep or awake (Rasch & Born, 2013). This may explain why it can be difficult to differentiate between dream memories and waking memories.

Dream recall is a complex phenomenon linked with our brain's activity during sleep. Studies like the one described above demonstrate how specific neural oscillations are linked to dream recall, but further research is necessary to understand the specific connections to the neural substrate underlying memory.

WHAT HAPPENS WHEN WE DREAM?
CHAOS THEORY AND THE SELF-ORGANIZING BRAIN

By Virginia Do, compiled by Simon Thill

The scientific study of dreams is met with many challenges such as subjective dream reporting, hindsight bias, and memory inaccuracies. Nevertheless, dreams have inspired numerous cultural, psychological, and scientific explanations. One of the first to formally posit that dreams may be functional — rather than a random byproduct — was none other than Sigmund Freud. In 1899, he published "The Interpretation of Dreams," proposing that dreams provide a window into our unconscious thoughts and repressed desires. Carl Jung, through his work on 'dreamwork' believed that dreams were a way for the unconscious to communicate with the conscious; dreams help individuals reach a 'collective unconscious.' Freud and Jung's sweeping psychodynamic theories are still prominent, but with advancements in neuroscience research and technology, scientists are utilizing neuroimaging techniques to delve deeper and more rigorously into the architecture of sleep and dreams.

Modern theories include but are by no means limited to the threat-simulation theory, which posits dreaming as an evolutionary rehearsal for threat response; the expectation-fulfillment theory, which suggests that emotional energy is consumed during sleep; the activation-synthesis theory, which interprets dreams as random brain activity without inherent meaning; and the continual-activation theory, which proposes that sleep has a role in transferring memories to long-term storage.

The marriage of neuroscience and chaos theory — the branch of mathematics dealing with complex, dynamical systems — offers a compelling perspective on the nature of dreams. While deterministic, a chaotic system is highly sensitive to initial conditions and produces seemingly random behavior. This mathematical model is used in weather prediction, market research, and crowd management, and has recently been used to analyze the human brain while dreaming.

The brain contains a mix of predictable and chaotic networks and various cognitive phenomena transition between the two. Pathways in the brain associated with goal-directed behavior are often straightforward and deterministic, while behavioral patterns are highly variable and difficult to predict due to their chaotic nature. The brain may be able to exist in a chaotic state while sleeping due to reduced volition, logic, and self-reflection from an inactive prefrontal cortex and limited sensory input. It may be that dreams, while seemingly random, are the product of a chaotic system that is highly sensitive to internal influences. Mathematics could play a key role in helping us understand why we dream and open new avenues for understanding the intricacies of the human mind.

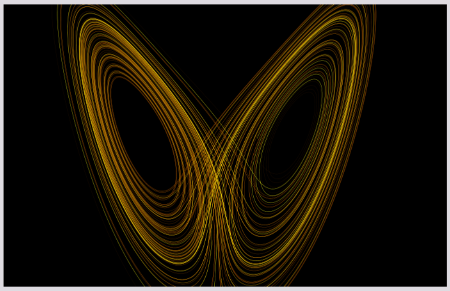


Fig 1. The Lorenz attractor is a classic example of a chaotic system - where small changes in its initial conditions produce drastically different results.

