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Livingstone, David

David Livingstone, through 30 years of heroic travel and Christian missionary work in southern, central, and eastern Africa—often in places where no white man had previously ventured—may have influenced Western attitudes toward Africa more than any other individual before him or since.

Early life. Born March 19, 1813, at Blantyre in Scotland, Livingstone grew up in a distinctively Scottish family environment of personal piety, poverty, hard work, zeal for education, and a sense of mission. His father's family was from the island of Ulva, off the west coast of Scotland; his mother, a Lowlander, was descended from a family of Covenanters, a group of militant Presbyterians. Both were poor; and Livingstone was reared as one of seven children in a single room at the top of a tenement building for the workers of a cotton factory on the banks of the Clyde. At the age of ten he had to help his family and was put to work in a cotton mill; and with part of his first week's wages he bought a Latin grammar. Brought up in the Calvinist faith of the established Scottish church, Livingstone, like his father, joined an independent Christian congregation of stricter discipline when he came to manhood. By this time he had acquired those characteristics of mind and body that were to fit him for his African career.

In 1834 an appeal by British and American churches for qualified medical missionaries in China made Livingstone determine to become a medical missionary. To prepare himself, while continuing to work part-time in the mill, he studied Greek, theology, and medicine for two years in Glasgow. In 1838 he was accepted by the London Missionary Society. The Opium War (1839–42) put an end to his dreams of going to China, but a meeting with Robert Moffat, the notable Scottish missionary in southern Africa, convinced him that Africa should be his sphere of service. On November 20, 1840 he was ordained as a missionary; he set sail for South Africa at the end of the year and arrived at Cape Town on March 14, 1841.

Ordained as missionary

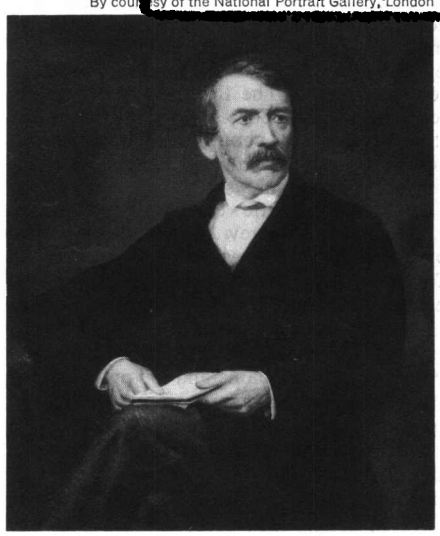
Initial explorations. For the next 15 years, Livingstone was constantly on the move into the African interior: strengthening his missionary determination; responding wholeheartedly to the delights of geographical discovery; clashing with the Boers and the Portuguese, whose treatment of the Africans he came to detest; and building for himself a remarkable reputation as a dedicated Christian, a courageous explorer, and a fervent antislavery advocate. Yet so impassioned was his commitment to Africa that his duties as husband and father were relegated to second place.

From Moffat's mission at Kuruman on the Cape frontier, which Livingstone reached on July 31, 1841, he soon pushed his search for converts northward into untried country where the population was reputed to be more numerous. This suited his purpose of spreading the Gospel through "native agents." By the summer of 1842, he had already gone further north than any other white man into the difficult Kalahari country and had familiarized himself with the local languages and cultures. His mettle was dramatically tested in 1844, when, during a journey to Mabotsa to establish a mission station, he was mauled by a lion. The resulting injury to his left arm was complicated by another accident, so that he could never again support the barrel of a gun steadily with his left hand and was obliged to fire from his left shoulder and to take aim with his left eye.

On January 2, 1845, Livingstone married Moffat's daughter, Mary, and she accompanied him on many of his journeys until her health and the family's needs for security and education forced him to send her and their four children back to Britain in 1852. Before this first parting with his family, Livingstone had already achieved a small measure of fame when, as surveyor and scientist of a small expedition, he had assisted in the discovery of Lake Ngami on August 1, 1849, and was awarded a gold medal and monetary prize by the British Royal Geographical Society. This was the beginning of his lifelong association with the society, which continued to encourage his ambitions as an explorer and to champion his interests in Britain.

