Designing Houses for Health - A Review

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CONTENTS:

DESIGNING HOUSES FOR HEALTH - A REVIEW

FORWARD

The 1% Home Truth
Sustainable Living

Ever considered this?
We live in our homes for about 10 years then we move, and that given current rates of demolition and new building, a house today may need to last about 1000 years. Therefore, it is feasible to suggest that individually, we occupy it for 1% of its life expectancy. In fact, it could have 100 different owners and occupiers. We are in effect, simply short-term users.

And then thought?
How can we expect to design a home when its use has the potential to change at least 100 times during its lifetime? It will need to cope with such a variety of users from lone livers to extended families. The 4 bed detached is no longer the preserve of the nuclear family. And who knows in what direction the fabric of our society and the cohabiting trends will be 50 years from now.

Our existing housing stock has had to adapt in order to survive. Victorian and Edwardian houses have done so with little complaint. I am sure that they would not have made the same considerations on design if they new that the house would need to last 1000 years – or would they? A house built today will in 100 years, be the 'Vicwardian' home of the future, we ask ourselves how well this will survive the same test of time.

Architecture shouldn't dictate how we live; it should engage, encourage and support our constantly evolving life

So to consider the impact of today's housing is to consider our legacy. What will our future generations say about our housing in comparison with the Edwardians? We would hope that we would be commended for our foresight; our keenness to embrace new technology and building methods but most of all our inherent ability to learn from the past in order to not compromise the future.

At VELUX, we have long held the belief that there are three main aspects to sustainable living. And they work in conjunction with each other to create a healthy building for its occupants over its lifetime.

- **Maximised energy efficiency and minimised carbon dioxide emissions**
- **Visionary architecture combined with improved health, well-being and comfort for people**
- **Appropriate use of renewable energy sources**

If a building can provide variety of shelter, health and well-being, and minimise its impact on the environment whilst creating excitement in its delivery, then it has the best chance of survival.

But today we often see these elements treated in isolation, as design statements in their own right. We contend that one will not stand on its own, and that sustainable living will only be achieved when they all play an equal part of the overall design philosophy and operation of a home. To be truly sustainable a home has to be flexible enough to cope with lifestyle, health and technological changes.

To be truly sustainable an architect must place people at the heart of the design. To simply design for the sake of signature or technological inclusion would be wrong.

Without people, a home does not exist. It should be a basic human right to expect the internal environment to be at least as healthy as the external one.

Sustainable living is about people, the building, the architecture and the environment, and most importantly the ability of a building to live with us and for us. To evolve and adapt as we do.

So, the 1% Truth is that people should be the heart of design.

For the past 60 years, VELUX have put people at the heart of our designs. We have created roof windows and complete houses, and each one is a result of many years of listening to people and understanding their needs. Over the next few years we will build some more houses. Our 'Model Home 2020' project is well underway with houses in Denmark, Germany, France and the UK that will be completed within the next 12 months.

Our ambition is to be a catalyst; one that will ensure people are at the heart of design. We build buildings to house people to live and work, and not merely as a means of shelter.

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DESIGNING HOUSES FOR HEALTH - A REVIEW

Dr. Richard Hobday

SUMMARY

We spend, on average, over 90 per cent of our time indoors. Most of this is now spent in our homes. The impact of such behaviour on our health is unknown, as few comprehensive studies of the indoor environment of British houses exist. This report reviews the current state of knowledge on healthy housing. It examines how homes can be arranged to promote health, rather than just maintain acceptable indoor conditions. Much remains unknown on the subject, but when brought together the sum of evidence is substantial.

It is unquestionably a good idea to make buildings sustainable and energy efficient. But they are not sustainable if they are unhealthy. When people are asked about indoor conditions, they express a preference for windows that open, fresh air, sunlight and control of their environment. Yet regulations now favour sealed buildings which impose close controls on internal conditions. This is a radical departure from the traditional approach to house construction in this country. Whether zero-carbon homes will be healthy places to live in is uncertain. The lack of published information on this is notable. If they are not, the costs to society could outweigh any benefits by a considerable margin.

Housing should do more than provide tolerable conditions: it should improve the health and satisfaction of residents. The current approach to housing design overlooks elements that are central to promoting well-being. These include sunlight, natural ventilation and radiant heating. A substantial portion of the British population suffers from respiratory illnesses, allergy and depression. The findings of this report suggest houses could be designed to reduce the burden of these and other illnesses.

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1. INTRODUCTION

The modern home is not arranged to promote health. Housing that enhances the well-being of its occupants is the exception in this country, as elsewhere. Current codes and regulations do not require it. No authoritative guidance is available on the subject. The expertise needed to build in this way is lacking:

> *"How to design and build good homes, schools, and workplaces remains a pressing, and largely unanswered, health question."* [1(p1453)]

Yet previous generations of architects, engineers, and scientists worked out how it could be done. Unfortunately, much that was once identified as being important for health in homes has been ignored or forgotten. Over the years, the idea that a building, in itself, could be therapeutic has fallen from favour. Designing homes for health promotion is now a lost art. Fortunately, there is renewed interest in creating healing environments in hospitals, as this literature review will show. The positive effects of architecture on patients' recovery have been demonstrated scientifically.[2-5] Evidence-based design is emerging in the health-care sector.[6] This follows medicine's move towards an evidence-based approach, in which research informs clinical decisions.[7] So far, the findings from hospitals have not transferred to housing. In the past, medical practice had a direct influence on house design. Today it does not appear to.

1.1 Housing and Public Health

More than a century ago, Florence Nightingale (1820-1910), who dedicated most of her life to health promotion, described the connection between housing and the health of the population as *"one of the most important that exists."* [8(p1261)] During the Victorian era, officials in housing and medicine worked together on housing laws aimed at protecting the public from disease. Safe and sanitary homes were seen as essential to public health.[9,10] Tuberculosis and other infectious diseases were common in 19th- and early 20th-century cities; and greatly feared. There was a belief that people who lived in sub-standard housing were at higher risk. Statistical evidence supported this view.[11] Improvements in ventilation, lighting, and crowding are credited with helping to reduce the prevalence of tuberculosis.[12] Town planning and good housing were seen as key to the betterment of public health.

A body of research published during the 1920s identified several factors that actively promote well-being in dwellings. One of them was that the human organism needs the stimulus of changing conditions if it is to prosper. The monotonous indoor environment typical of today's buildings was to be avoided. Fresh air and sunlight were considered especially important. Both prevented the spread of infection in buildings and both were being used therapeutically. Scientists discovered sunlight could kill bacteria in hospital wards, cure tuberculosis and rickets, and produce vitamin D in the body. Architects worked with doctors to create sanatoria and `open-air' hospitals. Typically, wards were cross-ventilated, with large south-facing windows and terraces where patients could be put in sunlight and fresh air under medical supervision.[13-15] Architects also arranged homes to promote health along these lines.

