THE EXPERIENCE OF LIGHT

BODY CLOCKS, NIGHT AND SLEEP

ARCHITECTURE FOR WELL-BEING AND HEALTH

D/A

DAYLIGHT & ARCHITECTURE
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Views towards the outside are a significant quality criterion for architectural spaces – and not only in office buildings.

THE EXPERIENCE OF DAYLIGHT

A considerable body of research shows that people prefer daylit spaces to those lacking natural light. Why should this be? If there is sufficient light to see, why would people prefer one source to another? To answer this question, we need to understand the evolved relationship between humans and natural light.

By Judith Heerwagen
Photography by Gerry Johansson

Imagine you are on a camping trip that lasts a lifetime. You and your small band of hunter-gatherers wake up with the first light of day. You huddle around the fading embers of the camp fire, eat leftovers from the night before and discuss the day's foraging activities. By the time the sun is fully up, you head into the bush using the bright light of day to identify edible fruits and berries and to track animals. By noon, the sun is hot and you seek the shade of a tree canopy for refuge and rest. As you snack on nuts and berries, conversation is drawn to the horizon where large storm clouds have begun to gather. You're a long way from camp and are concerned about getting back. Dark clouds gather, cutting out the sun overhead but providing dramatic shafts of light in the distance. It rains hard, but briefly, as you huddle under a rock outcropping for protection. As you head back, the clouds begin to break and a rainbow lights up the sky signalling the end of the storm. You get back to camp just in time for dinner. You discuss the day's events around the campfire as the sun begins to set, lighting the sky orange and pink. Dusk brings with it a greyness that hides the details of the landscape, making it more difficult to discern what is happening beyond the campsite. Soon it is dark and everyone gathers around the fire for warmth, light and companionship before going to sleep under the soft light of the moon.

Daylight from an evolutionary perspective

Prior to the advent of buildings, humans lived immersed in nature. Daily activities were aided or constrained by the presence or absence of daylight and by qualities of light that signalled time and weather. Our physiological systems – especially our sleep-wake cycles – were in synch with the diurnal rhythms of daylight, as were our emotional responses to light and darkness. The strong, consistent preference for daylight in our built-up environments today suggests that evolutionary pressures are likely to be influencing our responses.

Although all our sensory systems acting together were important to survival, the visual system is our primary mode of gathering information. Thus, light must have played a powerful role in information processing and survival. In ancestral habitats, light was likely to have had several key functions that are relevant to the design and operation of built-up environments. These include:

- Indicator of time. Natural light changes significantly over the course of the day, providing a signal of time that has been crucial to survival throughout human history. Being in a safe place when the sun was setting was not a trivial matter for our ancestors, and it is still important to human well-being.

- Indicator of weather. Light also changes with weather, from the dark, ominous colour of storms to rainbows and beams of light as clouds break up and recede. Attending to the variability in light and its relationship to changes in weather would have been highly adaptive (Orians and Heerwagen, 1992).

- Signal of prospect and refuge. The sense of prospect is signalled by distant brightness and refuge is signalled by shadow (Appleton, 1975, Hildebrand, 1999). Brightness in the distance aids assessment and planning because it allows for information to be perceived in sufficient time for action to be taken. High prospect environments include open views to the horizon and a luminous sky ('big sky'). A sense of refuge is provided by shadows from tree canopies, cliff overhangs, or other natural forms. Mottram (2002) suggests that allowing the eyes to rest on infinity (which the horizon represents visually) may be beneficial, even if the view is perceptually manipulated through visual images rather than actual distant views. Thus, our natural attraction to the horizon could be satisfied in many ways through the manipulation of light and imagery applied to vertical surfaces.

- Signal of safety, warmth, and comfort. Although we usually think of the sun as the primary source of light in the natural environment, fire also served as a source of light and comfort, both physical and psychological. Anthropologist and physician Melvin Konner (1982) suggests that the campfire served important cognitive and social functions in developing human societies. The campfire extended the day, allowing people to focus their attention not only on the daily grind of finding food and avoiding predators but also on thinking about the future, planning ahead and cementing social relationships through story-telling and sharing the day's experiences.

- Peripheral processing aid. Light also provides information about what is hap-

There is an innate need in human beings to be in touch with nature. The acceptance of buildings is therefore crucially dependent on the extent to which they enable contact with external surroundings.

pening beyond the immediate space one occupies. It illuminates the surrounding environment that impinges continually on our peripheral processing system. The importance of peripheral light is evident from the discomfort many people feel when they are in a lighted space with low lighting at the edges, leading to a perception of gloom. Lighting researchers suggest that negative responses to gloom may be associated with its natural function as an early warning signal that visual conditions are deteriorating (Shepherd et al, 1989).

- Synchronisation of bio- and social rhythms. As a diurnal species, light plays a critical role in our sleep-wake cycles and also synchronises social activities. Although we can now alter our activity cycle with the use of electric light, research evidence nonetheless shows that night work is still difficult and often results in drowsiness, difficulty sleeping, mood disturbances and increased cognitive difficulties at work (Golden et al, 2005). Some night work facilities are using bright interior light to shift biological rhythms and increase alertness. There is also evidence that people who experience seasonally-related depression prefer to be in brightly lit spaces (Heerwagen, 1990).

To summarise, light provides information for orientation, safety and surveillance, interpretation of social signals, identification of resources and awareness of hazards. Whether it is the changing colour of light associated with sunset or storms, the movement of fire or lightning, the brightness in the distance that aids planning and movement, or the sparkle of light off water – all these aspects of light have played a role in helping our ancestors make decisions about where to go, how to move through the environment, what to eat, and how to avoid dangers.

Human experience of daylight in the built-up environment

Given Homo sapiens immersion in a naturally-lit environment during our evolutionary history, it is not surprising that building occupants enjoy the very features that characterise daylight in natural landscapes.

Research on office buildings shows a high preference for daylit spaces and for specific features of daylight. A study of seven office buildings in the Pacific Northwest (Heerwagen et al, 1992) shows that more than 83% of the occupants said they "very much" liked daylight and sunlight in their workspace, and valued the seasonal changes in daylight. Interestingly, daylight design generally aims to eliminate direct beam sunlight from entering work areas due to glare and heat gain.

When the data were looked at with respect to the occupant's location, 100% of those in corner offices said the amount of daylight was "just right," as did more than 90% of those along the window wall in spaces other than the corner offices. Even those located in more interior positions were satisfied with the daylight, as long as they could look into a daylit space.

Daylight and work

We know that people like to be in daylit spaces and that they like indoor sunlight. However, when occupants in the above study were asked about light for work purposes, only 20% said daylight was sufficient for work. The vast majority said they used electric ceiling light "usually" or "always" to supplement daylight. Even those who rated daylight as "just right" also used electric lights regularly. Although the reasons for this situation are not clear, anecdotal evidence suggests that occupants

Views towards the outside are among the most important criteria for the acceptance of buildings. While providing variety within the everyday routine of life, they also help to prevent feelings of claustrophobia.

also supplement daylight with task lamps. It is possible that electric light, whether ceiling or task, reduces lighting contrasts on work surfaces that make some visual work difficult.

A post-occupancy evaluation of the first LEED Platinum building in the US, the Philip Merrill Environmental Center, shows very high satisfaction with daylight, despite concerns with visual discomfort (Heerwagen and Zagreus, 2005). This suggests that people may value the psychological benefits of daylight even when daylight creates difficulties for work due to glare and uneven light distribution.

Certainly, the kinds of visual tasks we perform in today's work environments are very different from our ancestors' daily tasks. Cooking, tool making, conversing, foraging, and hunting could be effectively carried out over a wide range of luminous conditions. In contrast, reading and computer work require a much greater degree of visual acuity that may be more difficult in some daylit environments. Yet a uniformly lit environment that may be appropriate for office work lacks the psychological, and perhaps biological, value of daylight.

