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RHYTHM & BLUES - BIO-ADAPTIVE AND NATURAL LIGHTING OF LARGE SCALE BUILDINGS

Synopsis key words ***Translucent glass wall, soffit lighting of spectral blue 480nm, 480nm, light brought into deep bio units correspond to latest neuroscientific research into light levels and human circadian rhythms, architecture, pixellated colonnade, wind, environment, ice.***

The sun

Man's physical and psychological evolution – like that of every other living organism - has been shaped by our environment and bio-chemistry.

However we are the first animal on the planet capable of imagining and realising new environments that in turn shape us and evolve as we evolve. Architecture can thus be defined as a neuro-design learning loop.

The sun has been at the heart of worship for millennia – the source of our world's warmth, energy and light – life itself.

Olafur Eliasson Tate Modern

The dawn of the Scandinavian Bronze Age has been traced back to 16th century BCE Icelandic drawings - Bronze Age 12C

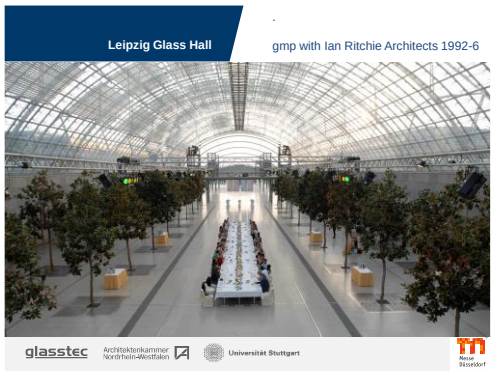
Atenism in Egypt 14C BCE

Light

It is light that informs the appearance of architecture and its interior spaces, and visually gives all form shape.

I would like to suggest that the history of architecture is also the history of the way light has entered into buildings – beginning with small openings in masonry walls and roofs, to infilling them with small pieces of paper or translucent skin (e.g.seal skin) or glass, to total glass enclosures (i.e. Crystal Palace, London, 1851). For the last thousand years or so, glass has been used almost exclusively worldwide to complete a buildings' protective enclosure against wind, rain and noise, while allowing visual contact to be maintained with the outside world.

Leipzig Glass Hall IRAL + gmp

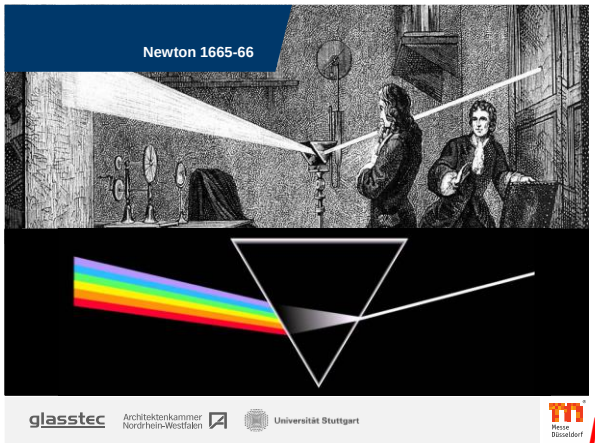


From this point of view, architectural development could be described as the desire to master gravitas by levitas, and the means to achieving this being the application of continual industrial innovation.

