SLEEP AS AN ESSENTIAL LUXURY: DISPARITIES IN ACCESS TO A VITAL PHYSIOLOGICAL PROCESS

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ABSTRACT

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The ultimate goal of this paper is to illustrate and explain the necessity for recognizing disparities in access to sleep that exist based on race and socioeconomic status in the United States.

The first section of the paper will focus on contextualizing the problem of sleep disparities through an overview of sleep science and current research on sleep disparities that exist between different socioeconomic and racial/ethnic groups, ultimately aiming to answer the question of "where are we now?" in terms of sleep science and sleep inequity. Here, I will summarize what is currently known about the physiology of sleep, sleep related disorders, and racial, ethnic, and socioeconomic-mediated differential outcomes in sleep health based on current scientific and medical literature. Of note here is the relatively short history of existing sleep disparities research, which in itself may be an indication of the inequities that exist in sleep and sleep medicine.

The second section will aim to summarize the history of sleep, along with the development of sleep deprivation and sleep disparities, ultimately aiming to answer the question of "how did we get here?" by identifying the emergence of inequity in sleep, alongside trends that led to the commoditization of sleep. This section will begin by chronologically tracing depictions of sleep behaviors and sleeping conditions through history, starting with a broad survey of ancient societies from different areas of the world. The research will then follow the historical development of sleep disparities between different socioeconomic classes in Medieval Western societies, the most well-documented of which being England and similar Western European countries. The remainder of the historical research will focus on framing an unequal culture of sleep deprivation that primarily arose following the Industrial Revolution.

The final section of this paper will consist of a discussion in which the information from the previous two sections is taken into consideration in proposing recommendations and hypotheses for the future development of sleep research and policies affecting or affected by sleep. This part of the paper will primarily emphasize that sleep is a key health determinant that is significantly impacted by structural inequalities disproportionately affecting certain groups of people, and that both scientific research and policymaking must recognize this in order to enact real change that results in better sleep for the majority in the United States.

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Introduction

Abnormal events, whether due to personal life matters or worldwide natural disasters, often cause levels of stress that can negatively impact a person's psychological and physical health. The events surrounding the COVID-19 pandemic have introduced new levels and varieties of stress, whose interactions with both social and biological factors necessitate further investigation and understanding. Various social factors such as geographic location, immigration status, socioeconomic status, and levels of discrimination faced in everyday life can have an impact on equity in health and well-being and are able to differentially affect our responses to stress. In a time period where these differences have been made clearer than ever, the effects that they can have on health are worth examining.

The World Health Organization's Constitution, which was adopted in 1948, states that Health is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity." In 1986, as part of the Ottawa Charter for Health Promotion, the WHO asserted that the fundamental conditions and resources for health are: "peace, shelter, education, food, income, a stable eco-system, sustainable resources, social justice, and equity." Notably absent from this list is any overt reference to sleep or rest. However, health and well-being cannot coexist with a lack of sleep. The general population's quality and quantity of sleep and rest, already undervalued determinants of health, show signs of decline every year. Further clashing with the WHO's imperative for social justice and equity is the reality that good quality sleep generally declines with socioeconomic status, while prevalence of sleep disorders and sleep related comorbidities increase (Grandner et al., 2013). Among others of its kind, a 2013 study from the University of Chicago reported that "lower socio-economic position was associated with poorer subjective sleep quality, increased sleepiness and/or increased sleep complaints."

We spend one-third of our lives sleeping, in a complex and essential neurophysiological state that shows little variation across cultures. The amount of sleep a person needs fluctuates throughout the life cycle, with the recommended nightly amount of sleep declining as age increases (Hirshkowitz et al., 2015). In America, regardless of the age group, people are consistently getting insufficient sleep.

Teenagers and adolescents are recommended to get at least eight hours of sleep per night, but 2017 surveys by the United States' Centers for Disease Control and Prevention (CDC) as part of a Youth Risk Behavior Surveillance System reported that only 25.4% of high school students in the US obtained a sufficient amount (sufficient being defined as 8 hours or more) of sleep during school nights (Monday through Friday) in the reporting period between September 2016 and December 2017 (Kann et al., 2018). CDC data from 2014 showed that 1 in 3 American adults over the age of 18 slept, on average, less than the recommended minimum of 7 hours per night. The distribution of adults with an average short sleep duration is uneven across the United States, with a distinctly higher concentration of those sleeping less than 7 hours per night on average coinciding with the "stroke belt" region commonly identified within the southeastern United States (CDC, 2014). This illustration of the connection between poor cardiovascular health and sleep also reveals a reciprocal relationship in which poor sleep causes and is caused by adverse health conditions. Insufficient quality and quantity of sleep have long been linked to increased risk for contributors of poor health, which include but are not limited to cardiovascular disease, obesity, diabetes, autoimmune diseases, and depression (Luyster et al., 2012; Chen et al., 2014).

Beyond having negative effects on individual health, sleep disturbances also contribute to traffic and industrial incidents that adversely affect the health of not only the person that was sleep deprived, but those who happened to be around them. Examples of industrial accidents that have been linked to sleep deprivation include nuclear incidents such as the Three Mile Island nuclear accident (1973) and the Chernobyl incident (1986), environmental disasters such as the Exxon Valdez Oil Spill (1989), and numerous automotive accidents, notably the Metro North Derailment (2013) that occurred in the New York City borough of the Bronx (Alcantara, 2020). Further examination of the circumstances of each of the aforementioned incidents led investigators to conclude that fatigue resulting from sleep disturbances or insufficient sleep was the leading contributor to the human error responsible for these accidents (Alcantara, 2020). The National Transportation Safety Board's investigation into the Metro North accident specifically revealed that the train's conductor had likely fallen asleep while operating the train and was later diagnosed with severe obstructive sleep apnea. The aforementioned risks associated with sleep disturbances have led to the CDC naming benchmarks for improving sleep health as national public health goals for both 2020 and 2030 (CDC, 2020). Despite the growing emphasis placed on improving sleep health, the goals set for 2020 were not able to be met.

Why is it so difficult for people to consistently get enough sleep? We might be able to assign some blame to the evolution of modern social beliefs that treat sleep as a luxury that is somewhat optional in a workaholic society. These social beliefs can majorly influence human attitudes and behaviors toward sleep, especially if they are held by the majority within a society. Those who view sleep as a luxury tend to treat it as a perpetual game of catch-up that must take a firm back seat to the demands of their various roles as students, teachers, workers, and parents, among others both easily defined and ambiguous. Interestingly, in societies where productivity is valued above all else, the ability to function on minimal sleep may even be considered a status symbol. The idea that social and personal attitudes toward sleep are to blame is reflected in dozens of articles and books, such as Arianna Huffington's best-selling *The Sleep Revolution,* in which she argues that "only by renewing our relationship with sleep can we take back control of our lives" (Huffington, 2016).

However, the reality is that most people are not simply choosing to get insufficient sleep because they believe it is not a necessity. I would argue that the explanations behind who gets to consistently get sleep of sufficient quality and quantity are much more complex, and that most people are familiar with the benefits of sufficient sleep and instead are simply incapable of getting the good night's rest they know they need. Rather than an individual level behavior, sleep can be seen as a social justice issue influenced by structural factors that affect who is able to obtain optimal sleep, as well as when, where, and how they are able to do this. Restricting a good portion of the American population's ability to sleep are several structural constraints that encompass factors such as poverty, circumstances that necessitate a person to hold multiple jobs and/or commute long distances, housing insecurity, and noise pollution, all of which determine whether a person is actually able to obtain sufficient sleep, regardless of the attitudes tied to culture and productivity that they may hold toward it.

Racial and ethnic differences are other major factors whose contributions are particularly pronounced in the distribution of sleep disturbances. As is the case in most other health conditions, population-based studies show that a greater percentage of racial and ethnic minorities reach the criteria for conditions such as severe sleep disordered breathing, sleep duration of less than six hours, and insomnia (Chen et al., 2014). The effect that racial and ethnic differences can have on sleep are especially pronounced when considering that they are also tied with the aforementioned socioeconomic factors. When racial, ethnic, and socioeconomic factors come into play alongside preexisting physical and mental health conditions, large disparities become apparent in the US population's ability to access sleep of sufficient quantity and quality. Sleep aids in the form of high-tech wearable devices and costly supplements and treatments make it even more apparent that sleep is becoming a luxury that few can afford. By understanding the development of factors that contribute to inequities in sleep health alongside initiatives already taken to close this gap, one could hope for the potential to restore a good night's sleep for all.

Part I: Sleep Science and Current Research

Chapter 1: Conceptualizing the Brain

Anatomical/Spatial References

Conceptualizing and locating the different sections of the brain can be done with points of reference, similar to the way compass directions can be used to locate different areas on a map. These anatomical references are best explained using a simple organism, the rat being a common example. When visualizing a rat standing normally on all four feet, the direction that points away from the tail and toward the nose is known as the **anterior** or **rostral** direction. The direction that points away from the nose and toward the tail is known as the **posterior** or **caudal** direction. The direction that points upward, out of the back, is known as the **dorsal** direction. The direction that points downward, out of the belly, is known as the **ventral** direction.