Surfing in Your Sleep

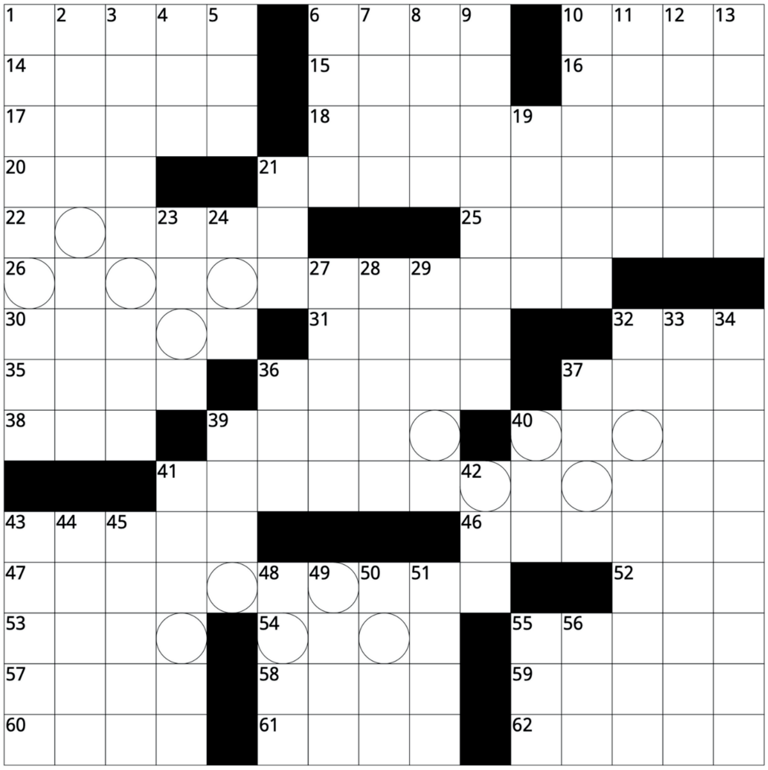
By Jason Wild

ACROSS

1 Secretly included, in an email
6 "_____ no idea!"
10 Created
14 Rowed
15 Alliance org. since 1949
16 "This guy walks into ___ ..."
17 To love, in Milan
18 Begins to eat
20 X, at times
21 Oscillations you experience in your sleep... and in this puzzle's circled letters
22 Finger-pointer
25 Most docile
26 Came across as
30 Last year's frosh
31 Neighbor of Swed.
32 Acidity nos.
35 Cuba and Aruba, e.g.: Abbr.
36 Astronomer Hubble
37 "Yuck!"
38 Once known as
39 Colorful coat
40 2023 Best Picture winner, briefly
41 Makes a comeback
43 Unit of ice cream
46 FBI operatives
47 Monthly fee for drivers, often
52 Youngster
53 American maritime protection gp.
54 Easter Island statues
55 Popular chip
57 Handsome, in Paris
58 Makeup of 55-across
59 Accomplish on behalf of
60 Part of NCAA, NAACP, and NBA: Abbr.
61 Actress Kendrick
62 Charge for a commercial

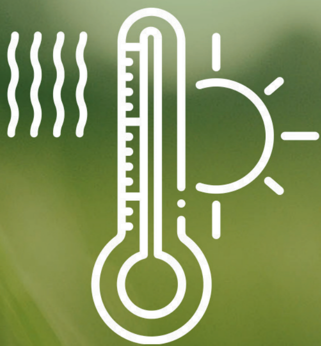
DOWN

1 Marina
2 You bend over backward to do it, in yoga
3 Ocean Spray offering since 1964
4 Always, in verse
5 JFK's predecessor
6 Price hike: Abbr.
7 "Very funny!"
8 Yours, in Tours
9 City center, typically
10 Sir's counterpart, often
11 Superior to
12 Coolidge's VP
13 Surrealist Max
19 Q-tip, e.g.
21 "I'm freezing!"
23 Indifferent responses
24 "___ in 'elephant'"



27 Conclude with
28 Football plays
29 New dorm for Hav.
32 Suer, in court
33 Completely, with "from"
34 Place to go just for kicks?
36 Corn unit
37 "La Belle et la ___"
39 Post-larval insect
40 Briefly, brain scan used to detect 21-across
41 "___: Maverick" (2022 action sequel)
42 Bowler, for one
43 Swim with the fishes, say
44 Lawyer's load
45 Killer whales
48 Village People hit
49 Apollo 11 destination
50 Make, as money
51 Singer and activist Simone
55 Rx watchdog
56 Fishing pole

WHO'S DRIVING CLIMATE CHANGE?