1.2 Healthy, Sustainable Housing

In 1929, Richard Neutra built the famous `Health House' in the Hollywood Hills of Los Angeles. His brief was to design a home that strengthened the health and well-being of its owner, Dr. Philip Lovell. The Health House provided Dr. Lovell with plenty of sunlight and fresh air.[16] Such thinking informed the work of other architects of the period such as Le Corbusier. In his influential manifesto *The Athens Charter*, he argued bringing in the sun was the architect's most urgent duty.[17]

The history of healthy, low-energy building in Britain begins in the 1930s, when E. Maxwell Fry built his `Sun House' in London. Fry used natural lighting, passive solar design and other strategies to reduce energy consumption. He used them to improve conditions for building's residents too. Like other architects of the period, notably Frank Lloyd Wright, Fry tried to build in harmony with the natural environment; an approach that was later characterised as `bioclimatic'.[18-20] This was not new. The Roman architect Vitruvius wrote about designing healthy, energy-efficient buildings along these lines two thousand years ago in his *Ten Books on Architecture.*[21]

As the slums in industrial towns and cities were cleared, and living conditions improved, the threat from infectious disease receded. The harmful effects of bad housing were not as obvious as they had been. The link between housing and the health of the public became less direct.[22] By the 1960s, the emphasis was on quantity, rather than quality. Builders used new, largely untested, technologies to meet the demand for homes; and did so on a large scale. Unfortunately, the prefabricated concrete tower blocks which were popular at the time proved to be hard to heat, prone to damp, were filled with asbestos and structurally unsound. And there was nowhere for children to play safely.[8,23] There are still divisions between the various professions who at one time would have worked together to avoid such mistakes.[12] But there has been some progress in preventing them happening again.

In 2004, the Housing Act introduced a new way in which local authorities can assess housing conditions in England and Wales. The Housing Health and Safety Rating System (HHSRS) gives an analysis of how dangerous a property is.[24] The HHSRS uses a risk assessment approach and provides ratings for defects based on factors that affect health and safety in homes. These include heating, lighting and ventilation. Meanwhile, urban planners and health officials have begun to work together again. The rapid increase in obesity has revived interest in the role of planning in public health.[25,26] The Commission for Architecture and the Built Environment (CABE) advocates good design and planning to improve health and economic and social value.[27,28] The World Health Organisation (WHO) promotes healthy sustainable urban planning via its Healthy Cities initiative.[29] However, so far there is no equivalent international programme for house design.

1.3 Zero Carbon or Health?

The healthy home is not the priority it once was. Government agencies now place more emphasis on reducing the impact of houses on the environment than improving the well-being of the people inside them. All new homes in England are to be zero carbon by 2016. The ambitious energy performance targets set out in the

Building Regulations and the Code for Sustainable Homes to achieve this may have major health implications. Yet there is a dearth of information on the subject:

> *"There is no published study of highly energy efficient homes in the UK that monitors the range of air quality and other factors that can affect occupant health and well-being."* [30(p34)]

Housing is not sustainable if it is unhealthy. Whether the latest generation of homes will meet the health needs of their occupants is uncertain. Given the chequered history of social housing - and of innovative building techniques - in this country it is an unfortunate oversight. With potential hazards within buildings gaining greater recognition, this may change. The spread of airborne infections is a concern, following the severe acute respiratory syndrome (SARS) epidemic in 2003.[31] Allergies are rapidly increasing worldwide, and are strongly linked to indoor air quality (IAQ).[32] Research shows improvements in IAQ, to levels above those typical of current practice and standards, decrease the risk of asthma and allergy in homes. They have also increased productivity in offices, and improved learning in schools.[33]

Meanwhile, a growing body of evidence shows illumination levels indoors are important to mental and physical well-being. When provided appropriately, light can have healing properties. In particular, recent findings support the principle that sunlit rooms can be healthier than those that are not. Studies of sunlight's impact on hospital patients show positive effects on the length of stay, mortality rate, perceived stress and pain.[2-5] Unfortunately, the benefits of creating airy, sunlit spaces in houses are not recognised by policy makers, planners and designers as much as they once were.

2. WHAT IS HEALTHY HOUSING?

In the 1860s, Florence Nightingale identified five essential points in securing health in houses. They were: pure air; pure water; efficient drainage; cleanliness; and light - especially sunlight.[34] This was when all five were largely absent from dwellings. Fortunately, there were fewer obstacles to getting fresh air and daylight into Britain's homes than there had been. Excise duty on glass was repealed in 1845 and the notorious Window Tax abolished in 1851.[35] As the drive to eliminate epidemic disease became more urgent, government agencies and other bodies began publishing guidance on healthy homes. One of the most authoritative and influential works was commissioned 70 years ago, by the American Public Health Association (APHA).

In 1938, a Committee on the Hygiene of Housing, appointed by APHA, published the *Basic Principles of Healthful Housing.*[36] This identified the fundamental needs of humans in their homes. These included physiologic and psychological requirements, protection against disease, protection against injury, protection against electrical shock and fire, and protection against toxic and explosive gases. In their report the APHA Committee argued housing should satisfy the following needs:

1. protection from the elements,
2. a thermal environment that will avoid undue heat loss,

3. a thermal environment that will permit adequate heat loss from the body,
4. an atmosphere of reasonable chemical purity,
5. adequate daylight illumination and avoidance of undue daylight glare,
6. direct sunlight,
7. adequate artificial illumination and avoidance of glare,
8. protection from excessive noise, and
9. adequate space for exercise and for children to play.

The Committee then gave a brief outline of how each of these needs should be met. In the years before, and in those that followed, legislators put building codes and standards in place to this end. Some of them defined conditions which are held to be to be so important they are required by law. Others were not compulsory. But whether legally enforceable or not, there was often a significant difference between the minimum standards they stipulated and ideal conditions for health. The same can be said of current controls and regulations. The health needs of many building occupants may not be satisfied, even if regulations and standards are adhered to.[33, 37,38]

2.1 Definition of Healthy Housing

Ideally, the environment within dwellings would be in keeping with the World Health Organisation's definition of health which is:

> *"... a state of complete mental, physical, and social well-being and not merely the absence of disease or infirmity."* [39(p1)]

By contrast, a recent pan-European study characterised a building as healthy simply if it did not cause or aggravate illnesses in building occupants.[40] This illustrates the disparity between minimal and optimal standards. There is no commonly agreed definition of healthy housing.[41] However, in 1990 the World Health Organisation did identify three levels of environmental conditions in dwellings, as follows:

1. Desirable	those which promote human health and well-being.
2. Permissible	those which are not ideal, but which are broadly neutral on their impact on health and well being.
3. Incompatible	those which, if maintained, would adversely affect health and well being.[42]

As yet, the World Health Organisation has not set out how to design to a `desirable' level. The principle that a house should promote health, rather than simply prevent disease, is not considered in current codes and standards. The Building Regulations

and Code for Sustainable Homes do not require this. Housing designed to comply with them will only achieve `permissible' environmental conditions; according to the World Health Organisation's criteria.