The nervous system is also divided into two symmetric halves by an invisible line known as the **midline**. Structures closer to the midline are referred to as **medial**, while structures further from the midline are referred to as **lateral.** Two structures that are located on the same side of the midline are said to be **ipsilateral**, while two structures that are located on opposite sides of the midline are **contralateral**.

Parts of the Brain

The brain is divided into three main divisions— the cerebrum, the cerebellum, and the brain stem.

The **cerebrum** is the most anterior and also the largest part of the brain; it is split into two cerebral halves, or hemispheres. The cerebrum is responsible for processes that involve somatosensory, motor, language, cognition, memory, emotions, hearing, and vision-related information. The left cerebral hemisphere receives sensations from and controls movements on the right side of the body, while the right cerebral hemisphere receives sensations from and controls movements on the left side of the body. The two hemispheres are connected by the corpus callosum. A **cortex** (Latin for “bark”) is any collection of neurons that form a thin sheet, which is usually found at the brain’s surface.

The **cerebral cortex** is an incredibly important component of the brain, found just under the surface of the cerebrum and forming the outer layer; it is sometimes referred to as gray matter. It processes sensory information, forms perceptions, and controls voluntary movement, learning, speech, and cognition. The cerebral cortex is further split into four lobes. The **frontal lobe** is the largest lobe and is located in front of the two cerebral hemispheres. The frontal lobe is primarily responsible for speech and language, prospective memory (i.e., memory that has to do with remembering plans that have been made), personality, and movement control. The **parietal lobe** is located posterior to the frontal lobe and is primarily concerned with receiving/processing sensory inputs, learning, language, sensorimotor planning, and spatial recognition. The **temporal lobe** is located posterior to the frontal lobe and inferior to the parietal lobe and is primarily concerned with processing and translating auditory information, visual and facial perception, and semantic memory (i.e., remembering things that are common knowledge). The **hippocampus** is an important structure located on the medial surface of the temporal lobe, and is responsible for declarative memory (i.e., memory that deals with remembering concepts and events that happened in life), which includes semantic memory, recognition memory, recollection, familiarity, and episodic memory (i.e., recalling an event and its associated details). Finally, the

occipital lobe is located posterior to the parietal and temporal lobes and is primarily concerned with processing and interpreting visual information.

The **cerebellum** is located in the posterior part of the brain, behind the cerebrum, and is important in regulating motor movement and controlling balance. The cerebellum is not able to initiate muscle contraction, but it coordinates gait, maintains posture, and controls muscle tone and voluntary muscle activity. Unlike the cerebrum, the left side of the cerebellum is concerned with movements of the left side of the body while the right side of the cerebellum is concerned with movements of the right side of the body.

The **brain stem** forms the stalk from which the cerebral hemispheres and the cerebellum sprout. It regulates vital functions such as breathing, consciousness, and control of body temperature. The brain stem is vital for life and damage to this area is usually fatal.

The **spinal cord** is contained within the vertebral column and serves as the major conduit of information from the skin, joints, muscles, and other parts of the body to the brain, and vice versa. The spinal cord communicates with the body via the spinal nerves.

Chapter 2: Normal Human Sleep

Definitions of Sleep

Sleep has been defined throughout the years in both science and everyday life as an absence of wakefulness, a state of reduced awareness and altered consciousness, and a restorative suspension of voluntary bodily functions, among other descriptors. However, in seeking to define sleep for the purposes of this paper—at least, as effectively as possible given the complexity of sleep as both a concept and activity—I turned toward the work of William C. Dement, a sleep medicine pioneer who is often referred to as "the father of sleep medicine." In a chapter on "normal sleep" authored by Dement and fellow prominent sleep scientist Mary Carskadon in the medical reference *Principles and Practice of Sleep Medicine,* their definition for sleep acknowledges the complex behavioral and physiological processes involved.

A simple behavioral definition for sleep is that it is a "reversible behavioral state of perceptual disengagement from and unresponsiveness to the environment" (Carskadon & Dement, 2011). Dement and Carskadon add to this definition that sleep is "typically (but not necessarily) accompanied by postural recumbence, behavioral quiescence, closed eyes, and all the other indicators one commonly associates with sleeping" (Carskadon & Dement, 2011). Other less common behaviors include "sleepwalking, sleep-talking, teeth grinding, and other physical activities." They also mention briefly that sleep process anomalies can manifest as "intrusions of sleep—sleep itself, dream imagery, or muscle weakness—into wakefulness." In other words, sleep abnormalities can occur at all times of day, and present themselves as either inappropriate sleep patterns and behaviors, or the inappropriate occurrence these sleep patterns and behaviors at times when they should not be occurring. The remainder of Dement and

Carskadon’s chapter on sleep is dedicated to the complex, more deeply studied physiological processes underlying sleep. The following overview of the physiology of normal human sleep draws from a compilation sleep science research, as well as textbooks and reference books on the subject.

Stages of Sleep

Naturally occurring sleep in humans typically follows a monophasic pattern, meaning that sleep occurs once over a 24-hour circadian cycle. During this sleep period, a person will progress from a wakeful state and move cyclically through stages of non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. These two distinct states of sleep are conserved in virtually all of the different types of mammals and birds whose sleep patterns have been studied so far—yet they remain vastly different from one another.

NREM Sleep

NREM sleep can be further divided into four stages that are measured and differentiated using **electroencephalography (EEG)**. The EEG is a technique that records the electrical activity of the brain by measuring voltage fluctuations that are generated by ionic currents in the brain’s neurons. The recording is taken from the surface of the scalp, which allows for a glimpse into the activity of the cerebral cortex. NREM sleep is generally associated with minimal mental activity and can be described as a “relatively inactive yet actively regulating brain in a movable body,” with each successive stage of NREM sleep representing an increase in the depth of sleep (i.e., the arousal thresholds are highest in stage 4 sleep and lowest in stage 1 sleep).

Brain activity at different stages of sleep is represented by the presence of different types of distinctive waveforms on the EEG. Wakefulness is characterized by a dominant presence of low amplitude beta waves in the brain, while the stages of NREM and REM sleep are characterized by their distinctive waveforms and patterns, to be discussed below.

The onset of sleep starts with **stage 1** (also called N1) sleep, which is brief and typically only lasts 1-7 minutes, more representative of a transition period between wakefulness and sleep than actual sleep. During this stage, sleep is easily interrupted by noise or movement. Stage 1 sleep is differentiated from wakefulness by the presence of theta wave activity and low-voltage, mixed frequency wave activity in the brain.

Stage 2 (also called N2) sleep follows stage 1 sleep and fluctuates in length depending on how many successive sleep cycles have been completed. The first sleep cycle typically sees stage 2 lasting 10-25 minutes, and it lengthens with each successive cycle until eventually reaching between 45 to 55 percent of the total sleep time. Brain activity during stage 2 sleep is characterized by relatively low-voltage, mixed frequency EEG activity, presence of theta waves, and presence of EEG features known as sleep spindles and K-complexes. Sleep spindles are bursts of oscillatory activity that occur for at least 0.5 seconds, and K-complexes are high amplitude waveforms. Research has suggested that sleep spindles are important in the process of memory consolidation; one study showed that individuals who learn a new task have a significantly higher density of sleep spindles than those in a control group (Gais et al., 2002).

Stages 3 and 4 (collectively also called N3) of sleep are commonly known collectively as **slow wave sleep** (SWS). Despite being consolidated into a single stage (N3) in the newest terminology used by the American Academy of Sleep Medicine, stage 3 and stage 4 of NREM sleep can be distinguished from each other based on some of their unique characteristics. Stage 3 usually only lasts for a few minutes, and the EEG during this stage is characterized by presence of high voltage, low frequency delta wave activity. Stage 4 is the last stage of NREM sleep and lasts for about 20 to 40 minutes in the first cycle, ultimately making up 10-15 percent of the total sleep time. Stage 4 represents the "deepest" NREM stage of sleep. During stage 4 sleep, the EEG is characterized by the further increased presence of high amplitude, low frequency delta waves.

REM Sleep

REM sleep occurs after stages 1-4 of NREM sleep, and is characterized by EEG activation, muscle atonia, and episodic bursts of rapid eye movements (Carskadon and Dement, 2011). The EEG itself is defined by the presence of desynchronized, low voltage, mixed frequency wave activity. REM sleep is also typically not divided into further stages. During a typical night of sleep, a person will cycle through all stages of NREM and REM sleep several times. An NREM/REM sleep cycle can last between 80-110 minutes, and humans typically have between four and six of these cycles during a normal night. Earlier cycles contain a prominence of slow wave sleep, while REM periods typically get longer and deeper within cycles that are later in the sleep period, which usually occur during the morning hours.

Dreams usually occur during REM sleep, and studies have shown that around 80% of vivid dream recall is due to waking up during REM sleep (Dement & Kleitman, 1957). The muscle atonia that occurs during REM sleep plays a role in immobilizing the body during these dreams, thus (mostly) preventing it from acting out the dreams. However, as will be covered in later chapters on sleep disorders, sometimes these immobilization processes can go wrong or completely fail. Additionally, REM sleep is thought to be an important stage for memory consolidation, alongside NREM sleep.

