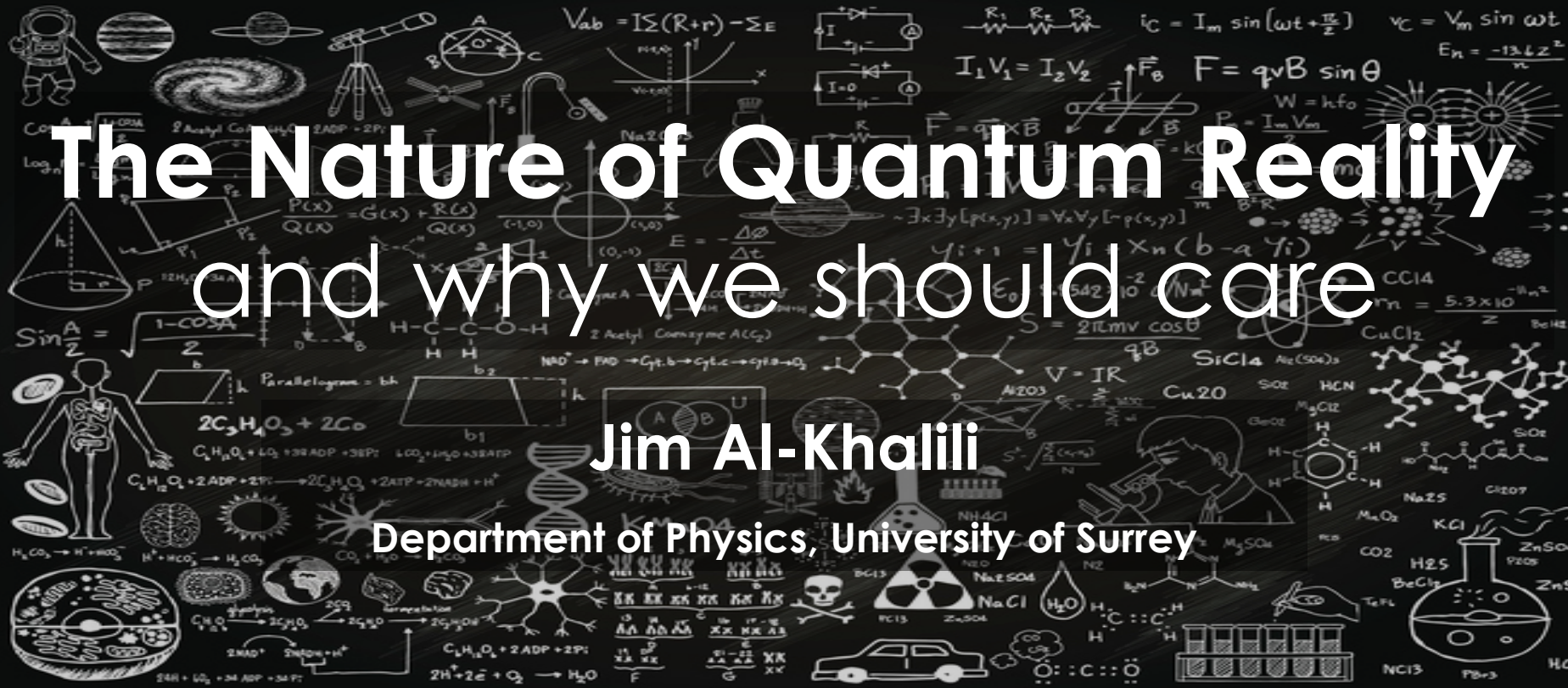
RAL Space

16th Appleton Space Conference
3rd December 2020



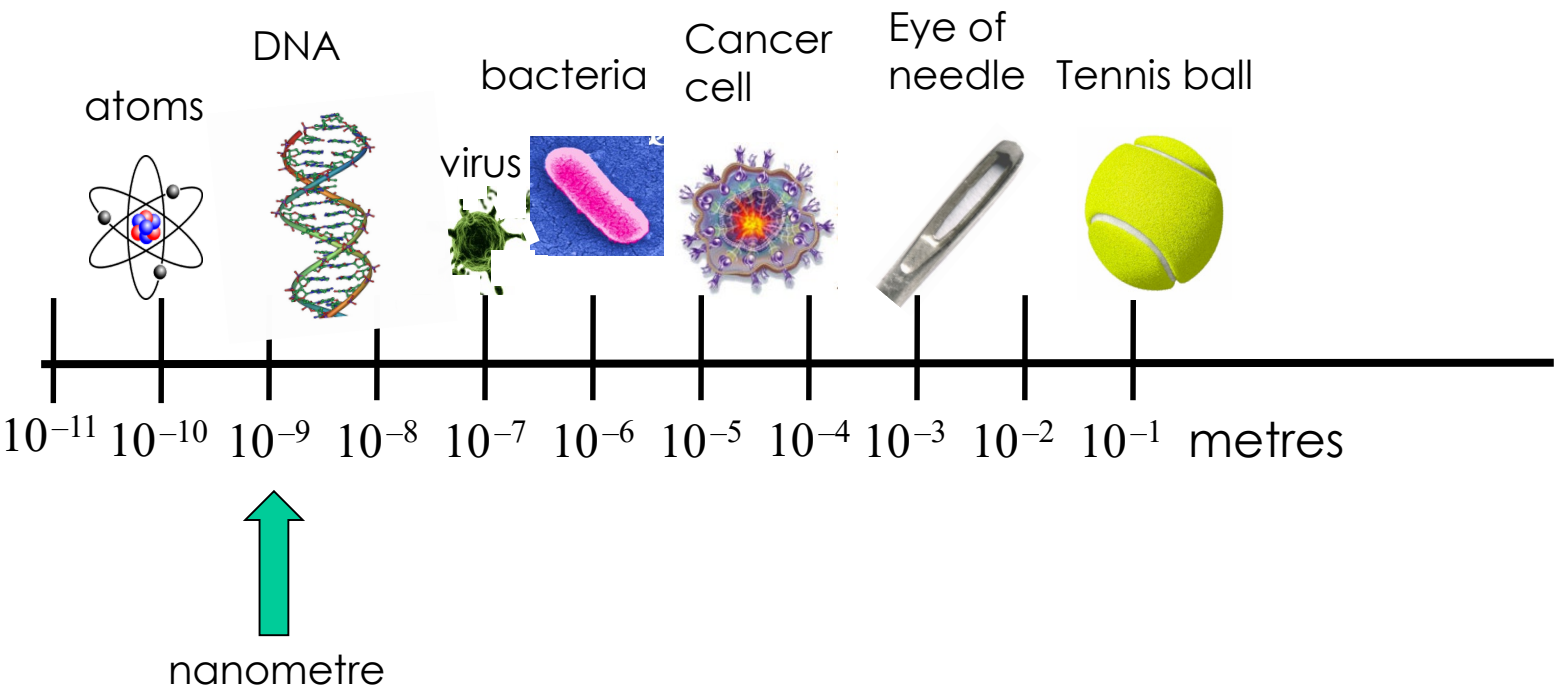
The Nature of Quantum Reality
and why we should care