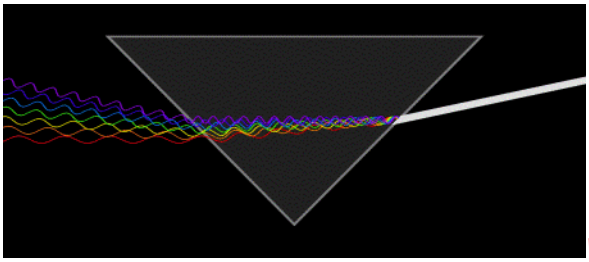
translucency

What is Light and how does it affect us

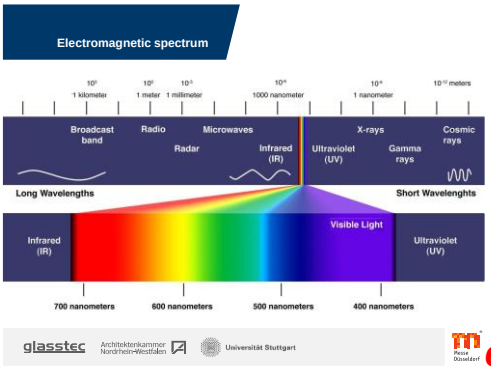
We now know that in some ways light behaves like a stream of particles (‘*photons*’), and in other ways it acts like a series of waves. Light comes in different colours - the rainbow of hues we call the visible spectrum. Each colour corresponds to waves with different wavelengths.



Newton 1666 + Pink Floyd 1973



wavelengths



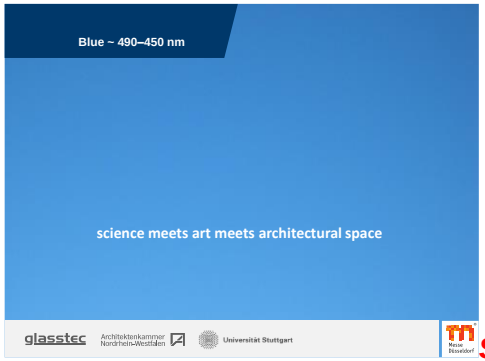
electromagnetic spectrum

Neuroscientists have begun to discover that the levels and wavelengths of light to which we are exposed affect us at the most profound biological and psychological level. Research shows that in humans light influences not only sleepiness and alertness, but hormone secretion, heart rate, body temperature, and gene expression.

Consequently there has been a shift toward appreciating more than just the aesthetic appearance and visual properties of architecture.

James Turrell has been working with the limits of human eye-brain perception for a few decades. He completely transformed the iconic, spiralling structure of the Guggenheim's rotunda with his site-specific installation, "Aten Reign". Turning it into a well of shifting light.

Aten Reign James Turrell 2013



science + art + architectural space

Neuroscience is beginning to provide evidence for what the best architects have always known intuitively: that we experience our environment on all sensory levels. We, and particularly artists, engage with it emotionally, sensually and physically long before we are able to make an intellectual judgement about a place or building.

And these same architects for centuries have depended on intuition and experience to create environments that generate desired reactions in the people who use the space: feelings of awe (delight) in cathedrals, and awe (fear) when standing near the edge of a cliff.

awe

feelings of powerlessness in totalitarian architecture, feelings of calm and contemplative intimacy with nature in a Japanese teahouse.

teahouse

Originally, the culture of Tea Ceremony was generated in the closed microcosmic space.

classic teahouse

There are increasing numbers of studies into the neurological basis of relationships between the architectural environment and the emotions and physiology of the people who inhabit it. As a consequence, the ability to design environments to elicit specific emotional and neurological responses is slowly becoming a science as much as an art.

We are beginning to be able to ask ourselves what kind of architecture and urban design has the capacity to sustain and nourish a meaningful human existence, and get answers based on science rather than current design fashion or particular political ideology.

SWC overview image

Since beginning the design of the Sainsbury Wellcome Centre for Neural Circuits and Behaviour at UCL in 2009 I have become more and more interested in *neuro-design* – to design with a deeper understanding of the impact of what we create upon the physical and mental well-being of the user and, in the wider sense, on the human environment.

I believe that understanding how the brain informs responses to our environment will be essential if architects and urban designers are to do this, especially as societies become ever more urbanised, and space, volume, vistas and horizons become a luxury in our cities.