Circadian Control of Sleep

For the most part, sleep and wake cycles occur reliably both in isolation and in synchronization with the 24-hour environmental light/dark cycle on a daily basis, due to rhythms set by a complex biological circadian clock network that is present in most living organisms—which can range from humans and other vertebrates to fungi and bacteria. Biological clocks play a vital role in coordinating the behaviors and internal biological processes of organisms with their external environment. Most vertebrate cells, tissues, and the biological systems that they comprise express their own circadian clocks, which are coded for by specific clock genes. These clock genes interact in "oscillatory transcriptional networks within cells," and work to regulate expression of many vital physiological and metabolic processes (Welsh et al., 2010). The importance of circadian regulation is apparent in the fact that nearly half of all mammalian genes are expressed rhythmically in one or more tissues (Welsh et al., 2010).

While circadian rhythms are most pertinent in relation to sleep when coupled with an external light/dark cycle, an important feature of circadian rhythms are that they can persist even in the absence of external stimuli—suggesting the existence of an autonomous internal clock. Indeed, when human subjects are completely isolated from environmental indicators of time, they demonstrate a free-running 24-hour circadian rhythmicity in their fluctuations of physiological processes such as body temperature and cortisol secretion (Sack et al., 1992). These free running rhythms can shift when influenced by factors from the environment, but generally stay within a reasonable range for a given organism.

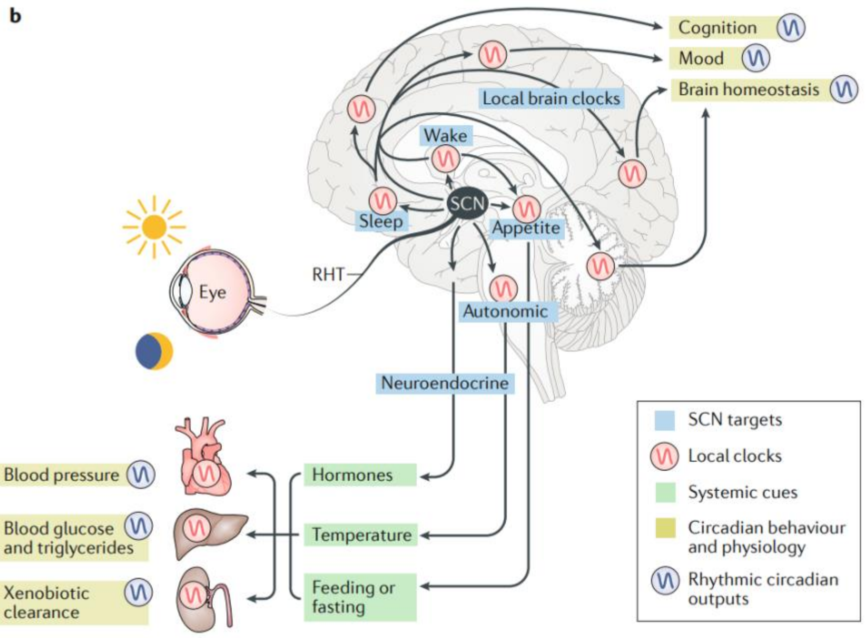

Fig.: Schematic of circadian organization in mammals, from Hastings et al., 2018.

In humans and other vertebrates, the circadian systems within the body are organized hierarchically. The rhythms of peripheral body systems are synchronized and controlled by the master pacemaker neurons that make up a structure in the hypothalamus of the brain, known as the suprachiasmatic nucleus (SCN). The neurons that make up the SCN are synchronized via intercellular signaling by the neurotransmitter gamma-aminobutyric acid (GABA) as well as peptide signaling (Hastings et al., 2003). Studies in which the SCN is surgically removed or in which lesions are introduced onto the SCN of laboratory animals resulted in the elimination of circadian rhythmicity in the output of measured behavioral and endocrine variables (Moore & Eichler, 1972). These results suggest that the SCN is necessary in its function as a pacemaker for synchronizing and maintaining the body's daily rhythms. In human patients with pituitary tumors or vascular disease disrupting the integrity of the SCN, circadian rhythms are also seen to disturbed (Welsh et al., 2010). Further, the implantation of fetal SCN tissue from donors into laboratory animals with lesioned SCNs partially restored circadian rhythmicity (Sujino et al., 2003). When implanting SCN tissue between species with abnormally long or short circadian periods, the circadian characteristics of the SCN donor were preserved, regardless of those originally present in the animal with the SCN lesion (Ralph et al., 1990). Experiments isolating the SCN either *in vivo* or *ex vivo* reveal that it is able to spontaneously fire action potentials in circadian cycles, suggesting that the SCN is able to autonomously keep time without sensory information or input from other body systems and processes (Green & Gillette, 1982).

However, the effectiveness of the SCN as a master biological clock for any given organism depends on its ability to synchronize with both environmental cues as well as all other peripheral circadian clocks that are dependent on its pacemaker ability. The rise and fall of the sun, which was and remains essential in dictating waking, working, leisure, and sleeping hours before the advent of artificial lighting, is perhaps the most important of these environmental cues.

The environmental stimuli that the SCN receives is in the form of direct photic (light) input from the retina of the eye. A study of the circadian rhythms of completely blind people demonstrated that most of these totally blind subjects had circadian rhythm abnormalities. Additionally, half of these blind subjects exhibited free-running circadian rhythms similar to those of people who were completely isolated from any environmental cues, despite these blind subjects living in normal society and having ample access to the same time cues as everyone else (Sack et al., 1992). These results suggest that light input to the retina is very important for synchronizing and maintaining normal circadian rhythms in humans.

The photic input from the retina to the SCN is “nonimage forming” in part due to the novel photoreceptors that are involved in receiving and relaying this input (Morin & Allen, 2005). A study conducted in mice who had near complete removal of the primary visual photoreceptors—rods and cones and their corresponding photopigments—showed that these mutated mice continued to demonstrate normal phase responses to light (Foster et al., 1991). The results of this study indicate that there must have been another, non-rod or cone type of retinal photoreceptor responsible for detecting and inducing light-based phase responses. A molecule called melanopsin was later identified to be present in mouse and monkey retinal ganglion cells (Provencio et al., 2000). Further studies on the topic have shown that a special class of retinal ganglion cells contain melanopsin as a photopigment and also project to the SCN, connecting light input from the retina to the output of the SCN and the subsequent circadian rhythms of many processes within the body.

Cellular Mechanisms of Circadian Rhythmicity

The actual cellular-level mechanism of circadian rhythmicity within the SCN and other biological tissues under circadian control mainly centers around self-sustaining transcriptional/translational feedback loops that optimize circadian timekeeping (Hastings et al., 2018). Free running circadian cycles are tracked using an internal timekeeping scale known as circadian time (CT). Dawn is denoted as CT0, and each circadian cycle is divided into 24 circadian hours (Hastings et al., 2018).

The core transcriptional/translational feedback loop involved in regulating circadian rhythms begins at CT0, with a gene called Circadian locomotor output cycles kaput (Clock) encoding the CLOCK protein transcription factor that forms heterodimers with the brain and muscle ARNT-like 1 (BMAL1) protein. These heterodimers function as the positive regulators in the feedback loop, activating the transcription of Period and Cryptochrome genes and driving the expression of the period and cryptochrome proteins. The period (PER) and cryptochrome (CRY) proteins form heterodimer complexes, which function as the negative regulators of the feedback loop. By the end of the circadian day (around CT12) the PER-CRY complexes build up and start to repress their own expression, resulting in PER and CRY mRNA levels falling and the existing PER-CRY complexes being degraded throughout the circadian night (CT12-CT24). This allows for the loop to begin again, about 24 hours after the previous CT0 transcription initiation. It is important to note that the core clock proteins discussed above (CLOCK, BMAL1, PER, CRY) and the genes encoding them are the most essential for generating and regulating circadian rhythms, but several other accessory clock proteins and their respective genes are also involved in regulating and maintaining the robustness of circadian rhythms in humans and other organisms.

The fluctuating status of the different molecules involved in this feedback loop provides information to the rest of the cell, via circadian output genes whose levels also fluctuate over the course of the circadian day and night. The output genes code for transcription factors that coordinate gene expression within cells, allowing for cyclic circadian control of the expression of many cell-specific genes. It is ultimately the variation in expression of these genes that drives the oscillation of many physiological, metabolic, and behavioral processes.

One of the most well-known examples of a process that occurs under a circadian rhythm is coincidentally also closely tied to sleep. The hormone melatonin is synthesized by the pineal gland within the brain at rates that are closely regulated by the SCN. In both nocturnal (active at night) and diurnal (active during the day) animals, melatonin levels typically peak in the middle of the night and are lowest during the day (Rea et al., 2005). In experiments where light with the appropriate wavelength was presented to the retina for sufficient durations during the night, melatonin synthesis was reduced in a dose dependent manner (Rea et al., 2005).

