1666

Transfusion of blood from one dog to another

In 1666, Boyle gave a somewhat gruesome account of one of the first instances of blood transfusion between animals, in this case two dogs. The following year, Richard Lower also performed the first transfusion of blood from a sheep into a human. He was one of the foremost surgeons of his day and was involved in pioneering discoveries in blood circulation and breathing. Although Lower understood the usefulness of blood transfusions following injury or other blood loss, in humans it often caused severe and sometimes fatal reactions, and 10 years later it was banned by Parliament. It was over 200 years later that an understanding of blood groups made routine transfusions possible. Lower’s work has been brought to life in An Instance of the Fingerpost by Iain Pears.

Daniel Glaser, Wellcome Trust.

Related scientific article

Title Tryals Proposed by Mr. Boyle to Dr. Lower, to be Made by Him, for the Improvement of Transfusing Blood out of One Live Animal into Another

Author R Boyle

Journal Philosophical Transactions

URL http://dx.doi.org/10.1098/rstl.1665.0147
An early blood transfusion from lamb to man, ca 1705.

© Wellcome Library, London
Portrait of Robert Boyle, by Johann Kerseboom, oil on canvas, 17th century.

© The Royal Society
1667

**Keeping a dog alive by blowing through its lungs with bellows**

Robert Hooke began his career as an assistant to physicist Robert Boyle, helping him to construct the air pump—a subject that stuck with him. In 1667, at the age of 32, Robert Hooke was asked by the Royal Society to perform a stimulating demonstration, and he returned with a dog restrained on its back with an open thorax, connected to two bellows. Using one of the bellows, Hooke showed that the ‘supply of fresh air’, rather than the ‘bare motion of the lungs’, kept the dog alive for hours. Using the second of the bellows to produce a positive pressure through rapid pumping, he then perforated the lungs to make his case. The continuous flow of air kept the dog alive. Around 250 years later, the first clinically useful ventilator equipment was used, for pumping air into the trachea via tubes, based on Hooke’s principle. This marked the beginnings of modern endotracheal anaesthesia. Hooke himself continued on the themes of stretching and elasticity to develop the fundamental Hooke’s Law: that an elastic body bends or stretches out of shape (strain) in direct proportion to the force acting on it (stress).

Andrew Parker, Natural History Museum.

**Related scientific article**

- **Title**: An Account of an Experiment Made by Mr. Hook, Keeping a dog alive by blowing through its lungs with bellows
- **Author**: R Hooke
- **Journal**: Philosophical Transactions
- **URL**: http://dx.doi.org/10.1098/rstl.1666.0043

Experiment on the respiration of a dog.

© Wellcome Library, London
**Isaac Newton's theory on light and colours**

Isaac Newton was at his brilliant best in this paper, alternating between theory and simple yet elegant experiments, between deep insights into the nature of light and immensely useful practical applications. His observations on the rainbow cast by a shaft of sunlight passing through a glass prism led on to the revolutionary discovery that colour is an inherent property of a ray of light, and that white light is a mixture of other colours. From this he realized that telescopes made from lenses would always yield slightly fuzzy images, because the different colours of light are focused at slightly different points, so he devised a telescope using mirrors: essentially the same design as the most powerful telescopes still in use today. Not bad for one paper, especially as the work was interrupted when he had to flee the plague (and scientists today think they have problems!).

David Wark, Department of Physics, Imperial College London.

Related scientific article

- **Title**: A Letter of Mr. Isaac Newton, Professor of the Mathematicks in the University of Cambridge; Containing His New Theory about Light and Colors
- **Author**: I Newton
- **Journal**: Philosophical Transactions
- **URL**: [http://dx.doi.org/10.1098/rstl.1671.0072](http://dx.doi.org/10.1098/rstl.1671.0072)
White light passing through a triangular prism in which the beam is split into the colours of the spectrum.

© David Parker/Science Photo Library
Isaac Newton’s diagram of an experiment on light with two prisms. From a letter to the Royal Society, 6th June 1672.

© The Royal Society
1677

**Observation of ‘little animals’ in rainwater**

Antonie van Leeuwenhoek devoted 50 years of his life to microscopy, grinding and polishing his own lenses to reach new levels of perfection. He achieved magnifications between ×30 and ×270, with a resolving power of up to 1.4 µm, using a secret technique for lighting and viewing his subjects; and so his discoveries began. He published material from the animal, vegetable and mineral worlds in unprecedented detail, by cutting thin sections with a razor. His first publication, in Philosophical Transactions, revealed the structure of mould, as well as the bee and the louse. Then, a few years later, van Leeuwenhoek unexpectedly saw signs of life in a single droplet of rainwater. Described simply as ‘little animals’, he had observed bacteria and protozoa, laying the foundations for the sciences of bacteriology and protozoology. van Leeuwenhoek also found ‘little animals’ in other bodies of water, including lakes, and on the surface of pepper and teeth. He, more than anyone else, unveiled the microscopic world. As well as the text of his paper being ‘English’d’, the spelling of Antonie van Leeuwenhoek’s name was also changed to Antony van Leewenhoeck in this publication.

Andrew Parker, Natural History Museum.

Related scientific article

**Title** Observations, Communicated to the Publisher by Mr. Antony van Leewenhoeck, in a Dutch Letter of the 9th of Octob. 1676.

**Author** A van Leewenhoeck

**Journal** Philosophical Transactions

**URL** [http://dx.doi.org/10.1098/rstl.1677.0003](http://dx.doi.org/10.1098/rstl.1677.0003)

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Silver coloured metal replica of Antonie van Leeuwenhoek's single lens microscope.

© The Royal Society
Antonie van Leeuwenhoek’s red chalk drawings of sand grains. From a letter to the Royal Society, 4th December 1703.

© The Royal Society
Observations of the total eclipse of the Sun in April 1715

Edmund Halley, a Fellow of the Royal Society, is most famous for his work on the orbits of comets, predicting when the one that now bears his name would be seen; however, his interests were more widespread. In 1715 the first total solar eclipse for 500 years took place over England and Wales. Halley, a talented mathematician, realized that such an event would generate a general curiosity and requested that the ‘curious’ across the country should observe ‘what they could’ and make a record of the time and duration of the eclipse. At the time, there were only two universities in England and their astronomy professors did not have much luck in observing the event: ‘the Reverend Mr Cotes at Cambridge had the misfortune to be oppressed by too much company’ and ‘Dr John Keill by reason of clouds, saw nothing distinctly at Oxford but the end’. The event did indeed capture the imagination of the nation and the timings collected allowed Halley to work out the shape of the eclipse shadow and the speed at which it passed over the Earth (29 miles per minute).

Lucie Green, Mullard Space Science Laboratory.

Related scientific article

Title Observations of the Late Total Eclipse of the Sun on the 22d of April Last Past, Made before the Royal Society at Their House in Crane-Court in Fleet-Street, London. by Dr. Edmund Halley
Author E Halley
Journal Philosophical Transactions
URL http://dx.doi.org/10.1098/rstl.1714.0025
Map showing the solar eclipse of 1715, by Edmond Halley.

© TopFoto / Fotomas
1727

An account of a boy whose sight was restored

What would happen if a person who was born blind could suddenly be made to see? This question bears on very fundamental issues: do we recognize shapes and colours because this knowledge is already wired into our brain, or do we have to learn to interpret the signals from our senses through experience? You can speculate about it, or you can actually do experiments. Cheselden was a surgeon who restored a 14-year-old boy’s sight and found the answer was yes and no. The boy was entranced by the colours he could now see, but he was unable to judge the distance between objects. Now, animal studies have shown that much of the neural machinery for vision is innate but that experience is required to tune the system.

Uta Frith, UCL Institute of Cognitive Neuroscience.

Related scientific article

Title  An Account of Some Observations Made by a Young Gentleman, Who Was Born Blind, or Lost His Sight so Early, That He Had no Remembrance of Ever Having Seen, and Was Couch'd between 13 and 14 Years of Age

Author  W Cheselden

Journal  Philosophical Transactions

URL  http://dx.doi.org/10.1098/rstl.1727.0038

Ophthalmology instruments, eye growths, a cataract operation and other eye defects. Line engraving by R. Parr, 1743–45.

© Wellcome Library, London
1731

Description of a new instrument for measuring angles

By the time John Hadley described his hand-held instrument for measuring the angular distance between two points in 1731, he was already a Fellow of the Royal Society, known for his contributions to mechanics and the reflecting telescope. The originality of Hadley’s quadrant (or octant, as it is often called) lay in the incorporation of two mirrors, allowing navigators at sea to more accurately measure the altitudes of stars and, hence, latitude. A patent and agreements with suppliers of his instruments were part of a marketing strategy. Quadrants made to Hadley’s design were immediately successful and two decades later were being used for the determination of longitude by the lunar-distance method. They remained in use until well into the nineteenth century.

Robert Fox, Museum of the History of Science, University of Oxford.

Related scientific article

Title  The Description of a New Instrument for Taking Angles
Author  J Hadley
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1731.0025

John Hadley’s reflecting quadrant for measuring the angular distance between two points, 1731.

