

The New Encyclopædia Britannica

Volume 4

MICROPÆDIA

Ready Reference

FOUNDED 1768

15TH EDITION



Encyclopædia Britannica, Inc.

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Chicago

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First Edition	1768-1771
Second Edition	1777-1784
Third Edition	1788-1797
Supplement	1801
Fourth Edition	1801-1809
Fifth Edition	1815
Sixth Edition	1820-1823
Supplement	1815-1824
Seventh Edition	1830-1842
Eighth Edition	1852-1860
Ninth Edition	1875-1889
Tenth Edition	1902-1903

Eleventh Edition

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Twelfth Edition

© 1922

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Thirteenth Edition

© 1926

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Fourteenth Edition

© 1929, 1930, 1932, 1933, 1936, 1937, 1938, 1939, 1940, 1941, 1942, 1943,
1944, 1945, 1946, 1947, 1948, 1949, 1950, 1951, 1952, 1953, 1954,
1955, 1956, 1957, 1958, 1959, 1960, 1961, 1962, 1963, 1964,
1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973

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Fifteenth Edition

© 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986,
1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1997, 1998, 2002, 2003

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Printed in U.S.A.

Library of Congress Control Number: 2002113989
International Standard Book Number: 0-85229-961-3

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mula $M(Fe_xO_y)$, where M represents any metal that forms divalent bonds, such as any of the elements mentioned earlier. Nickel ferrite, for instance, is $NiFe_2O_4$, and manganese ferrite is $MnFe_2O_4$; both are spinel minerals. The garnet mineral known as YIG, containing the rare-earth element yttrium, has the formula $Y_3Fe_5O_{12}$; it is used in microwave circuitry. The most familiar ferrite, known since biblical times, is magnetite (lodestone, or ferrous ferrite), $Fe(Fe_2O_4)$. Ferrites exhibit a form of magnetism called ferrimagnetism (*q.v.*), which is distinguished from the ferromagnetism of such materials as iron, cobalt, and nickel. In ferrites the magnetic moments of constituent atoms align themselves in two or three different directions. A partial cancellation of the magnetic field results, and the ferrite is left with an overall magnetic field that is less strong than that of a ferromagnetic material. This asymmetry on the part of the atomic orientations may be due to the presence of two or more different types of magnetic ions, to a peculiar crystalline structure, or to both. The term ferrimagnetism was coined by the French physicist Louis Néel, who first studied ferrites systematically on the atomic level. There are several types of ferrimagnetism. In collinear ferrimagnetism the fields are aligned in opposite directions; in triangular ferrimagnetism the field orientations may be at various angles to each other. Ferrites can have several different types of crystalline structures, including spinel, garnet, perovskite, and hexagonal.

The most important properties of ferrites include high magnetic permeability and high electrical resistance. High permeability to magnetic fields is particularly desirable in devices such as antennas. High resistance to electricity is desirable in the cores of transformers to reduce eddy currents. Ferrites of a type known as square-loop ferrites can be magnetized in either of two directions by an electric current. This property makes them useful in the memory cores of digital computers, since it enables a tiny ferrite ring to store binary bits of information. Another type of computer memory can be made of certain single-crystal ferrites in which tiny magnetic domains called bubbles can be individually manipulated. A number of ferrites absorb microwave energy in only one direction or orientation; for this reason, they are used in microwave wave guides.

Ferro, Spanish *HIERRO*, island, Santa Cruz de Tenerife *provincia*, Canary Islands *comunidad autónoma* ("autonomous community"), Spain, the westernmost and smallest of the Canary Islands in the North Atlantic. Ferro, the most westerly place known to ancient European geographers, was chosen about AD 150 by the classical geographer Ptolemy for the prime meridian of longitude, and until the 18th century some navigators continued to reckon from this line.

