

Wolfgang Amadeus Mozart



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The image shows a page of handwritten musical notation for Wolfgang Amadeus Mozart's Requiem, specifically the Dies Iræ section. The score is written on aged paper and includes parts for several instruments and voices. At the top, the text "Dies iræ" is written in a decorative script. Below it, the lyrics "Dies iræ, dies illa, solus dominus in caelis, terra, sub terra, quiescit cinis" are written in a smaller hand. The musical notation includes staves for strings (Violin I, Violin II, Viola, Cello, Double Bass), woodwinds (Flute, Oboe, Clarinet, Bassoon), and voices (Soprano, Alto, Tenor, Bass). The notation is dense and characteristic of the late 18th-century style.

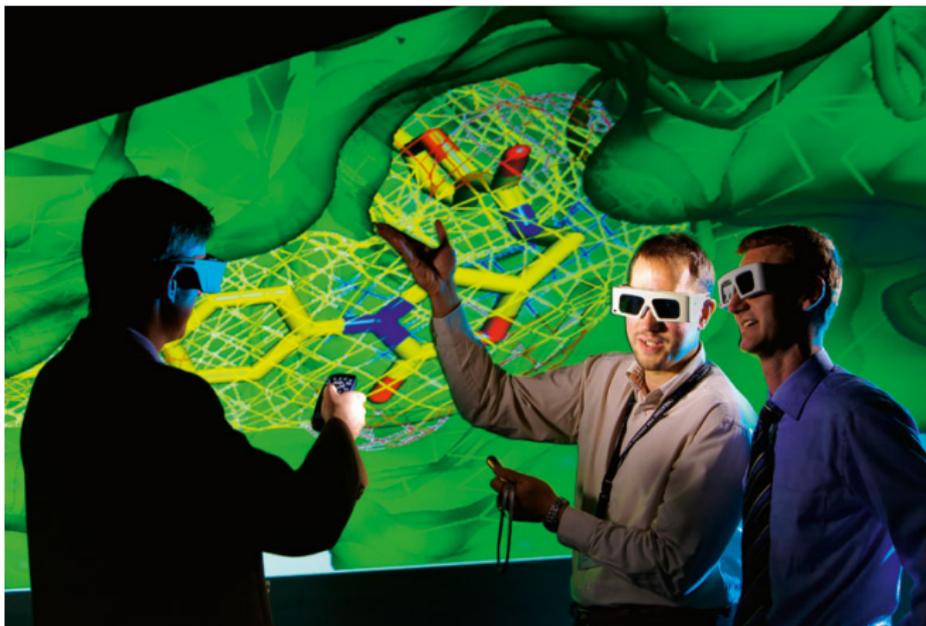
Wolfgang Amadeus Mozart: *Requiem* (K626), *Dies Iræ*

Wolfgang Amadeus Mozart

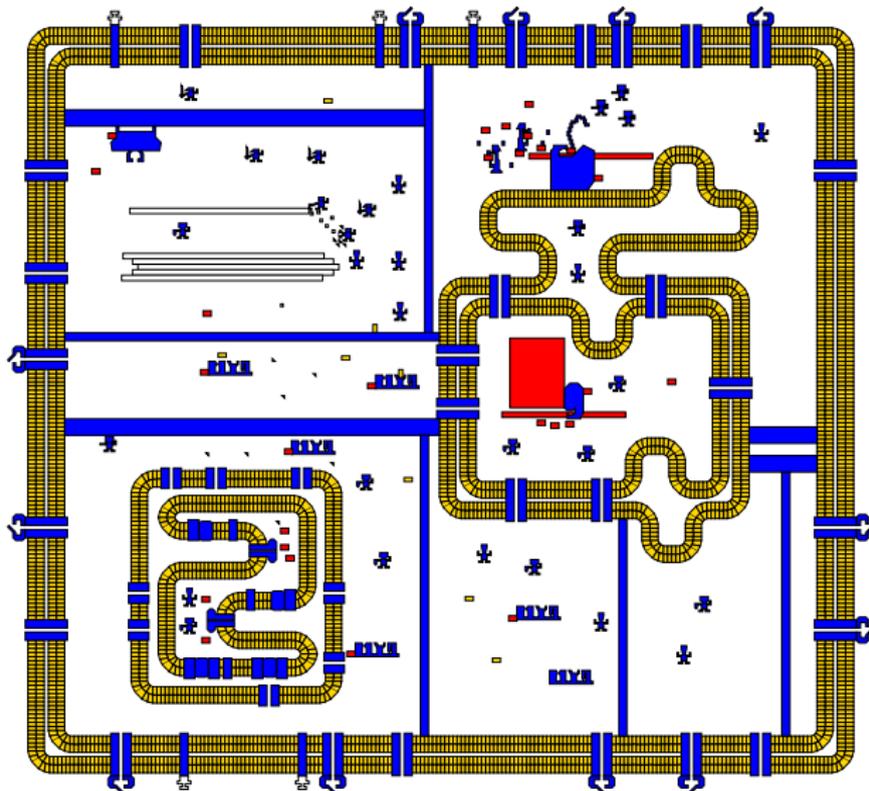


From Mozarts hair
to understanding protein architecture
and its importance for the life

Lukáš Žídek



Structural biology



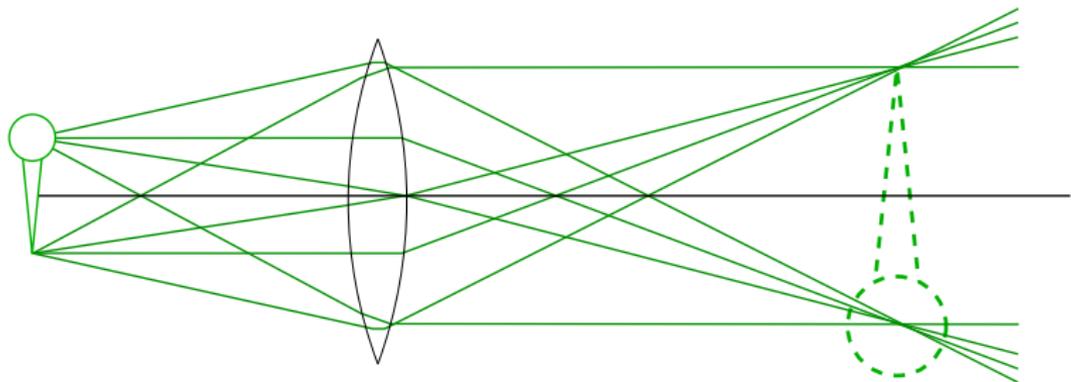






18th-century microscopes from the Musée des Arts et Métiers, Paris, Edal Anton Lefterov

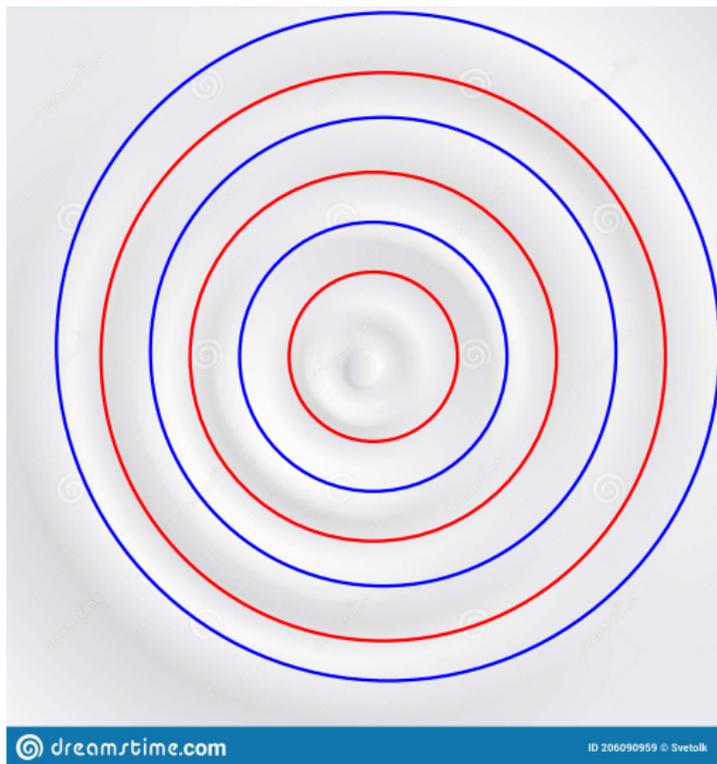
Light microscopy

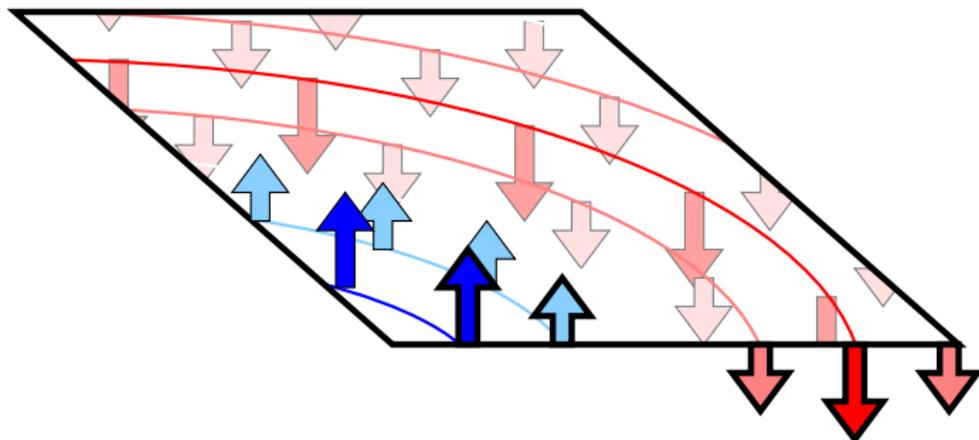




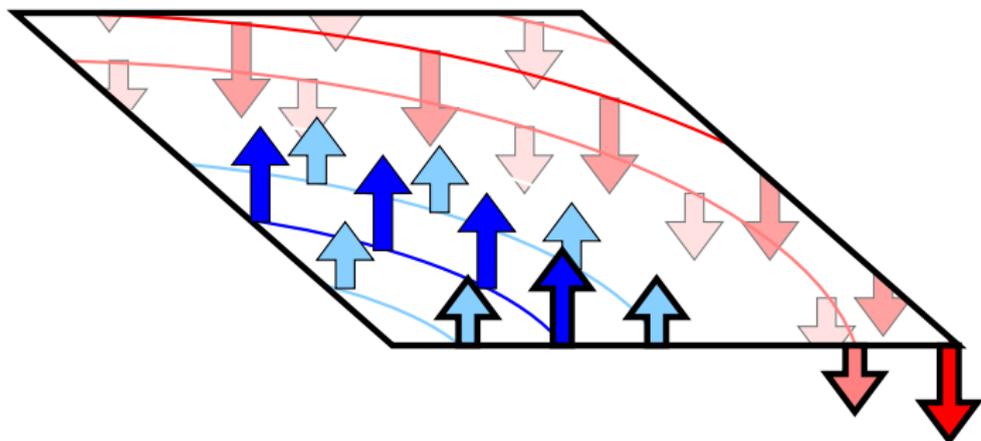
Waves



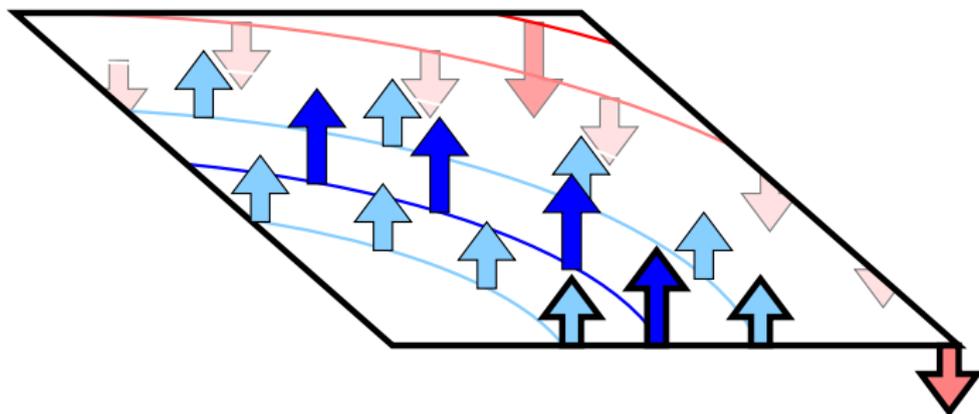




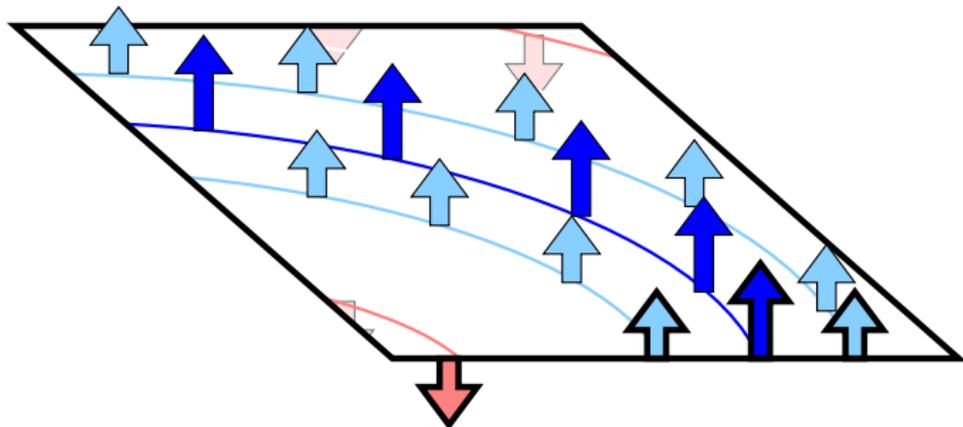
Electromagnetic waves



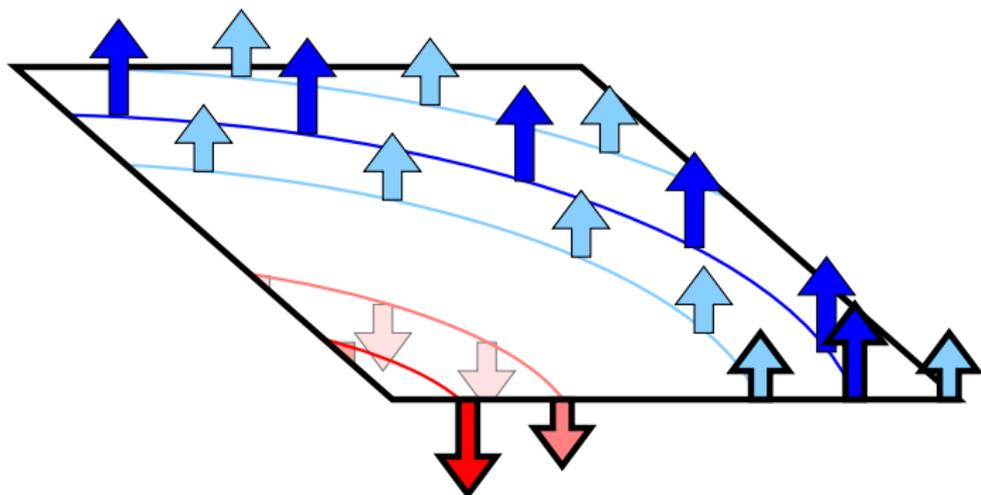
Electromagnetic waves



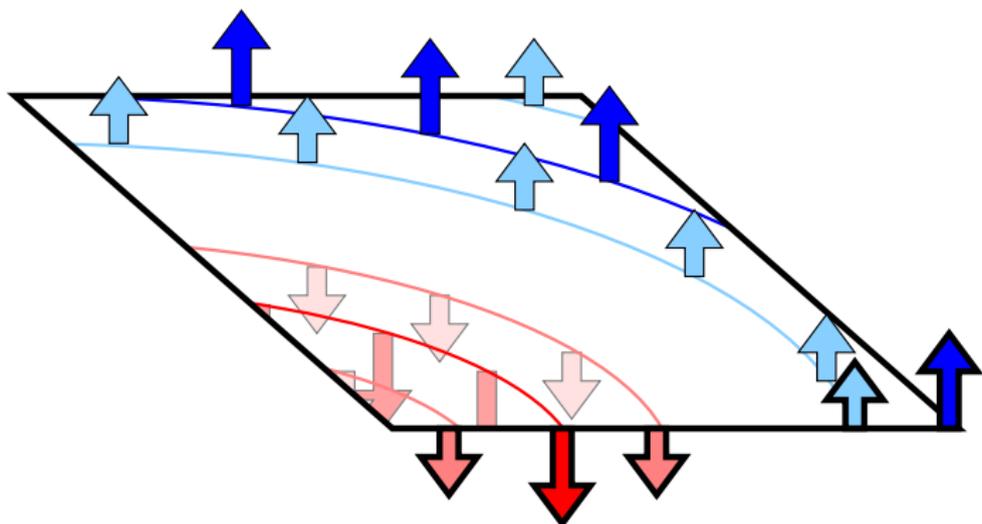
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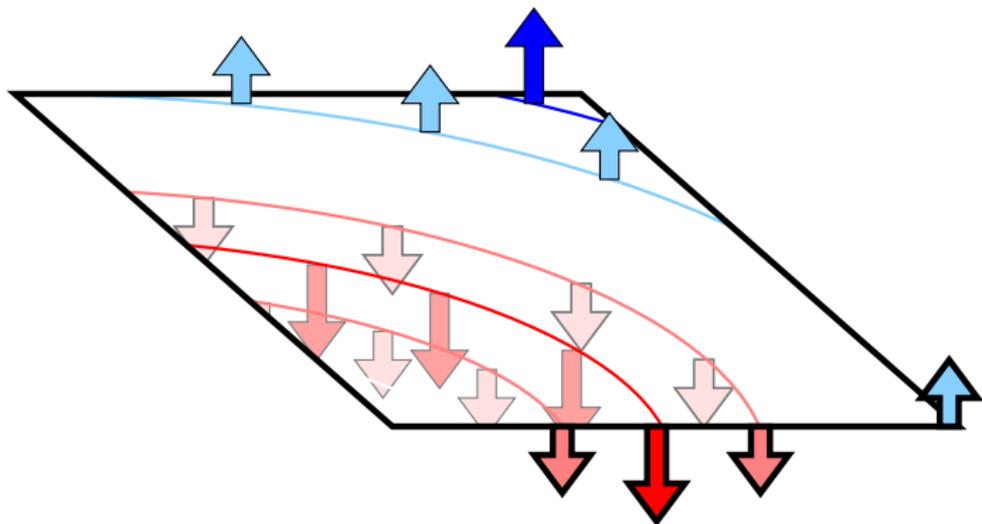
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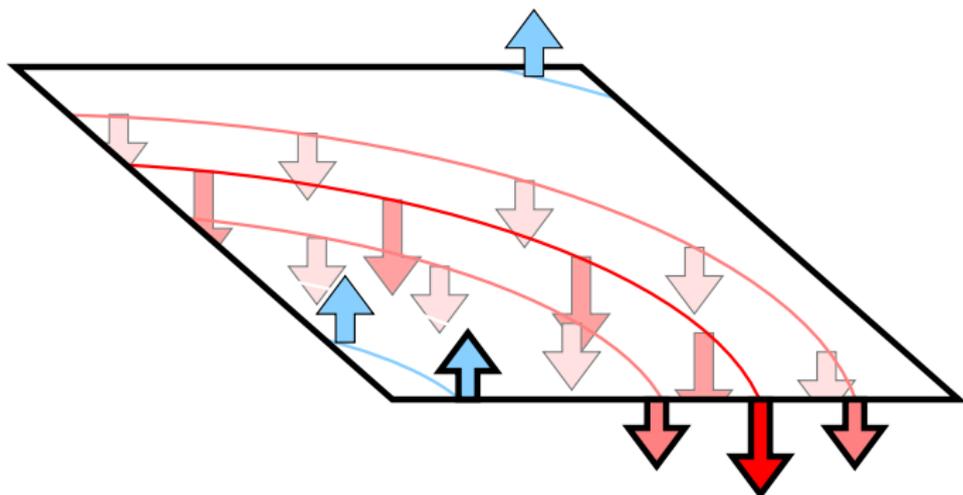
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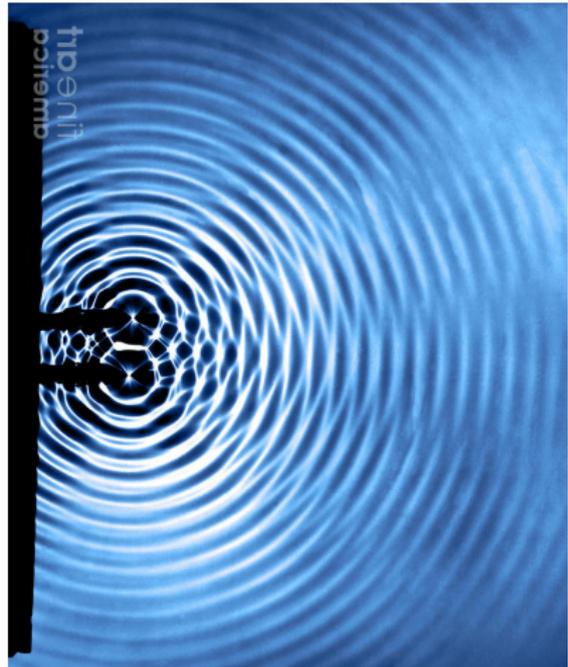
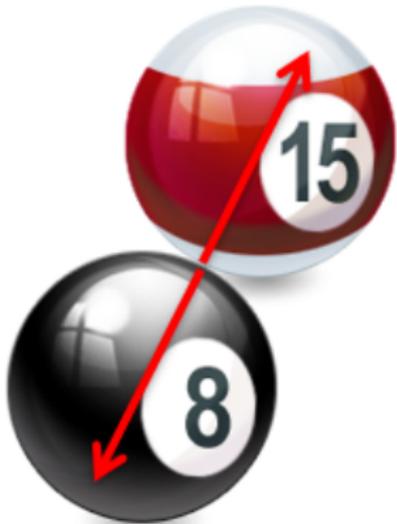


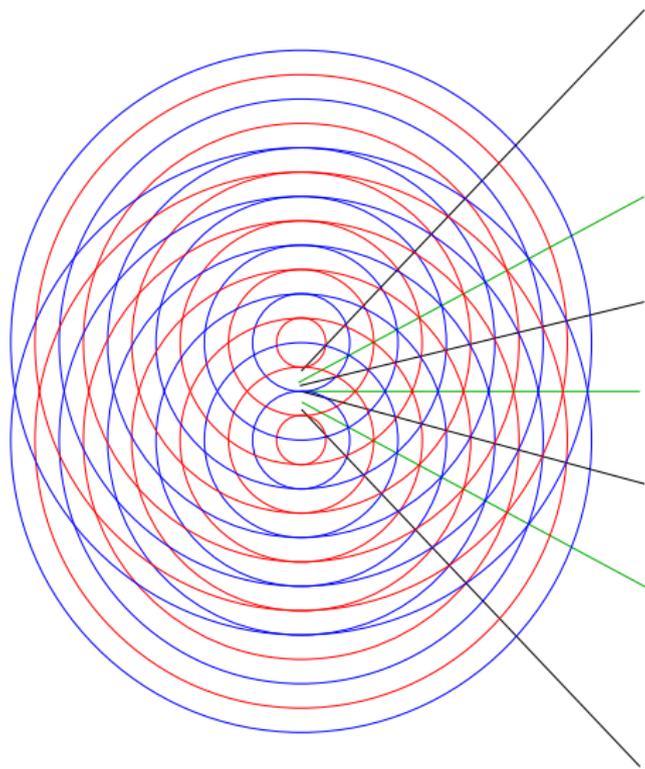
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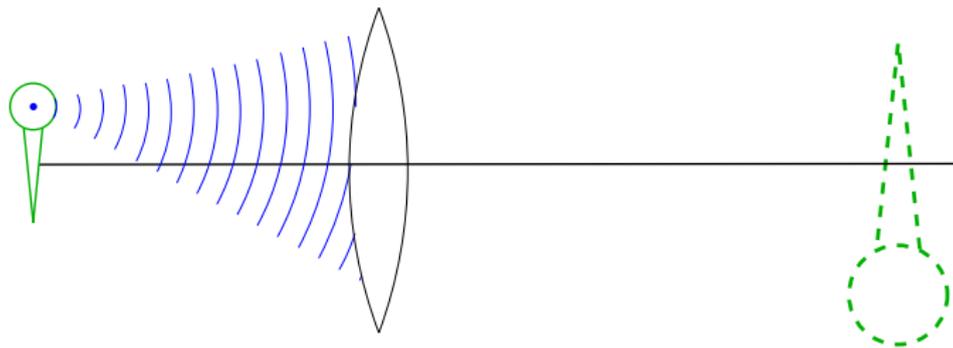
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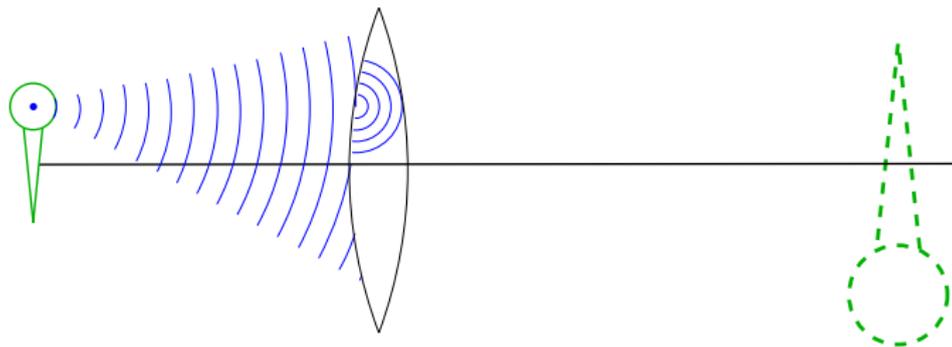