Climate change is a big issue and, no matter how hard we try, no one person is the cause or the solution to our climate crisis. Even so, there are some distinct drivers of climate change — good and bad.
In this issue, we'll introduce some of the things, people, and phenomena that have unexpectedly large or small effects on our climate.

FEATURE ON JONATHAN WILSON: CODECARBON, MACHINE LEARNING, & THE FUTURE OF ENVIRONMENTALISM

By Ben Fitzgerald

When programmers optimize a machine learning algorithm, they're thinking about saving time, reducing complexity, and cutting server costs. But how much are they thinking about their project's environmental impact?

This was the subject of a foundational "hallway conversation" between Professor Jonathan Wilson and Professor Sorelle Friedler. CodeCarbon was the result.

CodeCarbon, Wilson explains, is "an open source project that lets people understand… the energy use of a machine learning or AI program." By connecting to local electric grids, it calculates a program's carbon footprint. Programmers can then compare the carbon costs of running a program in different locations or hosting it on a different server. The location where code is run, Wilson argues, has a big impact on carbon footprint.

"If you're in a country or state with a ton of hydroelectricity," he says, "you'll emit extremely low C02 [compared to] Illinois or Missouri, one of those states with mostly coal-fired power plants. Same amount of time, same amount of electricity, much higher CO2 footprint from that of that same code running there."

The result? "You don't have to be an environmental scientist to understand the impact of the code that you're running."

Even before he started studying it, the environment was a big part of Wilson's life. During his childhood in Western California, frequent rains, mudslides, and wildfires taught him that, "the environment is always part of your life, whether you like it or not."

"It's difficult to live through that kind of experience and not understand that we live on a very thin surface of a very active planet," Wilson says.

But it wasn't until college that he took his first geology course and fell in love with environmental systems history.

Wilson's interest in computer science further contributed to this "engineering view of the world." Professor Wilson grew up tinkering with circuits and ended up earning a second major in computer science. As a Harvard PhD student, he applied mathematical models to the fossil record of land plants–an approach he termed "applied fluid dynamics." Currently, he is studying historical changes in CO2 concentration as a means of evaluating "possible effects of the experiment that we're conducting on our own atmosphere."

It's easy to see this synthesis of computer science and environmental studies in CodeCarbon. As the team's environmental scientist, Wilson was primarily responsible for developing a database of the carbon intensity of respective areas. This meant scouring–and evaluating–data from US energy companies and international governments. It also meant factoring in marginal impacts of carbon footprint, such as biomass decay in hydroelectric dams, that those with a non-scientific bend might miss.

One crucial component was converting carbon footprint statistics into metrics with which developers can empathize:

Fig 1. CodeCarbon promotional images

"IT'S HARDER TO AVOID A LOT OF CO2 EMISSIONS ASSOCIATED WITH COMPUTATION."

Jonathan Wilson

"[A program] emits 320 grams of CO2," Wilson says. "How many miles in a car is that? How many hours of television is that? …If you're doing a huge training set… in a really carbon intensive grid, it could [emit as much as] part of a flight."

The main impact of CodeCarbon, Wilson feels, is a broader conversation about the role of machine learning in climate change. This includes discussions about the importance of carbon offsets and the reduction of physical commuting.

"It's harder to avoid a lot of CO2 emissions associated with computation," Wilson says, "and people have been loving the idea of having CodeCarbon on their company's dashboard. Are we being efficient? Are we factoring in that the total package cost isn't just price or CPU usage–it's CO2 emissions?"

Boston Consulting Group is currently incorporating CodeCarbon on an organizational level. Meanwhile, Wilson's team has promoted CodeCarbon in communities of eco-friendly developers, such as Climate Action Tech, and on podcasts like Talking Python. In response, several developers have started expanding CodeCarbon's open source framework. CodeCarbon currently boasts 811 stars and 129 "forks" (expansions of its initial framework) on GitHub, suggesting that such development is well underway.