Opening the interior. With his family safely in Scotland, Livingstone was ready to push Christianity, commerce, and civilization—the trinity that he believed was destined to open up Africa—northward beyond the frontiers of South Africa and into the heart of the continent. In a famous statement in 1853 he made his purpose clear: "I shall open up a path into the interior, or perish." On November 11, 1853, from Linyanti at the approaches to the Zambezi and in the midst of the Makololo peoples whom he considered eminently suitable for missionary work, Livingstone set out northwestward with little equipment and only a small party of Africans. His intention was to find a route to the Atlantic coast that would permit legitimate commerce to undercut the slave trade and that would also be more suitable for reaching the Makololo than the route leading through Boer territory. (In 1852 the Boers had destroyed his home at Kolobeng and attacked his African friends.) After an arduous journey that might have wrecked the constitution of a lesser man, Livingstone reached Loanda on the west coast on May 31, 1854. In order to take his Makololo followers back home and to carry out further explorations of the Zambezi, as soon as his health permitted he began the return journey on September 20, 1854. He reached Linyanti nearly a year later on September 11, 1855. Continuing eastward on November 3, Livingstone explored the Zambezi regions and reached Quilimane in Mozambique on May 20, 1856. His most

By courtesy of the National Portrait Gallery, London



Livingstone, oil painting by F. Havill (died 1884), after photographs. In the National Portrait Gallery, London.

Discovery of Victoria Falls

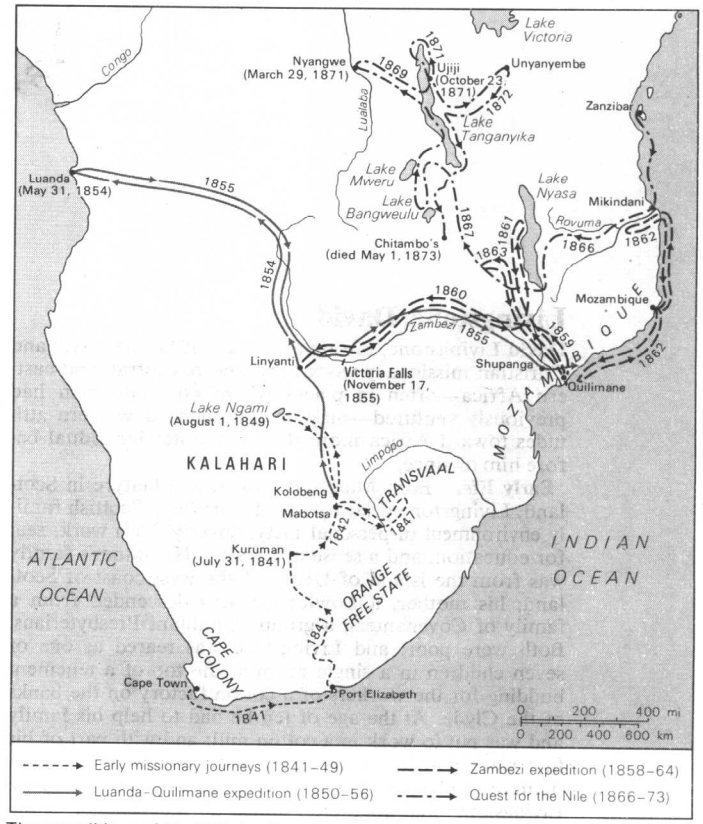
spectacular visit on this last leg of his great journey was to the thundering, smokelike waters on the Zambezi at which he arrived on November 17, 1855, and with typical patriotism named Victoria Falls after his queen. Livingstone returned to England on December 9, 1856, as a national hero. News from and about him during the previous three years had stirred the imagination and pride of English-speaking peoples everywhere to an unprecedented degree.

