the pulse hard and wiry, and to produce pallor, a whizzing sound in the ears, dizziness, and faintness. Its administration in a case of Bright's disease described by Dr Bence Jones was followed by epilepsy (see *Med. Times*, 1853, ii. 495). As a topical styptic application, gallic is inferior to tannic acid.[1] With glycerin it is combined to form the pharmaceutical preparation *glycerinum acidi gallici*.

GALLIENUS, P. Licinius (218–268), Roman emperor, son of the emperor Valerian, was born about 218. From 253 to 260 he reigned conjointly with his father, and gave proof of both bravery and ability, especially in the defeat near Milan of 300,000 Alemanni, with a force of only 10,000 Romans. When, however, his father was defeated and taken prisoner by Sapor, king of Persia, in 260, Gallienus made no effort to obtain his release, or to withstand the incursions of the invaders who threatened the empire from all sides. He occupied part of his time in dabbling in literature, science, and various trifling arts, but gave himself up chiefly to excess and debauchery. His generals rebelled against him in almost every province of the empire, and this period of Roman history came to be called the reign of the thirty tyrants, although in reality the usurpers numbered only nineteen. Gallienus was killed at Milan in 268 while besieging Aureolus, who had been proclaimed emperor by the Illyrian legions.

GALLINULE. See Moorhen.

GALLIO, Junius Annæus, proconsul or "deputy" of Achaia at the time of the apostle Paul's first visit to Corinth (53 A.D.), was the son of M. Annæus Seneca, a Roman eques and rhetorician, and was born at Cordova about the beginning of the Christian era. His mother's name was Helvia; and L. Annæus Seneca, the philosopher, and L. Annæus Mela, the geographer, were his full brothers, his own proper name being Marcus Annæus Novatus. After he had received a careful education from his father at Cordova, he went to Rome, where he attracted the notice of L. Junius Gallio, a rhetorician of some repute, who ultimately adopted him, thus conferring the name by which he is usually known. The terms on which he lived with his kindred and with the world are well illustrated in the epithet "dulcis" applied to him by Statius (*Silv.*, ii. 7, 32), and by Seneca (*Nat. Qu.*, 4 pref.—"nemo mortalium uni tam dulcis est quam hic omnibus"). It is probable that Gallio shared the misfortunes of his brother when the latter, having incurred the enmity of Messalina, was banished to Corsica; and that both returned together to Rome when Agrippina had selected Seneca to be tutor to Nero. Towards the close of the reign of Claudius, Gallio received the proconsulship of the newly constituted senatorial province of Achaia (Acts xviii. 12), but seems to have been compelled by ill health to resign the post within a few years (Pliny, *H. N.*, xxxi. 33; Seneca, *Ep.* civ.). In the fifth year of Nero we hear of him as having been again in Rome (Dio Cassius, lxi. 20, 21), and on the same authority we learn that he finally became one of the last victims of that emperor (lxii. 25). The statement of Jerome in the chronicle of Eusebius, that Junius Gallio "frater Senecæ, egregius declamator, propria se manu interfecit," appears to be founded on a confusion of names. Seneca's works, *De Ira* and *De Vita Beata*, are dedicated to Gallio, who himself appears to have written some treatises in natural history (Sen., *N. Q.*, v. 11). Compare Tacitus, *Ann.*, xv. 73; xvi. 17; Dio Cassius, lx. 35.

GALLIPOLI, the ancient Καλλίπολις, a seaport town of Turkey in Europe, in the province of Rumili and vilayet of Edirneh, at the north-east extremity of the Straits of Dardanelles, on a narrow peninsula 130 miles S.W. of Constantinople, and 90 miles due S. of Adrianople, in 40° 24′ N. lat. and 26° 40′ 30″ E. long. Nearly opposite is Lapsaki on the Asiatic side of the channel, which is here about 2 miles wide. The town of Gallipoli presents a miserable aspect; the streets are narrow, the houses mostly of wood and ill built, though there are a few better structures near the harbour, and the Anglo-French occupation of 1853–6 led to some improvements. The only noteworthy buildings are the large, crowded, and well-furnished bazaars, with leaden domes. There are several mosques, none of them remarkable, and many interesting Roman and Byzantine remains, especially a magazine of the emperor Justinian, a square castle and tower attributed to Bajazet I., and some tumuli on the south, said to be the tombs of the Thracian kings. The lighthouse, built on a cliff, has a fine appearance as seen from the Dardanelles. Gallipoli is the residence of a captain-pasha and the seat of a Greek bishop. It has two good harbours, and is the principal station for the Turkish fleet. From its position as the key of the Dardanelles, it was occupied by the allied French and English armies in 1854. Then the isthmus a few miles to the north of the town, between it and Boulair, was fortified with strong earthworks by English and French engineers mainly on the lines of the old works constructed in 1357, when the Turks first crossed over into Europe, nearly 100 years before they gained possession of Constantinople. These fortifications were renewed and enlarged in January 1878, on the Russians threatening to take possession of Constantinople. The peninsula thus isolated by the fortified positions has the Gulf of Saros on the N.W., and extends some 50 miles to the S.W. The guns of Gallipoli command the Dardanelles just before the strait joins the Sea of Marmora. The town itself is not very strongly fortified, the principal fortifications being further down the Dardanelles, where the passage is narrower. The district of Gallipoli is exceedingly fertile and well adapted for agriculture; a great variety of crops are raised, but, previous to the war of 1877–8, nearly all progress was stopped on account of the maladministration of the Turkish authorities. Nevertheless considerable quantities of the various cereals were exported, besides wine, oil, skins, cotton, sheep, &c., much of the trade being transit. The principal imports are manufactured goods, coal, sugar, coffee, rice, soap, iron. The line of railway between Adrianople and the Egean Sea has been prejudicial to the transit trade of Gallipoli, and several attempts have been made to obtain concessions for the construction of a railway that would connect this part with the Turkish railway system. There is little industry in Gallipoli, though previous to the war attempts had been made to extend and improve the manufacture of silk thread and silk goods, and some little business was done in the construction of coasting vessels. Steamers to and from Constantinople call regularly at Gallipoli. Widely different estimates have been given of the population of the town: it is probably somewhere about 25,000 or 30,000.

GALLIPOLI, an important seaport town of Italy, in the province of Lecce, and about 25 miles N.E. of the city of that name, beautifully situated on a rocky islet on the east shore of the Gulf of Taranto, and connected by a long stone bridge of twelve arches with the suburb of Lizza on the mainland. The town is well built and fortified, and has a castle erected by Charles I. of Anjou, a large cathedral, a gymnasium, and an episcopal seminary. It is chiefly noted for its extensive cisterns cut in the solid rock for containing the olive oil collected from all parts of Puglia; but it has besides a productive tunny fishery, and manufactures muslins, cotton stockings, and woollen goods. The harbour has been improved since 1855 by a new mole, but the entrance is still somewhat dangerous. In 1873 there entered 350 vessels with a total tonnage of 66,652 tons, 281 being Italian and 29 British. The principal exports are oil (of which 9628 tons were shipped in 1875), wine, oats, and cotton seed; and the imports, fish from Norway, manufactured goods from France, petroleum from the United States, staves from Austria, and wheat and barley from Greece and Turkey. The population of the town in 1871 was 7578, and of the commune 9951. Gallipoli preserves the name and almost certainly occupies the site of the ancient Callipolis, the "Beautiful City," founded, according to Dionysius, by a Spartan named Leucippus and a number of the citizens of Tarentum.