The island, with an area of 107 square miles (278 square km), is mountainous (reaching 5,000 feet [1,500 m]) and is ringed by sheer cliffs except near Valverde, the capital, where wooded slopes meet the sea. Ferro lacks a harbour, and landings are made at a short mole at Estaca, the port of the island. Mineral springs attract a small tourist trade, but the economy primarily depends on subsistence agriculture. Pop. (1999 est.) 8,082.

ferroalloy, an alloy of iron (less than 50 percent) and one or more other metals, important as a source of various metallic elements in the production of alloy steels. The principal ferroalloys are ferromanganese, ferrochromium, ferromolybdenum, ferrotitanium, ferrovandium, ferrosilicon, ferroboration, and ferrophosphorus. These are brittle and unsuitable for direct use in fabricating products, but they are a useful source of these elements for the alloy

steels. Ferroalloys usually have lower melting ranges than do the pure elements and can be incorporated more readily in the molten steel. They are added to liquid steel to achieve a specified chemical composition and provide properties needed to make particular products. They are in fact used in all steels—*e.g.*, plain carbon, stainless, alloy, electrical, tool, and so on.

Ferroalloys are prepared from charges of the **nonferrous** metal ore, iron or iron ore, coke or coal, and flux by treatment at high temperature in **submerged-arc** electric furnaces. An **aluminothermic reduction** process is used for making ferrovandium, ferrotitanium, and ferriobium (ferrocolumbium).

ferroaugite, iron-rich variety of the mineral augite (*q.v.*).

ferrocene, also called **DICYCLOPENTADIENYL-IRON**, the earliest and best known of the so-called sandwich compounds; these are derivatives of transition metals in which two organic ring systems are bonded symmetrically to the metal atom. Its molecular formula is $(C_5H_5)_2Fe$.

First prepared in 1951 by the reaction of sodium cyclopentadienide with iron(II) chloride, ferrocene occurs as highly stable orange crystals with a melting point of $174^\circ C$ ($345^\circ F$). Chemically, ferrocene behaves like benzene and other aromatic compounds in that it undergoes substitution reactions. The removal of one electron from the molecule raises the iron atom to the next-higher oxidation state (*i.e.*, from +2 to +3), leading to the formation of salts containing the blue ferricinium cation, $(C_5H_5)_2Fe^+$.

ferrochromium, alloy of chromium with 30 to 50 percent iron, used to incorporate chromium into steel. It is produced in an electric furnace using chromium ore, iron or iron ore, and carbon, usually anthracite coal. In the intense heat the carbon reduces the metal oxides to the molten alloy, which is poured out into slabs.

ferroelectricity, property of certain nonconducting crystals, or dielectrics, that exhibit spontaneous electric polarization (separation of the centre of positive and negative electric charge, making one side of the crystal positive and the opposite side negative) that can be reversed in direction by the application of an appropriate electric field. Ferroelectricity is named by analogy with ferromagnetism, which occurs in such materials as iron. Iron atoms, being tiny magnets, spontaneously align themselves in clusters called ferromagnetic domains, which in turn can be oriented predominantly in a given direction by the application of an external magnetic field.

Ferroelectric materials—for example, barium titanate ($BaTiO_3$) and Rochelle salt—are composed of crystals in which the structural units are tiny electric dipoles; that is, in each unit the centres of positive charge and of negative charge are slightly separated. In some crystals these electric dipoles spontaneously line up in clusters called domains, and in ferroelectric crystals the domains can be oriented predominantly in one direction by a strong external electric field. Reversing the external field reverses the predominant orientation of the ferroelectric domains, though the switching to a new direction lags somewhat behind the change in the external electric field. This lag of electric polarization behind the applied electric field is ferroelectric hysteresis, named by analogy with ferromagnetic hysteresis.