Livingstone recorded his accomplishments modestly but effectively in his *Missionary Travels and Researches in South Africa* (1857), which quickly sold over 70,000 copies and took its place in publishing history as well as in that of exploration and missionary endeavour. Honours flowed in upon him. His increased income meant that he was now able to provide adequately for his family, which had lived in near poverty since their return to Britain. He was also able to make himself independent of the London Missionary Society. After the completion of his book, Livingstone spent six months speaking all over the British Isles. In his Senate House address at Cambridge on Dec. 4, 1857, he foresaw that he would be unable to complete his work in Africa, and he called on young university men to take up the task that he had begun. The publication of *Dr. Livingstone's Cambridge Lectures* (1858) roused almost as much interest as his book; and out of his Cambridge visit came the Universities' Mission to Central Africa in 1860, on which Livingstone set high hopes during his second expedition to Africa.

The Zambezi expedition. This time Livingstone was away from Britain from March 12, 1858 to July 23, 1864. He went out originally as British Consul at Quilimane "for the Eastern Coast and independent districts of the interior, and commander of an expedition for exploring eastern and central Africa, for the promotion of Commerce and Civilization with a view to the extinction of the slave-trade." This expedition was infinitely better organized than Livingstone's previous solitary journeys. It had a paddle steamer, impressive stores, ten Africans, and six Europeans (including his brother Charles and an Edinburgh doctor, John Kirk). That Livingstone's by then legendary leadership had its limitation was soon revealed. Quarrels broke out among the Europeans and some were dismissed. Disillusionment with Livingstone set in among members of both his own expedition and of the abortive Universities' Mission that followed it to central Africa. It proved impossible to navigate the Zambezi by ship; and Livingstone's two attempts to find a route along the Rovuma River bypassing Portuguese territory to districts around Lake Nyasa (Malawi) also proved impractical. Livingstone and his party had been the first Britons to reach (September 17, 1859) these districts that held out promise of colonization. To add to Livingstone's troubles, his wife, who had been determined to accompany him back to Africa, died at Shupanga on the Zambezi on April 27, 1862. His eldest son, Robert, who was to have joined his father in 1863, never reached him and went instead to the United States, where he died fighting for the North in the Civil War on December 5, 1864. The British government recalled the expedition in 1863, when it was clear that Livingstone's optimism about economic and political developments in the Zambezi regions was premature. Livingstone, however, showed something of his old fire when he took his little vessel, the "Lady Nyassa," with a small, untrained crew and little fuel, on a hazardous voyage of 2,500 miles across the Indian Ocean and left her for sale in Bombay. Furthermore, within the next three decades the Zambezi expedition proved to be anything but a disaster. It had amassed a valuable body of scientific knowledge; and the association of the Lake Nyasa regions with Livingstone's name and the prospects for colonization that he envisaged there were important factors for the creation in 1893 of the British Central Africa Protectorate, which in 1907 became Nyasaland, and in 1966 the republic of Malawi.

Recall to England

Back in Britain in the summer of 1864, Livingstone, with his brother Charles, wrote his second book, *Narrative of an Expedition to the Zambesi and Its Tributaries* (1865). Livingstone was advised at this time to have a surgical



The expeditions of David Livingstone.

operation for the hemorrhoids that had troubled him since his first great African journey. He refused; and it is probable that severe bleeding hemorrhoids were the cause of his death at the end of his third and greatest African journey.

The quest for the Nile. Livingstone returned to Africa, after another short visit to Bombay, on January 28, 1866, with support from private and public bodies and the status of a British Consul at large. His aim, as usual, was the extension of the Gospel and the abolition of the slave trade on the East African coast; but a new object was the exploration of the central Africa watershed and the possibility of finding the ultimate sources of the Nile. This time Livingstone went without European subordinates and took only African and Asian followers. Trouble, however, once more broke out among his staff; and Livingstone, prematurely aged from the hardships of his previous expeditions, found it difficult to cope with. Striking out from Mikindani on the east coast, he was compelled by Ngoni raids to give up his original intention of avoiding Portuguese territory and reaching the country around Lake Tanganyika by passing north of Lake Nyasa. The expedition was forced south, and in September some of Livingstone's followers deserted him. To avoid punishment when they returned to Zanzibar, they concocted the story that Livingstone had been killed by the Ngoni. Although it was proved the following year that he was alive, a touch of drama was added to the reports circulating abroad about his expedition.