Attitudes toward Daylight and Electric Light

A study of office workers in a Seattle high-rise building asked respondents to compare the relative merits of daylight and electric light for psychological comfort, general health, visual health, work performance, jobs requiring fine observation, and office aesthetics (Heerwagen and Heerwagen, 1986).

The results show that the respondents rated daylight as better than electric light for all variables, especially for psychological comfort, health and aesthetics. They rated daylight and electric light as equally good for visual tasks.

At the time of this study in 1986, there was little evidence connecting daylight to health. Since that time, however, there has been a surge of research on the link between light and health, much of it focusing on the circadian system and seasonal affective disorder. Much of this work has been conducted in clinical settings with phototherapy. Since a review of this topic is provided elsewhere in this issue, it will not be addressed here.

However, it is worth noting a laboratory study that investigated lighting preferences of subjects with Seasonal Affective Disorder (SAD) compared to subjects that did not experience seasonal changes in mood or other behaviours (Heerwagen, 1990). Those who experienced seasonal changes chose significantly higher levels of brightness for all lighting sources compared to those who did not. This suggests that people experiencing SAD may indeed be 'light hungry' and could benefit from indoor environments with high daylight levels, such as atria, sunrooms and locations adjacent to windows.

But what do we know about other health impacts of daylight in the built-up environment? Research in hospital settings, looking at the relationship between room daylight levels and patient outcomes, found that bipolar patients in bright, east-facing rooms stayed in the hospital 3.7 fewer days on average than those in west-facing rooms (Benedetti and others, 2001). Similar results were found by Beauchamin and Hays (1996) for psychiatric in-patients; those in the brightest rooms stayed in the hospital 2.6 fewer days on average. However, neither of these studies provides data on the actual light levels in the patient rooms or light entering the retina, so it is difficult to draw conclusions about exposure levels.

More recent research in a Pittsburgh hospital actually measured room brightness levels. Walch and others (2005) studied 89 patients who had elective cervical and spinal surgery. Half the patients were located on the bright side of the hospital, while the other half were in a hospital wing with an adjacent building that blocked sun entering the rooms. The study team measured medication types and cost as well as psychological functioning the day after surgery and at discharge. The researchers also conducted extensive photometric measurements of light in each room, including light levels at the window, on the wall opposite the patient's bed, and at the head of the bed (which presumably would have been at or near the patient's eye level). The results showed that those in the brighter rooms had 46% higher intensity of sunlight. Patients in the brightest rooms also took 22% less analgesic medicine/hr and experienced less stress and marginally less pain. This resulted in a 21% decrease in the costs of medicine for those in the brightest rooms. The mechanisms linking bright light to pain are currently unknown, however.

Other potential benefits of indoor daylight include improved sense of vitality, decreased daytime sleepiness and reduced anxiety. For example, a large-scale survey of office worker exposure to light during the winter in Sweden shows that mood and vitality were enhanced in healthy people with higher levels of exposure to bright daylight (Partonen and Lönngvist, 2000). Another study shows that a half-hour exposure to bright daylight by sitting adjacent to windows reduced afternoon sleepiness in healthy adult subjects (Kaida et al., 2006). In that study, daylight levels ranged from about 1,000 lux to over 4,000 lux, depending upon sky conditions. Kaida et al. found that daylight was almost as effective as a short nap in reducing normal post-lunchtime drowsiness and increasing alertness.

Natural light at the place of work is not only a question of seeing. Surveys have shown that people place great value on daylight even when it is actually detrimental to vision.

Is daylight biophilic?
E.O. Wilson popularised the term "biophilia" in 1984 with the publication of his book, Biophilia. In it he describes biophilia as the human tendency to affiliate with life and life- like processes. Wilson never fully explained what he meant by "life-like processes." However, if we consider the characteristics of life, we can look at daylight as sharing some of these features. Daylight grows over the course of the day as the sun moves across the sky, it changes in colour and intensity, it provides sustenance for life, its absence at night provokes behavioural change, and the lengthening day after the long winter months evokes joy and a sense of well being.

Wilson and others describe biophilia as an evolved adaptation linked to survival. The evidence cited in this article suggests that daylight, in addition to being "life-like," has deeply-seated health and psychological benefits that may be difficult to support in electrically-lit environments. Clearly, we can design interiors with electric light that changes intensity and colour over time and that mimics other features of daylight. But will it feel the same? Can electrically-lit environments provide the same biological benefits as daylight? We don't yet know the answers to these questions, but we do know that such efforts would be more energy intensive and more costly.

The life-like and life-supporting qualities of daylight strongly suggest that daylight is a basic human need, not a resource to be used or eliminated at the whim of the building owner or designer. The presence of daylight and sunlight in buildings clearly affects our psychological and physiological experience of place. Its absence creates lifeless, bland, indifferent spaces that disconnect us from our biological heritage.

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BODY CLOCKS, LIGHT, SLEEP AND HEALTH

Over the last one and a half centuries, artificial light and the restructuring of working times have seemingly 'liberated' us from the diurnal cycles of light and dark that nature imparts on us. Yet recent research has shown that this separation from nature comes at a considerable cost, causing health and social problems. A reconnection to the rhythms of nature is therefore needed – and this will also have a profound influence on architecture.

By Russell G. Foster
Illustrations by Ulrika Nilsson Carlsson

Our lives are ruled by time and we use time to tell us what to do. But the digital alarm clock that wakes us in the morning or the wristwatch that tells us we are late for supper are unnatural clocks. Our biology answers to a profoundly more ancient beat that probably started to tick early in the evolution of all life. Embedded within our genes, and almost all life on earth, are the instructions for a biological clock that marks the passage of approximately 24 hours. Biological clocks or 'circadian clocks' (circa about, diem a day) help time our sleep patterns, alertness, mood, physical strength, blood pressure and much more. Under normal conditions we experience a 24-hour pattern of light and dark, and our circadian clock uses this signal to align biological time to the day and night. The clock is then used to anticipate the differing demands of the 24-hour day and fine-tune physiology and behaviour in advance of the changing conditions. Body temperature drops, blood pressure decreases, cognitive performance drops and tiredness increases in anticipation of going to bed. Whilst before dawn, metabolism is geared-up in anticipation of increased activity when we wake.

Few of us appreciate this internal world, seduced by an apparent freedom to sleep, work, eat, drink, or travel when we want. But this freedom is an illusion; in reality we are not free to act independently of the biological order that the circadian clock imparts. We are unable to perform with the same efficiency throughout the 24h day. Life has evolved on a planet that experiences profound changes in light over the 24h day and our biology anticipates these changes and needs to be exposed to the natural pattern of light and dark to function properly. Yet we detach ourselves from the environment by forcing our nights into days using electric light, and isolate ourselves in buildings that shield us from natural light. This short review considers some of the important consequences of our increasing detachment from the sun.

The day within

At the base of the brain, in a structure known as the anterior hypothalamus, is a cluster of about 50,000 neurones known as the suprachiasmatic nuclei or SCN. If this region is destroyed as a result of a stroke or tumour, then 24h rhythmicity is lost and physiology becomes randomly distributed across the day. The finding that individual SCN neurones, isolated from all other cells, show near 24-hour rhythms in electrical activity demonstrated that the basic mechanisms that generate this internal day must be part of a sub-cellular molecular mechanism. To date, approximately 14-20 genes and their protein products have been linked to the generation of circadian rhythms.

