

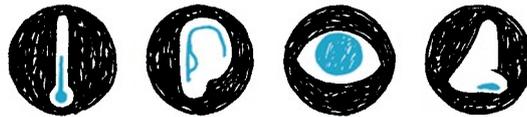
INDOOR ENVIRONMENT AND WELL-BEING

The Saint-Gobain Multi-Comfort Comic Book



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The Saint-Gobain Multi-Comfort Comic Book



Text by the Saint-Gobain Building Science team
Illustrations by Thomas Vieille for Saint-Gobain.

2016

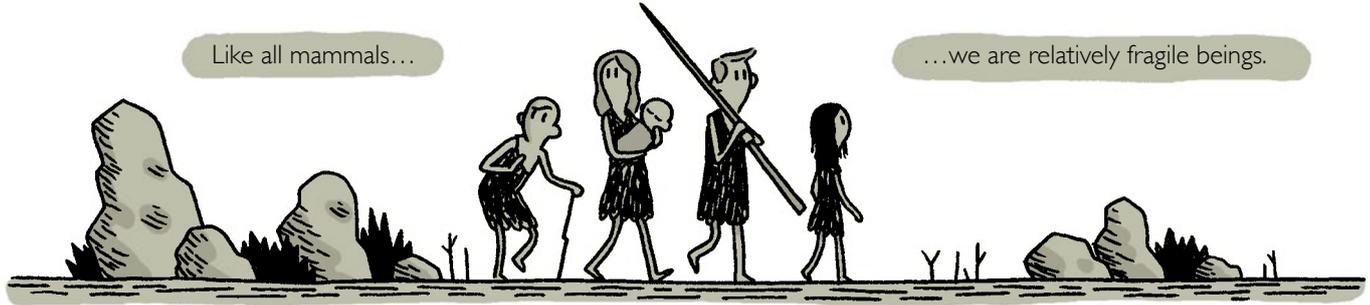
Contact for enquiries and comments:
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INTRODUCTION

On human beings, and their natural and built environments...

Like all mammals...

...we are relatively fragile beings.



Avoiding exposure to excessive heat, cold, rain or wind is one of our primary needs.



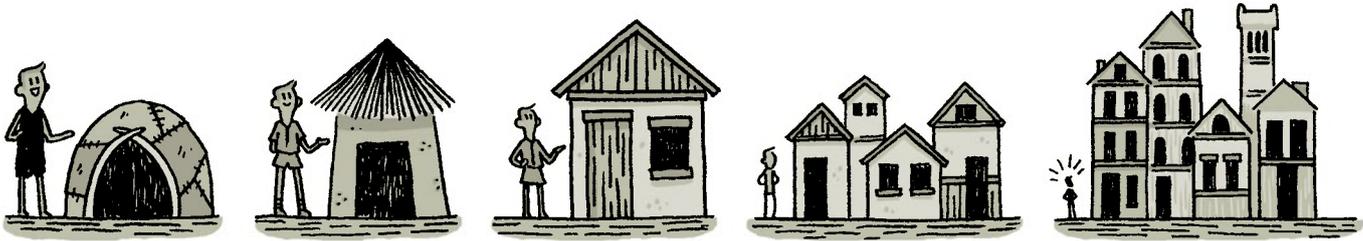
And so we have come up with various strategies



...to protect ourselves from the outside environment.



From caves, to huts, to houses, we have gradually transformed our habitat and way of living.



Industrialisation of the late 18th century marked the beginning of great change in the way people lived...



New building materials, energy sources, and the invention of electricity improved methods of lighting and heating. This encouraged the desire to better control indoor climates.



At the beginning of the 20th century, indoor comfort and well-being became specific subjects for consideration.



Today, in the urbanized world, people are spending around 90% of their time indoors.



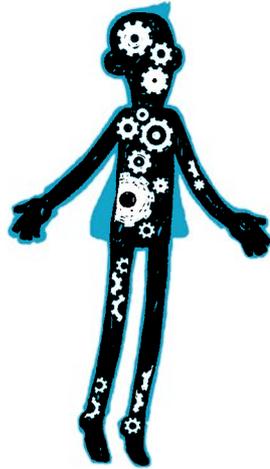
Being comfortable in life, work, play and sleep is key to well-being.

So... what is comfort, and how does it work?

Comfort is a state of physical ease and well-being in a given environment.



It is experienced via a number of conscious and unconscious interactions between three areas:



PHYSIOLOGICAL

The way our bodies work and interact with our environment.



PHYSICAL

The main parameters of the environment around us (indoor temperature, sound level, quantity and quality of light, fresh air supply...).



PSYCHOLOGICAL

The way we feel as a whole (if we are tired, happy...) and the kind of social environment we live in.

Our perception of indoor comfort is affected by four main factors:

THERMAL COMFORT

(determined by air temperature, humidity, etc.)

VISUAL COMFORT

(determined by view, luminosity, etc.)

ACOUSTIC COMFORT

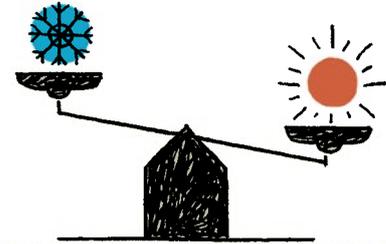
(determined by noise from outdoors, vibrations, etc.)

AIR QUALITY

(determined by fresh air supply, pollutants, odours, etc.)



The correct balance of these factors gives us indoor environments that we are happy to occupy, where we function efficiently and feel well.



Understanding these comfort factors is crucial to design happy, healthy, energy-efficient buildings.



Why is designing for comfort important?

Technological advances have led to the improvement of many aspects of living indoors, particularly artificial lighting, heating and cooling

BUT

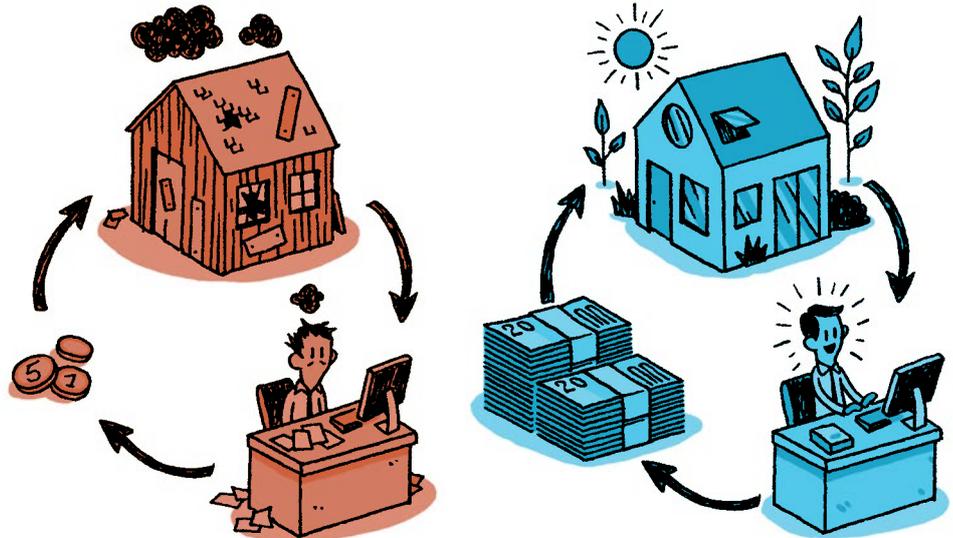
these same advances also introduced unwanted consequences...

HEALTH

Present day housing conditions are linked to numerous health issues (respiratory illnesses, allergies, tiredness...). Currently only a minority of all housing stock can be classified as healthy. It is possible to change this!



Spending on healthy and comfortable buildings is increasingly recognized as a wise investment, as it directly improves productivity and reduces medical costs.