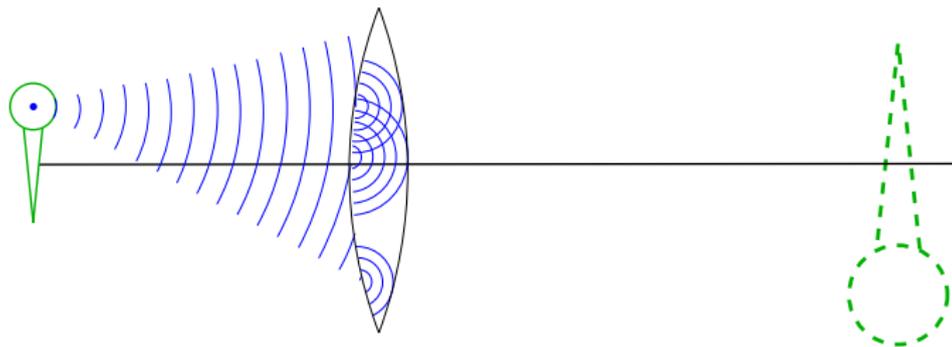
Light microscopy



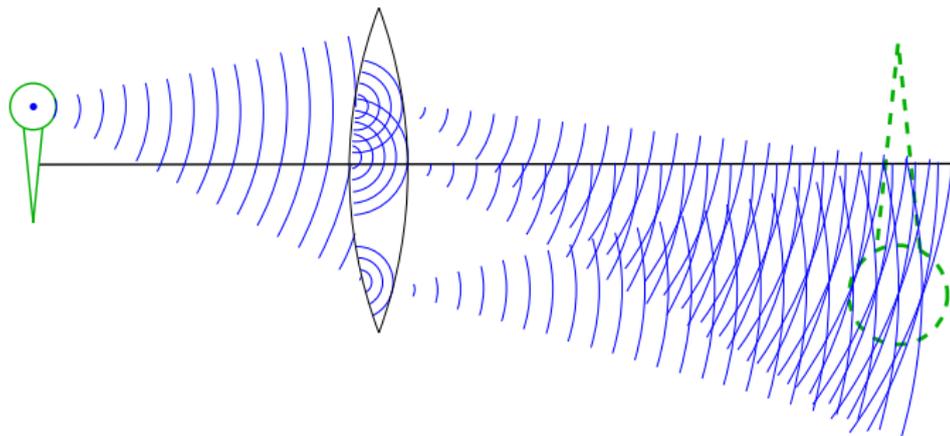
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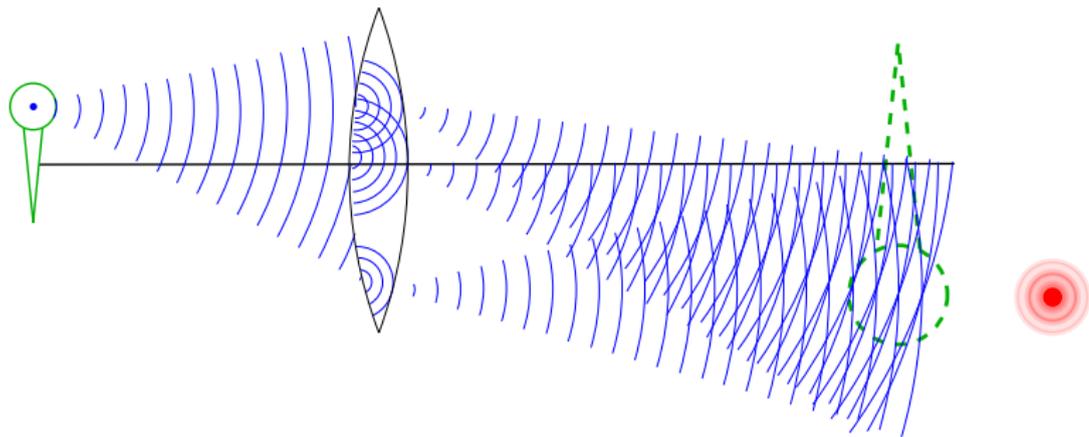
Light microscopy



Light microscopy



Light microscopy



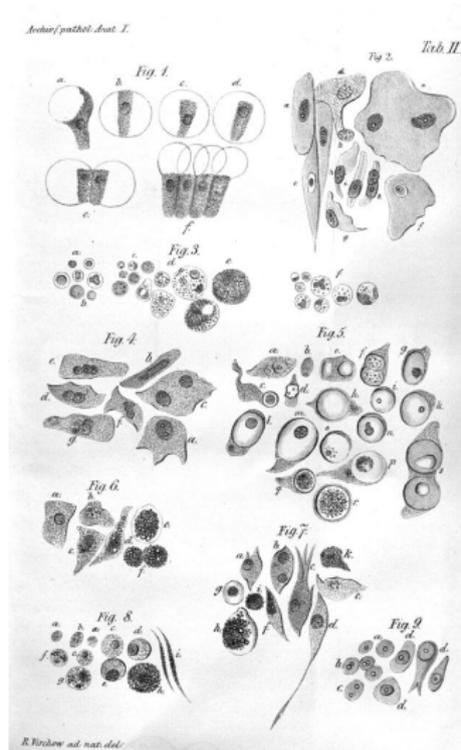




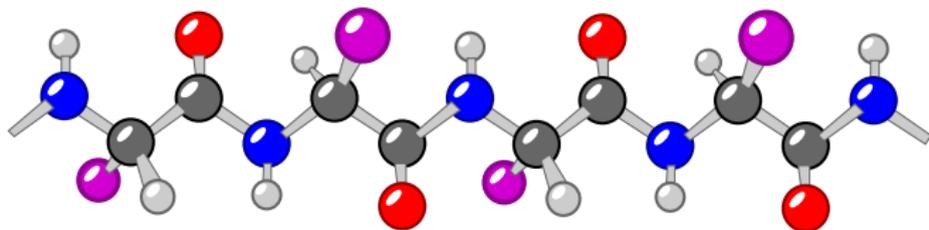
Wilhelm Konrad Röntgen



Anna Berta Röntgen's hand



Archiv für Pathologische Anatomie und Physiologie, 1847



Franz Hofmeister

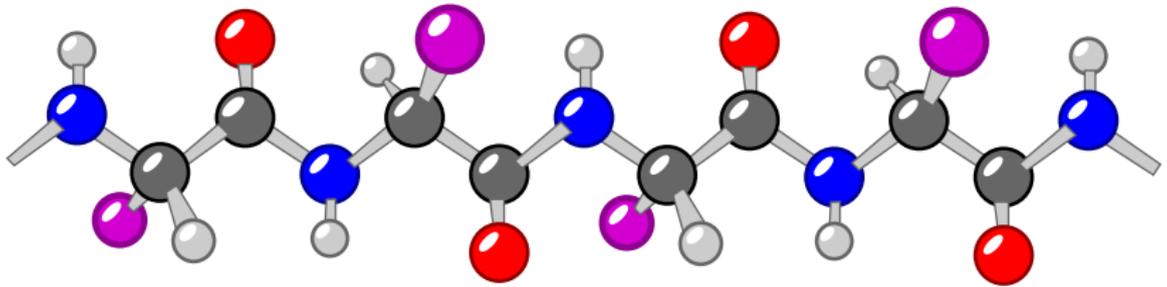


Herrmann Emil Fischer

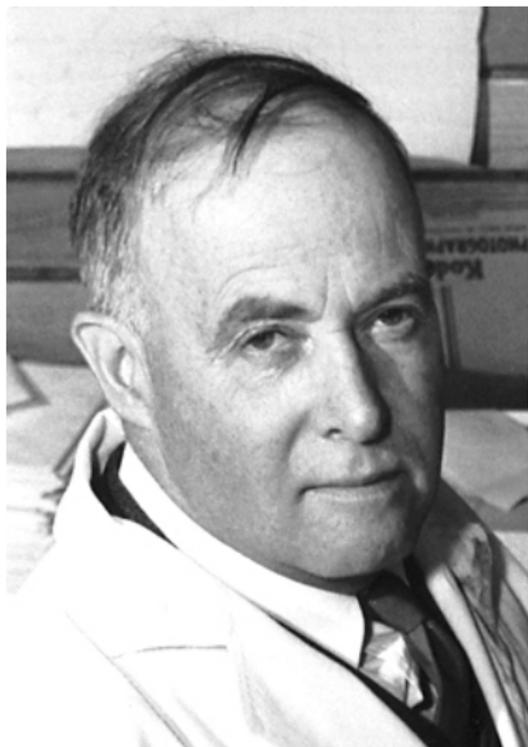


Charles University, Faculty of Medicine, Praha-Nové Město

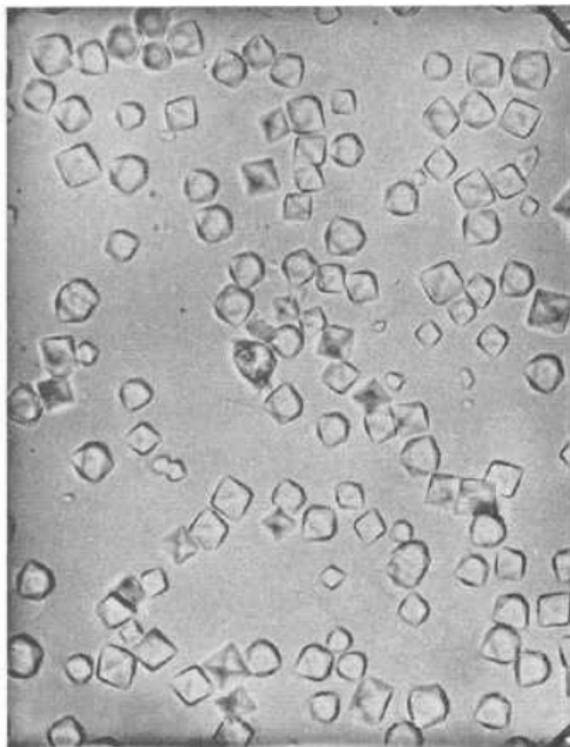
Proteins 1902



Protein crystals

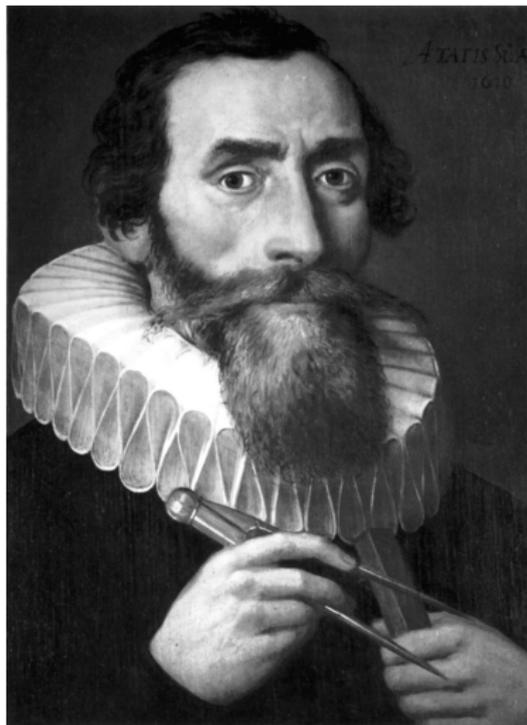


James B. Sumner



urease crystals

Protein crystals

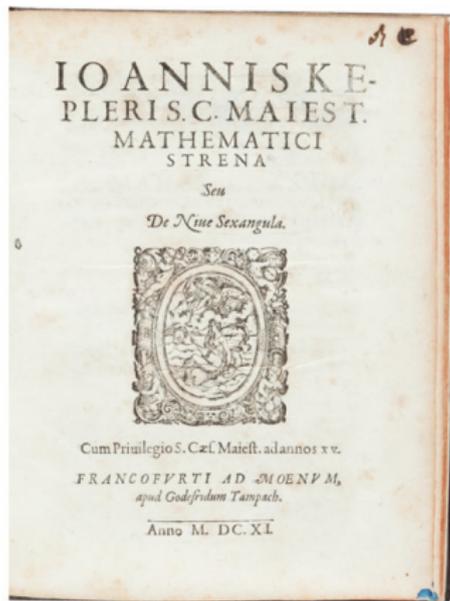


Johannes Kepler

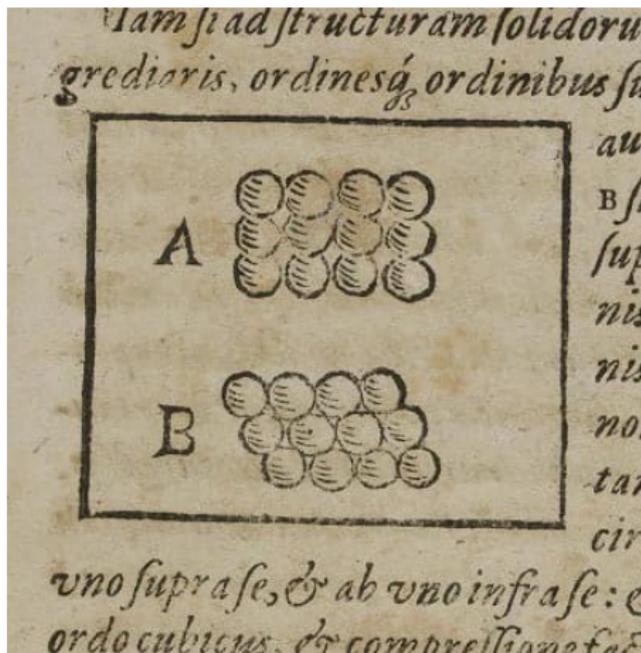


Karlova 4, Praha

Protein crystals

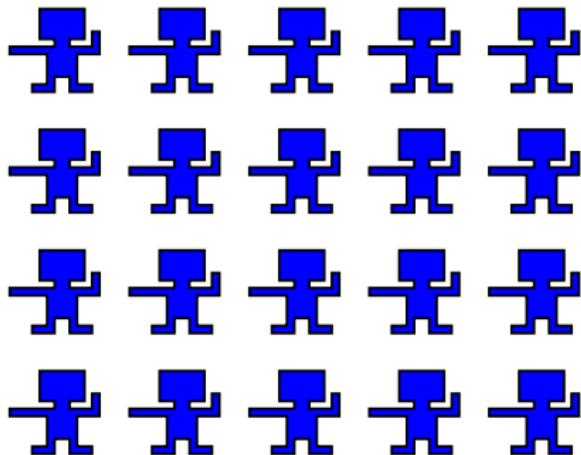
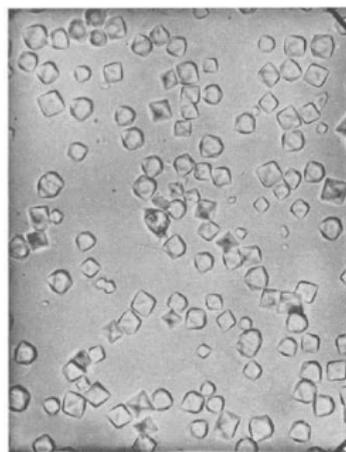
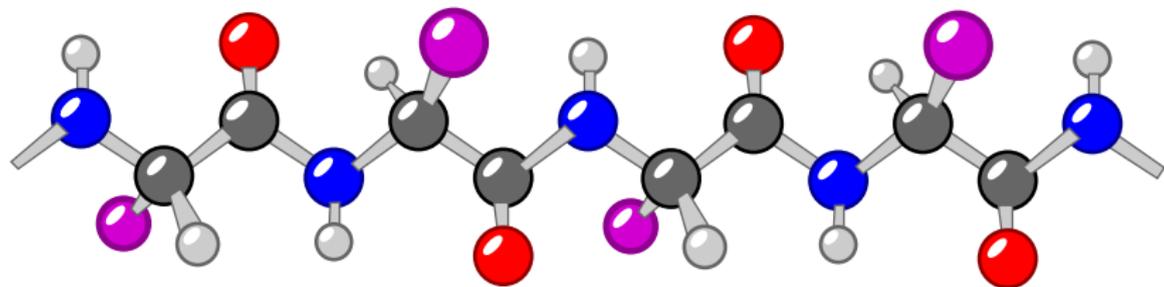


Imaged by Heritage Auctions, HA.com



Johannes Kepler: *Strena seu de nive sexangula*, 1611

Protein crystals



Crystals diffract X-rays

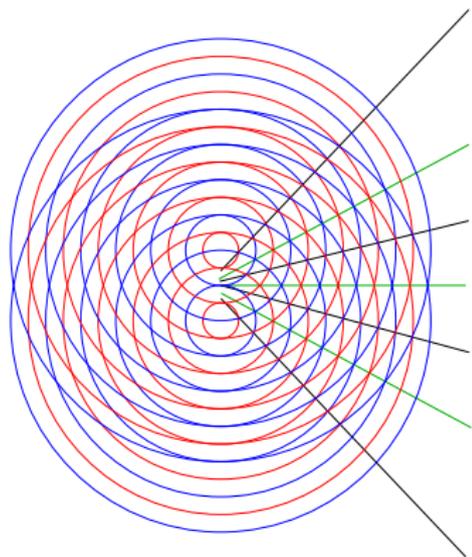


Max von Laue

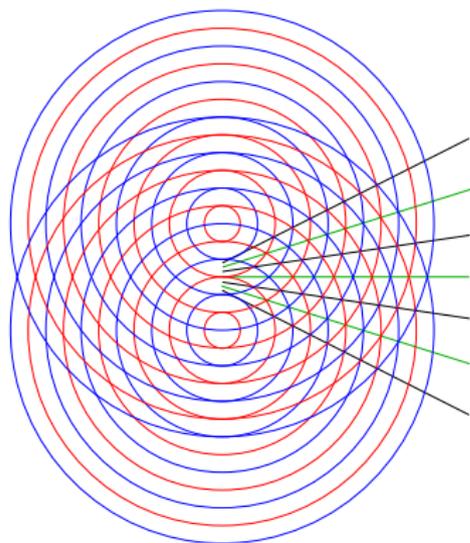
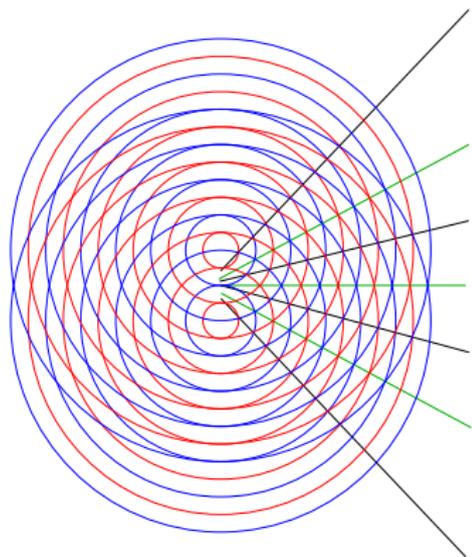


CuSO_4

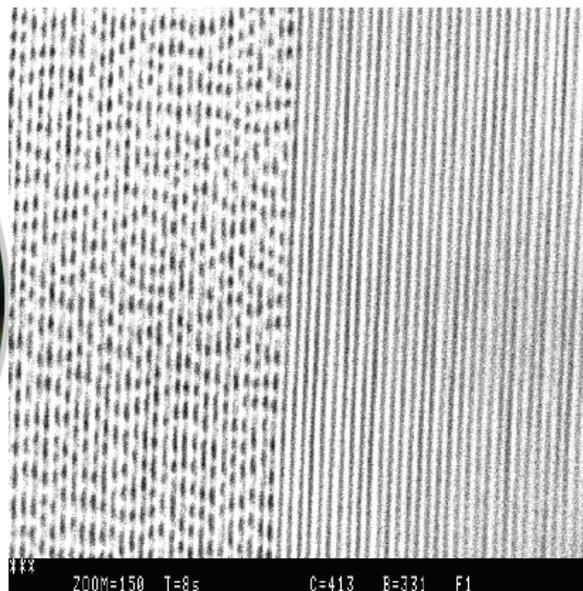
Crystals diffract X-rays



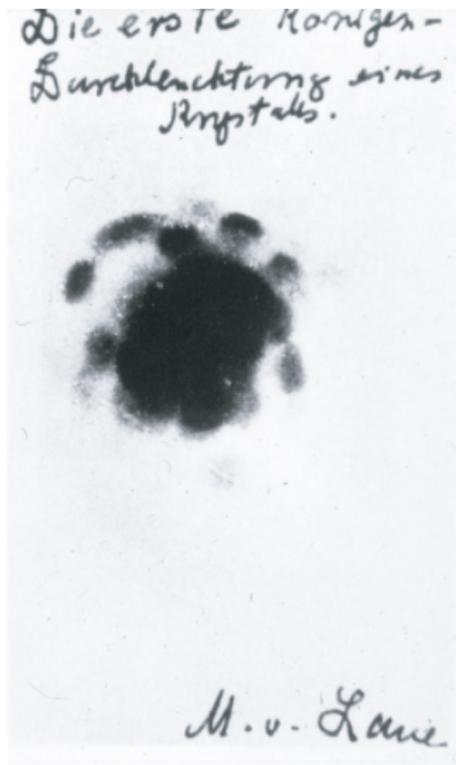
Crystals diffract X-rays



Crystals diffract X-rays



Crystals diffract X-rays



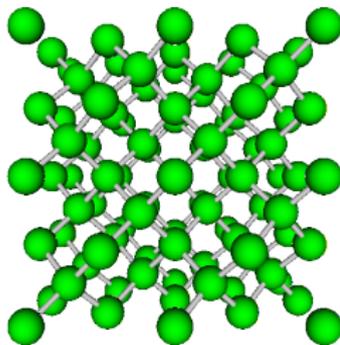
Max von Laue

Structure from diffraction



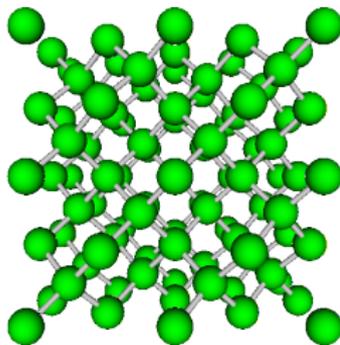
Silicon

Structure from diffraction

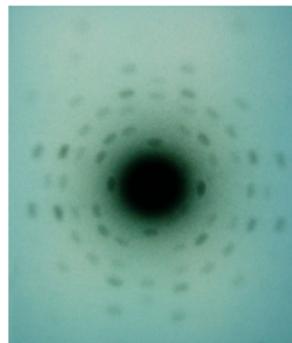


Silicon

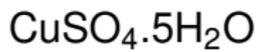
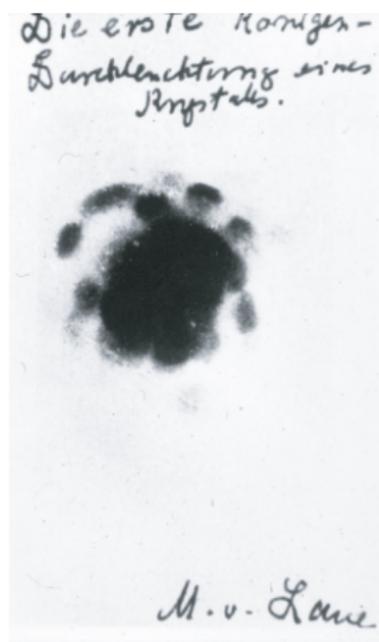
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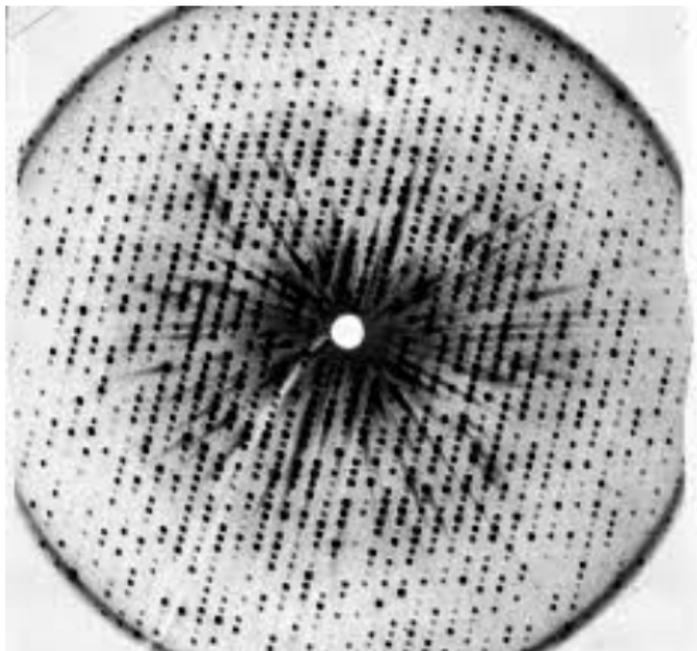
Silicon