Drama mounted as Livingstone moved north again from the south end of Lake Nyasa. Early in 1867 a deserter carried off his medical chest, but Livingstone pressed on into central Africa. On November 8, 1867, he discovered Lake Mweru, and on July 18, 1868, Lake Bangweulu. Assisted by Arab traders, Livingstone reached Lake Tanganyika in February 1869. Despite illness, he went on, and arrived on March 29, 1871, at his ultimate northwesterly point, Nyangwe, on the Lualaba leading into the Congo River. This was farther west than any European had penetrated. Returning to Ujiji on the eastern shore of Lake Tanganyika on October 23, 1871, Livingstone was a sick and failing man, and the arrival of H.M. Stanley, a cor-

respondent of the *New York Herald*, provided him with desperately needed food and medicine. Livingstone felt strong enough to join Stanley in exploring the northern reaches of Lake Tanganyika and then accompanied him to Unyanyembe, 200 miles eastward. But he refused all of Stanley's pleas to leave Africa with him, and on March 14, 1872, Stanley departed for England to add, with journalistic fervour, to the saga of David Livingstone.

Rescue by Stanley

Replenished by Stanley's supplies, Livingstone moved south again, obsessed by his quest for the Nile sources and his desire for the destruction of the slave trade. But his illness overcame him. On May 1, 1873, at Chitambo's village in the Ilala district of what is now Zambia, Livingstone's African servants found him dead, kneeling by his bedside as if in prayer. In order to embalm Livingstone's body, they removed his heart and viscera and buried them in African soil. In a difficult journey of nine months, they carried his body to the coast. It was taken to England and, in a great Victorian funeral, was buried in Westminster Abbey on April 18, 1874. *The Last Journals of David Livingstone* were published in the same year.

Influence. In his time and since, the example of Livingstone has been one of the most powerful in stimulating the interest of the outside world in Africa. His discoveries—geographic, technical, medical, and social—provided a complex body of knowledge that is still being explored. In spite of his paternalism and Victorian prejudices, Livingstone believed wholeheartedly in the African's ability to advance into the modern world. He was, in this sense, a forerunner not only of European imperialism in Africa but also of African nationalism.

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(G.A.S.)

Livy

With Sallust and Tacitus, Livy ranks as one of the three great Roman historians. His history of Rome from the foundation of the city (*Ab urbe condita*) established itself as a classic in his own lifetime and exercised a profound influence on the style and philosophy of historical writing down to the 18th century.

Early years and career. Livy (Titus Livius) was born at Patavium (Padua) in northern Italy in 59 BC (or possibly 64 BC). Little is known about his life and nothing about his family background. Patavium, a rich city, famous for its strict morals, suffered severely in the Civil Wars of the 40s. The wars and the unsettled condition of the Roman world after the death of Caesar in 44 BC probably prevented Livy from studying in Greece, as most educated Romans did. Although widely read in Greek literature, he made mistakes of translation that would be unnatural if he had spent any length of time in Greece and had acquired the command of Greek normal among his contemporaries. His education was based on the study of rhetoric and philosophy, and he wrote some philosophical dialogues that do not survive. There is no evidence about his early career. His family apparently did not belong to the senatorial class, however distinguished it may have been in Patavium itself, and Livy does not seem to have embarked on a political or forensic profession. He is first heard of in Rome after Octavian (later known as the emperor Augustus) had restored stability and peace to the empire by his decisive naval victory at Actium in 31 BC. Internal evidence from the work itself shows that Livy had conceived the plan of writing the history of Rome in or shortly before 29 BC, and for this purpose he must have already moved to Rome, because only there were the records and information available. It is significant that another historian, the Greek Dionysius of Halicarnassus, who was to cover much the same ground as Livy, settled in Rome in 30 BC. A more secure age had dawned.