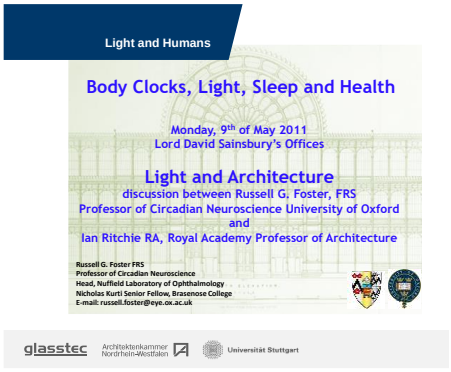
When designing the SWC building, we used the results of recent research in the cognitive sciences to create an environment which would serve not only the physical needs of the unusual community of scientists who would be working within it but also promote their interaction with each other while supporting their individual creativity and intellectual endeavours.

John O'Keefe, [2014 Nobel Laureate], is the director of the SWC. He, along with Peter Dayan, who heads the Gatsby Computational Theoretical Unit, were our key scientific advisors as we designed the building from the inside first, and then to the outside.

I will focus this talk on the aspect of light, and in particular on blue at the wavelength of 480-481nm which we have used in the building.

Humans evolved while exposed to different spectra of light in the morning, the afternoon and evening. So it follows that human physiology is affected by daily and seasonal changes in the visible light spectrum.

The level of light and its colour is important to our health, but how?

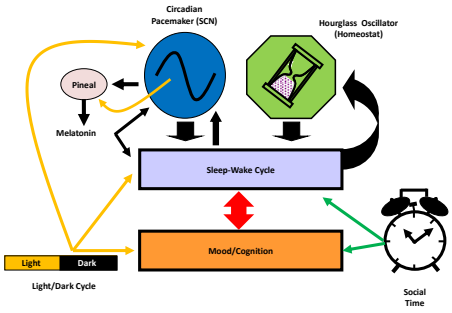


science meets art meets architecture

Russell Foster is the Professor of Circadian Neuroscience at Oxford, who has worked on how the core mechanisms of sleep and 24-hour circadian rhythms are generated and regulated within the central

nervous system; and he uses this fundamental knowledge for translational studies – to inform therapeutic approaches that will improve the quality of life.

Drivers and modulators of sleep/wake



Detection

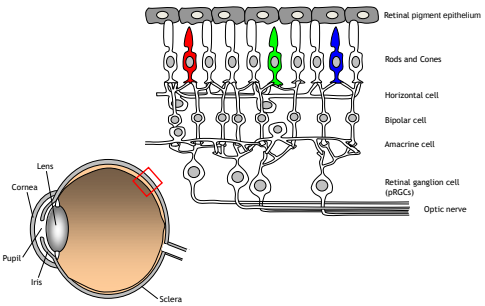
"Brightness" "Image or Contrast"

- Time of day cues for circadian + sleep systems
- Mood
- Alertness
- Heart Rate
- Pupil Constriction

Environmental Lighting

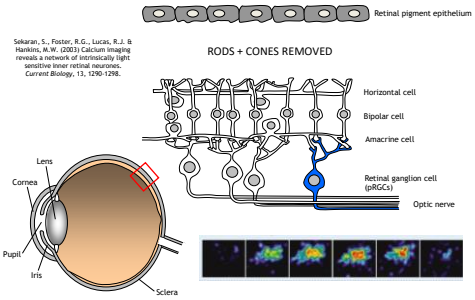
Typical Range Lux	Situation
100,000	Bright sunny day
10,000	Cloudy day
1000 - 2000	Watch repairman's bench
100 - 1000	Typical office setting
200 - 1000	Night sports field
1 - 10	Residential street lighting
0.25	Cloudy moonlight

Eye and Retina

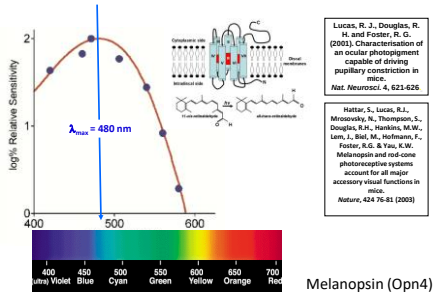


He discovered non-visual photoreceptors within the eye - photosensitive retinal ganglion cells (pRGCs) that detect the overall amount of light in the environment.