Structure from diffraction



Structure from diffraction



Structure from diffraction

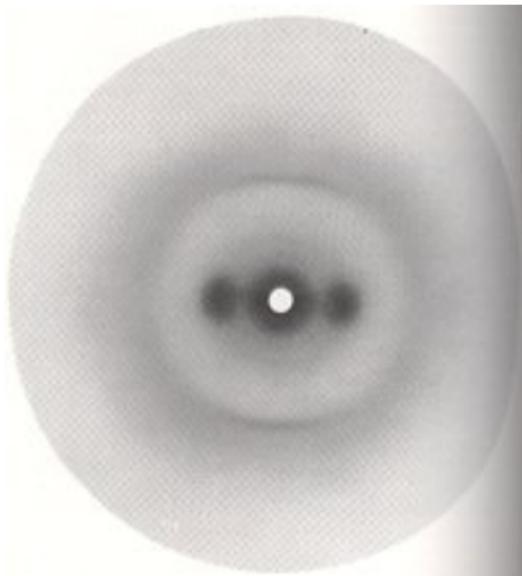


William T. Astbury

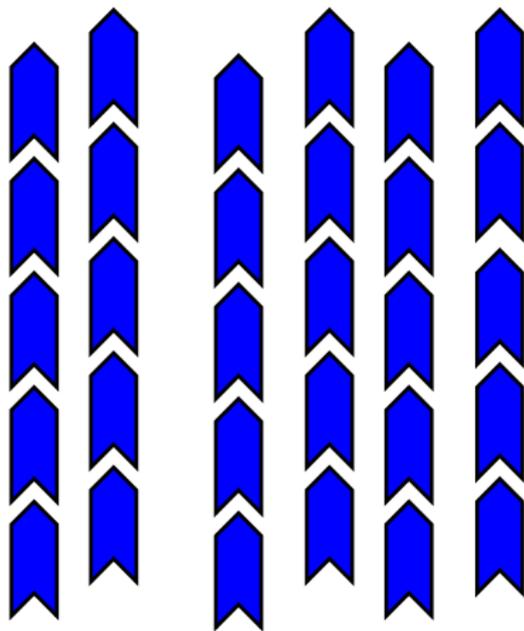
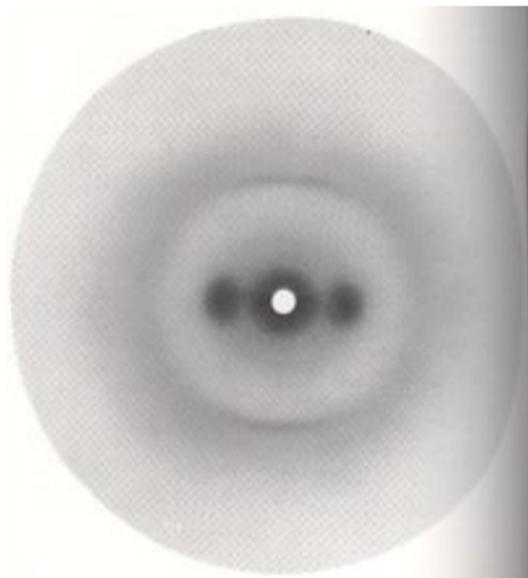


Mozart's hair

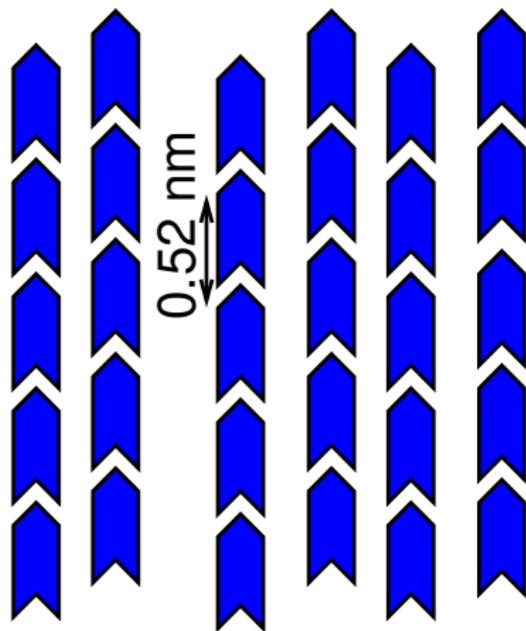
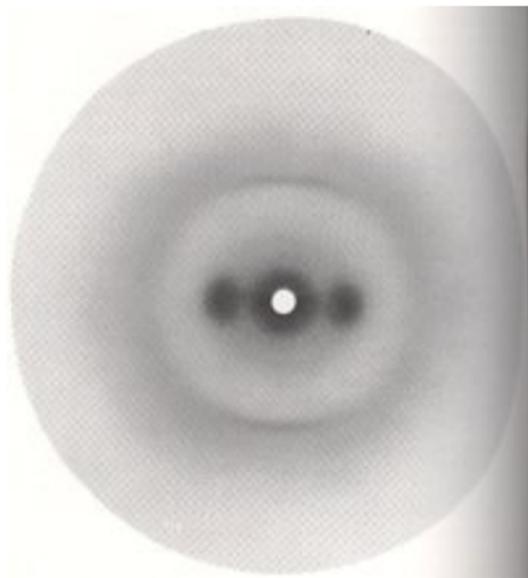
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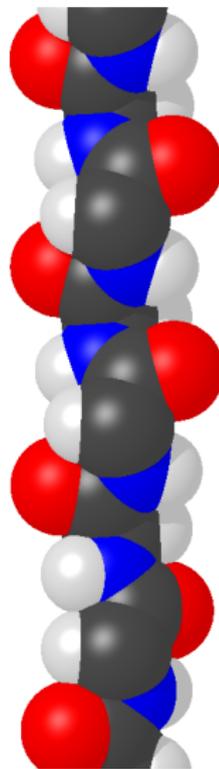
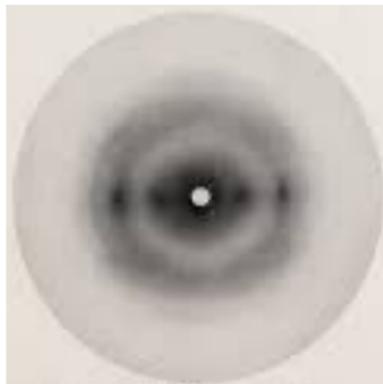
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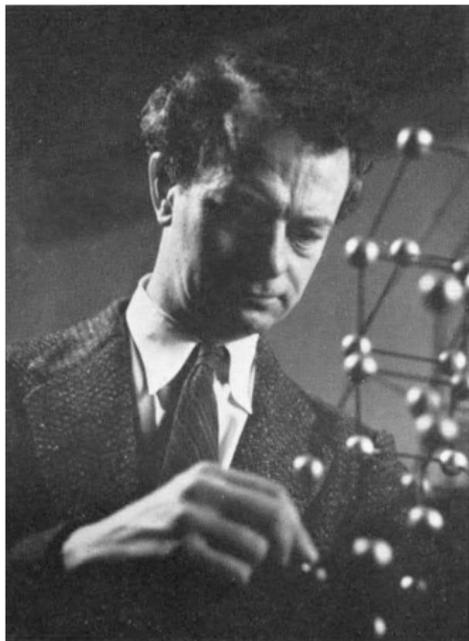
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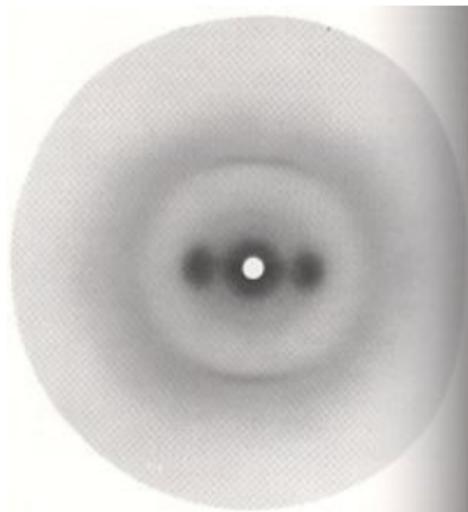
Structure from diffraction



Structure from diffraction

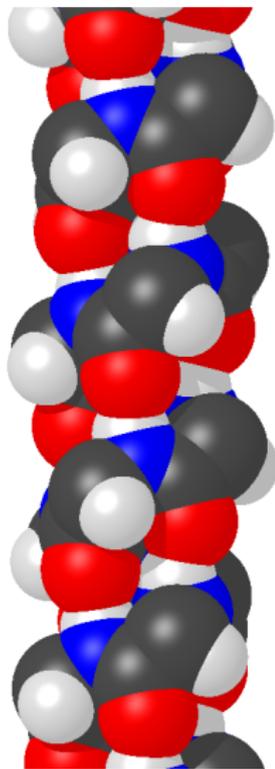
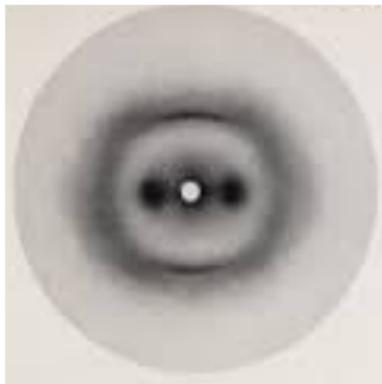


Linus Pauling

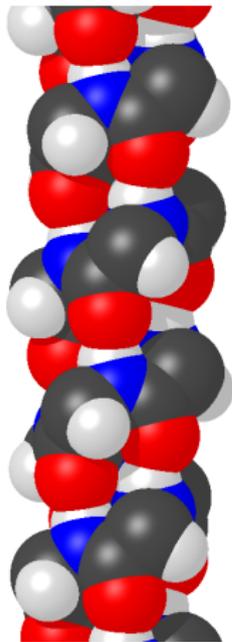


Mozart's hair

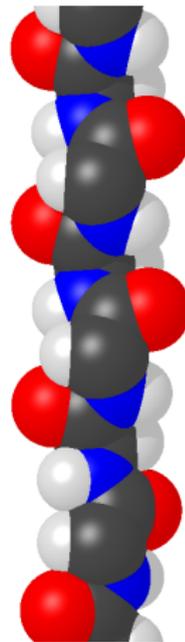
Structure from diffraction



Structure from diffraction

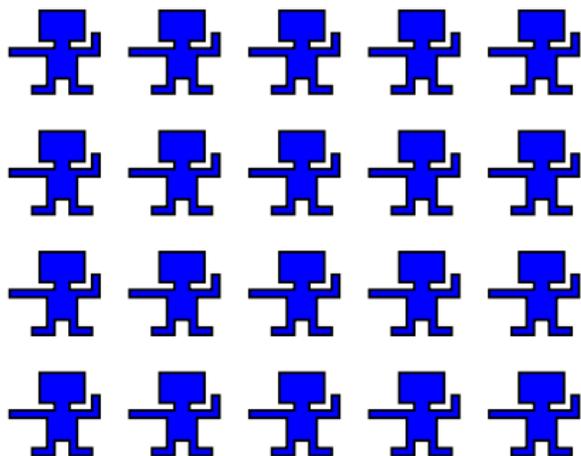
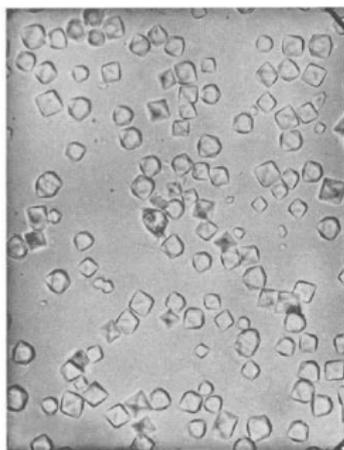


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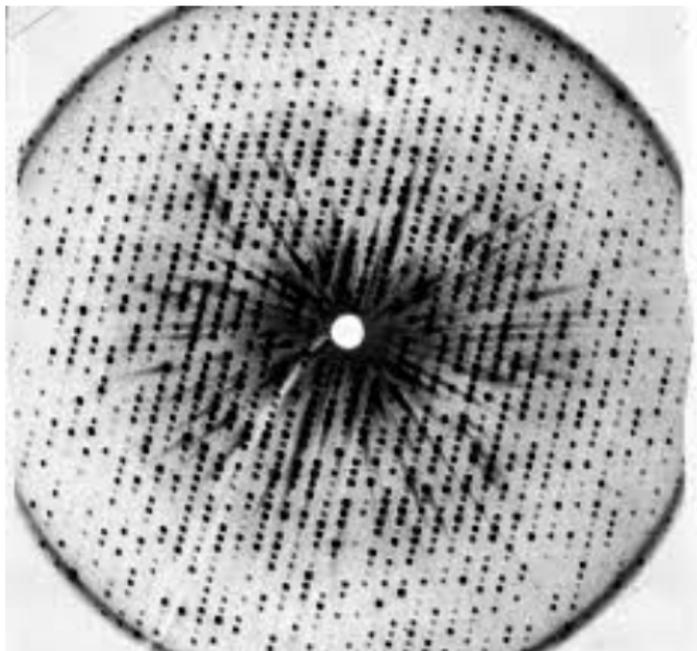


β

Protein crystallography



Protein crystallography



Protein crystallography

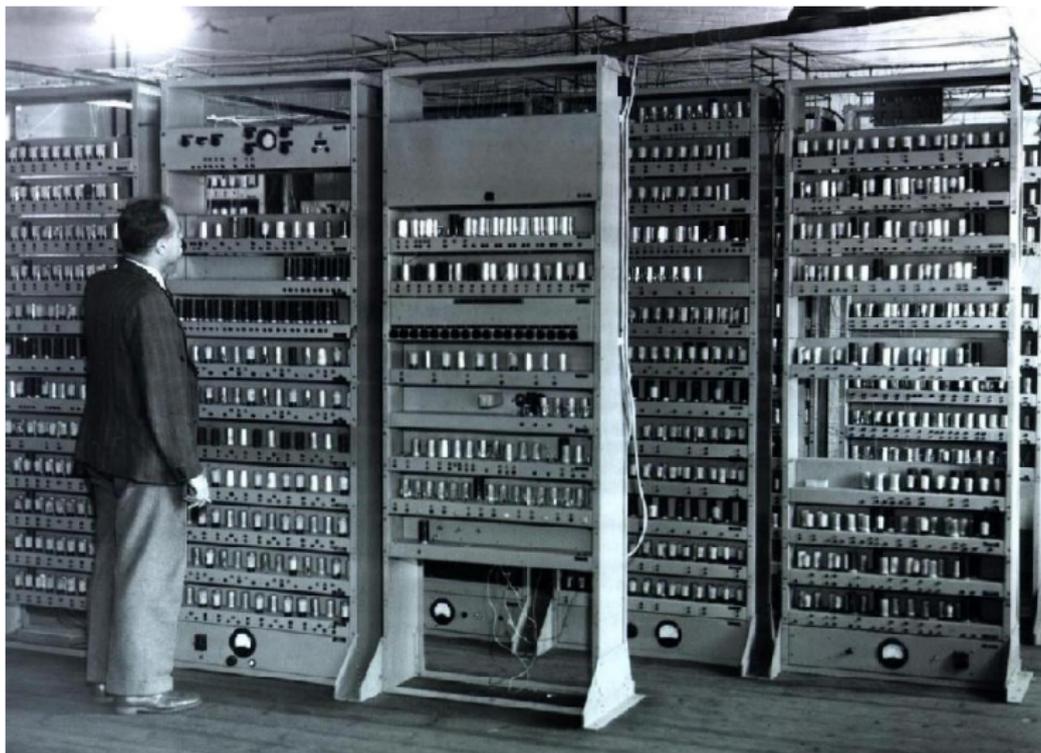


Max Perutz, John Kendrew

Protein crystallography

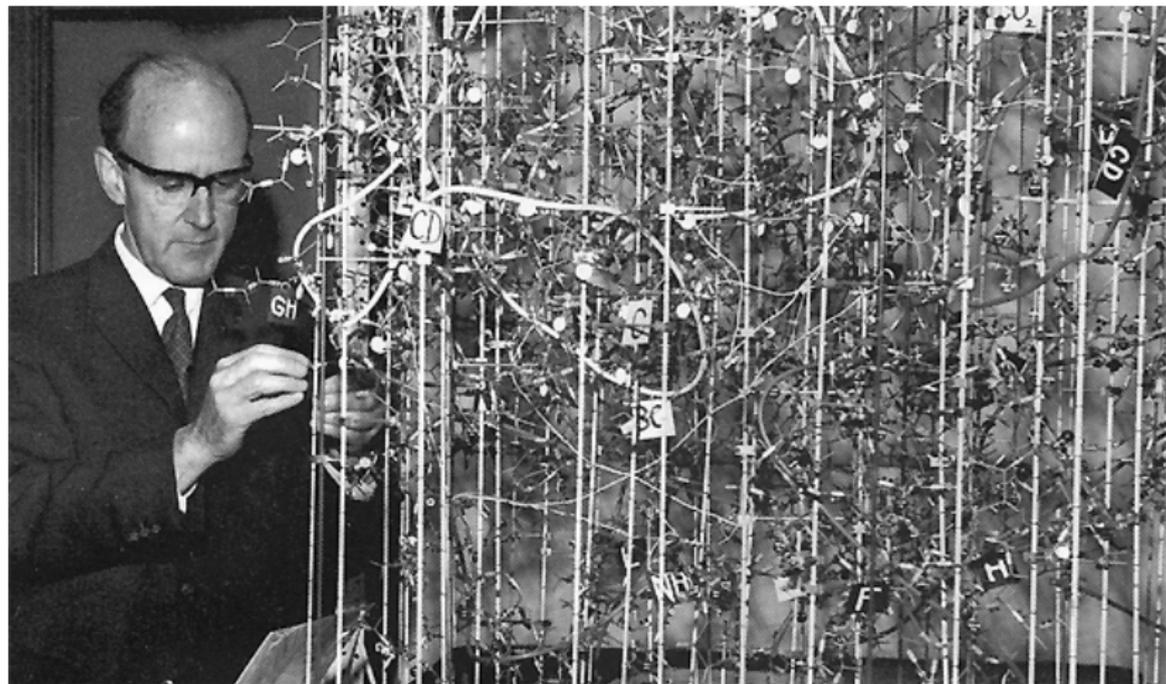


Protein crystallography

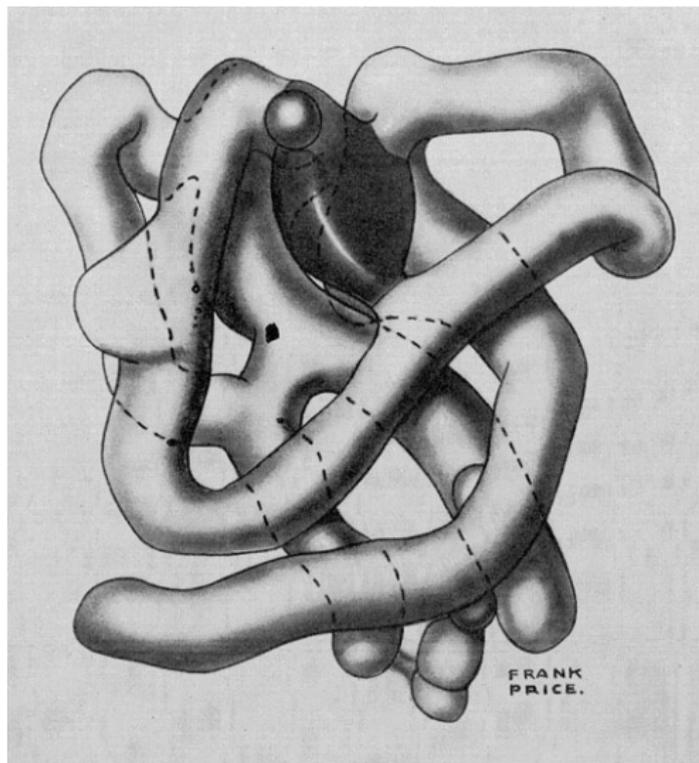


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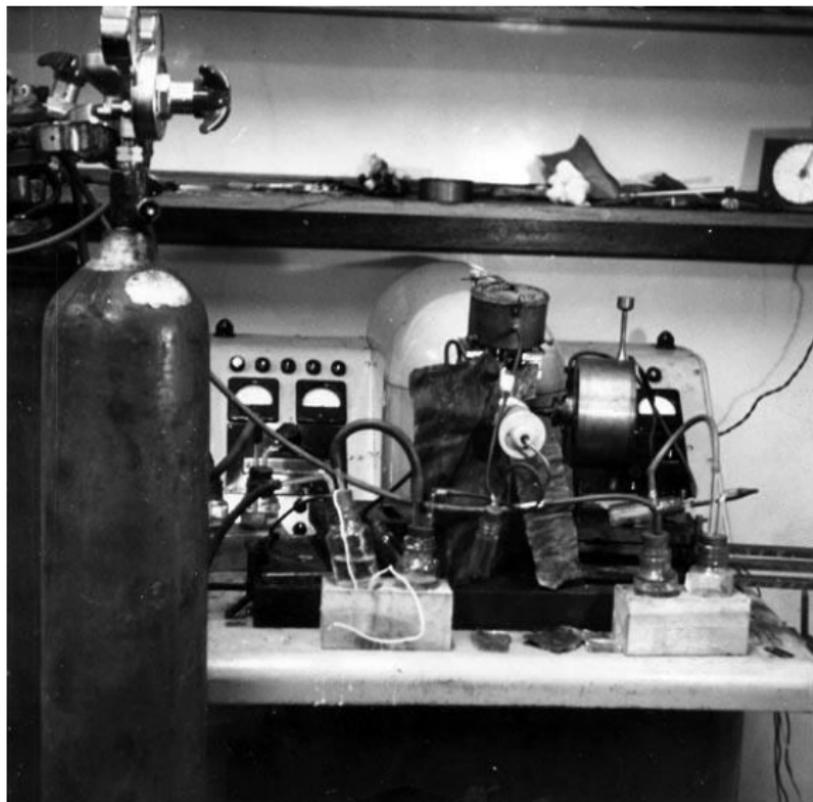
Protein crystallography



Protein crystallography



Protein crystallography



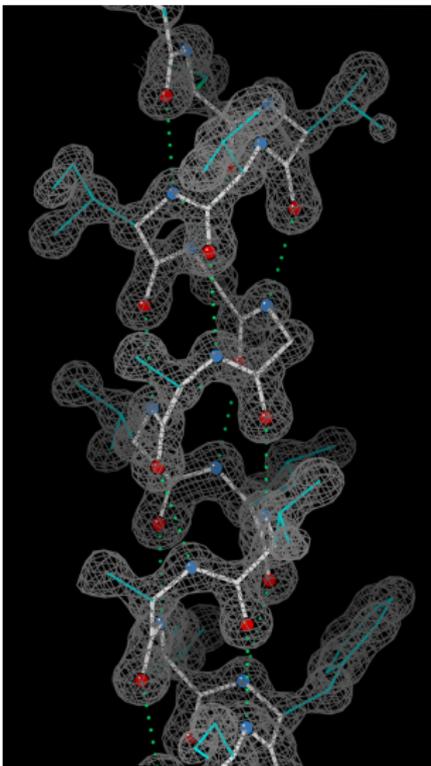
Diffractometer in 1940's

Protein crystallography

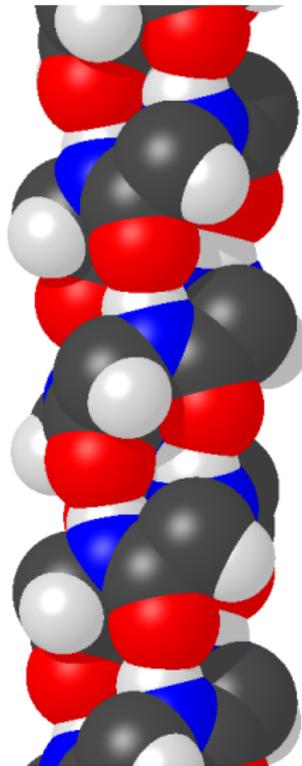
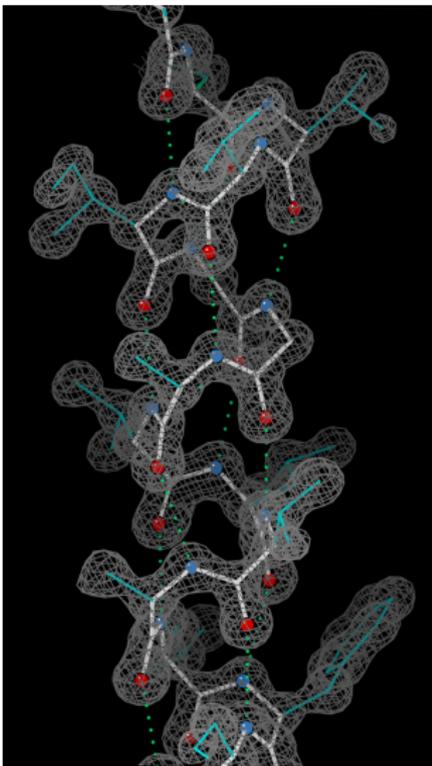


European Synchrotron Radiation Facility Grenoble

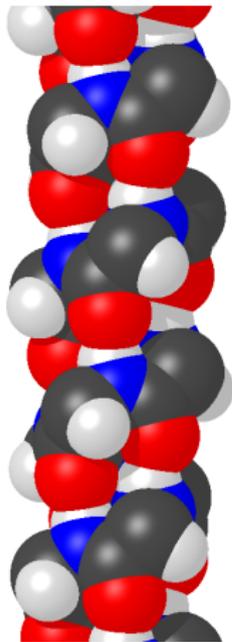
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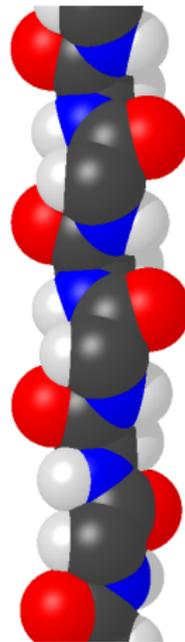
Protein crystallography