Circadian Entrainment

Variations in light input to the SCN can manifest as shifts in a light/dark cycle due to travel across time zones, seasonal and geographical changes in the length of day (i.e., shifts in the photoperiod), and the use of artificial lighting in a substantially altered pattern from normal. These external inputs elicit a shift in the circadian timing of the SCN and subsequently, the circadian rhythms present in peripheral systems of the body. This adaptation to new environmental cues by the body's circadian clock is called entrainment, and this process may occur often, especially in individuals who frequently travel across time zones. The "lag" associated with the experience of jet lag when traveling across time zones arises from a lag that occurs when the circadian clock must adjust and entrain to the altered light/dark cycle of a different time zone.

Chapter 3: Insufficient and Disordered Human Sleep

Types of Sleep Disorders

Sleep complaints are among the most common reasons for people to seek medical attention, second to only complaints of pain (Mahowald & Schenck, 2005). The third edition of the *International Classification of Sleep Disorders (ICSD-3)* Diagnostic and Coding Manual identifies seven major categories under which most of the nearly 100 (and counting) officially identified sleep/wake disorders can fall. These categories include insomnia disorders, sleep-related breathing disorders, central disorders of hypersomnolence, circadian rhythm sleep-wake disorders, sleep-related movement disorders, parasomnias, and a miscellaneous "other sleep disorders" category for those who do not fit into the previously defined categories (Sateia, 2014).

Excessive Daytime Sleepiness

Many of these sleep/wake disorders are associated with excessive daytime sleepiness, which is defined by the *ICSD-3* as "daily episodes of an irrepressible need to sleep or daytime lapses into sleep." Excessive daytime sleepiness often results in impaired cognition and ability to focus, which can lead to consequences that range from poor performance in the classroom and workplace to major industrial and automotive disasters. One of the biggest risks associated with daytime sleepiness involves a task that has become all but unavoidable in daily life for the majority of Americans.

According to a CDC study that analyzed survey data collected from adults in 19 states and the District of Columbia over the years 2009-2010, 4.2% of drivers aged 18 or older reported falling asleep while driving in just the 30 days before they were surveyed. The same survey data indicates that adults who reported falling asleep at the wheel were also more likely to self-report an average sleep duration of less than or equal to six hours per night, to be snorers, and to find themselves unintentionally falling asleep during the day (CDC, 2013). The National Highway Traffic Safety Administration (NHTSA) estimates from police and hospital reports that 91,000 police-reported crashes in 2017 involved drivers suffering from drowsiness, and that these crashes resulted in over 50,000 people injured and nearly 800 deaths that year. The NHTSA also cites a consensus amongst traffic safety, sleep science, and public health communities that these numbers are an underestimate of the impact of drowsy driving. Drowsy-driving crashes peak in frequency in the hours between midnight and 6 AM or in the afternoon hours between 2 PM and 4 PM. Not surprisingly, these time periods coincide with dips in the circadian cycle that correspond to lower levels of alertness.

Insomnia Disorders

Insomnia is a term that has historically been used to describe a range of symptoms and diagnoses, both in medical literature and in the general population. As a general term, insomnia is most frequently used to describe the plight of an individual who experiences long-term difficulty falling asleep. However, insomnia can also be used as a descriptor of symptoms such as frequent waking during the night or in some sleep literature, any physiological or behavioral indication of disturbed sleep. The *ICSD-3* consolidates all insomnia-related sleep diagnoses under a single disorder, termed chronic insomnia. The criteria for a diagnosis of chronic insomnia include “a [patient] report of sleep initiation or maintenance problems,” “adequate opportunity and circumstances to sleep,” and “daytime consequences” that arise from the symptoms being considered for diagnosis. Notable here is the stipulation that someone diagnosed with chronic insomnia must be presented with adequate opportunity and circumstance to sleep, which serves as an important delineator between chronic insomnia as a purely medical condition and chronic insomnia as a product of a person's situation along with their condition.

The *ICSD-3* also notes that insomnia occurs as a commonly expected symptom of many medical and psychiatric conditions, and that the diagnosis of a chronic insomnia disorder should only be given if the insomnia is the focus of the clinical evaluation and treatment. Comorbid medical and psychiatric disorders and nighttime or shift work are among some risk factors that can precipitate insomnia in individuals already predisposed to the disorder (Roth, 2007). This relationship also goes the other way; studies estimate that about 75%-90% of people with insomnia demonstrate an increased risk for comorbid medical disorders, which can include gastroesophageal reflux disease (GERD), neurodegenerative diseases, and pain conditions (Roth, 2007). Insomnia is also commonly comorbid with other sleep disorders, which it can either occur as a result of or lead to.

Sleep-Related Breathing Disorders

There are four subcategories of sleep-related breathing disorders: obstructive sleep apneas (OSAs), central sleep apnea (CSA) syndromes, sleep-related hypoventilation disorders, and sleep-related hypoxemia disorder (Sateia, 2014).

Sleep apnea refers generally to a sleep disorder in which breathing repeatedly stops and starts during the night. Obstructive sleep apnea is characterized by recurring episodes of upper airway obstruction during sleep and is also associated with cycles of blood oxygen desaturation and reoxygenation, heightened sympathetic activity, and intra-thoracic pressure changes. In

OSA, obstruction of the airway is due to the narrowing of the pharyngeal airway during sleep (Osman et al., 2018).

The *ICSD-3* lists the criteria for diagnosis of OSA as either "signs/symptoms (e.g., associated sleepiness, fatigue, insomnia, snoring, subjective nocturnal respiratory disturbance, or observed apnea)," or the existence of an "associated medical or psychiatric disorder (i.e., hypertension, coronary artery disease, atrial fibrillation, congestive heart failure, stroke, diabetes, cognitive dysfunction, or mood disorder) coupled with five or more predominantly obstructive respiratory events (obstructive and mixed apneas, hypopneas, or respiratory effort-related arousals, as defined by the American Academy of Sleep Medicine scoring manual) per hour of sleep."

The culmination of these symptoms results in frequent waking during sleep, which causes daytime fatigue and sleepiness (McNicholas, et al., 2007). Certain groups of people are more susceptible to OSA than others; obesity is an important risk factor for OSA, prevalence of OSA increases with age, and certain genetically determined craniofacial features can contribute to increased incidence of sleep apnea. OSA, like other forms of sleep apnea, is especially prevalent in men—Franklin and Lindberg's 2015 review of eleven epidemiological studies on OSA between 1993 – 2013 indicates that the mean prevalence of OSA accompanied by excessive daytime sleepiness was 6% in men compared to 4% in women (Franklin & Lindberg, 2015).

Central sleep apnea (CSA) differs from obstructive sleep apnea in that there is a lack of respiratory effort that occurs when airflow is stopped, while in OSA the lack of airflow is not due to cessation of respiratory drive but rather the physical blockage of the upper airway (Eckert et al., 2007). CSA patients usually either suffer from impaired central drive, where respiratory output from the neurons in the brain stem is impaired ("won't breathe") or impaired respiratory motor control, where central nervous system respiratory output is normal but the mechanism for breathing fails ("can't breathe").

Impaired central drive can arise for a number of reasons, including tumors or trauma-induced lesions on brain stem structures and respiratory depression due to acute narcotic use, though the mechanism is unclear and other factors can contribute (Eckert et al., 2007). Impaired respiratory motor control can arise due to abnormalities in upper motor neurons, lower motor neurons, or respiratory muscles. Impaired respiratory motor control is common in many neuromuscular conditions, such as myasthenia gravis and amyotrophic lateral sclerosis (ALS). CSA can result in many of the same symptoms as OSA, which include but are not limited to frequent awakening at night, excessive daytime sleepiness, and increased risk for cardiovascular disease (Eckert et al., 2007). CSA is less commonly seen in patients than OSA is, with surveys estimating a 0.9% prevalence of CSA in the general population compared to the 4-6% prevalence of OSA (Donovan & Kapur, 2016).

Sleep-related hypoventilation disorders and hypoxemia both result in lowered arterial oxygen concentrations, and until recently were placed within the same category and usually diagnosed solely based on monitoring for sustained lowered arterial oxygen concentrations. However, according to the newest edition of the *ICSD*, the criteria for a diagnosis of a sleep-related hypoventilation disorder requires that elevated arterial CO_2 levels while sleeping be demonstrated, which are defined as a level greater than 45 mmHg or "disproportionately increased relative to levels during wakefulness" (Casey et al., 2007). This is due to the technical specification that hypoventilation is defined by elevation of arterial CO_2 in addition to or instead of decline in arterial O_2, while hypoxemia can be defined by just the latter (Sateia, 2014).

Sleep-related hypoventilation and hypoxemia disorders encompass a large range of conditions. Obstruction of the lower airways in conditions such as chronic obstructive pulmonary disease (COPD) and asthma that are worsened during sleep are among the most common of these conditions. These conditions are often exacerbated during sleep, because lung function in healthy individuals varies in a circadian rhythm, with peak lung function occurring around 4:00 PM and the minimum lung function occurring around 4 AM (Calhoun, 2003). Sleep-related hypoventilation and hypoxemia can also manifest alongside neuromuscular disorders such as ALS and pulmonary pathologies such as cystic fibrosis (Casey et al., 2007).