Wilson has no shortage of opinions on ways to further combat climate change. But he is adamant that change must move quickly.

“We’re kind of at an ‘all hands on deck’ moment,” Wilson says. “Regardless of where you are, I think there are roles for both regulation and private sector change… At this point, it’s like moving all the pieces on the board forward. There’s not one strategy to solve this problem.”

A few of these steps include building local “micro-grids” of renewable energy, encouraging greater regulation of the fossil industry, and attacking issues on the “near term time scale” like hydrofluorocarbon (HFC) emission.

When asked whether he felt optimistic about the fight against climate change, Wilson took a few pensive seconds to gather his thoughts.

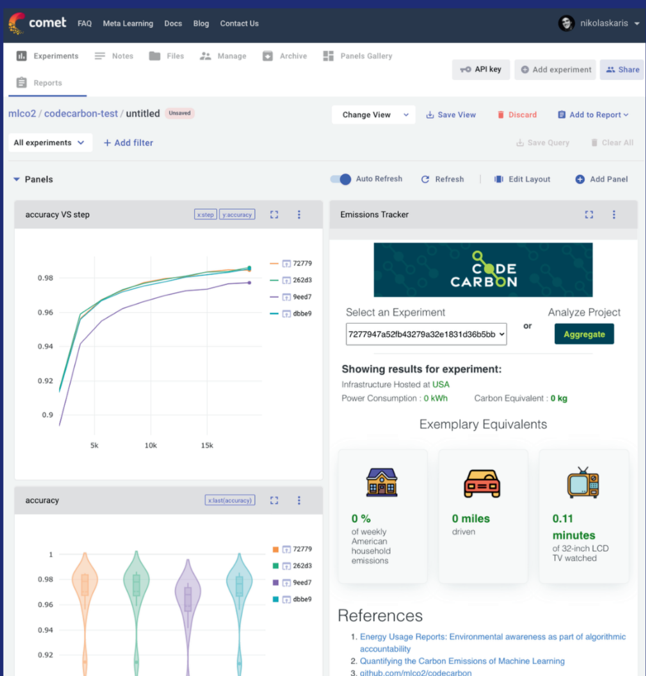


Fig 2. CodeCarbon in action, taken from https://codecarbon.io

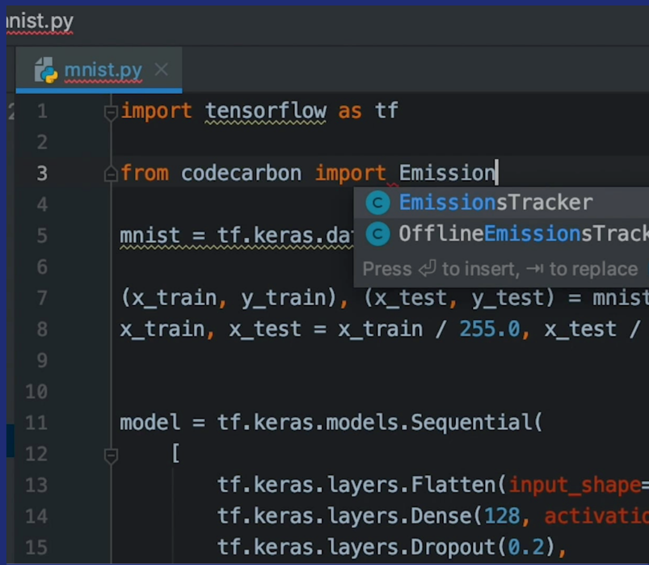


Fig 3. Developer’s view of CodeCarbon, taken from CodeCarbon in action, taken from https://codecarbon.io.io

“I think it’s okay to be aware of humanity’s impact on the planet,” he answered. “Humanity has a huge footprint, and in a lot of places, it’s rarely good… And I think that can naturally lead to a feeling of pessimism and despair.”