Protein structure



α

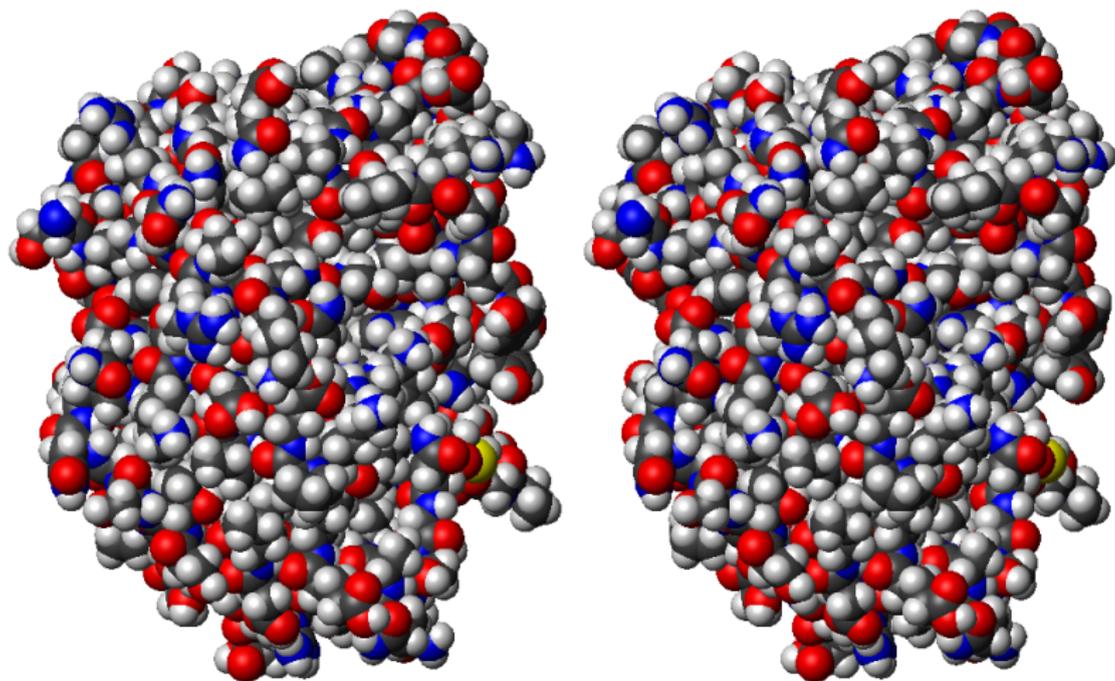


β

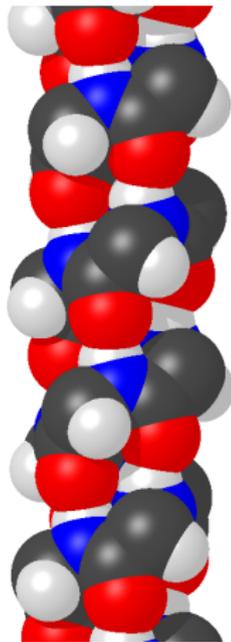
Protein structure



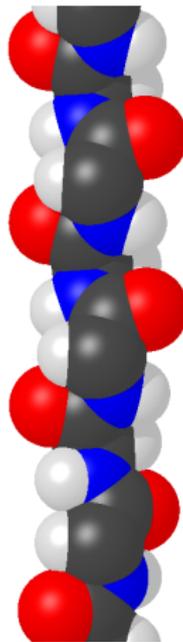
Protein structure



Protein structure



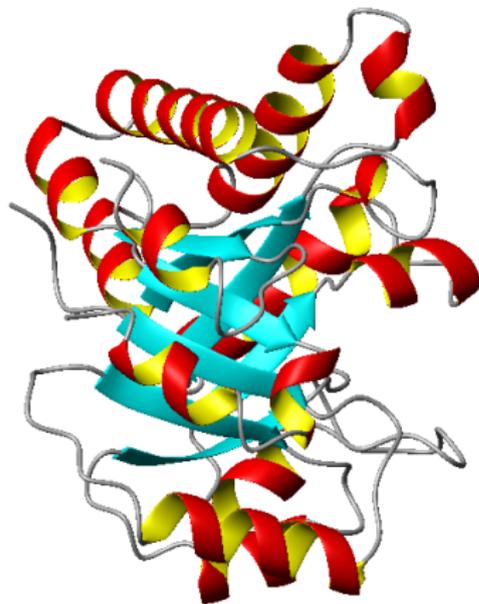
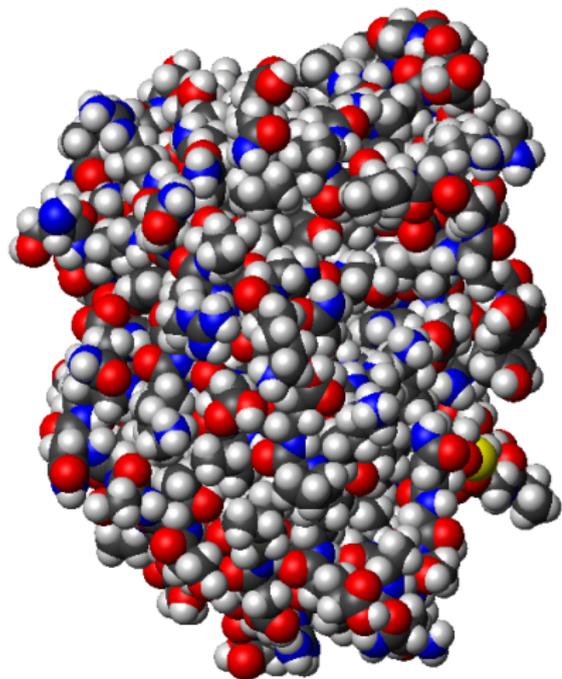
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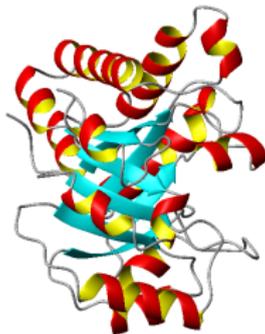
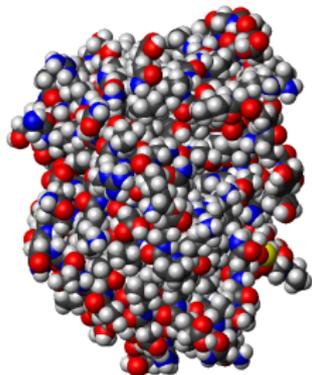
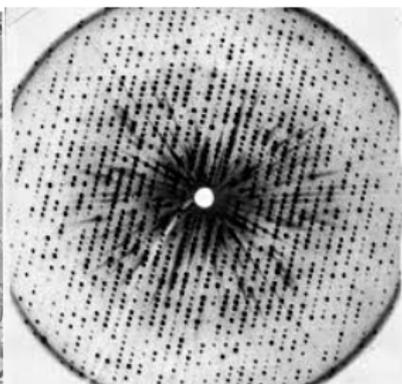
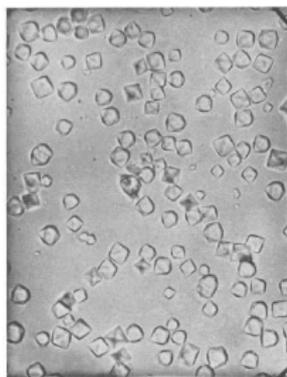
β



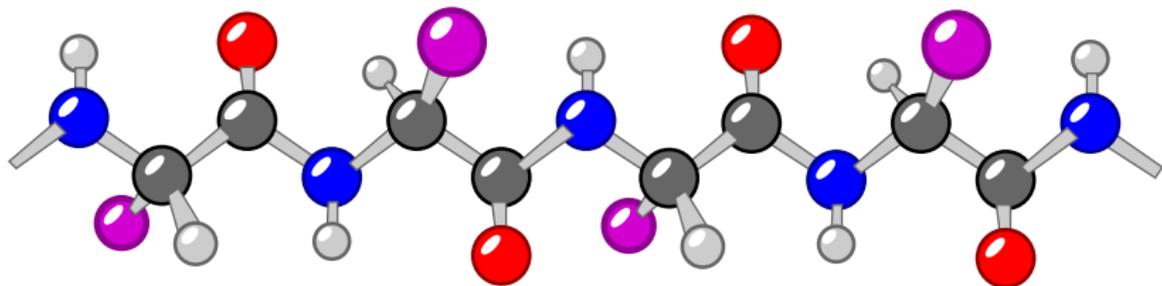
Protein structure



Protein structure



How is structure encoded



How is structure encoded

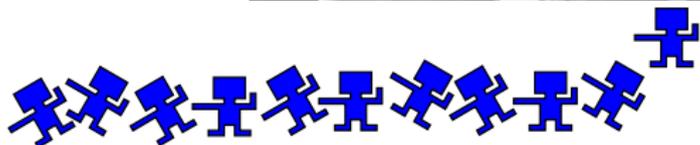
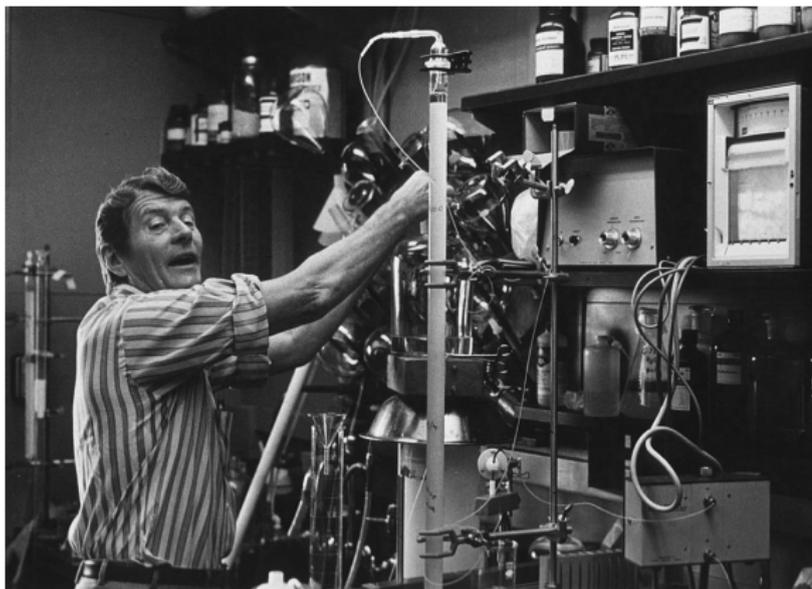


How is structure encoded

Myoglobin

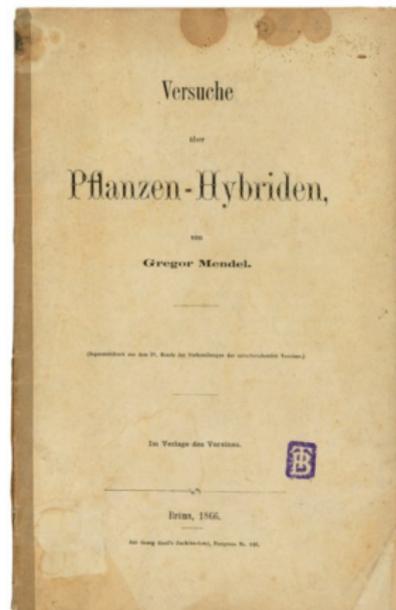
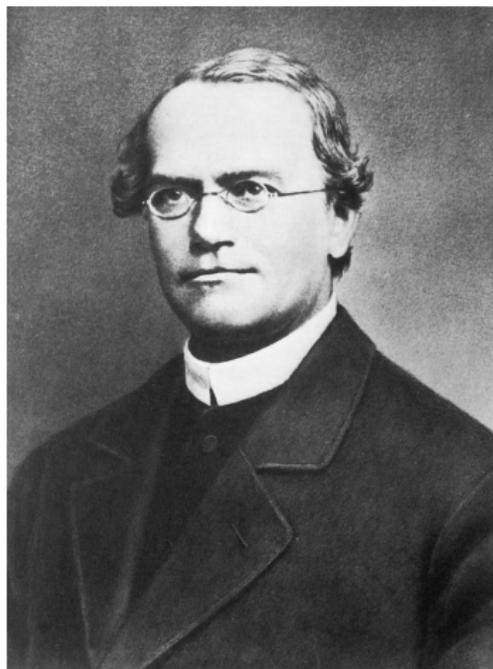
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How is structure encoded



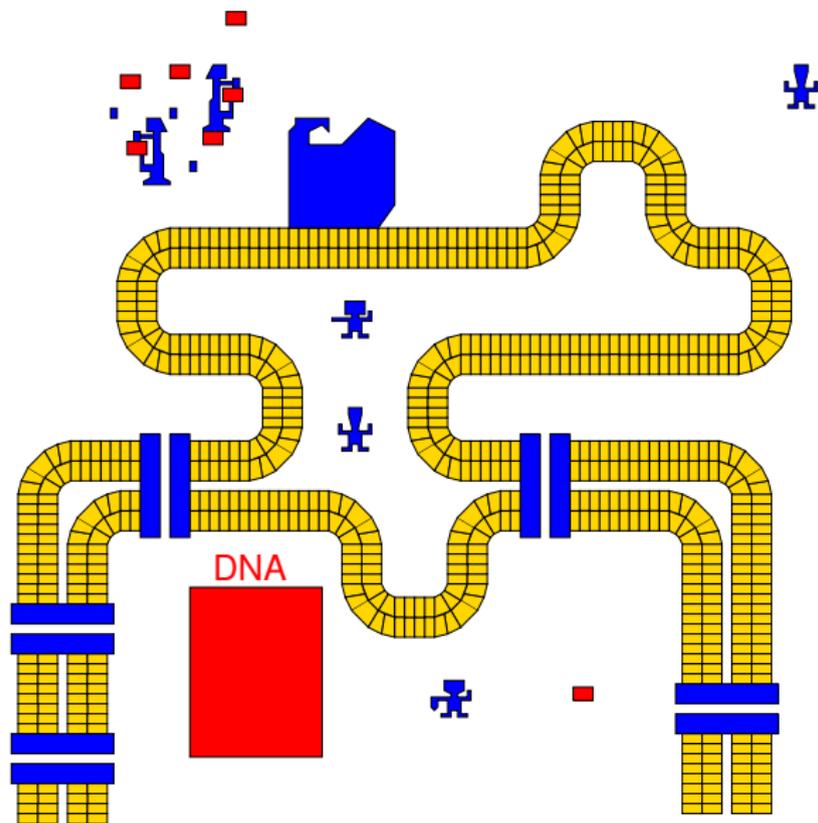
Christian Anfinsen: refolding ribonuclease, 1961

How is structure encoded

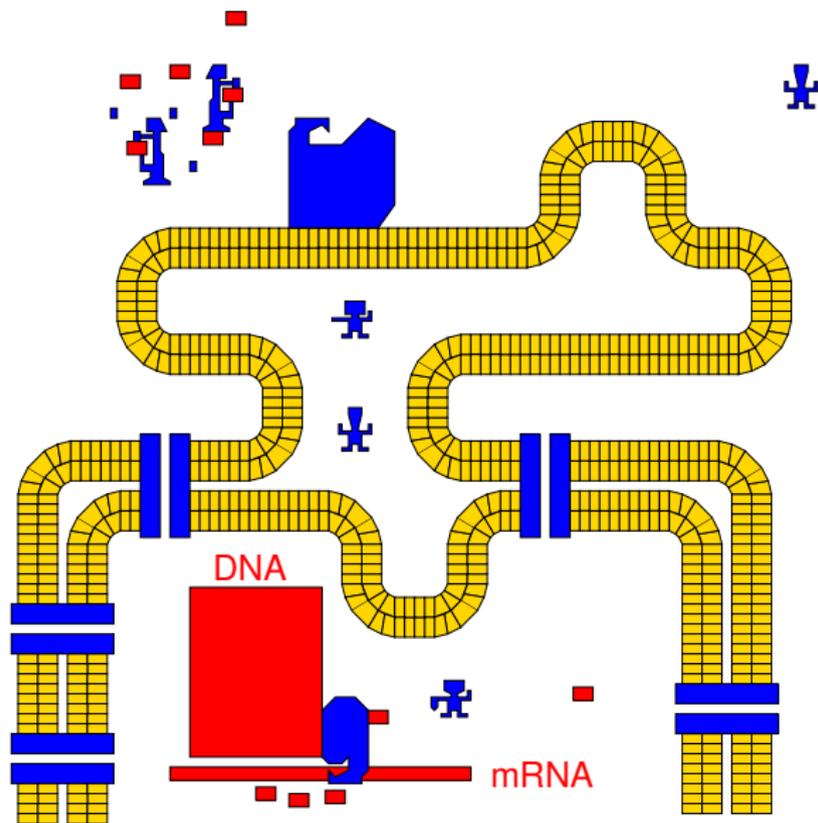


Johann Gregor Mendel: *Versuche über Pflanzen-Hybriden*,
1866

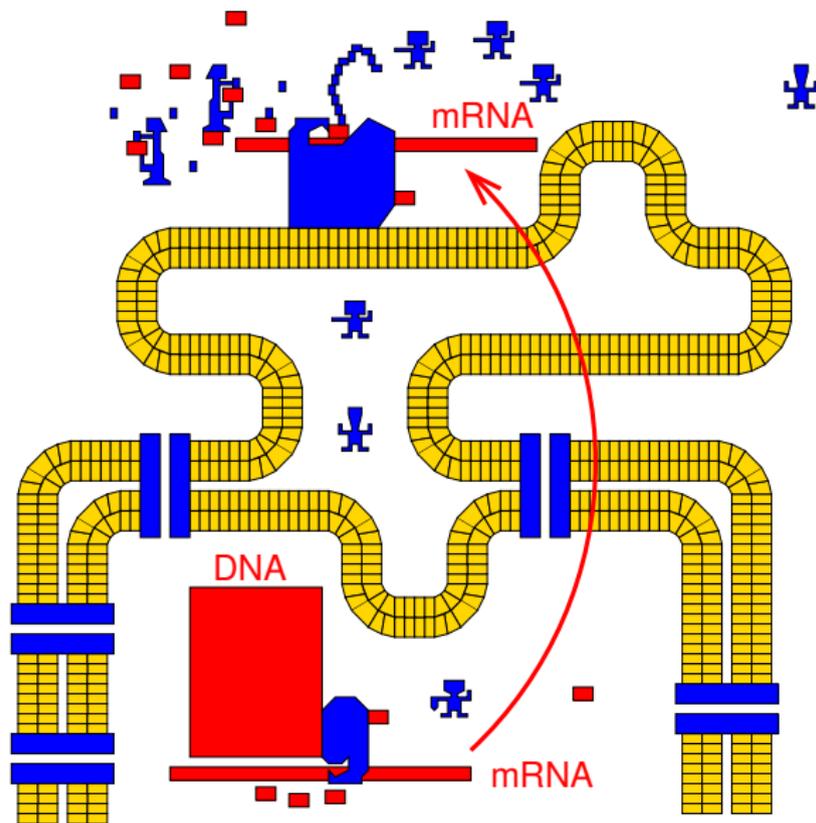
How is structure encoded



How is structure encoded



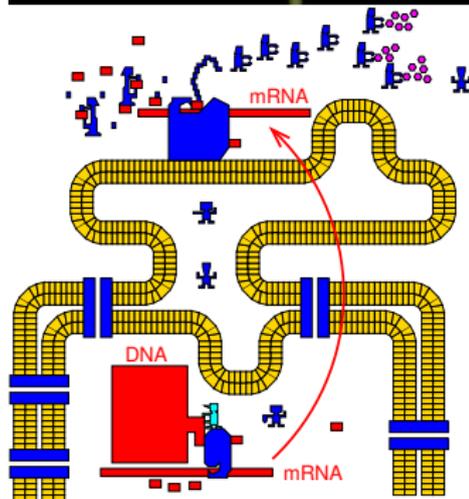
How is structure encoded



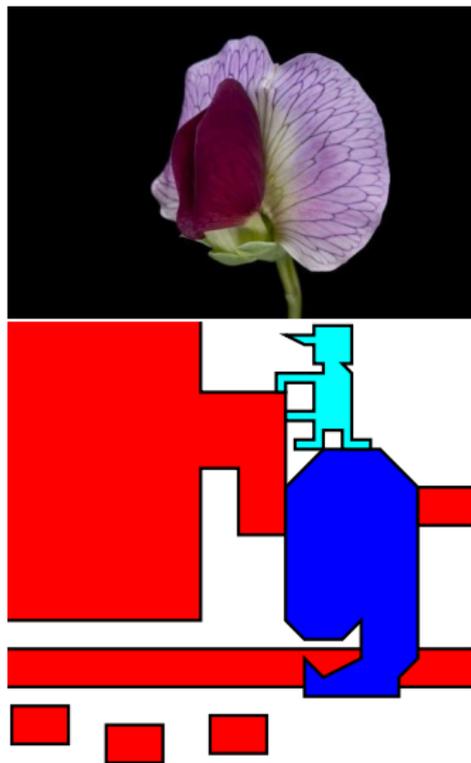
How is structure encoded



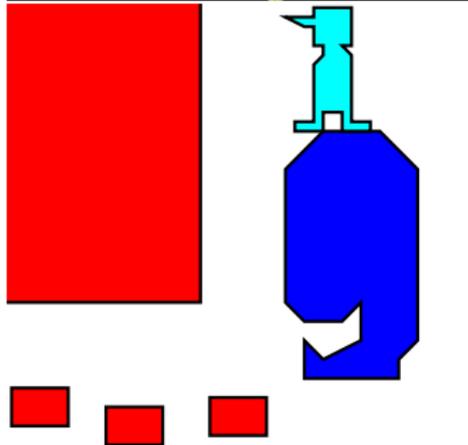
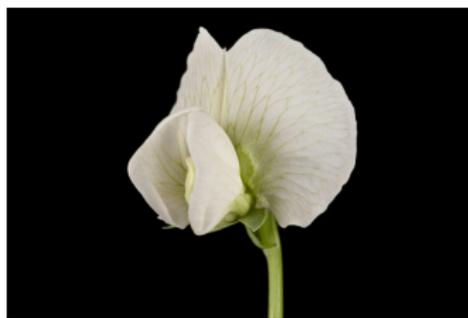
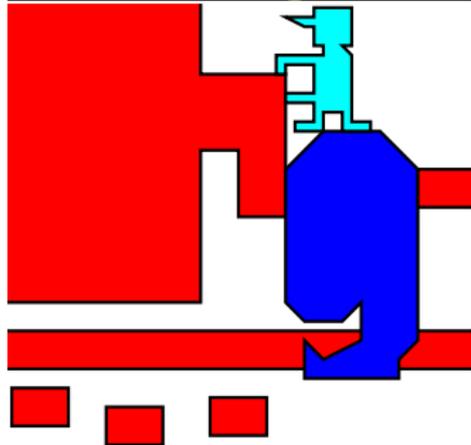
How is structure encoded



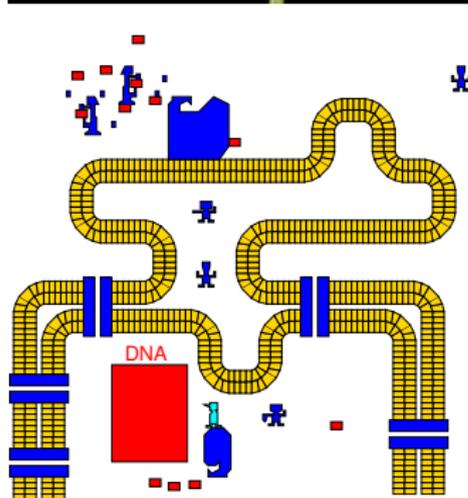
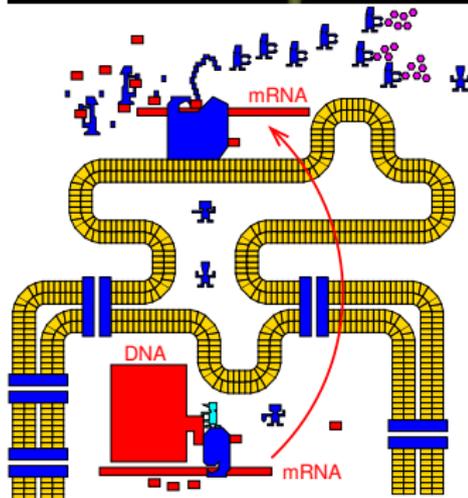
How is structure encoded



How is structure encoded



How is structure encoded



How is structure encoded

Year	organism	size
1977	bacteriophage ϕ X174	5 386
1984	Epstein-Barr virus	172 282
1995	<i>Haemophilus influenzae</i>	1 830 137
2003	<i>Homo sapiens</i>	3 088 286 401

- we determined thousands protein structures
- we know they are encoded genetically
- we can read genetic information

Article

Highly accurate protein structure prediction with AlphaFold

<https://doi.org/10.1038/s41586-021-03819-2>

Received: 11 May 2021

Accepted: 12 July 2021

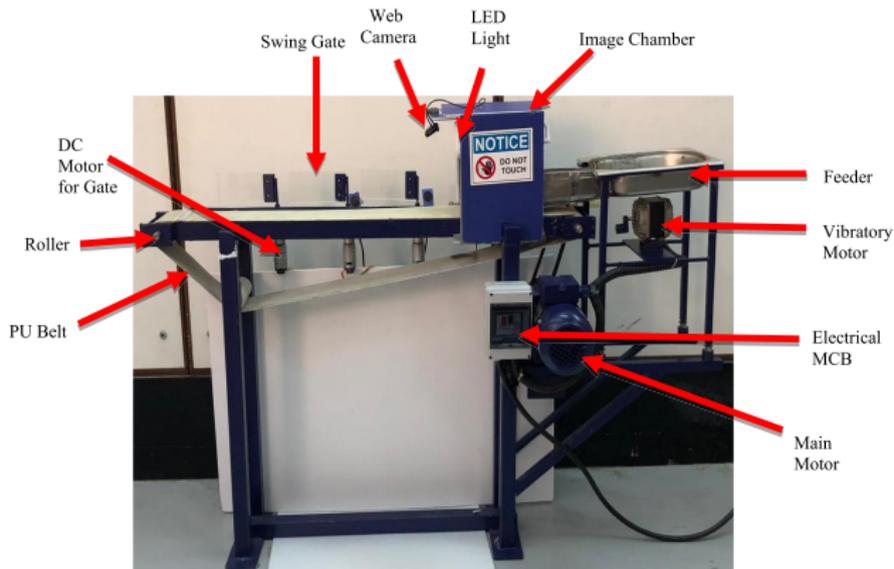
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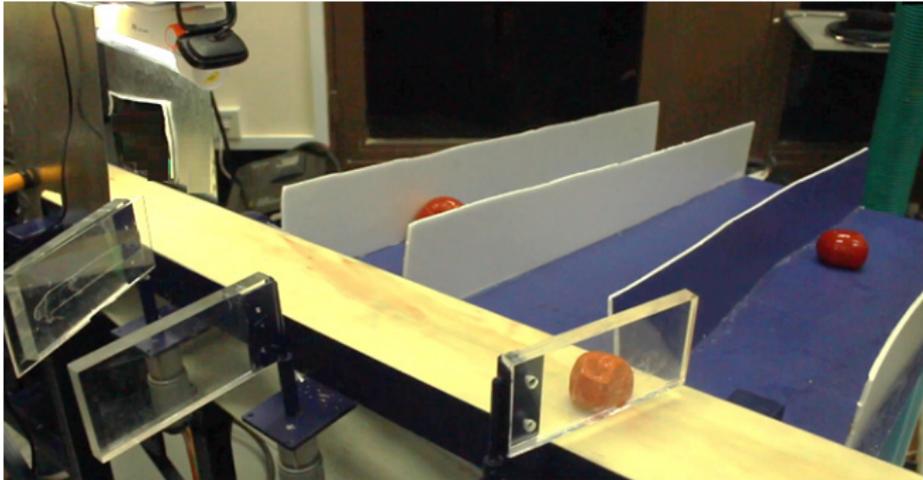
John Jumper^{1,4}, Richard Evans^{1,4}, Alexander Pritzel^{1,4}, Tim Green^{1,4}, Michael Figurnov^{1,4}, Olaf Ronneberger^{1,4}, Kathryn Tunyasuvunakool^{1,4}, Russ Bates^{1,4}, Augustin Židek^{1,4}, Anna Potapenko^{1,4}, Alex Bridgland^{1,4}, Clemens Meyer^{1,4}, Simon A. A. Kohl^{1,4}, Andrew J. Ballard^{1,4}, Andrew Cowie^{1,4}, Bernardino Romera-Paredes^{1,4}, Stanislav Nikolov^{1,4}, Rishub Jain^{1,4}, Jonas Adler¹, Trevor Back¹, Stig Petersen¹, David Reiman¹, Ellen Clancy¹, Michal Zielinski¹, Martin Steinegger^{2,3}, Michalina Pacholska¹, Tamas Berghammer¹, Sebastian Bodenstern¹, David Silver¹, Oriol Vinyals¹, Andrew W. Senior¹, Koray Kavukcuoglu¹, Pushmeet Kohli¹ & Demis Hassabis^{1,4}

Predicting structure



Haggag, M. et al, IEEE Access 7 (2019) 106890–106898.