2.2 Promoting Health

One important predictor of health and longevity is a positive mood. There is a strong link between feeling good and living longer. A series of recent studies show negative emotions are associated with increased disability due to mental and physical disorders, increased incidence of depression, increased suicide and increased mortality. One classic study showed people in the lowest quartile for positive emotions died on average 10 years earlier than those in the highest quartile. Positive emotions protect against death and disability. And happiness is associated with and precedes numerous successful outcomes in life.[43]

In 2001, the World Health Organisation predicted by 2020 depression will be the second leading cause of death and disability worldwide.[44] One reason depression is expected to take an even more prominent position than presently, is the population is getting older. According to the Audit Commission, by 2029 nearly 40 per cent of people living in England will be 50 or over.[45] The risk for developing depression increases with old age. Depressive symptoms are present in almost one-third of the elderly population. Once present, the outlook for elderly people with depression is poor.[46] Also, the number of people with Alzheimer's disease, which is the most common form of dementia, is expected to quadruple by 2050. The most prominent symptom of Alzheimer's disease is cognitive decline; others include disturbed sleep patterns and depression.[46] Against this background, designing homes to promote positive mood states could have a major impact on public health. Currently, there is little information or guidance available on the subject. However, it used to be considered good practice. One reason Florence Nightingale and others from the past insisted on sunlit interiors is they can engender a sense of well-being. (See Section 3.3 below)

2.3 Evidence and Research

Over the last 30 years, research has mainly focused on the impact of poor housing on physical rather than mental health. Cold, damp indoor environments have been a particular concern. Findings do suggest cold conditions, and the increased incidence of dampness, house dust mites, moulds and fungi that go with them, are linked to poor health. However, proving these and other potential hazards cause illness is difficult. Related factors, such as low income, poor nutrition, and overcrowding make it hard to untangle the relationships between housing and health.[8] In 2005, the WHO European Centre for Environment and Health tried to quantify how human health was negatively affected by bad housing. They assessed hundreds of studies and reviewed the strength of the findings from each of them. Of 25 housing-health risk factors identified, only 13 had `sufficient evidence' to estimate the disease burden, 10 had `some evidence,' and 2 had `insufficient evidence.' They concluded the evidence base needed improvement.[47]

The way in which recent research has been conducted has not helped matters. Critics say it has been too focused, unbalanced, or of little practical relevance.[48] Studies have tended to examine specific features and have not taken the mental, physical and social aspects of housing together. There is little comprehensive, empirical published work on factors that hinder or promote health and well-being.[49] Also, research findings may not reflect accurately occupants' individual needs or preferences. They are rarely asked what they want or like, or what is important to them. Only recently have some investigators begun to ask these questions.[37,50] Not surprisingly, there have been calls for academics, professionals and policy-makers to take a broader more holistic approach to housing and health.[11,38, 51]

> *"...the expertise needed to address indoor environmental quality is scattered among diverse research fields and disciplines. This fragmentation of knowledge, inherently linked to the multidisciplinary nature of health and the indoor environment, makes it difficult to create an integrated comprehensive knowledge base that is needed to set an agreed-upon agenda for policymaking."* [52(p985)]

There is evidence that raising the standard of older homes can produce tangible health benefits.[53] By contrast, there has been little research into the health effects of living in the latest generation of house designs. Whether a tight building envelope, with mechanical heat-recovery ventilation provides a healthy living environment in the British climate has yet to be determined.[30]

2.4 Changes in Housing and the Public's Health

The decline in epidemic diseases over the last century resulted in a significant extension of life expectancy. As the population ages, chronic diseases such as depression, cancer, heart disease, arthritis, osteoporosis and metabolic diseases assume ever greater public health significance. There has been, with few exceptions, little scientific inquiry into the relationship between housing and such diseases, or of housing and the health of an ageing population. Until recently, house design has not addressed the needs of the elderly, as a WHO report concludes:

> *"Looking back in time, the housing stock development does not match the social changes and the gain in life expectancy of the last decades. Today, people spend years and years in dwellings that have not been designed to meet the needs and lifestyles of the moment as well as the needs and lifestyles of the future."* [54(p39)]

The current version of the Code for Sustainable Homes requires compliance with the Lifetime Homes criteria to achieve a Level 6 rating. But there is no standard aimed at promoting health in the elderly.

3. CONDITIONS IN MODERN HOUSING

Figures for the United States, Canada, and Germany, show that people spend most

of their time indoors in private homes.[55,56] In 1989, the average US citizen spent 93 per cent of their 24-hour day indoors.[57] Since then, computers, video games, and television programming have become more readily available. So time spent inside dwellings may have increased.[58] It follows from this that most of the air people breathe is indoor air. According to one estimate, more than half of the body's intake during a lifetime is air inhaled in the home.[32] This can be dangerous. Contaminants can be many times higher than the air outside - occasionally 100 times higher.[12] Also lighting levels inside houses are much lower than those outside. Prolonged exposure to low light levels can have adverse effects. Seasonal affective disorder (SAD) is a depressive illness that occurs in relation to daylight exposure.[59] Recent research supports the hypothesis that people in industrialised countries do not get enough daily light exposure for optimal health.[60-64]

3.1 Lower Ventilation Rates

The environment in households has changed down the years in several important respects. Years ago, codes and standards set high ventilation rates to dilute air to minimise the risk of infection. While tuberculosis posed the main threat indoors, many other potentially lethal respiratory diseases have been linked to housing. They include diphtheria, scarlet fever, pneumonia, meningitis, whooping cough, measles, mumps, and rubella.[65] With improvements in sanitation, hygiene and public health, the need to control them became less urgent. The rationale for ventilation changed; and air change rates fell. Rather than prevent infection, the aim was to create comfortable conditions and remove odours produced by occupants.[66]

> *"During the last century, health issues have generally not been involved in reflections about the need for ventilation; instead, perceived air quality has been the measure. The topic has been whether the odor in a room is perceived as acceptable by visitors directly on entering the premises, or by occupants."* [32(p53)]