Central Disorders of Hypersomnolence

Central disorders of hypersomnolence are defined by the *ICSD-3* as disorders which result in excessive daytime sleepiness that cannot be explained by any other sleep disorder, specifically those resulting in disturbed sleep (such as OSA, CSA, sleep related hypoventilation or hypoxemia, and circadian rhythm abnormalities). People suffering from narcolepsy, in contrast to those who suffer from sleep disorders resulting in disturbed sleep, typically get adequate sleep and wake up feeling refreshed but get sleepy 1-2 hours later. These disorders are typically linked to intrinsic sleep/wake abnormalities within the CNS but can also arise as a result of certain medical conditions, substance use, or behaviorally induced insufficient sleep (Sateia, 2014).

Narcolepsy is a chronic neurological condition that affects the brain’s ability to control sleep-wake cycles. There are two main types of narcolepsy, type 1 and type 2. Both types of narcolepsy are characterized by excessive daytime sleepiness, as well as disordered regulation of REM sleep (Scammell, 2015). In people with narcolepsy, REM sleep can occur at any time of the day and elements of REM sleep (such as skeletal muscle paralysis, rapid eye movement, and vivid dreams) can intrude into wakefulness.

Type 1 narcolepsy (formerly called narcolepsy with cataplexy) is diagnosed on the basis of deficiency in a neuropeptide hormone called hypocretin (also called orexin) due to the loss of hypothalamic neurons that produce it (Scammell, 2015). Hypocretin increases activity in the regions of the brain that suppresses REM sleep, so deficiencies in hypocretin in people with narcolepsy can result in elements of REM sleep—such as vivid hallucinations and paralysis—to intrude during the day (Scammell, 2015). Sudden episodes of muscle paralysis, commonly caused by feelings of strong emotion, are called cataplexy and occur in patients with type 1 narcolepsy. Type 2 narcolepsy includes most of the same symptoms of type 1 narcolepsy, but its cause is unknown as levels of hypocretin are typically normal and cataplexy is not present. Additionally, in most cases the symptoms associated with type 2 narcolepsy are less severe than those of type 1 narcolepsy (Scammell, 2015).

Circadian Rhythm Disturbances

Because so many important behavioral and physiological processes in humans fall under circadian control, disruption of circadian rhythmicity is associated with the onset and exacerbation of a range of mental and physical disorders, as well as the overall impairment of productivity, performance, and cognition (Vitaterna et al., 2001). The circadian clock is tightly linked with the sleep-wake cycle —Vitaterna et al. also note that in most animals, the timing of sleeping and waking in nature is generally aligned with the body's circadian control of sleep and other physiological processes that demonstrate circadian rhythmicity. While humans may also be able to feel the effects of their internal biological clock dictating when to sleep and wake, they are unique in their superior determination and means by which to ignore it. The widespread adoption of artificial lighting gives people the ability to select their sleep/wake cycles, regardless of what their circadian biology dictates.

As discussed in the previous chapter, light is the most potent factor involved in the environmental entrainment and synchronization of circadian rhythms. Thus, the effects of light exposure during the night for diurnal species (species that are active during the day) such as humans can be significant. Male Diurnal Nile Grass rats exposed to dim light at night for a period of three weeks demonstrated impaired learning and memory when solving a maze while also showing an increase in depressive-like responses compared to rats who were kept in constant darkness during the night (Fonken et al., 2012). The depressive-like responses were assessed by a forced swim test, in which the latency to float increased for rats exposed to light at night, and a sucrose anhedonia task, in which the rats exposed to mice showed a decreased preference for sucrose solution.

Another study conducted on human participants involved a 10-day long desynchronization protocol, in which they experienced adjusted 28-hour sleep-wake cycles to simulate circadian misalignment via a “28-hour day.” This misalignment led to a significant decrease in leptin, increases in insulin and glucose, complete reversal of the daily cortisol rhythm, and an increase in mean arterial pressure during wakefulness (Scheer et al., 2009).

Chapter 4: Disparities in Sleep Health and Sleep Access

Race has been used as a variable in sociological, medical, and epidemiological research for centuries, and despite the prevalence of race as a variable in research, there is no clear-cut definition for it. Some researchers define it as a biological category based on genetic characteristics, but there is no evidence of certain genetic markers that definitively delineate between different races. Most researchers categorize race based on social construction instead, where the existence of a single ancestor of a certain racial group confers this group membership to a given individual (Grandner et al., 2016). Ethnicity is another variable used to categorize groups in research and is sometimes used in place of race. Ethnicity refers more to shared culture, values, history, and (usually) geographic ancestry than biological and genetic characteristics. Both race and ethnicity are subjective categorizations that represent a great amount of heterogeneity, but are important for understanding identity, culture, and variations in health outcomes. Most researchers now categorize race/ethnicity based on self-identification of the respondent. For the purposes of this paper, racial/ethnic categorization in the various studies cited will be assumed to be based off self-identification, unless stated otherwise.

Racial and Ethnic Disparities in Sleep Duration and Quality

In 2015, the National Sleep Foundation conducted a systematic literature review of articles published between 2004 – 2014 in order to formulate age-specific sleep duration recommendations. The subsequent recommendations based on this literature review are summarized in the table below.

Table 1: Recommended sleep duration by age group from the National Sleep Foundation (Hirshkowitz et al., 2015)

Age Group	**Recommended Sleep Duration**
Newborns: (0 – 1 months)	14 – 17 hours
Infants: (4 – 11 months)	12 – 15 hours
Toddlers: (1 – 2 years)	11 – 14 hours
Preschoolers: (2 – 5 years)	10 – 13 hours
School-Aged Children: (6 – 13 years)	9 – 11 hours
Teenagers: (14 – 17 years)	8 – 10 hours
Young Adults: (18 – 25 years)	7 – 9 hours
Adults: (26 – 64 years)	7 – 9 hours
Older Adults: (64+ years)	7 – 8 hours

Several studies, mostly in the form of reviews and meta-analyses, have documented disparities in sleep in the general and adult population based on race/ethnicity. A 2013 review of epidemiologic and community-based data on sleep complaints reported by US adults showed that Black Americans reported higher rates of long (≥ 9 hours) and short (≤ 5 hours) sleep than their White counterparts (Adenekan et al., 2013). As part of the Coronary Artery Risk Development in Young Adults (CARDIA) study, the time in bed, sleep latency (time required to fall asleep), sleep duration, and sleep efficiency (percentage of time in bed spent sleeping) of 669 participants was recorded over a period of three days using wrist activity monitors and sleep logs. The participants ranged between 38 – 50 years old; 58% were women, and 44% were Black. The average sleep duration was 6.7 hours for White women, 6.1 hours for White men, 5.9 hours for Black women, and 5.1 hours for Black men. After adjustment for socioeconomic status, employment status, household demographics, lifestyle factors, and apnea risk, race-sex differences in sleep duration still remained (Lauderdale et al., 2006). A study analyzing data from the 2007 – 2008 National Health and Nutrition Examination Survey (NHANES) cohort (n = 4, 850) found that Blacks, non-Mexican Hispanics/Latinos, and those identifying as Asian/other were significantly more likely than non-Hispanic whites to report very short sleep, which was defined as five or fewer hours of sleep per night (Whinnery et al., 2013). This study also looked at ethnicity, acculturation, and country of origin as factors possibly affecting sleep duration. Survey respondents born in Mexico were less likely than those born in the US to report very short and short sleep (Whinnery et al., 2013). Respondents from exclusively Spanish-speaking households were 2-3 times less likely to report very short sleep compared to those who lived in primarily English-speaking households (Whinnery et al., 2013). Studies also looked at abnormally long sleep duration; the results of the National Health Interview Survey conducted in 2005 indicated that Blacks in the US were more likely to experience both short sleep (<5 hours) and long sleep (>9 hours), which suggests not only disparity in abnormally short sleep duration, but also abnormally long sleep duration (Nunes et al., 2008).

Racial/ethnic disparities in sleep duration exist for children as well. Guglielmo et al. completed a literature review of racial/ethnic sleep disparities in US school-aged children and adolescents, examining 23 studies (Guglielmo et al., 2018). Of these 23 studies, all of them indicated racial/ethnic disparities in at least one measure of sleep—and 17 out of 18 of the studies that measured sleep duration found that Black and Latinx children and adolescents had shorter average sleep durations than White children and adolescents (Guglielmo et al., 2018). A prospective cohort study examining parent-reported sleep patterns of 338 Hispanic and Caucasian school-aged children indicates that when the median cohort age was 8.8 years old, sleep duration was shorter in Hispanic than Caucasian children. However, this difference was not seen at a second time point, when the median age of the cohort was 13.3 years old. Additionally, the authors found that Hispanic children had significantly later bedtimes at both bedtimes (Combs et al., 2016). During adolescence, individuals usually begin to sleep less. One study compared self-reported sleep duration on a sample of young adolescents of mean age 12.31 years old. The results of this study revealed that Hispanic and African American students reported shorter sleep duration than White and Asian students (Marczyk Organek et al., 2015). Few studies compared sleep duration between minority racial/ethnic groups, but those that did indicated that Black children were more likely than Hispanic children to have shorter sleep duration on average (Wong et al., 2013).