Predicting structure



Haggag, M. et al, IEEE Access 7 (2019) 106890–106898.

Predicting structure

Input training images for the three classes: unripe, ripe, and overripe.

Class	Images		
Unripe (Green/Green-red)			
Ripe (red)			
Defective (Overripe/rotten)			

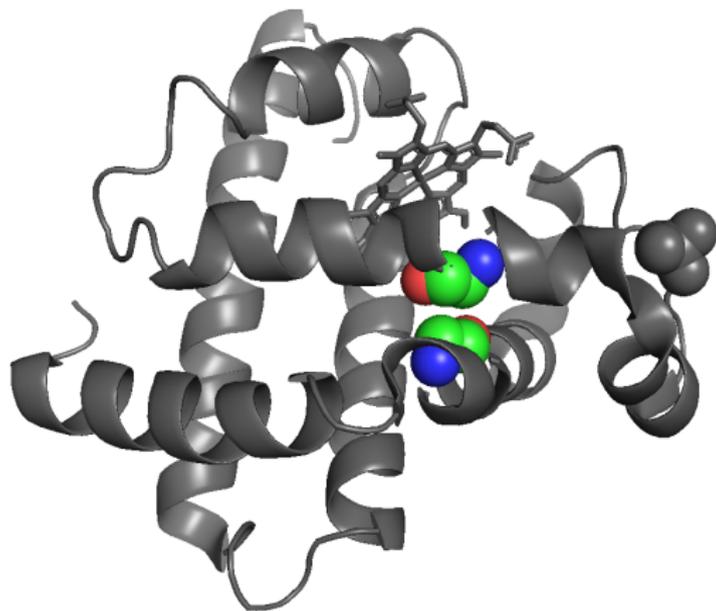
Haggag, M. et al, IEEE Access 7 (2019) 106890–106898.

Predicting structure

		24	64
<i>Physeter macrocephalus</i>	sperm whale	HGQ	HGVTV
<i>Balaena mysticetus</i>	bowhead	HGQ	HGNTV
<i>Sus scrofa</i>	pig	HGQ	HGNTI
<i>Orycteropus afer afer</i>	aardvark	HGQ	HGTTV
<i>Equus caballus</i>	horse	HGQ	HGTVV
<i>Homo sapiens</i>	man	HGQ	HGATV

G small

Predicting structure

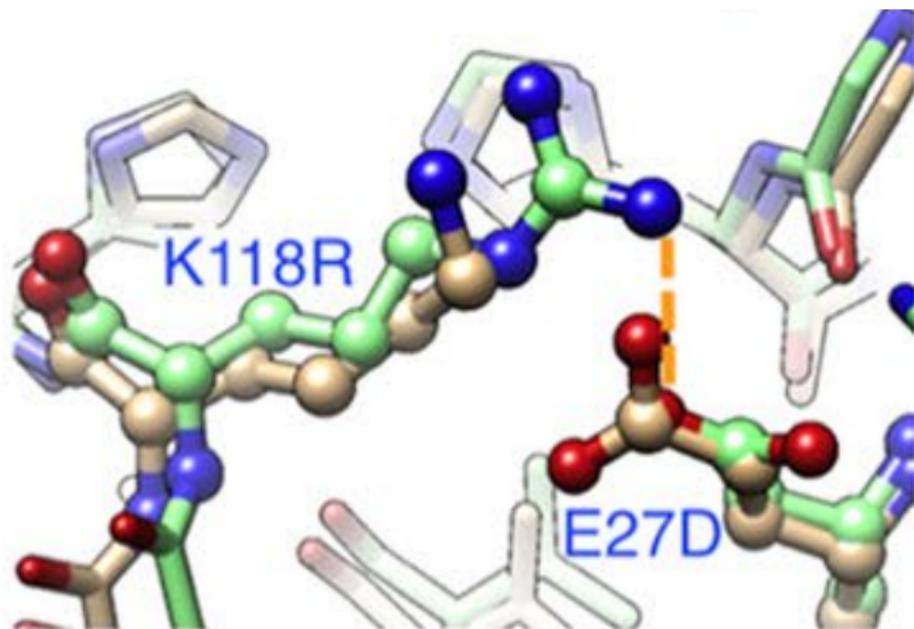


Predicting structure

<i>Physeter macrocephalus</i>	sperm whale	26	116
<i>Balaena mysticetus</i>	bowhead	Q D H	HS R H
<i>Sus scrofa</i>	pig	Q E H	QS K H
<i>Orycteropus afer afer</i>	aardvark	Q E H	QS K H
<i>Equus caballus</i>	horse	Q E H	HS K H
<i>Homo sapiens</i>	man	Q E H	QS K H

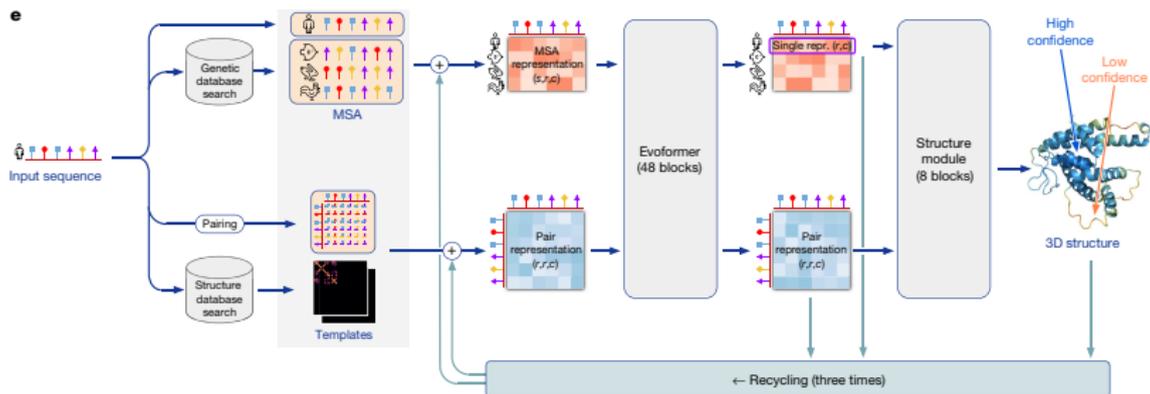
short-**D** ⊖ ... ⊕ **R** - l o n g
l o n g - **E** ⊖ ... ⊕ **K** - short

Predicting structure



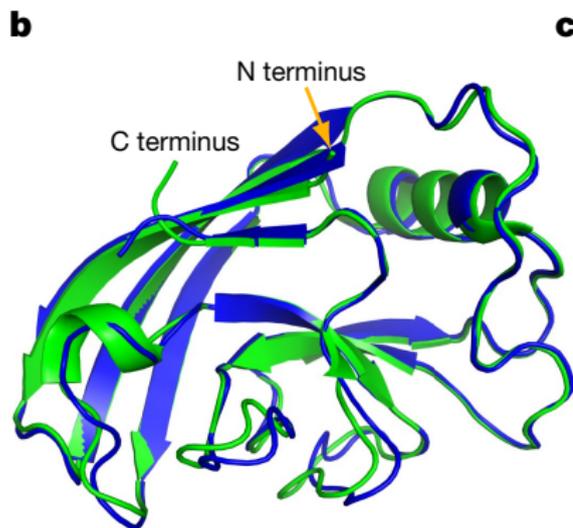
Isogai, Y., et al. Sci Rep 8 (2018) 16883.

Predicting structure



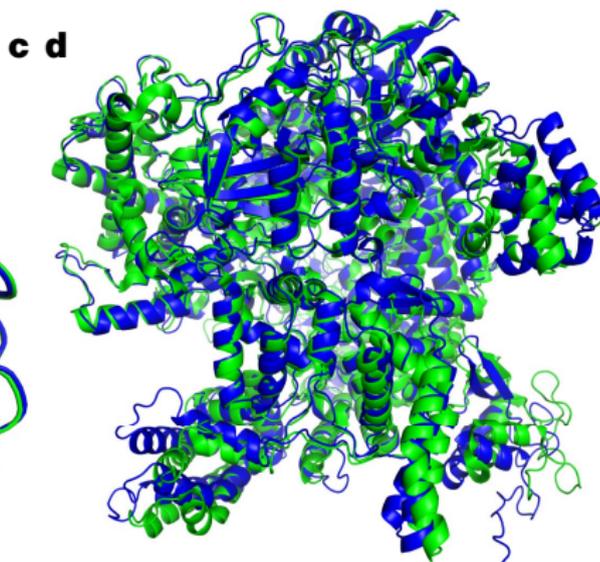
Jumper et al., Nature 596 (2021) 583–593

Predicting structure



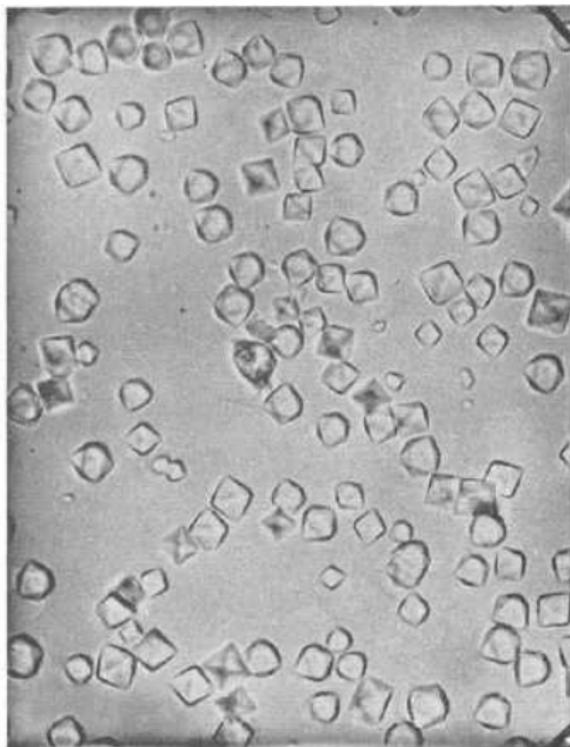
AlphaFold Experiment

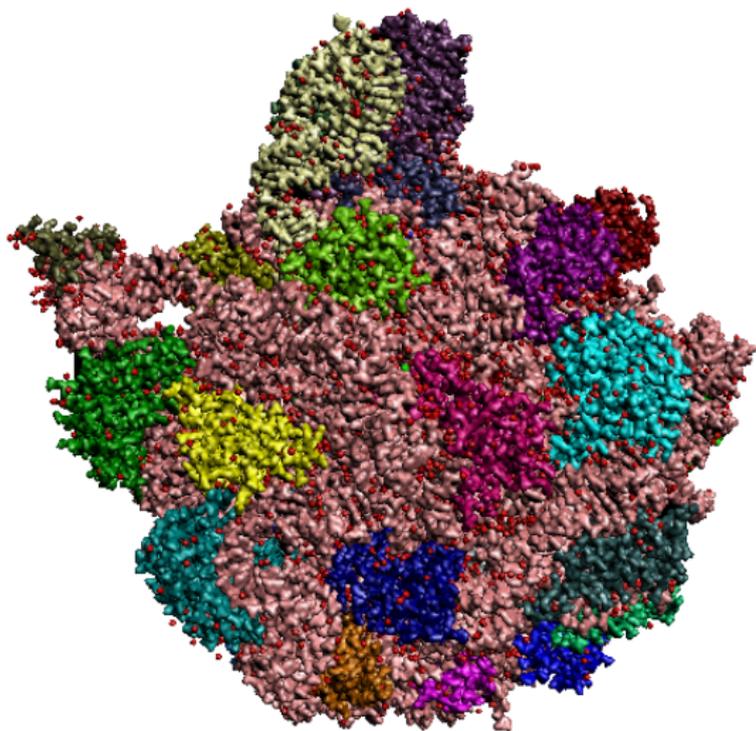
Jumper et al., Nature 596 (2021) 583–593



AlphaFold Experiment

Crystallization







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EXPLORER

ENTERPRISE

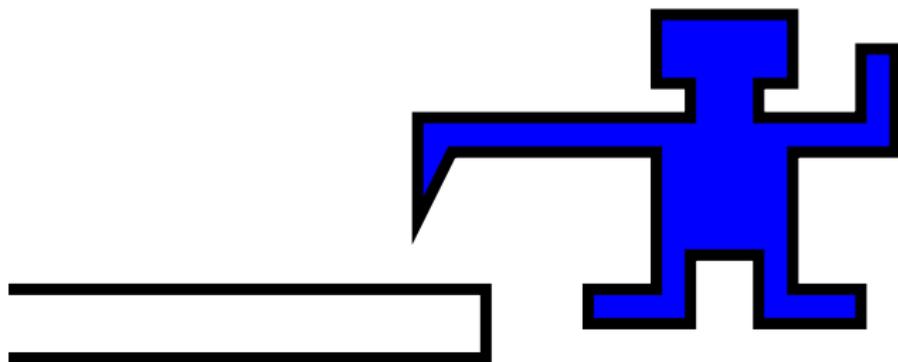
Spot Explorer is designed for developers eager to explore how flexible mobile robots can be adapted for tasks ranging from industrial inspection to entertainment.

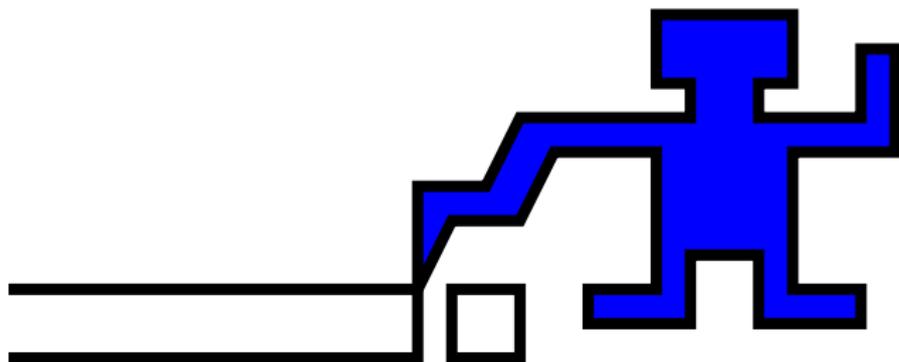
Spot comes ready to operate, right out of the box. With its flexible API and payload interfaces, Spot can be customized for a variety of applications. Spot is available for commercial use only.

\$74,500.00

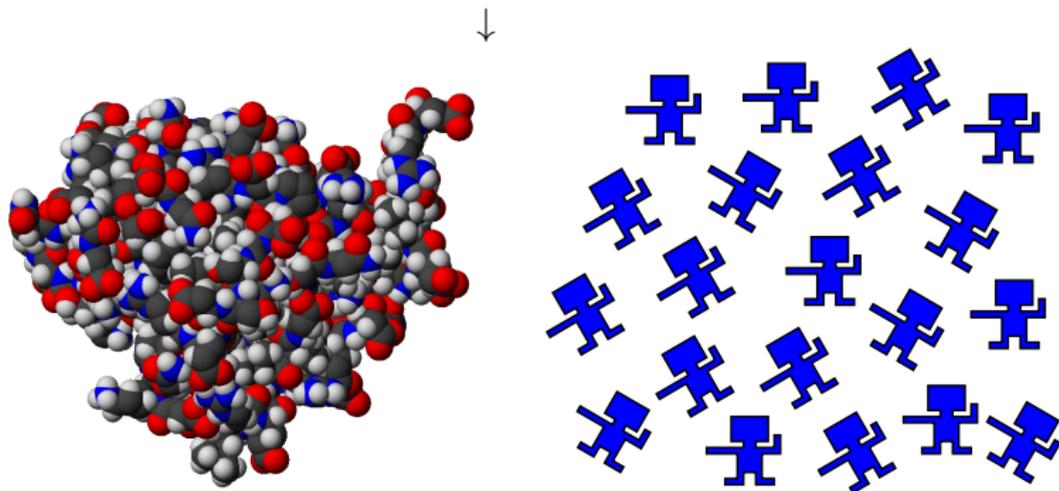
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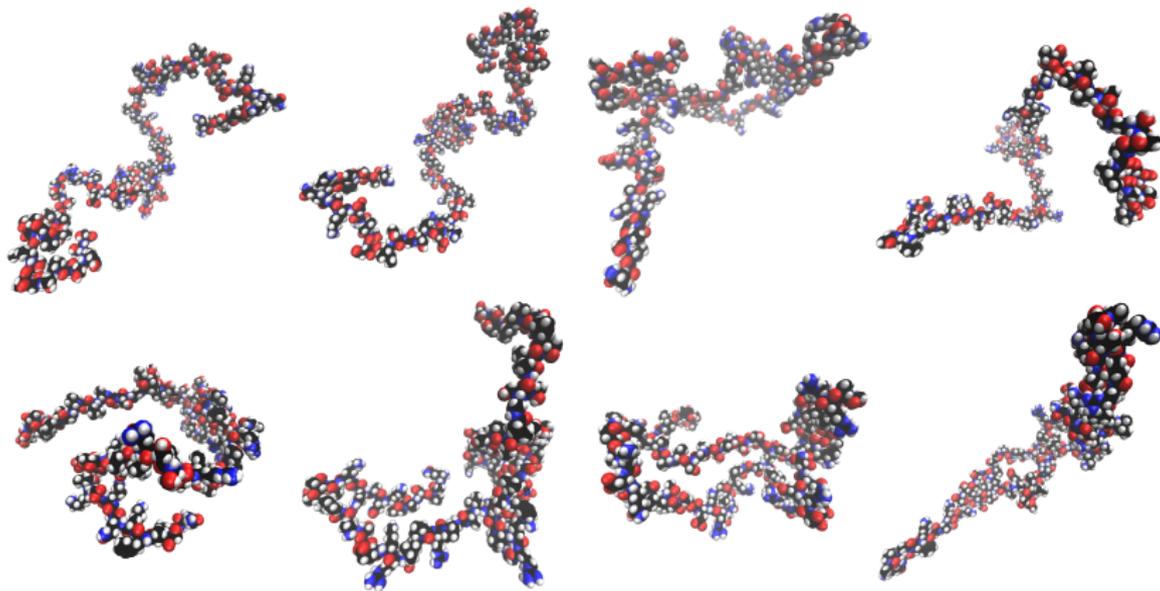


Intrinsically disordered proteins

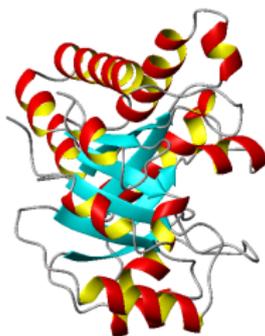
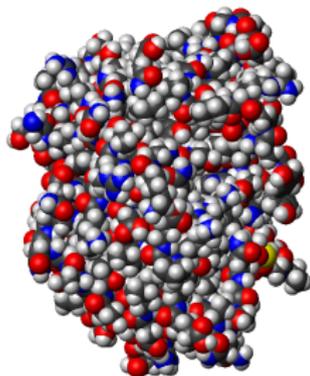
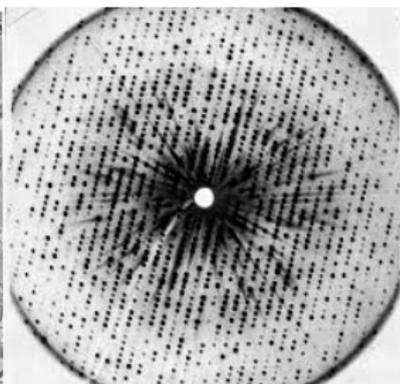
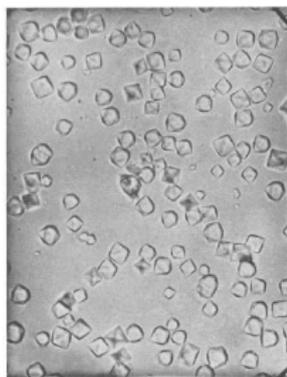
- 25–40 % proteins from eukaryotic genome contain disordered sequences longer than 30 amino acids
- Related to various human diseases
- Well-defined biological function

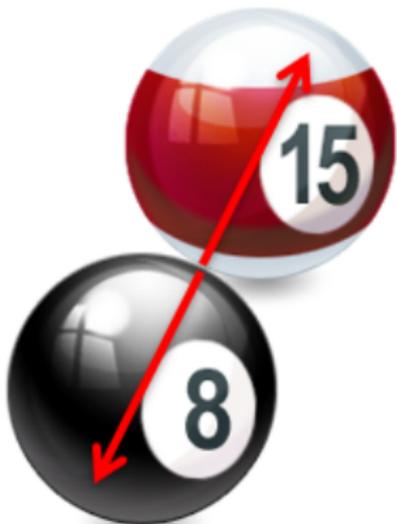


Intrinsically disordered proteins



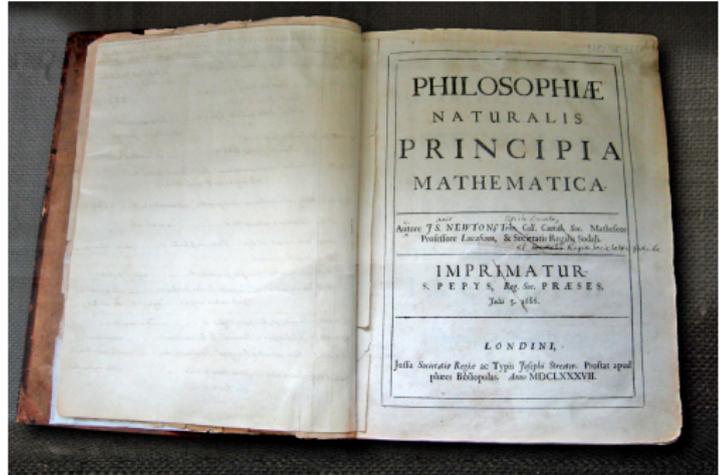
Protein structure from X-ray diffraction







Isaac Newton.



Isaac Newton: *Philosophiæ Naturalis Principia Mathematica*, 1687



THE
LONDON, EDINBURGH AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FOURTH SERIES.]

MARCH 1861.

XXV. On Physical Lines of Force. By J. C. MAXWELL, Professor of Natural Philosophy in King's College, London.*

PART I.—The Theory of Molecular Forces applied to Magnetic Phenomena.

IN all phenomena involving attractions or repulsions, or any forces depending on the relative positions of bodies, we have to determine the magnitude and direction of the force which would act on a given body, if placed in a given position.

In the case of a body acted on by the gravitation of a sphere, this force is inversely as the square of the distance, and in a straight line to the centre of the sphere. In the case of two attracting spheres, or of a body not spherical, the magnitude and direction of the force vary according to more complicated laws. In electric and magnetic phenomena, the magnitude and direction of the resultant force of any point is the main subject of investigation. Suppose that the direction of the force at any point is known, then, if we draw a line so that in every part of its course it coincides in direction with the force at that point, this line may be called a *line of force*, since it indicates the direction of the force in every part of its course.

