Quantum Biology

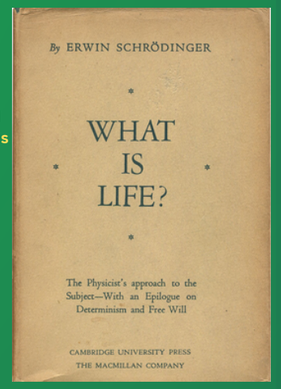
Biology in the Quantum level
(量子生物學)

This field bridges **Biology** and **Quantum Mechanics**, offering new insights into how life operates at a **fundamental** level.

Timeline of Quantum Biology[1]

1920s and 1940s: **Niels Bohr** and **Erwin Schrödinger** propose that quantum mechanics **may apply to biological systems**

1953: The book Schrödinger published (*What is Life?*) influenced **James Watson** and **Francis Crick**, leading to the discovery of double helix structure of DNA



1966: **Don Devault** and **Britton Chance** see electron tunneling in enzymes
(refer to quantum tunneling)

1974: **John Hopfield** develops **theoretical model** of electron tunneling in enzymes

1976: **Magnetoreception (磁感)** first observed in birds by **Wiltschkos (Roswitha and Wolfgang Wiltschko)**

Klaus Schulten proposes **radical pair mechanism** and **fast triplet reaction** to explain **Magnetoreception**
(the relation between quantum mechanics and Magnetorecception will be explained)

This sense is crucial for **migratory birds** (like **European robins 歐亞鴝**), helping them navigate accurately across vast distances

1989: **Berkeley (柏克萊加州大學) group** observes quantum tunneling in enzymes

2000: **Thorsten Ritz** proposes model for **quantum compass** in **cryptochrome 隐花色素 (a type of flavoprotein黃素蛋白)** molecule in **European robin**'s eye
(flavoproteins are proteins that contain a nucleic acid derivative of riboflavin or vitamin B2)

2007: **Gregory Engel** and **Graham Fleming** discover long-lived **quantum coherence (量子相干性)** in **FMO (Fenna–Matthews–Olson) complex** in **photosynthesis**
(these terms will not be discussed nor explained)

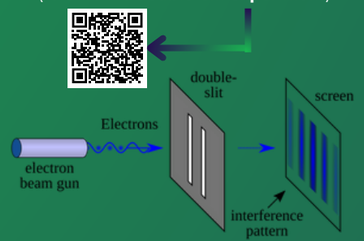
Related Quantum Mechanics concepts
(simplified) (basic concepts)

Wave-particle duality
(波粒二象性)

$$\lambda = \frac{h}{p}$$

de Broglie's matter wavelength formula

Hydrogen atom (or **H+/H-**) and **Electrons**
(or any matter)
can have the behaviours of both a **particle** and a **wave**
(refer to the **double-slit experiment**)



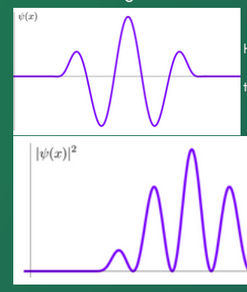
By Original: NekoJaNekoJa Vector: Johannes Kalliauer , CC BY-SA 4.0.

Don't know interference? Ask a nearby physics teacher. (Wave Motion II 3B and Atomic World E2)

Wave function
(波函數)

Ψ psi

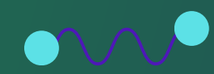
It provides the **probability** for finding a **particle** in a particular position (or state). Below are two graphs demonstrating a single wave function



In the first graph, there are negative values. However, it does not mean low probability. Instead, the squared wave function (second graph) gives the probability density.

This is only possible because the **particle** is **not measured.** It exists in **superposition(疊加態)**. After measuring, the **wave function collapses.** **The particle** exists in a **definite state**. (simplified)

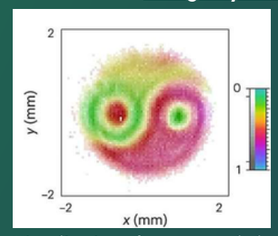
Quantum entanglement
(量子纏結)



"spooky action at a distance"
-Albert Einstein

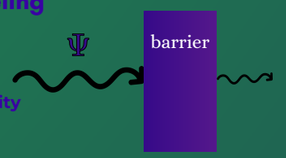
A phenomenon where **two particles** become **linked**, so that **the state of one particle instantly influences the state of the other**, **no matter how far apart they are**.

When **particles** are **entangled**, their **wave functions cannot be described independently**; they must be considered as **a single system**.



Visualisation of two entangled photons (yin-yang pattern) [5]

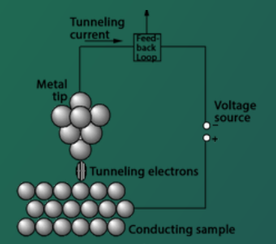
Quantum tunneling
(量子穿隧效應)



A consequence of **Wave-particle duality** and **Wave function**

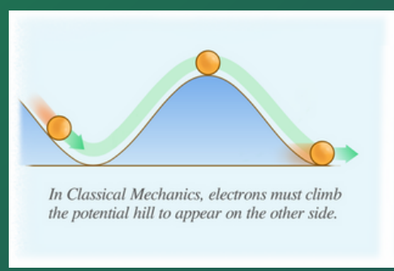
A phenomenon where **particles *can* pass through** a **barrier** that they normally wouldn't be able to cross

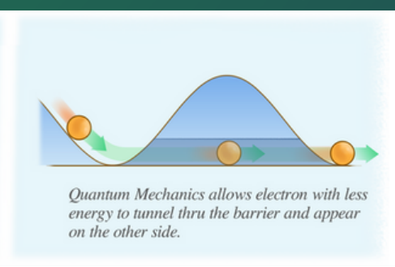
Below are two diagrams. One simplifies quantum tunneling, while the other is more detailed



Scanning Tunneling Microscopes (STM) are based on the concept of Quantum Tunneling

Consider **a particle with energy E** that is confined in a box which has **a barrier of height V**. Classically, the box will **prevent these particles from escaping** due to the **insufficiency in kinetic energy of these particles** to get over the barrier. However, if the **thickness of the barrier is thin**, the particles **have some probability** of penetrating through the barrier **without sufficient energy** and appear on the other side of the box





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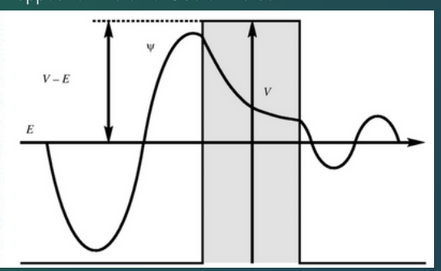

There is still some probability behind the barrier, but it is diminished