Jim Al-Khalili

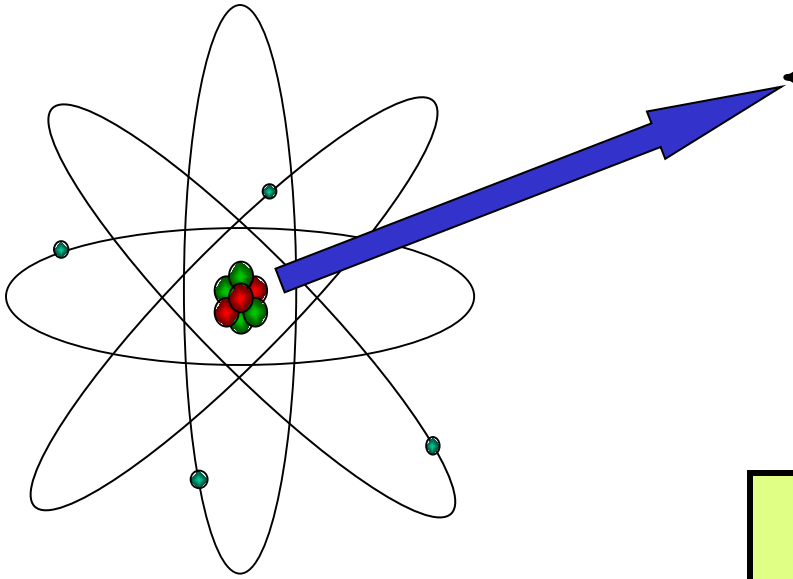
Department of Physics, University of Surrey

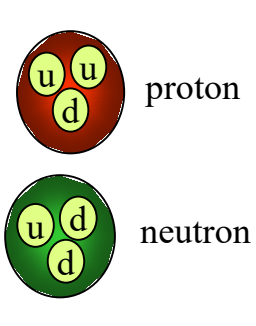
But where is the boundary between the quantum world and the classical world?

??????????