GALLIUM, so called in honour of France (Gallia), symbol Ga, atomic weight 69·9, a metal discovered, August 27, 1875, by M. Lecoq de Boisbaudran, in the spectroscopic examination of zinc-blende from Pierrefitte in the valley of Argeles, Hautes Pyrénées, and since found to exist in blende from several other localities, notably in that of the mines of Lüdrich and Apfel at Bensberg, on the Rhine, which contains nearly 16 milligrammes per kilogramme. Its density and approximate atomic weight, and other of its characters, were predicted by Mendeljeff, in accordance with his law that the properties of the elementary bodies, as also the constitution and properties of their combinations, are periodic functions of their atomic weights (see article Chemistry, vol. v. p. 543, col. 2). Gallium may be prepared by a process the chief features of which are the treatment of the ore, which contains the metal in only very minute quantity, with zinc; the removal, from a hydrochloric acid solution of the gelatinous precipitate thereby produced, of various foreign metals by means of hydrogen sulphide; the fractionation of the residual liquid with sodium carbonate, gallium being thrown down before zinc by that reagent; the formation of a sulphate from the resultant precipitate; and, lastly, the electrolysis of a potash solution of the purified oxide obtained therefrom, the metal appearing on the negative platinum electrode. Solid gallium is greyish-white, of octahedral crystallization, and remarkably hard and resistant even at a temperature little below its melting point, and is but slightly malleable and flexible, though thin plates of it will bear bending several times without breaking. It melts when held in the fingers, its point of fusion being 30°·15 C. (86°·27 Fahr.). The liquid metal is of a silvery white colour, and adheres to glass, forming a mirror resembling that of mercury. It exhibits in a remarkable degree the phenomenon of superfusion, but when some degrees below its melting point crystallizes immediately if a small fragment of the solid metal attached to a platinum wire be inserted into it. At 24°·5 C. (76°·1 Fahr.) the specific gravity of the solid metal is 5·956, and of the liquid 6·069; the specific heat of the former between 12° and 23° C. is 0·079, giving atomic heat 5·52, and that of the latter between 119° and 106° C. is 0·0802 (Berthelot, *Compt. Rend.*, lxxxvi. 786–7). At a red heat in air gallium is not perceptibly volatilized. It is little affected by cold nitric acid, but dissolves readily in hydrochloric acid; with potash solution it liberates hydrogen. It furnishes a deliquescent and very soluble chloride, $GaCl_3$ or Ga_2Cl_6, a corresponding bromide and iodide, and an ammonio-gallic alum. Its oxide is more soluble in ammonia than is alumina. In basicity it holds a place intermediate between aluminium and indium. It is precipitated by alkaline carbonates and barium carbonate, but not by hydrogen sulphide and ammonium sulphide in the absence of zinc. Gallium affords two brilliant lines in the violet part of the spectrum.

See L. de Boisbaudran, in *Chemical News*, 1877, i. pp. 148, 157, 167; also L. de Boisbaudran and E. Jungfleisch, *Compt. Rend.*, lxxxvi., pp. 475–478 and 577–579, and *Journ. Pharm. Chim.*, ser. 4, xxvii. pp. 338–340—quoted in *Phil. Mag.*, 1878, p. 319, and *Journ. Chem. Soc.*, "Abstracts," 1878, pp. 556 and 837.

GALLOWAY, Thomas (1796–1851), a Scottish mathematician, was born at Symington, in the upper ward of Lanarkshire, 26th February 1796. After receiving such education as the schools of his own and adjoining parishes could give, he entered in 1812 the university of Edinburgh, where he distinguished himself specially in mathematics. In 1823 he was appointed one of the teachers of mathematics at the military college of Sandhurst, and on the death of Sir John Leslie in 1832 he was an unsuccessful candidate for the vacant chair of natural philosophy in Edinburgh. In the following year he was appointed actuary to the Amicable Life Assurance Office, the oldest institution of that kind in London, and in this situation he remained till his death, November 1, 1851. Galloway was a voluminous though, for the most part, an anonymous writer, and took a leading part in the proceedings of the principal scientific societies of London. He contributed largely to the seventh edition of the *Encyclopædia Britannica*, and also wrote several scientific papers for the *Edinburgh* and *Foreign Quarterly Reviews*. His *Encyclopædia* article "Probability" was published separately.

GALLS. In animals galls occur mostly on or under the skin of living mammals and birds, and are produced by Acaridea, and by dipterous insects of the genus *Œstrus*. Signor Moriggia[1] has described and figured a horny excrescence, nearly 8 inches in length, from the back of the human hand, which was caused by *Acarus domesticus*. What are commonly known as galls are vegetable deformities or excrescences, due to parenchymatous hypertrophy, and, according to the definition of Lacaze-Duthiers, comprise "all abnormal vegetable productions developed on plants by the action of animals, more particularly by insects, whatever may be their form, bulk, or situation." For the larvæ of their makers the galls provide shelter and sustenance. The exciting cause of the hypertrophy, in the case of the typical galls, appears to be a minute quantity of some irritating fluid, or virus, secreted by the female insect, and deposited with her egg in the puncture made by her ovipositor in the cortical or foliaceous parts of plants. This virus causes the rapid enlargement and subdivision of the cells affected by it, so as to form the tissues of the gall. Oval or larval irritation also, without doubt, plays an important part in the formation of many galls. Though, as Lacaze-Duthiers remarks, a certain relation is necessary between the "stimulus" and the "supporter of the stimulus," as evidenced by the limitation in the majority of cases of each species of gall-insect to some one vegetable structure, still it must be the quality of the irritant of the tissues, rather than the specific peculiarities or the part of the plant affected, that principally determines the nature of the gall. Thus the characteristics of the currant-gall of *Spathegaster baccarum*, L., which occurs alike on the leaves and on the flower-stalks of the oak, are obviously due to the act of oviposition, and not to the functions of the parts producing it; the bright red galls of the saw-fly *Nematus gallicola* are found on four different species of willow, *Salix fragilis*, *S. alba*, *S. cæprea*, and *S. cinerea*;[2] and the galls of a Cynipid, *Biorhiza aptera*, usually developed on the rootlets of the oak, have been procured also from the deodar.[3] Often the gall bears no visible resemblance to the structures out of which it is developed; commonly, however, outside the larval chamber, or gall proper, and giving to the gall its distinctive form, are to be detected certain more or less modified special organs of the plant. The gall of *Cecidomyia strobilina*, formed from willow-buds, is mainly a rosette of leaves the stalks of which have had their growth arrested. The small, smooth, seed-shaped gall of the

[1] On the therapeutics of gallic acid see further R. Neale, "Clinical notes upon the use of gallic acid in various diseases," *Medical Times*, 1855, i. 458 *sq.*; and W. Bayes, "On Gallic Acid," *Association Medical Journal*, 1854, p. 506.

[1] Quoted in *Zoological Record*, iv., 1867, p. 192.
[2] P. Cameron, *Scottish Naturalist*, ii. pp. 11–15.
[3] *Entomologist*, vii. p. 47.