Most of his life must have been spent at Rome, and at an early stage he attracted the interest of Augustus and was even invited to supervise the literary activities of the young Claudius (the future emperor), presumably about AD 8. But he never became closely involved with the literary world of Rome—the poets Horace, Virgil, and Ovid, as well as the patron of the arts, Maecenas, and others. He is never referred to in connection with these men. He must have possessed sufficient private means not to be dependent on official patronage. Indeed, in one of the few recorded anecdotes about him, Augustus called him a "Pompeian," implying an outspoken and independent turn of mind. His lifework was the composition of his history.

Livy's history of Rome. Livy began by composing and publishing in units of five books, the length of which was determined by the size of the ancient papyrus roll. As his material became more complex, however, he abandoned this symmetrical pattern and wrote 142 books. So far as it can be reconstructed, the shape of the history is as follows (books 11–20 and 46–142 have been lost):

Plan of the history

1–5 From the foundation of the city until the sack of Rome by the Gauls (386 BC)
6–10 The Samnite wars
11–15 The conquest of Italy
16–20 The First Punic (Carthaginian) War
21–30 The Second Punic War (until 201 BC)
31–45 Events until the end of the war with Perseus (167 BC)
46–70 Events until the Social War (91 BC)
71–80 Civil wars until the death of Marius (86 BC)
81–90 Civil wars until the death of Sulla (78 BC)
91–103 Events until the triumph of Pompey in 62 BC
104–108 The last years of the Republic
109–116 The Civil War until the murder of Caesar (44 BC)
117–133 From the death of Caesar to the Battle of Actium
134–142 From 29 to 9 BC

Apart from fragments, quoted by grammarians and others, and a short section dealing with the death of the orator and politician Cicero from Book 120, the later books after Book 45 are known only from summaries. These were made from the 1st century AD onward, because the size of the complete work made it unmanageable. There were anthologies of the speeches and also concise summaries, two of which survive in part, a 3rd-century papyrus from Egypt (containing summaries of Books 37–40 and 48–55) and a 4th-century summary of contents (known as the *Periochae*) of the whole work. A note in the *Periocha* of Book 121 records that that book (and presumably those that followed) was published after Augustus' death in AD 14. The implication is that the last 20 books dealing with the events from the Battle of Actium until 9 BC were an afterthought to the original plan and were also too politically explosive to be published with impunity in Augustus' lifetime.

The sheer scope of the undertaking was formidable. It presupposed the composition of three books a year on

average. Two stories reflect the magnitude of the task. In his letters the statesman Pliny the Younger records that Livy was tempted to abandon the enterprise but found that the task had become too fascinating to give it up; he also mentions a citizen of Cádiz who came all the way to Rome for the sole satisfaction of gazing at the great historian.

Livy's historical approach. The project of writing the history of Rome down to the present day was not a new one. Historical research and writing had flourished at Rome for 200 years, since the first Roman historian Quintus Fabius Pictor. There had been two main inspirations behind it—antiquarian interest and political motivation. Particularly after 100 BC, there developed a widespread interest in ancient ceremonies, family genealogies, religious customs, and the like. This interest found expression in a number of scholarly works: Titus Pomponius Atticus, Cicero's friend and correspondent, wrote on chronology and on Trojan families; others compiled lengthy volumes on Etruscan religion; Marcus Terentius Varro, the greatest scholar of his age, published the encyclopaedic work *Divine and Human Antiquities.* The standard of scholarship was not always high, and there could be political pressures, as in the attempt to derive the Julian family to which Julius Caesar belonged from the legendary Aeneas and the Trojans; but the Romans were very conscious and proud of their past, and an enthusiasm for antiquities was widespread.