The Atom





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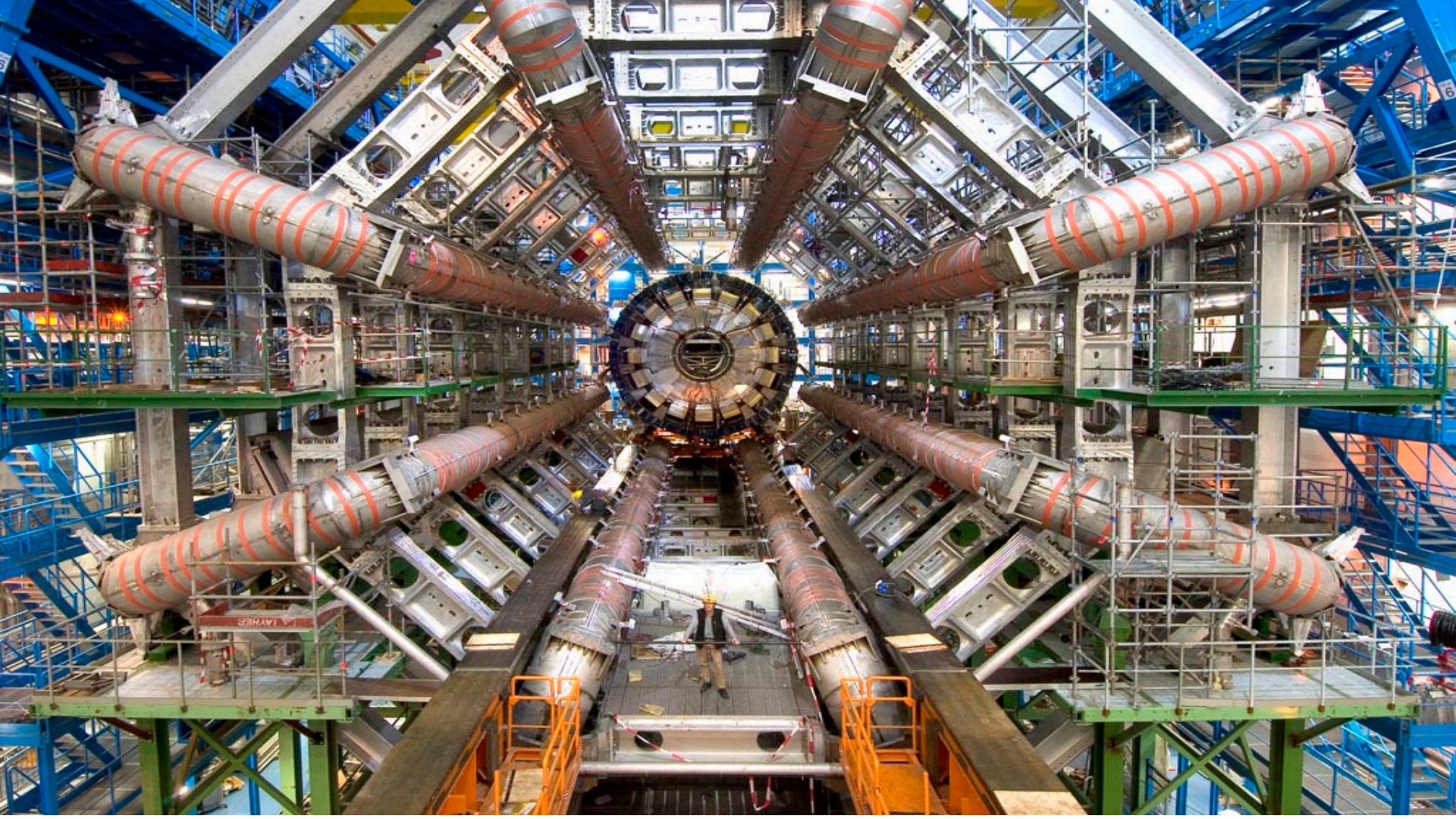
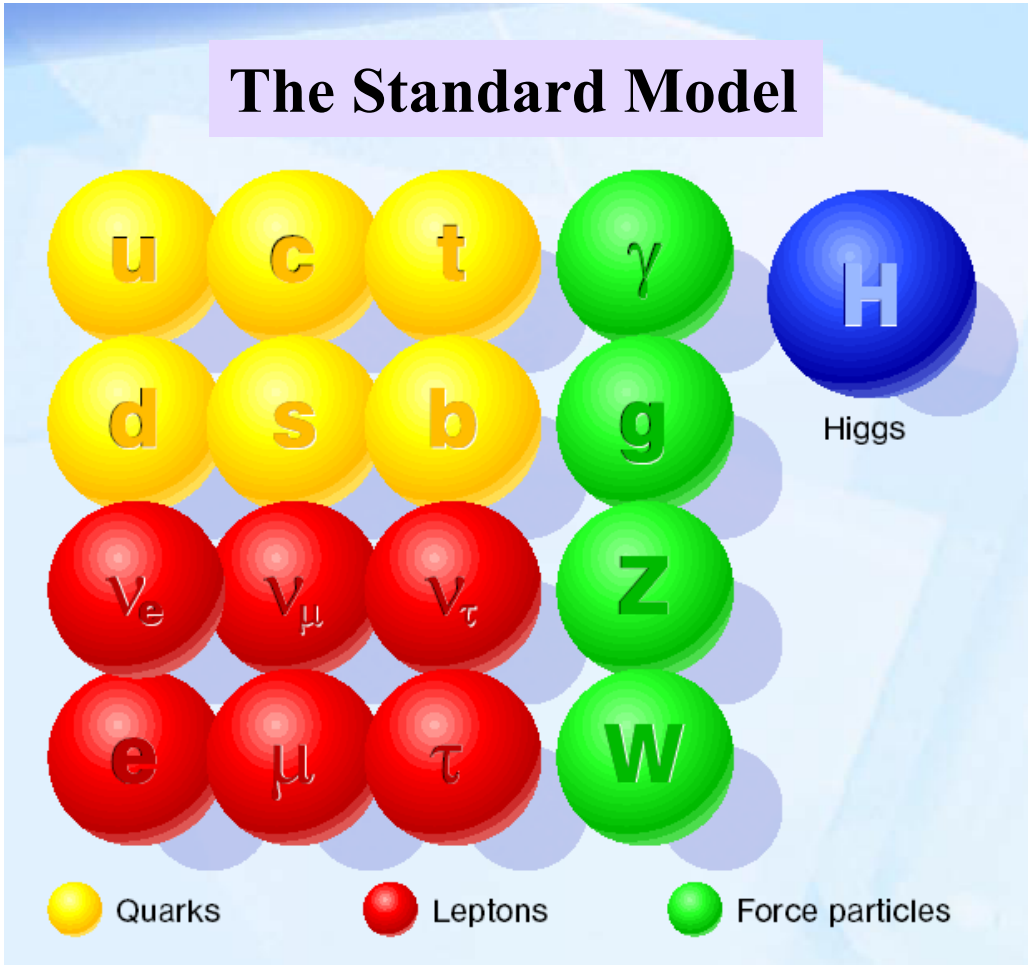
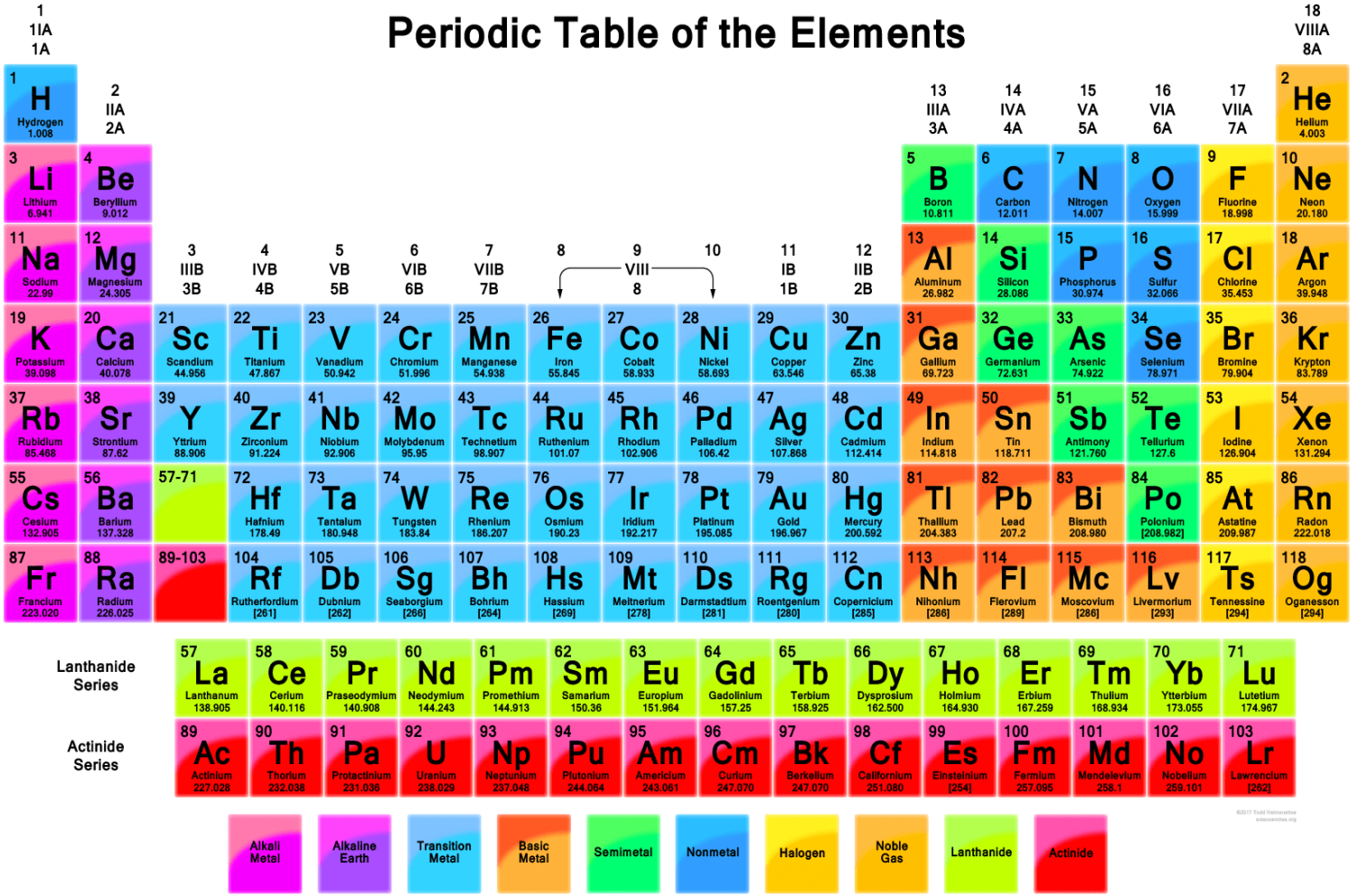