“Despair can be like a hammock. It can be a comfortable place to rest in it for a little while, but you don't want to live your life in it. One has to have hope that people can change and that there is a possibility of things getting better in order to. That's a precondition for solving the problem.”

“IT’S OKAY TO BE AWARE OF HUMANITY’S IMPACT ON THE PLANET”

Jonathan Wilson

THE MONEY BEHIND CLIMATE CHANGE

HOW FINANCIAL INSTITUTIONS ARE HELPING AND HARMING THE PLANET

By Celeste Cubbage

Climate change is the issue of this century, and scientists in every field are working towards innovative solutions to our climate crisis. However, many in academia forget that scientific advancement alone cannot solve this problem.

Consider this: *A professor discovers a potentially carbon-free source of electricity. Now what?*

The answer is that the professor needs money – either to support continued research or to take their idea to market. Unfortunately, scientific discoveries cannot suddenly appear at scale and need a certain amount of funding to come to fruition.

So, how do money and financial institutions fit into solving climate change?

The United Nations states that climate finance, when it is properly allocated, is critical in the path to climate justice. However, more often than not, financial institutions improperly allocate funds to sources that are actively encouraging climate change.

CNBC reported that between 2016 and 2020, 60 of the world's largest investment and commercial banks had attributed $3.8 trillion in funding to fossil fuels.

The top 4 banks responsible include JP Morgan (number 1 with $434.1 B), Citi Bank, Wells Fargo, and Bank of America. This information, from a report titled "Banking on Climate Chaos", found that banks had not only continued to support fossil fuels, but the amount of money had actually increased from 2016 to 2020.

Banks are not the only financial institutions investing major capital into fossil fuels, asset management firms have over $500 billion combined in oil, gas, and coal. The Guardian reported in 2019 that the top three offenders were Vanguard with $161 billion, BlackRock with $87 billion, and State Street with $37 billion.

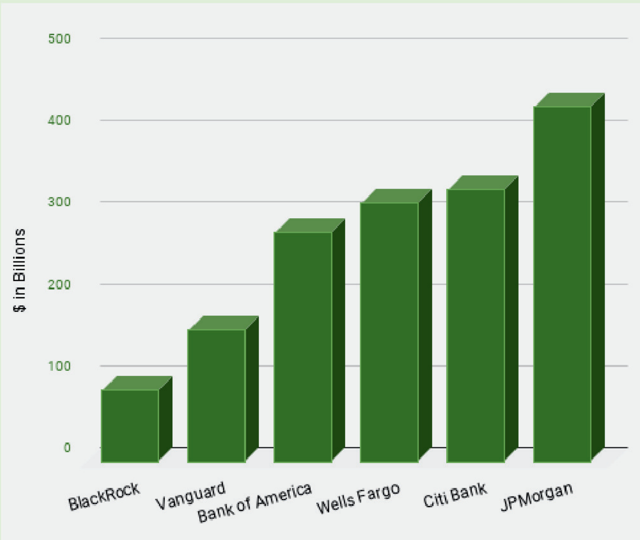


Fig 1. Investments into Fossil Fuels as reported by "Banking on Climate Chaos" and The Guardian

The amount of money that is still poured into the fossil fuel industry is substantial in its number but also its effect on the climate. In his paper "Climate as Investment", Larry Lohmann claims that:

"it is estimated that the assets of the fossil fuel businesses currently supported by the financial markets, if burned, would already push atmospheric levels of carbon dioxide beyond 500 parts per million."

While banks and private investment firms are not responsible for the actual burning of these fossil fuels, they are directly responsible for funding their continued use.

"Banking on Climate Chaos" is a project commissioned by several organizations including an NGO called Reclaim Finance. Reclaim Finance, founded in March 2020 by Lucie Pinson, winner of the Goldman Environmental Prize, is an organization aimed at using finance to fight against climate change rather than supporting it. They believe putting financial pressure on industries is a critical component of the climate change solution. This belief is not new – the method of using financial resources as a tool to combat climate change is often called "green financing".