© The Royal Society
Flying a kite in an electrical storm

In the 1750s electricity was a largely unknown and mysterious entity. Franklin made the radical suggestion that the lightning seen during storms was electricity flowing from the clouds to the earth. Given that at the time many believed the weather, and in particular lightning bolts, was caused by supernatural forces, his ideas appeared very radical. He went further, however, suggesting that this electricity of the clouds could be collected artificially by flying a kite into a storm. It worked and, miraculously, did not kill him. On the same principle, he invented lightning conductors for the tops of tall buildings: a piece of science that ironically benefited the Church more than anyone else, putting a stop to the periodic destruction of Church towers by lightning that had been happening throughout history.

Mark Miodownik, King's College London.

Related scientific article

Title  A Letter of Benjamin Franklin, Esq; to Mr. Peter Collinson, F. R. S. concerning an Electrical Kite
Author  B Franklin
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1751.0096
Benjamin Franklin flies a kite in a thunder storm. Frontispiece to *The Life of Benjamin Franklin*, 1848.

© The Royal Society
An account of inoculation with small pox

Sir Hans Sloane gives a fascinating account of how the practice of variolation was introduced to England, this being an operation ‘performed by making a very slight incision in the skin of the arm’ and introducing into it ‘a dossil dipped in the ripe matter of a favourable kind of small-pox’. This would then induce a milder disease that protected against a more severe natural infection. Sloane describes how the procedure (reports of its efficacy had arrived from abroad) was first tested on six condemned criminals and subsequently on ‘half a dozen of the charity-children belonging to St. James’s parish’. Variolation became popular, especially among the upper classes, until it was eventually replaced by vaccination. The remarkable Sir Hans is also credited with ‘inventing’ milk chocolate.

Sunetra Gupta, Department of Zoology, University of Oxford.

Related scientific article

Title  An Account of Inoculation
Author  H Sloane and T Birch
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1755.0073
Chelsea Physic Garden established in the grounds of Chelsea Manor owned by Hans Sloane. Engraving by John Haynes, 30th March 1751.

© The Royal Society
Hans Sloane worked as a physician in Jamaica; he brought cocoa pods back to England and developed milk chocolate.

© The Royal Society
Refraction of light through achromatic lenses

In this paper, John Dollond described achromatic lenses made from a combination of crown glass (which has a low refractive index) and flint glass (which has a high refractive index) that focused all colours to the same point. This avoided the unwanted colouring effects that had previously been thought to be unavoidable when light was refracted. The innovation required great skill, especially in the grinding of flint glass, and Dollond’s mastery of the art earned him immediate recognition, notably by the Royal Society, which awarded him its Copley Medal in 1758 and made him a Fellow in 1761. Dollond had begun as a silk-weaver and only turned to instrument making in his mid-forties. Achromatic lenses quickly became standard elements of refracting telescopes and other optical devices. Dollond’s career reflects the ease with which the worlds of trade, practice and science overlapped in his day. Today’s firm of Dollond and Aitcheson had its origins in the business that Dollond and his son founded in 1750.

Robert Fox, Museum of the History of Science, University of Oxford.

Related scientific article

Title An Account of Some Experiments concerning the Different Refrangibility of Light
Author J Dollond and J Short
Journal Philosophical Transactions
URL http://dx.doi.org/10.1098/rstl.1757.0099
Dollond microscope featuring the achromatic combination of lenses, a method patented by Dollond’s of London in 1758.

© Science Museum/SSPL
1763
The success of willow bark in the treatment of fever

In 1763, Edmund (probably Edward) Stone, a vicar in Chipping Norton, Oxfordshire, wrote to the Royal Society detailing 5 years of experiments and observations on the use of dried, powdered willow bark in curing fevers. Typically for the period, he combined his ecclesiastical work with a lively interest in science, including mathematics, astronomy, botany and medicine. Originally noting the bark’s bitter taste, he thought it might be similar to the Peruvian bark, or cinchona, an expensive imported fever remedy. Also influenced by the Doctrine of Signatures, a theory that many remedies were found close to the illnesses they cured, he noticed that the willow grew in the same moist conditions that often caused fevers. Subsequent efforts to find the active principle of the bark led to the discovery of salicylic acid, and to the production of acetylsalicylic acid, which was first synthesized in 1899 under the trade name of aspirin. Aspirin is now one of the world’s most used medicines—over 40 million pounds of the substance being produced annually in the United States alone.

Tilli Tansey, Wellcome Trust Centre for the History of Medicine, UCL.

Related scientific article

Title An Account of the Success of the Bark of the Willow in the Cure of Agues
Author E Stone
Journal Philosophical Transactions
URL http://dx.doi.org/10.1098/rstl.1763.0033
White willow (*Salix alba*). Edmund Stone experimented on the uses of dried willow bark as a cure for fevers.

© Permission granted to use under GFDL by Kurt Stueber
An essay on chance

Bayes had an amazing insight that completely changed our reasoning about probabilities. This makes it easier to think about one’s chances in gambling and dealing in insurance. Recently, Bayes’ theorem was used to filter spam e-mail. This paper, published after Bayes’ death, was known by specialists, but now Google shows over 5 million hits if you search for ‘Bayesian’. But what is so groundbreaking about the Reverend Thomas Bayes’ concept? Without it our way of doing science would be much less accurate. Furthermore, understanding probabilities in the Bayesian way probably comes closest to the most fundamental thing that the brain has to do. The Bayesian approach is therefore at the heart of current models about the brain.

Uta Frith, UCL Institute of Cognitive Neuroscience.

Related scientific article

**Title**  An Essay towards Solving a Problem in the Doctrine of Chances

**Author**  T Bayes and Mr. Price

**Journal**  Philosophical Transactions

**URL**  [http://dx.doi.org/10.1098/rstl.1763.0053](http://dx.doi.org/10.1098/rstl.1763.0053)

The Gaming House, the sixth painting in William Hogarth's 'A Rake's Progress' series, showing Tom
Rakewell gambling away his fortune, 1733.

© By courtesy of the Trustees of Sir John Soane's Museum

Early dice found in Williamsburg, Virginia.

© Photo by Joe Fudge/Daily Press.
1769

Observations on the transit of Venus

This paper forms part of the incredible effort made in observing the transit of Venus across the face of the sun in 1769. The transit received a lot of attention in Britain and a special committee was set up to oversee the event. Edmund Halley had previously made the calculation to translate the timings of the transit, as seen from different locations on the Earth, to a distance between the Earth and the Sun. This distance is a fundamental unit in astronomy known as the Astronomical Unit (AU). The ratio of the distances from the Sun to all the planets were known, and using the exact value of 1AU allowed the determination of the actual spacing of all the planets. Contributions from the UK included sending Captain James Cook to make observations in Tahiti under support from the Royal Society.

Lucie Green, Mullard Space Science Laboratory.

Related scientific article

**Title**  Account of Several Phaenomena Observed during the Ingress of Venus into the Solar Disc  
**Author**  W Hirst  
**Journal**  Philosophical Transactions  
**URL**  [http://dx.doi.org/10.1098/rstl.1769.0031](http://dx.doi.org/10.1098/rstl.1769.0031)

Diagram showing the phases of the transit of Venus, 1769.

© The Royal Society
Mozart: an account of a very remarkable young musician

At 8 years old Wolfgang Mozart was a sensation in London, but Barrington was a sceptical observer. Was Wolfgang as young as he claimed to be? Was he really that talented? At the Mozarts’ lodgings Barrington set the most difficult tests. Wolfgang played a five-part duet scored in different keys by sight ‘in a masterly manner’. He even corrected his father, who accompanied him. On request he extemporized songs embodying love or rage. Barrington also noted that little Wolfgang was as playful and distractible as any ordinary child. A favourite cat was given preference over playing the harpsichord. Barrington was convinced and wrote that the young boy’s musical gifts were ‘amazing and incredible almost as it may appear’.

Uta Frith, UCL Institute of Cognitive Neuroscience.

Related scientific article

- **Title**: Account of a Very Remarkable Young Musician
- **Author**: D Barrington
- **Journal**: Philosophical Transactions
- **URL**: [http://dx.doi.org/10.1098/rstl.1770.0008](http://dx.doi.org/10.1098/rstl.1770.0008)

Wolfgang Amadeus Mozart (aged 14) in Verona, by Saverio dalla Rosa, 1770.

© [wikimedia commons](https://commons.wikimedia.org)
Observations on gases

Why do things burn? Priestley’s view, the common one in his day, was that combustion consisted of the vigorous release of a hypothetical substance, phlogiston. But his paper of 1772, on the properties of several recently discovered gases, and another in 1774, in which he announced the preparation of the gas we now know as oxygen, provided crucial evidence for the modern theory, according to which oxygen from the atmosphere combines with the burning substance. This theory, developed by the French chemist Antoine Lavoisier, was one that Priestley never accepted. Priestley built his reputation as one of the foremost European chemists of his day whilst working as a nonconformist minister in Leeds. Underlying all he did was a religiously inspired conception of science as the study of God’s creation.