In addition to abnormal sleep duration, there are also racial/ethnic disparities in the incidence of sleep disorders, as well as differences in sleep architecture (the relative composition of sleep by each of the NREM and REM sleep stages and their characteristic waveforms and frequencies). A meta-analysis of 14 studies representing 1,010 Black Americans and 3,156 White Americans indicates that Black Americans have poorer continuity of sleep (suggesting more frequently disturbed sleep), less slow wave sleep, and a greater proportion of stage 2 sleep (Ruiter et al., 2011). The differences in sleep continuity and duration were found to be likely moderated by factors such as psychosocial stressors, health behaviors, and preexisting medical disorders. Differences in sleep architecture have been found to be significantly correlated with genetic background (Ambrosius et al., 2008).

Sleep disordered breathing encompasses OSA, CSA, hypoventilation/hypoxemia, and all other disorders in which respiration is impaired during sleep. Several studies have shown racial/ethnic disparities in the incidence of sleep disordered breathing, with prevalence differences in Black vs White Americans being most pronounced. A study of children aged 2 – 18 years old showed that Black children were approximately 3.5 times more likely to have sleep disordered breathing than other children (Redline et al., 1999). Young Black adults under 26 years of age are 88% more likely than their White counterparts to have obstructive sleep apnea, while the evidence for this disparity seems to diminish with increasing age of subjects studied (Redline et al., 1997).

In several of the papers cited above, psychosocial stressors were hypothesized to contribute toward the observed racial/ethnic disparities in sleep duration and quality. While many psychosocial stressors are influenced by factors such as socioeconomic status, employment status, or living environment, discrimination is a significant psychosocial stressor that is more often linked to race and/or ethnicity. One study examined the relationship between perceived discrimination and sleep duration and difficulties within a sample of 2, 983 Black, Hispanic, and White adults. Discrimination, which included both racial and non-racial experiences of small and large magnitude, workplace harassment, and similar stressors were assessed via a questionnaire and examined against self-reported measures of sleep duration and sleep difficulty. The results of the analysis indicated that discrimination was associated with shorter sleep duration and greater sleep difficulties, and that the association between experiences of discrimination attributed to race/ethnicity and sleep duration was independent of other types of stressors (Slopen & Williams, 2014).

Socioeconomic Disparities in Sleep Duration and Quality

Socioeconomic position (SEP) is a common concept used in research and is often implicated in health research. SEP is a highly complex construct, arising from the individual and combined effects of several social and economic factors that influence the position that individuals and/or groups hold within the structure of a society (Galobardes et al., 2006). Common indicators of socioeconomic position include education (both of the individual and their parents), housing conditions and household amenities, income level, and occupation (Galobardes et al., 2006). Income is also sometimes measured as relative to poverty, which for the purposes of the studies below was assessed as total household income above or below $20,000.

The CDC collects data about US residents regarding health-related risk behaviors, chronic health conditions, and utilization of preventative services via the Behavioral Risk Factor Surveillance System, or BRFSS (CDC.gov). Information from the BRFSS is helpful in analyzing behavior related aspects of sleep, such as duration of sleep and whether or not an individual is getting sufficient sleep. Analysis of data from the 2009 BRFSS indicates that incidence of self-reported insufficient sleep decreases with increasing income, and average reported duration of sleep gets shorter as household income decreases (Grandner et al., 2015).

Another CDC administered survey, the National Health and Nutrition Examination Survey (NHANES), provides information on the health and nutritional status of children and adults in the US and is useful for studying prevalence of sleep-related disorders and symptoms. The NHANES dataset assesses self-reported sleep syndromes such as latency to sleep, disrupted sleep, daytime sleepiness, and snoring alongside socioeconomic assessments of poverty, education level, and food security, among others (CDC.gov). The results of Grandner et al.’s analysis of the NHANES dataset from 2007-2008 indicate that lower socioeconomic status was generally associated with increased likelihood of sleep latency > 30 minutes (Grandner et al., 2013). Additionally, lower education was generally associated with more sleep symptoms, while household food security was consistently related to sleep continuity and poor sleep quality (Grandner et al., 2013).

Occupation is not only tied to income level, which has been demonstrated to have an effect on sleep duration and quality, but also work schedules. Shift work typically refers to any work schedule that falls outside the range of hours between 7 AM and 6 PM (Redeker et al., 2019). Shift work can consist of fixed early morning, evening, and night work, as well as rotating shift work and roster work (Kecklund & Axelsson, 2016). Altered light exposure due to shift work can result in circadian disruption, which often results in circadian misalignment of key physiological and metabolic processes. Altered immune function, cardiometabolic stress, and cellular stress are all outcomes associated with shift work (Kecklund & Axelsson, 2016). Circadian disruptions and altered sleeping patterns can also result in disturbed sleep, which contributes to sleep deprivation and exacerbation or development of sleep disorders. The consequences of shift work can also lead to cognitive impairment in the form of poorer working and short-term memory, impaired executive function, and poor emotional regulation (Kecklund & Axelsson, 2016).

While environmental factors affecting sleep are not explicit measures of socioeconomic position, they are often closely associated. Low-income individuals and households often must live in lower-income environments due to economic necessity. Housing in lower-income communities is usually in poorer condition and can expose residents to environmental stressors such as mold, moisture, and insects, as well as psychosocial stressors such as violence and social isolation (Hood, 2005). The cumulative effect of these stressors can contribute significantly to sleep duration and quality, especially when compounded on top of preexisting racial/ethnic and socioeconomic disparities.

Part II: The Historical Development of Sleep and Sleep Disparities

Chapter 5: A Brief History of Sleep

This thesis will focus primarily on examining the evolving problems of sleep inequity as they exist in the United States. However, a brief understanding of sleep as a recurring theme throughout the entirety of humankind may help to frame the history of sleep within the perspective of the United States' short lifespan as a nation. The concept of sleep has been documented in ancient texts across several different cultures and geographical areas, some of which will be explored briefly below. The remainder of the section will consist of a short survey of sleep in pre-industrial Western society, from the late Middle Ages to the advent of the Industrial Revolution.

Sleep in Ancient India

The *Upanishads* are early Hindu philosophical texts which date back to before the sixth century BCE. The *Chandogya Upanishad*, one of the oldest Upanishads, describes the four states of consciousness as waking, dream-filled sleep, dreamless deep sleep, and beyond deep sleep (Upanishads – an Overview, ScienceDirect). The later written *Mandukya Upanishad* goes on to name the state beyond deep sleep as *turiya*, meaning "the fourth" in Sanskrit. *Turiya* is explained as a state of pure consciousness, serving as a sort of background for the aforementioned three common states of consciousness. The *Mandukya Upanishad* also describes three intermediate states that fall between the three common states of consciousness. *Unmani* is defined as the intermediate between waking and dreaming, *ahladini* the intermediate between dreaming and deep sleep, and *samadhi* the intermediate between deep sleep and *turiya*. The *Upanishads* represent sleep, specifically the states of deep sleep and *turiya*, as more than just a bodily function but also means for transcending and connecting with the divine. The scientific advances that led to formal definitions of sleep stages in 1937 and the discovery of REM sleep in 1953 seem to have confirmed and validated much of these ancient understandings of sleep and the various sleep stages.

Sleep in Ancient Greece and Rome

Early Western civilizations, notably those of the Greeks and Romans, recognized gods of sleep, named Hypnos and Somnos, respectively. There is no shortage of commentary on sleep from prominent thinkers of the time, as well. Heraclitus, a Greek philosopher active around 500 BCE, wrote that “man kindles a light for himself in the night-time, when he has died but is alive. The sleeper, whose vision has been put out, lights up from the dead; he that is awake lights up from the sleeping” (Heraclitus, ca. 500 BCE). This fragment has been interpreted as stating that sleep is an essential intermediate stage between two powerful extremes of wakefulness and death. Another of Heraclitus’ fragments states that “the waking have one common world, but the sleeping turn aside each into a world of his own” (Heraclitus, ca. 500 BCE). This fragment could be interpreted as a commentary on how people live—when sleeping, an individual’s dreams and experiences are unique, but when waking everyone experiences the same reality, and the same truth should be recognizable to all. Heraclitus believed that many people chose to live as they slept, turning aside to their own world and not recognizing the truths they experienced. In this way, he may have also thought of sleep as a state of blissful ignorance to the realities of waking life.

About 100 years later, the prominent Greek philosopher Aristotle's thoughts on the subject were recorded in a text titled *On Sleep and Sleeplessness,* as part of the *Parva Naturalia*, a collection of short treatises on natural phenomena surrounding the body and soul. He asserts the necessity of sleep, recognizing that "it is inevitable that every creature which wakes must also be capable of sleeping, since it is impossible that it should continue actualizing its powers perpetually" (Aristotle, 350 BCE). Just as it is in modern society, sleep in ancient times was regarded as a necessity by which people recharged to stay productive in waking life.