2 ENVIRONMENT

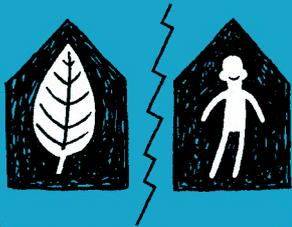
To construct, operate and maintain artificial indoor environments, we use up significant natural resources.



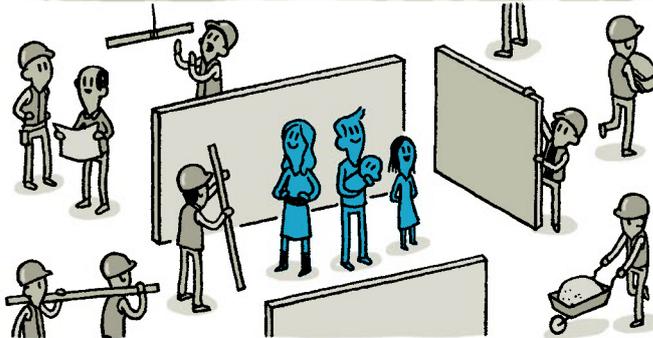
In industrialised countries, buildings represent 40% of the total energy consumption. Appropriate design of the building envelope can make a huge difference in reducing our impact on the environment.



Improvements in comfort and health, on one hand, and reductions in environmental impact on the other, can sometimes appear as conflicting goals.



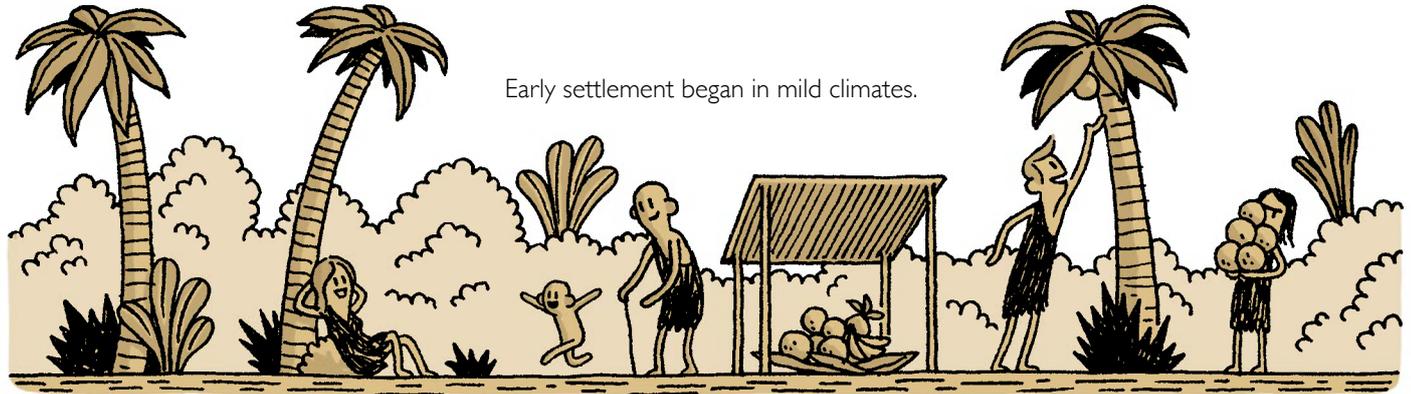
However, both these goals are key for all stakeholders in the building industry: architects, installers, builders, developers and operators, as well as occupants.



Saint-Gobain's objective is to deliver the best solutions possible to build more sustainably.



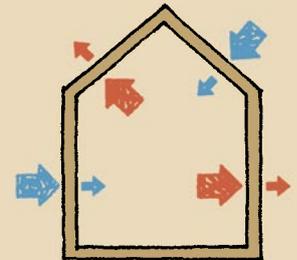
! THERMAL COMFORT



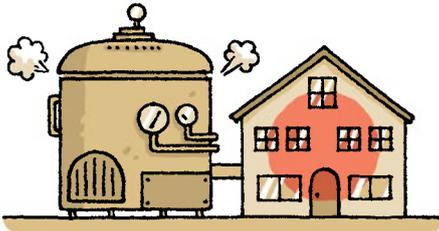
Early settlement began in mild climates.

As man moved North, he had to develop different kinds of shelter to be comfortable throughout the seasons.

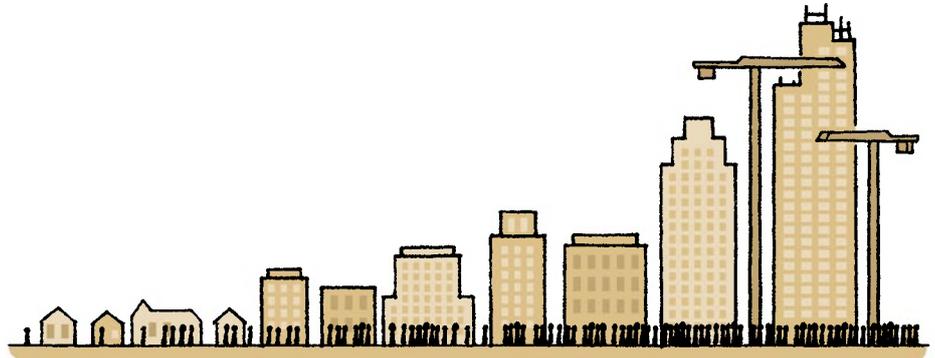
The building envelope, as filter between the interior and the exterior, gradually became more sophisticated.



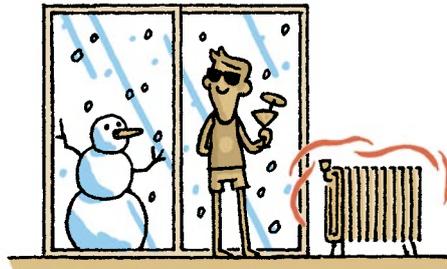
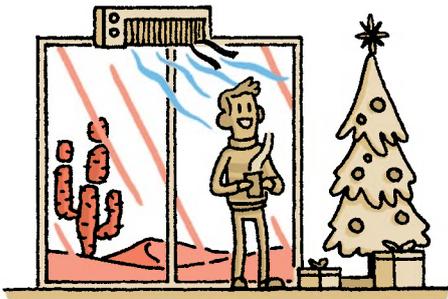
During the 20th century we gained unprecedented control over our thermal environment, mainly thanks to energy-consuming equipment.



As we advance into the 21st century, world population, urbanized areas and expectations of comfort continue to grow...



Striving to reduce energy dependency in buildings, while satisfying comfort demands, is more important than ever.



Designing efficient building envelopes is one of the first steps to consider.



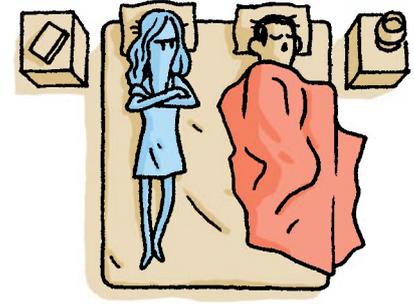
Today we spend more and more time indoors, where we expect a level of thermal comfort that ensures well-being and efficiency.



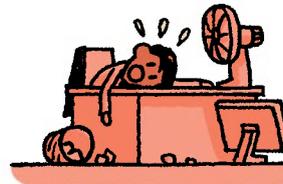
While extremes in temperature can be fatal...



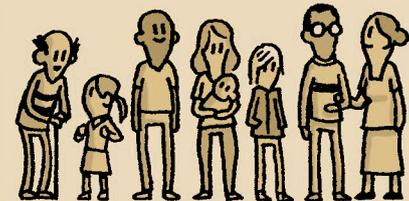
even gentle fluctuations have marked us all with pleasure or discomfort.



Concentration, manual dexterity, and occurrence of accidents are influenced by both high and low temperatures.