Robert Fox, Museum of the History of Science, University of Oxford.

Related scientific article

**Title**  Observations on Different Kinds of Air

**Author**  J Priestley and W Hey

**Journal**  Philosophical Transactions

**URL**  [http://dx.doi.org/10.1098/rstl.1772.0021](http://dx.doi.org/10.1098/rstl.1772.0021)
Reconstruction of Joseph Priestley's electrical machine which could generate and store electricity.

© The Royal Society
1775

**Hot stuff: survival in 260°F heat**

In 1775 Charles Blagden, Secretary of the Royal Society, entered a room heated by a furnace to at least 260°F (around 127°C). At this temperature the ‘greatest part of a beefsteak was pretty well done in 13 minutes’ and eggs that were removed after 20 minutes were found to be ‘roasted quite hard’. Yet Dr Blagden and his colleagues were unharmed by an 8-minute exposure and their core temperature did not change. Furthermore, their dog, wrapped in a blanket to protect its feet from burning on the floor, remained there for 30 minutes and was ‘little so affected during the whole time as to show signs of pleasure whenever we approached the basket’. Blagden and colleagues showed that the reason humans and dogs are able to survive such heat is owing to evaporative cooling, either from sweating, as in the case of humans, or from panting, as in the case of the dog.

Frances Ashcroft, University of Oxford.

Related scientific article

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Anatomical illustration of a sweat gland.

© Medical Art Service, Munich/Wellcome Images
Captain James Cook’s methods for preserving the health of his crew

'We had on board large quantities of malt, of which was made sweet-wort ... and given from one or two pints in the day to each man'. So writes Captain James Cook in this article to explain how he lost not a single man to scurvy on this, his second, voyage (1772–1775). As late as 1740, long sea voyages were losing in the region of two-thirds of their sailors to scurvy. Cook also discusses the merits of ‘sour krout’ (i.e. pickled cabbage), ‘portable broth’ and, more familiarly, ‘a rob of lemons and oranges’ (although he had ‘no great opinion’ of the latter and considered them too costly). While we are still in doubt whether it was the malt, which Cook reckoned to be the best anti-scorbutic, or simply the practice of frequently replenishing the ship’s fresh food that caused this dramatic decline in deaths from scurvy, it remains one of the earliest triumphs in the study and endorsement of proper nutrition.

Sunetra Gupta, Department of Zoology, University of Oxford.

Related scientific article

Title  The Method Taken for Preserving the Health of the Crew of His Majesty's Ship the Resolution during Her Late Voyage Round the World
Author  J Cook
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1776.0023
Portrait of James Cook, a watercolour on ivory miniature painting.

© The Royal Society
A regulator, made by John Shelton, which accompanied James Cook on his second and third voyages to the Pacific Ocean.

© The Royal Society
Edward Jenner is widely regarded as the 'father of vaccination' for pioneering smallpox inoculation at the beginning of the nineteenth century. However, he first achieved scientific fame for this little known paper on how baby cuckoos, hatched from eggs laid in other birds’ nests, displaced the natural inhabitants of that nest. From careful observations of birds’ nests, and experimental manipulation of eggs, Jenner reported that a baby cuckoo ‘with the assistance of its rump and wings’ could get underneath a baby bird and eject it from its nest. His views were met with some incredulity, although the paper was the basis of his election to Fellowship of the Royal Society. It was not until the 1920s that a film finally provided unequivocal evidence that his observations, made over 100 years earlier, had been correct.

Tilli Tansey, Wellcome Trust Centre for the History of Medicine, UCL.

Related scientific article

**Title**  Observations on the Natural History of the Cuckoo  
**Author**  E Jenner  
**Journal**  Philosophical Transactions  
**URL**  [http://dx.doi.org/10.1098/rstl.1788.0016](http://dx.doi.org/10.1098/rstl.1788.0016)
Investigating the composition of Dr. James’s Fever Powder

James’s Powder, or more properly Dr. James’s Fever Powder, was one of the most ubiquitous patented medicines from the mid-eighteenth century to the early twentieth century. Patients included George III, Oliver Goldsmith and Horace Walpole, who claimed the powders ‘can cure most complaints that are not mortal, or chronical’. Patented in 1746, the remedy was the subject of numerous attempts to establish its formula. This private analysis (i.e. not on behalf of the Royal Society) established that the powder consisted of antimony and calcium phosphate, and it was Pearson’s formula that was adopted by the first British Pharmacopoeia in 1864. Pearson, a doctor and one of the most famous medical lecturers of his day, was convinced that something was missing, although his detailed descriptions in the end tell us nothing about what the drug did. There is no modern evidence of its usefulness, and even with modern fever-reducers such as paracetamol there is still debate about how they work.

Daniel Glaser, Wellcome Trust.

Related scientific article

Title   Experiments and Observations to Investigate the Composition of James's Powder.
Author  G Pearson and J Banks
Journal  Philosophical Transactions
URL     http://dx.doi.org/10.1098/rstl.1791.0024
Advertisement for Dr. James's powder for fevers.

© Wellcome Library, London
**Discovery of a comet by the first recognized female scientist**

Caroline Herschel was the sister of the famous astronomer William Herschel. She assisted her brother in his observations and documented his results, but it is often forgotten that she was an excellent astronomer in her own right. In 1786 Caroline Herschel discovered her first of several comets and was rewarded by being paid a salary of £50 by King George III to become her brother's assistant. This was the first time a woman had been recognized in a scientific position. This paper announces the discovery of her sixth comet, which, unknown to Caroline Herschel, had already been sighted by the comet hunter Charles Messier just under 2 weeks earlier.

Lucie Green, Mullard Space Science Laboratory.

Related scientific article

- **Title**: An Account of the Discovery of a Comet
- **Author**: C Herschel
- **Journal**: Philosophical Transactions
- **URL**: [http://dx.doi.org/10.1098/rstl.1794.0001](http://dx.doi.org/10.1098/rstl.1794.0001)
Reproduction of a portrait of Caroline Herschel by Tielemann, 1829.
The invention of the first electric battery

This letter describes the invention of the voltaic pile—the first electric battery. Alessandro Volta built a stack of alternating silver and zinc discs, separated by cardboard soaked in salt water, and demonstrated that an electric current flowed when the top and bottom of the pile were connected. Indeed, he got an electric shock by touching the top of the pile with one hand and the bottom with the other. Volta drew attention to the striking analogy of his apparatus with the electric organs of the electric eel and the *Torpedo* ray. The unit of electrical potential was named the ‘volt’ in Volta’s honour. The letter, written in French by an Italian scientist to an English institution, demonstrates that even in 1800 science was an international activity. An English abstract was published later.

Frances Ashcroft, University of Oxford.

Related scientific article

**Title**  On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds  
**Author**  A Volta  
**Journal**  Philosophical Transactions  
**URL**  [http://dx.doi.org/10.1098/rstl.1800.0016](http://dx.doi.org/10.1098/rstl.1800.0016)

Dial of a voltmeter designed to measure 0–20 volts. This unit ‘volt’ is named after the Italian physicist Alessandro Volta.

© Ton Kinsbergen/Science Photo Library
Alessandro Volta demonstrates his newly invented battery or 'voltaic pile' to Napoleon.

© J-L Charmet/Science Photo Library
Colour vision and the wave theory of light

This paper, about how colours are generated and perceived, argues that light is a wave. Young had to defend this position against the view of Newton and others, who believed that light was made up of particles. While the wave theory gained in favour during the nineteenth century, it was not until the twentieth century that Einstein showed both views to be correct depending on the context. Young, a doctor, also originated the idea that human colour vision can be explained by three separate colour systems: red, green and blue (RGB). He also explained several ways in which colours can be generated in nature. Furthermore, Young produced a fundamental description of how materials stretch, still called Young’s modulus, and helped to unravel Egyptian hieroglyphs.

Daniel Glaser, Wellcome Trust.

Related scientific article

Title  The Bakerian Lecture: On the Theory of Light and Colours
Author  T Young
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1802.0004
Diagram demonstrating Thomas Young's theory that light is a wave.

© The Royal Society
1805

The motion of the Sun and Solar System

William Herschel was one of the greatest astronomers of all time, and was completely self-taught. He became a Fellow of the Royal Society in 1781 and was interested in the construction of the Heavens. Astronomers had observed the stars to have ‘proper’ motions as they shifted their relative positions in the sky over the years. This observation had prompted the question of whether the Sun and, as such, the orbiting planets also moved in space. If the Solar System were moving it would manifest itself in the apparent motions of other stars. In this paper Herschel proposed the Sun was indeed moving (‘highly probable that that sun has a proper motion’) and in a later work went on to find the direction in which it moved relative to other heavenly features. This was a key step in building up a picture of the dynamics of the stars local to us within our Galaxy.

Lucie Green, Mullard Space Science Laboratory.

Related scientific article

Title  On the Direction and Velocity of the Motion of the Sun, and Solar System
Author  W Herschel
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1805.0018

Diagram showing the motion of the Sun and the Solar System, by William Herschel.