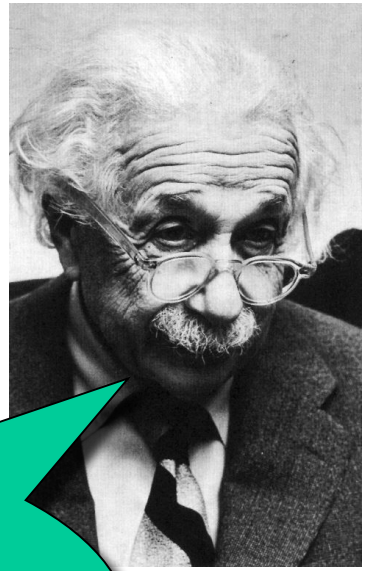

The Standard Model
u
c
t
γ
H
Higgs
d
s
b
g
ν_e
ν_μ
ν_τ
Z
e
μ
τ
W
Quarks
Leptons
Force particles

Periodic Table of the Elements



And yet, arguments about what this all means rage to this day

*It is wrong to think that the task of physics is to find out how nature **is**. Physics only concerns what we can **find out** about nature.*

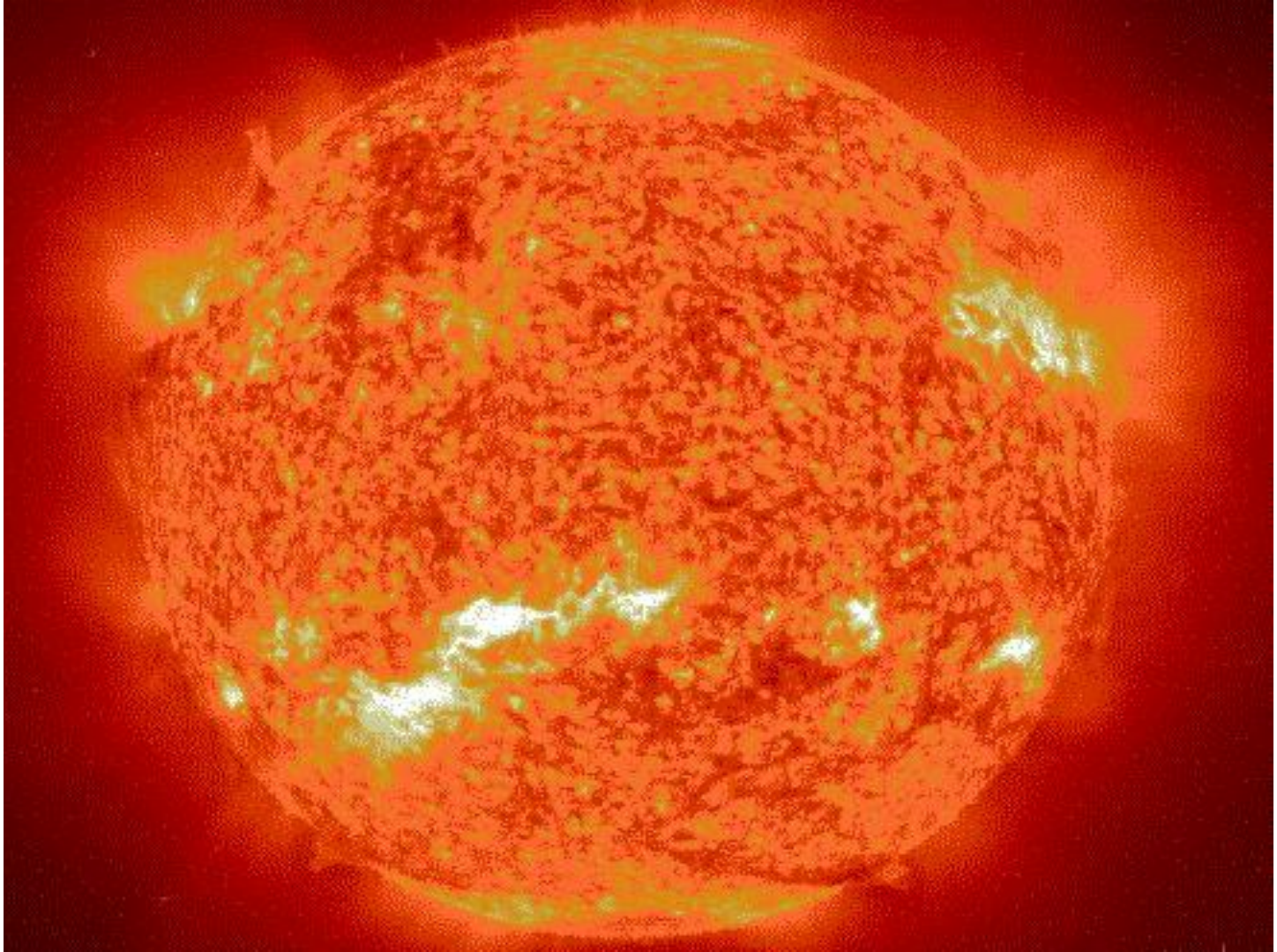


*The job of physical theories is to approximate as closely as possible to the truth of **physical reality**.*