The basic principles behind thermal comfort are largely universal, but thermal sensitivity varies from one person to another.



The
PHYSIOLOGICAL
aspect of thermal comfort

Human bodies, as with all mammals, are thermal engines that generate and dissipate energy.

We have different ways to balance our constant heat exchange with the environment.

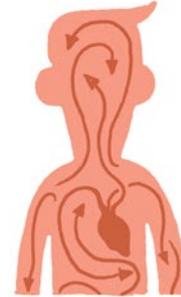
For example,
by shivering...



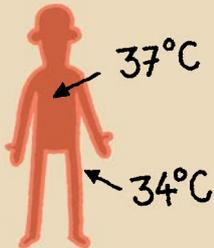
perspiring...



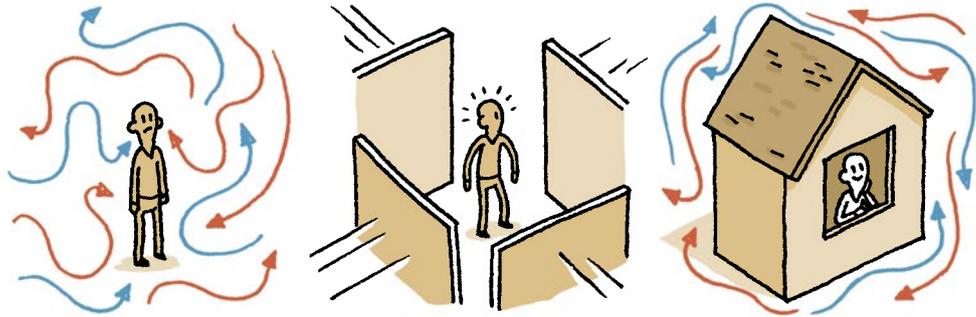
or modifying our blood
flow to regulate heat
distribution.



The objective of our metabolism is to regulate our body temperature with minimal effort (if possible).



Hence the need to be able to control the physical environment surrounding us.

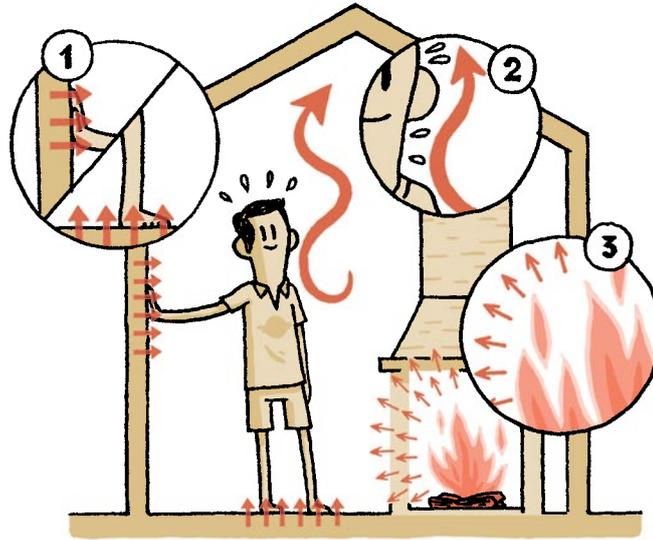


The

PHYSICAL

aspect of thermal comfort

Thermal energy (heat or cold) can be transferred by **3** means which, together with moisture changes, influence our perception of the environment.



① Conduction is energy transferred via a solid.

② Convection is energy transferred from a solid to an adjacent gas or liquid.

③ Radiation is energy emitted from a surface.

An overall balanced thermal environment is key to feeling comfortable...



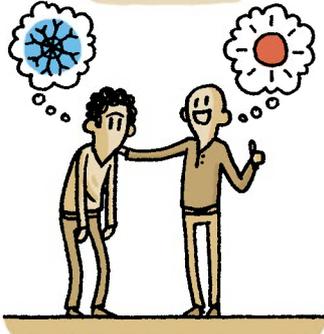
but our bodies are very sensitive and local variations can cause great discomfort.



The **SOCIO PSYCHOLOGICAL** aspect of thermal comfort

Many other factors influence our perception of our thermal environment:

Our current emotional state, mood or level of fatigue...



our thermal history and social background...



as well as other environmental factors such as noise or glare.



Our perception of heat also depends on varying tolerance levels.



For instance, the more control we have over our thermal environment,



the better we feel and the more productive we are;



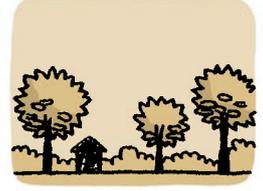
whether or not we chose to exert this control.



Designing for thermal comfort

There is no 'one size fits all' recipe for thermal comfort.

Solutions vary depending on the local climate...



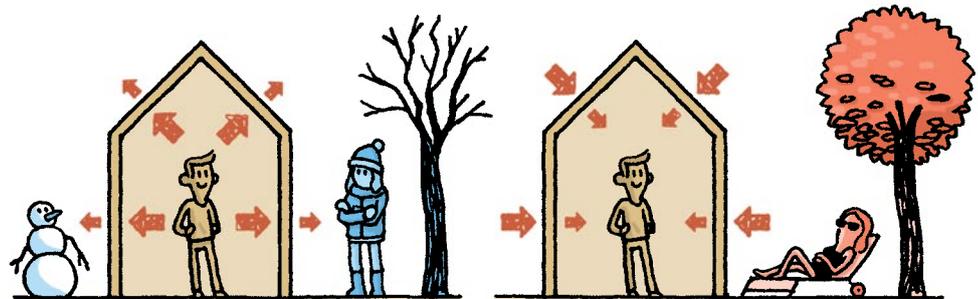
as well as the type of activity performed by the building occupants.



The building envelope acts as a filter between the exterior and interior climates.

Designing it efficiently implies the consideration of **5** main factors:

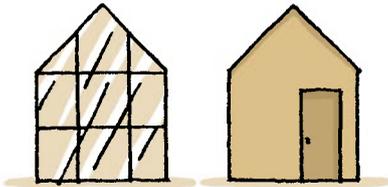
1 INSULATION reduces heat loss during cold seasons and heat gain during warm seasons.



② SOLAR GAIN is influenced by the building's insulation levels, its shape and orientation,



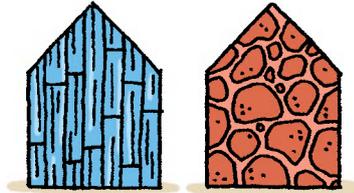
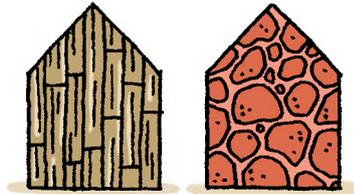
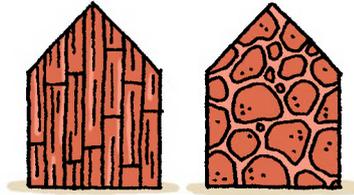
the window-to-opaque-wall surface ratio,



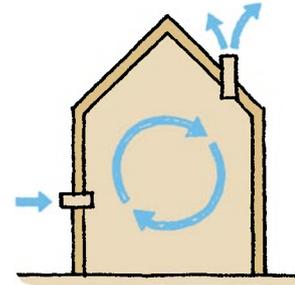
the type of glazings, shade or shading devices...



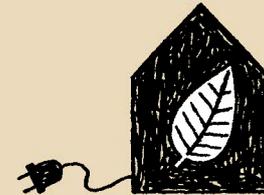
③ THERMAL INERTIA varies according to the mass and materials of a building. High-inertia envelopes remain relatively stable in the face of temperature change.



④ AIR-TIGHTNESS and ⑤ VENTILATION enable the control of air exchanges with the outside.



A well-designed building envelope can dramatically reduce the need for mechanised systems required to ensure thermal comfort, so reducing the carbon footprint.