© The Royal Society
The invention of the Davy Safety Lamp

This paper describes Sir Humphry Davy’s invention for a safe form of lighting to be used in mines. The Davy Safety Lamp surrounds the flame with a fine wire mesh that allows gas in but does not allow the flame out. Explosive gases that collected in mines, including methane, were responsible for many deaths. This practical and specific paper shows that top scientists can be motivated by practical solutions to real problems, and his invention arguably saved many lives. Sir Humphry Davy was a chemist who discovered many elements and experimented on gases, including laughing gas (to which he became addicted). He was also famous as a public lecturer, particularly at the newly founded Royal Institution.

Daniel Glaser, Wellcome Trust.

Related scientific article

Title   An Account of an Invention for Giving Light in Explosive Mixtures of Fire-Damp in Coal Mines, by Consuming the Fire-Damp
Author  H Davy
Journal  Philosophical Transactions
URL     http://dx.doi.org/10.1098/rstl.1816.0003
Early miner's safety lamp by Humphry Davy, with narrow cylindrical gauze.

© The Royal Society
1822

Elephant, rhinoceros, hippopotamus, bear, tiger and hyena fossilized remains discovered in Yorkshire

Although Buckland believed in a flood in the time of Noah, he rejected flood geology, a principle upheld in universities at the beginning of the nineteenth century. Buckland pointed to the variety of strata that existed in rocks, and argued that these must have been laid down over geological time, not during a single event. He concluded that the foreign animals, known from their bones found in Yorkshire caves, had once actually lived in England, and were not carried off from the tropics in the floodwaters of the biblical deluge. Buckland inferred that the word ‘beginning’ in Genesis actually meant an undefined period of time, which had witnessed a long line of extinctions and ‘creations’ of new species. Although rather obvious today, the idea that life has existed on Earth for millions of years was a radical and dangerous departure from the near-exclusively scriptural philosophy of Buckland’s days. Buckland would next write the first full account of what would later be called a ‘dinosaur’ – Megalosaurus.

Andrew Parker, Natural History Museum.

Related scientific article

Title  Account of an Assemblage of Fossil Teeth and Bones of Elephant, Rhinoceros, Hippopotamus, Bear, Tiger, and Hyaena, and Sixteen Other Animals; Discovered in a Cave at Kirkdale, Yorkshire, in the Year 1821
Author  W Buckland
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1822.0017
Fossilized teeth of a hyena discovered in Yorkshire by William Buckland, 1822.

© The Royal Society
How the Earth’s atmosphere changes with height

John Dalton wrote about a subject of tremendous importance for the global environment: the chemical composition of the atmosphere. He began by stating some familiar laws, and then described a laboratory experiment in which two gases were mixed. Dalton recognized an important limitation of his laboratory experiment. His laboratory was small in size, but the atmosphere is much larger; thus, air pressure would vary between that at the Earth’s surface and that further up in the atmosphere. Dalton then drew on another important ‘science tool’, the thought experiment, and thus arrived at his conclusions. Science is an ongoing process: a chain of experiments and reasoning. So, just as the laboratory experiment was limited, and required a new way of thinking, Dalton immediately recognized the limitations of that too: ‘All that we have said hitherto has been relating to “quiescent” atmospheres ... How the case would be with regard to the earth’s atmosphere, such as it actually is, ... is not very easy to ascertain ...’ And, indeed, there was still much to learn; we return to this important topic over a century later in the 1946 timeline entry on the Brewer–Dobson circulation.

Bjoern Hassler, University of Cambridge.

Related scientific article

Title On the Constitution of the Atmosphere
Author J Dalton
Journal Philosophical Transactions
URL http://dx.doi.org/10.1098/rstl.1826.0017
John Dalton's table of symbols representing elements and compounds. From A New System of Chemical Philosophy, 1808.

© The Royal Society
Mathematical theory of suspension bridges

In the early 1800s the industrial revolution was in full swing. James Watt created his steam engine in 1765, Davy invented his safety lamp for miners in 1815, and Stephenson’s Rocket was chosen for the Manchester to Liverpool railway in 1829. Bridges were urgently needed, and when Thomas Telford proposed a suspension bridge over the Menai Straits his plans came to the attention of Davies Gilbert, an accomplished mathematician, who would later be President of the Royal Society. Gilbert was convinced that the suspension chain was too shallow, and at his suggestion it was changed to its present form. He backed up his views with mathematical calculations of the ‘catenary’ shape of a hanging cable, and his results appeared in 1826, the year the bridge opened. A novel feature was his calculation of the hanging form of an efficient cable whose sectional area varies to ensure uniform stress throughout. With roadways carried by wrought iron chains, the bridge had a record-breaking span of 580 feet. The work of Gilbert, son of a Cornish curate, illustrates how mathematics was contributing to front-line engineering projects of his day.

Michael Thompson, Dept of Applied Mathematics & Theoretical Physics, University of Cambridge.

Related scientific article

Title  On the Mathematical Theory of Suspension Bridges, with Tables for Facilitating Their Construction
Author  D Gilbert
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1826.0019

Menai suspension bridge, which links the island of Anglesey and the mainland of Wales.

© Photograph by Mick Knapton
1837

Progress towards modern photography

It is generally agreed that Daguerre in France was the founder of photography. However, his initial process required such long exposures as to render portraiture impractical. Fox Talbot, who studied classics and mathematics at Cambridge and was a Fellow of both the Royal Astronomical Society and the Royal Society, succeeded in dramatically reducing the time required to obtain an image. He achieved this by enhancing 100-fold the efficiency of the process of developing the initially invisible chemical image on light-sensitive paper; so, much less light was needed to produce an image. He also showed how positive images could be made from negatives by pressing the latter against a sheet of photographic paper beneath a glass plate that was then exposed to light. While his ‘calotype’ process did not yield sharp enough images to be adopted generally, it nonetheless constituted a crucial step in the development of modern conventional photography.

Richard Gardner, formerly University of Oxford

Related scientific article

Title   An Account of Some Recent Improvements in Photography
Author  H F Talbot
Journal  Proceedings
URL     http://dx.doi.org/10.1098/rspl.1837.0169
An Early Attempt at Photography from Norwich, a photogenic drawing by C. B. Rose, ca 1840.

© The Royal Society
Experimental daguerreotype, by J. F. Goddard, 1841.

© The Royal Society
Observations of distant galaxies with a 58 foot long telescope

The history of astronomy, since Galileo, has been marked by the construction of steadily more powerful observing instruments. First there were optical telescopes, which were slowly improved in their ability to image more sharply and to see fainter objects. Then we added the ability to ‘see’ in radio waves, microwaves, X-rays, infrared, gamma rays and, now, even non-electromagnetic probes such as neutrinos. Soon, hopefully, gravitational radiation will also be added to this list. Each new window we have opened has revealed amazing new discoveries that have forever altered our view of our universe. Lord Rosse (former President of the Royal Society) provided one of the great leaps in our progress with his construction of huge metal-mirrored reflecting telescopes, culminating in the ‘Leviathan of Parsonstown’, a 58 foot long monster with a mirror 72 inches in diameter. Such was the quality of the optics, and the cleverness of the mounting system that he invented, that he was able to see faint objects with unprecedented resolution. Amongst the many resulting discoveries was his observation that nebulae, which had appeared as faint smudges in lesser telescopes, showed remarkable spiral structure. This was an important step along the way to realizing that we live in just such a spiral galaxy and thus understanding the true large-scale structure of the cosmos.

David Wark, Department of Physics, Imperial College London.

Related scientific article

Title Observations on the Nebulæ
Author Earl of Rosse
Journal Philosophical Transactions
URL http://dx.doi.org/10.1098/rstl.1850.0026

Stereoscopic photograph of the Earl of Rosse’s 58 foot telescope, the ‘Leviathan of Parsonstown’.

© The Royal Society
1850

Movement as heat: the foundations of thermodynamics

If you ever wonder why the tyres of your car affect the miles per gallon you get, look no further – read on. This is one of those research papers that reveal the laws that lurk behind common experiences. Anyone who has ever burnt himself or herself sliding down a banister or felt the hot tyres of a car after a journey knows that movement and heat are related. At the time this paper was written the question was, why does drilling metal cause it to get so hot you could fry an egg on it? Joule and his contemporaries understood that heat is just a form of motion: moving atoms are heat! By doing so they laid the foundations for the science of thermodynamics, the thorn in every engineer’s life but, nevertheless, the basis by which all engines are designed.

Mark Miodownik, King's College London.

Related scientific article

- **Title**: On the Mechanical Equivalent of Heat
- **Author**: J P Joule
- **Journal**: Philosophical Transactions
- **URL**: [http://dx.doi.org/10.1098/rstl.1850.0004](http://dx.doi.org/10.1098/rstl.1850.0004)
James Joule's water friction apparatus, which demonstrates that kinetic energy can be converted into heat energy in water.

© Science Museum/SSPL
A relationship between gravity and electricity?