Green finance, as defined by the World Economic Forum, is any structured financial activity that is created with the specific goal of having a positive environmental impact. Examples can include investment in clean energy start-ups, green stock indices, or "green bonds".

Dorrit Lowson, Haverford Class of '97 and Computer Science Major, is the founder of a company called Change Finance which focuses on sustainable use of financial capital. :

"WE HAVE TO TAKE A LONGER-TERM LENS, AND THAT IS WHERE LARGER FINANCIAL INSTITUTIONS ARE FAILING,"

Dorrit Lowson

When asked about the current effect of financial markets on our climate she responded:

"[it is] Undeniable that 2022 markets showed that fossil fuels are still making a lot of money for people. Fossil fuels were up 40% when everything else was down and that made a lot of profit. If you are investing with a short-term lens it's profit here and now – it's hard to divorce. [...] We have to take a longer-term lens, and that is where larger financial institutions are failing."

As Lowsen says, large asset managers are not thinking about the long-term health of the planet - just short-term profits. Realistically, investing in fossil fuels is unsustainable as it will lose money as the effects of climate change become more drastic and the switch to renewable energy is undeniable.

Lowsen believes it is possible to make investment sustainable as long as you direct your funds in the right direction.

While green financing is not the only solution, as financing itself will never solve climate change, putting money towards solving climate change will always be better than directing funds towards harming it.

CAPITALISM AND THE ANTHROPOCENE

By Lulu Potter

The Anthropocene, defined as a new epoch where human civilization has significantly impacted the planet's biosphere and geology (Waters et al, 2016), has become ubiquitous in politics around Climate Change. Geologic time is divided up—from most broad to most specific—into eons, eras, periods, epochs, and ages. The (current) Quaternary period is divided into epochs based on climate change events such as the last glacial period that inaugurated the beginning of the Holocene—the officially recognized geologic epoch we live in today. In this proposed change, the Anthropocene refers to a new epoch where humanity is responsible for a climate change event (Figure 1).

As of yet, the Anthropocene has not been recognized by the International Commission on Stratigraphy or International Union of Geological Sciences as a geological epoch, despite advocacy by the Anthropocene Working Group (AWG, 2019). The beginnings of the Anthropocene are hotly debated with proposed start-dates including the Industrial Revolution, the Atomic Age or even the Neolithic Revolution (Malm, 2016).

While the details of the Anthropocene are fuzzy, there is urgency to adopt the idea. As the British Geological Survey comments, the Anthropocene "has resonated in so many communities" beyond just the geological community.

In "Anthropocene or Capitalocene?," environmental sociologist Jason W. Moore explains that the Anthropocene captures the magnitude human impact on the geo/biosphere, and crucially, becomes a way for scientists, activists and the public to talk about the irrevocable damage done to our planet. *Science is political, and what is at stake is much larger than the precise subdivisions of geologic time, but rather the ideas used to mobilize the fight for our future.* For this reason, Moore and others argue, the 'anthro' of Anthropocene falls short. Humanity, in general, is not responsible for the supreme environmental degradation. Carbon dioxide emissions are disproportionately linked to the production of a few wealthy nations (Weidmann et al, 2020), and sectors like the military-industrial complex account for approximately 5.5% of global emissions (Parkinson & Cottrell, 2022).