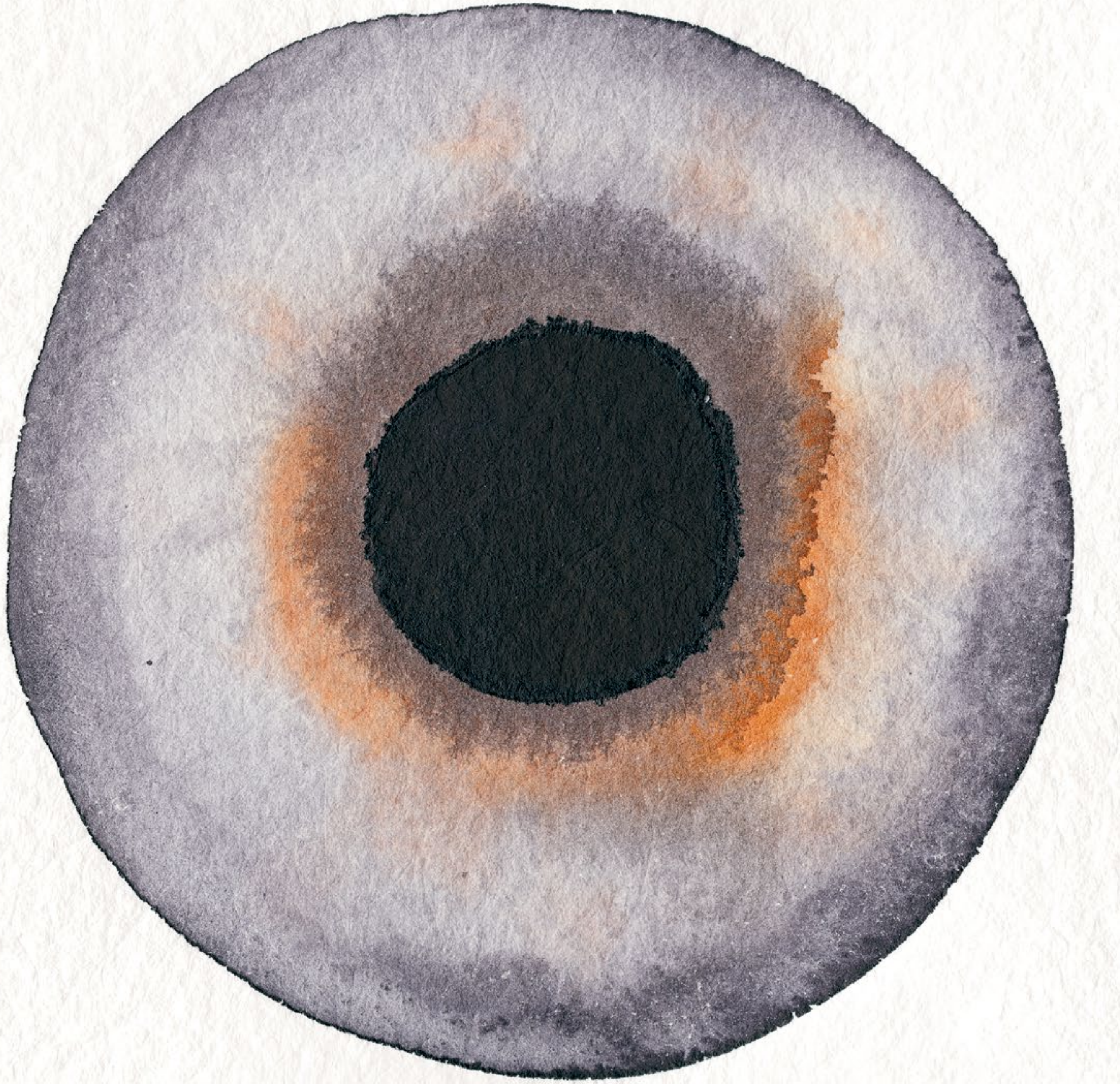
At the heart of the molecular clock is a negative feedback loop that consists of the following sequence of events: the clock genes are transcribed and the messenger RNAs (mRNAs) move to the cytoplasm of the cell and are translated into proteins; The proteins interact to form complexes and then move from the cytoplasm into the nucleus and inhibit the transcription of their own genes; the inhibitory clock protein complexes are then degraded and the core clock genes are once more free to make their mRNA and hence fresh protein. This negative feedback loop generates a near 24-hour rhythm of protein production and degradation that encodes the biological day.

The original assumption was that SCN neurones collectively drive or impose a 24h rhythm on physiology and behaviour. However, the discovery that isolated cells from almost any organ of the body produce clock genes/proteins in a circadian pattern led to a major shift in our understanding. We now appreciate that the SCN acts as a master pacemaker, coordinating the activity of all cellular clocks in a manner that has been likened to the conductor of an orchestra, regulating the timing of the multiple and varied components of the ensemble. In the absence of the SCN, the individual cellular clocks of the organ systems drift apart and coordinated circadian rhythms collapse – a state known as internal desynchronisation. Internal desynchronisation is the main reason why we feel so awful as a result of jet lag. All the different organ systems, the brain, liver, gut, muscles etc., are working at a slightly different time. Only when internal time has been re-aligned can we function normally once more.

Our body clocks are different – genes and hormones?

Our body clocks are not all the same. If you are alert in the mornings and go to bed early you are a 'lark', but if you hate mornings and want to keep going through the night, then you are an 'owl'.

These terms have been used to describe the real phenomenon of diurnal preference – the times when you prefer to sleep and when you do your best work. Diurnal preference is determined partly by our clock genes. Exciting research in recent years has shown that small changes in these genes have been linked to the fast clocks (shorter than 24h) of larks or slower clocks (longer than 24h) of owls. But it is not just our genes that regulate our diurnal preference. Sleep timing changes markedly as we age. By the time of puberty, bed times and wake times drift to later and later hours. This tendency to get up later continues until about the age of 19.5 years in women and 21 years in men. At this point there is a reversal and a drift towards earlier sleep and wake times. By the



The eye establishes a connection to the outer world not only for our sense of sight but also for our sense of time and for many temporal processes in our body.

age of 55–60 we are getting up as early as we did when we were 10. These and allied results demonstrate that young adults really do have a problem getting up in the morning. Teenagers show both delayed sleep and high levels of sleep deprivation, because they are going to bed late but still having to get up early in the morning to go to school. These real biological effects have been largely ignored in terms of the time structure imposed upon teenagers at school. Of the few studies undertaken, later starting times for schools have been shown to improve alertness and the mental abilities of students during their morning lessons. Ironically, whilst young adults tend to improve their performance across the day, their older teachers show a decline in performance over the same period! The mechanisms for this change in diurnal preference remain poorly understood, but are thought to relate to the marked changes in our steroid hormones (e.g. testosterone, oestrogen, progesterone) and their rapid rise during puberty and subsequent slower decline.

Light clocks and alertness

A clock is not a clock unless it can be set to local time – and the molecular clocks within the SCN are normally adjusted (entrained) by daily exposure to light around dawn and dusk detected by the eyes. Failure to expose the clock to a stable light/dark cycle results in drifting or 'free-running' circadian rhythms or disrupted cycles. Detachment from solar day is common in industrialised societies and the special case of shift workers will be discussed below; however isolation from robust dawn and dusk signals occurs in many different instances. For example, paediatric and adult intensive care units frequently utilise low and constant light. In such an environment circadian rhythms would be expected to drift and become desynchronised. The result, as discussed below in the sub-section 'Disrupting the clock', will be a weakened health status of the patient. Light does more than regulate the timing of circadian rhythms – it also has a direct effect on alertness and performance. Brain imaging following light exposure shows increased activity in many of the brain areas involved in alertness, cognition and memory (thalamus, hippocampus, brainstem) and mood (amygdala). Furthermore, increased light has been shown to improve concentration, the ability to perform cognitive tasks and to reduce sleepiness. As a result, inappropriate light exposure in a building will not only disrupt sleep and circadian timing but also levels of alertness and performance. We will return to this topic below.