Standards based on comfort remained in place until the energy crisis of the 1970s. At this time, air change rates fell further to save fuel. But later in the decade, the phenomenon that became known as sick building syndrome (SBS) first appeared. This syndrome was thought to be related to inadequate ventilation, and was sometimes called `tight building syndrome'.[67] It became such a concern in the USA that minimum ventilation guidelines for offices went back to where they had been before the energy crisis. As the WHO observed some years later:

> *"If energy based standards are in conflict with health needs, the priority should be given to the health requirements of the space occupants."* [42(p44)]

The air inside a dwelling includes a mixture of particulates, gases such as nitrogen dioxide, ozone and carbon monoxide, volatile organic chemicals (VOCs), and biological agents such as bacteria and viruses. Contaminants come from outside and from various indoor sources. The latter include construction materials, carpets, furnishings, the occupants, pets, household items, and everyday practices such as heating, cooking, cleaning, and home repair.[68-70] Personal exposure to them has

increased because of reduced air exchange rates and increased time spent indoors.[71]

The main purpose of ventilation is to remove such pollutants, or dilute them to levels that are not harmful to health, or do not cause discomfort. Traditionally, houses in Britain have relied on a combination of infiltration of air through the fabric and window opening for fresh air. This is set to change in response to the performance targets set in the Building Regulations and the Code for Sustainable Homes. There is an expectation that houses built to Code Level 4 or above will need mechanical ventilation with heat recovery (MVHR) to achieve an acceptable indoor climate. However, the health effects of this are unknown.[30] Significantly, the amount of outdoor air needed to keep building occupants healthy has been debated for years, and remains uncertain.[72] In addition, there appear to be no modern studies that have tried to associate indoor air conditions with positive well-being.[73]

When ventilation rates are measured in buildings, the results often reveal significant gaps between the design intent and performance.[72] Studies from many countries show high levels of dissatisfaction in buildings in which ventilation standards are met.[33] A more immediate concern is the accumulation of chemical pollutants indoors. They can be persistent in homes, presenting health risks for years beyond their use.[71] The air change rates typical of modern dwellings may be low enough for chemical reactions to occur.[70] Organic pollutants in indoor air can react with ozone, producing highly reactive compounds. These can, in turn, react with the skin or mucous membranes. There is strong evidence of an association between IAQ and lung cancer, allergies, other hypersensitivity reactions such as multiple chemical sensitivity and SBS.[32]

Ventilation standards have moved on from controlling body odour to diluting non-occupant contaminants.[72] A key aim of Part F of the Building Regulations is to limit the accumulation of pollutants and moisture that would otherwise be harmful to occupants. The document sets exposure limits for nitrogen dioxide, carbon monoxide, and VOCs. Part F offers guidance on how these criteria can be met; but does not address the airborne spread of infection.[74]

In recent decades, relatively little research work was done on the airborne transmission of bacteria and viruses. It seems that the threat to health posed by airborne microbes has been underestimated.[75-77] They are still a cause for concern. Pandemic influenza has recently been at the top of the health agenda, while multi- and extensive drug-resistant tuberculosis is a threat to public health.[78-81] Ventilation and airflow in buildings may have played a significant role in some of the 2003 SARS outbreaks.[82] SARS could re-emerge, or another novel infectious agent could appear which prospers in the modern built environment.[83] There is strong evidence that ventilation and air movement in buildings is involved in the spread of other infectious diseases such as measles, tuberculosis, chickenpox, influenza and smallpox.[31] New data suggest influenza can be transmitted via the airborne route.[84,85]

Modern buildings are not arranged to prevent diseases spreading. In recent years the trend has been to design new and retrofit old buildings to reduce the contribution of fresh outdoor air to indoor ventilation. Significantly, the minimum amount of ventilation needed to prevent the spread of infectious diseases such as SARS, influenza and tuberculosis is unknown. Much more fresh air may be needed than is

currently specified for hospitals, schools, offices, and homes.[15,31,86-88]

Should airborne infections become more problematic, an airtight building envelope, with mechanical heat-recovery ventilation, may not be the safest option. Pathogens can be transported through ventilation systems, as has been documented for measles and tuberculosis.[31] Mechanical ventilation systems could increase transmission of these and other diseases. Also, over time, dust can build-up in ductwork. This can be a source for chemicals, allergens and microbes in the indoor air.[30] If a mechanical ventilation system is not designed, installed, commissioned, maintained or operated properly, the effects could be severe. Surveys of MVHR in housing have revealed serious faults. Also, the energy benefits of such systems in a mild climate have been questioned.[89]

Even if airborne infections do not become more viralent, ventilation in housing remains a major health concern. Respiratory disease kills one in four people in the UK which is well above the European average. It is the most common long-term illness among children, and costs the NHS more than any other disease area.[90]

3.2 Internal Temperature Rise

While ventilation rates have fallen, internal temperatures have increased markedly. In 1970, only 31.3 per cent of British homes had central heating. They achieved average temperatures of 13.8°C compared with an average of 11.3°C in non-centrally heated homes. Taken together, the average temperature in British housing was just 12.1°C in 1970. By 2006, some 90.1 per cent of British homes had central heating and the occupants enjoyed average temperatures of 18°C. Non-centrally heated homes averaged 15.5°C. Overall, average internal temperatures had risen to 17.7°C. So even in homes without central heating, average temperatures rose by 4.2°C.[91]

Lack of central heating is associated with an increase risk of dying in winter; and excess winter mortality is an important health issue in Britain.[92] There is evidence that warmer less humid housing improves health. Eliminating damp and mould and raising temperatures to comfortable levels can have a positive impact. For example, a study of residents in blocks of flats in the Easthall area of Glasgow showed they experienced a significant fall in blood pressure when their accommodation was upgraded. They also gained an improvement in general health, as shown by a reduction both in medication use, and in hospital admissions. About one in three houses in Scotland, and one in five houses in Britain overall, are badly affected by cold, damp and mould. The results of the Glasgow study suggest there is much that could be done to the existing housing stock to improve public health.[93] However, the potential for success of projects such as this may depend on the baseline condition of the housing. It seems interventions of this kind require careful targeting if they are to be successful.[53]

Paradoxically, while the widespread adoption of central heating may have saved lives, it may also have had a negative impact on children's health. Increased average house temperatures, reduced background ventilation rates and other changes may have led to a significant increase in house dust mite concentrations. This, in turn,

could be the causal factor in the rising incidence of asthma in children.[94] The UK has amongst the highest prevalence of respiratory symptoms and asthma worldwide. Studies indicate that between the mid-1960s and the mid-1990s, asthma prevalence in the UK increased by about 5 per cent a year.[95] In addition to asthma, increased temperatures have been linked to another common problem; they may be contributing to rising obesity levels. The human body expends less energy in temperature ranges typical of climate-controlled settings.[96] (See section 4.2)