By drawing a sufficient number of lines of force, we may indicate the direction of the force in every part of the space in which it acts.

Thus if we draw into filings on paper near a magnet, each filing will be magnetized by induction, and the consecutive filings will unite by their opposite poles, so as to form filices, and these filices will indicate the direction of the lines of force. The beautiful illustration of the position of magnetic force afforded by this experiment, naturally leads to make us think of



James Clerk Maxwell: *On physical lines of force*, 1861

Physics 1900: Mystery No. 1

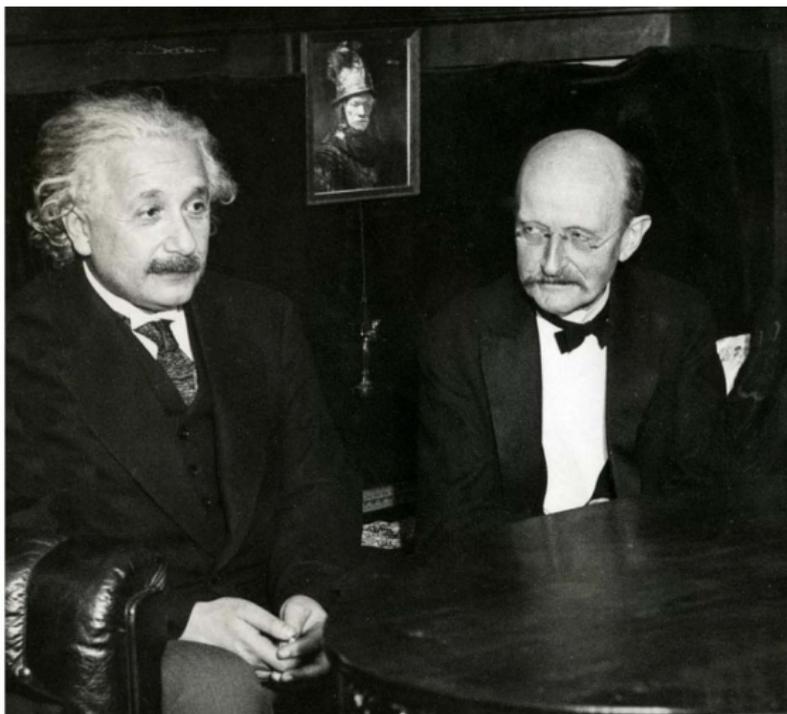


Black body radiation



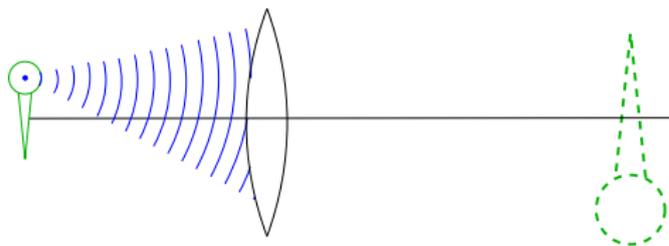
Photoelectric effect



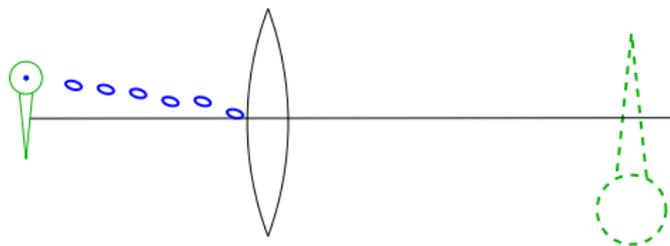


Albert Einstein and Max Planck

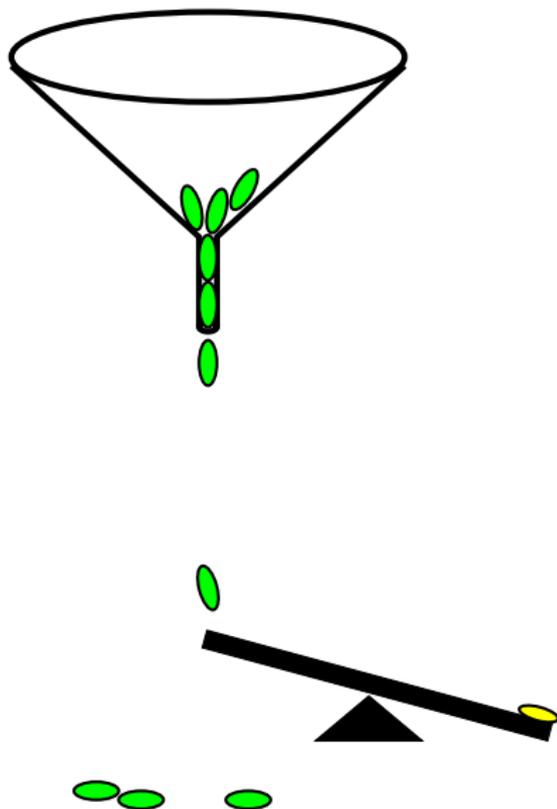
Physics 1900: Mystery No. 1



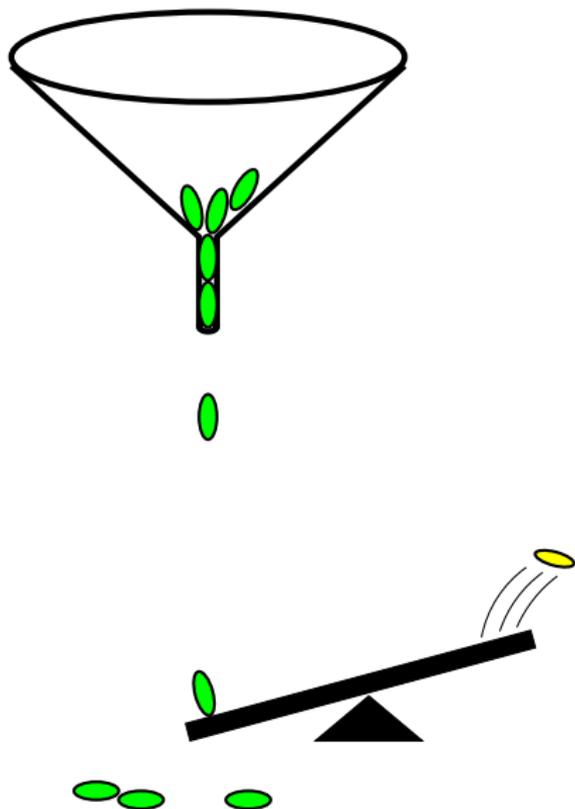
Physics 1900: Mystery No. 1



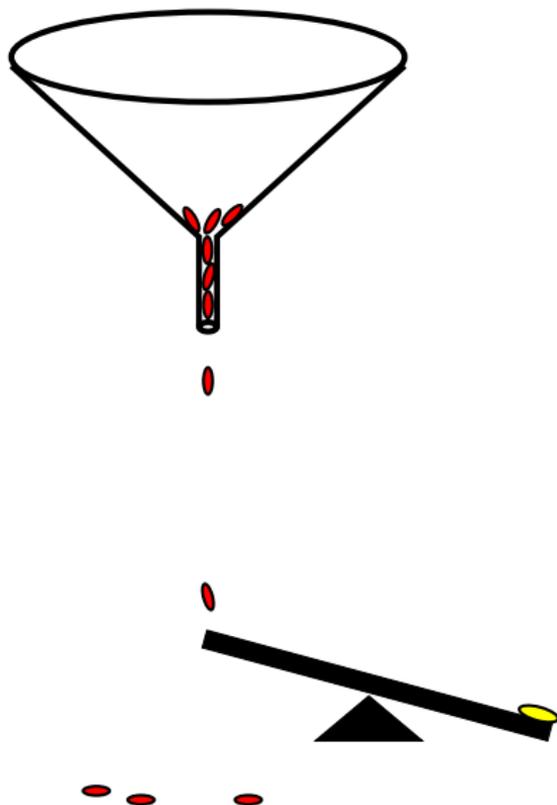
Physics 1900: Mystery No. 1



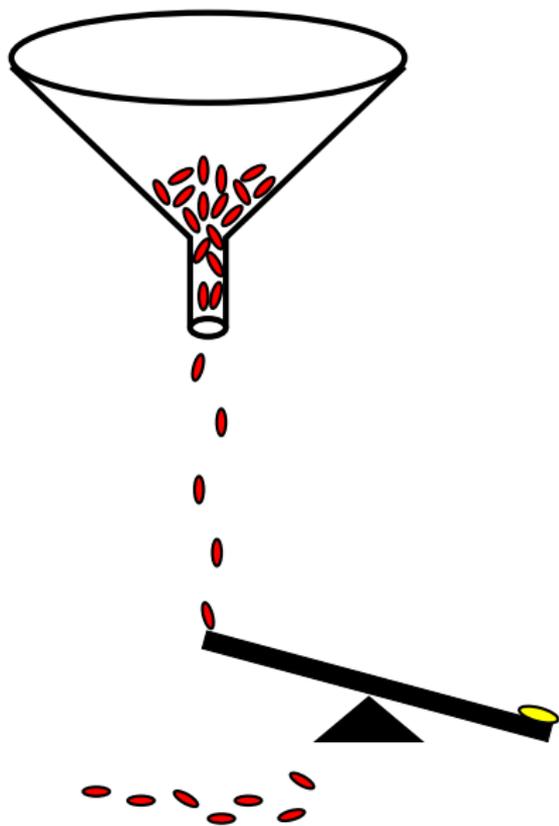
Physics 1900: Mystery No. 1



Physics 1900: Mystery No. 1



Physics 1900: Mystery No. 1



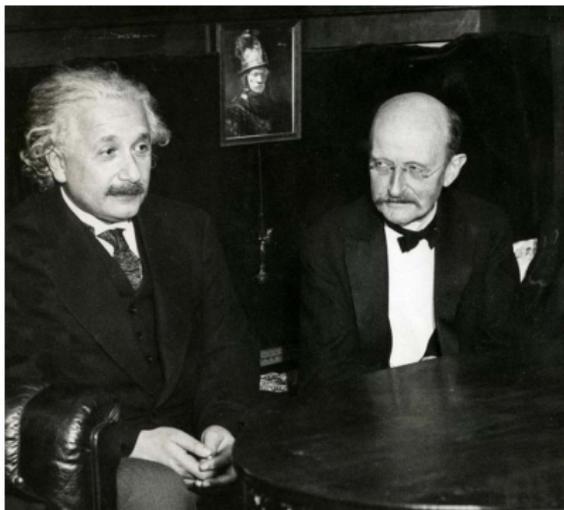
6. Über einen
die Erzeugung und Verwandlung des Lichtes
betreffenden heuristischen Gesichtspunkt;
von A. Einstein.

Zwischen den theoretischen Vorstellungen, welche sich die Physiker über die Gase und andere ponderable Körper gebildet haben, und der Maxwell'schen Theorie der elektromagnetischen Prozesse im sogenannten leeren Raume besteht ein tiefgreifender formaler Unterschied. Während wir uns nämlich den Zustand eines Körpers durch die Lage und Geschwindigkeiten einer zwar sehr großen, jedoch endlichen Anzahl von Atomen und Elektronen für vollkommen bestimmt ansehen, bedienen wir uns zur Bestimmung des elektromagnetischen Zustandes eines Raumes kontinuierlicher räumlicher Funktionen, so daß also eine endliche Anzahl von Größen nicht als genügend anzusehen ist zur vollständigen Festlegung des elektromagnetischen Zustandes eines Raumes. Nach der Maxwell'schen Theorie ist bei allen rein elektromagnetischen Erscheinungen, also auch beim Licht, die Energie als kontinuierliche Raumsfunktion aufzufassen, während die Energie eines ponderablen Körpers nach der gegenwärtigen Auffassung der Physiker als eine über die Atome und Elektronen erstreckte Summe darzustellen ist. Die Energie eines ponderablen Körpers kann nicht in beliebig viele, beliebig kleine Teile zerfallen, während sich die Energie eines von einer punktförmigen Lichtquelle ausgesandten Lichtstrahles nach der Maxwell'schen Theorie (oder allgemeiner nach jeder Undulationstheorie) des Lichtes auf ein stets wachsendes Volumen sich kontinuierlich verteilt.

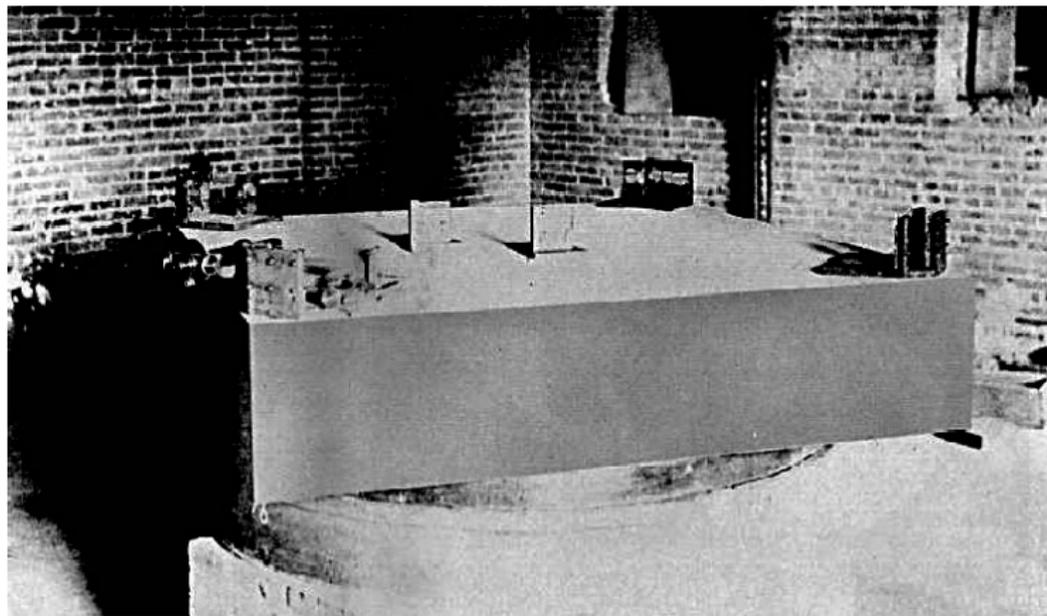
Die mit kontinuierlichen Raumsfunktionen operierende Undulationstheorie des Lichtes hat sich zur Darstellung der rein optischen Phänomene vortrefflich bewährt und wird wohl nie durch eine andere Theorie ersetzt werden. Es ist jedoch im Auge zu behalten, daß sich die optischen Beobachtungen auf zeitliche Mittelwerte, nicht aber auf Momentanwerte beziehen, und es ist trotz der vollständigen Bestätigung der Theorie der Beugung, Reflexion, Brechung, Dispersion etc. durch das



1905: Quantum mechanics

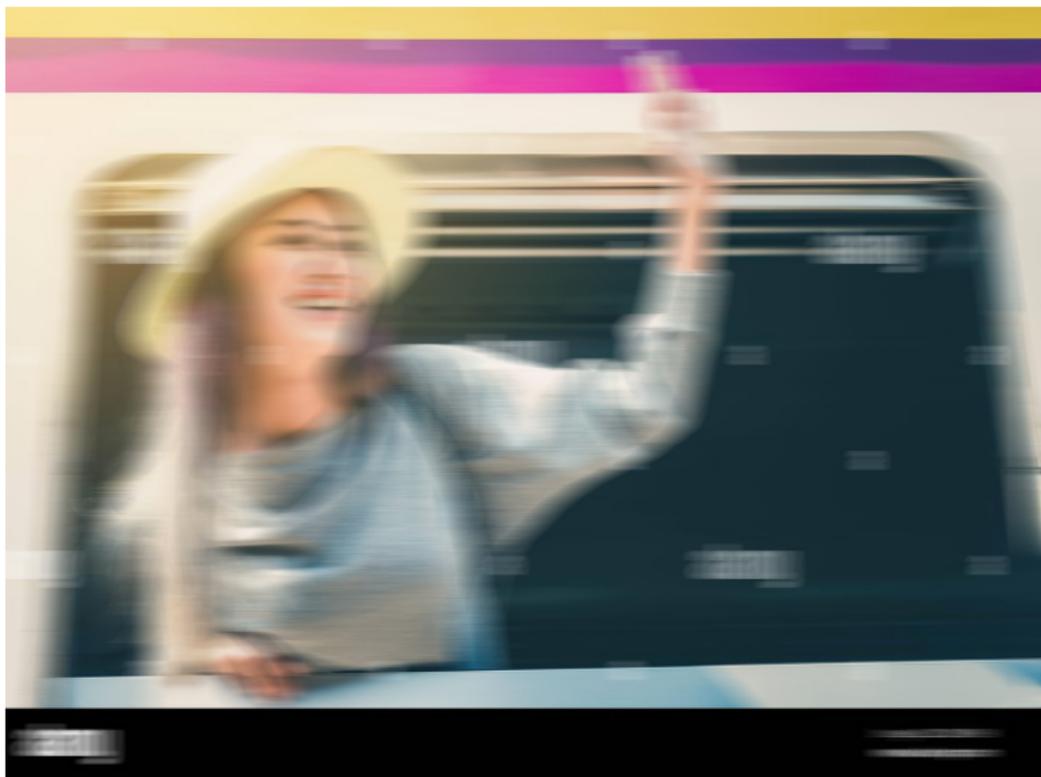


Physics 1900: Mystery No. 2



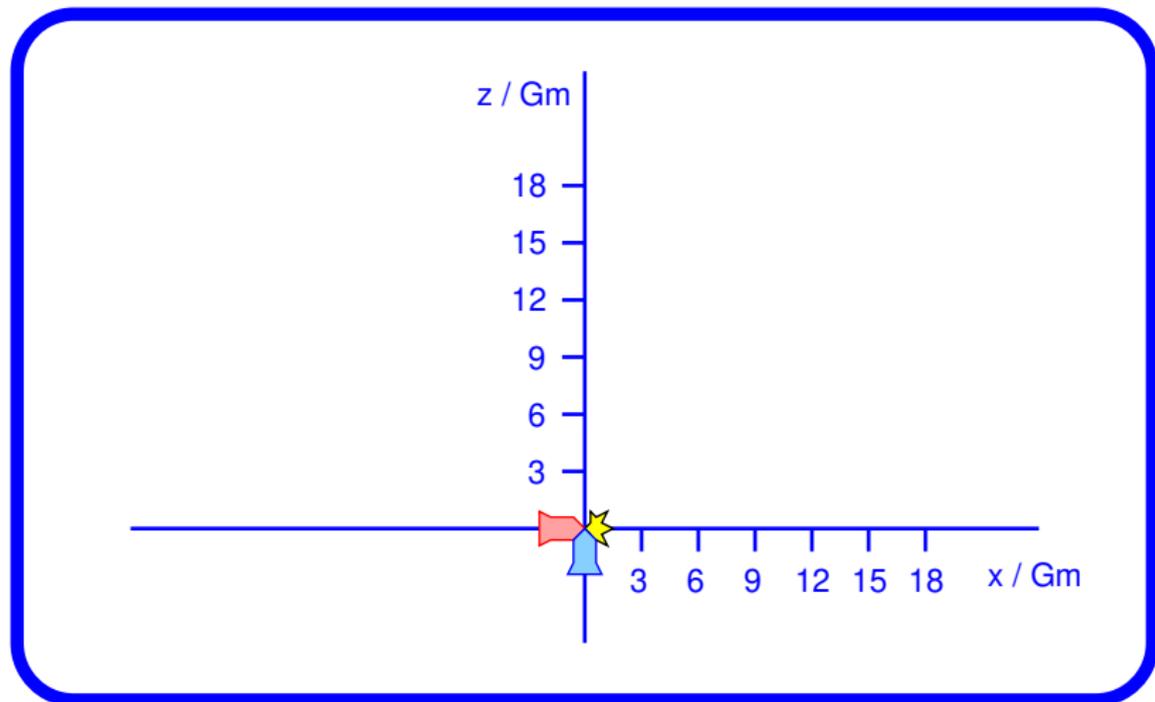
Michelson and Morley: constant speed of light, 1887

Physics 1900: Mystery No. 2

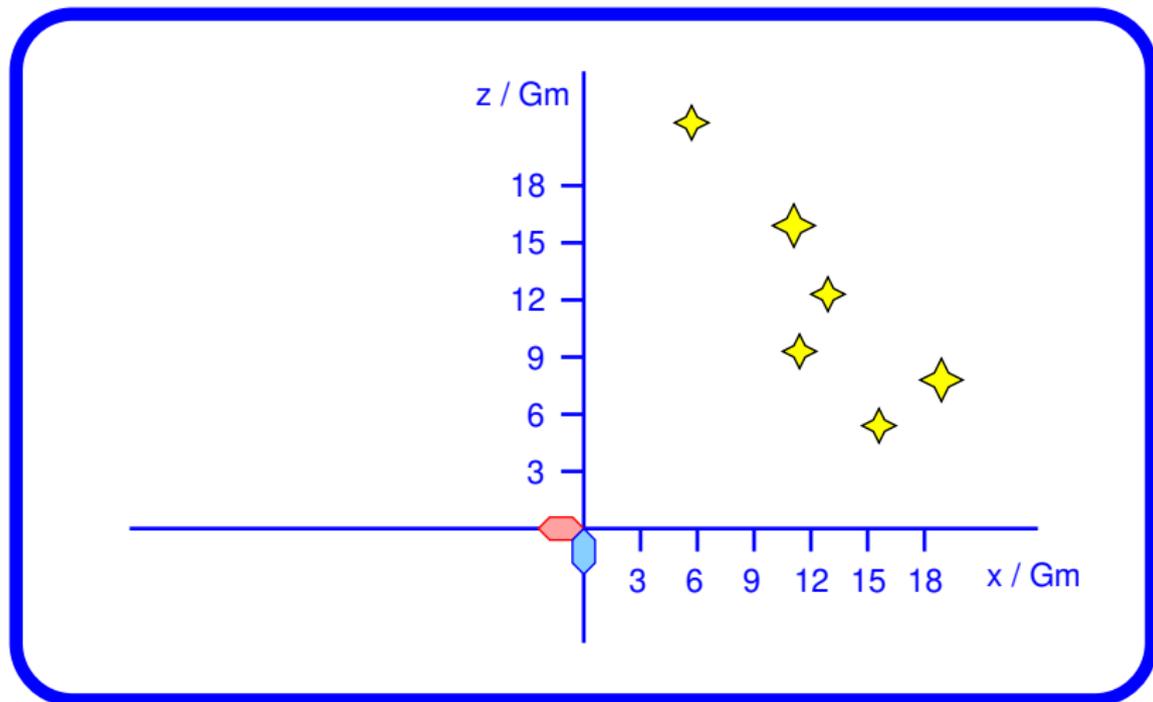




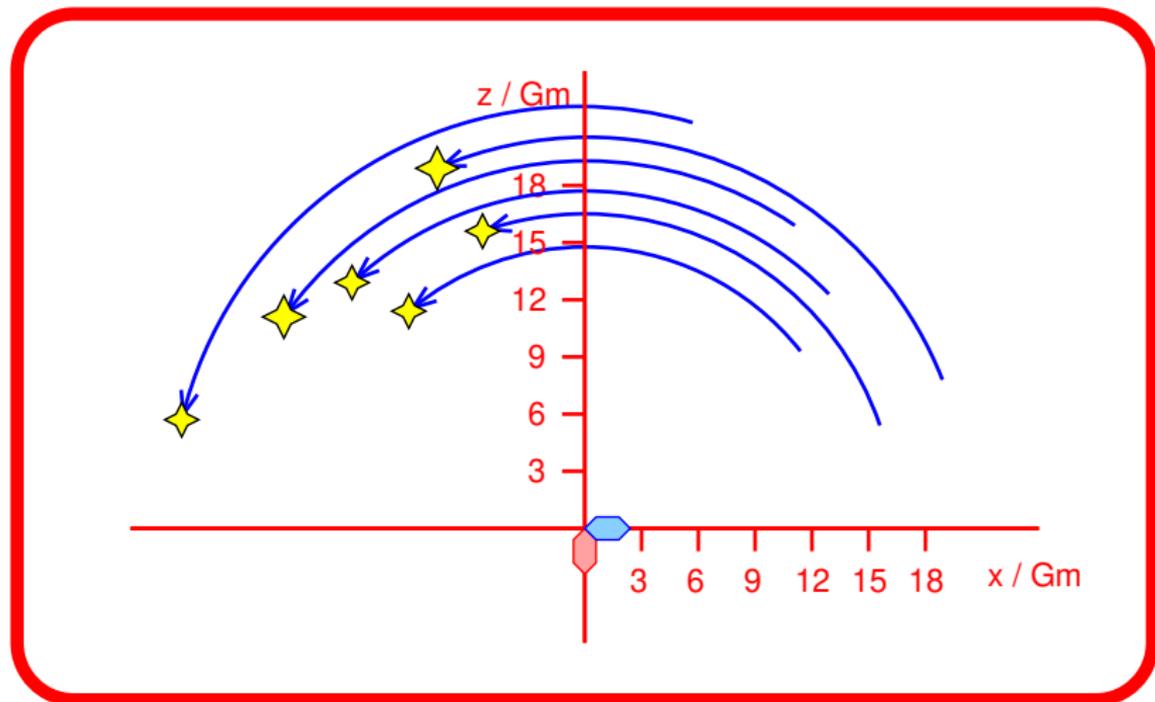
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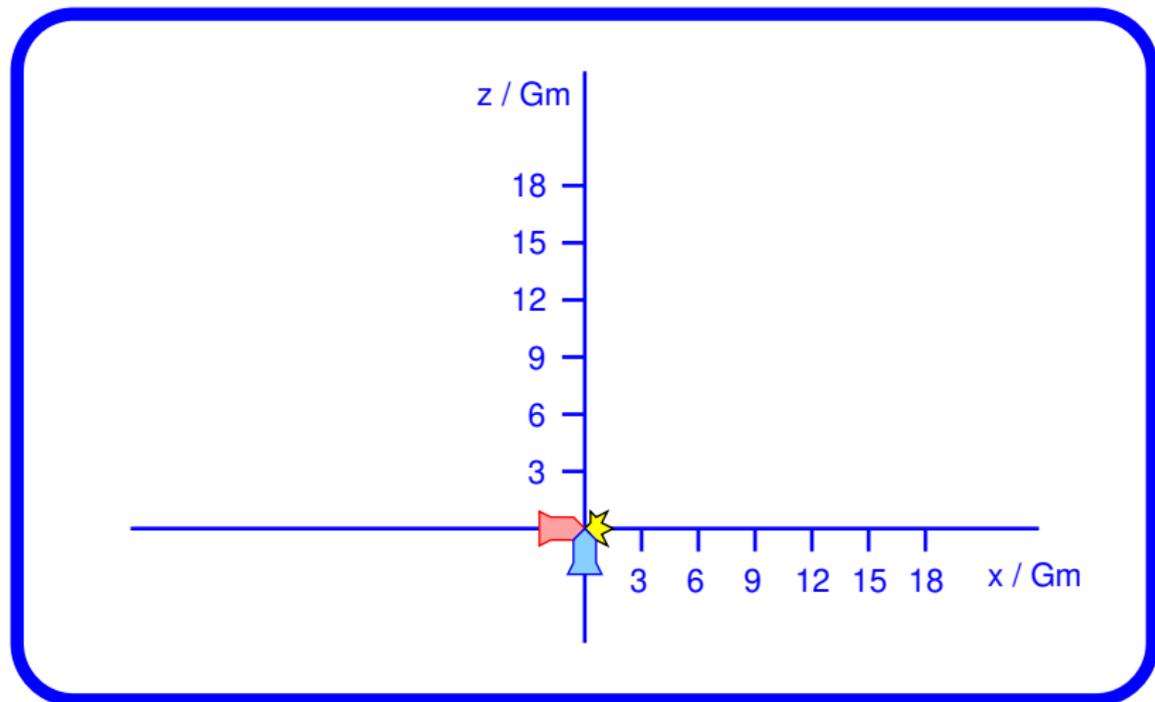
Physics 1900: Mystery No. 2