Our understanding of how light regulates circadian rhythms and alertness has been advanced dramatically over the past few years with the discovery of an entirely new photoreceptor system in the eye. This novel photoreceptor is not located in the part of the eye containing the rods (night vision) and cones (day vision) that are used to generate an image of the world, but in the ganglion cells that form the optic nerve. Most ganglion cells form a functional connection between the eye and the brain, but a small number of specialised ganglion cells (1–3%) are directly light-sensitive and project to those parts of the brain involved in the regulation of circadian rhythms, sleep, alertness, memory and mood. These photosensitive retinal ganglion cells (pRGCs) contain a light-sensitive pigment called Opn4, which is most sensitive in the blue part of the spectrum with a peak sensitivity at 480 nm – very similar to the 'blue' of a clear blue sky. This light-detection system has evolved to be anatomically and functionally independent of the visual system, and probably evolved before vision as the main way to detect light for entraining daily rhythms. Remarkably, the pRGCs can still detect light to shift the circadian clock or affect alertness even in animals or people where the rods and cones used for vision are completely destroyed and who are otherwise totally visually blind. This raises important implications for ophthalmologists who are largely unaware of this new photoreceptor system and its impact on human physiology.

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In view of the colour sensitivity of Opn4, we would predict that blue light should be the most effective wavelength (colour) for shifting circadian rhythms and alerting the arousal systems. In all studies undertaken to-date, this has been shown to be the case. Blue light exposure at night is most effective at shifting the timing of the circadian clock, reducing sleepiness, improving reaction times and activating areas of the brain mediating alertness and sleep. In addition to its spectrum, light timing, duration, pattern and history all interact to influence circadian rhythms and alertness. Light timing is particularly important. Light can either advance (go to bed earlier) or delay (go to bed later) the circadian system depending on the timing of exposure. Under conditions of solar light

Inner timepiece: special photoreceptors in the ganglion cells of the optic nerve synchronise our inner clock with the cycles of light and dark in our environment – and thus with local time.

exposure, light around dusk causes a delay of the clock, whereas light exposure around dawn will advance the clock. This delaying and advancing effect of light keeps the SCN locked onto to the solar day. Such differential effects of light become vitally important when trying to understand the impact of jet lag, shift work (see below), or building design on sleep/wake timing.

The pRGCs are not as sensitive to light as the rods and cones, so that short light exposure that is easily detected by the visual system is not recognised by the pRGCs. However, dim light can have an effect if it is delivered over long periods of time. Thus relatively dim indoor room light from bedside lamps and computer screens (less than 100 lux) can have measureable effects on the clock and arousal systems over several hours, and may exacerbate sleep disorders. Collectively, these effects of light – spectral composition, time of exposure and brightness – have widespread clinical and occupational applications in not only treating sleep disorders and fatigue but in the architecture of hospitals, schools, offices, retail space and domestic buildings.

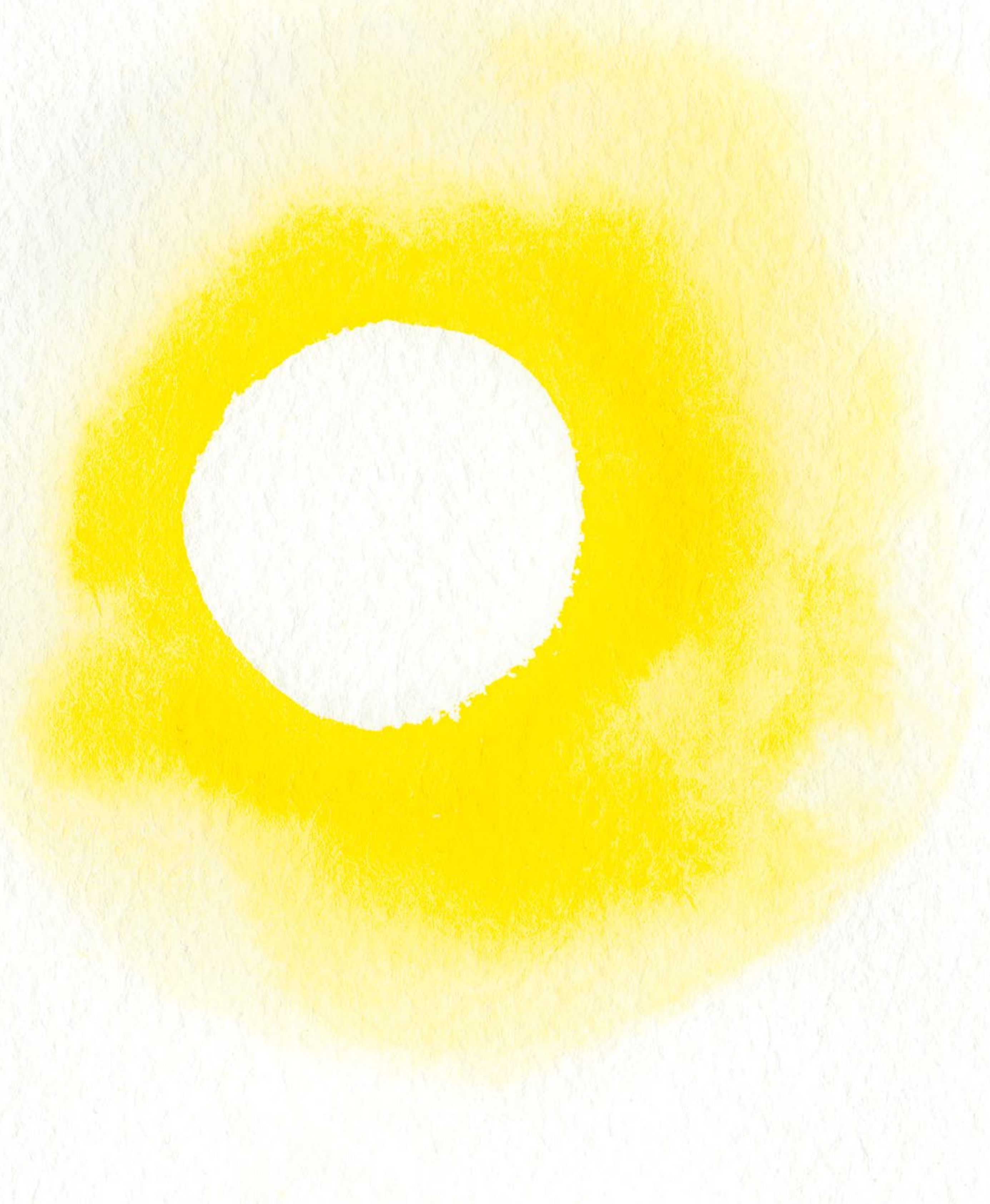
Disrupting the clock – shift work and 24/7

The introduction of electricity and artificial light in the 19th century and the re-structuring of work times have progressively detached us from the solar 24-hour cycles of light and dark. The consequence has been disruption of the circadian and sleep systems. Much has been written about the effects of this disruption, and in general terms the effects are clear (Table 1). Sleep and circadian rhythm disruption results in performance deficits that include increased errors, poor vigilance, poor memory, reduced mental and physical reaction times and reduced motivation. Sleep deprivation and disruption are also associated with a range of metabolic abnormalities, including the glucose/insulin axis. For example, sleep disrupted individuals take longer to regulate blood-glucose levels and insulin can fall to levels seen in the early stages of diabetes — abnormalities that can be reversed by normal sleep. Such results have suggested that long-term sleep and circadian rhythm disruption might contribute to chronic conditions such as diabetes, obesity and hypertension. Furthermore, obesity is strongly correlated with sleep apnoea and hence additional sleep disturbance. Under these circumstances a dangerous positive feedback loop of obesity and sleep disturbance can often result.

Sleep loss and circadian rhythm disruption are most obvious in night-shift workers. More than 20% of the population of employment age work at least some of the time outside the 07.00–19.00 day.