Photosensitive Retinal Ganglion Cells (pRGCs)



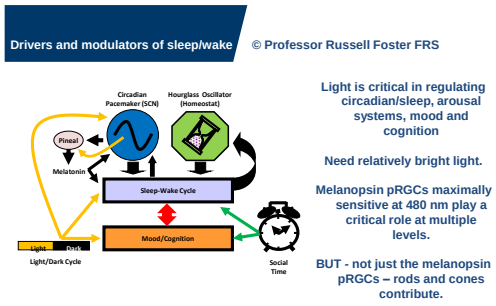
Opsin/Vitamin A based photopigment - λ_{max} at 480 nm



Melanopsin (Opn4)

They integrate changes in light levels and wavelength throughout the day and feed these directly into receptors in the brain's circadian clock – which must be reset on a daily basis in order to remain in synchrony with external environmental time. It is responsible for regulating the circadian rhythms of our brain's core body temperature, brain wave activity, hormone production, cell regeneration, and other biological activities.

pRGCs are particularly sensitive to a very intense 480-481nm stimulus; this means that this wavelength of blue light has the maximum effect in regulating our circadian clock. It also makes us most alert.



https://en.wikipedia.org/wiki/Intrinsically_photosensitive_retinal_ganglion_cells

glasstec Architektenkammer Nordrhein-Westfalen Universität Stuttgart Messe Düsseldorf

conclusions of light and biorhythm

Lighting is a perfect example of neuro-scientific research giving the architecture added value.

windows in façade

For the architect it is to understand how the buildings we design affect the circadian clock. We need to ask ourselves if our architecture allows appropriate and natural cycles of light into buildings, particularly during winter months in northern latitudes and for people in modern cities who often spend more than 90 % of their lives indoors.

It is easy for them to become disassociated with the natural outdoor cycles of light, which can have significant cumulative effects: imbalanced sleep–wake cycles and sleep debt, stress, obesity, type 2 diabetes, and mood swings, to name a few.

One entire wall of the SWC is made of a structural translucent cast glass incorporating white insulation, which not only allows soft daylight to filter through the entire building while reducing the need for artificial lighting but also allows the change of day – cloudy, sunny - to night to register on the walls. The inner surface of the glass wall is different to the external surface – as it is designed as a continuous whiteboard for the scientists to use.

windows in PI office

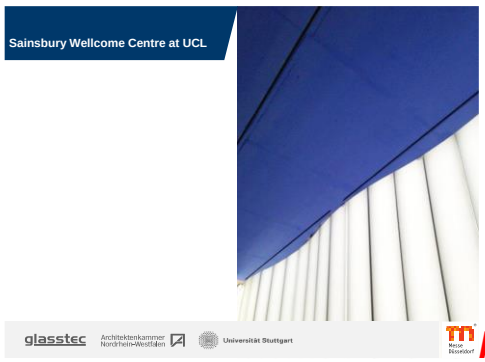
Integrated in the façade are clear glass windows which give a degree of personal control to the scientists: views out, fresh air to enter, and provide privacy and reflections of westerly sunlight through their cast glass louvres. The scientists are given choices to modify their environment.

admin offices & blue lighting

The colour blue – or more precisely 480 nanometres, according to Professor Russell Foster, is the wavelength that not only sets our body clock if we are exposed to it in the early part of the day, but also makes us most alert.

It is visible in the morning sky. Throughout the lab areas of the building the soffits are painted a spectral wavelength blue of 480 nanometres.

In non-lab spaces - concealed blue lighting edges the acoustic ceiling panels. We also introduced biodynamic lighting in below ground level circulation areas.



blue ceiling

A broader view

A lack of daylight exposure disrupts our circadian rhythm and reinforces our responses to stressful and anxiety-provoking experiences. Sufficient daylight improves the communication between the regions of the brain that are central to our handling of stressful emotions.

Obviously light brought deep into a building is one aspect of building design that can ease stress. However, human stress and hormonal changes in response to the other aspects of our environment are also being studied at a neurological level.

Definitive empirical studies need to be done, but indications are that building design has a real biological and neurological impact.

This is not unexpected, given what we are learning about the links between stress, emotions and neurogenesis in the hippocampus - an important part of the limbic system, the region that regulates emotions. The hippocampus is associated mainly with memory, in particular long-term memory. The organ, as John O'Keefe's research has shown plays an important role, in spatial navigation but also in learning, mood, and emotion.

Calming aspects in the built environment also relate to elements such as noise levels and types of sound – for example the sounds of water and the rustle of leaves are soothing. Views of and access to outdoor spaces seem to be correlated with mental and physical health in terms of heart rate and stress levels as well as improved mood and cognition.

isolation and togetherness

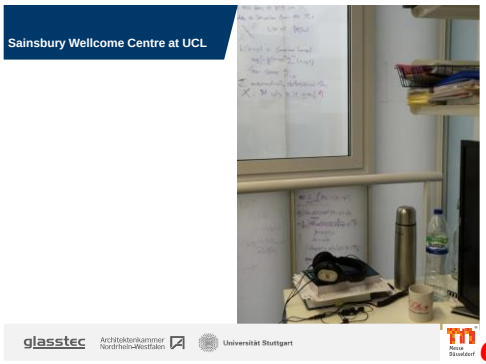
Allowing the scientists freedom to personalise their space is vital to their well-being. As architects we are too often too precious about users changing what we have created for them. This attitude is wrong, particularly when designing an adaptable building with a lifespan in excess of 60 years. The interior of the spaces within this building can be

open, closed, bathed in direct and diffused natural light or blacked-out for experimental research.

We created a range of volumes within this building: from the small and intimate, to the large and shared. When isolation or togetherness are a matter of choice, the result is contentedness instead of depression.

SWC Roof Garden

There are outdoor spaces designed to encourage feelings of contact and interaction with the natural world – greenery supporting wildlife and the weather. The roofs have several spaces, some open, partly covered, and enclosed.



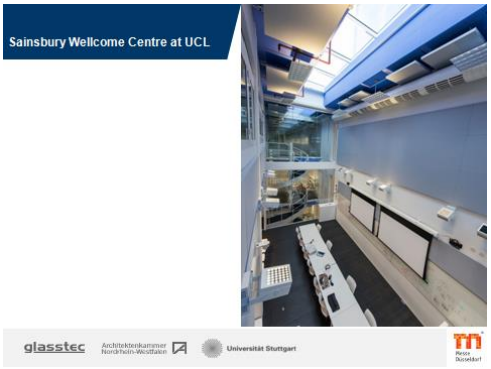
office space

In the SWC the adaptable nature of the spaces allows for both private offices and write-up desk spaces and their lighting to be intimate within the communality. John O'Keefe instigated a survey of UCL student researchers as to whether they would like individual cubbyholes or open spaces for their write-up areas.

To our surprise, and that of the client, the consensus was for open areas. To accommodate both ease of interaction and privacy if desired, the edges of the write-up desks are for the most part curved, providing an extra sense of privacy and reflecting the wave of the building.

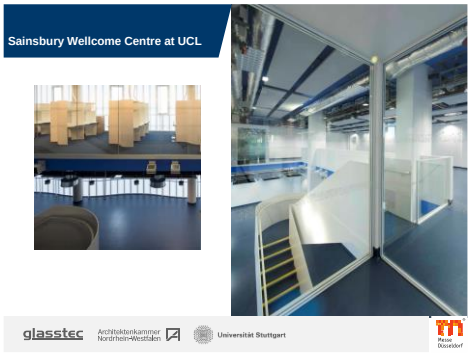
write-up

In an environment where a lot of creative work is being done by individuals, the opportunity for natural cross-communication between disciplines to happen is especially important. It is impossible to predict whether these will happen over a cup of coffee, down the pub, or on a staircase. It's not important – the fact that there are multiple 'happenchance' spaces and visual connections is what we believe to be important on the basis that interaction is a vital aspect of research and being human.

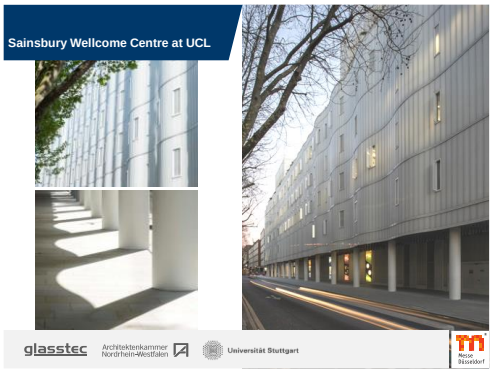


GCNU lecture + tea atrium interaction space

There is a tall, naturally lit or blacked-out lecture and seminar space for the theoretical computational neuroscientists – and a space which can be engaged with 'accidentally' from the internal windows at high level.



double-height



undulating north façade

I have hardly touched on beauty in design, or neuro-aesthetics – inherited (DNA) and acquired (environmental) information through which we apparently assess aesthetics.

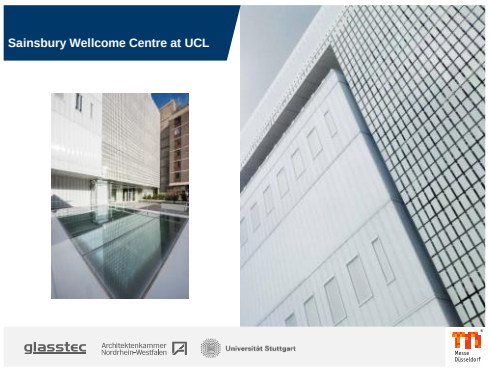
Briefly, we were concerned that not just the inhabitants of the building but people in the surrounding streets and neighbourhood should also feel comfortable with and be interested in the new building.

There are both artistic and metaphorical elements to the exterior façade in addition to its functional aspects. The undulating façade suggests calm – the undulations of the sea and light, and also a metaphor for the melting polar ice caps.

arctic sea light ripple ice block concept

melting corner

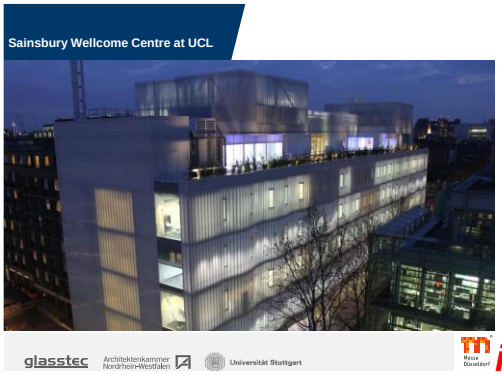
The whiteness of its mass refers to an iceberg and light. As the façade turns the corner of the building the glass becomes more immaterial, as ice melts.



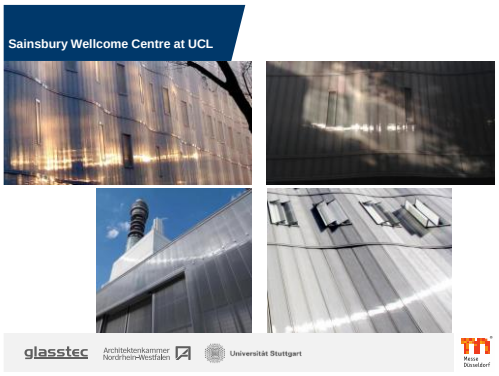
south wall

The building's south wall is fractured, as would an ice flow, and also ripples in response to the wind.

For me, beauty is non-linear. This is captured in the pixellated south wall's movements in the wind, and the way light behaves on the micro-undulations of the cast glass.



internally lit the building glows at night

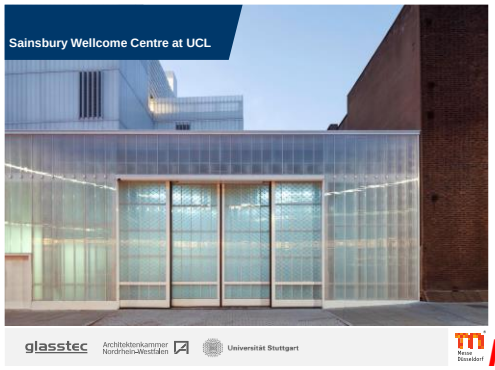


light on the north wall

The aesthetics of the Sainsbury Wellcome Centre has a fugitive, even ethereal quality which comes from the idea of composing with and using glass to exploit soft light reflections through the ribbed profile of its external surface, (which helps it to be self-cleaning) and to allow the façade to play – the louvres - akin to piano keys – to be dynamic rather than static.

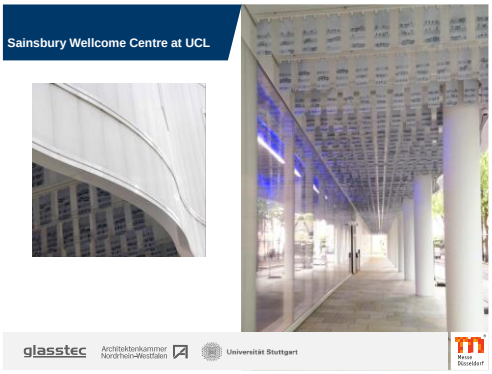
The whiteness of the façade reflects light into the surrounding built environment during the day without glaring reflections, and at night its translucence permits interior light to permeate the walls to illuminate the façade – again, without harsh glare.

light on the south wall



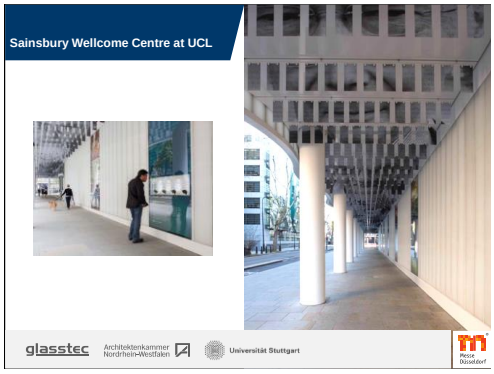
layered depth of light

There is also applied art to the building – all related to the brain - as a way of communicating what is happening inside to the outside, making the building less anonymous to passers-by.



colonnade pixels of Bach music & UCL Nobel laureates pixels

The colonnade has a thousand suspended pixels. One side contains J.S. Bach: Musical Offering (1747): Ricercar a 3 – recommended by the Principal of the Royal Academy of Music as one of the mind's greatest ever compositions.



music and Nobel laureates portraits pixels

On the other side are eleven portraits of Nobel Laureates in Physiology or Medicine who have stepped into UCL at some point in their careers.

These portraits are recognised at ‘sweet’ points as one walks along – a little play on perception.

vitrines

illusion perception deception inversion distortion

There are also five ‘vitrines’ towards one end of the colonnade which explain some visual phenomena and the way the brain can confuse us: - distortion, deception, inversion, illusion and perception.

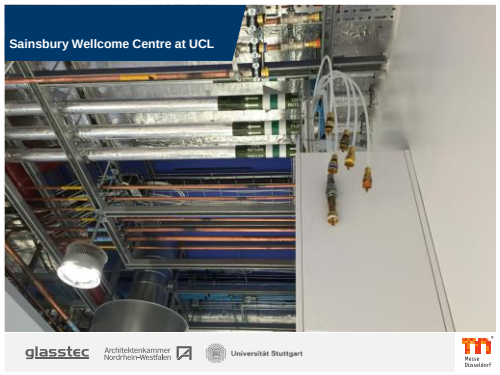
projected image of a firing neuron above the public park at the west end of the building