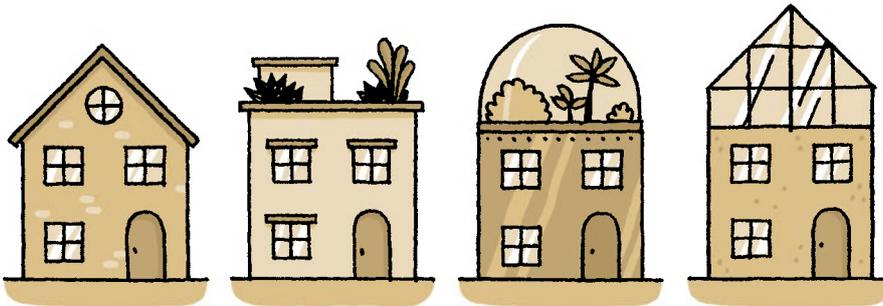


The **FUTURE**

Although our basic thermal comfort requirements are likely to remain the same in the future, our outdoor environment is likely to change.

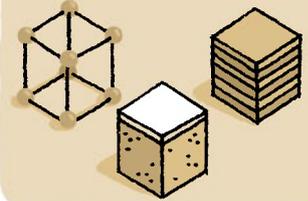


These changes, as well as a new approach to energy consumption, will require buildings to be capable of evolving over time in order to be both comfortable and energy efficient.



Climate change will play an increasingly important role in the design of the built environment.

New systems and materials will continue to be developed and refined.



A key factor in this evolution will be an increased critical reflection of what levels of thermal comfort will be considered acceptable: should we just put on a jacket rather than turn up the heat?



ACOUSTIC COMFORT



Our ears developed in natural environments, where we are still the most acoustically comfortable.

Their main purpose has always been to warn us of approaching danger...



and to allow verbal communication.

But today's world is much more

Urban densification, together with greater numbers of noise-producing equipment and activity, have dramatically changed our sound environment.



An acoustically 'comfortable' environment can be defined by the quality of desired sounds...



and the absence of unwanted sounds.



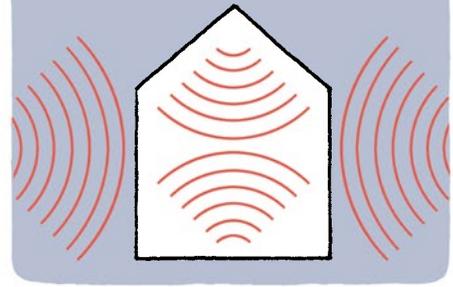
Being able to produce sound without annoying other people is also part of acoustic comfort.



With this definition in mind, it is clear that the modern environment brings new acoustic challenges to our day-to-day lives.



Taking these challenges into account when designing a building is key for the well-being of its occupants.



Besides hearing loss, exposure to noise can have numerous undesirable effects on health.



It can be particularly harmful at night in disturbing our sleep patterns.



Scientific studies, however, show that in well-designed sound environments students learn more effectively, patients recover faster, and stress is reduced.



Protection from noise exposure contributes to a sense of security and privacy.



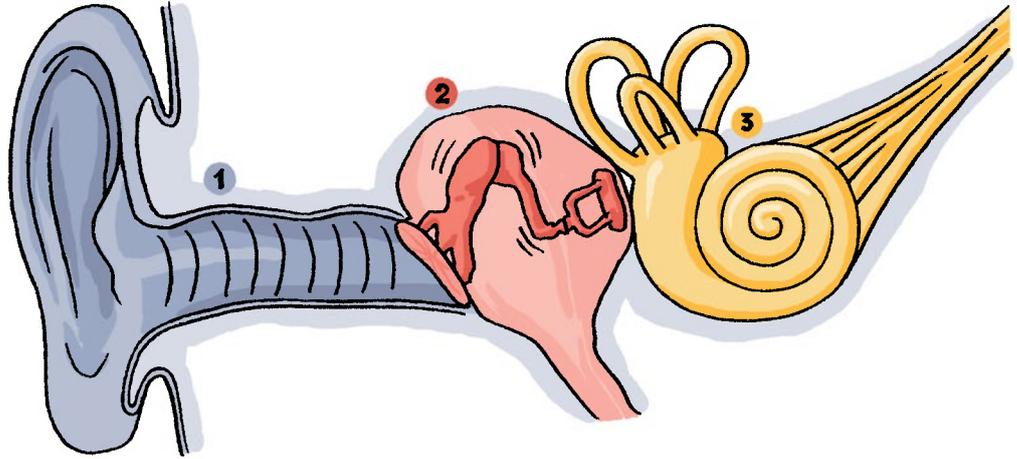
The

PHYSIOLOGICAL

aspect of acoustic comfort

The human ear is comprised of **3** parts:

1 The OUTER EAR receives sound.



2 The MIDDLE EAR transmits vibration to...

3 the INNER EAR which translates this vibration into information...

which is then sent to the brain.

Hearing is the only human sense that fully functions while we sleep.



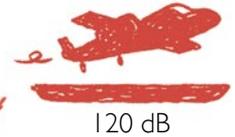
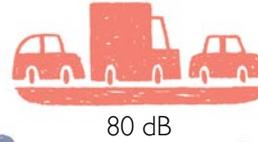
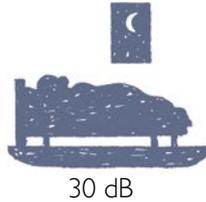
The

PHYSICAL

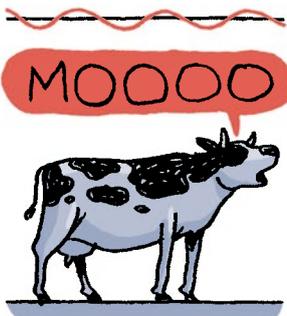
aspect of acoustic comfort

Sound is a vibration which is a pressure fluctuation that propagates through a medium such as air or water.

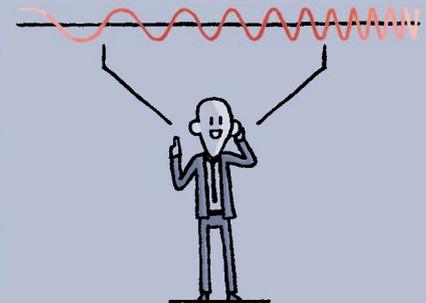
The distinction between loud and quiet sounds is made by the difference in scale of the pressure changes, commonly measured in decibels.



The pitch of a sound is expressed as its frequency (measured in Hertz - Hz), which is the number of vibration cycles per second.



The healthy human ear is sensitive to frequencies ranging from around 20Hz to 20,000Hz.



The

SOCIO PSYCHOLOGICAL

aspect of acoustic comfort

The effect of sound on well-being also depends on individual psychological responses.

Several parameters interact:

the familiarity of a sound,



its predictability,



its controllability,



personal sensitivities...



For instance we are always more tolerant of noise from well-liked neighbours than from others...



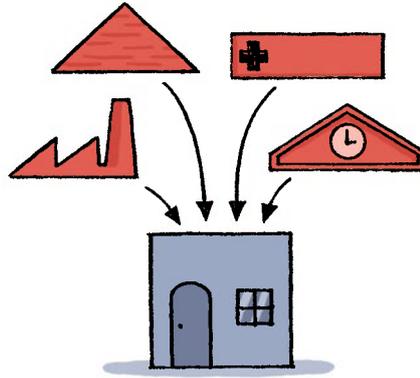
and the acceptance of noise always depends on the type of activity performed...