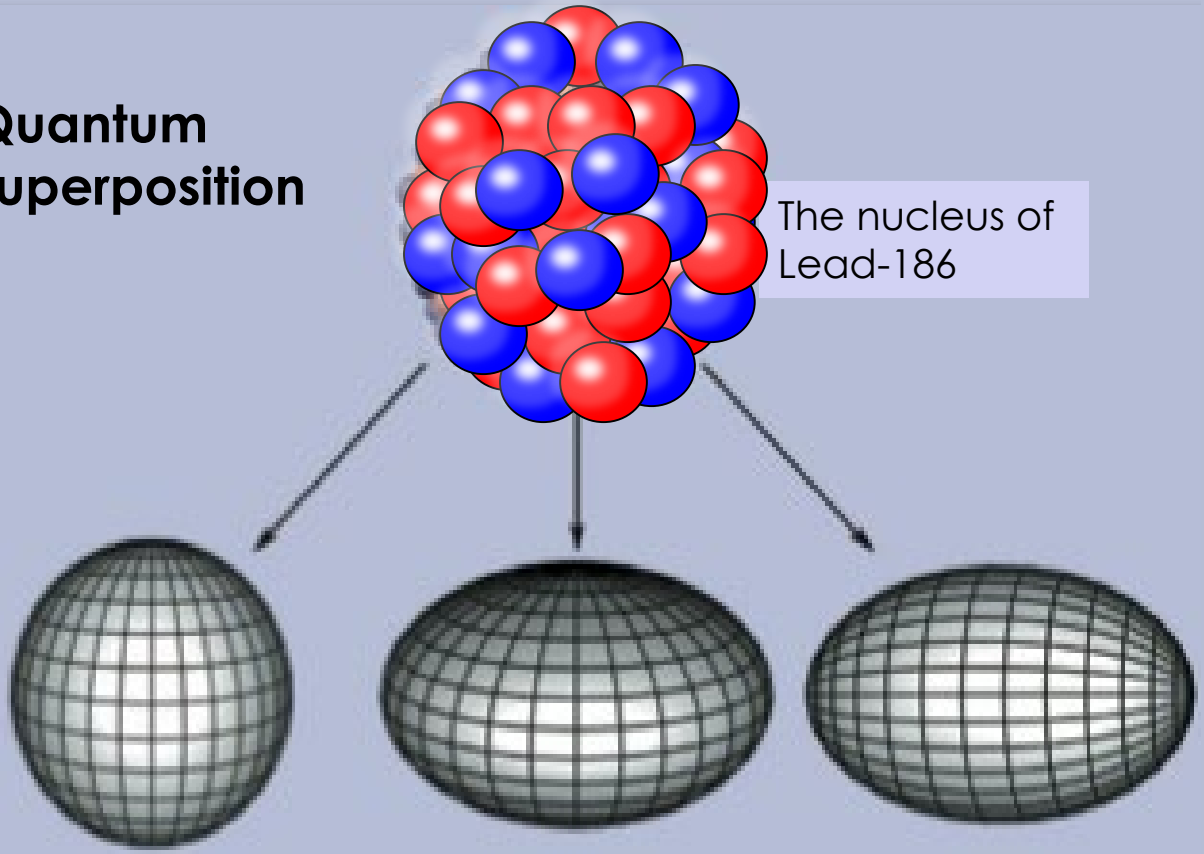
Quantum technologies of the 21st century include quantum computing, quantum sensing, quantum cryptography and even quantum teleportation

Non-trivial quantum phenomena include:

- Long-lived quantum coherence
- Superposition
- Tunnelling
- Entanglement

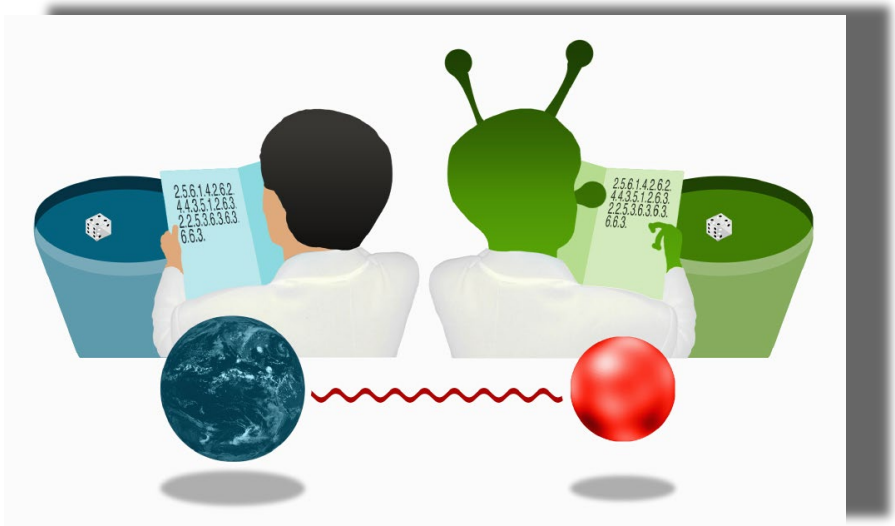


Quantum superposition



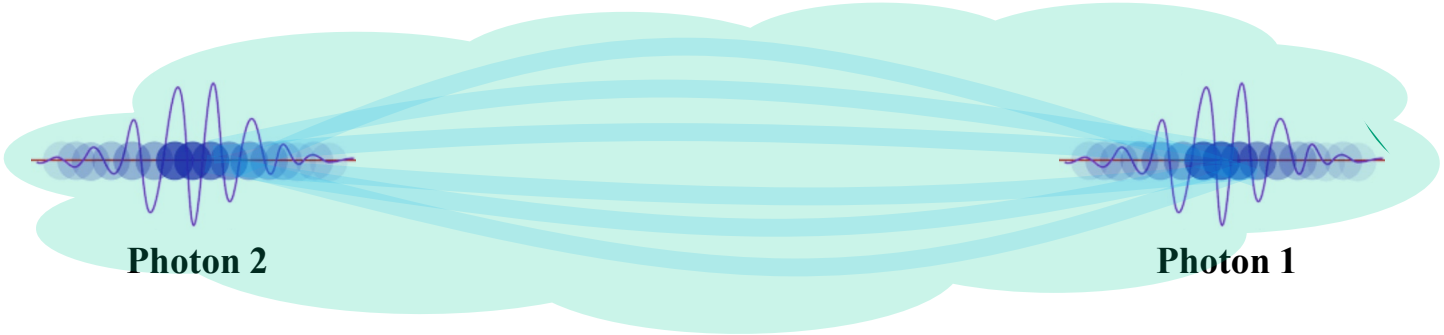
Entanglement

This is due to instantaneous connections between two or more quantum particles which can be very far apart.

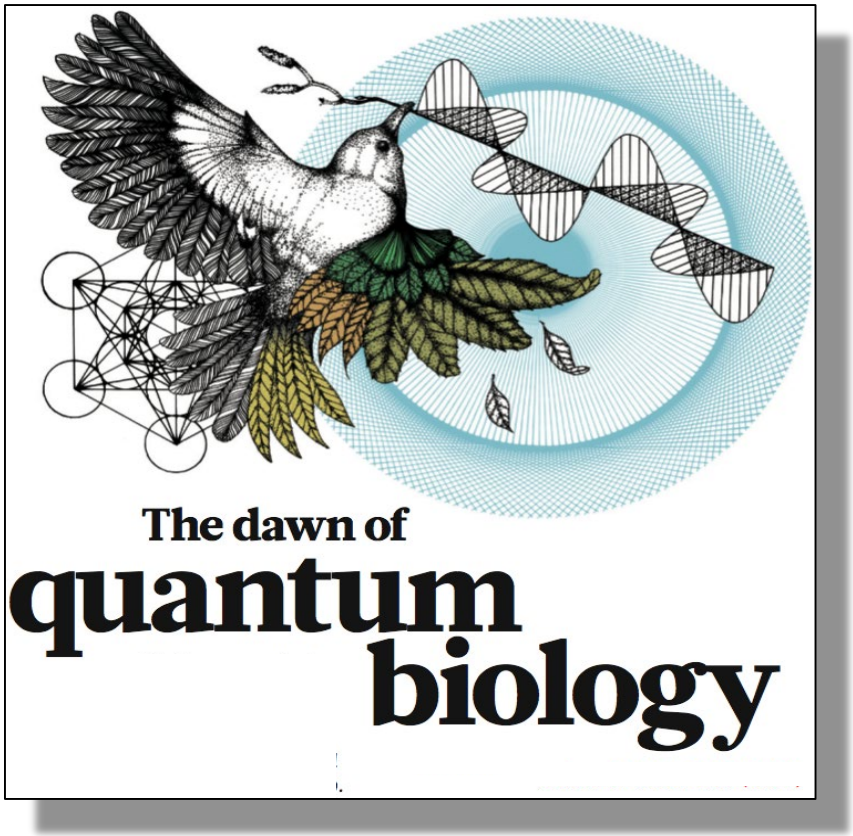


The Einstein-Podolski-Rosen Paradox – 1935

The photons are entangled



An arbitrary distance apart



Article in ***Nature*** by Philip Ball (Nature 474 (2011) 272-274)

2015: The first book on the new field of quantum biology

Co-author, Johnjoe McFadden
(professor of molecular genetics)

So, when did I get involved?

ELSEVIER

BioSystems 50 (1999) 203–211

Bio Systems

A quantum mechanical model of adaptive mutation

Johnjoe McFadden [a,*], Jim Al-Khalili [b]