3.3 Lighting and Health

Illumination levels indoors are import to mental well-being.[97] Lethargy, sadness and despair have long been associated with lack of light.[16] During the 1980s, the link between light deprivation and depressive illness was scientifically proven.[98] The subsequent discovery of 'non-visual' receptors in the eye provided an anatomical basis for the biological effects of light. Bright-light therapy is now established as an effective treatment for a range of psychiatric conditions.[46] In particular, seasonal and non-seasonal depression.[99] Both forms of depression are influenced by environmental illumination.[100]

Surveys consistently show people prefer natural light. They believe working by daylight results in less discomfort and stress and is better for their overall and visual health.[101-104] While daylight may not be inherently better than artificial lighting for most visual tasks, it is better for health. The human body has a biological clock in the centre of the brain. This internal clock controls a range of physiological functions, such as hormone production, core body temperature cycles, sleep-wake cycles, and alertness patterns. Light entrains this circadian clock (*circa,* about; *diem*, a day) to the solar 24-hour day. Without light it `runs free' at an average of about 24.25 hours. The light levels needed to regulate the body's circadian rhythms are higher than those needed for visual tasks.[105] Natural light is more effective for this than electric sources. First, it provides a higher light level at the eye. Second it is more closely matched to the spectral sensitivity of the eye's non-visual receptors than most artificial light sources.[106] People prefer lighting levels which are significantly higher than current indoor lighting standards. These match levels where biological stimulation of the circadian system can occur. And building users prefer lighting that follows the daylight cycle instead of a constant level of illumination.[107]

3.4 Sunlight and Indoor Lighting

The sun is the body's external timekeeper.[108] Without the time-cues given by the sun and, to a lesser extent, by the normal daily routines of breakfast, work, lunchtime, bedtime and so on, the underlying rhythm of the body can become disturbed. This can cause a range of health problems. Disruption of the body's circadian rhythms has been linked to depression, sleep problems, heart disease, diabetes, obesity, and breast and prostate cancer.[109,110]

Opportunities to benefit from light of sufficient intensity to have a favourable impact on psychological and physiological well-being can be limited in houses if they are not arranged for the sun. The intensity of illumination can be several orders of

magnitude lower than that outside. Electric lighting in houses provides somewhere between 150 lux and 600 lux, while outside at noon sunshine can deliver 100,000 lux. In a sunlit room there can be as many as 60,000 lux falling on a plane surface.[111] During the first half of the last century, it was widely held that sunlit houses were healthier than those that excluded the sun's rays. When the American Public Health Association identified direct sunlight as a basic health requirement in 1938, their Committee on the Hygiene of Housing wrote:

> *"No definite quantitative limits can be set; but it is clearly desirable for all dwellings, and essential for those occupied by persons who are housebound, that direct sunlight should enter at some places and hours, even in winter. Sunlight, particularly through its ultraviolet components, provides valuable physiological stimulation."* [36(p358)]

A growing body of evidence supports the principle that sunlit rooms can be healthier than those that are not. Research in hospitals shows heart attack victims stand a better chance of recovery if they are in sunlit wards,[112] so do premature babies with jaundice.[113] In one study patients in wards exposed to an increased intensity of sunlight suffered less stress and less pain, and needed 22 per cent less analgesic medication each hour to cope with it.[114] Depressed psychiatric patients recover better if they get some sun while in hospital.[115,116] Researchers have also found that low levels of sunlight more than double the risk of cognitive impairment in people with a history of depression.[100]

Meanwhile, experiments with bright light - using light at levels above those normally found in houses - show it has benefits beyond relieving the symptoms of depression. During the winter months it seems to be effective at improving vitality and reducing distress.[63] Continued, high intensity daily bright light can improve sleep patterns in the elderly and reduce the incidence of delirium in hospital patients.[117-119] Also, exposure to bright light may help with dementia. In one study, increasing light levels in the day-rooms of nursing homes to 1,000 lux slowed down the rate of cognitive decline in demented patients. It also improved their depressive symptoms and disturbed sleep patterns.[120] Findings such as these may explain why people who live and work in solar houses, offices and apartments have a high opinion of them.[121,122]

3.5 Sunlight as Disinfectant

Long before the non-visual effects of daily bright light exposure were investigated scientifically, Florence Nightingale identified sunlight as key to promoting health in the sick-room. She wrote:

> *"Direct sunlight, not only daylight, is necessary for speedy recovery, except, perhaps in certain ophthalmic and a small number of other cases."* [123(p17)]

Nightingale also insisted on sunlight because she believed it had a `purifying' effect and reduced the risks of cross- and re-infection. Later, in 1877, two British scientists showed light, and especially sunlight, has a bactericidal effect - even when it has passed through glass.[124] Their work prompted other scientists to study the effects of

exposing bacteria to the sun's rays. Soon, sunlight was being hailed as `nature's disinfectant' and an important weapon in the fight against infectious disease. Before antibiotics became widely available, sunlit rooms and hospital wards were held to be hygienic, while those that did not admit the sun's rays were not. Today, in marked contrast, the germicidal properties of sunlight are rarely considered when buildings are being planned. One recent NHS hospital design guide even states that windows are "*...not directly an infection control issue.*" [125(p41)] Lack of sunlight may be a much more important factor in the spread of infection in buildings than is currently appreciated.[126]

The WHO does recognize there is value in the germicidal effect of light in homes - but only in lavatories. And direct sunlight is not mentioned.[65] Their guidance on healthy housing states natural lighting should be provided to water closets wherever possible because it kills bacteria. It also says special glass, which transmits a higher proportion of ultraviolet rays, should be used in WCs. Where it is not, and ordinary window glass is fitted, windows should be left open in warm weather for at least three hours. This is to allow shorter wavelength ultraviolet radiation to enter and help in bactericidal action.[65]

There is a growing awareness of the presence of potentially pathogenic microbes in buildings. One of the so-called 'superbugs' that infect hospitals is becoming established in the wider community. The MRSA bacterium, or methicillin resistant *Staphylococcus aureus,* has long been a problem in wards and nursing homes where it infects patients weakened by disease or injury. But a strain has emerged that can infect healthy young people who have had no prior hospital exposure. Again, tuberculosis has re-emerged as a major health concern; mainly in the developing world, but also in the more developed countries of Europe. Then there are new pathogens, such as SARS and avian flu.[15,127-131] With drug-resistant bacteria and novel viruses posing an increasing threat to public health, sunlight's germicidal properties merit more attention than they currently receive. Perhaps less so in housing than in care homes and doctors' waiting rooms, but they should not be ignored.