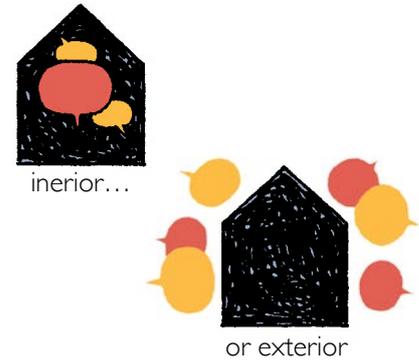
Designing for acoustic comfort

To design acoustically comfortable buildings, it is important to take into account the needs of the occupants, as well as a variety of external and architectural factors:

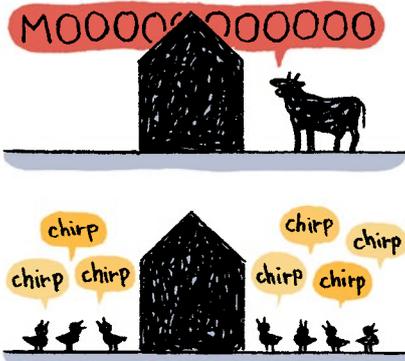
the activities to be performed,



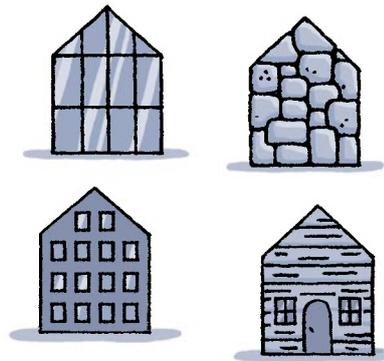
the types of noise to be managed,



the spectrum of noise to be managed,



the construction system and materials...

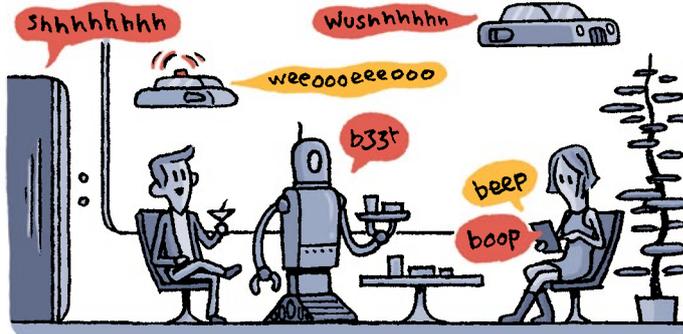


However, sound is difficult to predict. Computer simulations are very useful but cannot replace on-site testing and the experience of an acoustic engineer.



The F U T U R E

Indoor acoustic landscapes will necessarily change in the coming decades.



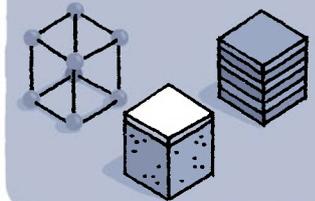
The development of better-insulated buildings will reduce our tolerance to interior noise.



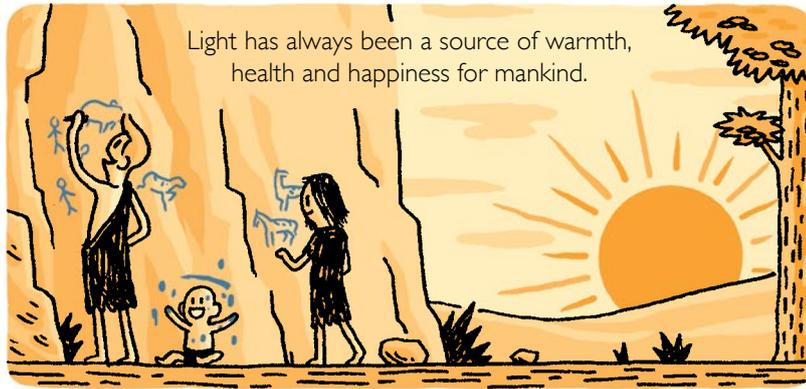
Particularly as the change in living habits will mean that more and more different activities will have to coexist in the same buildings.



Materials, construction systems and technology will have to evolve to counteract these growing challenges.



VISUAL COMFORT



We need light to be able to perform most tasks.



So, from very early on, we have tried to replicate natural light.

But early forms of artificial lighting were expensive and weak.

Therefore, the hours of daily activity closely followed the hours of natural daylight.



Advances in the late 19th century freed us from total daylight dependence...



and enabled us to spend more and more time indoors.



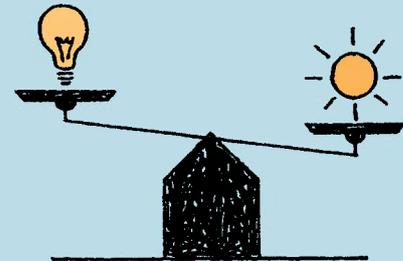
As our day-to-day lives radically changed, building design and indoor visual environments evolved.



Though we are now able to provide adequate artificial lighting day and night, it is well established that daylight and a view to the exterior are essential to our well-being.



A careful balance between natural and artificial lighting is recognised as the best solution for our comfort and health.



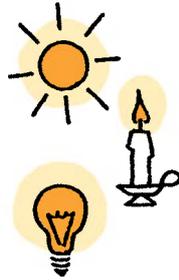
Visual comfort is much further reaching than simply being able to see well enough to perform a given task.

Light has QUALITATIVE and QUANTITATIVE aspects.

QUALITY

To be able to fully describe light, one needs to discuss its many aspects:

its source,



its distribution,



its tone and color,



its intensity...



QUANTITY

Being able to control light levels is also key to visual comfort: both too little and too much light can be a source of discomfort.



Sharp contrast or major changes in light levels can cause stress and fatigue, as the human eye is permanently adapting to light levels.

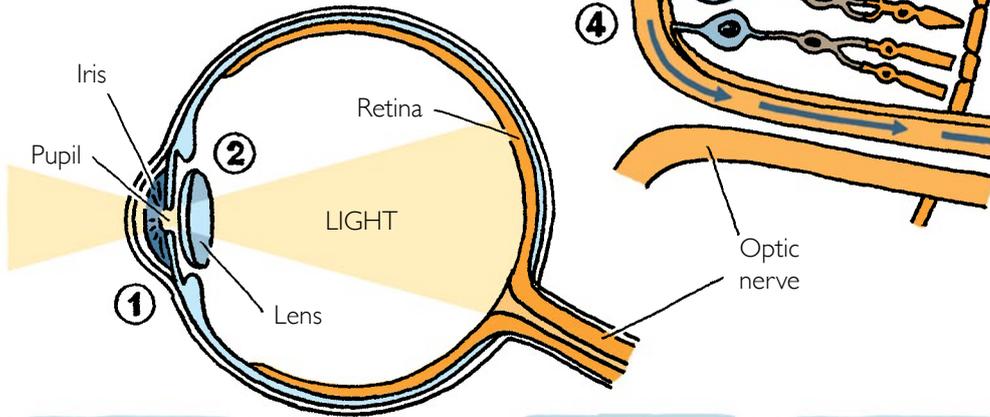


The

PHYSIOLOGICAL

aspect of visual comfort

The human eye is a light-sensitive organ:



1 A diaphragm (the iris and pupil) adjusts the total quantity of light entering the eye.

2 A lens adjusts the focus.

3 Light triggers photochemical reactions in the rods and cones at the back of the retina.

4 Information is transmitted through bipolar and ganglion cells to the optic nerve and the brain.

Scientists recently discovered that some cells are also responsible for 'non-visual effects' on our sleep/wake rhythms, our heartbeat, and the workings of our organs.



Thus, light has a direct effect on the regulation of various biological functions such as sleep, mood, alertness, etc.