The history of science is littered with heroic stories about experiments that demonstrate what we think to be true. Often experiments like this one, which tell us what is not true, are ignored. The author, Michael Faraday, was a real scientist’s scientist, responsible for great conceptual advances (drawings of the ‘field lines’ from a magnet are an example of his way of looking at the world), a gifted mathematician and an exceptional experimentalist. His Law of Induction coupled the apparently distinct phenomena of electricity and magnetism, quantifying how a moving magnet will induce an electric current in a loop of wire. If changing magnetic fields could induce a current, how about changing gravitational fields? If you believe that, at the deepest level, all forces have some common cause (as Faraday did, and we still do today), then why not? In this paper he tries to demonstrate such an effect by moving a heavy mass near a coil of wire (or a coil of wire near a heavy mass), but despite changing every variable he could try, he saw no effect. Today’s knowledge rests on the bedrock of such experiments that, while largely forgotten, live on in the theories they give shape to.

David Wark, Department of Physics, Imperial College London.

Related scientific article

Title  The Bakerian Lecture. Experimental Researches in Electricity. Twenty-Fourth Series
Author  M Faraday
Journal  Philosophical Transactions
URL  http://dx.doi.org/10.1098/rstl.1851.0001
Michael Faraday holding a bar magnet.

© The Royal Society
**1858**

**Observations of the early stages of inflammation**

In this detailed article, Joseph Lister sets out his careful observations on the early stages of inflammation. Inflammation is the complex process by which the body responds to any kind of assault—be it by an obvious wound or by invisible microbes—and that can, in excess, perversely cause more damage than good. This paper gives us a fascinating glimpse into the dedication involved in studying such a complex phenomenon using the rather blunt tools available at the time. It was through similar careful scientific observations that Lister became convinced of the idea that certain diseases were caused by microbes and earned the title ‘The Father of Modern Antisepsis’ by advocating the use of carbolic acid in hospital wards and particularly during surgical procedures.

Sunetra Gupta, Department of Zoology, University of Oxford.

Related scientific article

**Title**  On the Early Stages of Inflammation  
**Author**  J Lister  
**Journal**  Philosophical Transactions  
**URL**  http://dx.doi.org/10.1098/rstl.1858.0031

![The Lister antiseptic carbolic spray.](https://wellcomecollection.org/ Collection: Wellcome Library, London)
Use of Lister's carbolic spray in surgery, 1858.

© Wellcome Library, London
Few papers in the history of physics have had the impact of this paper, Maxwell’s great synthesis of the nineteenth century theory of electromagnetism. He extended what was already known about electricity and magnetism with one crucial addition, called the displacement current, where changing electric fields generate magnetic fields. The resulting theory is the first success at unifying forces, as it describes electricity and magnetism as just two different aspects of the same underlying phenomenon. However, it goes far beyond that, as Maxwell also showed that light consists of electromagnetic waves, explaining, in one leap, all of classical optics. His theory is one of the pillars of classical physics, but it also contains hints of the theory of special relativity, and therefore the seed of the modern physics revolution that was to follow.

David Wark, Department of Physics, Imperial College London.

Related scientific article

**Title**  A Dynamical Theory of the Electromagnetic Field

**Author**  J C Maxwell

**Journal**  Philosophical Transactions

**URL**  [http://dx.doi.org/10.1098/rstl.1865.0008](http://dx.doi.org/10.1098/rstl.1865.0008)
James Clerk Maxwell, Scottish physicist.

© Science Photo Library
The proof that fingerprints are unique

Coming a few years after the first observation that fingerprints appeared to be unique, this was the first systematic proof that you could identify an individual from a fingerprint. Galton’s classification system, which he describes at length, was adopted by Scotland Yard and is still in use today. The paper’s almost obsessive cataloguing and classification was typical of Galton, who was fascinated by measurement of everything from the weather to the mind. Darwin’s cousin, he was one of the first to realize the implications of evolution for mankind. He originated the phrase ‘nature versus nurture’ and became devoted to the improvement of the human through selective breeding, inventing eugenics.

Daniel Glaser, Wellcome Trust.

Related scientific article

**Title**  The Patterns in Thumb and Finger Marks. On Their Arrangement into Naturally Distinct Classes, the Permanence of the Papillary Ridges that Make Them, and the Resemblance of Their Classes to Ordinary Genera

**Author**  F Galton

**Journal**  Philosophical Transactions B

**URL**  [http://dx.doi.org/10.1098/rstb.1891.0001](http://dx.doi.org/10.1098/rstb.1891.0001)

Francis Galton’s diagram of 'primary' patterns, which he believed all fingerprint patterns are based on.

© The Royal Society
In 1898, very little was known about the temperature and chemical composition of the Sun’s outer atmosphere, called the corona. The British astronomer Norman Lockyer worked on these fundamental questions using the technique of spectroscopy, in which the Sun’s light is split into its component colours as with a prism. This technique reveals a series of dark and bright lines, produced by specific gases at specific temperatures. In this article, Lockyer summarized the work done on a previously unseen bright line that he discovered in 1869. Understanding this line showed that the corona is much hotter than the Sun’s surface, throwing open a puzzle in solar physics that is yet to be answered. Lockyer is also famous for having discovered helium on the Sun by the same method before it was found on the Earth.

Lucie Green, Mullard Space Science Laboratory.

Related scientific article

Title  Preliminary Note on the Spectrum of the Corona  
Author  N Lockyer  
Journal  Proceedings  
URL  http://dx.doi.org/10.1098/rspl.1898.0087  

Norman Lockyer's pattern showing the spectrum of the corona (the Sun's outer atmosphere).  
© The Royal Society
Identification of the first hormone

Hormones—we have all heard of them but what do they do? The word derives from the Greek and means ‘to set in motion’. It is used to describe chemical messengers released by one cell that act on cells elsewhere in the body. This paper describes how William Bayliss and Ernest Starling identified the first hormone. They called it secretin, because it stimulated ‘a copious secretion of pancreatic juice’, a watery bicarbonate-rich fluid that neutralizes the acid entering the upper part of the small intestine from the stomach. The scientists showed that secretin was released from intestinal cells in response to the presence of food in the gut and that it was transported via the bloodstream to the pancreas, where it stimulated secretion of pancreatic ‘juice’. Their work opened up a major new field of biological research with direct medical application.

Frances Ashcroft, University of Oxford.

Related scientific article

Title  Croonian Lecture: The Chemical Regulation of the Secretory Process
Author  W M Bayliss and E H Starling
Journal  Proceedings
URL  http://dx.doi.org/10.1098/rspl.1904.0045

Neuroendocrine cells (light blue) in the human small intestine. These cells secrete hormones such as secretin.

© S. Schuller, Wellcome Images
1909

Reflection of alpha-particles from thin foil

This paper is a nice example of how a truly revolutionary scientific breakthrough can be hidden in an apparently simple and mundane experimental result. Geiger and Marsden bombarded thin foils with \`alpha particles\` (heavy charged particles emitted by certain radioactive decays) and found that a small number (fewer than one in a thousand) were reflected back off the foil. While the paper betrays little excitement, in the atomic model of the day alpha particles should just punch right through, so the authors’ advisor, Ernest Rutherford, later wrote ‘It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you’. Rutherford went on to show how the results could be explained on the assumption that all the positive charge in the atom was concentrated in a tiny nucleus at the atom’s centre, and nuclear physics was born.

David Wark, Department of Physics, Imperial College London.

Related scientific article

**Title**  On a Diffuse Reflection of the `alpha-Particles`

**Author**  H Geiger and E Marsden

**Journal**  Proceedings A

**URL**  [http://dx.doi.org/10.1098/rspa.1909.0054](http://dx.doi.org/10.1098/rspa.1909.0054)

Ernest Rutherford (left) and Hans Geiger with the instrument they used to detect and count `alpha particles` from a radioactive source.

© Science Museum/SSPL
Life at the top

Climb too high, too fast and you will succumb to mountain sickness: headache, nausea, vomiting, shortness of breath and, in the worst cases, fatal swelling of the brain and lungs. Ascend more slowly and these noxious effects are reduced. This vivid and entertaining paper, with extraordinary illustrations, is the first scientific account of the effects of acute exposure to high altitude on the human body and of what happens when you acclimatize. Among other things, it documents the marked increase in red blood cells that occurs after a few days. This enables the blood to carry more oxygen, helping to compensate for the lower oxygen concentration in the air at altitude. Haldane, who led the expedition to Pikes Peak (originally Pike's Peak), was an intrepid Oxford scientist who solved many other physiological problems often by carrying out (dangerous) experiments upon himself. In particular, he produced the first time/depth tables that enabled divers to avoid the bends. They are still used today.

Frances Ashcroft, University of Oxford.

Related scientific article

**Title**  Physiological Observations Made on Pike's Peak, Colorado, with Special Reference to Adaptation to Low Barometric Pressures  
**Author**  C Gordon Douglas et al (including J S Haldane)  
**Journal**  Philosophical Transactions B  
**URL**  [http://dx.doi.org/10.1098/rstb.1913.0006](http://dx.doi.org/10.1098/rstb.1913.0006)
Experiment to determine the total respiratory exchange while walking on the flat, Pikes Peak, Colorado, 1913.