Antiquarian interest of Roman historians

Previous historians had been public figures and men of affairs. Fabius Pictor had been a praetor, the elder Cato had been consul and censor, and Sallust was a praetor. So, too, many prominent statesmen such as Sulla and Caesar occupied their leisure with writing history. For some it was an exercise in political self-justification (hence, Caesar's *Gallic War* and *Civil War*); for others it was a civilized pastime. But all shared a common outlook and background. History was a political study through which one might hope to explain or excuse the present.

Livy was unique among Roman historians in that he played no part in politics. This was a disadvantage in that his exclusion from the Senate and the magistracies meant that he had no personal experience of how the Roman government worked, and this ignorance shows itself from time to time in his work. It also deprived him of firsthand access to much material (minutes of Senate meetings, texts of treaties, laws, etc.) that was preserved in official quarters. So, too, if he had been a priest or an augur, he would have acquired inside information of great historical value and been able to consult the copious documents and records of the priestly colleges. But the chief effect is that Livy did not seek historical explanations in political terms. The novelty and impact of his history lay in the fact that he saw history in personal and moral terms. The purpose is clearly set out in his preface:

Interest in personal and moral aspects of history

> I invite the reader's attention to the much more serious consideration of the kind of lives our ancestors lived, of who were the men and what the means, both in politics and war, by which Rome's power was first acquired and subsequently expanded, I would then have him trace the process of our moral decline, to watch first the sinking of the foundations of morality as the old teaching was allowed to lapse, then the final collapse of the whole edifice, and the dark dawning of our modern day when we can neither endure our vices nor face the remedies needed to cure them.
>
> What chiefly makes the study of history wholesome and profitable is this, that in history you have a record of the infinite variety of human experience plainly set out for all to see, and in that record you can find for yourself and your country both examples and warnings.

Although Sallust and earlier historians had also adopted the outlook that morality was in steady decline and had argued that people do the sort of things they do because they are the sort of people they are, for Livy these beliefs were a matter of passionate concern. He saw history in terms of human personalities and representative individuals rather than of partisan politics. And his own experience, going back perhaps to his youth in Patavium, made him feel the moral evils of his time with peculiar intensity. He punctuates his history with revealing comments:

> Fortunately in those days authority, both religious and secular, was still a guide to conduct and there was as yet no sign of our modern scepticism which interpets solemn compacts to suit its own convenience (3.20.5). Where would you find nowadays in a single individual that modesty, fairness and nobility of mind which in those days belonged to a whole people? (4.6.12).

In looking at history from a moral standpoint, Livy was at one with other thinking Romans of his day. Augustus attempted by legislation and propaganda to inculcate moral ideals. Horace and Virgil in their poetry stressed the same message—that it was moral qualities that had made and could keep Rome great.

The preoccupation with character and the desire to write history that would reveal the effects of character outweighed for Livy the need for scholarly accuracy. He showed little if any awareness of the antiquarian research of his own and earlier generations; nor did he seriously compare and criticize the different histories and their discrepancies that were available to him. For the most part he is content to take an earlier version (from Polybius or a similar author) and to reshape it so as to construct moral episodes that bring out the character of the leading figures. Livy's descriptions of the capture of Veii and the expulsion of the Gauls from Rome in the 4th century BC by Marcus Furius Camillus are designed to illustrate his piety; the crossing of the Alps shows up the resourceful intrepidity of Hannibal. Unfortunately, it is not known how Livy dealt with the much greater complexity of contemporary history, but the account of Cicero's death contains the same emphasis on character displayed by surviving books.

It would be misplaced criticism to draw attention to his technical shortcomings, his credulity, or his lack of antiquarian curiosity. He reshaped history for his generation so that it was alive and meaningful. It is recorded that the audiences who went to his recitations were impressed by his nobility of character and his eloquence. It is this eloquence that is Livy's second claim to distinction.