The

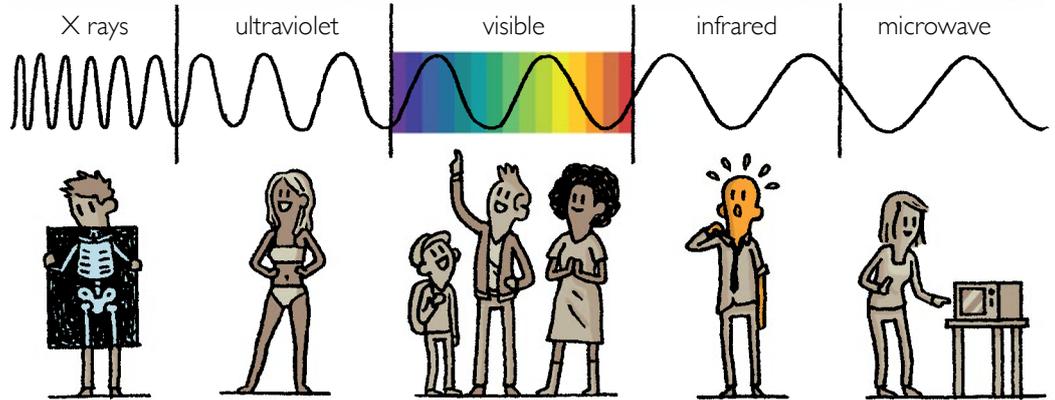
PHYSICAL

aspect of visual comfort

The sun, or an electric light bulb, emits energy...

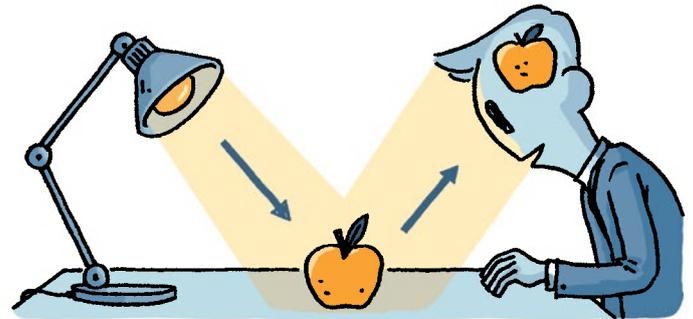
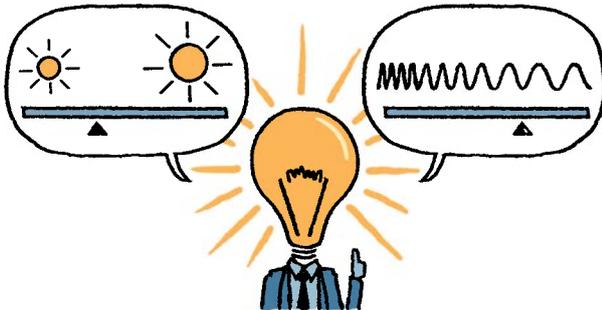


of which a limited range of wavelength is perceptible to the human eye as light.



The perception of light is determined by the amount of radiation energy that enters the eye and the spectrum of this light.

Light transports information about its own source, whether natural or artificial, and about what it encounters.



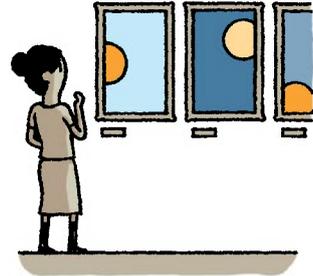
The
SOCIO PSYCHOLOGICAL
aspect of visual comfort



Light has a profound effect on the way we feel and experience time and space, both consciously and unconsciously.



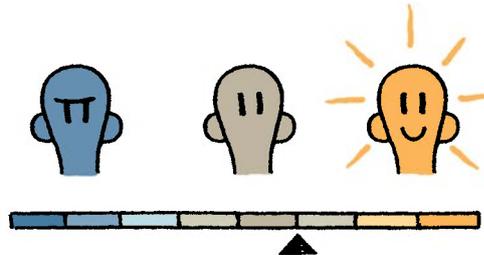
Our personal history and culture also shapes the way we appreciate light and visual environments.



Extreme variations in preferred range of illuminances exist depending on age and culture.



But whatever the nationality, age or social category, light directly influences the mood and health of all humans.



Non-visual effects of light play an important role in this respect. Their discovery is fairly recent and they remain the subject of active scientific research.



The specificities of natural daylight

Natural daylight is the reference illumination source to which our eyes are naturally adapted...

so that we nearly always find it more comfortable and attractive than artificial lighting.

In hospitals, daylight accelerates recovery and reduces the need for pain-relief.

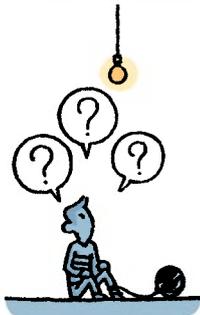
In schools it improves alertness and the learning process.



By its variations, it also provides information, maintaining our social and psychological equilibrium.

Spaces lit by daylight appear naturally beautiful and spacious. It plays a major role in defining the aesthetic quality of a space.

Daylight also brings a precious (and free) energy source. However it can be somewhat unpredictable and difficult to control.

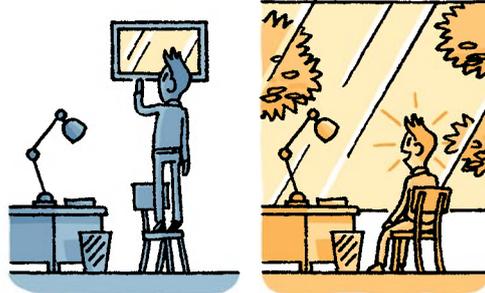


Designing for visual comfort

There is no universal definition of visual comfort as it is a relatively complex issue.

Nevertheless several factors are now commonly accepted as key to designing visually comfortable environments:

① An access to views,



② daylight provision in sufficient quantity,



③ uniform distribution...



④ and a good combination of natural and artificial light.



5 adequate task lighting,



6 control to ensure the absence of glare and high contrasts,



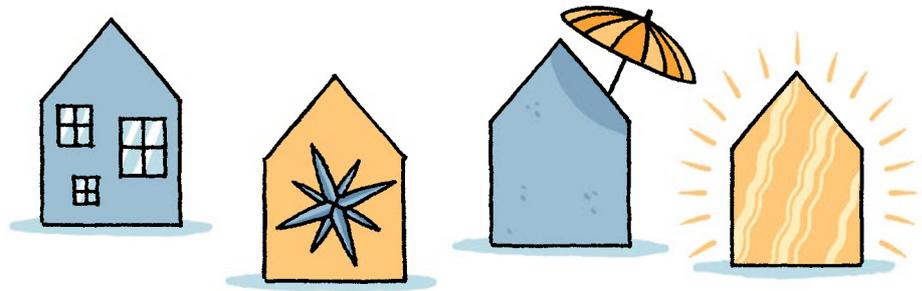
7 an aesthetically pleasing space.



Building design and choice of materials and equipment obviously play a decisive role.

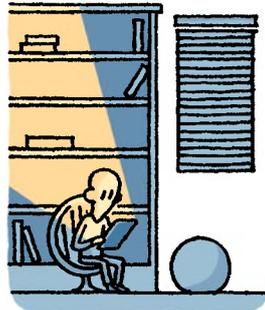


The size and position of the openings, the orientation of the facades, solar protection devices and the reflectance of the surfaces are some of the tools available to achieve visual comfort.



The FUTURE

As our habits continue to change, so will our lighting needs. For example, if reading e-books becomes standard, the way we light places to read will have to change.



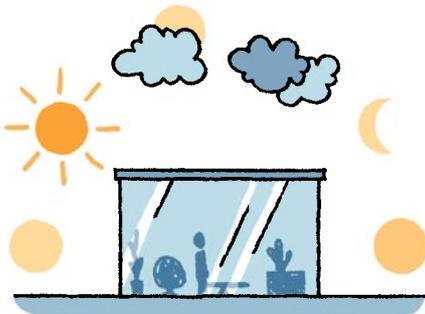
Concerns about energy efficiency and health have brought daylight to the forefront of building design.