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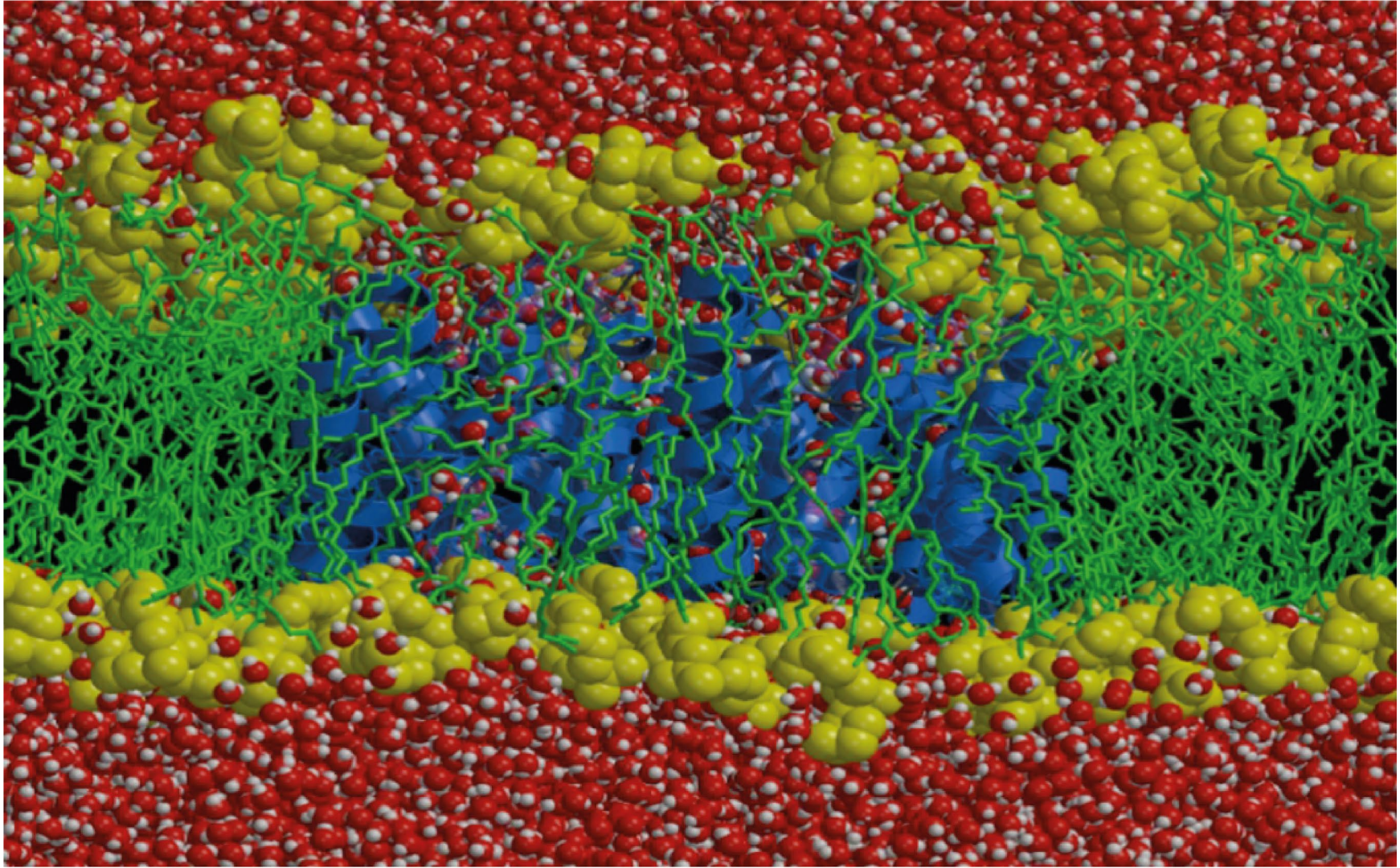
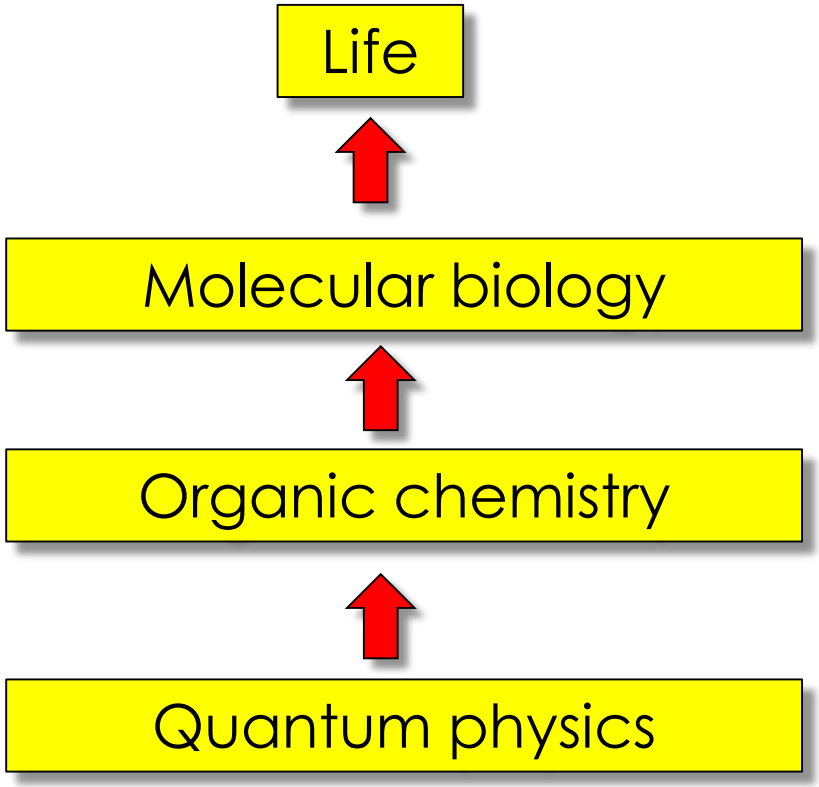
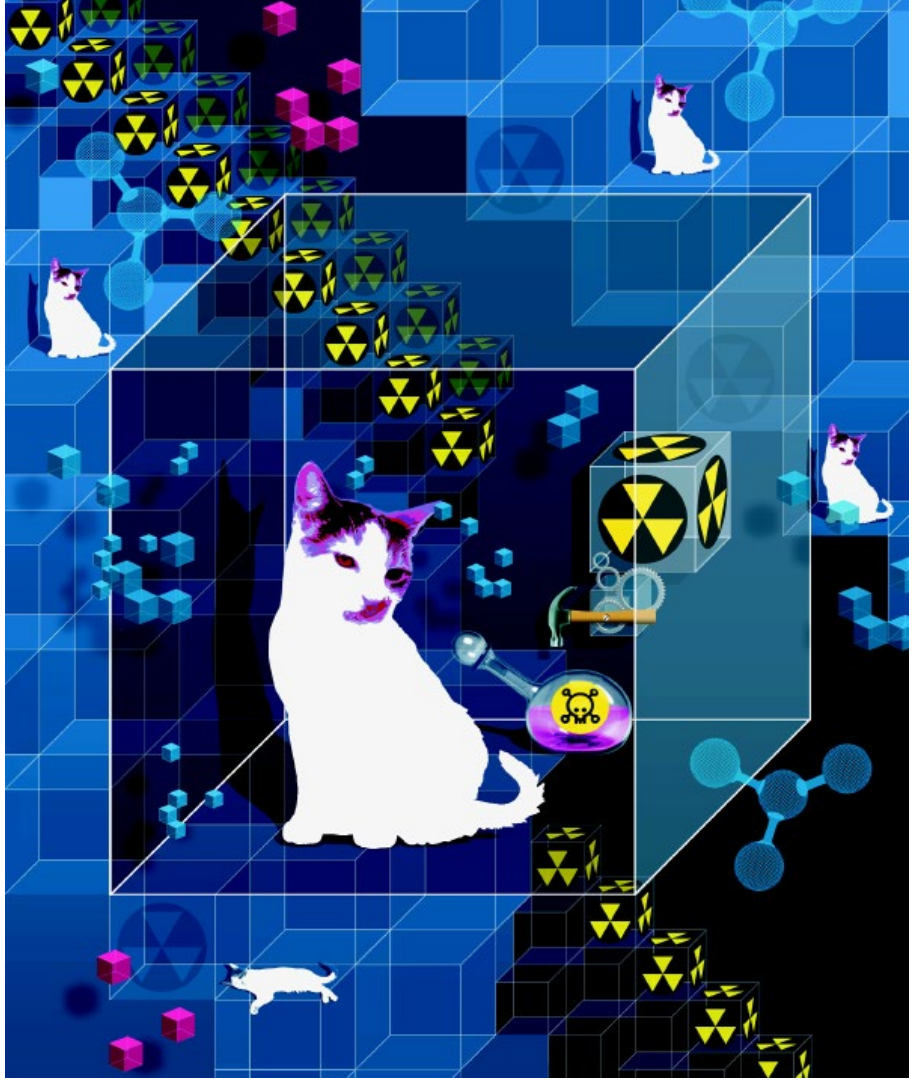
Received 10 August 1998; accepted 15 January 1999