Josephine Arendt at the University of Surrey makes the point: "Because of their rapidly changing and conflicting light-dark exposure and activity-rest behaviour, shift workers can have symptoms similar to those of jet lag. Although travellers normally adapt to the new time zone, shift-workers usually live out of phase with local time cues". Even after 20 years of night-shift work, individuals will not normally shift their circadian rhythms in response to the demands of working at night. Despite the great variety and complexity of 'shift systems', none have been able to alleviate fully the circadian problems associated with shift work. Metabolism, along with alertness and performance, are still high during the day when the night-shift worker is trying to sleep and low at night when the individual is trying to work. A misaligned physiology, along with poor sleep, in night-shift workers has been associated with increased cardiovascular mortality, an eight-fold higher incidence of peptic ulcers, and a higher risk of some forms of cancer. Other problems include a greater risk of accidents, chronic fatigue, excessive sleepiness, difficulty sleeping and higher rates of substance abuse and depression. Night-shift workers are also much more likely to view their jobs as extremely stressful.

So why don't shift-workers shift their clocks? After all, if we travel across multiple time zones we do recover from jet lag and entrain to local time. The answer seems to be that the pRGCs that entrain the circadian system are fairly insensitive to light. The clock always responds to bright natural sunlight in preference to the dim artificial light commonly found in the workplace. It is not obvious but shortly after dawn, natural light is some 50 times brighter than normal office lighting (300–500 lux), and at noon natural light can be 500 to 1,000 times brighter – even in Northern Europe. Thus exposure to strong natural light on the journey to and from work, combined with low levels of light in the workplace, entrains the night-shift worker onto local time. In this way biological and social time are persistently misaligned in night-shift workers. In the absence of any natural light, however, the clock will eventually respond to man-made light. Theoretically this information could be used to develop practical countermeasures to the problems of working at night. However, most night-shift workers prefer not to be adapted to a reversed sleep-wake cycle as they like to spend their work-free time with family and friends at maximum alertness. One suggestion has been to select individuals for shift work on the basis of their diurnal preference – 'owls' have naturally better alertness at later hours and make better night-shift workers, while 'larks' are usually better at adapting to early morning shifts.



Long phases of human evolution took place in bright sunlight. However, this has been changing since the beginning of the industrial age – with consequences for our health and psyche that are only gradually becoming known today.

There is increasing evidence of a complex and important interaction between circadian rhythm/sleep disruption and the immune system. Rats deprived of sleep readily die of septicaemia, and in humans the activity of natural killer cells can be lowered by as much as 28% after only one night without sleep. Sleep disruption also alters many other aspects of the immune system including circulating immune complexes, secondary antibody responses, and antigen uptake. Cortisol provides an important link between the immune system, sleep and psychological stress. Sleep disruption and sustained psychological stress increase cortisol levels in the blood. Indeed, one lost night of sleep can raise cortisol by nearly 50% on the following evening. High levels of cortisol act to suppress the immune system, so excessively tired people are more likely to acquire an infection. In this context, night-shift workers are at a higher risk of certain types of cancer and there has been considerable speculation as to the cause. In view of the considerable physiological stress and sleep loss associated with night-shift work, immune impairment could provide a mechanistic link with the increased risk of cancers in night-shift workers.

Conclusions and perspectives

The discussion in this article has considered both the biology of internal time and some of the general problems we face if we ignore the role of sleep and circadian timing in our lives. It is now clear that poor sleep, mood changes, decreased cognitive performance, reduced communication skills and a higher risk of disease can arise from the demands of a 24/7 society. One of the consequences of this impairment of brain function is the reliance by large sections of society on daytime stimulants and night-time sedatives to replace the order normally imposed by the circadian system. Shift-work is perhaps the most extreme example, but we should not ignore the fact that many of our children in schools, healthcare professionals in hospitals, and manufacturing and business workforces are isolated from natural light. This will not only increase their likelihood of circadian rhythm and sleep disturbance but also have a significant impact upon their cognition, mood and sense of well-being. We are a species that has evolved under bright light conditions – even on an overcast day in Europe, natural light is around 10,000 lux, and may be as high as 100,000 lux on bright sunny days. Yet we live in homes and work in offices, factories, schools and hospitals that are often isolated from natural light and where artificial light is often around 200 lux and seldom exceeds 400–500 lux. We live our lives in dim caves. Modern architectural design has the opportunity, by letting light into our lives, to liberate humanity from the gloom and allowing our bodies to use the natural pattern of light and dark to optimise our biology.

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Table 1
Consequences of Circadian Rhythm Disruption and Shortened Sleep

Drowsiness/microsleeps/unintended sleep
Abrupt mood shifts
Increased irritability
Anxiety and depression
Weight gain
Decreased socialisation skills and sense of humour
Decreased motor performance
Decreased cognitive performance
Reduced ability to concentrate and remember
Reduced communication and decision skills
Increased risk-taking
Reduced quality, creativity and productivity
Reduced immunity to disease and viral infection
Feelings of being chilled
Reduced ability to handle complex tasks or multi-task
Increased risk of substance abuse

ARCHITECTURE FOR WELL-BEING AND HEALTH

By Koen Steemers

To truly enhance human well-being, building design needs to move beyond optimising single parameters such as temperature and humidity, to more holistic approaches that take their cues in health-supporting human behaviours. Based on the Five Ways to Well-Being that have recently been established by scientists, this article outlines some essential rules of thumb that designers can follow in order to nudge building users into a healthier way of living.

'BUITEN DE VESTE' SCHOOL IN STEENBERGEN, THE NETHERLANDS, **PHOTO: THEKLA EHLING**

The design of our built environment affects our health and well-being, and can have long-term implications for quality of life. The publication of Nudge: Improving health, wealth and happiness by Richard Thaler and Cass Sunstein in 2008 was influential in revealing that behaviour can be strongly influenced by context[1]. People can be nudged into making better decisions in largely automatic, non-coercive and simple ways, through changing what Thaler and Sunstein refer to as "choice architecture". Can architecture create choice architecture? The role that architecture can play seems evident: "Designled interventions can make better choices easier or constrain behaviours by making certain actions more difficult"[2].

The purpose of this article is to outline the definition(s) of health and well-being, and to determine the potential implications and opportunities for housing design. The emphasis will be on the presence of well-being rather than the absence of ill health. There can be no doubt that negative physical health-related considerations associated with, for example, poor indoor environmental quality should be avoided. However, this essay will focus instead on supporting positive mental well-being, which, in turn, has implications for physiological health. There is an established body of expertise related to the study of physical health with increasing quantitative evidence, but research into well-being in the built environment is a relatively recent and largely qualitative area of investigation that is nevertheless beginning to reveal consistent and widely accepted findings. These findings are interpreted here in terms of architectural design.

When we discuss well-being in buildings, it is more important to incorporate a wide range of both quantitative and qualitative health considerations rather than to focus on single, narrowly defined criteria. Such 'silo thinking' tends not to aid good design (perfectionism can be crippling) and often different criteria are in tension. An alternative approach is to determine 'good enough' strategies which increase diversity and adaptability, and that are user-centred. This is not to deny the potentially chronic health impacts of poor indoor environmental quality on certain sectors of the population (i.e. large impact for a small population), but rather to balance and complement this with strategies to improve well-being for the wider population (i.e. modest improvement for a large population).

The structure of this article is divided into three sections. The first section reviews the spatially relevant definitions of well-being and their relationships to health. The second section draws on research to define the implications and opportunities for architecture. Finally, the last section provides rules of thumb and architectural propositions that exemplify the findings.

Defining health and well-being

The World Health Organisation now defines health not as the absence of ill-health but as "a state of complete physical, mental and social well-being"[3]. The definition of health has been changing and now includes an awareness of the interrelationships between social and psychological, as well as medical, factors. The way in which an individual functions in society is seen as part of the definition of health, alongside biological and physiological symptoms. Health is no longer simply a question of access to medical treatment but it is determined by a range of factors related to the quality of our built environment[4].

This wider definition of health comes at a time of increasing pressures on health services as a result of an ageing population, in-

"Whether people are healthy or not, is determined by their circumstances and environment. To a large extent, factors such as where we live, the state of our environment, genetics, our income and education level, and our relationships with friends and family all have considerable impacts on health ..."

World Health Organization:
The determinants of health,
http://www.who.int/hia/evidence/doh/en/

'BUITEN DE VESTE' SCHOOL IN STEENBERGEN, THE NETHERLANDS, **PHOTO: THEKLA EHLING**

creasing obesity, rising mental health problems and higher expectations[5]. Thus, the narrow focus on individual symptoms and medical treatment is no longer sufficient or sustainable, and a more holistic appreciation of the spectrum of health-related considerations, including the prevention of ill-health, is timely. This approach sees "health and well-being as interdependent; it holds 'prevention' as important as 'cure', and looks for long-term solutions rather than more immediately attainable treatments"[6]. Staying healthy in your home and in your community is the way to limit the increasing pressure on health services, and thus designing the home, neighbourhood and work environment to improve health and well-being is an opportunity that presents itself.

In the field of sustainable development, reference is often made to the 'triple bottom line' of physical, economic and social. The health and well-being triple bottom line could be summarised as health, comfort and happiness. In order to draw more direct parallels with the built environment, we can refer to Vitruvius and his tripartite model of the three elements required for a well-designed building[7]:

I "firmitas" or firmness (health)
II "utilitas" or commodity (comfort)
III "venustas" or delight (happiness)

Health is referred to in this context in more conventional terms – as the absence of disease – and typically measurable in terms of symptoms such as body temperature or blood chemistry. Comfort is widely understood to be a "condition of mind which expresses satisfaction" with the environment[8] – whether thermal, visual, acoustic, etc. – and thus incorporates both qualitative psychological considerations (e.g. expectation, control) and quantitative physical parameters (e.g. temperature, air movement). Happiness colloquially refers to emotions experienced, potentially ranging from contentment to joy. Happiness is therefore primarily a subjective and qualitative consideration. Despite this, research over the last decade has begun to define well-being, which will be addressed in more detail in this paper.

One key challenge is the quantification of health and well-being, and thus the assessment of the overall health performance of design. At one end of the spectrum, physical ill health is typically identifiable and measureable in terms of the symptoms and causes. For example, air quality (e.g. VOCs, PM or CO_2) and its impact, particularly on vulnerable occupants (e.g. those with lung conditions, the young and the old), can be quantified, and even treatments of both the occupants and the buildings can be prescribed (e.g. improved ventilation, the removal of offending materials, design interventions to prevent mould growth, etc.). Although subjective assessment of air quality, particularly related to odour, can offer useful insights, often health-threatening indicators can only be measured. Specific criteria and design strategies to tackle chronic physiological health problems can be defined, and there is a wealth of expertise to support this[9].

At the other end of the health and well-being spectrum is mental well-being or happiness. As we move from the deterministic-medical to the subjective-psychological end, the common perception is that the emphasis changes from quantitative to qualitative. However, it is now evident that even within the sphere of the subjective parameters there are emerging methodologies and indicators that can be defined. For example, in the field of thermal comfort there has seen a development from narrow and precise physiological comfort theory, based on the seminal work of Fanger[10], to a more holistic understanding that has led to the adoption of adaptive comfort theory[11]. Similarly, health research has extended from the treatment of symptoms to incorporate a wider and more holistic appreciation of well-being of the population. It is the topic of well-being that is the primary focus of this essay.

The notion of well-being consists of two key elements: feeling good and functioning well. Feelings of happiness, curiosity and engagement are characteristic of someone with a positive sense of themselves. Having positive relationships, control over your own life and a sense of purpose are all attributes of functioning well. International evidence has recently been gathered to measure well-being, demonstrating that this field has now emerged as a rigorous discipline[12].

Recent research has demonstrated connections of key physical design characteristics with the Five Ways to Well-Being (Connect, Keep Active, Take Notice, Keep Learning and Give), which have been associated with positive mental health.[13] Based on these findings, the following paragraphs reveal how the provision of local urban and domestic resources can impinge on the five healthy behaviours. This supports current theory and research, which shows that a sufficient quantity and quality of diverse environmental, social and physical resources can influence human cognition, which, in turn, can increase the healthy behaviours of the wider population.

'BUITEN DE VESTE' SCHOOL IN STEENBERGEN, THE NETHERLANDS, **PHOTO: THEKLA EHLING**

'BUITEN DE VESTE' SCHOOL IN STEENBERGEN, THE NETHERLANDS. PHOTO: THEKLA EHLING

DESIGN AND WELL-BEING

The relationship between architecture and health has historically received little attention, beyond the design requirements of healthy buildings. Recent work has changed this and has established a more holistic awareness of the role of architecture in health. An example of this in the UK includes the publication of reports by the Royal Institute of British Architects[14] and the Commission for Architecture and the Built Environment[15]. This is supported by an increasing wealth of medical research related to physical health[16] and mental health[17]. The emphasis has been on ill health as a result of the effects of environmental characteristics such as overcrowding, noise, air quality and light. These effects are typically described as direct (i.e. consequences on physical and mental health) as well as indirect (e.g. through social mechanisms)[18]. However, rather than focusing on ill health, the definition and study of well-being has been emphasising the behaviours that support a 'flourishing' population. It is the built-environment characteristics that support such positive behaviour, which is a key point of discussion here.

The science of well-being is a relatively recent area of enquiry. However, the UK Government's 'Foresight' project, related to well-being[19], provides the critical mass of evidence that led to the definition of the Five Ways to Well-Being mentioned above[20]. These represent the key behaviours that have been shown to relate to improved well-being. Each behaviour is associated with subjective well-being as reported in research papers, notably in medical journals, that draw on large-scale and meta-analysis of exacting studies. Thus there is no shortage of evidence to support the assertion that such behaviours, the Five Ways, result in improved well-being.

I Connect: the quantity and quality of social connections (e.g. talking and listening to family or strangers) correlates with reported well-being as well as physical health[21].

II Keep Active: there is ample evidence from global and meta-studies to demonstrate that physical activity reduces symptoms of mental and physical ill-health[22].

III Take Notice: being mindful – paying attention to the present and being aware of thoughts and feelings – is a behaviour that reduces symptoms of stress, anxiety and depression[23].

IV Keep Learning: aspirations are shaped in early life, and those who have higher aspirations tend to have better outcomes. Such aspirations are modified by the environment[24]. The evidence shows that, also later in life, those participating in music, arts and evening classes, for example, attain higher subjective well-being[25].

V Give: evidence has emerged that prosocial rather than self-centred behaviour has a positive impact on happiness. Such consequences of altruistic behaviour are related both to spending on others as opposed to oneself[26] and through volunteering and offering help[27].

The critical next question is to discuss how the Five Ways to Well-Being relate to and are influenced by the built environment.

Connect
The provision of local 'everyday public spaces' creates opportunities for people to connect, and is a significant resource of well-being for individuals and the wider community[28]. Although not all users have the same requirements and expectations of a social space, key qualities include: location – accessible and proximity to other communal resources (school, market) to support casual encounters; places to stop and sit, on a park bench or at a café table, so that encounters can be more than fleeting; adaptability – spaces without specific or prescribed functions that enable spontaneous, impromptu activities; homeliness – a sense of safety and familiarity; pleasantness – clean and peaceful, or bustling and lively; specialness – unique qualities, aesthetics, or subjective memories. When a space is pedestrian-oriented as opposed to car-oriented, this is correlated with a sense of community, due to the perception of the pedestrian environment being particularly strongly related to opportunities for social interaction[29]. And finally, natural, green or landscape qualities have been widely and for a long time associated with a range of health benefits[30]. In summary, "public spaces that brought people together and where friendships and support networks were made and maintained were key to a general sense of well-being"[31].

Keep Active
Physical activity (walking, cycling, sports, etc.) is widely associated with reducing causes of chronic conditions and the burden of disease, disability and premature death. Design characteristics associated with increasing activity include access to physical activity facilities (e.g. sports centres and equipment), convenient and proximate access to destinations (work, shops, school, public transport), high residential density (which is associated with greater proximity to facilities and destinations), land use (e.g. mixed use) and walkability (convenient and safe pavements, traffic calming features)[32]. Although there are some potential additional benefits to physical activity in an outdoor and preferably natural environment, exercise indoors can be equally effective[33]. Design strategies to promote indoor physical activity include: the provision of (shared) exercise space, encouraging stair use through the distribution (separation) of functions over different floor levels, and creating attractive experiences along circulation routes (views, art, daylight, greenery).

Take Notice
Being mindful and taking notice of a design intervention in a population is a behaviour for which there is only recent evidence. However, in a randomised control test, the provision of art, planting and landscaping, wildlife features (e.g. insect boxes), and seating are examples of the kind of interventions that resulted in significantly increased observations of people stopping to take notice[34]. The same study also showed that diverse types of open space (combining green as well as hard landscaping) and a higher relative proportion of public to private space is also associated with increased reported mindfulness.

Keep Learning
There is evidence from educational research that the physical environment of the home and classroom are mediating variables that influence intellectual development. Domestic parameters include a home that is clean and uncluttered, appears safe for play and is not dark or monotonous[35]. The distance and orientation of seating in relation to others will influence the level of interaction and dialogue. For example, in a circle of seats, people facing each other will converse more than people adjacent to each other. Unobstructed eye contact is an important variable particularly in an educational context, making a semicircle classroom seating arrangement most effective[36]. At a more prosaic level, in order to support learning, interior environments need to be physically and thermally comfortable, safe, well lit, quiet and have clean air. However, there is evidence that learning will improve when comparing a poor environment (a run-down and poorly maintained space) with an adequate one (one that is 'good enough'), but that further and more extravagant facilities (specialised spaces or digital equipment) does not show further improvements in learning[37]. As previously mentioned, the opportunity to engage in art, music and evening classes increases well-being and thus such activities should be accommodated in the design of homes (light, cleanable spaces for art, soundproof spaces for music) and neighbourhoods (local communal spaces for classes).

Give
The presence of environmental stressors reduces helping behaviour, but little further explicit evidence is available beyond that which has been discussed above, which relates the physical environment with neighbourhood social capital[38]. There is evidence that people are less altruistic in urban than in rural environments, which, if nothing else, confirms that the integration of green space and contact with nature can be valuable[39]. Although it is difficult to observe atruism and its explicit relationship to design parameters, it can be shown that self-reported altruistic behaviour is more prevalent in neighbourhoods that incorporate the positive environmental and physical characteristics of space design (diversity, proximity, accessibility and quality) that have already been mentioned[40].

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PHOTO: THEKLA EHLING

TOUR BOIS-LE-PRÊTRE IN PARIS, FRANCE. PHOTO: THEKLA EHLING

Design should be responsive to user needs, behaviours and requirements, offering users a freedom of choice and control over their environment.

RULES OF THUMB FOR DESIGN

It is evident from the available research that there are no singular or universal design solutions to ensure that every health parameter is optimised, and that the inhabitants and wider population will flourish. As a minimum, designers should ensure that direct physical health parameters (e.g. air quality) achieve a level that is considered 'good enough' to avoid ill health, whilst not impinging on the opportunity for design to integrate wider wisdom and to nudge occupants into positive health behaviours.

The fact that there are numerous strategies related to different settings and users suggests that it is important to design adaptable environments. This is particularly relevant in the context of demographic change and climate change, but also changes in work, life styles and the availability of new technology. Design should thus be responsive to user needs, behaviours and requirements, offering users a freedom of choice and control over their environment.

A number of rules of thumb emerge and are grouped below into key themes:

Neighbourhood and nature
There is a large amount of research related to the design of neighbourhoods that supports health and well-being. Some of the design characteristics that emerge consistently are:

A High density mixed-use development to encourage walking and cycling (Keep Active) to access local services (Connect) – including access to public transport, health, social services, etc. – and reduce the reliance on the car.

B The availability of diverse public open space (in higher proportion than private gardens), including a variety of high quality and accessible green space (for play, exercise, contemplation, allotments, socialising, etc.) and hard landscape (ideally traffic free or reduced – for play, outdoor eating, etc.). This supports all Five Ways to Well-Being.

C Providing facilities and interest (Take Notice) in public open space – such as a biodiverse environment(encouraging a richness of flora and fauna), seating and wifi – adds to the potential for social interaction (Connect and Give) and extends the use of the space.

D The threshold between the home and a neighbourhood, particularly in high-density scenarios, can be mediated with vegetation, both to give close contact with nature but also to provide a degree of separation and privacy.

E Views of the neighbourhood and nature from the home are associated with psychological benefits and encourage social interaction (Connect) and supervision (Take Notice), so low window sills and openable windows are valuable aspects).

Moving and access
As we lead increasingly sedentary lifestyles, encouraging a modest level of activity becomes important in order to improve cardiac health, counteract obesity and maintain general fitness (Keep Active). The recommended level of activity is at least 30 minutes of moderate exercise (>3 mets, cycling or brisk walking) on five or more days per week, or 20 minutes of vigorous physical activity (>6 mets, jogging or gym exercises) three or more days per week[41]. Although gyms have

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become increasingly popular for some (and can also support Connect), achieving improvement in fitness for all is the main goal. Moving up and down stairs is a simple and effective solution, which counters the tendency for choosing a bungalow house for retirement (resulting in reduced exercise at a time of life when it is important to stay active, and ending up with what is colloquially referred to as 'bungalow knees'). Three-storey homes are likely to increase personal energy expenditure and can contribute to increased housing density, which in turn leads to other sustainable design opportunities. Research on human energy expenditure in buildings has revealed that typical office workers are less physically active away from work, with an overall activity level marginally below the recommended levels. Thus even modest increases in domestic and neighbourhood activity levels through design can be health-enhancing. Climbing one floor by stairs accounts for 3.3% of extra daily energy expenditure, and getting up 20 times from a seated position equates to about 10% of a healthy daily total of metabolic activity[42]. Some stealthy design strategies to Keep Active are suggested:

- **A** Make circulation an enjoyable experience and provide rewards for the movement (avoid boring corridors, aim for good natural light, views, opportunities for spatial variation and encounter (Connect), use art, etc.). This also supports Take Notice.
- **B** Separate key spaces with stairs, which provide the most intense personal energy expenditure, to encourage movement (put the living space on a different level from the kitchen/dining area, don't have toilets on every floor level).

Conversely, for those who are physically disabled or are wheelchair users, it is clear that all housing design must accommodate this. There are numerous guidance documents related to this[43], but some key considerations include:

- **A** Accessible dimensions for circulation areas (which can contribute to a more generous experience for all).
- **B** Level access thresholds throughout (valuable for families with prams).
- **C** Window sill heights to enable views out when seated (views out, especially of natural scenes, are conducive to well-being).
- **D** Electrical sockets not too low, and worktops, handles, thermostats and light switches not too high (allowing all users control over their home environment).
- **E** The potential for a lift to be installed and/or the adaptation of the home for single-floor living (bedroom and bathroom on the ground floor – also useful for temporary ill health and privacy if designed well).

Such design considerations should also incorporate strategies to ensure that partners and carers of wheelchair users are encouraged to remain active.