American *Cynips seminator*, Harris, according to Mr W. F. Bassett,[1] is the petiole, and its terminal tuft of woolly hairs the enormously developed pubescence of the young oak-leaf. The moss-like covering of the "bedeguars" of the wild rose, the galls of a Cynipid, *Rhodites rosæ*, represents leaves which have been developed with scarcely any parenchyma between their fibro-vascular bundles; and the "artichoke-galls" or "oak-strobile," produced by *Aphilothrix gemmæ*, L., which insect arrests the development of the acorn, consists of a cupule to which more or less modified leaf-scales are attached, with a peduncular, oviform, inner gall.[2] Mr E. Newman held the view that many oak-galls are pseudobalani, or false acorns: "to produce an acorn has been the intention of the oak, but the gall-fly has frustrated the attempt." Their formation from buds which normally would have yielded leaves and shoots is explained by Parfitt as the outcome of an effort at fructification induced by oviposition, such as has been found to result in several plants from injury by insect-agency or otherwise.[3] Galls vary remarkably in size and shape according to the species of their makers. The polythalamous gall of *Aphilothrix radicis*, found on the roots of old oak-trees, may attain the size of a man's fist; the galls of another Cynipid, *Andricus occultus*, Tschek,[4] which occurs on the male flowers of *Quercus sessiliflora*, is 2 millimetres, or barely a line, in length. Many galls are brightly coloured, as, for instance, the oak-leaf hairy galls of *Spathegaster tricolor*, which are of a crimson hue, more or less diffused according to exposure to light. The variety of forms of galls is very great. Some are like urns or cups, others lenticular. The "knoppern" galls of *Cynips polycera*, Gir., are cones having the broad, slightly convex, upper surface surrounded with a toothed ridge. Of the Ceylonese galls "some are as symmetrical as a composite flower when in bud, others smooth and spherical like a berry; some protected by long spines, others clothed with yellow wool formed of long cellular hairs, others with regularly tufted hairs."[5] The characters of galls are constant, and as a rule exceedingly diagnostic, even when, as in the case of ten different gall-gnats of an American willow, *Salix humilis*, it is difficult or impossible to tell the full-grown insects that produce them from one another. In degree of complexity of internal structure galls differ considerably. Some are monothalamous, and contain but one larva of the gall-maker, whilst others are many-celled, and numerously inhabited. The largest class are the unilocular, or simple, external galls, divided by Lacaze-Duthiers into those with and those without a superficial protective layer or rind, and composed of hard, or spongy, or cellular tissue. In a common gall-nut that authority distinguished seven constituent portions:—an epidermis; a subdermic cellular tissue; a spongy and a hard layer, composing the parenchyma proper; vessels which, without forming a complete investment, underlie the parenchyma; a hard protective layer; and lastly, within that, an alimentary central mass inhabited by the growing larva.[6]

Galls are formed by insects of several orders. Among the Hymenoptera are the gall-wasps (*Cynips* and its allies), which infect the various species of oak. They are small insects, having straight antennæ, and a compressed, usually very short abdomen, with the second, or second and third segments greatly developed, and the rest imbricated, and concealing the partially coiled ovipositor. The transformations from the larval state are completed within the gall, out of which the imago, or perfect insect, tunnels its way,—usually in autumn, though sometimes, as has been observed of some individuals of *Cynips Kollari*, after hibernation.

The phenomena of development in *Cynips* and associated genera present many features of interest. Not fewer than 12,000 living specimens of *C. Kollari*, Gir. (*C. tigricola*, Hart.), from Devonshire galls, were examined by the late Mr Frederick Smith,[7] of the British Museum, and proved to be all females, as also were the flies obtained in two successive years from some of these by breeding on isolated oak trees in the neighbourhood of London. The same observer detected among about 1200 flies of the gregarious species *Aphilothrix* (*Cynips*) *radicis* not a single male. In many thousands of Cynipids, representing 28 species, Hartig failed to discover any male. Von Schlechtendal, on the other hand, between 24th April and 1st May 1871, from three galls of *Rhodites rosæ*, L., obtained in the previous year, bred only 2 females and 32 males. These males were of the normal coloration and shape; but some which appeared in the latter part of May, when the females were in larger numerical proportion, were varieties of three kinds, partly resembling the females in coloration.[8] Walsh[9] ascertained with respect to the galls of the American Black Oak, that their growth commences in May, and is completed in a few weeks, and that near the middle of June about a fourth of them yield both male and female fully developed gall-flies of the species *Cynips spongifica*, Osten-Sacken. In the remainder of the galls the larvæ do not attain their pupal condition till more than two months later, and the flies they produce, which appear about October, are all females. This autumnal brood has been experimentally ascertained to cause the generation of oak-apples in the following spring on trees not previously infected. Mr W. F. Bassett[10] considers that most, if not all, species of *Cynips* are double-brooded, and that one of the two broods consists of females only. "There are," he remarks, "so many one-gendered species, that we may reasonably suppose each to be the progenitor of the equally numerous double-gendered species, whose relationships have not yet been observed."

Among the commoner of the galls of the *Cynipidæ* are the "oak-apple" or "oak-sponge" of *Andricus terminalis*, Fab.; the "currant" or "berry galls" of *Spathegaster baccarum*, L., above mentioned; and the "oak-spangles" of *Neuroterus lenticularis*,[11] Oliv., generally reputed to be fungoid growths, until the discovery of their true nature by Mr Frederick Smith;[12] and the succulent "cherry-galls" of *Dryophanta scutellaris*, Oliv. The "marble" or "Devonshire woody galls" of oak-buds, which often destroy the leading shoots of young trees, are produced by *Cynips Kollari*,[13] already alluded to. They were first introduced into Devonshire about the year 1847, had become common near Birmingham by 1866, and two or three years later were observed in several parts of Scotland.[14] They contain about 17 per cent. of tannin.[15] On account of their regular form they have been used, threaded on wire, for making ornamental baskets. The large purplish Mecca or Bussorah galls,[16] produced on a species of oak by *Cynips insana*, Westw., have been regarded by many writers as the Dead Sea fruit, mad-apples (*mala insana*), or apples of Sodom (*poma sodomitica*), alluded to by Josephus and others, which, however, are stated by E. Robinson (*Bibl. Researches in Palestine*, vol. i. pp. 522–4, 3d ed., 1867) to be the singular fruit called by the Arabs *'Ösher*, produced by the *Asclepias gigantea* or *procera* of botanists. What in California are known as "flea seeds" are oak-galls made by a species of *Cynips*; in August they become detached from the leaves that bear them, and are caused to jump by the spasmodic movements of the grub within the thin-walled gall-cavity.[1]

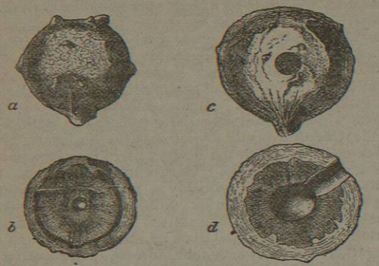

FIG. 1.—*a*, Aleppo "blue" gall; *b*, ditto in section, showing central cavity for grub; *c*, Aleppo "white" gall, perforated by insect; *d*, the same in section (natural size).