Notably, Aristotle also provided some of the earliest recorded commentary on the physiological principles underlying sleep, concluding that "sleep is a sort of concentration, or natural recoil, of the hot matter inwards" (Aristotle, 350 BCE). The hot matter Aristotle refers to here is blood carrying the evaporations of consumed food, which he then believed would go to the brain before traveling to and paralyzing the primary sense-organ in the heart, thus inducing sleep. He uses this explanation to account for the onset of sleepiness occurring most commonly after a meal, or after the consumption of spirituous substances such as wine. He also observes that infants sleep a great deal due to the "disproportionately large size of the upper parts compared with the lower during infancy," which causes the "impetus of the evaporation upward" to be excessive (Aristotle, 350 BCE). In this early text, Aristotle also makes reference to a connection between sleep and immune responses, writing that illnesses that form "moist and hot secretions," such as fevers, frequently cause feelings of drowsiness and induce sleep (Aristotle, trans. 350 BCE). While the exact mechanisms behind the physiology of sleep that Aristotle describes may be inaccurate, many of the observations that he made remain pertinent today.

Chapter 6: Pre-Industrial Sleep

Proposed Patterns of Pre-Industrial Sleep

Historian A. Roger Ekirch argues that before the advent of artificial light, very few civilizations were thought to have slept through the night as is commonly done today. Textual evidence cited by Ekirch indicates that it was more likely that the majority of preindustrial people followed biphasic or even polyphasic sleep patterns, in which the sleeping period was broken up into two or more segments, with periods of wakefulness in between. Among the most well-known of these texts is the *Odyssey*, written in the 8th century BCE, in which Homer refers to a "first sleep." Ekirch interprets this reference as being one of the earliest written mentions of segmented sleep. After a first sleep lasting around four hours, individuals were thought to wake sometime after midnight for a roughly one-hour period of quiet wakefulness before returning to sleep for a phase that was similar in length as the first. During the waking period in between the two sleeps, people were thought to engage in activities such as prayer, writing, sex, or even petty crime in the cover of night.

In 1992, an experiment seeking to uncover natural human sleep patterns was conducted by Thomas A. Wehr at the National Institute of Mental Health (NIMH). In this study, seven healthy adults were exposed to a short photoperiod of 10 hours of light per day and a totally dark bedroom for the remaining 14 hours at night, over a period of four weeks. These experimental conditions were designed to imitate the natural photoperiods that existed before the advent of widespread artificial light. The short photoperiod was implemented after participants experienced a week of baseline conditions, consisting of 16 hours of light and 8 hours of darkness per day.

Wehr found that, under the short photoperiod, the participants' sleep duration became divided into (usually) two bouts, each several hours in duration with a one to three-hour waking interval between them. After averaging each individuals' nightly sleep profiles over the four weeks, Wehr noticed that a "remarkably symmetrical bimodal pattern emerged" (Wehr, 1992). While not entirely conclusive, the results of this study suggest that the apparent natural response to pre-industrial sleep conditions is reflective of the biphasic sleep pattern that people followed at the time.

Sleep in Medieval Europe

The apparent reverence that early civilizations had for sleep as a connection with the divine stands in stark contrast to the attitudes toward sleep and the night-time that had begun to arise later in Western history. European paintings and literature beginning in the 15th century depicted nighttime as "a forbidding place plagued by pestilential vapors, diabolical spirits, natural calamity, and human depravity, the four horsemen of the nocturnal apocalypse" (Ekirch, pp. 123). The same way that their early ancestors learned to avoid the dangers of darkness by sleeping in caves, medieval people likely continued to reserve nighttime for sleep because, in the absence of light, it was too inefficient and too dangerous to do anything else.

Medical opinion in the late Middle Ages did not progress far past Aristotle's time, with most still holding the belief that once food has been digested, the "fumes ascend to the head…where through coldness of the brain, they congeal" to stop the senses, procuring sleep (*The Haven of Health*, 1588). In fact, the only difference between the physiological explanations for sleep in 350 BCE and the 1500s (and beyond) was that the primary sense organ had been discovered to be the brain, rather than the heart. The common association of sleep with inactivity and monotony is likely part of the reason for why “our entire history…is only the history of waking men,” as it was perhaps best put by the 18th century scholar Georg Christoph Lichtenberg.

That is not to say that the topic of sleep faded entirely into obscurity. People living in pre-industrial Western society continued to write about the restorative benefits of sleep— in adages such as the Italian “bed is a medicine,” and various iterations of a saying that is most famously attributed to American founding father Benjamin Franklin: “early to bed and early to rise makes a man healthy, wealthy, and wise.” The latter quote reflects not only the apparent importance of sleep, but also the relevance of the timing by which one went to bed and woke up. The emphasis on early rising may have influenced or been influenced by the then—and still now—common practice of scorning excessive sleeping. Strong Puritan values present in England and later, America, were influential in the condemnation of excess sleep due to its association with the sins of idleness and sloth.

Socioeconomic Sleep Equity in Pre-Industrial Times

The 17th century French poet Nicolas Boileau-Déspreaux wrote that “sleep like other things is sold, / And you must purchase your repose with gold,” in response to the high cost of obtaining quiet sleeping quarters in Paris at the time. Even in pre-industrial times, the inequity in access to sufficient quality and quantity of sleep between socioeconomic classes was clear. The inability for people to be productive and work during sleep was a major contributor to the rise of attitudes reflected in sayings such as “six hours’ sleep for a man, seven for a woman, and eight for a fool” (Ekirch, pp.). These attitudes were especially pertinent when considering individuals of lower social classes who relied on the ability to work long, arduous hours for their livelihood.

Many wealthier families employed servants to help with “ordinances of the bedchamber,” which included tasks such as washing feet, beating beds, and setting chamber pots, making a comfortable sleep easier for the wealthy while delaying rest for the employed poor. In an extreme example, King Henry VIII of England’s bed was “arrayed” with pillows, blankets, and linen sheets every night by ten attendants after the bottom mattress had been “stabbed with a dagger to guard against an assassin” (Ekirch, pp. 253). More fortunate servants, such as those in France in the 1700s, received narrow cots to support their straw mattresses (Ekirch, pp. 259). Others were less lucky and slept in their masters’ cellars, “sometimes” having a “bit of blanket” for bedding. Similar to modern times, the urban poor fared even worse, as illustrated in a 1732 observation by the London Court of Common Council stating that “divers[e] poor vagrant children are suffered to skulk in the night-time, and lie upon bulks, stalls, and other places in the public street.” Sleep is arguably much more difficult when attempted in a public space without protection from the hard ground, harsh climates, and urban and natural noise.

The quality and quantity of the beds, typically the most expensive articles of furniture in a house, could have served as indicators of a family’s social class in pre-industrial times (Ekirch, pp. 257). By the mid 16th century, well-off homes were furnished with “elevated bedsteads with canopies, feather mattresses, and heavy curtains to ward off drafts, insects, and inquisitive eyes” (Ekirch, pp. 258). Wealthy families were able to afford weather-specific bedclothes, such as linen sheets and wool blankets, in order to ensure maximum comfort (Ekirch, pp. 258). Families of lower socioeconomic class were unable to afford multiple beds, or in some cases even a single bed, sometimes sleeping on straw and covering up with only the clothes that they wore.

Not only was the cost of bedsteads prohibitive, but they occupied valuable space in cramped dwellings. A lack of bed space and bedding meant that lower class families often were forced to sleep in close proximity, cramming three or more to a mattress to conserve resources and generate warmth. Sleeping so closely together in these conditions was likely to have resulted in more uncomfortable, frequently interrupted sleep for these individuals compared to those who had the means to sleep in their own beds.

On the other hand, it was usually the wealthier individuals and families who had the means to regularly use artificial lighting sources such as candles and later, gas lamps, which may have resulted in inadvertent hampering of their ability to sleep by participation in leisure or work activities that kept them awake past dark (Ekirch, 2005). Still, this was a voluntary impairment of sleep, perhaps reflected in modern day habits such as staying up to work overtime or watching a TV series into the night.

Illness and Sleep in Pre-Industrial Times

Regardless of social rank, most people living in pre-industrial Western society were at some point in their lives afflicted by sickness that affected the quality of their sleep. Symptoms of common ailments such as heartburn, toothaches, cluster headaches, and congestive heart failure tended to be worse at night (Rose, 1989). Without many of the medications and treatments available today, these ailments and their symptoms were more likely to lead to either prolonged sleep loss, or highly interrupted sleep patterns.

The darkness of night seemed to also magnify mental illnesses and stressors that were prevalent in pre-industrial times. Diaries recorded by Lady Sarah Cowper, a British woman who wrote extensively on her life in London spanning between 1700 and 1716, provide valuable insight on the way sleep factored into the mental health of members of the upper class in Western pre-industrial society. In one such entry, Cowper wrote that “if bodily disease abates…pain of the mind succeeds," to "break my rest in the night" (Burton, 1938). Observers of the urban poor in London remarked that "they sleep, but they feel their sleep interrupted by the cold, the filth, the screams and infants' cries, and by a thousand other anxieties" (Camporesi, 1989). Of these anxieties, many were rooted in fears both worldly—such as those concerned with theft or injury—and supernatural, such as those surrounding witchcraft or demons.