© The Royal Society
Eclipse expeditions: testing Einstein’s Theory of General Relativity

Few fundamental physics experiments have attracted as much contemporary press attention as the results of the eclipse expeditions in 1919. The expeditions were organized by Arthur Eddington to test the prediction of Einstein’s Theory of General Relativity that light would be bent by the gravitational field of the Sun. As a result, the experiment and its results have become somewhat shrouded in myths, to which reading this reasonably accessible paper is a useful antidote. Some say that Eddington’s expedition to Principe produced definitive proof of general relativity, others that the results were in fact ambiguous. The reality is that there was not one expedition, there were two (a second went to Sobral in Brazil), and that the data they provided were indeed a remarkable confirmation of general relativity. They did not ‘prove’ general relativity is right all by themselves, of course, because the idea of a single definitive experiment is itself a myth. However, these results did move general relativity from the ‘no evidence’ to the ‘may well be true’ category and turned Einstein into a worldwide celebrity. Therefore, their importance to the history of physics is certainly no myth.

David Wark, Department of Physics, Imperial College London.

Related scientific article

**Title**  A Determination of the Deflection of Light by the Sun's Gravitational Field, from Observations Made at the Total Eclipse of May 29, 1919  
**Author**  F W Dyson, A S Eddington and C Davidson  
**Journal**  Philosophical Transactions A  
**URL**  [http://dx.doi.org/10.1098/rsta.1920.0009](http://dx.doi.org/10.1098/rsta.1920.0009)
Observation of the total eclipse of 29th May 1919.

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The mathematical foundations of theoretical statistics

Without statistics empirical sciences that compare data from populations, like behavioural sciences, plant sciences and genetics, would be unthinkable. How do you know whether an observation taken from a small sample is valid? For example, one bed of plants gets fertilizer A, another fertilizer B, and a third gets no fertilizer at all. Is the difference in growth between the three samples due to chance or is it actually significant? Fisher produced statistical tests that tell us. In fact, Fisher introduced all the important principles of experimental design and analysis, which are still in constant use; for example, factorial and blocked designs. The F-value (to report the outcome of analysis of variance) is the most quoted statistic, another technique that Fisher introduced and which still carries his initial.

Uta Frith, UCL Institute of Cognitive Neuroscience.

Related scientific article

Title  On the Mathematical Foundations of Theoretical Statistics
Author  R A Fisher
Journal  Philosophical Transactions A
URL  http://dx.doi.org/10.1098/rsta.1922.0009
Ronald Fisher, statistician.

© Godfrey Argent Studio
1928

Spinning electrons

Two of the pillars of the modern physics revolution at the beginning of the twentieth century are special relativity (which has big effects when things are moving very fast) and quantum mechanics (which mostly affects the very small). These new theories marked a spectacular advance in our ability to explain nature, but there was one glaring flaw—quantum mechanics as originally formulated did not include relativity, so could not deal with very small, very fast things. That problem was first successfully attacked by Paul Dirac with his theory of the electron. In these papers he formulated a new, relativistic version of quantum mechanics embodied in what we now call the Dirac equation, which predicts that each electron will possess an intrinsic angular momentum (or ‘spin’). This had already been guessed because of the multiplicity of atomic states; however, Dirac not only explained it, he could also predict the correct value for the resulting splitting in atomic energy levels. The equation, however, goes far beyond that, because its solutions have another inherent multiplicity—for every positive energy state, there is also a negative energy state. After a few false starts, Dirac correctly interpreted this as a prediction of the existence of anti-matter, a prediction that was verified only a few years later by Carl Anderson with the discovery of the electron’s anti-particle, the positron.

David Wark, Department of Physics, Imperial College London.

Related scientific article

**Title**   The Quantum Theory of the Electron
**Author**  P A M Dirac
**Journal** Proceedings A
**URL**     [http://dx.doi.org/10.1098/rspa.1928.0023](http://dx.doi.org/10.1098/rspa.1928.0023)
Portrait of Paul Dirac, by Clara Ewald, 1939.

© The Royal Society
The genius of jumping genes

Barbara McClintock led a life littered with scientific honours, all awarded in recognition of her outstanding work on ‘jumping genes’. These are mobile genetic elements known as transposons that can move from one region of the genome to another. McClintock showed that changes in the colour of maize kernels are due to transposons producing insertions, deletions and translocations in the genome (indeed as much as 50 per cent of the maize genome is caused by transposons). Transposons are not confined to maize. They are found in all plants and animals, and they share many similarities with viruses. They can also cause human disease by disrupting gene functions. It took many years for McClintock’s work to be recognized, but she was finally awarded a Nobel Prize for her discovery and description, some 40 years earlier, of transposition.

Frances Ashcroft, University of Oxford.

Related scientific article

Title  Barbara McClintock. 16 June 1902–2 September 1992
Author  N V Fedoroff
Journal  Biographical Memoirs of Fellows of the Royal Society (published 1994)(Copyright NAS)
URL  http://dx.doi.org/10.1098/rsbm.1994.0039

© Carnegie Institution for Science
1939

**Metal fatigue**

Metals get tired—odd but true. It is called metal fatigue and is the reason why even a child can break a steel coat hanger with little difficulty: the back and forth motion induces small changes in the crystalline structure. The effect was noticed by early railway engineers, but it was not explained until Orowan and other metallurgists started to unravel the puzzle through a combination of theory and microscopic examination. The work was largely ignored by engineers but not by the novelist Nevil Shute, who wrote *No Highway* in 1948 about an aircraft disaster caused by metal fatigue; the subsequent film starred Jimmy Stewart. A few years later, reality caught up with fiction when the Comet aircraft did actually start to fall out of the sky, and it was only then that the science was taken seriously. We all have Orowan and his metallurgist colleagues to thank for our ability to fly safely.

Mark Miodownik, King's College London.

Related scientific article

**Title**  Theory of the Fatigue of Metals

**Author**  E Orowan

**Journal**  Proceedings A

**URL**  [http://dx.doi.org/10.1098/rspa.1939.0055](http://dx.doi.org/10.1098/rspa.1939.0055)

Fatigue cracks of the upper fuselage of the Comet aircraft which crashed due to metal fatigue in January 1954.

© Science Museum/SSPL
1940

The development of penicillin

In 1928, Alexander Fleming of St Mary’s Hospital in London discovered that a mould called *Penicillium notatum* had antibiotic activity, but failed in several bids to purify the active factor enough to investigate its clinical potential. At the start of the Second World War, a small team under Howard Florey, Oxford University’s Professor of Pathology, took up this challenge with the aim of improving the treatment of the commonly infected wounds of combatants. This goal was achieved largely through the ingenuity of a junior member of Florey’s team called Norman Heatley. The results on patients suffering from very severe bacterial infection were both rapid and spectacular. Mass production of this antibiotic, which was named penicillin after the mould producing it, was achieved in America. Fleming, together with Florey and his colleague Chain, subsequently received the Nobel Prize.

Richard Gardner, formerly University of Oxford.

Related scientific article

- **Title**: Howard Florey and the development of penicillin
- **Author**: H Harris
- **Journal**: Notes and Records (published 1999)
- **URL**: [http://dx.doi.org/10.1098/rsnr.1999.0078](http://dx.doi.org/10.1098/rsnr.1999.0078)
Howard Florey examining fully grown *Penicillium* mould.

© The Royal Society
A *Penicillin* cartoon strip from True Comics, No. 41, December 1944.

© The Royal Society
Just like Dalton in 1826, Dobson, Brewer and Cwilong investigated the conditions high up in the atmosphere that are of tremendous importance for both the ozone layer and climate change. However, writing some 100 years later, they were able to get much closer to the real atmosphere, with all its dynamical, physical and chemical processes. Like Dalton, the authors offered some real scientific enquiry. They talked about what was known, and proposed where further work was needed. The article foreshadows important developments in the understanding of our global environment, such as Brewer–Dobson circulation, named after two of the authors. The Brewer–Dobson circulation is a global circulation pattern in the atmosphere, whereby air is pulled up in the tropics, then moved polewards through the stratosphere, and finally pushed down at the poles. Carried by this circulation—very slowly, but persistently—CFCs (chlorofluorocarbons) are all pulled high up into the atmosphere. There, after a chain of chemical reactions, they cause polar ozone depletion (the ‘ozone hole’). Such global circulation patterns, not just in the atmosphere but also in the oceans, play an important role in our understanding of global change and how it can be mitigated.

Bjoern Hassler, University of Cambridge.

Related scientific article

Title  Bakerian Lecture. Meteorology of the Lower Stratosphere
Author  G M B Dobson et al
Journal  Proceedings A
URL  http://dx.doi.org/10.1098/rspa.1946.0010
Annual variations of temperatures in the troposphere and stratosphere, by Dobson, 1946.

© The Royal Society
Diagram showing the principle of the eye-observation frost-point hygrometer, by Dobson, 1946.