Common gall-nuts, nut-galls, or oak-galls, the Aleppo, Turkey, or Levant galls of commerce (German, *Galläpfel*, *Levantische Gallen*; French, *Noix de Galle*), are produced on *Quercus infectoria*, a variety of *Q. Lusitanica*, Webb, by *Cynips* (*Diplolepis*, Latr.) *tinctoria*, L., or *C. gallæ tinctoriæ*, Oliv. Aleppo galls (*gallæ halepenses*) are brittle, hard, spherical bodies, ⅝–¾-inch in diameter, ridged and warty on the upper half, and light brown to dark greyish-yellow within. What are termed "blue," "black," or "green" galls contain the insect; the inferior "white" galls, which are lighter coloured, and not so compact, heavy, or astringent, are gathered after its escape (see fig. 1). Less valued are the galls of Tripoli (Tarapius or Tarabulus, whence the name "Tarablous galls"). The most esteemed Syrian galls, according to Pereira, are those of Mosul on the Tigris. Other varieties of nut-galls, besides the above mentioned, are employed in Europe for various purposes. Commercial gall-nuts have yielded on analysis from 26 (H. Davy) to 77 (Buchner) per cent. of tannin (see Vinen, *loc. cit.*), with gallic and ellagic acids, ligneous fibre, water, and minute quantities of proteids, chlorophyll, resin, free sugar, and, in the cells around the inner shelly chamber, calcium oxalate. Oak-galls are mentioned by Theophrastus, Dioscorides (i. 146), and other ancient writers, including Pliny (*Nat. Hist.*, xvi. 9, 10; xxiv. 5), according to whom they may be produced "in a single night." Their insect origin appears to have been entirely unsuspected until within comparatively recent times, though Pliny, indeed, makes the observation that a kind of gnat is produced in certain excrescences on oak leaves. Bacon describes oak-apples as "an exudation of plants joined with putrefaction." Pomet[2] thought that gall-nuts were the fruit of the oak, and a similar opinion obtains among the modern Chinese, who apply to them the term *Mu-shih-tsze*, or "fruits for the foodless."[3] Hippocrates administered gall-nuts for their astringent properties, and Pliny (*Nat. Hist.*, xxiv. 5) recommends them as a remedy in affections of the gums and uvula, ulcerations of the mouth, and some dozen more complaints. The drug has been used in the treatment of intermittent fevers,[4] but appears to be adapted only for their mildest phases.[5] In India it is given also in chronic diarrhœa, dysentery, gonorrhœa, and several other diseases.[6] In British pharmacy gall-nuts are used in the preparation of the two astringent ointments *unguentum gallæ* and *unguentum gallæ cum opio*, and of the *tinctura gallæ*, and also as a source of tannin and of gallic acid (*q.v.*). They have from very early times been resorted to as a means of staining the hair of a dark colour, and they are the base of the tattooing dye of the Somali women.[7] On the Continent they are employed in tanning. With respect to the technical application of gall-nuts, see further BLASTING, vol. iii. p. 808, DYEING, vol. vii. p. 579, and INK. In consequence of the increased consumption in dyeing of sumach, myrobalans, and new chemical substances, the British importations of gall-nuts have on the whole declined considerably.

The quantities and values of galls imported into the United Kingdom in 1877 were as follows:—From Germany, 1963 cwts., £7759; Turkey, 6420 cwts., £20,712; Egypt, 1702 cwts., £6244; China, 11,748 cwts., £32,715; British India (Bombay and Scinde), 2131 cwts., £2230; other countries, 2411 cwts., £7176; total, 26,425 cwts., of the value of £76,834, against 25,884 cwts., value £64,704, in 1876.

The gall-making Hymenoptera include, besides the *Cynipidæ* proper, certain species of the genus *Eurytoma* (*Isosoma*, Walsh) and family *Chalcididæ*, *e.g.*, *E. hordei*, the "joint-worm" of the United States, which produces galls on the stalks of wheat;[8] also various members of the family *Tenthredinidæ*, or saw-flies. The larvæ of the latter usually vacate their galls to spin their cocoons in the earth, or, as in the case of *Athalia abdominalis*, Klg., of the clematis, may emerge from their shelter to feed for some days on the leaves of the gall-bearing plant.

The dipterous gall-formers include the gall-midges, or gall-gnats (*Cecidomyidæ*), minute slender-bodied insects, with bodies usually covered with long hairs, and the wings folded over the back. Some of them build cocoons within their galls, others descend to the ground to become pupæ. The true willow-galls are the work either of these or of saw-flies. Their galls are to be met with on a great variety of plants of widely distinct genera, *e.g.*, the ash, maple, hornbeam, oak,[9] grape-vine,[10] alder, gooseberry, blackberry, pine, juniper, thistle, fennel, meadowsweet,[11] common cabbage, and cereals. In the northern United States, in May, "legions of these delicate minute flies fill the air at twilight, hovering over wheat-fields and shrubbery. A strong north-west wind, at such times, is of incalculable value to the farmer."[12] Other gall-making dipterous flies are members of the family *Trypetidæ*, which disfigure the seed-heads of plants, and of the family *Mycetophilidæ*, such as the species *Sciara tilicola*,[13] Löw, the cause of the oblong or rounded green and red galls of the young shoots and leaves of the lime.

Galls are formed also by hemipterous and homopterous insects of the families *Tingidæ*, *Psyllidæ*, *Coccidæ*, and *Aphidæ*. *Coccus pinicorticis* causes the growth of patches of white flocculent and downy matter on the smooth bark of young trees of the white pine in America.[14] The galls of examples of the last family are common objects on lime-leaves, and on the petioles of the poplar. An American Aphid of the genus *Pemphigus* produces black, ragged, leathery, and cup-shaped excrescences on the young branches of the hickory.

The Chinese galls of commerce (*Woo-pei-tsze*) are stated to be produced by *Aphis Chinensis*, Bell, on *Rhus semialata*, Murr. (*R. Bucki-amela*, Roxb.), an Anacardiaceous tree indigenous to N. India, China, and Japan. They are hollow, brittle, irregularly pyriform, tuberculated or branched vesicles, with thin walls, covered externally with a grey down, and internally with a white chalk-like matter, and insect-remains (see fig. 2). The escape of the insect takes place on the spontaneous bursting of the walls of the vesicle, probably when, after viviparous (thelytokous) reproduction for several generations, male winged insects are developed. The galls

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[1] See in *Proc. Entom. Soc. of London for the year* 1873, p. xvi.
[2] See A. Müller, *Gardener's Chronicle*, 1871, pp. 1162 and 1518; and E. A. Fitch, *Entomologist*, xi. p. 129.
[3] *Entomologist*, vi. pp. 275–8, 339–40.
[4] *Verhandl. d. zoolog.-bot. Ges. in Wien*, xxi. p. 799.
[5] Darwin, *Variations of Animals and Plants under Domestication*, ii. p. 282.
[6] "Recherches pour servir à l'Histoire des Galles," *Ann. des Sci. Nat.*, xix. pp. 293 *sqq.*
[7] *Zoologist*, xix., 1861, pp. 7330–3.
[8] *Jahresber. des Vereins f. Naturk. zu Zwickau*, 1871, p.
[9] *American Entomologist*, i., 1868, p. 103.
[10] *Proc. Entom. Soc. of London for the year* 1873, p. xv.
[11] According to Dr Adler, alternation of generations takes place between *N. lenticularis* and *Spathegaster baccarum* (see E. A. Ormerod, *Entomologist*, xi. p. 34).
[12] See Westwood, *Introd. to the Mod. Classif. of Insects*, ii., 1840, p. 130.
[13] For figures and descriptions of insect and gall, see *Entomologist*, iv. p. 17; vii. p. 241; ix. p. 53; xi. p. 131.
[14] *Scottish Naturalist*, i., 1871, p. 116, &c.
[15] Vinen, *Journ. de Pharm. et de Chim.*, xxx., 1856, p. 290; "English Ink-Galls," *Pharm. Journ.*, 2d ser., iv. p. 520.
[16] See Pereira, *Materia Medica*, vol. ii. pt. i. p. 347; *Pharm. Journ.*, 1st ser., vol. viii. pp. 422–4.

[1] See R. H. Stretch and C. D. Gibbes, *Proc. California Acad. Nat. Sciences*, iv. pp. 265 and 266.
[2] *A Complete History of Drugs* (translation), p. 169, Lond., 1748.
[3] F. Porter Smith, *Contrib. towards the Mat. Medica . . . of China*, p. 100, 1871.
[4] Cullen, *Mat. Med.*, ii. p. 46, 1789.
[5] E. J. Waring, *Pharm. of India*, p. 463, 1868.
[6] E. J. Waring, *Remarks on . . . Bazaar Medicines . . . of India*, Lond., 3d ed., 1875.
[7] R. F. Burton, *First Footsteps in E. Africa*, p. 178, 1856.