3.6 Sunlight, Daylight and Skylight

Daylight is a combination of sunlight and skylight, the latter being solar radiation that has reached the earth's surface after scattering in the atmosphere. Confusion arises because people often refer to daylight when, in fact, they mean skylight. This is an important distinction, not least in buildings. Designers calculate how much natural light there will be in a room as a percentage of the amount of skylight outdoors. The Daylight Factor has been the method of choice for the last 50 years or so. But the Daylight Factor should really be called the Skylight Factor because it ignores the sun. It takes no account of the orientation of a building or the local climate.[16] The Code for Sustainable Homes awards credits for meeting the Daylight Factors recommended in the British Standard on Lighting for Buildings (BS 8206-2).[132] All living rooms, dining rooms and studies in new homes must achieve a minimum average Daylight Factor of at least 1.5 per cent. Kitchens must achieve a minimum average Daylight Factor of at least 2 per cent but there are no criteria for bedrooms. These are modest requirements; and they do not include sunlight.

The British Standard on Lighting discusses the importance of natural light in the well-being and satisfaction of building occupants. The recently revised version now refers to seasonal depression and the entrainment of circadian rhythms. It points out high levels of daylight are important to people of limited mobility, such as those in nursing homes and hospital wards. And there are references to vitamin D deficiency and sunlight's germicidal properties, as well as the harmful effects of ultraviolet radiation.

British Standard 8206-2 states interiors in which occupants have a reasonable expectation of sunlight should receive a minimum of 25 per cent of probable sunlight hours. During the winter months, between the 23rd of September and the 21st of March, at least 5 per cent of probable sunlight hours should be admitted. The British Standard also points out that the controlled entry of sunlight is especially valued where occupants have little direct contact with the outside world. And it notes that dissatisfaction can arise as much from the permanent exclusion of sunlight as from an excess. Unfortunately, the criteria set out in BS 8206-2 are not compulsory. So there is no obligation to design for sunlight. The Code for Sustainable Homes does not require sunlight penetration - only skylight. By contrast the 2009 draft of the Mayor's *London Housing Design Guide* does. This states dwellings should receive direct sunlight in at least one habitable room in all months of the year.[133]

3.7 Sunlight Outdoors

Besides being the human body's external timekeeper, the sun is its main source of vitamin D. Several studies have found alarmingly high rates of vitamin D deficiency throughout Europe, North America, the Middle East and elsewhere. [134-136] In Britain rickets, the classic disease of vitamin D deficiency, is resurgent.[137] Also, a recent nationwide survey showed that more than half of the adult population in this country have insufficient levels of vitamin D and one in six have a severe deficiency during winter and spring. This survey also found a marked gradient of prevalence across the UK, with highest rates of vitamin D deficiency in Scotland, northern England, and Northern Ireland.[138] Elderly and institutionalised people are at high risk of deficiency. So too are infants, children, adolescents, and pregnant women, particularly those with dark skin. Health professionals have been slow to recognise the scale of this problem; even though it has been highlighted in the medical literature for several years.[139] While there are risks to sun exposure, the benefits have been overlooked.[134,140]

Increasing evidence suggests that vitamin D plays a central role in maintaining a healthy immune system. Vitamin D, and by implication the sun, may offer protection against heart disease, hypertension, internal cancers, multiple sclerosis, diabetes, rheumatoid arthritis, osteoporosis, fractures, falls, depression and infections.[135,141,142] Unfortunately, housing, streets and cities are not as sympathetic to sunlight as they might be. Getting out into the sun to generate vitamin D can be difficult. This is recognised in southern Australia where vitamin D deficiency is a now major problem. So much so, the Chief Health Officer of Victoria recently published *Vitamin D & the Built Environment in Victoria: A Guideline for Planners, Engineers, Architects & Policy Makers in Local & State Government.*[143] The 2009 draft of the Mayor's *London*

Housing Design Guide also addresses access to the sun.[133] It states development proposals should show that communal open space takes advantage of direct sunlight. It also states balconies should receive direct sunlight.

Elsewhere, less consideration has been given to the problem of sunlight deprivation. Advice, guidance and expert opinion on planning does not always consider sunlight.[144,145] Nevertheless, the outside of a dwelling built for health should be arranged for the sun. The occupants can then get out in it, should they wish to do so. In addition, carefully orienting a house for the sun can keep walls clear of snow, and paths clear of ice. In milder weather, it helps to keep buildings and their surroundings clean and dry. And there are more opportunities to dry washing outdoors.[16]

4. DESIGNING FOR HEALTH

The challenge of designing to promote health and well-being is not new. Architects and planners confronted it in the past. They sometimes worked closely with leading doctors and scientists of the day to this end. As noted earlier, Florence Nightingale set out how to create healthy, healing environments in the 1860s. During the Crimean War, thousands of British soldiers died of infections while under her care within the walls of the infamous Scutari Hospital.[146] One insight she gained from this was that the environment in which patients found themselves could contribute to their recovery, or it could hasten their demise. Another was patient mortality rates were much lower in temporary field hospitals than they were in large hospital buildings.
Miss Nightingale concluded making conditions indoors as close as possible to those outdoors was both therapeutic and hygienic.

In her view, variations of weather, temperature and season were important factors in the maintenance of health in healthy people. So the same should apply to the sick: patients needed to be exposed to the same continuous changes temperature and humidity that were occurring outdoors. Weather permitting, the windows of sick wards should be kept open. She stressed the importance of plenty of fresh air through open windows, and the need for direct sunlight.[123]

4.1 The Healing Environment

Florence Nightingale stipulated the first canon of nursing was that air indoors had to be as fresh as it was outside; without chilling the patient.[34] This could not be achieved by mechanical means as, in her opinion, no system of artificial ventilation could supply air which was sufficiently fresh. There was no guarantee that the incoming air would not mix with vitiated air. Nightingale held that if a hospital had to be ventilated artificially, it was because the original construction was defective. Also, she believed warm-air heating was unhealthy. Radiant heat was natural: air heated by metal surfaces was to be avoided; particularly if it was supplied by the ventilation system. It kept patients at one fixed temperature, day and night, during all the time they were in hospital. As she put it:

> *"To shut your patients tight in artificially warmed air is to bake them in a slow oven."* [123(p16)]

Two of the features which distinguished Nightingale or pavilion wards from others of the time is they were extensively glazed, with a minimum of one window to every two beds, and they could be cross-ventilated. This meant that the wards could admit plenty of sunlight and fresh air. Nightingale considered sunlight to be second only in importance to fresh air in providing a healthy environment for the sick. Access to sunlight was not to be sacrificed because of bad design, or to save energy:

> *"Window-blinds can always moderate the light of a light ward; but the gloom of a dark ward is irremediable....The escape of heat may be diminished by plate or double glass. But while we can generate warmth, we cannot generate daylight, or the purifying and curative effect of the sun's rays."* [123(p19-20)]