Together with Cicero and Tacitus, Livy set new standards of literary style. The earliest Roman historians had written in Greek, the language of culture. Their successors had felt that their own history should be written in Latin, but Latin possessed no ready-made style that could be used for the purpose: for Latin prose had to develop artificial styles to suit the different genres. Sallust had attempted to reproduce the Greek style of Thucydides in Latin by a tortured use of syntax and a vocabulary incorporating a number of archaic and unusual words, but the result, although effective, was harsh and unsuitable for a work of any size. Livy evolved a varied and flexible style that the ancient critic Quintilian characterized as a "milky richness." At one moment he will set the scene in long, periodic clauses; at another a few terse, abrupt sentences will mirror the rapidity of the action. Bare notices of archival fact will be reported in correspondingly dry and formal language, whereas a battle will evoke poetical and dramatic vocabulary, and a speech will be constructed either in the spirit of a contemporary orator such as Cicero or in dramatically realistic tones, designed to recapture the atmosphere of antiquity. "When I write of ancient deeds my mind somehow becomes antique," he wrote. Livy died at Patavium in AD 17.

His literary style

The work of a candid man and an individualistic thinker, Livy's history was deeply rooted in the Augustan revival and owed its success in large measure to its moral seriousness. But the detached attempt to understand the course of history through character (which was to influence later historians from Tacitus to Lord Clarendon) represents Livy's great achievement.

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(R.M.Og.)

Llanos

The Llanos (Plains), a grassland, or savanna, that stretches across northern South America, occupy one-third of Venezuela and about one-fifth of Colombia. The Llanos are delimited by the Andes Mountains in the west and north, the Lower Orinoco River and the Guiana Highlands in the east, and the Río Guaviare and the Amazonian rain forest in the south. The region covers an area of some 220,000 square miles (570,000 square kilometres) and is comparable in size to France or Texas.

The savanna was named by the Spaniards in the 16th century and has been used as a vast cattle range since then. Until the mid-1900s, settlement was limited to widely scattered ranches known as *hatos* ("cow herds"), a few villages, and missionary stations along the lower courses of the region's rivers. Since the 1930s the region has experienced economic growth. (For a related physical feature, see ORINOCO RIVER.)

Physical features

Relief. Most of the Llanos lies within 1,000 feet above sea level. The High Plains (Llanos Altos) are most conspicuous near the Andes, where they form extensive platforms between rivers and are some 100 to 200 feet above the valley floors. Away from the mountains they are increasingly fragmented, as in the dissected tableland of the central and eastern Venezuelan Llanos (the Sabana de Mesas) and the hill country south of the Río Meta in Colombia (the Serranía).