The Effect of Environment on Sleep in Pre-Industrial Times

The adverse effects of both mental and physical illnesses were further aggravated and complemented by a variety of environmental factors that were present during sleeping hours. As previously suggested, with the exception of the extremely wealthy, most people living in pre-industrial Western society did not have the luxury of comfortable, quiet sleeping quarters. Beyond purely an insufficient quality and lack of bed and bedding, the sleeping quarters themselves were often poorly insulated and located directly adjacent to noisy streets, especially in crowded urban cities. The construction of buildings was also relevant to determining the quality of sleep for those who dwelled within. Homes with wooden frames fixed in the earth were frequently infested with rodents, whose activity threatened to take down the walls and rafters of homes while disturbing those who tried to sleep in their presence. "Shrinking timber, loose boards, drafty doors, broken windows, and open chimneys" are cited as just some of the consequences of poorly constructed homes, the impacts of which were made more severe by concurrent inclement weather events (Ekirch, 2005).

Even on its own, bad weather was a cause for stress and a major environmental disturbance, affecting residents both of cities and the countryside. A lack of insulation and modern air conditioning and heating methods meant that freezing winter temperatures were especially brutal. One writer at the London-based *Lloyd's Evening Post* complained that he had "often been kept awake for hours by the coldness of my legs and feet," and that despite having "loaded myself with cloaths" and "my bed heated till I could scarce bear the touch…night after night have I shivered through the winter" (Earle, 1893).

While loading up on sheets and blankets may have been helpful for warding off the cold, the same bedding also provided excellent housing for insects such as lice, fleas, and bedbugs, which swarmed, crawled over, and bit people's skin while they attempted to sleep (Ekirch, pp. 275). Animal and insect activity was worse in areas with warmer climates, such as Italy, where scorpions and tarantulas were commonly found. Many of the early North American colonies, notably Virginia, were infamous for their humid summers and the resulting vicious mosquito swarms which thrived in such a climate (Ekirch, pp 276).

Foul odors were also amplified in hot and humid air. Even wealthy families who had access to chamber pots had them placed near their beds for the sake of convenience, which also subjected them to the smells that were emitted from the excrement within. While these chamber pots could and were likely to be cleaned by servants, lower class families only had access to worse alternatives which included urinating outside when weather permitted or using the fireplace and chimney as a toilet (Ekirch, pp. 275). Affluent households were able to use perfume-burners to somewhat mask septic smells, but lower-class families and individuals were mostly resigned to tolerating these scents as they attempted to sleep (Ekirch, pp. 277).

Chapter 7: Post-Industrial Sleep

The Transitioning of Sleep in an Industrial Society

The 18th century marked the beginning of a period of transition for the way people slept. Even before the advent of the Industrial Revolution, the roots of a Protestant work ethic were well established in the moral opposition held against all forms of idleness, including sleep. This attitude was first reflected in Puritan preaching, which was best exemplified by the influential New England Puritan minister, Cotton Mather, who "equate[d] sleep with the avoidance of divine service and a lack of consciousness of one's earthly obligations" (Derickson, 2014).

The Rise of Capitalist Industrialization

However, it was not until the primary form of work began to transition from farm based agrarian labor to factory work that a major shift in the attitudes toward and practices of sleep began to occur. In *the Sociology of Work,* sociology professor Stephen Edgell explains the process of capitalist industrialization as having thought to have started in England toward the end of the 18th century. This new form of labor economy was adopted soon afterward in the United States, France, and Germany before gradually spreading out to the rest of the world and contributing heavily to the development of the global economy as we know it today. Edgell defines industrial capitalism in terms of two component concepts that comprise it.

On its own, industrialization is the process of social and economic change whereby a human society is transformed from a primarily agricultural economy to one based on the manufacturing of goods. Often, individual manual labor is replaced by the harnessing of “inanimate energy sources such as electricity, gas, or nuclear power,” to enable mechanized mass production (Edgell, 2012). This large scale of production necessitated the establishment of specialized workplaces such as factories in which labor could be concentrated. The concept of time became more pertinent than before, mostly due to a greater need for the time synchronization of labor in processes involving multiple specialized forms of labor and machinery.

As a separate concept, capitalism refers to a “profit-oriented system based on the private ownership of production, on an individual/family or corporate basis, that operates in a competitive market system in which the owners of capital employ free wage labor on a monetary basis.” The interconnectedness of industrial and capitalist society was evidenced in the shift toward recruitment of workers based on skill rather than their parentage. In a society where profit was prioritized, a worker’s ability to be productive was highly valued. This shift was additionally reflected in the move from working and living at home in a rural community to working away from home in an urban area. People were more frequently beginning to separate their work and home lives, interacting extensively with those they knew exclusively from working in the same place.

The Concept of Time in Industrial Capitalism

Pre-industrialization, work tended to be more task-oriented and was heavily influenced by the seasons and weather. This meant that the working day varied in terms of both intensity and length, peaking during harvest times and becoming shorter in the winter once specific activities had been completed.

Industrial work, which revolved around the rise of the factory, operated on a more rigid schedule. There were fewer holidays, both religious and secular, and much longer working hours that were strictly timed. The fast pace of work in a capitalist society was primarily made possible by newly developed industrial technology and machines, which were owned by the employers by which the working class of the time were dependent on for work.

Work became more regular, with time being measured in increasingly more precise increments as synchronization of labor in the factory became more important. In *the Sociology of Work*, Edgell asserts that “the advantage of time is that it provides management with a standardized unit with which to co-ordinate the human and non-human elements of production and to measure the contribution of labor, with or without reference to output” (Edgell, 2012). This advantage, he concludes, “may explain the tendency for pay to be based on the amount of time spent at work and the requirement to ‘clock on and off’ accompanied by a schedule of fines or dismissal for repeated lateness” (Edgell, 2012). In her book *the Overworked American: The Unexpected Decline of Leisure* Juliet Schor estimates that the total number of hours worked were nearly doubled between the years of 1600 and 1830 in Britain, increasing from fewer than 40 hours per week to over 70. In a society that valued making as much money as possible as a priority, time itself became money.

Part III: Conclusion and Moving Forward

Human beings have been sleeping ever since the beginning of time as we know it, and before there were humans, there were other organisms that experienced and needed regular sleep or sleep-like states. Despite the long history that sleep holds, the study of sleep medicine is a relatively young field. The field of modern sleep medicine did not truly develop until the electrical activity of the brain was discovered, dating back to when Richard Caton, a British physician, was the first to record electrical activity in animal brains in 1875 (Shepard et al., 2005). It was not until 1937 that distinct sleep stages were first delineated, when Alfred Loomis documented characteristic EEG patterns for NREM sleep and divided it into five phases that form the basis for the sleep stages still recognized today (Shepard et al., 2005). REM sleep was not discovered until 70 years ago in 1951, by Nathaniel Kleitman. Since then, there has been dramatic progress made in the field of sleep medicine in terms of diagnosis, treatment, and understanding of this complex process.

Research on sleep disparities is also relatively new, with much of modern sleep medicine less concerned with factors such as race/ethnicity or socioeconomic position when optimizing for sleep health in the population. Despite the lack of attention paid to them, disparities in sleep have existed throughout much of history and have only been exacerbated by the advent of technology and an increasingly globalized, 24-hour society. Given the clear relationship between sleep duration/quality and racial/ethnic and socioeconomic factors seen in the literature, more attention should be paid to disparities in sleep not only based on the aforementioned factors, but also on more multifaceted and diverse forms of classification, such as age, sex, immigrant status, and the various combinations of any and all of these factors.

This is not to say that sleep disparities research is not already ramping up—the National Institutes of Health's project database indicates 258 active projects including the term "sleep disparities" in the project title, which will be able to add new insights to preexisting research. Based on the existence of an NIH research project grant titled "Mechanisms and Consequences of Sleep Disparities in the US" (grants.nih.gov) that is taking applications through July 2022, I would predict that the amount of research into sleep disparities is only going to go up.

Intersectional studies on sleep disparities will be essential to generating robust, high quality data for clinicians and researchers to use in efforts to improve equality in sleep health. It is not enough that disparities in sleep health be further investigated and understood—research studies and trials should also be implemented to target diagnosis and treatment of sleep disorders and comorbidities in groups who are unequally affected by sleep disparities. Increased training opportunities for minority researchers and integration of cross-cultural education for researchers and clinicians may help to accomplish these goals.

However, not all barriers to reducing disparities in sleep health can be overcome through research. Many of these barriers are due to broader structural factors that are a result of and continue to create inequity in society until they are addressed in the form of policy change or actions of similar societal magnitude. An example of a policy change that could be proposed to improve minority sleep outcomes would be to delay school start times. Research has shown that early school start times disproportionately affect minority and low-income students, and policies that work to reduce this impact could potentially help to reduce sleep disparities.

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Biography

Jina Zhou was born in Orange County, California on June 15, 1999. She moved to Sugar Land, Texas in 2007 and resided there before moving to Austin to attend the University of Texas at Austin in 2017. During her time at UT, Jina was involved in service organizations, undergraduate research, and tutoring both on and off campus. She graduated in May 2021 with a BS in Biochemistry, a BA in Plan II Honors, and a certificate in Elements of Computing. Jina will move to Washington, DC in the fall to begin her career in software engineering with Capital One.