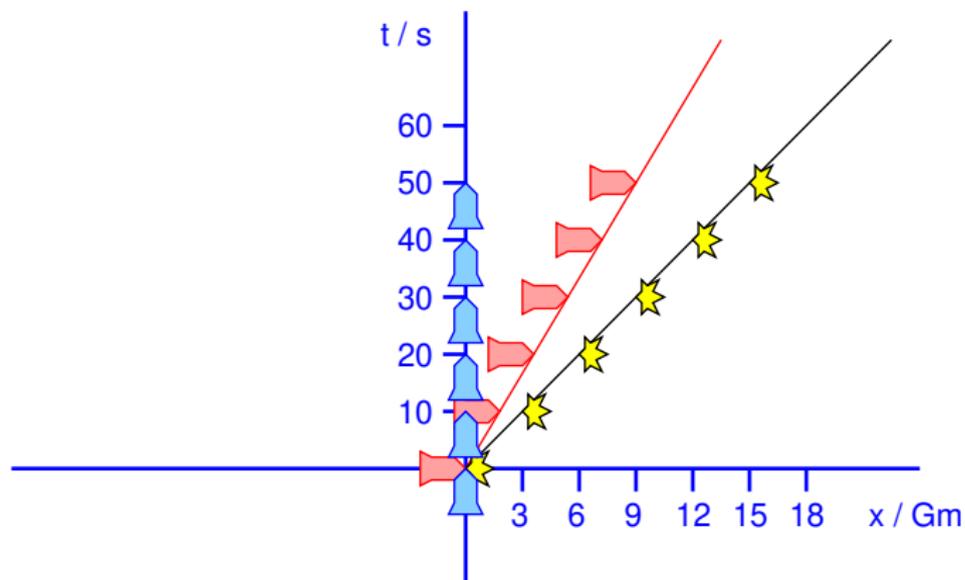
Physics 1900: Mystery No. 2



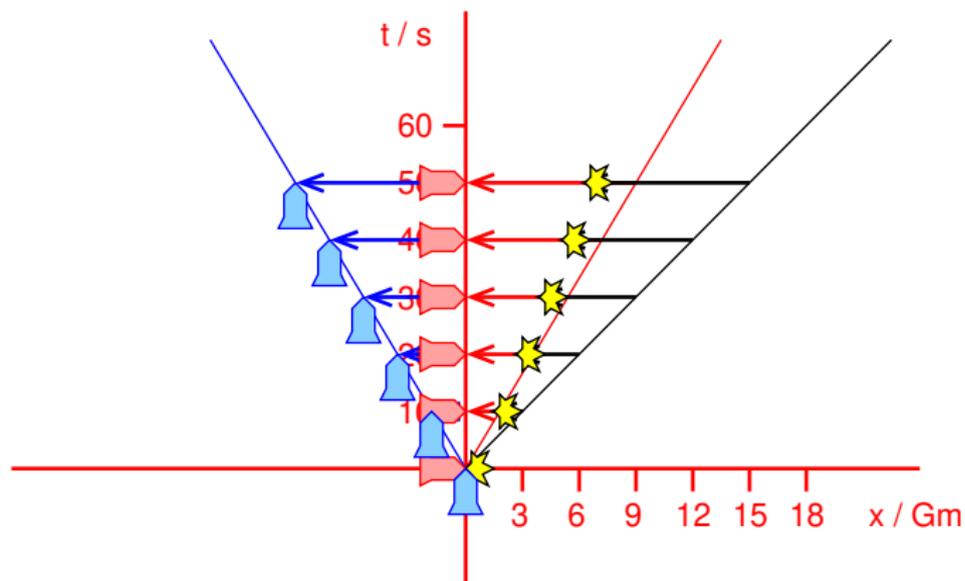
Physics 1900: Mystery No. 2



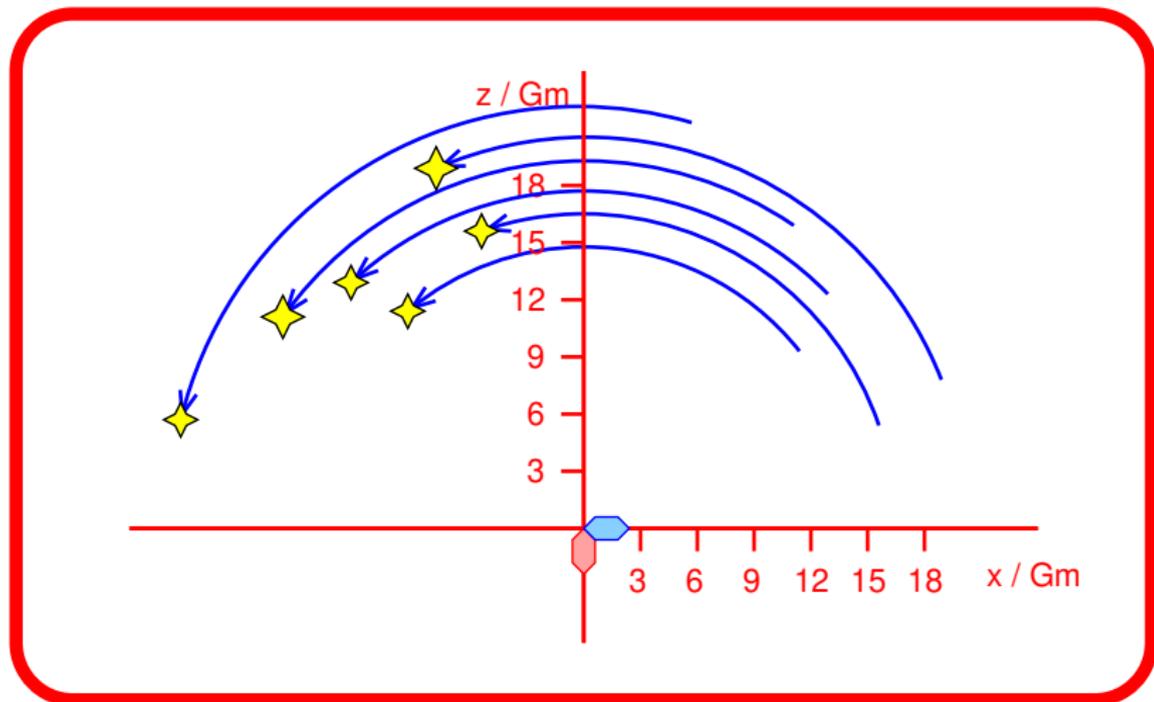
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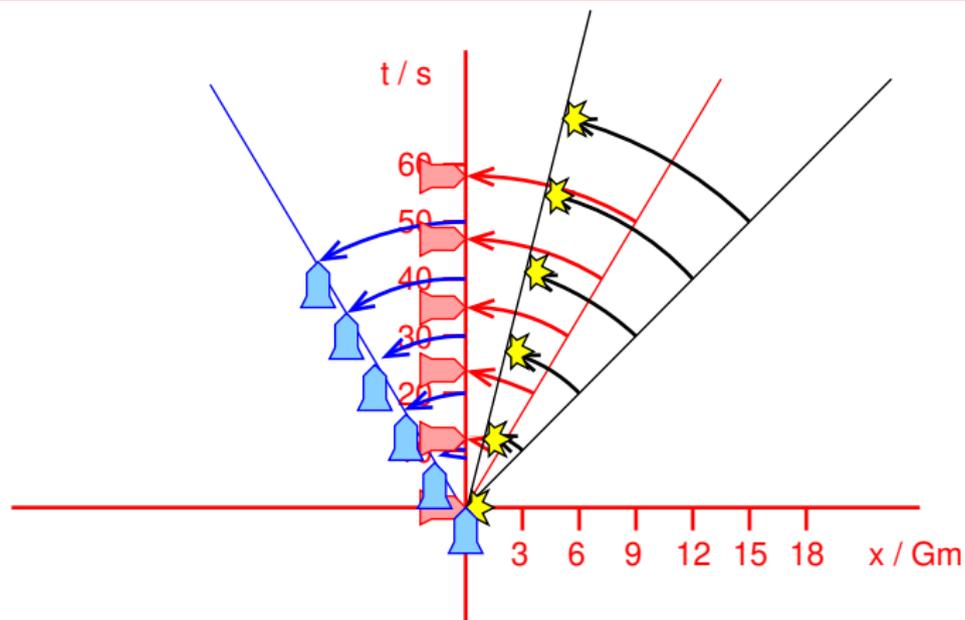
Physics 1900: Mystery No. 2



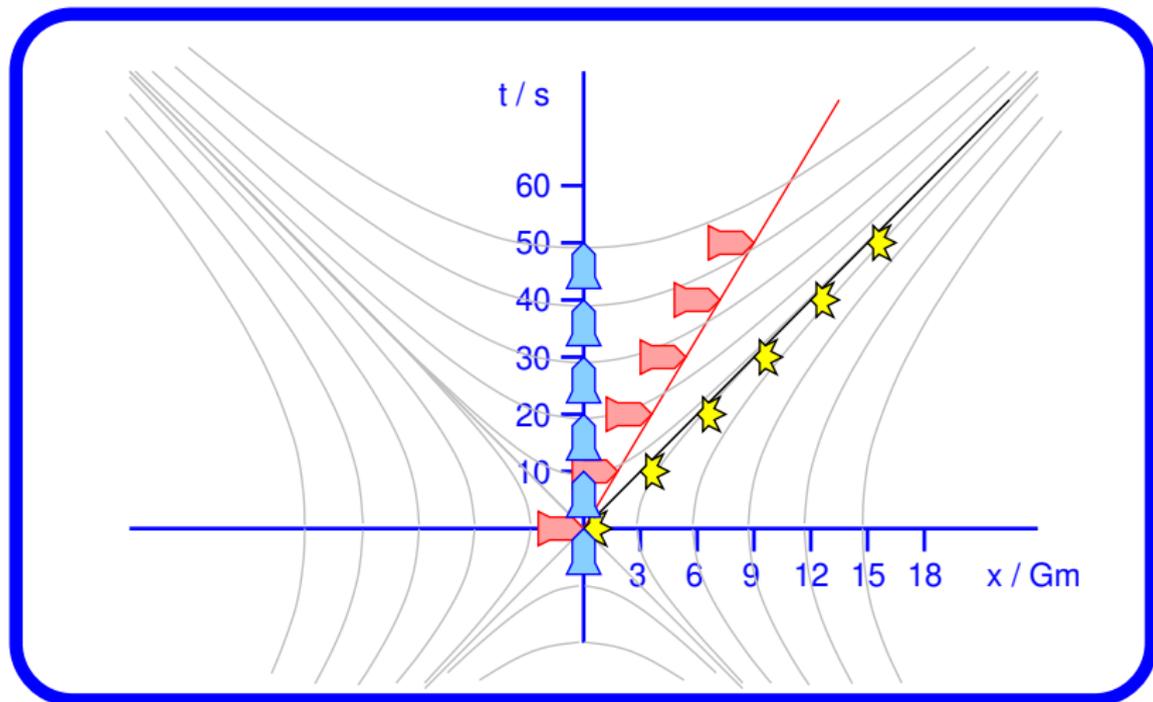
Physics 1900: Mystery No. 2



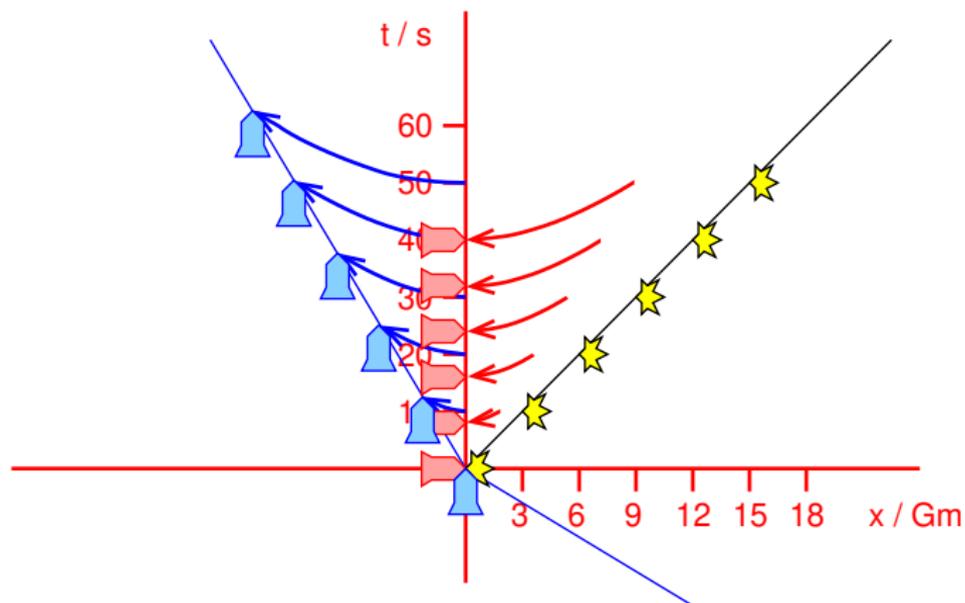
Physics 1900: Mystery No. 2



Physics 1900: Mystery No. 2



Physics 1900: Mystery No. 2



1905: (Special) theory of relativity

891

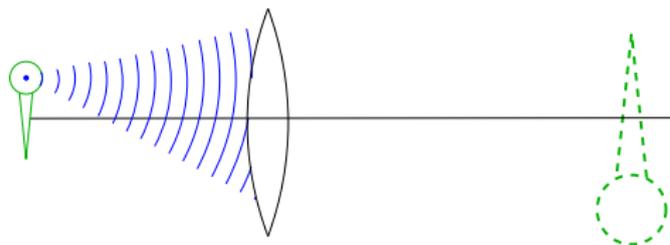
3. Zur Elektrodynamik bewegter Körper; von A. Einstein.

Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhafte scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewege sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, dagegen im Leiter eine elektromotorische Kraft, welcher an sich keine Energie entspricht, die aber — Gleichheit der Relativbewegung bei den beiden ins Auge gefaßten Fällen vorausgesetzt — zu elektrischen Strömen von derselben Größe und demselben Verlaufe Veranlassung gibt, wie im ersten Falle die elektrischen Kräfte.

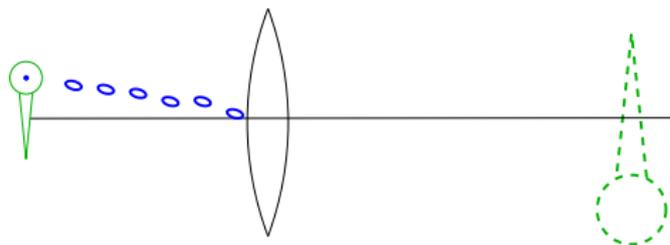
Beispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium“ zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche



1905: Quantum mechanics



1905: Quantum mechanics

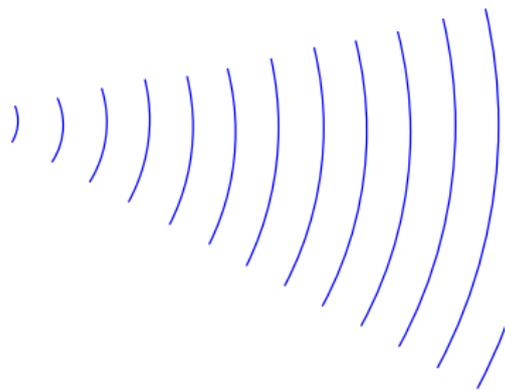


1924: Matter and wave-particle duality



Louis Victor Pierre Raymond, 7th Duc de Broglie

1924: Matter and wave-particle duality



Louis Victor Pierre Raymond, 7th Duc de Broglie

Matter and wave-particle duality



George Paget Thomson



Clinton Davisson, Lester Germer

Electron microscope



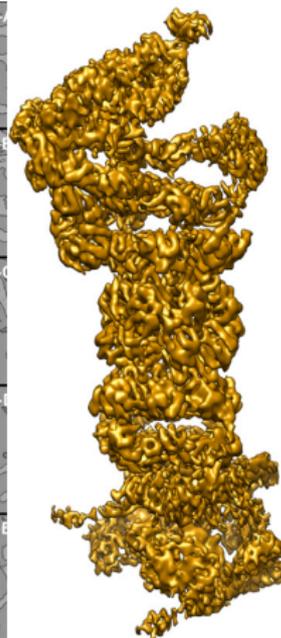
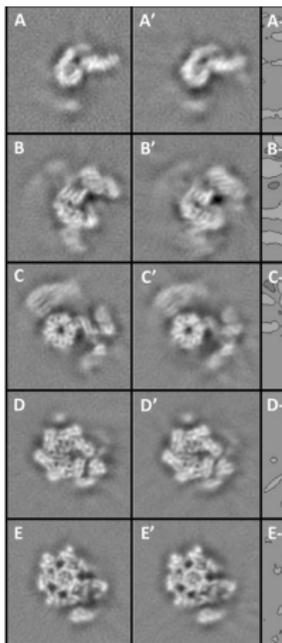
Ernst Ruska

Electron microscope



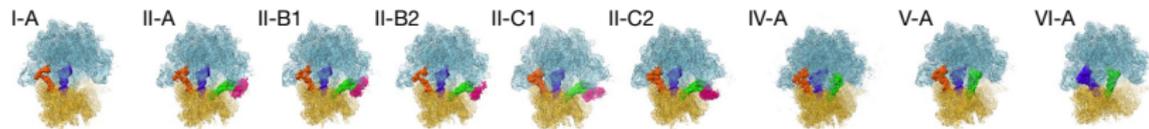
Bacterium *Bacillus subtilis*, Peter Highton, 1968

Electron microscope



F. Förster, Proc. Natl. Acad. Sci. USA 109 (2012) 14870–14875.

Electron microscope



A. B. Loveland, Nature 584 (2020) 640–645.

1905: (Special) theory of relativity

891

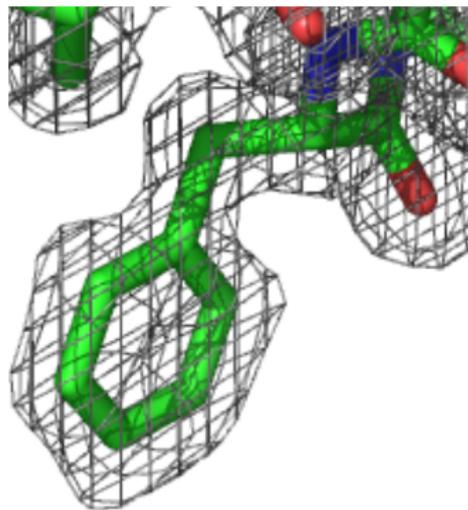
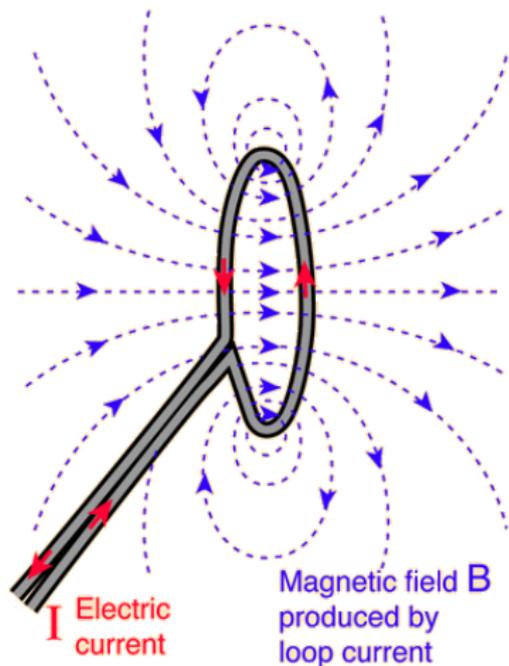
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Daß die Elektrodynamik Maxwells — wie dieselbe gegenwärtig aufgefaßt zu werden pflegt — in ihrer Anwendung auf bewegte Körper zu Asymmetrien führt, welche den Phänomenen nicht anzuhafte scheinen, ist bekannt. Man denke z. B. an die elektrodynamische Wechselwirkung zwischen einem Magneten und einem Leiter. Das beobachtbare Phänomen hängt hier nur ab von der Relativbewegung von Leiter und Magnet, während nach der üblichen Auffassung die beiden Fälle, daß der eine oder der andere dieser Körper der bewege sei, streng voneinander zu trennen sind. Bewegt sich nämlich der Magnet und ruht der Leiter, so entsteht in der Umgebung des Magneten ein elektrisches Feld von gewissem Energiewerte, welches an den Orten, wo sich Teile des Leiters befinden, einen Strom erzeugt. Ruht aber der Magnet und bewegt sich der Leiter, so entsteht in der Umgebung des Magneten kein elektrisches Feld, dagegen im Leiter eine elektromotorische Kraft, welcher an sich keine Energie entspricht, die aber — Gleichheit der Relativbewegung bei den beiden ins Auge gefaßten Fällen vorausgesetzt — zu elektrischen Strömen von derselben Größe und demselben Verlaufe Veranlassung gibt, wie im ersten Falle die elektrischen Kräfte.