[8] A. S. Packard, jun., *Guide to the Study of Insects*, p. 205, Salem, 1870.
[9] On the Cecidomyids of *Quercus Cerris*, see Fitch, *Entomologist*, xi. p. 14.
[10] See, on *Cecidomyia cenephila*, Von Haimhoffen, *Verhandl. d. zoolog.-bot. Ges. in Wien*, xxv., 801–10.
[11] See *Entomologist's Month. Mag.*, iv., 1868, p. 233; and for figure and description, *Entomologist*, xi. p. 13.
[12] A. S. Packard, jun., *Our Common Insects*, p. 203, Salem, U.S., 1873. On the Hessian fly, *Cecidomyia destructor*, Say, the May brood of which produces swellings immediately above the joints of barley attacked by it, see Asa Fitch, *The Hessian Fly*, Albany, 1847, reprinted from *Trans. New York State Agric. Soc.*, vol. vi.
[13] J. Winnertz, *Beitrag zu einer Monographie der Sciarinen*. p. 164, Vienna, 1867.
[14] Asa Fitch, *First and Second Rep. on the Noxious . . . . Insects of the State of New York*, p. 167, Albany, 1856.

are gathered before the frosts set in, and are exposed to steam to kill the insects.[1]

Chinese galls examined by Viedt[2] yielded 72 per cent. of tannin, and less mucilage than Aleppo galls. Several other varieties of galls are produced by Aphides on species of *Pistacia*.

M. J. Lichtenstein has established the fact that from the egg of the Aphis of Pistachio galls, *Anopleura lentisci*, is hatched an apterous insect (the gall-founder), which gives birth to young Aphides (emigrants), and that these, having acquired wings, fly to the roots of certain grasses (*Bromus sterilis* and *Hordeum vulgare*), and by budding underground give rise to several generations of

Fig. 2.—*a*, Chinese gall (half natural size); *b*, ditto, broken, showing thin-walled cavity; *c*, Japanese gall (natural size).

apterous insects, whence finally comes a winged brood (the pupifera). These last issuing from the ground fly to the Pistachio, and on it deposit their pupæ. From the pupæ, again, are developed sexual individuals, the females of which lay fecundated eggs productive of gall-founders, thus recommencing the biological cycle (see *Compt. Rend.*, Nov. 18, 1878, p. 782, quoted in *Ann. and Mag. Nat. Hist.*, 1879, p. 174).

Of other insects which have been recognized as gall-makers there are, among the Coleoptera, certain Curculionids (gall-weevils), and species of the exotic *Sagridæ* and *Lamiadæ*, and an American beetle, *Saperda inornata* (*Cerambycidæ*), which forms the pseudo-galls of *Salix longifolia* and *Populus angulata*, or cottonwood. Among the Lepidoptera are gall-forming species belonging to the *Tineidæ*, *Ægeriidæ*, *Tortricidæ*, and *Pterophoridæ*. The larva of a New Zealand moth, *Morova subfascuta*, Walk. (*Cacoëcia gallicolens*), of the family *Drepanulidæ*, causes the stem of a creeping plant, on the pith of which it apparently subsists, to swell up into a fusiform gall.[3]

Mite-galls, or *acarocecidia*, are abnormal growths of the leaves of plants, produced by microscopic Acaridea of the genus *Phytoptus* (gall-mites), and consist of little tufts of hairs, or of thickened portions of the leaves, usually most hypertrophied on the upper surface, so that the lower is drawn up into the interior, producing a bursiform cavity. Mite-galls occur on the sycamore, pear, plum, ash, alder, vine, mulberry, and many other plants; and formerly, *e.g.*, the gall known as *Erineum quercinum*, on the leaves of *Quercus Cerris*, were taken for cryptogamic structures. The lime-leaf "nail-galls" of *Phytoptus tiliæ* closely resemble the "trumpet-galls" formed on American vines by a species of *Cecidomyia*.[4] Certain minute Nematoid worms, as *Anguillula scandens*, which infests the ears of wheat, also give rise to galls.

Besides the larva of the gall-maker, or the householder, galls usually contain inquilines or lodgers, the larvæ of what are termed guest-flies or cuckoo-flies. Thus the galls of *Cynips* and its allies are inhabited by members of other cynipideous genera, as *Synergus*, *Amblynotus*, and *Synophrus*; and the pine-cone-like gall of *Salix strobiloides*, as Walsh has shown,[5] is made by a large species of *Cecidomyia*, which inhabits the heart of the mass, the numerous smaller cecidomyidous larvæ in its outer part being mere inquilines. In many instances the lodgers are not of the same order of insects as the gall-makers. Some saw-flies, for example, are inquilinous in the galls of gall-gnats, and some gall-gnats in the galls of saw-flies. Again, galls may afford harbour to insects which are not essentially gall-feeders, as in the case of the Curculio beetle *Conotrachelius nenuphar*, Hbst., of which one brood eats the fleshy part of the plum and peach, and another lives in the "black knot" of the plum-tree, regarded by Walsh as probably a true cecidomyidous gall. The same authority (*loc. cit.*, p. 550) mentions a willow-gall which provides no less than sixteen insects with food and protection; these are preyed upon by about eight others, so that altogether some twenty-four insects, representing eight orders, are dependent for their existence on what to the common observer appears to be nothing but "an unmeaning mass of leaves." Among the numerous insects parasitic on the inhabitants of galls are hymenopterous flies of the family *Proctotrypidæ*, and of the family *Chalcididæ*, *e.g.*, *Callimome regius*, the larva of which preys on the larvæ of both *Cynips glutinosa* and its lodger *Synergus facialis*. The oak-apple often contains the larvæ of *Braconidæ* and *Ichneumonidæ*, which Von Schlechtendal (*loc. sup. cit.*, p. 33) considers to be parasites not on the owner of the gall, *Andricus terminalis*, but on inquilinous *Tortricidæ*. Birds are to be included among the enemies of gall-insects. Oak-galls, for example, are broken open by the titmouse in order to obtain the grub within, and the "button-galls" of *Neuroterus numismatis*, Oliv., are eaten by pheasants.

On galls and their makers and inhabitants see further—J. T. C. Ratzeburg, *Die Forst-Insecten*, Th. iii. pp. 53 *sq.*, Berlin, 1844; T. W. Harris, *Insects injurious to Vegetation*, Boston, U.S., 2d ed., 1852; C. L. Koch, *Die Pflanzenläuse Aphiden*, Nuremberg, 1854; T. Hartig, *Die Familien der Blattwespen und Holzwespen*, Berlin, 1860; Walsh, "On the Insects, Coleopterous, Hymenopterous, and Dipterous, inhabiting the Galls of certain species of Willow," *Proc. Ent. Soc. Philadelphia*, iii., 1863–4, pp. 543–644, and vi., 1866–7, pp. 223–288; T. A. Marshall, "On some British Cynipidæ," *Ent. Month. Mag.*, iv. pp. 6–8, &c.; H. W. Kidd and Albert Müller, "A List of Gall-Bearing British Plants," *ib.*, v. pp. 118 and 216; G. L. Mayr, *Die mitteleuropäischen Eichengallen in Wort und Bild*, Vienna, 1870–71, and the translation of that work, with notes, in the *Entomologist*, vols. vii. *sq.*; also, by the same author, "Die Einmiethler der mitteleuropäischen Eichengallen," *Verhandl. d. zoolog.-bot. Ges. in Wien*, xxii. pp. 669–726; and "Die europäischen Torymiden," *ib.*, xxiv. pp. 53–142 (abstracted in *Cistula Entomologica*, i., Lond., 1869–76); F. Löw, "Beiträge zur Kenntniss der Gallmücken," *ib.*, pp. 143–162, and 321–328; J. E. von Bergenstamm and P. Löw, "Synopsis Cecidomyidarum," *ib.*, xxvi. pp. 1–104; Perris, *Ann. Soc. Entom. de France*, 4th ser., vol. x. pp. 176–185; R. Osten-Sacken, "On the North American Cecidomyidæ," *Smithsonian Miscellaneous Collections*, vol. vi., 1867, p. 173; E. L. Taschenberg, *Entomologie für Gärtner und Gartenfreunden*, Leipsic, 1871; J. W. H. Traill, "Scottish Galls," *Scottish Naturalist*, i., 1871, pp. 123, &c.; Albert Müller, "British Gall Insects," *The Entomologist's Annual for* 1872, pp. 1–22; B. Altum, *Forstzoologie*, iii., "Insecten," pp. 250 *sq.*, Berlin, 1874; J. H. Kaltenbach, *Die Pflanzen Feinde aus der Classe der Insecten*, Stuttg., 1874; A. d'Arbois de Jubainville and J. Vesque, *Les Maladies des Plantes Cultivées*, pp. 98–105, Paris, 1878. (F. M. B.)

GALLUPPI, Pasquale (1770–1846), a distinguished Italian philosopher, was born on 2d April 1770, at Tropea, in Calabria. He was of good family, and after completing his education at the academy of Tropea and the university of Naples he entered the public service, and was for many years employed in the office of the administration of finances. Altogether apart from academic influences he pursued his favourite studies, and it was not till he had reached the age of sixty, and had become widely known by his writings on philosophy, that he was called to a chair in the university of Naples. This chair he held till his death in November 1846. Galluppi's first work was an essay on analysis and synthesis (*Sull' Analisa e sulla Sintesi*) published in 1807. This was followed by the important *Saggio filosofico sulla critica della conoscenza*, in 6 volumes, published from 1819 to 1832. In the *Lettere filosofiche sulle vicende della filosofia relativamente ai principii delle conoscenze humana, da Cartesio sino a Kant*, 1827, by which, through the translation into French (by M. Peisse, 1844), he is best known to foreigners, Galluppi traces his own philosophical development from the empiricism of the 18th century writers through the Kantian criticism to his final speculative view, one in many respects resembling the doctrines of the Scotch school as amended by Hamilton. His systematic work, *Elementi di filosofia* (4 vols. 1832), was long used as a text-book for instruction in the Italian colleges. Of other writings may be mentioned the *Lezioni di logica e di metafisica* (1832–3, 5 vols., 1842); the *Filosofia della Volonta* (3 vols., 1832–1842, incomplete); and the *Storia della Filosofia* (1842), of which only the first volume was published. Galluppi, though in many respects Kantian, can hardly be said to have taken up fully the speculative significance of the *Critique of Pure Reason*. He accepts the Kantian demonstration of the necessary unity of consciousness as the indispensable factor in knowledge, regards our knowledge of the ego as knowledge of substance, maintains that in external perception, or, as he puts it, in sensation, we are directly cognizant of the real thing, and holds that the existence of the unconditioned is given in knowledge as the necessary correlate of the conditioned, but rejects entirely the *a priori* element which is the distinguishing characteristic of the Kantian doctrine of cognition. All judgments, according to him, are ultimately identical—a relic of the empiricism of Condillac which is totally irreconcilable with the fundamental principles of his philosophy. On the other hand, Galluppi exaggerates the place and importance of the moral reason; with Kant he finds objective truth in the ideas of desert and duty, and admits that ethical judgments are *a priori*, without endeavouring to explain, in accordance with his theoretical views, how such judgments are at all possible.

A good view of Galluppi's place in Italian philosophy is given in Ferri, *Essai sur l'Histoire de la Phil. en Italie au XIX^me^ Siècle*, vol. i., Paris, 1869. See also V. Botta, in Ueberweg's *History of Phil.* (Eng. transl., vol. ii., appendix ii.); Prof. Barzellotti, "Philosophy in Italy," in *Mind*, October 1878.

GALLUS, C. Cornelius, a Roman poet, orator, and politician, was born of humble parents at Forum Julii (Fréjus), in Gaul, about the year 66 B.C. At an early age he removed to Rome, where he was taught by the same master as Virgil and Varius. In political life he espoused the cause of Octavianus, and as a reward for his services was made prefect of Egypt. His conduct in this position afterwards brought him into disgrace with Augustus, and dreading the exposure of his arrogance, extortion, and cruelty, he put an end to his life by throwing himself on his sword, in the year 26 B.C. Gallus enjoyed a high reputation among his contemporaries as a man of intellect. He associated on terms of equality with Virgil, Ovid, Varius, Asinius Pollio, and others, and on account of his four books of elegies Ovid claimed for him the first place among the elegiac poets of Rome. His fame as an orator was hardly inferior to his renown as a poet; but as not a fragment of his composition has descended to our times, we have no means of judging the worth of his literary pretensions, and have to content ourselves with the somewhat partial estimate of his personal friends.

See Ch. C. Völker, *Commentatio de C. Galli Vita et Scriptis*, part i., Bonn, 1840; part ii., Elberfeld, 1844.

GALT, John (1779–1839), a Scottish novelist, was born at Irvine, in Ayrshire, on May 2, 1779. He received his early education at Irvine and Greenock, and read largely from one of the public libraries while serving as a clerk in a mercantile office. His first compositions appeared in the *Greenock Advertiser* and the *Scots Magazine*. In 1804 he went to settle in London, where he continued to work at a poem on the *Battle of Largs*, which was published anonymously. After unsuccessful attempts to succeed in business, Galt left for the Continent, and met Byron and Sir John Hobhouse at Gibraltar, with whom he had a tour in the Mediterranean. He remained abroad for three years, and then returned to London. His early works are the *Life and Administration of Wolsey*, *Voyages and Travels*, *Letters from the Levant*, the *Life of Benjamin West*, *Historical Pictures*, the *Wandering Jew*, and a volume of dramas; but he first showed his real power in *The Ayrshire Legatees*, which appeared in *Blackwood's Magazine* in 1820. This was followed in 1821 by his masterpiece—*The Annals of the Parish*; and, at short intervals, *Sir Andrew Wylie*, *The Entail*, *The Steam-Boat*, and *The Provost* were published. These are all in his happiest manner, and are unsurpassed as studies of Scottish character. His next works were *Ringan Gilhaize*, a story of the Covenanters; *The Spaewife*, which relates to the times of James I. of Scotland; *Rothelan*, a novel founded on the reign of Edward III.; *The Omen*, which was favourably criticized by Sir Walter Scott; and *The Last of the Lairds*, another picture of Scottish life. In 1826 he visited America for the second time, in connexion with the establishment of the Canada Company—an undertaking which involved him in great difficulties, and ultimately proved disastrous to his worldly prospects. It is pleasant to remember that, although Galt's connexion with Canada was unfortuate for himself, his youngest son, Sir Alexander Galt, has had a distinguished career there, and was, for some time, finance minister of the colony. In 1827 Galt founded Guelph in Upper Canada, passing on his way the township of Galt on the Grand River, named after him by the Hon. William Dixon. In 1829 he returned to England commercially a ruined man, and devoted himself with great ardour to literary pursuits, of which the first fruit was *Lawrie Todd*—one of his best novels. Then came *Southennan*, a tale of Scottish life in the times of Queen Mary. In 1830 he was appointed editor of the *Courier* newspaper—a post he soon relinquished. His untiring industry was seen in the publication, in rapid succession, of a *Life of Byron*, *Lives of the Players*, *Bogle Corbet*, *Stanley Buxton*, *The Member*, *The Radical*, *Eben Erskine*, *The Stolen Child*, his *Autobiography*, and a collection of tales entitled *Stories of the Study*. In 1834 appeared his *Literary Life and Miscellanies*, dedicated by permission to William IV., who sent the author a present of £200. As soon as this work was published Galt retired to Greenock, where he lingered on in bad health till his death on the 11th of April 1839.

Galt, like almost all voluminous writers, was exceedingly unequal. His masterpieces are *The Ayrshire Legatees*, *The Annals of the Parish*, *Sir Andrew Wylie*, *The Entail*, *The Provost*, and *Lawrie Todd*. *The Ayrshire Legatees* gives, in the form of a number of exceedingly diverting letters, the adventures of the Rev. Dr Pringle and his family in London. The letters are made the excuse for endless tea-parties and meetings of kirk session in the rural parish of Garnock. The *Annals of the Parish* are told by the Rev. Micah Balwhidder, Galt's finest character. This work is a splendid picture of the old-fashioned Scottish pastor and the life of a country parish; and, in rich humour, genuine pathos, and truth to nature, it is unsurpassed even by Scott. Like his other Scotch novels, it is a fine specimen of the homely graces of the Scottish dialect, and preserves much

[1] See E. Doubleday, *Pharm. Journ.*, 1st ser., vol. vii. p. 310; and Pereira, *ib.*, vol. iii. p. 377.

[2] *Dingler's Polyt. Journ.*, ccxvi. p. 453; *cf. supra* Gallic Acid.

[3] For figure and description see *Zoology of the Erebus and Terror*, ii. pp. 46, 47, 1844–75.

[4] On the mite-galls and their makers, see F. Löw, "Beiträge zur Naturgesch. der Gallmilben (*Phytoptus*, Duj.)," *Verhandl. d. zoolog.-bot. Ges. in Wien*, xxiv., 1874, pp. 2–16, with plate; and "Ueber Milbengallen (Acarocecidien) der Wiener-Gegend," *ib.*, pp. 495–508; Andrew Murray, *Economic Entomology*, *Aptera*, pp. 331–374, 1876; and F. A. W. Thomas, *Aeltere und neue Beobachtungen über Phytopto-Cecidien*, Halle, 1877.

[5] *Proc. Entomol. Soc. Philadelphia*, iii., 1864, p. 549.

vigorous Doric phraseology fast passing out of use even in country districts. In this novel Mr Galt used, for the first time, the term "Utilitarian," which has since become so intimately associated with the doctrines of John Stuart Mill and his followers (see *Annals of the Parish*, chap. xxxv., and a note by Mr Mill in *Utilitarianism*, chap. ii.). In *Sir Andrew Wylie* the hero entered London as a poor lad, but achieved remarkable success by his shrewd business qualities. The character is somewhat exaggerated, but excessively amusing. *The Entail* was read thrice by Byron and Scott, and is the best of Galt's longer novels. Leddy Grippy is a wonderful creation, and was considered by Byron equal to any female character in literature since Shakespeare's time. *The Provost*, in which Provost Pawkie tells his own story, portrays inimitably the jobbery, bickerings, and selfseeking of municipal dignitaries in a quaint Scottish burgh. In *Lawrie Todd* Galt, by giving us the Scot in America, has accomplished a feat which Sir Walter never attempted. This novel exhibits more variety of style and a greater love of nature than his other books. The life of a settler is depicted with unerring pencil, and with an enthusiasm and imaginative power much more poetical than any of the author's professed poems.

Galt's humour is broader and more contagious than Scott's; and his pictures of the sleepy life of old Scottish towns are unrivalled in literature. He is generally called an imitator of Scott; but the *Annals of the Parish* existed in MS. before *Waverley* was published. As Galt is preeminently an illustrator of west-country Scottish life, his range may be said to be narrower than Scott's; but within it he is supreme. It would be difficult to overrate the immense services which Galt has rendered alike to the history of the manners and to the history of the language of the Scottish people.

For further information about Galt, see his *Autobiography*; *The Literary Life of John Galt*; and a biographical memoir by his friend the late Dr Moir of Musselburgh, prefixed to *The Annals of the Parish*. (T. GI.)

GALOIS, Evariste (1811–1832), an eminently original and profound French mathematician, born 26th October 1811, killed in a duel May 1832. A necrological notice by his friend M. Auguste Chevalier appeared in the *Revue Encyclopédique*, September 1832, p. 744; and his collected works are published, *Lionville*, t. xi. (1846), pp. 381–444, about fifty of these pages being occupied by researches on the resolubility of algebraic equations by radicals. But these researches, crowning as it were the previous labours of Lagrange, Gauss, and Abel, have in a signal manner advanced the theory, and it is not too much to say that they are the foundation of all that has since been done, or is doing, in the subject. The fundamental notion consists in the establishment of a group of permutations of the roots of an equation, such that every function of the roots invariable by the substitutions of the group is rationally known, and reciprocally that every rationally determinable function of the roots is invariable by the substitutions of the groups; some further explanation of the theorem, and in connexion with it an explanation of the notion of an adjoint radical, is given under Equation, No. 32. As part of the theory (but the investigation has a very high independent value as regards the Theory of Numbers, to which it properly belongs), Galois introduces the notion of the imaginary roots of an irreducible congruence of a degree superior to unity; *i.e.*, such a congruence, $F(x) \equiv 0$ (mod. a prime number p), has no integer root; but what is done is to introduce a quantity i subjected to the condition of verifying the congruence in question, $F(i) \equiv 1$ (mod. p), which quantity i is an imaginary of an entirely new kind, occupying in the theory of numbers a position analogous to that of $-\sqrt{-1}$ in algebra.

GALUPPI, Baldassarre (1706–1785), a musical composer, was born in 1706, in the island of Burano, near Venice. His father, a barber by profession, was a musical amateur, and prepared his son for the music school of Venice called Conservatorio degl' Incurabili, where the great Lotti became his master. His first opera, written at the age of sixteen, was a failure; but his comic opera named *Dorinda*, produced seven years later, was a great success, and laid the foundation of the youthful composer's fame. He was a prolific writer, and no less than seventy of his operas are enumerated, none of which, however, have kept the stage. Some of these were written for London, where Galuppi resided between 1741 and 1744, but his masterpiece in tragic opera was produced at St Petersburg in 1766. The composer had been induced by liberal offers to accept a position as imperial conductor of music, and to leave his native country for Russia, where he lived in high honour at the court of the czar, and is said to have in return done much for the progress of his art in Russia by introducing amongst other things Italian church-music. In 1768 he left Russia, and resumed his position as organist of the cathedral of St Mark at Venice, to which he had been appointed in 1762, and which had been kept open for him during his absence. He died in 1785, and left 50,000 lire to the poor of Venice. His best comic opera bears the title *Il mondo della luna*. The libraries of Dresden and Vienna preserve several of his operas in MS. At Vienna also some of his works of sacred music may be found. Others are in Paris and Rome.

GALVANI, Luigi (1737–1798), an eminent Italian physiologist, after whom galvanism received its name, was born at Bologna, September 9, 1737. It was his wish in early life to enter the church, but by his parents he was educated for a medical career. At the university of Bologna, in which city he practised, he was in 1762 appointed public lecturer in anatomy, and soon gained repute as a skilled though not eloquent teacher, and, chiefly from his researches on the organs of hearing and genito-urinary tract of birds, as a comparative anatomist. His celebrated theory of animal electricity he enunciated in a treatise, "De viribus electricitatis in motu musculari commentarius," published in the 8th volume of the memoirs of the Institute of Sciences at Bologna in 1791, and separately at Modena in the following year, and elsewhere subsequently. The statement has frequently been repeated that, in 1786, Galvani had skinned some frogs to make broth for his wife, who was in delicate health; that the leg of one of these, on being accidentally touched by a scalpel which had lain near an electrical machine, was thrown into violent convulsions; and that it was thus that his attention was first directed to the relations of animal functions to electricity. From documents in the possession of the Institute of Bologna, however, it appears that twenty years previous to the publication of his *Commentary* Galvani was already engaged in investigations as to the action of electricity upon the muscles of frogs. The observation that the suspension of certain of these animals on an iron railing by copper hooks caused twitching in the muscles of their legs led him to the invention of his metallic arc, the first experiment with which is described in the third part of the *Commentary*, wherein it is registered September 20, 1786. The arc he constructed of two different metals, which, placed in contact the one with a nerve and the other with a muscle of a frog, caused contraction of the latter. In Galvani's view the motions of the muscle were the result of the union, by means of the metallic arc, of its exterior or negative electrical charge with positive electricity which proceeded along the nerve from its inner substance. Volta, on the other hand, attributed them solely to the effect of electricity having its source in the junction of the two dissimilar metals of the arc, and regarded the nerve and muscle simply as conductors. Galvani in one of his memoirs recorded the observation that muscular contractions may be caused in a prepared frog merely by bending back the legs and bringing them into contact with the lumbar nerves, as also when a nerve is touched at two different points with a morsel of muscle taken from a living frog, phenomena not satisfactorily explicable on the theories of Volta; but after the death of the Bologna professor very little was heard of animal electricity till, in 1827, the study of the subject was resumed by Nobili. On Galvani's refusal, from religious scruples, to take the oath of allegiance to the Cisalpine republic on its establishment, he was removed from his professorship. Deprived thus of the means of livelihood, he retired to the house of his brother Giacomo, where he soon fell into a feverish decline. The republican Government, in consideration of his great scientific fame, eventually, but too late, determined to reinstate him in his chair at the university of Bologna. He died December 4, 1798. A quarto edition of his works was published at Bologna in 1841–42, by the Academy of Sciences of the Institute of that city, under the title *Opere edite ed inedite del professore Luigi Galvani*.

See Volta, "An Account of some Discoveries made by Mr Galvani, of Bologna," in *Phil. Trans.*, 1793, pp. 10–44; J. L. Alibert, *Elogio Storico di Luigi Galvani, Traduzione dal Francese*, Bolog., 1802, fol.; Arago, in "Alexandre Volta," *Œuvres Complètes*, ed. Barral, t. i. p. 242, 1854; and H. M. Noad, *Manual of Electricity*, chap. x.; also Electricity, vol. viii. p. 9, col. 1, and Volta.

GALVANISM. See Electricity and Physiology.

GALVANOMETER, an instrument used for indicating or measuring currents of electricity, wherein advantage is taken of the force exerted by such currents on movable magnets in their neighbourhood.[1] When a galvanometer is used for indicating merely, without measuring, it is sometimes called a galvanoscope. If we consider only such instruments as have come into actual use, this definition is strict enough for practical purposes. If we were to consider all the instruments that have been or might be made, some would come under the definition whose resemblance to the modern galvanometer would not at first sight be apparent. Such, for instance, is the electromagnetic balance of Becquerel,[2] which consists of two bar magnets hung from the scale pans of a delicate balance each in the axis of a cylindrical bobbin of wire—one being over, the other under its corresponding bobbin (see fig. 1). The north poles of both magnets hang

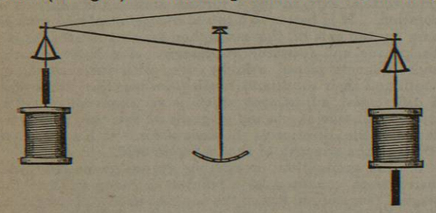

Fig. 1.

downwards, and the current to be measured is sent round the bobbin, so that each of the magnets is repelled. Weights are put into the left-hand scale until equilibrium in the original position is restored. The weight thus added is proportional to the current strength, so long as the induced magnetism of the magnets can be neglected. This instrument has fallen into disuse.

In a complete galvanometer of modern construction the following parts may occur:—(1) the coil or multiplier, (2) the needle or movable magnet or magnets, (3) the astatizing apparatus, (4) the deflecting or adjusting magnet, (5) the graduation or reading apparatus, (6) the damping apparatus, (7) accompanying the galvanometer, as a piece of auxiliary apparatus, we may also have a box of shunts. It would be easy to make a more minute enumeration of parts, but the above will serve our present purpose. On the other hand, it is not always that each of the above organs is represented separately; some may be wanting in certain cases, and the functions of two or more may be combined.

1. The multiplier or coil consists of a ring-shaped channel of elliptical, rectangular, or circular shape—usually the last, the cross section being in general rectangular. Into this is wound, as closely and regularly as possible, a quantity of silk-covered wire. The material chosen for the wire is usually copper, which should be as soft as possible in order to secure high conductivity. White silk is preferred for the insulating covering, on account of its freedom from iron, though this is for most purposes a needless refinement. Great care should be taken that the wire is dry when it is wound. It is usual, in order to secure and render permanent the insulation, to steep the whole coil in melted paraffin; after this has been done, there is little risk of loss of insulation, provided the layers have been carefully tested during the winding. The idea of the multiplier in sensitive galvanometers is to bring the greatest number of coils of wire within the least possible distances of the magnet. It is evident, therefore, that the insulating covering should be as thin as is consistent with good insulation; this consideration assumes great importance when coils of very fine wire have to be wound. After the wire has reached a certain fineness the proportion of space occupied by insulating matter is so great that further reduction of the section of the wire simply increases the resistance without enabling us to pack more turns into the same space. In general the section of the wire ought to be chosen with reference to the use which the galvanometer is intended to serve. The following ideal case will enable the reader to comprehend the principle which regulates the choice of multiplier under given circumstances. Suppose the dimensions of the channel, and the whole space which the wire is to fill, to be given, and the whole external resistance also given, then it may be shown that the section of the wire[3] ought to be chosen so that the resistance of the galvanometer shall be equal to the external resistance. The case contemplated here is that where we have a simple external circuit; many cases can be reduced to this at once, and we shall consider below a more complicated case of considerable practical importance. Theoretically the section of the wire ought to vary with the distance of the winding from the axis of the coil. The law is that the diameter of the wire in each layer ought to be proportional to the linear dimension of that layer. This is sometimes roughly carried out in practice by winding the outer layers of thicker wire than the inner.[4] The proper form of the longitudinal section of the coil depends on the use for which the instrument is destined, and will be more properly discussed when we describe particular instruments. In a certain class of galvanometers called differential, the wire on the coil is wound double, so that two currents can be sent through side by side in the same or in opposite directions.

2. The needle consists of a piece of magnetized steel,

[1] For another definition see the article Electrometer.

[2] For a brief history of the construction of galvanometric apparatus see art. Electricity, vol. viii. p. 13.

[3] In this and all that follows the silk covering is either neglected or is supposed to vary in thickness as the diameter of the wire.

[4] The cross section of the coil is not a matter of indifference in sensitive galvanometers; but the question is hardly of sufficient importance to need discussion here. Information on the subject will be found in W. Weber's *Electrodynamische Maasbestimmungen*, Thl. ii.; H. Weber, *Pogg. Ann.*, 1869; Maxwell's *Electricity and Magnetism*, vol. ii. secs. 716 *sqq.*: Jenkin's *Electricity and Magnetism*, cap. xiii. sec. 9.