Life
Molecular biology
Organic chemistry
Quantum physics



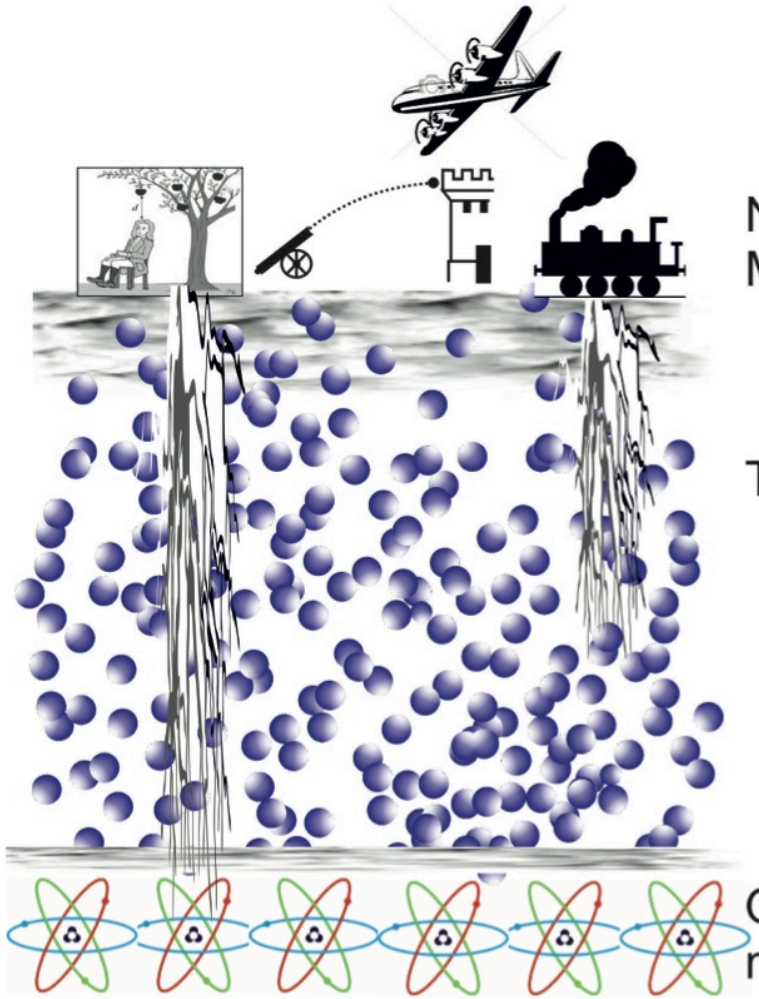
Quantum superposition

+

Quantum entanglement

=

Schrodinger’s cat


Newtonian
Mechanics
Thermodynamics
Quantum
mechanics

Candidates for quantum effects in biology

1. Enzyme action (*confirmed in late 1980s*)
2. Photosynthesis (*well-established*)
3. Magnetoreception in birds (*leading candidate*)
4. How we smell (*gaining respectability*)
5. DNA mutations (*open question*)

Where are we today with quantum biology?

- The field is still in its infancy – it is still speculative;
- There is still widespread skepticism among biologists, mainly surrounding the ‘so what” question;
- It does appear that certain mechanisms inside living cells require a helping hand from the quantum world;
- We have yet to understand *how* this is possible;
- Has Nature hit upon shortcuts that give it an advantage?
- Can we learn from nature to develop new or more efficient quantum devices?

Quantum biology

UNIVERSITY OF SURREY

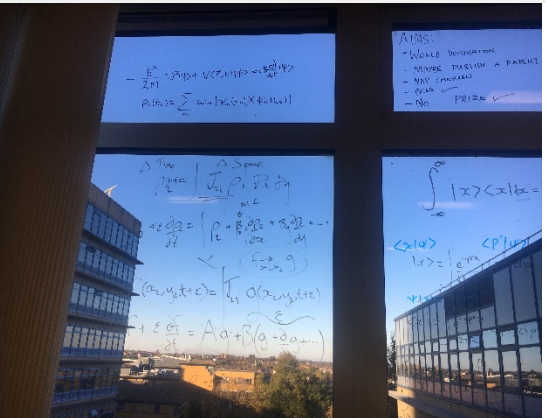
The first new science of the 21st century, quantum biology offers an opportunity to change the way we see the world.

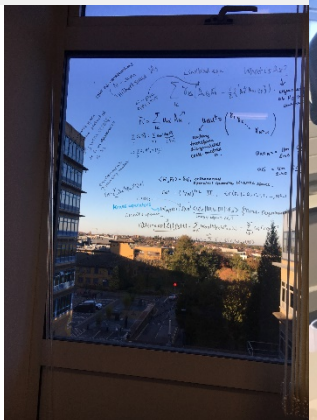
Published: 22 December 2017

PRESS RELEASE

World's first training Centre for Quantum Biology established at the University of Surrey with £1m support from the Leverhulme Trust

The University of Surrey has been awarded £1million from the prestigious **Leverhulme Trust** to establish the world's first doctoral training centre for quantum biology.





If you are not astonished by quantum mechanics then you have not understood it!

Niels Bohr