Florence Nightingale also believed a view through a window was important to the recovery of the sick. And if they could see out of two windows instead of one while in bed, so much the better. She had suffered the debilitating effects of a windowless environment as a patient during the Crimean War.[34] Recent research in intensive care units strongly suggests that a lack of windows does have a damaging effect on patients and causes higher rates of depression, anxiety and post-operative delirium.[147,148] In addition, a view from a window can reduce stress and pain. Natural landscapes have a positive health effect, while urban landscapes can have a negative effect.[149]

4.2 Comfort or Health?

Scientific research now supports Florence Nightingale's observations on importance of a view, fresh air and light in patient recovery. This follows a long period when the idea that a hospital ward could be therapeutic was unfashionable. During the second half of the last century, the emphasis moved from putting patients in wards that supported healing to ones that provided a more comfortable environment for hospital patients and staff. Few studies were to test the premise that hospital architecture affects therapeutic outcomes.[150] Some wards were built without any windows at all.[147,148] Florence Nightingale's insights were ignored. A similar fate befell the findings of the eminent British scientist Sir Leonard Erskine Hill (1866-1952). He examined health in buildings, and reached similar conclusions to Miss Nightingale.

From 1914 to 1930, Professor Hill was director of the Department of Applied Physiology at the National Institute for Medical Research.[151] He carried out an extensive study of indoor conditions, during which he identified several factors that promote health in buildings. In marked contrast to more recent studies, Sir Leonard Hill's approach to the subject was both comprehensive and holistic. He concluded the human body requires the stimulus of constantly changing conditions if it is to prosper. The environment within a building needed to be as close as possible to ideal outdoor conditions, namely: cool breezes around the head; the radiant heat of the

sun; and warm ground to stand on.[152]
Outdoors the wind moves at a greater velocity at head than foot level, because of the friction of the moving air against the ground. Hill reasoned that if the head is cooled out of doors at a greater rate than the feet, then the same conditions should apply indoors:

> *"The ideal method of warming and ventilating rooms would give radiant heat, a warm floor, and agreeable movement of cool air - the conditions of a sunny spring day out of doors."* [152(p37)]

In his view, the radiant heat of an open fire and the ventilation provided by its chimney, and by an open window when necessary, was the most healthful in the damp British climate. The radiant energy of a fire was important as it made up for the absence of sunlight.[153] Significantly, Professor Hill anticipated gas-fired central heating. While recognising its benefits in terms of energy efficiency and cleanliness, he had strong reservations on health grounds. Central heating can create a monotonous, over-warm, still atmosphere. He felt such conditions would not promote health in people who spend too much time indoors.[154] Hill reasoned a warm, humid atmosphere of this kind reduced the body's capacity to produce heat. This, in turn, lessens the appetite, depth of breathing, muscular tone, vigour of circulation and provoked relaxation and sleep. The depression of the metabolism by too sedentary a life in too confined an atmosphere was, he felt, a contributory cause of infection and other ailments.

Professor Hill made an important distinction between comfort and health. He argued the aim should not be to pamper individuals by giving them comfortable indoor conditions, but to keep them strong and fit. Hill's premise was that humans have an inherent need to challenge and exercise their thermoregulatory system.[154]

There is some support for the view that designing for comfort may not be healthy in the longer term. The human body's sympathetic autonomic nervous system controls both the cardiovascular and thermoregulatory systems. An increase in cardiovascular activity raises metabolic heat output which, in turn, must be balanced by the thermoregulatory system.[155] It is widely recognised that the cardiovascular system requires exercise for health. Professor Hill's research suggests the thermoregulatory system may need it too. Current standards limit the thermal stimulation occupants may need for long-term health.[156] As noted earlier, the increased use of central heating may be contributing to rising obesity levels.[96] Sir Leonard Hill alluded to this in the 1920s. He argued inadequate ventilation and stagnant heating, combined with overeating and taking too little exercise, posed a significant threat to health.

Incidentally, in 1913 a Select Committee of the House of Commons called on Leonard Hill to give evidence on the ventilation of the Debating Chamber. He criticised the system then in place as likely to produce that most undesirable condition in legislators; cold feet and hot heads. He proposed a method designed to create variable air movement around the heads of the Members, while avoiding chilling their feet.[157]

4.3 Ideal Conditions

In the years following Professor Hill's investigations, comfort became more important than health promotion. A widespread belief took hold that the indoor environment must be carefully controlled.[37] Current codes and standards specify environments that minimise discomfort. However, there is no scientific evidence that this has health benefits. Indeed, a neutral, closely controlled environment may compromise well-being over the longer term.[156] Designing for comfort runs counter to a basic principle identified by Sir Leonard Hill, and by Florence Nightingale before him. Both held that indoor conditions should follow those outdoors; and occupants should not be isolated from natural changes in humidity, temperature and light levels. Another related factor is the control of indoor conditions. Research shows involving the users in the control of their own environment is important if they are to enjoy a high level of satisfaction with indoor conditions.[37] That satisfaction, in turn, correlates with health.[158]

> *"People feel better and have better mental health when they can control their surroundings. When opportunities for control over the environment are thwarted, helplessness can occur."* [159(p544)]

When this happens, either at work or at home, it can increase the risk of developing depression and anxiety.[160] Housing design can heighten users' sense of control by giving them the scope to regulate environmental stimuli.[161] Current housing standards do not favour such control. If occupants open windows to improve air quality, this may negate the energy savings from MVHR systems.[30] Also, if housing is designed to keep sunlight penetration to a minimum this also limits occupants' scope for control. Surveys show sunlight is usually welcome in buildings as long as steps are taken to avoid glare or thermal discomfort. Much depends on occupants' ability both to control the amount they let into a room and change their position to it once it is in.[162,163] However, if sunlight is kept to a minimum, and MVHR is in place, the occupants of new energy-efficient housing may have less control over lighting levels, thermal conditions and ventilation than they might like.