© The Royal Society
1950

The first atomic explosion

The world’s first atomic explosion took place under conditions of top security in New Mexico in July 1945. Two years later, the USA cautiously released movie records of this secret ‘Trinity’ explosion. To everyone’s amazement, using only these declassified pictures of the expanding fireball, the talented British mathematician Geoffrey Taylor was able to calculate the energy of the explosion. He published his findings in 1950, announcing that the explosion had the energy of 16 800 tons of the chemical explosive TNT. His method involved plotting, in an ingenious way, the radius of the spherical shock wave against the time from detonation: this showed the movie to be in perfect agreement with a theory that he had developed 4 years before the explosion. G. I. Taylor (1886–1975) came from a family of mathematicians, and made major contributions to the turbulent flow of fluids, perhaps stimulated by his lifelong love of sailing. He was honoured with a knighthood in 1944. His energy estimate of the Trinity test featured in a novel by Tom McMahon.

Michael Thompson, Dept of Applied Mathematics & Theoretical Physics, University of Cambridge.

Related scientific article

**Title**  The Formation of a Blast Wave by a Very Intense Explosion. II. The Atomic Explosion of 1945  
**Author**  G I Taylor  
**Journal**  Proceedings A  
**URL**  [http://dx.doi.org/10.1098/rspa.1950.0050](http://dx.doi.org/10.1098/rspa.1950.0050)

![The 'ball of fire' following the atomic explosion at t=127msec showing the relative sharpness of its edge.](image)

© The Royal Society
In 1934 Alan Hodgkin set out to discover how electrical impulses are generated and conducted along nerve fibres. He was later joined by Andrew Huxley at the marine biological laboratory in Plymouth, where they experimented on the giant nerve fibre of the squid. A few weeks after their first informative experiments, the Second World War broke out and work was suspended for 8 years. Subsequently, they showed that the nerve impulse results from a rapid influx of positively charged sodium atoms into the nerve cell quickly followed by an exit of similarly charged potassium atoms. Because these atoms carry an electric charge this produces a transient change in voltage that sweeps along the nerve fibre. As the Cambridge computer was broken (there was only one at the time!) they had to use a hand-cranked calculator to analyse their data. Despite these various setbacks, the results were spectacular and the authors were awarded the Nobel Prize for their work. They also both became President of the Royal Society—Huxley doing so almost 100 years after his grandfather, Thomas Henry Huxley, who was widely known as ‘Darwin’s Bulldog’.

Frances Ashcroft, University of Oxford.

Related scientific article

**Title**  Propagation of Electrical Signals Along Giant Nerve Fibres

**Author**  A L Hodgkin and A F Huxley

**Journal**  Proceedings B

**URL**  [http://dx.doi.org/10.1098/rspb.1952.0054](http://dx.doi.org/10.1098/rspb.1952.0054)
Photomicrograph of an electrode inside a giant axon. From 'Action potentials recorded from inside a nerve fibre', by Hodgkin and Huxley.

The discovery of the structure of DNA, the genetic code and the building blocks of life, is one of the most iconic moments in the history of science. Watson and Crick’s paper in *Nature* in 1953 is one of the most famous ever published. But that paper, as is almost always true for rapid, groundbreaking publications, did not contain enough detail to allow the scientific community to assess it properly. They, therefore, followed it up with this paper that sets out the evidence much more fully. Given how famous the discovery is today, it is hard to imagine how gradually the idea was accepted by fellow scientists, let alone the general public.

Daniel Glaser, Wellcome Trust.

Related scientific article

**Title**  The Complementary Structure of Deoxyribonucleic Acid  
**Author**  F H C Crick and J D Watson  
**Journal**  Proceedings A  
**URL**  [http://dx.doi.org/10.1098/rspa.1954.0101](http://dx.doi.org/10.1098/rspa.1954.0101)
A rough scale of the structure of DNA, by Crick and Watson, 1954.

© The Royal Society
1956

**Natural selection in the peppered moth**

An increase in the frequency of the melanic (darker) morphs of the peppered moth (*Biston betularia*) following the Industrial Revolution is one of the best known examples of natural selection operating at an observable timescale. The lighter forms of the species when 'at rest on lichened boughs were often almost invisible'—to paraphrase the words of Bernard Kettlewell, who conducted some of the important studies to establish the truth of this. But when these boughs turned a sorry shade of grey due to widespread pollution, they found themselves more exposed to birds searching for food, thus favouring their darker cousins. In this article, J. B. S. Haldane—who had remarkable insights into how mathematics can help us understand evolution—raised questions about the precise mechanisms of heredity and the properties of the genes that led to this shift.

Sunetra Gupta, Department of Zoology, University of Oxford.

Related scientific article

**Title**  The Theory of Selection for Melanism in Lepidoptera  
**Author**  J B S Haldane  
**Journal**  Proceedings B  
**URL**  [http://dx.doi.org/10.1098/rspb.1956.0038](http://dx.doi.org/10.1098/rspb.1956.0038)
The peppered moth (*Biston betularia*) in its natural habitat.

© Brian Stone http://thenaturalstone.blogspot.com
Continental drift: how Africa and South America have drifted apart

Learning how the ancient continents of Rodinia, Gondwanaland and Pangaea were moulded together and then torn apart, you might think that you were reading The Lord of the Rings. But this is the amazing story of real continents drifting about on the Earth’s surface over millions of years. As long ago as 1596, the Dutch map maker Abraham Ortelius had observed that the shapes of continents on opposite sides of the Atlantic Ocean seem to fit together, suggesting that Africa and South America had been violently ripped apart. So started the controversial theory of ‘continental drift’, claiming that the continents once formed a single landmass, pieces of which broke off and then drifted to their present positions. In 1965, Sir Edward Bullard presented his paper on The Fit of the Continents around the Atlantic to a Symposium at the Royal Society. This, together with evidence of matching fossils and rock magnetism, strengthened the consensus that drift had indeed occurred. Today the theory of plate tectonics explains the forces that drive the process in which continents are moving at speeds up to 5 cm per year. This, incidentally, is a little faster than your nails grow!

Michael Thompson, Dept of Applied Mathematics & Theoretical Physics, University of Cambridge.

Related scientific article

Title   The Fit of the Continents around the Atlantic
Author  E Bullard et al
Journal  Philosophical Transactions A
URL     http://dx.doi.org/10.1098/rsta.1965.0020
Map showing the fit of Africa and South America, by Edward Bullard, 1965.

© The Royal Society
1970

**Are there black holes in space?**

The idea that the gravitational attraction between two bodies gets stronger as they get closer together goes back at least to Newton. Inherent in this is a paradox for point particles—as the distance between them goes to zero the force becomes infinite and the laws of physics break down. In classical physics there are no real point particles, so this is not a serious problem. However, in this article, Stephen Hawking and Roger Penrose showed that in General Relativity, Einstein’s theory of gravity, the problem appears very serious indeed. General Relativity predicts black holes: regions of space where the gravitational attraction is so great that even light cannot escape. Hawking and Penrose showed that, within the boundary of a black hole, space becomes so strongly curved that the production of a true singularity is inevitable. Thus, General Relativity contains the seeds of its own destruction, as it predicts the inescapable production of points where it must break down. However, General Relativity does not describe the world at the quantum level, so many (most?) physicists believe that a true theory of quantum gravity will rid us of these troublesome singularities. Unfortunately, despite the heroic efforts of generations of theorists, a successful theory of quantum gravity still eludes us. So for any prospective young physicists reading this, there is still work to be done!

David Wark, Department of Physics, Imperial College London.

**Related scientific article**

**Title**  The Singularities of Gravitational Collapse and Cosmology  
**Author**  S W Hawking and R Penrose  
**Journal**  Proceedings A  
**URL**  [http://dx.doi.org/10.1098/rspa.1970.0021](http://dx.doi.org/10.1098/rspa.1970.0021)

Two black holes on a collision course.

© NASA
1974

The structure of insulin

Insulin is an essential regulator of blood glucose concentration, as it is the only hormone capable of lowering blood glucose. Insufficient insulin leads to diabetes, an escalating problem in Western societies and one that costs the National Health Service over 1 million pounds an hour. This review lecture by Dorothy Hodgkin recounts how she and her colleagues solved the atomic structure of insulin. It was a long and difficult journey—she started work on the problem in 1934 but it was not solved until 1969, and a further period was necessary to improve the resolution. Dorothy Hodgkin is the only UK female scientist to win the Nobel Prize—she won it before her insulin triumph, for solving the structures of vitamin B12 and penicillin.

Frances Ashcroft, University of Oxford.