However, the benefits of daylighting must not be outweighed by the problems of overheating and glare.



And since daylight varies all the time, a balance has to be found between natural and artificial sources.



Hence the role of the lighting designer is changing from specifying artificial lighting to understanding natural light.



Active systems to balance light sources have become a lively research field.



INDOOR AIR QUALITY

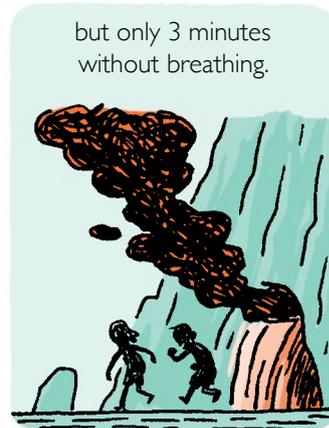
Air is a vital necessity.



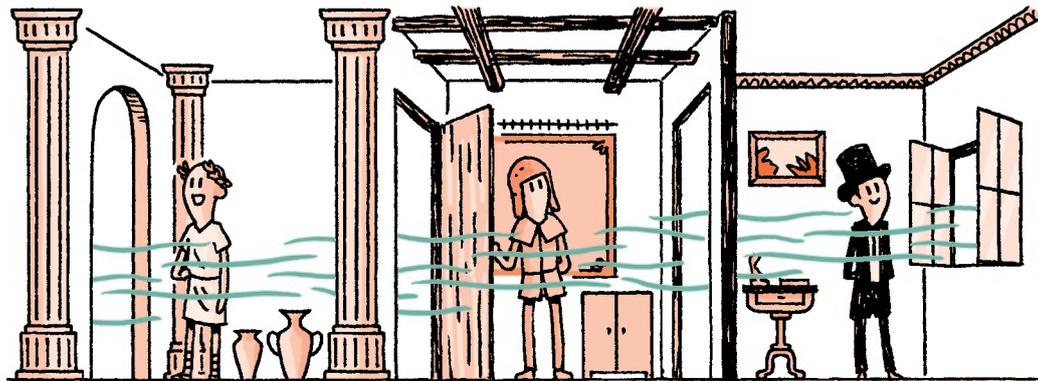
We can live 30 days
without eating, 3 days
without drinking...



but only 3 minutes
without breathing.



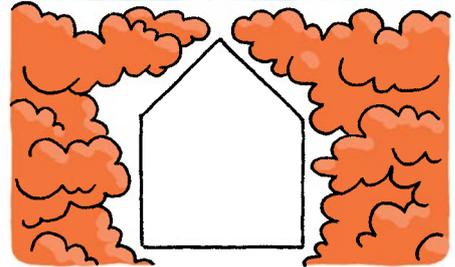
Throughout the ages,
air quality in buildings
has been recognized as
a source of well-being
and essential to good
health, for instance in
preventing the spread
of diseases.



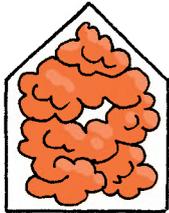
The quality of air has dramatically changed over the last couple of centuries.



As pollution levels have risen, attention has been given to the threats of outdoor air pollution on human health and the environment.

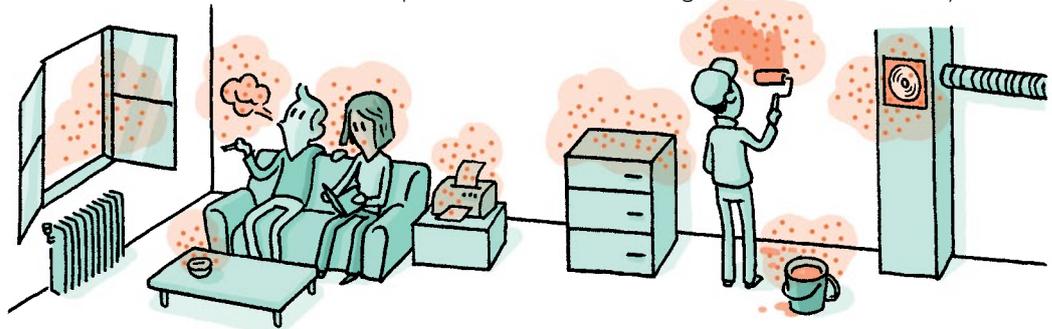


It is only in the last few decades that any attention has been paid to indoor air quality.



The sources of indoor pollution can be divided into **4** categories:

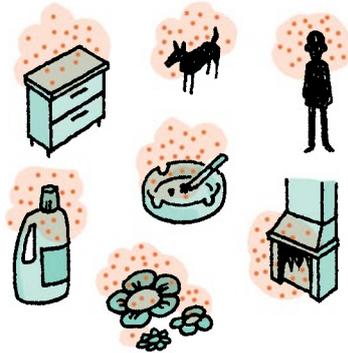
- 1** Outdoor sources
- 2** Occupant-related activities and products
- 3** Building materials and furnishings
- 4** Poorly maintained ventilation systems.



In sufficient concentration, pollutants can have a direct effect on health. Their effects on our well-being can be less easily quantifiable.



ODOURS originate from various sources.



They are generated by volatile molecules that the human nose can detect at very low levels of concentration.



Some volatile molecules can also cause **SENSORY IRRITATIONS**. Generally, the threshold for sensory irritation is higher than for odour perception.



The sensation of **STUFFINESS** results from the overall pollution load and lack of fresh air. Different pollutants at very low concentrations but combined can affect our well-being.



Good air quality is defined by the absence of health-threatening pollutants, bad smells, sensory irritations, and stuffiness.



The

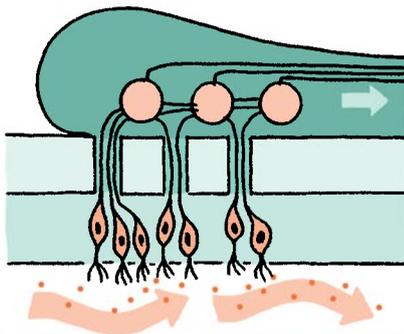
PHYSIOLOGICAL

aspect of indoor air quality

We inhale and exhale an average of 12,000 litres of air per day.
Our ability to assess the quality of this air involves **2** senses.

1 OLFACTION

The olfactory nerve in the nose detects molecules.

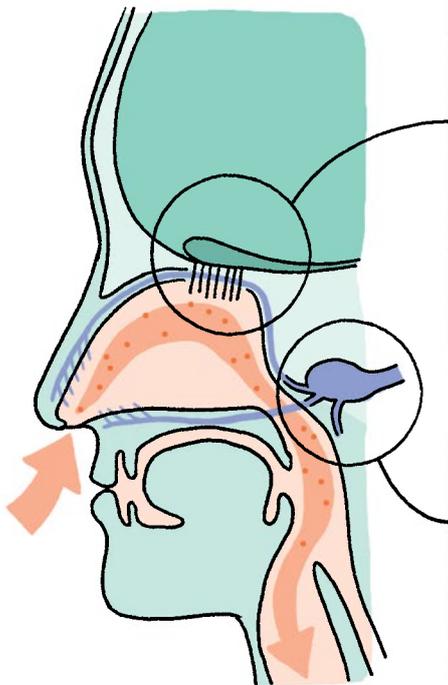


The information is sent to be interpreted as smell in several parts of the brain: the cortex, where conscious perception is formed, and the limbic system, which controls mood and emotions.



2 THE COMMON CHEMICAL SENSE

This is the ability to sense irritants.
The process is fairly similar, but involves different nerves.