4.4 Healthy Heating

There are also concerns about the way MVHR systems provide heating. The WHO's guidance on healthy housing states that convective heating must be designed and maintained so as not to give rise to noise nuisance or distribute dust and bacteria around a building. Their guidance also states that:

> *"Radiant heating is preferred to heating by convected warm air wherever possible."* [65(p162)]

This is consistent with the findings of Sir Leonard Hill and Florence Nightingale before him. Again, heating to promote health is not considered in current standards and codes. There is a dearth of authoritative guidance on the subject. But evidence that heating can be arranged to promote health in housing does exist. There is a tried and tested way to heat a home that meets the dual requirements of health promotion and energy efficiency; it is to use the radiant energy of the sun. Two

thousand years ago, the architects and engineers of Imperial Rome recognised the value of such an approach. In the 1st century BC, Vitruvius included guidance on what is now known as passive solar design in his *Ten Books of Architecture*. The citizens of Rome considered solar energy to be so important they had right-to-sunlight legislation. Unfortunately, we do not.[16]

The Romans also made extensive use of radiant energy in buildings with their under-floor *hypocaust* heating technology. As with passive solar architecture, they were not the first to do so. The Koreans developed under-floor heating many centuries before the Romans and still prefer it to other forms of heating. Almost all buildings in Korea and northern China have radiant floor heating.[164] Also, in Germany, Austria and Denmark, some 30 to 50 per cent of new residential buildings have under-floor systems.[165]

Convective heat acts mainly on the skin. By contrast, radiant energy has a marked biochemical effect. As well as acting on the surface of the body, it stimulates deeper-lying tissues. This influence extends to the internal organs, the central nervous system and enzymatic processes.[166] Also, with a radiant heat source, air temperatures can be kept lower than with convective systems. The building fabric is warm but the air within it can be kept cooler:

> *"...comfortable conditions can exist with radiant heating at at a lower air temperature, so that, with normal clothing, the tone of the muscular system is high, and there is a feeling of freshness and vigour."* [166(p28)]

Studies show people perceive air quality to be better at lower air temperatures.[167] A further benefit of radiant floor heating is it provides more uniform floor-to-ceiling gradients than convective heating. A 3^{o}C drop in vertical temperature can cause the lower limbs to feel cold and cause reflex changes in the temperature of the upper respiratory tract.[65] Radiant floor heating keeps the feet warm. One effect of this is to raise the temperature of the nasal mucosa.[168,169] This, in turn, improves the ability of the nose to condition inspired air.[170] Conversely, if the feet become chilled, this causes a constriction of the blood-vessels in the nose. Recently, vasoconstriction of the upper airways has been proposed as a mechanism that reduces defence against infection. It cuts off the blood flow that supplies the white cells that fight respiratory illness.[171] This is not a new idea. Sir Leonard Hill conducted experiments on this in the 1920s and reached similar conclusions.[152] He was also an advocate of under-floor heating; as was E Maxwell Fry, who included it in his Sun House.[16,153]

One advantage of a warm floor surface is that it can quicken blood flow in the feet through vasodilation. This can improve some vascular-related disorders. In the 15th century, Korean floor heating systems were used to treat weak and elderly patients.[172] Coming up to date, a further benefit of under-floor heating is that carpets are not needed. This removes a major source of house dust mite and other pollutants. In addition, there is less movement of dust; and the higher surface temperatures reduce condensation and mould growth. And there are potential energy savings: lower indoor air temperatures reduce ventilation heat losses.[165]

4.5 What Do People Want?

As noted earlier, scientists and health researchers do not seek the views of homeowners and occupiers as keenly as they might. And when they are asked to express an opinion, much that could be of value is ignored:

> *"In general we do not ask the occupant what did he like or why did he like it, but always what didn't you like, in order to prevent diseases and disorders in the future. But taking into account the positive effects of certain parameters should be just as important. To study that with the human being as the ultimate sensor at component level seems an important direction for the future."* [38(p815)]

Research in low-energy office buildings and apartments does provide some useful insights. A recent European survey of 164 office and apartment buildings identified several examples that performed well both in terms of energy performance and user satisfaction. Occupants preferred natural ventilation, passive solar heating and measures that allowed them to adapt the internal environment to their needs as much as possible.[173] Buildings with passive solar design had among the best energy performance of those audited. And comfort, air quality and well-being were the same, or better, in solar buildings than in the others surveyed.[122] The authors of the study concluded designers of low-energy buildings should follow two basic principles:

> *"...prefer, as far as possible, passive (architectural) to active (technical) ways to ensure comfort in buildings and design for the building user. In particular, the building user should be able to adapt his indoor environment to his needs...Openable windows and absence of restrictions to open the windows (noise, pollution, security) have a positive affect on performance."* [40(p14)]

This is consistent with historical and other recent evidence. People want natural ventilation, with operable windows. They want sunlight and direct control of their environment.[37] Yet the current approach to house design runs counter to this.

Dwellings that perform well in energy and environmental terms are not necessarily the most life-enhancing. A substantial portion of the British population suffers from respiratory illnesses, allergy and asthma symptoms, and depression. There is evidence that changes in house design could reduce these and other illnesses. Decreasing their prevalence would lead to lower health-care costs, reduced sick leave, and shorter periods of illness-impaired performance at work. A greater awareness of the potential economic and social benefits of houses that maximise health might see more of them built.[174] The current aim of providing tolerable indoor conditions should be replaced by something more ambitious and worthwhile.

5. CONCLUSIONS

It used to be held that housing should support and promote health. Much that was known on this subject has been, and continues to be, overlooked. The quest for energy efficiency now assumes greater importance. This may have adverse consequences: measures aimed at reducing carbon emissions from homes could pose a risk to residents.

In the past, experts took a more comprehensive and human view of the indoor environment than is the case today. Research is now split between disciplines and is not of as much practical value as might be. Findings are published in specialised peer-review journals and are not available in an accessible form. More needs to be done to make them useful and relevant to policy-makers and practitioners. This review is a first step in this process. It is not exhaustive. But it does bring together enough information for those who wish to design healthy housing to make a start.

The major findings are:

- People spend more than 90 per cent of their time indoors; most of it in their homes.
- The principle that a house should promote health, rather than simply prevent disease, is not considered in current regulations and standards.
- Highly energy efficient, zero carbon housing may be unhealthy.
- In the health-care sector, the positive effects of architecture on patient recovery have been demonstrated scientifically. The findings now inform hospital design; but they have not transferred to the housing sector.
- When people are asked about indoor conditions, they express a preference for windows that open, fresh air, sunlight and control of their environment.
- Regulations now favour sealed buildings that impose close control on internal conditions.
- The weight of evidence suggests healthy housing should have:
    - Windows that open
    - Views of Nature
    - Cross-ventilation
    - Radiant heating
    - High levels of natural light
    - Direct sunlight

Two thousand years ago, Vitruvius explained how to design healthy sustainable buildings. Much of what he wrote is relevant today. Some of it is still ahead of current practice. Notably, he insisted architects should have a working knowledge of

medicine. Florence Nightingale and then Sir Leonard Hill described how to create healthy indoor conditions. Their findings have been ignored; and promoting health in housing attracts little scientific interest. Given the time people now spend in their homes, and the demands of an ageing population, there is an urgent need for research and guidance. Policy-makers should give more consideration to the link between housing and the health of the population. Similarly, society might benefit if the building professions had a better understanding of the impact of their work on health and well-being.

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NOTES: