

**RAVENSBOURNE SCHOOL OF DESIGN
NEUROSCIENCE AND ARCHITECTURE
26 JANUARY 2017**

IAN RITCHIE

1. Intro slide



2. Inventiveness



Universe & Brain *Scale of neuroscience and the universe*

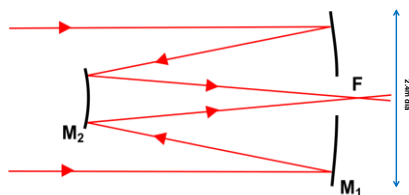
3. Scale: 3 neurons v. universe

4. Hubble

5. Galaxy - fuzzy and sharp

We have looked back in time at the universe through the Hubble Space Telescope. Launched in 1990, it is a remarkable instrument travelling at 16,000mph in a low orbit around the earth while observing distant galaxies in the near ultraviolet, visible and near infrared spectra using a Ritchey-Chrétien telescope.

6. Ritchey-Chrétien diagram



ritchey-chrétien telescope - diagram

Initially, however, the mirror was out of focus by about 2 microns - a tiny fraction of the width of a human hair. It was, in fact, a case of spherical aberration, the result of a small, undocumented washer a technician had inserted in a device called a null corrector that was used to check the mirror's shape during its fabrication years earlier. In 1993 a service mission was sent to fix it at an additional cost of a billion dollars - all because of a misplaced washer!

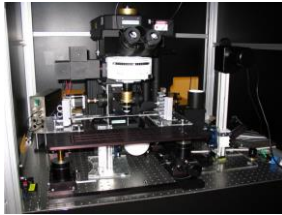
7. Dark Energy

What do we know about the universe? Or about our brains?

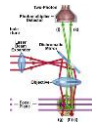
Neuroscience research is focused on the brain which, according to Woody Allen in his film 'Sleeper', is his second favourite organ.

We look into our brains through one and two-photon microscopes.

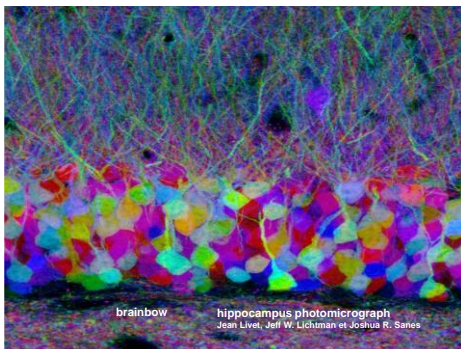
8. Two-photon microscope + two-photon optical diagram



two-photon microscope



9. Brainbow



This technique enables researchers to distinguish between neighbouring neurons by illuminating them in different colours. This image shows part of the hippocampus, a brain region critical for learning and memory.

How big and how complex is our brain?

The human brain weighs about 1.5kg and is actually very soft, jelly-like, and deep red in colour. It is made up of over 100 billion nerve cells, with each brain cell connected to around 10,000 other cells, which equals around 1000 trillion connections.

[10^{15} - a quadrillion (1 trillion is 1,000,000,000,000; one million million; 10^{12}).]

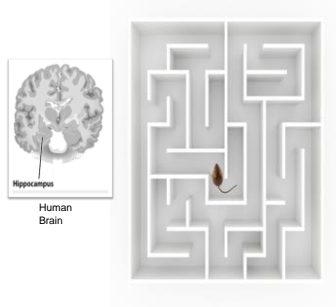
10. Milky Way

As a visual comparison, some estimates put the number of *stars* in the Milky Way between 100 and 200 billion; and a similar number of *galaxies* in the universe.

I recall Sir Martin Rees writing that one human brain was more complex than the universe. Maybe, but understanding the biology of the brain - however mind-bogglingly complex - and understanding how the brain informs responses to our environment, is essential if we are to better evolve towards creating healthy human societies.

11. How does the Brain understand space?

How does the brain understand space?

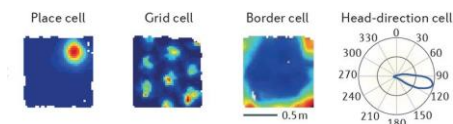


12. John O'Keefe

How does the brain understand space?



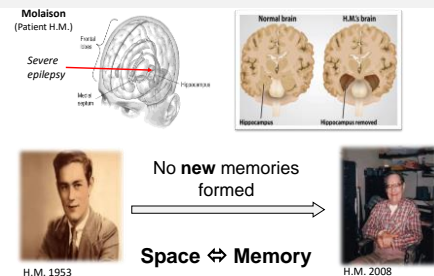
13. Place Cell, Grid Cell, Border Cell, Head - direction Cell



navigation cells

14. What does the Hippocampus do in humans?

What does the hippocampus do in humans?



John O'Keefe's work has been on Place Cells within the brain - which help us navigate in our environment.

Our ability to navigate through space, to know where we are and what movements to make next are governed by cognitive maps based on four cell types acting together. Consider the threshold to a house, or in front of a reception desk, or the edge of a building.

All of these are sensed and processed by our brain, and we make choices about what to do next, very often on the basis of risk and reward.

Architects design spaces and places. What better partner for this project?! We had to learn his language, and he ours.

Bio-Adaptive and Natural Lighting of Large Scale Buildings

Rhythm & Blues - 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.

15. The Sun - Olafur Eliasson Tate Modern

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

17. Atenism in Egypt 14th century 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 buildings - beginning with small openings in masonry walls and roofs, to infilling them with small pieces of paper or translucent skin or glass, to total glass enclosures.

For the last thousand years or so, glass has been used almost exclusively worldwide to complete the building's protective enclosure against wind, rain and noise, while allowing visual contact to be maintained with the outside world.

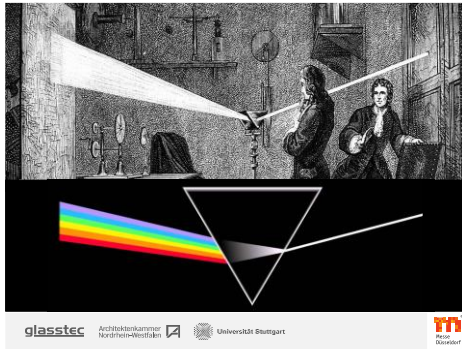
18. The Pantheon

19. Translucency

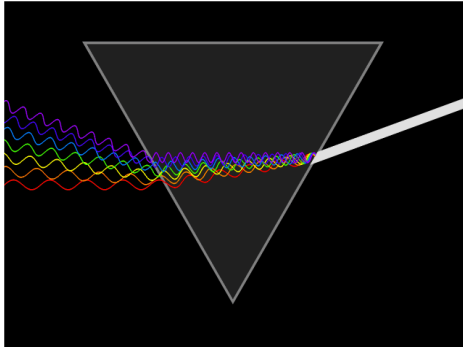
What is Light and how does it affect us?

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.

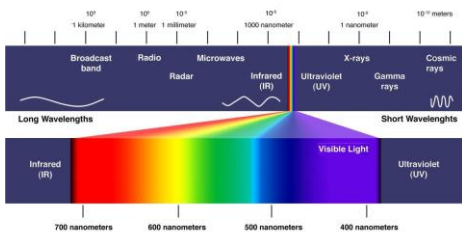
20. Newton 1666



21. Wavelengths



22. Electromagnetic spectrum



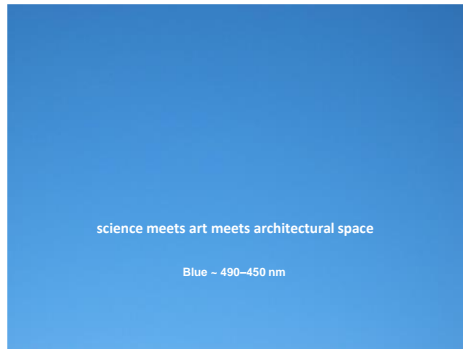
Neuroscientists have begun to discover that the levels and wavelengths of light to which we are exposed affect us at the most profound biological and psychological level. Research shows that in humans light influences not only sleepiness and alertness, but hormone secretion, heart rate, body temperature, 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 several decades. He completely transformed the iconic, spiraling structure of the Guggenheim's rotunda with his site-specific installation, "Aten Reign", turning it into a well of shifting light.

23. Aten Reign - James Turrell 2013

24. Science + art + architectural space



The Architecture

Neuroscience is beginning to provide evidence for what the best architects have always known intuitively: that we experience our environment on all sensory levels.

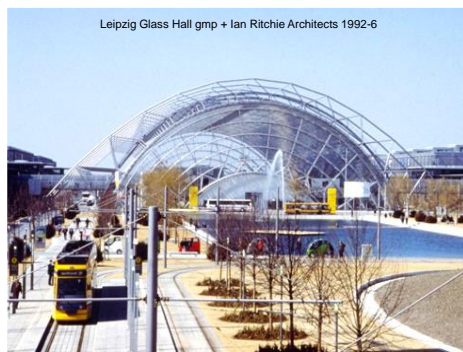
We, and particularly artists, engage with it emotionally, sensually and physically long before we are able to make an intellectual judgement about a place or building.

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: for example, feelings of awe and spirituality in cathedrals.

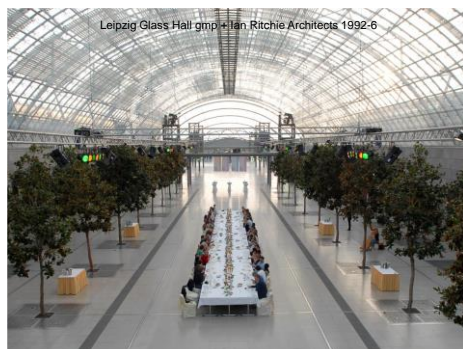
25. Awe

And total transparency?

26. Awe and the complete glass enclosure of the Leipzig Glass Hall



27. Leipzig Glass Hall



Feelings of calm and contemplative intimacy with nature in a Japanese teahouse

28. Contemporary Japanese teahouse

29. And light came from the walls - a glow giving intimacy

Architects & Engineers and where we are:

As an architect who has also been a director of a firm of engineers, a professor at the Royal Academy's post-graduate art school and at a University engineering faculty, I often make this comparison between engineers and architects:

Given a target the engineer will pull the string of his bow and fire the arrow directly into the bulls-eye. The architect will pull the string of his bow and fire into the sky and see where it lands!

The role of the architect is to design for the body in space and for the mind and spirit. At present, we design using a mixture of instinct, art and engineering.

The Engineering:

In the past, buildings were often constructed using engineering which might be considered inadequate by today's standards:

Egyptian temple pillars were over-engineered; European Gothic cathedrals were built higher and higher in a religious architecture-race, until they became unstable. One design solution was flying buttresses - often as an afterthought as walls began to crack. And sometimes the building collapsed.

We now have far greater engineering knowledge and construction techniques and are able to predict material behaviour with computing power to create buildings undreamt of in the past - buildings that seem to float, tall enough to dwarf cathedrals, made of materials (such as glass and synthetic fibres) seemingly incapable of supporting the loads they support. Understanding the laws of physics and engineering has not inhibited our creativity, Far from it - understanding has given creativity wings.

However, do we really know what enables an architect during the design process to produce a beautiful building, one which makes the human spirit soar, or makes a human being feel comfortable and nurtured, or are we still flying by the seat of our pants?

What are you actually doing as an artist and architect to cause people to do different things and feel differently than they do in their daily lives?

I want to know!

We need to learn how to design with the mind in mind. Neuroscience is beginning to offer insights to enable us to quantify the design process which has so far consisted of a creative mixture of instinct, art and engineering. The ability to design environments to elicit specific emotional and neurological responses should become a science as much as an art. This understanding will release the architect's imagination in another sphere of creativity.

30. Our brain and what it sees

Only 10% of what your brain
uses to see comes from your
eyes.

90% comes from the brain
itself!

Perception is not just through
the eyes.

Our brain did not evolve to
experience the world

Neuroscience Building & how it was designed

31. SWC at dusk

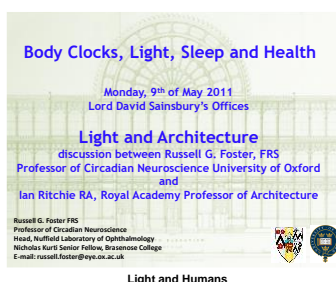


John O’Keefe, the 2014 Nobel Laureate, was the then director of the SWC. He, along with Peter Dayan, who heads the Gatsby Computational Theoretical Unit, were our key scientific advisors as we designed the building from the inside to outside.

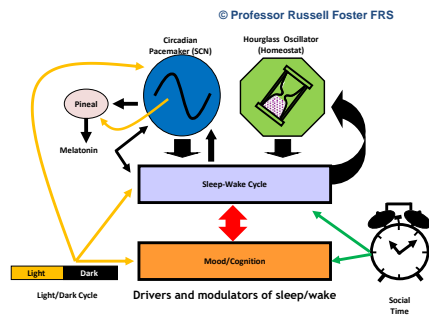
Russell Foster - Professor of Circadian Neuroscience at Oxford, is a member of the SWC Governing Council along with Richard Axel, Richard Morris, Marc Tessier-Lavigne - President of Rockefeller University, and Professor Sir John Tooke - President of the Academy of Medical Sciences and Vice Provost (Health) and Head of the Medical School at UCL. His work on lighting is a perfect example of neuroscience research giving the architecture added value.

Scientific research has discovered ganglion receptors in the back of the retina that aren’t used for vision. They integrate changes in light levels throughout the day and feed these directly into receptors in the brain’s circadian clock - governing the response of the brain to the changing time of day. What’s for the architect to understand, is how circadian disruption can affect many aspects of mental function, mental health and physical functions and health.

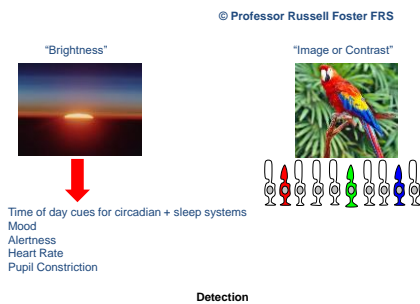
32. Body Clocks, Light, Sleep and Health



33. Sleep/Wake Cycle



34. Detection

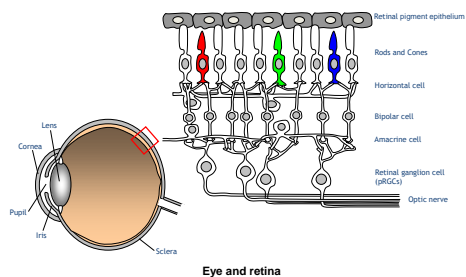


35. Environmental Artificial Lighting

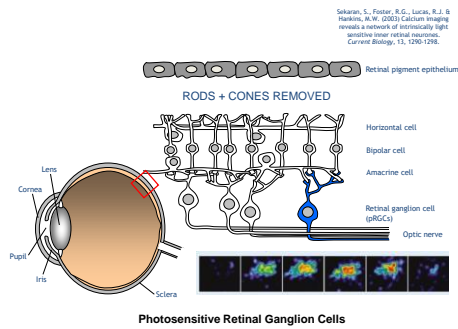
Typical Range Lux	Situation
100,000	Bright sunny day
10,000	Cloudy day
1000 - 2000	Watch repairman's bench
100 - 1000	Typical office setting
200 - 1000	Night sports field
1 - 10	Residential street lighting
0.25	Cloudy moonlight

Environmental lighting

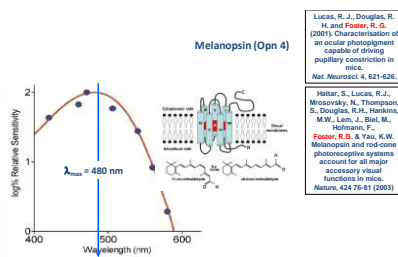
36. Rods and Cones



37. Ganglion Receptors

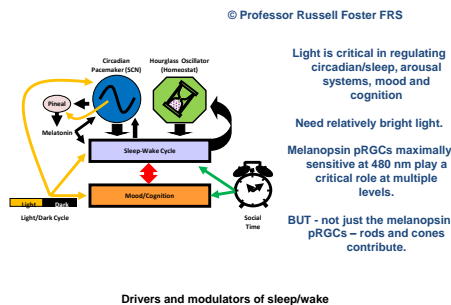


38. Optimum Photopigment 480nm



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

39. Drivers and Modulators



Does our architecture allow appropriate and natural cycles of light into buildings, particularly for people who spend a lot of time inside?

One entire wall of the SWC is of translucent glass, which not only allows soft daylight to filter into the building but enables the soft change of day to night to register on the walls.

40. SWC undulating wall



Why did I put a wave in the building? There are several reasons: Outside, the curves echo the rhythm of the Georgian architecture that surrounds it - affirming our culturally defined notion of beauty. The curvy façade also reflects my sense of humour.

41. SWC undulating wall



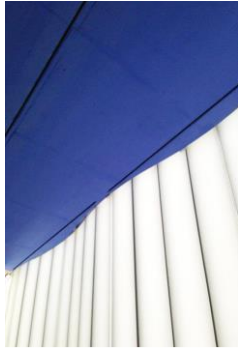
Having met neuroscientists all over the world, I became acutely aware of their pan-disciplinary skills - physics, biology, electronics, chemistry, electro-mechanical engineering, etc. The wavy façade suggests that the experimentalists have a significant brain wavelength, while the theoretical computational neuroscientists are on another wavelength altogether - hence the increase in frequency where they are housed over three floors in the middle. They originally wanted to be on the roof with the garden - but that would have privileged them and isolated them - so there was some coercion!

Inside: did I 'know' if the creative, idiosyncratic neuroscientists would like curvy interior walls? I guessed they would.

42. Admin offices & blue lighting



43. Ceiling



And the colour blue - or more precisely 480 nanometres. According to Russell this is the wavelength that makes us most alert.

44. Windows in PI office



A lot of new design seems to focus on creating a calming environment. Definitive empirical studies need to be done, but indications are that building design has a real biological and neurological impact. This is not unexpected.

Stress responses and hormonal changes in response to the environment are being studied at a neurological level. Calming effects relate to elements like light levels, noise levels and types of sound - for example the sounds of water are soothing.

45. Windows in the north façade glass wall



Sightlines, 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 healing. The translucent wall has integrated windows to allow fresh air - and louvres to provide privacy and also to reflect sunlight.

46. Roof Garden



In the SWC the roof garden, seminar-cafeteria and administration at the same level, are designed to encourage feelings of contact and interaction with the natural world - greenery and weather.

47. Isolation



Isolation or togetherness can encourage contentedness or depression. Offices, classrooms and hospitals are particular building typologies in which these factors are particularly relevant, as is the issue of the control of one's personal environment.

48. Write-up and office space



In the SWC the adaptable nature of the spaces allows for both private and write-up desk spaces, and their lighting, to be intimate within communality. It accommodates 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.

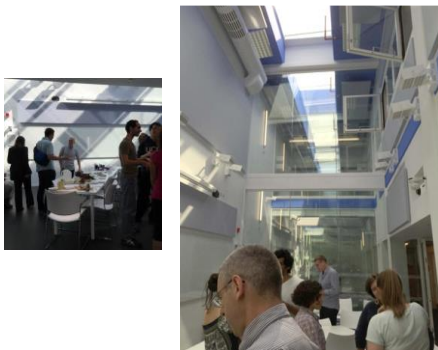
There are many spaces for chance encounters -soft and hard areas - intended and accidental.

49. Interaction spaces - Accidental



Principal floor circulation routes are designed with sightlines through the entire building. Along them are spaces which act as meeting places to encourage chance encounters to become discussions where information is shared.

50. Interaction space - Intentional



51. Interaction space -GCNU lecture + tea atrium



And of course the roof has many spaces, some covered.

52. Double height lab



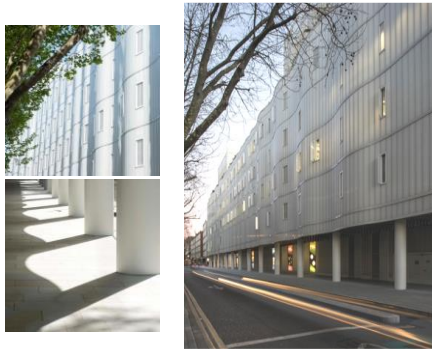
53. Double height lab



The most difficult barrier to connexity is vertical separation - people on separate floors without visual contact.

This is the primary reason why we designed the labs as two-storey open houses - offering visual connection between floors of activity, as well as having the potential for large vertical spatial experiments. These are not atria.

54. Images of north façade

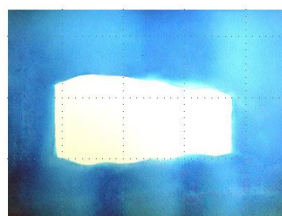


I've shown you images of the building and some of the design directions informed by our recent harvesting of neuroscientific knowledge.

Beauty in Design

Now I will explain to you the building's architectural design metaphors and intentions.

55. Undulations and climate



IR inking concept

The whiteness of its mass refers to an iceberg, and it is melting at the corners. As the wavy façade turns the corner the glass becomes more immaterial, like water flowing - a metaphor for climate change.

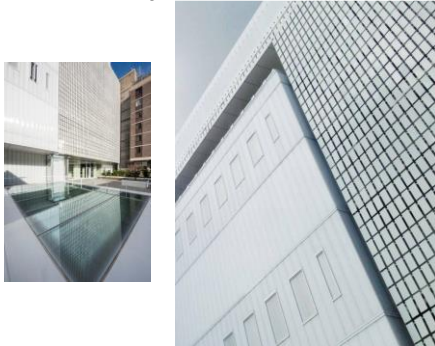
56. Corner melt



57. Ice flow

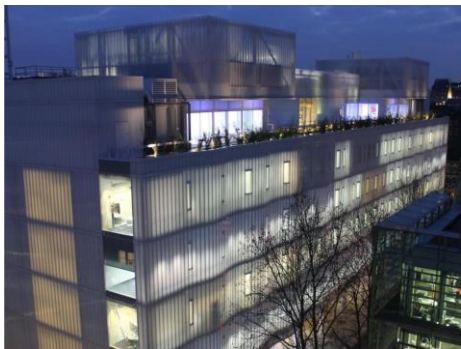
There are both artistic and metaphorical elements to the exterior

58. South façade



On the south side the building surface fractures as in an ice flow

59. Glowing façade



White in the daylight and white at night.

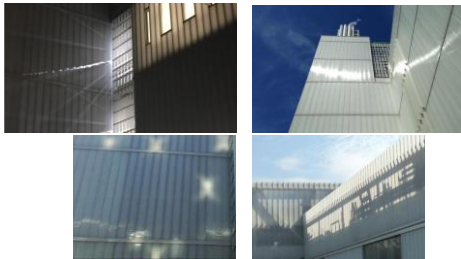
Windows are dark in daylight and at night we see light fittings when we look up.

60. Building image - Light on the undulating north side



Cast glass, and its exterior treatment offers us a different range of reflections, which can avoid reflecting too much uncomfortable glare.

61. and south façade



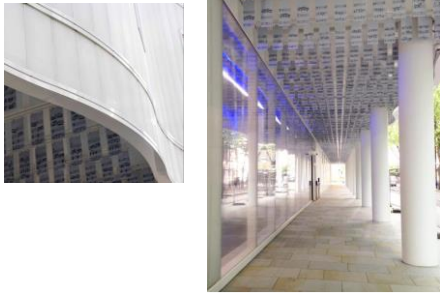
62. and west



Applied art

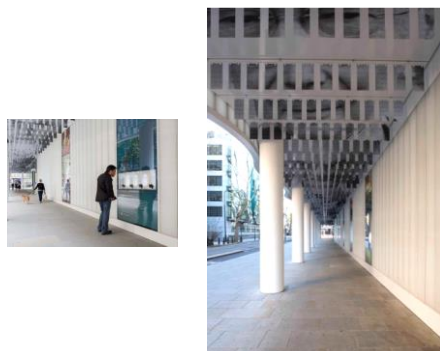
There is also applied art to the building - all related to the brain as a way of communicating the inside activities to the outside, making the building less anonymous.

63. Colonnade pixels of Bach music & UCL Nobel Laureates (54)



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 and described him as:

64. Nobel Laureates close up



"The distillation of three perfectly interweaving lines, of shared melody in perfect form and harmony, reflects the ultimate in unveiling the mysteries of the musical mind.

Bach's famous visit to Potsdam to visit Frederick the Great on May 7th in 1747 inspired a theme in his 'Musical Offering' which conflates the Renaissance knotty-ness of the old Ricercar with the staged luminosity of the fashionable Enlightenment. As artists so often do, the return to first principles at the end of a creative life leads to works where not a note, a word or a figure could be removed without reigning incoherence. Bach's raw scientific data absorbed and lost into the realms of the ear, heart and mind is just the start of a 40-minute work which hurls the 16th-century towards the late-19th in a single arc of creative genius."

65. Bach music pixels close up



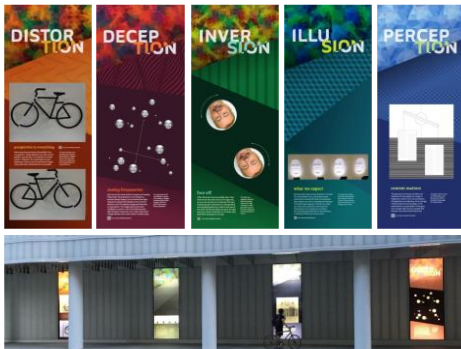
On the other side are eleven Nobel Laureates in Physiology or Medicine who have stepped into UCL at some point in their careers. One bay of pixels was left blank for the next one to come out of the Centre. It turned out to be John O'Keefe!

66. Nobel Laureates close up



These images are recognised at 'sweet' points as one walks along - a little play on perception.

67. Vitrines



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.

68. Image of neuron firing (58)



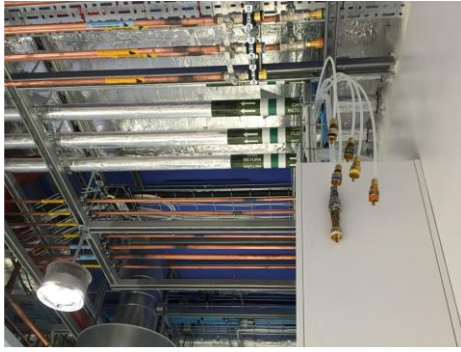
Finally there is a facility to project large neuro-images on the west end wall.

I have hardly yet touched on beauty in design, or neuro-aesthetics - inherited (DNA) and acquired (environmental) information through which we apparently assess aesthetics and about which Semir Zeki at UCL has written.

Adaptability and Flexibility

Above all - from the inside to outside - adaptability of space and flexibility of serving the spaces

69. Flexibility of services



Adaptable spaces

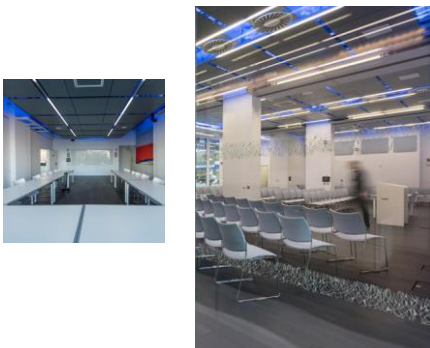
Architects should be keen to understand how best to provide spaces that work best for the occupants. The challenge is that our needs change throughout the day, across time, according to our state of health, or the tasks we're being asked to engage in. Nothing stays the same and predicting change is fun.

70. SWC experimental labs



How can architects design for adaptability and flexibility? For us they are different aspects. Adaptability is physical organisation and dimensions of space changing. Flexibility is softer, flexible light, flexible quiet, flexible temperature, smell and colour. As designers if we begin to react to these dynamic needs we can move architecture in the right direction

71. SWC Lecture theatre and SWC Canteen - seminar space



What would a completely adaptive architecture look like? It is certainly not one that would appear radical internally, nor do I suspect, externally. We have already made a start with the Sainsbury Wellcome Centre.

72. Thinking and design process

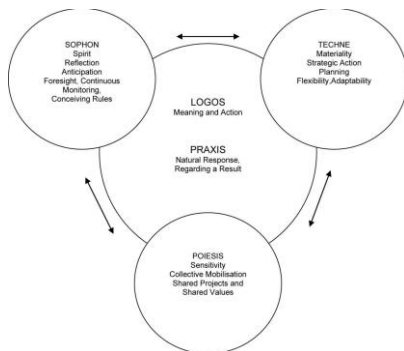


thinking + design process

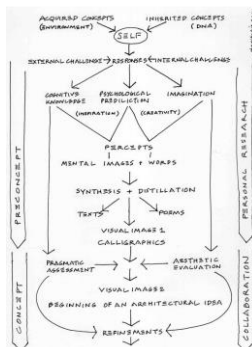
73. Traditional



74. iR thinking



75. Percepts...



76. Vesalius contemplating his brain

De humani corporis fabrica libri septem



Vesalius 1543

77. Descartes' mind and body

From earliest times philosophers have tried to define when matter becomes mind. They were joined in the attempt by psychologists, then theoretical neuroscientists and most recently by neuroscientists - whose focus is on the experimental biology of the brain. Perhaps now, in tandem with theoretical investigation, there will be more profound insights into perception, cognition and behaviour. This is the basis of the creation of Sainsbury Wellcome Centre for neural networks and behaviour at UCL, and we have used some of those insights in its design.

78. Dreaming of a Project Poem extract

Dreaming of a Project [extract]

Architects are not magicians,
They are dreamers.
My architecture starts
in the spaces I create in my mind.
Space is in here and out there,
it is a continuum between inside and outside,
mental and physical.

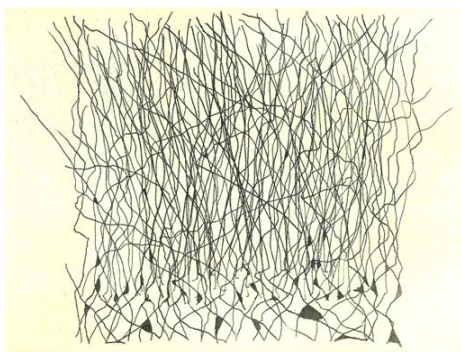
Architecture has two distinct phases:
the mental dream and reality's nightmare.
Being an optimist I know
that the dream is always there,
like the sunshine behind the darkest cloud
and the snowflake in the rain.

We can imagine two futures,
the one we dream of
and the one left to fate.
Or we can imagine one future,
the one we dream of
and the one we left to fate.

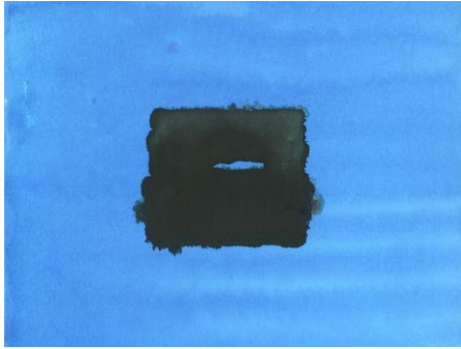
To be able to read our reality
requires a reference - our dreams -
and some of our dreams question
reality's reality.

Now I am designing
with the mind in mind.
Dreams? I try to build mine
avoiding the nightmares.

79. Etching

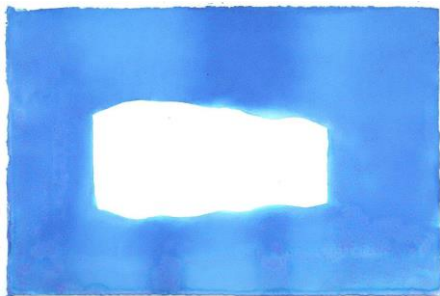


80. No knowledge



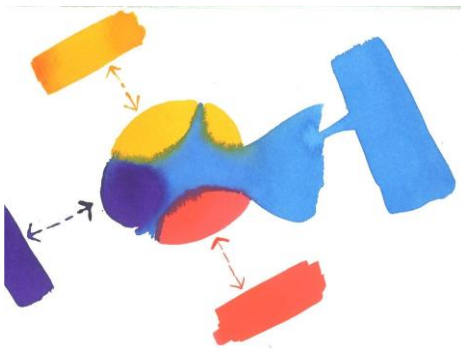
We knew nothing about the needs of systems experimentalists and theoretical computational neuroscientists.

81. Iceberg inking

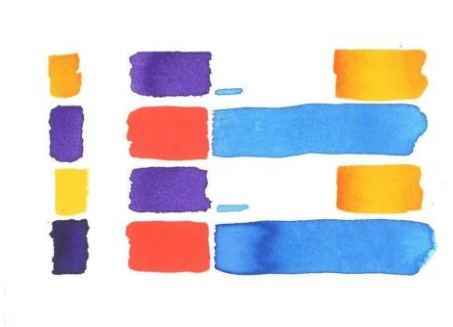


Ice block concept

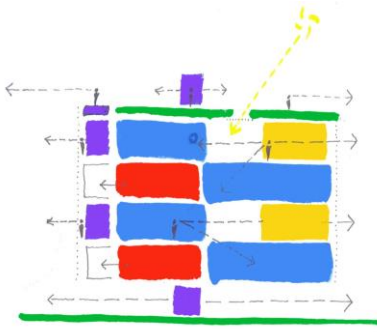
82. Fluid spaces and organisation



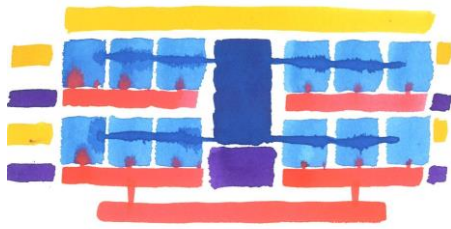
83. Structuring space



84. section



85. long section



86. Cast glass and ice shelf

87. South side

88. Image: South side animation (53)



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 ribbed cast glass.

89. Night time light on the north wall and animation



The aesthetics of the Sainsbury Wellcome Centre has a fugitive, even ethereal quality which comes from the idea of how to compose with and use glass in ways which have not been done before, to exploit light reflections through the micro-profile of the glass surface, and to allow the façade to play akin to a piano through the design of privacy louvres.

90. Why does the SWC work?

Why does the **SWC** work?

91. Sequential slides



Isolated labs



Open-plan shared labs



Mixed scale, multi-level labs



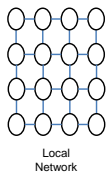
Local Network



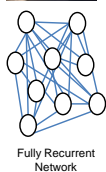
Fully Recurrent Network



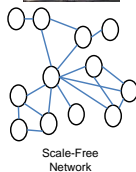
Scale-Free Network



Local Network

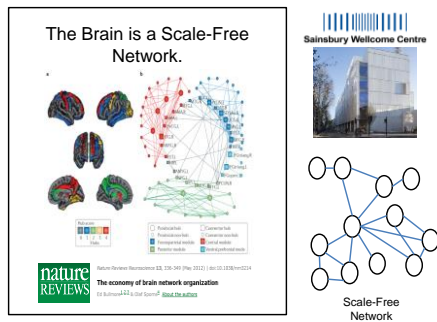


Fully Recurrent Network



Scale-Free Network

92-4. Scale free brain and building



95. Proust - looking with eyes fresh

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*

Conclusion

Out of the SWC design work there is a neurodesign opportunity opening up at UCL - an embryo called 'Think Space'.

The short term aim is to foster working relationships between neuroscientists, architects and designers, and in the longer term allow us to create better environments, cities and buildings. As an architect I'm interested in the bridge between neuroscience and architecture. I would like new information and facts from behavioural neuroscience to help me imagine new forms of space and, simply put, design better. I'm hopeful that designers will benefit from the exploration of quantitative and qualitative aspects between architectural, neurological, philosophical, and aesthetic concepts of space.

There is immense value in understanding how we can appreciate spaces, how we can design better environments for people. How can a teaching space for 5 year-olds work better as an environment for learning? How should it adapt to become one for adolescents? However, I'm interested in more than that.

The world is a vast consumption machine. Neuroscience is already being used to peek into the deeper mindset of potential customers, to encourage trust and discover approaches to achieve the desired goal, which is always - sale.

That is, as designers, we're up against a well-designed wall. Everything we do is measured by one simple statement - "will it attract the consumer?"

The consumer is not free. He's formed from birth by ever more sophisticated targeted advertising.

We have to break free of this if we want a more humane world.

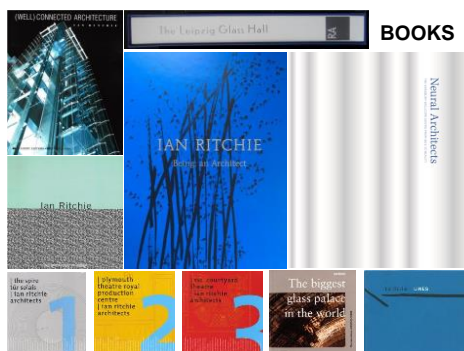
I would like to be able to believe that with a greater understanding of why we react the way we do - and an empirical understanding of what we find beautiful and why, our reactions to beauty, and what exactly makes the human spirit soar is probably as good a place to begin as any - we just might be able to create not just buildings which are good for humans, but cities and societies as well.

Our Earth is 45 million centuries old, but this century is special. It's the first when one species - ours - can determine the biosphere's fate.

What a tragedy if we do not understand anything important about ourselves before we ruin the Earth.

Is that what a black hole could really mean?

96. Books



97. End



END