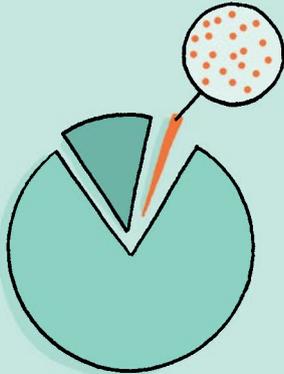
The

PHYSICAL

aspect of indoor air quality

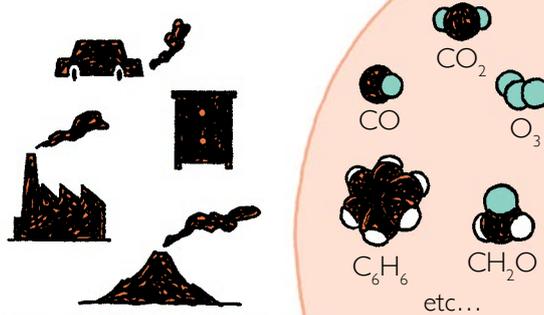
Air is a gas mainly composed of oxygen (21%) and nitrogen (78%).

The remaining 1% can concentrate a number of pollutants.

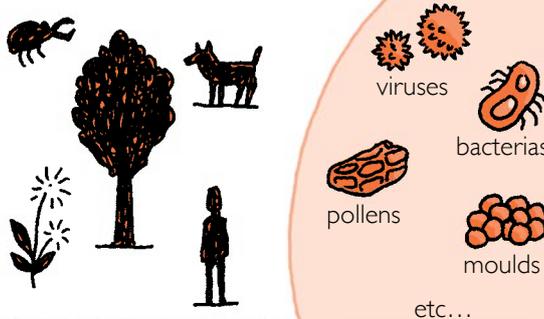


The different indoor pollutants can be classified into **2** main categories:

1 PHYSICO-CHEMICAL pollutants



2 BIOLOGICAL pollutants



Exposure to pollutants is influenced by environmental parameters such as ventilation rate, air velocity, temperature, relative humidity, the activities taking place, and the frequency and duration of exposure.



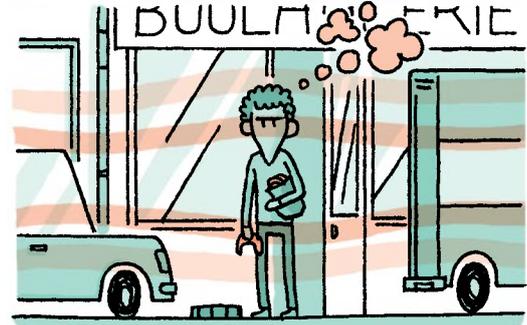
The
**SOCIO
PSYCH
SOCIOLOGICAL**
aspect of indoor air quality

The quality of air has a profound effect on our conscious and subconscious mind.

Odours are deeply linked to our emotional state, motivation and memory.



If unpleasant, they can cause mental distraction and have a negative impact on mood and stress levels.



The presence of pollutants in buildings is shown to decrease efficiency. For instance, high concentration of CO₂ impairs our ability to take decisions.



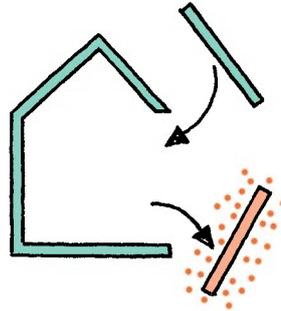
This is why we are usually more creative, alert and efficient in well-ventilated schools or offices.



Designing for indoor air quality

To improve indoor air quality, **3** factors have to be considered:

1 REMOVING
or minimising emissions
of pollutants at source.

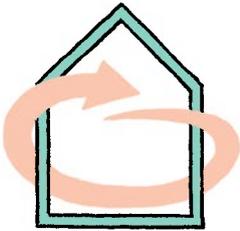


However, it is not always economic, practical or even possible.



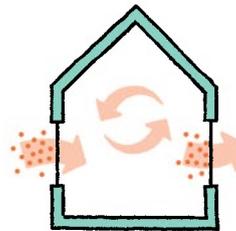
2 VENTILATING

The appropriate extraction and replacement of air depends on levels of occupancy, activity, etc...

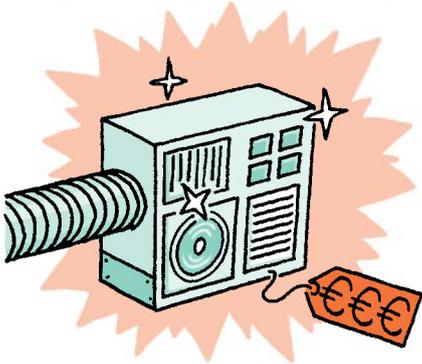


3 PURIFYING
the air by filtering incoming
air and indoor air.

However, these filters need to be maintained to prevent the ventilation system itself from becoming a source of pollution.



Mechanical ventilation can be very efficient (when used appropriately)...



but one should not forget the benefits of natural ventilation, particularly in terms of health and cost.



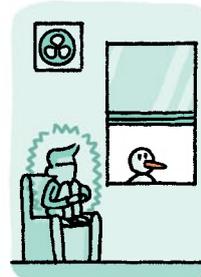
User control and contact with the outside world are key to feel comfortable.



However, the benefits of natural ventilation depend on what this outside world consists of.



Ventilation can be a source of noise or thermal discomfort. A balance is to be found to reach the optimum solution.



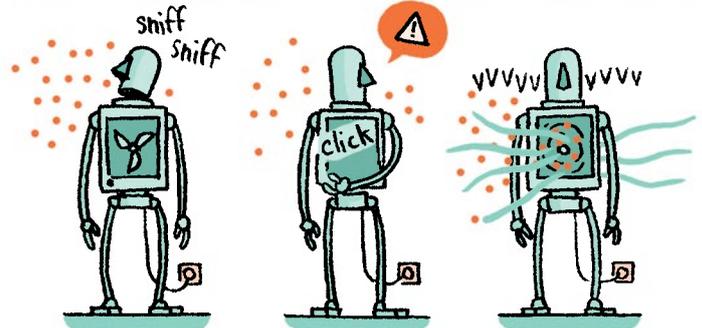
An idea gaining ground is for hybrid ventilation: natural ventilation in mid-season and mechanical in winter and summer.

The
FUTURE

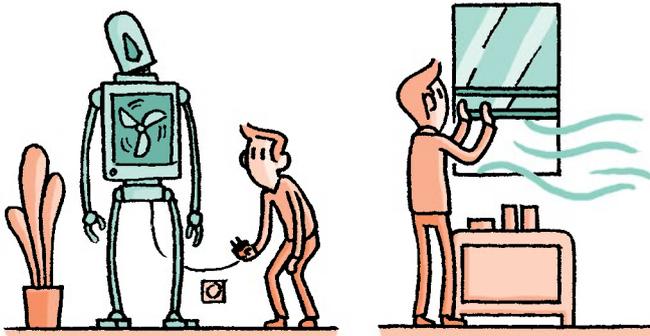
Our indoor air quality needs will probably remain the same.



However, our understanding of indoor chemistry will surely evolve, allowing us to better detect and interpret the thousands of indoor air pollutants.



In order to improve energy efficiency, the use of mechanical ventilation systems will likely change.



New means of renewing air efficiently while maintaining a comfortable thermal environment will have to be developed.



CONCLUSION

We spend nearly all of our life indoors,



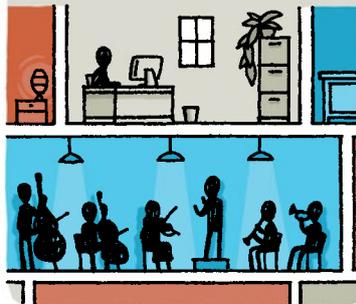
so living in comfortable and healthy environments is crucial and should not be left to chance.



Adapting buildings to the activities and needs of their occupants is key,



both at individual and collective levels.



With this in mind, Saint-Gobain is seeking to contribute to the development of buildings that are healthier, more sustainable and more comfortable for their occupants.