NEURODESIGN IN THE FUTURE & WHAT WE SHOULD BE DOING

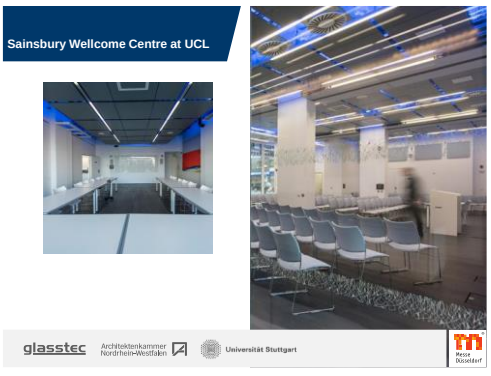
Architects should be keen to understand how best to provide spaces that work best for the occupants. As we are discovering, the challenge is that our environmental needs change throughout the day according to our state of health or the tasks we're being asked to engage in. Nothing stays the same, but predicting change is fun.

Adaptability refers to physical organisation and dimensions of space that can be changed to suit varying needs. Every space in the building has been designed to accept change.

We sought with the Sainsbury Wellcome Centre to give the scientists as much freedom as possible to change their environment – physically and with a 'plug & play' services approach - within naturally lit spaces that are also provided with black-out and lighting controls that can be tuned to their needs.



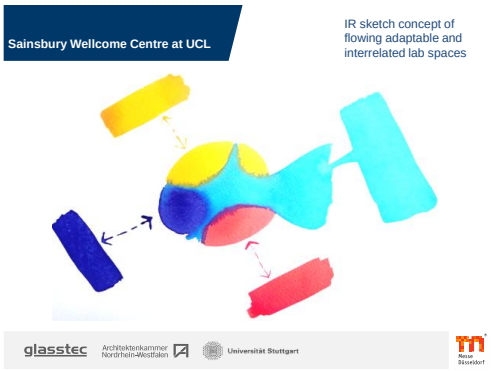
'plug & play' services



SWC Lecture theatre and Brasserie adaptability

Flexibility is softer – services (e.g. cables), light, sound, temperature, smell and colour.

Rather than prescribing a set light level throughout the building, we have designed the lighting to accommodate the specific needs of the scientists in addition to the use of the space as a whole.



Concept of flowing adaptable lab spaces

Research indicates that not only light level but exposure to various colours of the spectrum - blue, red, orange, white – might affect our heart rates, alertness and efficiency when performing various tasks. The evidence is as yet incomplete, but it may well be that in the future architects will come to consider spectral range, intensity and pattern of light to be as important for function and health as they are to vision.

As designers, if we begin to react to and design with these dynamic needs in mind we can move architecture in the right direction.

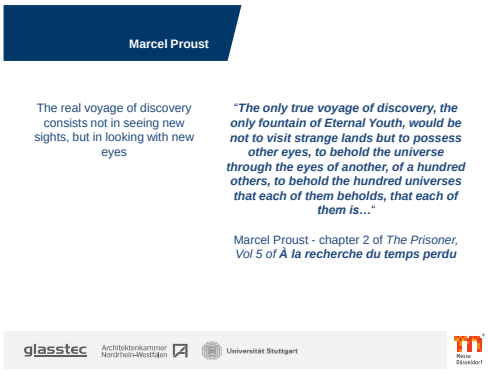
As architects we need to be aware that what we design matters, and of the role our creations play in influencing human behaviour. We have now begun to apply some knowledge from neuroscience to design better buildings and environments. Perhaps architects and designers should be engaging in more depth with neuroscientists, and become more active in identifying the empirical knowledge needed that will help us design better urban spaces and buildings to fulfil architecture's moral imperative: to make our environments better places in which to live and thrive.

Since designing with the neuroscientists, I have come to understand that it is possible to design with the mind in mind.

The real voyage of discovery consists not in seeing new sights, but in looking with new eyes

"The only true voyage of discovery, the only fountain of Eternal Youth, would be not to visit strange lands but to possess other eyes, to behold the universe through the eyes of another, of a hundred others, to behold the hundred universes that each of them beholds, that each of them is…"

Marcel Proust - chapter 2 of *The Prisoner, Vol 5 of* ***À la recherche du temps perdu***



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