Related scientific article

- **Title**: The Bakerian Lecture, 1972: Insulin, its Chemistry and Biochemistry
- **Author**: D C Hodgkin
- **Journal**: Proceedings A
- **URL**: [http://dx.doi.org/10.1098/rspa.1974.0085](http://dx.doi.org/10.1098/rspa.1974.0085)

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Reconstruction of a bizarre creature, *Opabinia regalis*, from fossilized remains

When Harry Whittington revealed a reconstruction of *Opabinia*—an ancient creature that lived around 508 million years ago—at a Palaeontological Association meeting, it was greeted with loud laughter, such was its alien form. Its flattened body is around 5cm long, with overlapping side blades and tail fan. It has five eyes and a long, flexible snout terminating in a jaw. But this is just one of many bizarre-looking animals found in the Canadian Burgess shale quarries, albeit a classic example. Although first discovered by Charles Walcott in 1909, it took Whittington and his ‘Cambrian project’ (with Derek Briggs and Simon Conway Morris), beginning in 1967, to decipher the enigmatic Burgess shale fossils. Whittington and his team concluded that these fossils were not remnants of a bygone kind of life, but long-extinct relatives of today’s fauna. But they were the first of their kind, and so the nature of the Cambrian explosion, as pondered by Buckland and Darwin, was finally revealed.

Andrew Parker, Natural History Museum.

Related scientific article

**Title**  The Enigmatic Animal *Opabinia regalis*, Middle Cambrian, Burgess Shale, British Columbia  
**Author**  H B Whittington  
**Journal**  Philosophical Transactions B  
**URL**  [http://dx.doi.org/10.1098/rstb.1975.0033](http://dx.doi.org/10.1098/rstb.1975.0033)
Reconstruction of *Opabinia regalis*.
Identification of flawed reasoning in the evolutionary debate

Not all scientific articles take the form of discoveries or experiments. Gould and Lewontin’s entertaining paper—one of the best known in modern biology—was instead a powerful rebuke against sloppy thinking! It diagnosed a subtle yet flawed line of reasoning creeping into evolutionary debate: because evolution by natural selection can generate structures (a bird’s feather, or an enzyme) that appear perfectly ‘designed’ for the task they perform, some researchers had begun to imply that the mere existence of such structures was sufficient proof that they had arisen via natural selection for the role they perform today. Gould and Lewontin explain how this logical short cut can lead to error—in each instance, natural selection must be empirically tested and not taken as given.

Oliver Pybus, University of Oxford.

Related scientific article

Title  The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme
Author  S J Gould and R C Lewontin
Journal  Proceedings B
URL  http://dx.doi.org/10.1098/rspb.1979.0086
Spandrels inside St Mark's Basilica, Venice.

© Aleister Crowley
Spandrels on King's College chapel ceiling, Cambridge. Product of evolution

© Gunnar Wrobel
1980

**Edge detection: a visual tool of the human brain**

How do human beings recognize objects? It is not enough just to see them as a camera does. The brain has to translate the picture that is received by the eye into thoughts so that we know what we are looking at. Objects in the world are not nicely arranged—one can be in front of another, on top or underneath. The brain has to solve the problem of which bit of the visual scene goes with which object. David Marr in this paper with Ellen Hildreth had the idea that edges are key, and that differences in brightness tell you where edges are. They used mathematical equations to work out how the brain might do this. This work inspired others to build robots, which not only can see objects but can also recognize them.

Uta Frith, UCL Institute of Cognitive Neuroscience.

Related scientific article

- **Title**  Theory of Edge Detection
- **Author**  D Marr and E Hildreth
- **Journal**  Proceedings B
- **URL**  [http://dx.doi.org/10.1098/rspb.1980.0020](http://dx.doi.org/10.1098/rspb.1980.0020)
Domo is a humanoid robot designed by MIT to assist people with everyday tasks. Domo is able to recognize and manipulate objects.

© Photo courtesy of Aaron Edsinger
Double-barrelled protein pores

Ion channels are tiny, gated pores that sit in the membranous envelope that surrounds each cell of the body. Their opening and closing underlies the electrical impulses of nerve and muscle cells. They are also responsible for the electric shock of the *Torpedo* ray. Chris Miller provided the first demonstration that chloride channels are unique in having two pores per channel—like a double-barrelled shotgun that selectively spits out negatively charged chloride ions. Recently, the atomic structure of these proteins has been solved and their two-pore nature confirmed. Mutations in the genes that code for chloride channels cause many types of human disease, including various forms of muscle and kidney disorders, and understanding the structure and function of the channels involved helps explain what goes wrong in disease.

Frances Ashcroft, University of Oxford.

Related scientific article

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Chloride channel structure showing two pores per channel.

© Supplied by Chris Miller
Solar flares observed from the Hinotori satellite

The Japanese Hinotori satellite was the first space mission dedicated to understanding the huge explosions that take place in the Sun’s atmosphere called solar flares. The first observation of a solar flare was made by British astronomer Richard Carrington in 1859. They were seen to occur in regions known as sunspots, which represent areas of strong magnetic field at the Sun’s surface. However, in the following decades little progress was made in understanding how the explosions were powered. The Hinotori spacecraft was launched in 1981 and given its name, meaning firebird, after successfully making it into orbit. It is Japanese tradition not to name the spacecraft until this time. The results gave a new insight into the characteristics of flares, allowing a better picture of the magnetic environment that produces them and the role that electrons play in transferring the energy. Japan has since continued the solar physics research with the Yohkoh and Hinode missions, in which UK scientists and engineers have been heavily involved.

Lucie Green, Mullard Space Science Laboratory.

Related scientific article

Title     Observations from the Hinotori Mission
Author    T Sakurai et al
Journal   Philosophical Transactions A
URL       http://dx.doi.org/10.1098/rsta.1991.0085
Drawing of the Hinotori satellite.

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1991
The effects of diet on human health

Elsie Widdowson FRS was one of the foremost nutritional scientists of the twentieth century. She gained her PhD in 1933, but, as was then common for women, was unable to get a scientific job. She retrained as a dietician, during the course of which she met Robert McCance FRS, and together they created a formidable intellectual partnership. During the Second World War they defined the nutritional value of foodstuffs upon which food rationing was based, and examined numerous aspects of human metabolism. Widdowson developed a particular interest in the relationship between diet and the growth and health of the developing foetus and infant growth, and published several reports and papers that influenced governments and aid agencies around the world. This paper, written when she was in her eighties, reviewed contemporary diets, health and disease, with particular reference to the introduction of agriculture and the consequent effects on human nutrition and world population. She emphasized that, in times and areas of nutritional scarcity, it was infants and young children who suffered most.

Tilli Tansey, Wellcome Trust Centre for the History of Medicine, UCL.

Related scientific article

Title  Contemporary Human Diets and their Relation to Health and Growth: Overview and Conclusions
Author  E M Widdowson et al
Journal  Philosophical Transactions B
URL  http://dx.doi.org/10.1098/rstb.1991.0118
Elsie Widdowson, 1981.

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1994
Concepts on how to quantify the extent of biological diversity

Robert M. May foresaw that the new technologies of molecular biology had the potential to cast an entirely new spotlight on life on Earth. Indeed, the last 20 years have seen our view of biodiversity revolutionized as the invisible, microbial world has been illuminated. People interested in biodiversity are typically interested in ‘furries and featheries’, but that is not what biodiversity is actually about. In his words, ‘As one moves down the size spectrum of organisms, from the romantic large mammals and birds, through nondescript small arthropods, on down to protozoan, bacterial and viral species, not only does concern for diversity and conservation fall away, but it even changes sign’. How to open eyes, curiosity and interest to the world of the small remains an unsolved challenge.

Sean Nee, University of Edinburgh.

Related scientific article

- **Title**: Conceptual Aspects of the Quantification of the Extent of Biological Diversity
- **Author**: R M May
- **Journal**: Philosophical Transactions B
- **URL**: [http://dx.doi.org/10.1098/rstb.1994.0082](http://dx.doi.org/10.1098/rstb.1994.0082)

A ciliate protozoan. This tiny single-celled organism is found in freshwater. It feeds on bacteria and decaying organic matter.
Polar bear (sow and cub), near Kaktovik, Barter Island, Alaska.

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2008

**Geoengineering: big ideas to battle global warming**

Switch off lights! Leave your 4×4 at home! This may help, but the magnitude of global warming forces scientists to think big. They want to filter sunlight by positioning a trillion sunshades in space; launch fleets of robot ships spraying water into the atmosphere; fertilize carbon-absorbing plankton by dumping tons of iron into the oceans. Massive interventions such as these are proposed and critically assessed in a Theme Issue of the Society's *Philosophical Transactions*. They may be risky, but could become less risky than doing nothing. In a scene-setting paper, James Lovelock outlines his idea for stimulating blooms of algae that sequester carbon dioxide to the ocean floor. He emphasizes the extreme dangers of climate change, drawing on parables from simple models such as ‘daisy world’. Stocked with competing species of black daisies (absorbing the Sun’s heat) and white daisies (reflecting sunlight), this world evolves in ways similar to that of Earth. He ends with ethical advice. We should focus less on ‘human rights’ and more on ‘human obligations’ to preserve the biodiversity of Gaia, our living planet.

Michael Thompson, Dept of Applied Mathematics & Theoretical Physics, University of Cambridge.

Related scientific article

**Title**  A geophysiologist's thoughts on geoengineering  
**Author**  J Lovelock  
**Journal**  Philosophical Transactions A  
**URL**  [http://dx.doi.org/10.1098/rsta.2008.0135](http://dx.doi.org/10.1098/rsta.2008.0135)

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