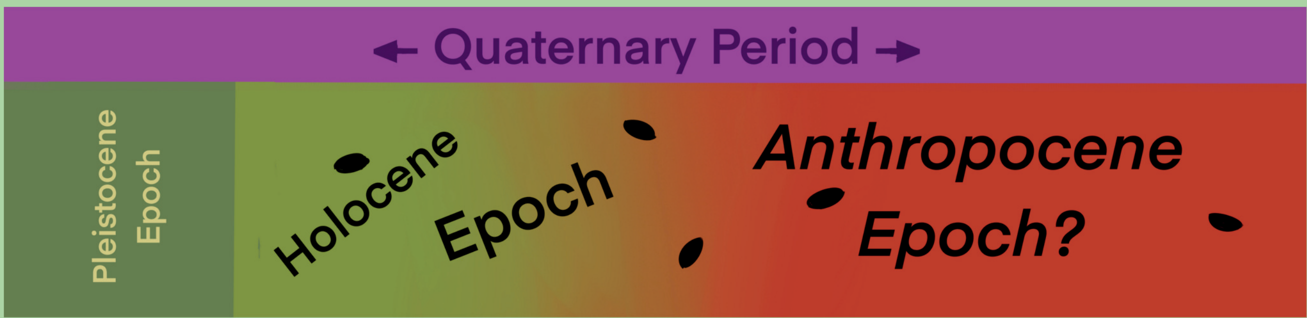


Fig 1. Proposed Anthropocene Geological Time Scale (Lewis & Maslin, 2015).

At worst, Moore argues, rooting climate change in all of humanity can look like blaming the number of people, or overpopulation. Soaring birth rates in the Global South are a burden on the planet, as the common racist and eugenicist refrain goes; studies show that the 1% contributes the same amount of emissions as the poorest 66% of humanity (Ashfaq et al, 2023).

Moore presents the need for a structural explanation for the causes of climate change. Structural explanation neither roots societal issues in individual maleficent people/ companies nor essentializes them as inherent to human nature. It instead explains the causes behind climate change through the institutions of state, economy and culture that shape our relationship to the planet's ecosystems and resources. The institutions that create climate change are not essential to human civilization, but rather specific to the last few centuries.

Moore has one specific social structure in mind as a cause for climate degradation: capitalism. Capitalism is understood differently by a diversity of perspectives. Following Marxist critiques of economy, Moore understands capitalism to be the social/economic system where production of things (coats, cars, fossil fuels, etc) is for profit. Things are commodified because their primary valuableness is derived from their ability to be exchanged for money on the market (Figure 2).

Humans have always used natural resources to produce things useful for themselves and society, but Marxist intellectual traditions contend that widespread production specifically for profit is recent (Wolff & Leopold, 2021). Under capitalism, the fossil fuel industry not only heats our homes and fills our cars, but it also exists as a means for making money. Capitalism has changed humanity's relationship to the environment, and Moore refers to this as the *Capitalocene*.

Figure 2. Diagram of Commodity Cycle. Money is used extract fossil fuels and then the fossil fuels are sold for more money.

Capitalocene is an "ugly word for an ugly system" that exploits workers, disregards the environmental impacts of industrial production and commodifies natural resources as a means to increase capital. Capitalocene understands that environmental crises are built into the structure of capitalism. Capitalocene responds to inadequacies in the politics around Anthropocene by blaming a system, capitalism, rather than individuals or humanity as whole. So long as profitability is the bottom line, green energy and environmental sustainability will have trouble usurping fossil fuels quickly enough to prevent complete climate collapse. Despite falling behind in the Paris Agreement goal of cutting half of emissions by 2030, fossil energy production continues to expand (Sanderson, 2023), because *fossil capital is too profitable*. Demanding even the reduction of fossil fuels cuts to the heart of capitalism.

Historically, the social and natural sciences have been methodologically divided, but in climate change they may find common ground (Wainwright, 2010). The causes behind climate change are rooted in social structures, the mechanisms can be explained by the natural sciences, and the solutions lie somewhere in between. Capitalocene does not supplant Anthropocene. Trading one term for another is not the point. Furnishing our environmental knowledge and activism with the role of capitalism is an important tool for combating climate change.

CLIMATE NIHILISM: WHAT CAN REALLY BE DONE?