Eating
Poor nutritional eating habits can lead to obesity and related health problems. The preparation and cooking of (fresh) food can become a more social activity if the kitchen is designed to enable interaction with other members of the household or community.

At a community level, the provision of neighbourhood allotments to grow fresh

TOUR BOIS-LE-PRÊTRE IN PARIS, FRANCE. **PHOTO: THEKLA EHLING**

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food is recognised as enhancing health and well-being due to fresh produce, physical exercise and social interaction. Furthermore, the reduced reliance on the car for shopping and the avoidance of packaging and food miles, reduce the energy and other resources required, thus improving environmental sustainability.

With respect to the design of the home, the strategy is to create a sense of theatre related to cooking, and enabling audience participation through the design of accessible worktops and adjacent seating. To support communal eating, and the social interactions that result, the dining area/table should be in close proximity to the kitchen. Conversely, the lounge/tv area should be less accessible from the kitchen (potentially upstairs to encourage physical exercise), limiting the temptation for tv dinners but also providing potential separation in terms of noise, odours and pollutants.

Indoor environmental quality

Light: natural light has a range of advantages over electric light, including its variability and efficiency, and creating an awareness and link to the outside conditions. Apart from being a free source of light within a home, and thus part of an energy efficient strategy, it will animate spaces and can create drama and diversity. Furthermore, the benefits to physical health are now well understood and can counteract seasonally affective disorder (sad). However, over-illumination can be detrimental to comfort and disrupt sleep. A number of rules of thumb emerge:

A Orient rooms used in the morning ww(bedrooms and kitchen) to the morning light to provide a dose of light to stimulate the circadian rhythm (sad light-box therapy typically prescribes 10,000 lux for 30 minutes in the morning).

B Main habitable rooms should receive 'good' daylight (above 3% average daylight factor), and a key family room should have access to direct sunlight for at least 2 hours per day.

C Windows with high head heights provide more access to daylight by an increased sky view (which is particularly important in dense neighbourhoods) and better daylight distribution in the room.

D Bedrooms in particular should have effective blackout options to support good sleep patterns, for example in the form of thermal shutters (for cold periods) and/or with adjustable louvres (for secure night time ventilation in warm conditions).

E Personal control over the amount of daylight provides welcome opportunities for the inhabitant to adjust conditions to suit their patterns of use, and results in a greater sense of satisfaction with their environment. Windows should offer a range of conditions (e.g. light that is from above, the side, direct, diffuse, adjustable by shutters, louvres and blinds).

Temperature: as with light, the thermal design strategy should create both comfortable and stimulating conditions that can exploit the climatic conditions to improve energy efficiency. The body senses the thermal environment not just in terms of the air temperature, but also radiant conditions (e.g. sunlight), air movement (e.g. natural ventilation) and the conduction of heat via surface materials (wood feels warm, stone feels cool). Each of these thermal characteristics is a function of, and an opportunity for, design:

"Design-led interventions can make better choices easier."[48]

A Exploit solar radiation to create sunny places to be on cool days, such as window seats (with warm surfaces) and sun spaces. Use heavyweight materials to absorb and retain the warmth.

B Allow the user to adapt so that on hot days there are opportunities to find cool, shady places to sit on more conductive surfaces in a breeze.

C Adaptive comfort theory reveals that thermal conditions can fluctuate and vary, rather than be constant or 'optimised'. Occupant control and the adaptability of the design, to suit the users' needs and preferences as they vary over time, are key factors to success.

D To cool a building down during hot spells, design openings that allow the creation of night time ventilation that is secure (e.g. through louvered sections) and exploits stack and cross ventilation principles (e.g. use the height of a staircase to enable warm air to rise and escape at the top).

Sound: as with other aspects of environmental design, acoustic conditions can be used to create opportunities to support user needs and preferences. Although noise can cause stress, acoustic contact with the neighbourhood and nature can be valuable. Similarly, within the home there are places and moments when acoustic privacy is welcome, although complete acoustic separation is rarely required.

A To encourage Keep Learning behaviours, it is important to provide quiet, calm spaces for reading and studying.

B To support activities such as music and indoor exercise without disturbing others, acoustic separation to some spaces is valuable.

C Design openable windows so that people have the opportunity to connect and talk with passing neighbours.

D In order to exploit natural ventilation in an urban environment, particularly at night, and when quiet conditions for learning or sleeping are sought, the design should incorporate noise-attenuated air paths.

E Separate noise-creating sources – such as washing machines and dishwashers – from living and study spaces to support social and learning activities.

F Consider the acoustics as one progresses through the house: a gravel path will alert the occupant to visitors arriving; an echoey hallway and stairwell can signal when people are gathering; a carpeted corridor dampens the noise to the study; and soft furnishings and bedding creates a tranquil environment for sleep.

Design quality: there are a number of other design characteristics that impact on the Five Ways behaviours; these are briefly outlined below:

A The colour of our environment, such as interior walls, can impact on our learning behaviour and, in certain spaces, can be used to support learning. Research has concluded that "red enhances performance on a detail-oriented task [such as doing homework], whereas blue enhances performance on a creative task [like art of social debate]"[44].

B Ceiling heights can play a role in our social perspective and ability to focus.

TOUR BOIS-LE-PRÊTRE IN PARIS, FRANCE. **PHOTO: THEKLA EHLING**

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Recent findings show that when people are in a low-ceilinged space, they are better at focussed tasks, such as studying or reading. More generous spaces prime us to feel free, which tends to lead people to engage in more abstract styles of thinking; they are better able to take a wider perspective and see what aspects are in common, particularly appropriate for social gathering spaces[45].

C The form of space influences our sense of comfort and beauty. Curved forms are perceived as pleasant and in recent experiments, "participants were more likely to judge spaces as beautiful if they were curvilinear than if they were rectilinear". The researchers went on to conclude that this "well-established effect of contour on aesthetic preference can be extended to architecture"[46].

D Thus blue, tall and curvilinear spaces, with views of the blue sky, are more likely to be pleasant, sociable and creative environments. Conversely, red, low-ceilinged, rectilinear environments are more likely to encourage focus, concentration and study.

Conclusion

Designing for well-being and health includes a plethora of opportunities and a range of criteria. The strategy is that designs are good enough to meet the quantitative health measures but are also adaptable to and integrated with a broader set of principles to support well-being. There is a potential risk that. in an attempt to design the technically 'perfect' environment, we risk reducing the importance of the stimuli that encourage occupants to be active, aware and engaged. Designs should 'nudge' users in to positive behaviours, not by making them comfortable and controlling their environment excessively closely, but by providing a range of suitable stimuli for behaviour change. An extreme example of this is the design for the Bioscleave House by Gins and Arakawa, intended to "strengthen life by challenging it … to stimulate physiological and psychological renewal by creating living environments that would be intentionally uncomfortable"[47]. It achieves this by, amongst other things, changing floor-to-ceiling heights, distinct use of colour, uneven and sloping floor surfaces, and uncomfortable door sizes. This intentionally disorientating approach demonstrates an extreme approach, but a moderate and pragmatic orchestration of architecture to promote well-being is clearly viable.

One of the opportunities of architecture is that, through the design of form, space and materiality, it can order our relationships with each other and our environment by creating interactive settings for life. It can do this in such a way as to provide opportunities to improve our sense of well-being, enrich our lives, make our lives healthier and more pleasurable. For example, the shaft of sunlight in a recessed window seat that creates a moment of warmth and calm, combined with a glimpse of nature, soft and acoustically absorbent seat materials, and the tactile delight of the smooth grip to adjust a wooden shutter. Our well-being is intimately linked with such moments of delight. To an extent, such stimuli happen all the time, often without being recognised or designed, but when they are orchestrated throughout a building the effect is cumulative. A poor building has few such moments and leaves our lives impoverished, whereas a successful piece of architecture is one where there is an accumulation of many moments of delight that support the five ways of well-being.

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