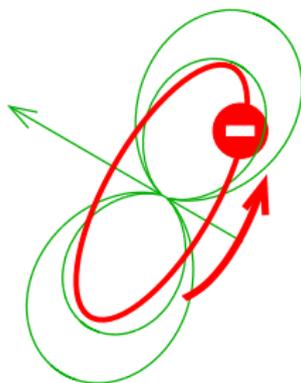
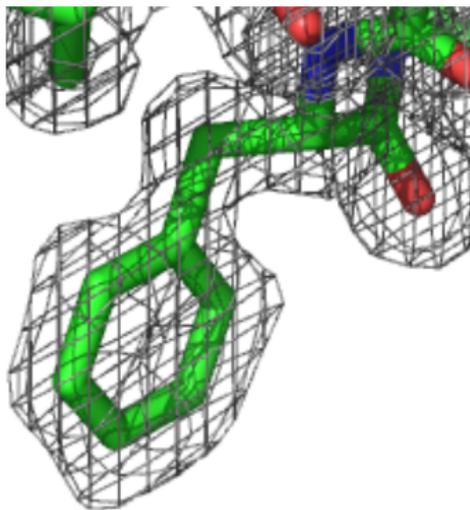
Beispiele ähnlicher Art, sowie die mißlungenen Versuche, eine Bewegung der Erde relativ zum „Lichtmedium“ zu konstatieren, führen zu der Vermutung, daß dem Begriffe der absoluten Ruhe nicht nur in der Mechanik, sondern auch in der Elektrodynamik keine Eigenschaften der Erscheinungen entsprechen, sondern daß vielmehr für alle Koordinatensysteme, für welche die mechanischen Gleichungen gelten, auch die gleichen elektrodynamischen und optischen Gesetze gelten, wie dies für die Größen erster Ordnung bereits erwiesen ist. Wir wollen diese Vermutung (deren Inhalt im folgenden „Prinzip der Relativität“ genannt werden wird) zur Voraussetzung erheben und außerdem die mit ihm nur scheinbar unverträgliche



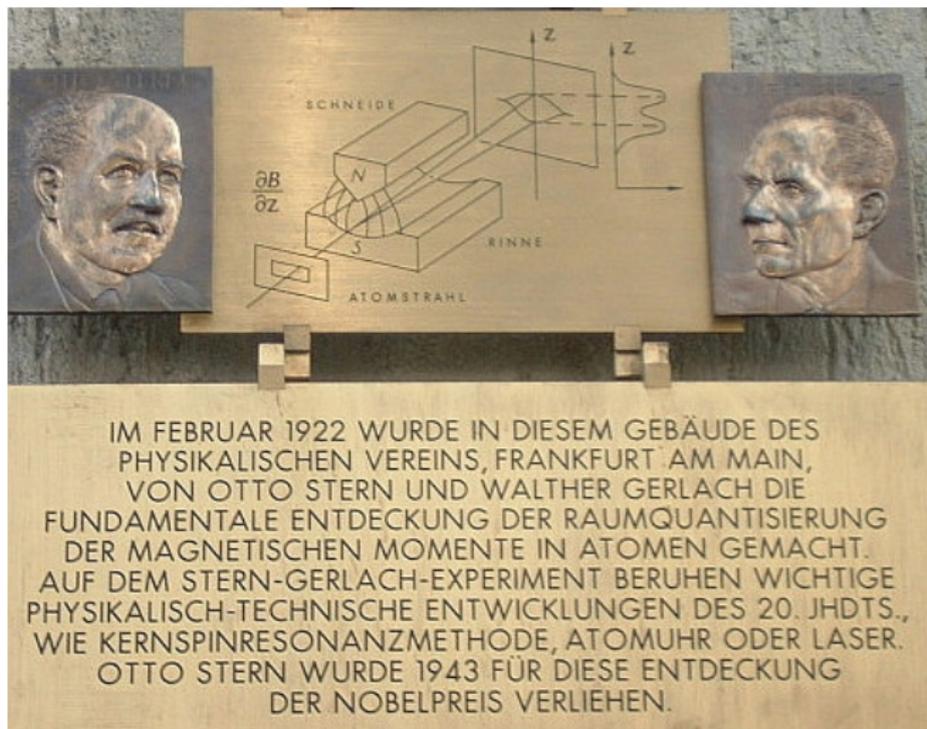
Molecules are electromagnetic



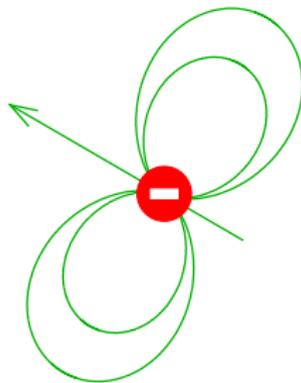
Molecules are electromagnetic



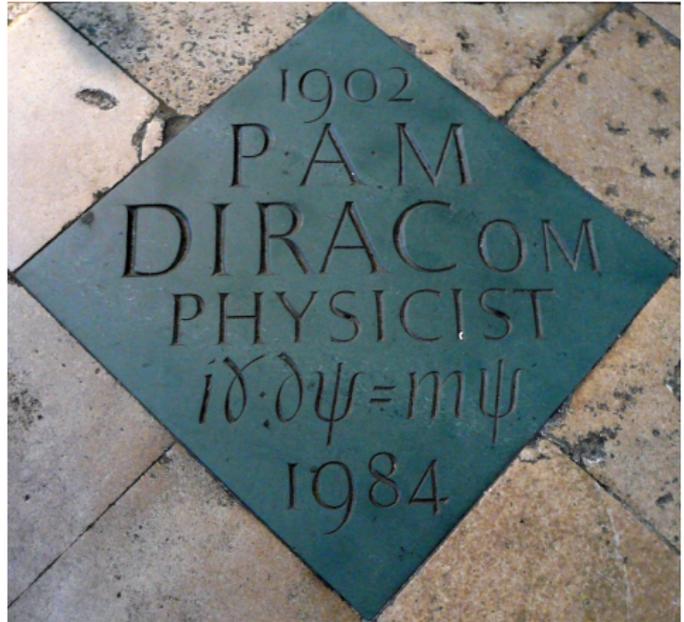
Molecules are electromagnetic



Electron is electromagnetic



1928: Quantum electrodynamicic

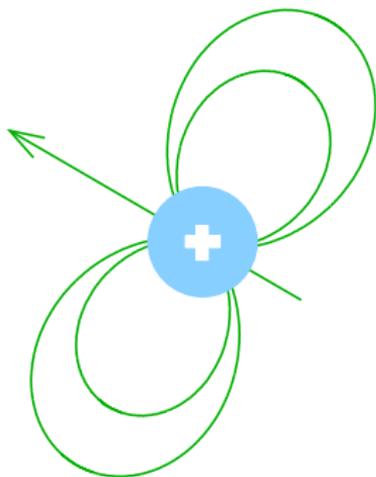


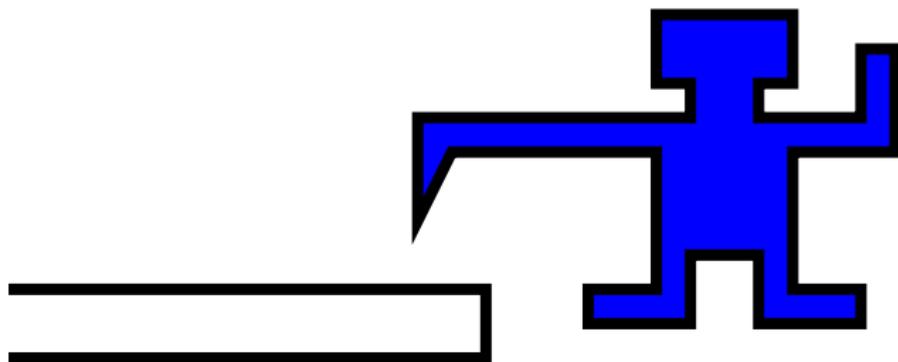
Paul Dirac

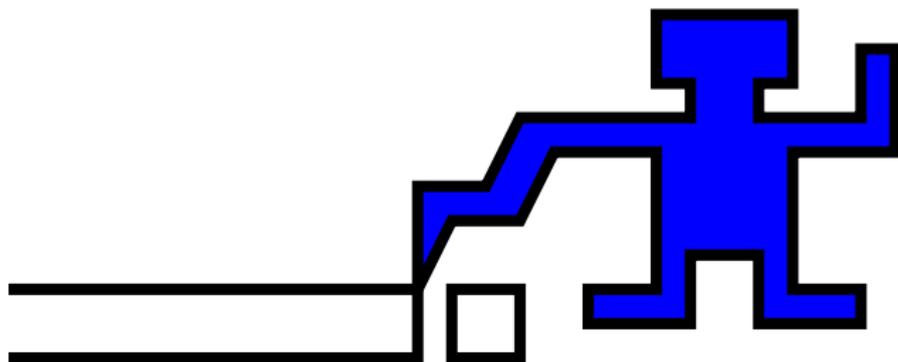
Hydrogen nucleus as an electromagnet



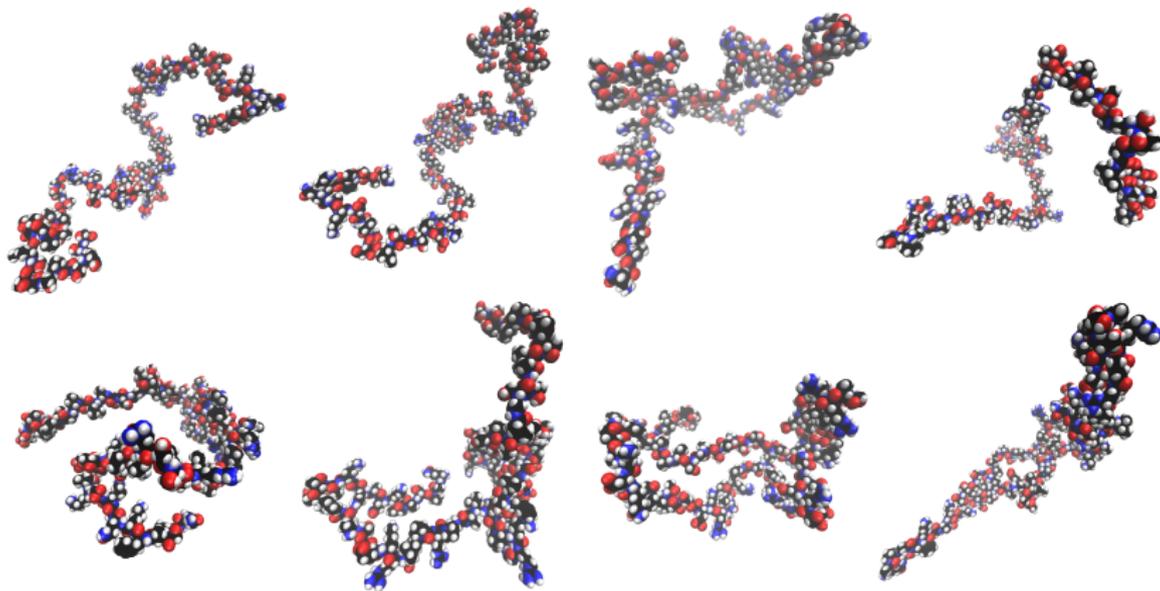
Otto Stern



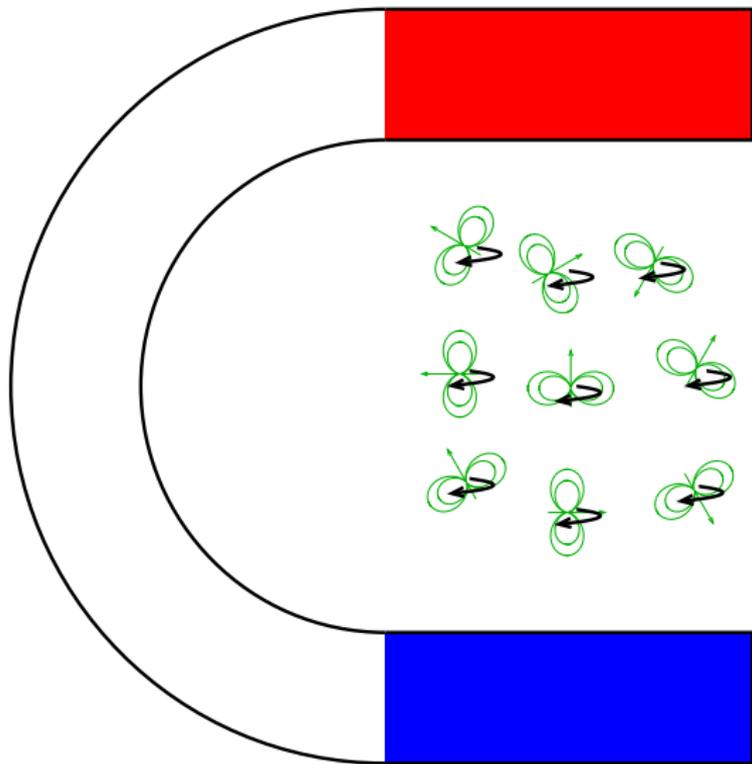




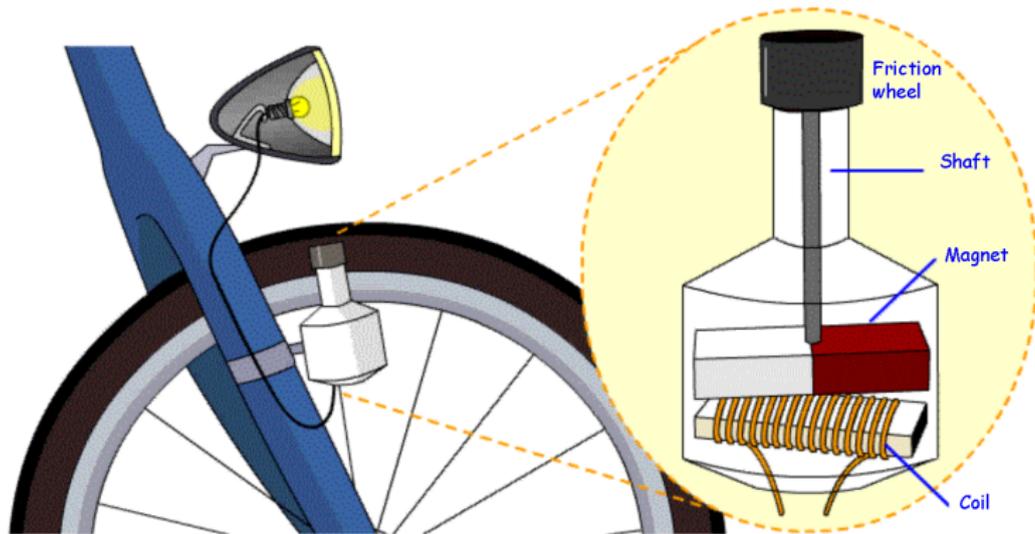
Intrinsically disordered proteins



Nuclear magnetic resonance

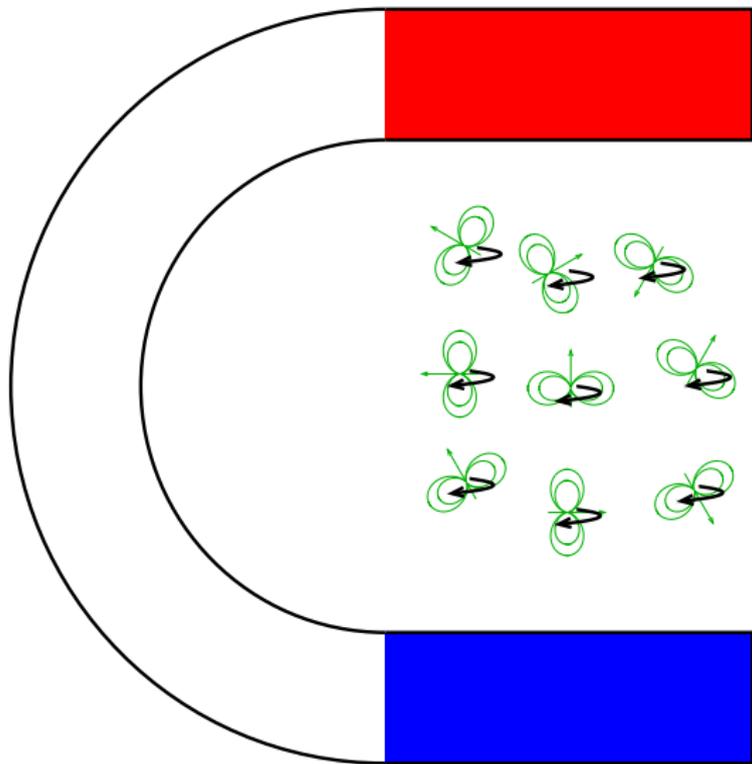


Nuclear magnetic resonance



J. Garcia-Ferrero, *Sustainability* **13** (2021) 12904

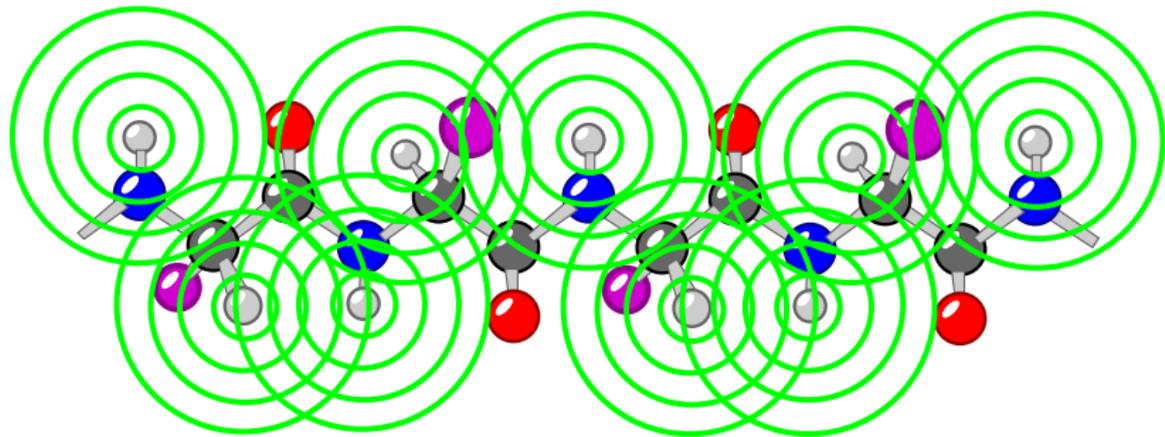
Nuclear magnetic resonance



Nuclear magnetic resonance



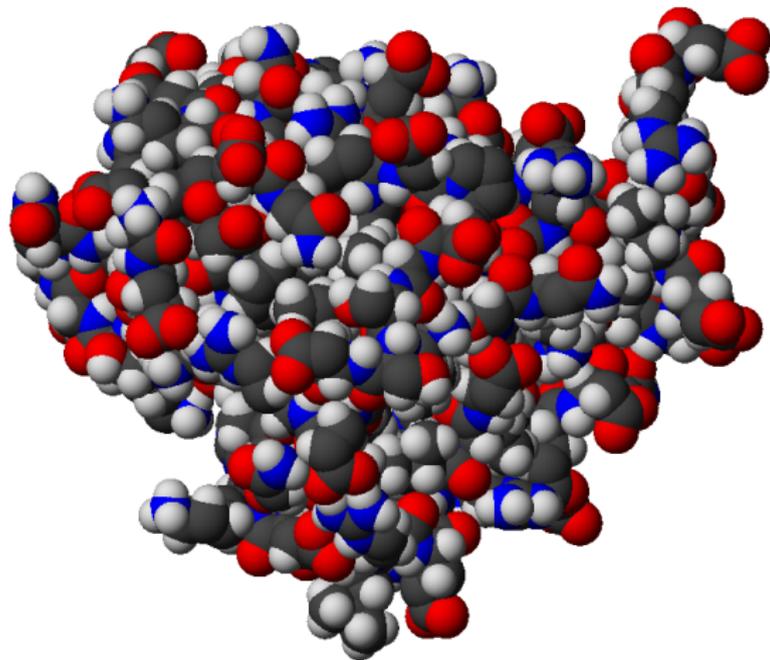
Nuclear magnetic resonance



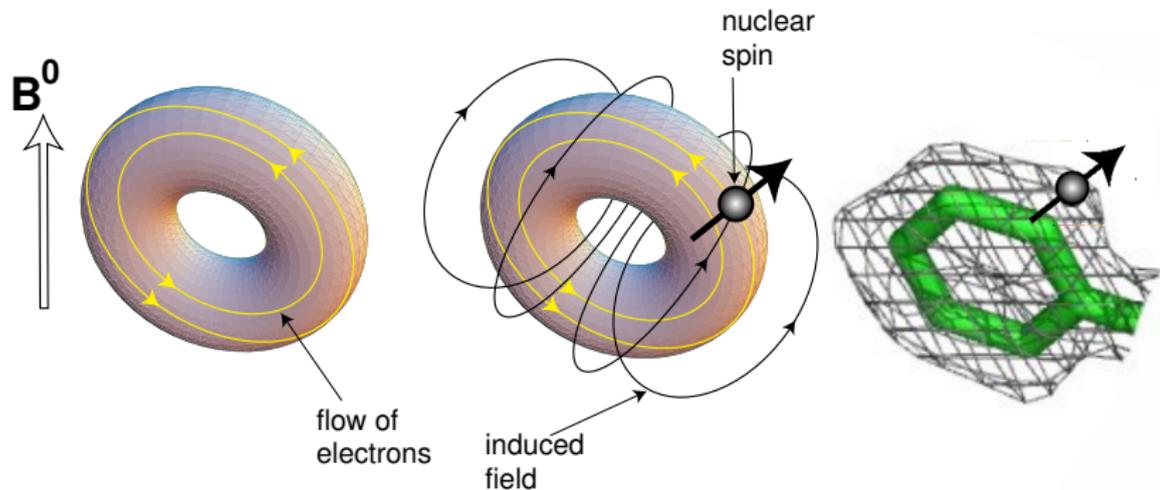
Nuclear magnetic resonance



Nuclear magnetic resonance

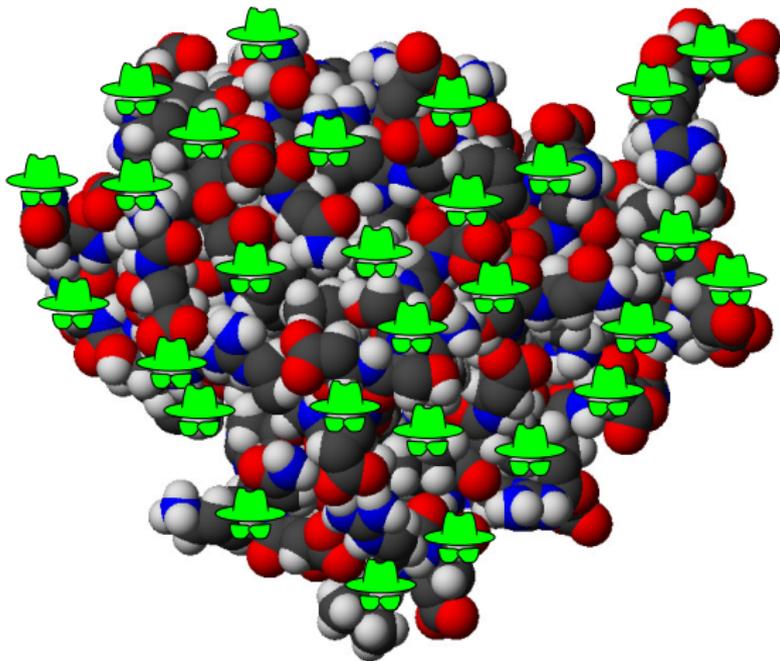


Nuclear magnetic resonance



reproduced from M. H. Levitt: Spin Dynamics

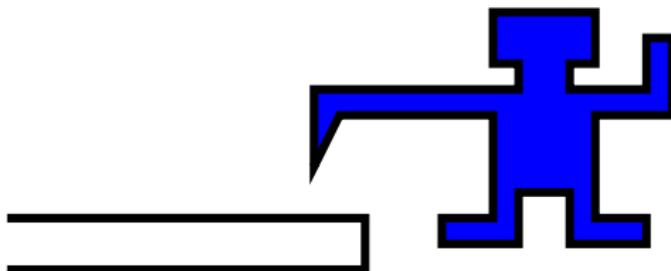
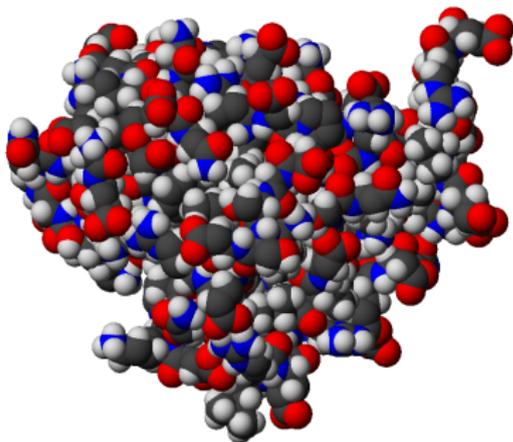
Nuclear magnetic resonance



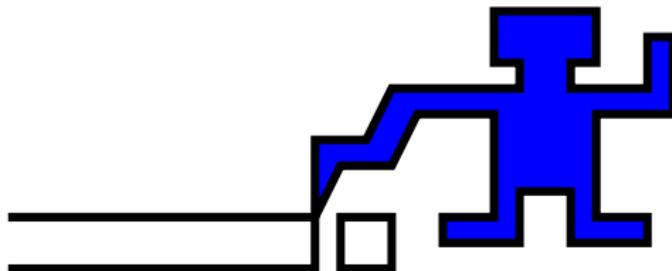
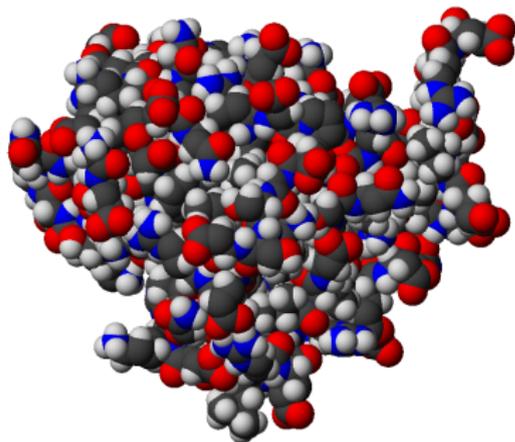
Nuclear magnetic resonance



Nuclear magnetic resonance



Nuclear magnetic resonance



Serendipitous discoveries



Wilhelm Konrad Röntgen



ruka Anny Berty Röntgenové

Serendipitous discoveries



$$f(x) \rightarrow F(1/x)$$

Serendipitous discoveries



Jean Baptiste Joseph Fourier

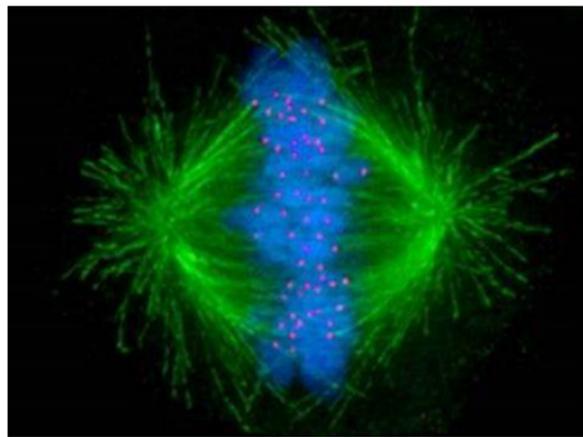


THÉORIE
ANALYTIQUE
DE LA CHALEUR,
Par M. FOURIER.



Jean Baptiste Joseph Fourier

Serendipitous discoveries



Barnett Rosenberg

Serendipitous discoveries



Barnett Rosenberg