By Simon Thill

Some of the articles in this package can be difficult to read. The scope of the problem can seem insurmountable and any progress that is made is too little, too late. According to the Intergovernmental Panel on Climate Change's (IPCC) 2023 report, humanity has already raised global average temperatures 1.1°C above 1850–1900 levels, principally through the emission of greenhouse gasses. The effects of this change have been widespread and drastic, including adversely changing weather patterns in ways that most directly affect vulnerable communities. The "deep, rapid, and sustained reductions in greenhouse gas emissions" necessary to produce "a discernible slowdown in global warming within around two decades" (IPCC) seem unlikely to occur, especially with politicians such as Donald Trump stating "I don't believe in climate change" and "global warming is a total, and very expensive, hoax!" People around the world have increasingly been reporting feeling a sense of despair about the environment, which experts call climate anxiety. Studies have also reported a related phenomenon, called eco-paralysis, where an individual's sense of doom prevents them from taking part in any climate action. Increasingly many studies have been published about climate anxiety-related phenomena and some groups, including the Yale School of Public Health, have surprising findings about possible ways to mitigate symptoms.

Suffering from climate anxiety is mentally and physically debilitating and is often associated with feeling overwhelmed by the scope of the problems at hand, as well as feelings of hopelessness or doom. Studies have found that climate anxiety is especially prevalent in younger generations, with a 2021 survey by Hickman et al. of 10,000 16 to 25-year-olds across 10 countries reporting that 56% of those surveyed believed that humanity is doomed and 36% were hesitant to have children.

As Yale Sustainability explains, there is a difference between climate anxiety and worry. Worrying about the climate is justified and if your concern motivates you to make positive changes it can be a good thing. However, researchers around the world have found that some people's concern is becoming "overwhelming and debilitating, it keeps you from living your life."

Recently, the Yale School of Public Health conducted a survey of nearly 300 undergraduate and graduate students at universities in the United States to analyze the causes and symptoms of climate anxiety. They found that climate anxiety was only correlated to symptoms of depression in individuals who did not engage in collective action.

Collective action such as community outreach, peer education, participation in advocacy groups, and more unites people who share a common goal in a pursuit towards change. The results of this study suggest that this may reduce feelings of sadness and hopelessness relating to climate anxiety, although "there is definitely more research to be done, and we can't make any claims about causality or the direction of the relationships." However, some potential explanations for their findings are that working with a large group of people creates a sense of community, and could combat feelings of hopelessness by increasing individuals' senses of self-efficacy. A great way to get involved in collective action at any stage of your life is to become more involved in politics and local elections. Researching which candidates prioritize sustainability, working with others to support them, and encouraging people to vote are great ways to work with a group of people to make a difference.

While this study found that individual actions, such as reducing your plastic consumption, composting, and recycling did not have the same correlation with reduced symptoms of depression, this does not mean that they are not necessary and will not have an effect on the environment and your mental health. According to the Center for Behaviour and the Environment, human consumption of global materials in 2017 was 3 times as high as it was in 1970 and the amount of resources consumed in 2018 surpassed the amount that can be renewed naturally in one year by 70%. Since then, the numbers have only grown and today high-income nations consume over 10 times the amount of resources as low-income nations. These numbers are clearly not sustainable and show that a significant change in consumption and individual behavior will be necessary.

By composting, using less electricity, and using public transportation you contribute to a change that is not only positive, but necessary. Living a less wasteful lifestyle also positively contributes to one's health, well-being, and of course, will save you money. In fact, even if you don't care about the environment at all, a purely economical argument could be made of why you should live a sustainable lifestyle.

If you believe you are suffering from climate anxiety, it's important to reach out to loved ones or a therapist for support. And if you have feelings of hopelessness or doom that keep you from participating in climate activism, it's important to remember that both collective and individual actions can have a positive impact on your mental health and the environment. An action that everyone can take is communicating the fact that fixing the environment is possible, and that we all have the ability to make a meaningful difference.

Fig 1. A Yale Sustainability study found that participating in collective actions, such as protests, is correlated with reduced symptoms of depression from climate anxiety.

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