Ferroelectricity ceases in a given material above a characteristic temperature, called its Curie temperature, because the heat agitates the dipoles sufficiently to overcome the forces that spontaneously align them.

ferrohortonolite, silicate mineral, a member of the forsterite-fayalite series (*q.v.*) of olivines.

ferromagnetism, physical phenomenon in which certain electrically uncharged materials strongly attract others. Two materials found in nature, lodestone (or magnetite, an oxide of iron, Fe_3O_4) and iron, have the ability to acquire such attractive powers, and they are often called natural ferromagnets. They were discovered more than 2,000 years ago, and all early scientific studies of magnetism were conducted on these materials. Today, ferromagnetic materials are used in a wide variety of devices essential to everyday life—*e.g.*, electric motors and generators, transformers, telephones, and loudspeakers.

Ferromagnetism is a kind of magnetism that is associated with iron, cobalt, nickel, and some alloys or compounds containing one or more of these elements. It also occurs in gadolinium and a few other rare-earth elements. In contrast to other substances, ferromagnetic materials are magnetized easily, and in strong magnetic fields the magnetization approaches a definite limit called saturation. When a field is applied and then removed, the magnetization does not return to its original value—this phenomenon is referred to as hysteresis (*q.v.*). When heated to a certain temperature called the Curie point (*q.v.*), which is different for each substance, ferromagnetic materials lose their characteristic properties and cease to be magnetic; however, they become ferromagnetic again on cooling.

The magnetism in ferromagnetic materials is caused by the alignment patterns of their constituent atoms, which act as elementary electromagnets. Ferromagnetism is explained by the concept that some species of atoms possess a magnetic moment—that is, that such an atom itself is an elementary electromagnet produced by the motion of electrons about its nucleus and by the spin of its electrons on their own axes. Below the Curie point, atoms that behave as tiny magnets in ferromagnetic materials spontaneously align themselves. They become oriented in the same direction, so that their magnetic fields reinforce each other.

One requirement of a ferromagnetic material is that its atoms or ions have permanent magnetic moments. The magnetic moment of an atom comes from its electrons, since the nuclear contribution is negligible. Another requirement for ferromagnetism is some kind of interatomic force that keeps the magnetic moments of many atoms parallel to each other. Without such a force the atoms would be disordered by thermal agitation, the moments of neighbouring atoms would neutralize each other, and the large magnetic moment characteristic of ferromagnetic materials would not exist.

There is ample evidence that some atoms or ions have a permanent magnetic moment that may be pictured as a dipole consisting of a positive, or north, pole separated from a negative, or south, pole. In ferromagnets, the large coupling between the atomic magnetic moments leads to some degree of dipole alignment and hence to a net magnetization.

The French physicist Pierre-Ernest Weiss postulated a large-scale type of magnetic order for ferromagnets called domain structure. According to his theory, a ferromagnetic solid consists of a large number of small regions, or domains, in each of which all of the atomic or ionic magnetic moments are aligned. If the resultant moments of these domains are randomly oriented, the object as a whole will not display magnetism, but an externally applied magnetizing field will, depending on its strength, rotate one after another of the domains into alignment with the external field and cause aligned domains to grow at the expense of nonaligned ones. In the limiting state called saturation, the entire object will comprise a single domain.

Domain structure can be observed directly. In one technique, a colloidal solution of small magnetic particles, usually magnetite, is

placed on the surface of a ferromagnet. When surface poles are present, the particles tend to concentrate in certain regions to form a pattern that is readily observed with an optical microscope. Domain patterns have also been observed with polarized light, polarized neutrons, electron beams, and X rays.

In many ferromagnets the dipole moments are aligned **parallel** by the strong coupling. This is the **magnetic** arrangement found for the elemental metals iron (Fe), nickel (Ni), and cobalt (Co) and for their alloys with one another and with some other elements. These materials still constitute the largest group of ferromagnets commonly used. The other elements that possess a **collinear** ordering are the rare-earth metals **gadolinium** (Gd), **terbium** (Tb), and **dysprosium** (Dy), but the last two become ferromagnets only well below room temperature. Some alloys, although not composed of any of the elements just mentioned, nevertheless have a **parallel** moment arrangement. An example of this is the Heusler alloy CuAlMn_3 , in which the manganese (Mn) atoms have magnetic moments, though manganese metal itself is not ferromagnetic.

Since 1950, and particularly since 1960, several ionically bound compounds have been discovered to be ferromagnetic. Some of these compounds are electrical insulators; others have a **conductivity** of **magnitude** typical of semiconductors. Such compounds include **chalcogenides** (compounds of oxygen, sulfur, selenium, or tellurium), **halides** (compounds of fluorine, chlorine, bromine, or iodine), and their combinations. The ions with permanent dipole moments in these materials are manganese, chromium (Cr), and europium (Eu); the others are diamagnetic. At low temperatures, the rare-earth metals **holmium** (Ho) and **erbium** (Er) have a nonparallel moment arrangement that gives rise to a substantial spontaneous magnetization. Some ionic compounds with the spinel crystal structure also possess ferromagnetic ordering. A different structure leads to a spontaneous magnetization in **thulium** (Tm) below 32 kelvins (K).

Above the Curie point (also called the Curie temperature), the spontaneous magnetization of the ferromagnetic material vanishes and it becomes **paramagnetic** (i.e., it remains weakly magnetic). This occurs because the thermal energy becomes sufficient to overcome the internal aligning forces of the material. The Curie temperatures for some important ferromagnets are: iron, 1,043 K; cobalt, 1,394 K; nickel, 631 K; and gadolinium, 293 K.

ferrosalite, a silicate mineral intermediate in composition between hedenbergite and diopside (q.v.).

ferrosilite, silicate mineral belonging to the orthopyroxene (q.v.) series.

ferrotremolite, iron-rich variety of the silicate mineral actinolite (q.v.).

ferrotype (photography): see tintype.

Ferrovie dello Stato (FS), English **STATE RAILWAYS**, largest railway system of Italy. FS operates lines on the mainland and also on the islands of Sicily and Sardinia, which are linked to the mainland by train ferries. The Italian railway system was nationalized in 1905. In 1986 its status was changed from a government department to a state corporation, but since 1991 portions of the high-speed network have been privatized.

The FS system controls about four-fifths of Italy's rail network. All the main routes, constituting half the system, have been electrified. The most heavily traveled line in the system is from Milan in the north to Naples in the south, extending down the peninsula through the important rail junction of Bologna and then through Florence and Rome. Other heavily traveled lines run through the industrial north from Turin to Milan to Venice and

from Milan to Genoa. A high-speed passenger route opened between Rome and Florence in the 1970s, and by 1989 high-speed service was available to most major Italian cities. International routes run northward from Turin through the Fréjus Tunnel into France, from Milan through the Simplon and St. Gotthard tunnels to Switzerland, from Verona to Austria and Germany by way of the Brenner Pass, and from Venice to Vienna and eastern Europe. Milan is the southern terminus for container traffic from Rotterdam, Neth.

Ferry, Jules (-François-Camille) (b. April 5, 1832, Saint-Dié, France—d. March 17, 1893, Paris), French statesman of the early Third Republic, notable both for his anticlerical education policy and for his success in extending the French colonial empire.



Ferry
H. Roger-Viollet

Ferry pursued his father's profession of law and was called to the Paris bar in 1855. Soon, however, he made a name for himself as a biting critic of the Second Empire, especially by his articles (1867–68) in the newspaper *Le Temps* attacking Baron George-Eugène Haussmann's administration of Paris.

During the Franco-German War (1870–71), Ferry administered the *département* of Seine, holding the powers of prefect, and was appointed mayor of Paris in November 1870. His administration of the besieged and hungry capital won him the nickname "Ferry-la-Famine," which haunted him the rest of his life. Ferry was minister to Greece (1872–73) and thereafter for six years was in the republican opposition to the conservative governments and to the presidency of Patrice MacMahon. He then held several offices, serving twice (1880–81, 1883–85) as premier and once (1883–85) as minister of foreign affairs.

Ferry is best known for his government's establishment of free, compulsory, secular education, brought about mainly by a law of 1882. This policy was accompanied by other anticlerical measures, notably decrees (1880–81) dissolving the Jesuits and other congregations not authorized under the Concordat of 1801 between France and the papacy and forbidding their members to direct or teach in any educational establishment. Ferry also played a major part in the dramatic extension of France's colonial territories. Ferry and a few enthusiastic colonialists, in the face of popular apathy or hostility, were largely responsible for France acquiring Tunisia (1881), northern and central Vietnam (Tonkin and Annam; 1883), Madagascar (1885), and the French Congo (1884–85). Public anger over the continuing expenditures needed to complete the conquest of Tonkin swept Ferry from office in March 1885. Despite continuing unpopularity, he was elected to the Senate by Vosges in 1891 and became its president in 1893. The violent polemics aroused against him at this time, however, caused a madman to shoot him, and he died from the wound.

Ferryland, village, southeastern Newfoundland, Canada. It lies on the eastern side of the Avalon Peninsula, about 40 miles (65

km) south of St. John's. First visited by Portuguese and French fishermen early in the 16th century, it was named Ferryland, probably derived from the Portuguese *farelhão* ("small promontory"). It was colonized when Sir George Calvert (later Lord Baltimore) obtained a charter for a portion of the peninsula in 1623. The colony showed promise until its proprietors procured the patent for Maryland and vacated the peninsula in 1629. Sir David Kirke, count palatine of the island, took over the village (1638) and established his headquarters there. Ferryland now is a quiet fishing community and a government fish-bait depot, catering to visitors who are attracted by its historic past, including the ruins of its founding-father's mansion. Pop. (1991) 717.

Ferryville (Tunisia): see Manzil Bū Ruqaybah.

Fersen, Fredrik Axel von (b. April 5, 1719, Stockholm, Sweden—d. April 24, 1794, Stockholm), soldier and politician who led Sweden's Hat Party during the 18th-century Age of Freedom—a 52-year period of parliamentary government in his country.

Educated in Sweden and abroad, Fersen entered the Swedish army in 1737. In 1739 he was given leave to join the French army, in which he soon distinguished himself in the War of the Austrian Succession (1740–48). Returning to Sweden, he joined the ruling Hat Party in the Riksdag (parliament). His position in the party was enhanced not only by his father's having been a founder but also



Fredrik Axel von Fersen; pastel by Gustaf Lundberg; in Gripsholm Castle, Sweden

By courtesy of the Svenska Porträllarkivet, Stockholm

by Fersen's marriage into the prominent Hat family of De la Gardie (1752). He was elected speaker of the noble chamber of the Riksdag in 1756, and he used this powerful office to check all efforts by the crown to regain the power it had lost to the Parliament in 1720.

Fersen served with distinction in the Seven Years' War (1756–63). Afterward he unsuccessfully tried to effect an alliance between the Hats and the crown against a rise of a new generation of rivals (the Nightcap, or Cap, Party) to his own party. When King Gustav III began to reassert the governing power of the monarchy in 1772, Fersen at first supported him, but he again led an antiabsolutist faction after the start of the disastrous Russo-Swedish War of 1788–90. Fersen retired from public life in 1789.

Fersen, Hans Axel von (b. Sept. 4, 1755, Stockholm, Sweden—d. June 20, 1810, Stockholm), Swedish-French soldier, diplomat, and statesman who was active in counterrevolutionary activity after the French Revolution of 1789 and the rise of Napoleon.

The son of Fredrik Axel von Fersen, Hans, like his father, transferred from the Swedish to the French army. He served under the Count de Rochambeau, who aided the American forces during the United States War of In-