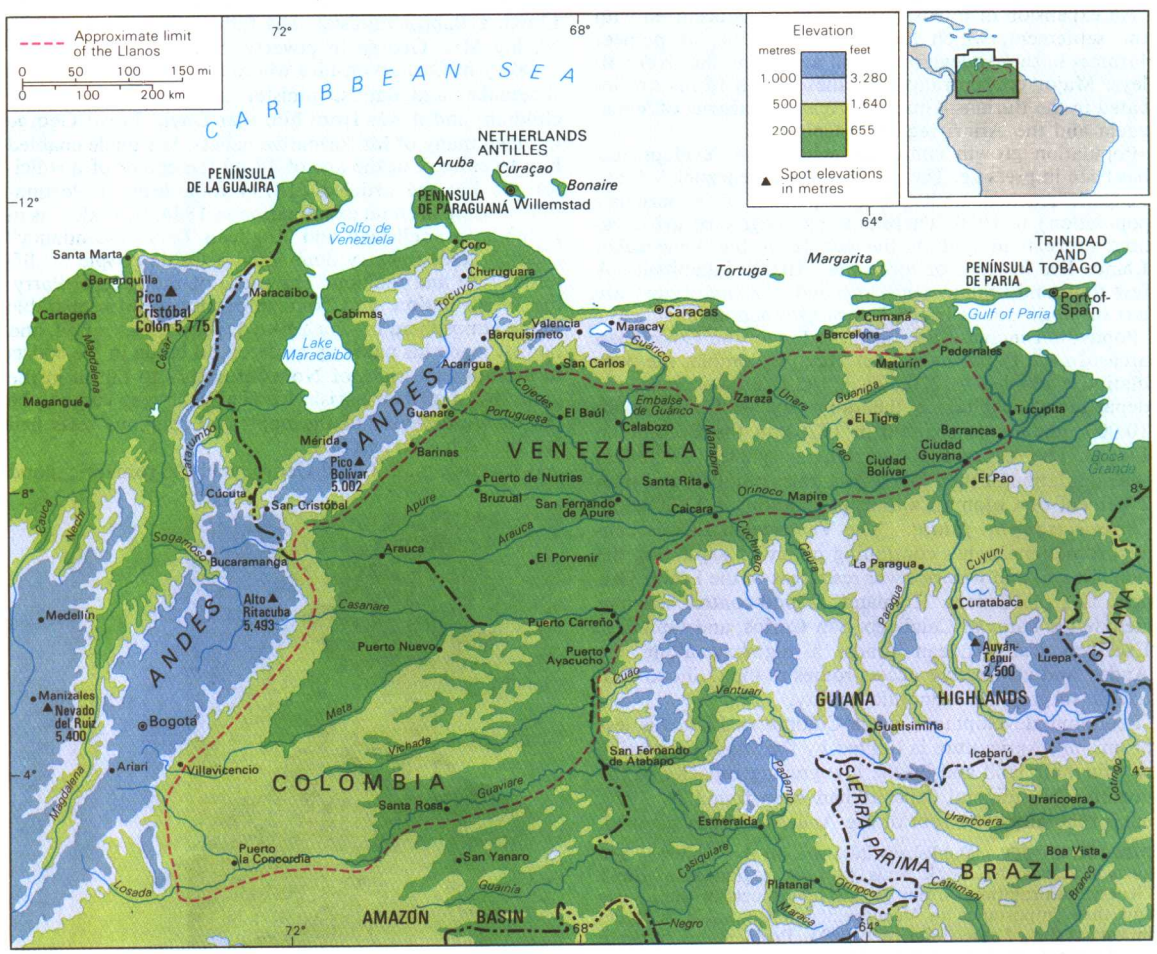
The Low Plains (Llanos Bajos) are defined by the Río Apure in the north and the Río Meta in the south. The lowest portion of the Llanos, west of the Orinoco Valley, is annually converted into an inland lake by the flooding of the region's rivers.

Soils and drainage. The Llanos are drained by the Orinoco River and its left-bank tributaries, including the Guaviare, Meta, Apure, and Cojedes rivers. Seasonal changes between saturation and dehydration have led to advanced laterization of the soil, the process in which the base minerals have been leached away or incorporated into insoluble iron and aluminum silicates. Fine-grained soils form hardpans (cemented layers of soils), and in gravel regions, iron-cemented quartz conglomerates underlie the surface. Excessive acidity and the lack of nutrient bases, organic matter, and nitrogen make virtually all mature soils infertile.

Climate. The wet and dry seasons result from the annual migration of the Intertropical Convergence Zone, a low-pressure trough between the hemispheric easterlies, or trade winds. The zone remains south of the Equator from December to March, bringing the entire Llanos under the influence of the Northeast Trades, which cause the dry and hot summer weather. The zone enters the Llanos from the south in April, reaches its northernmost position along the north coast in July, and moves south again until December. The passage of the zone brings the rainy winter period.

Monthly precipitation is seldom less than ten inches in the Colombian Llanos between April and November. The rains peak about midyear in the Venezuelan north, with monthly totals of around ten inches. Annual precipitation is highest near the Andes, where Villavicencio receives 180 inches; and there is a pronounced decrease toward the central plains, where Puerto de Nutrias receives 45 inches.

Mean daily temperatures are above 75° F (24° C) throughout the year, and the annual range does not sur-



The Llanos.

pass 7° F (4° C). Daily maximum temperatures rise above 95° F (35° C) in the dry period; the dry winds and nocturnal cooling bring relief with normal minimum temperatures between 65° and 75° F (18° and 24° C).

Vegetation and animal life. Most of the Llanos is treeless savanna. In the low-lying areas, swamp grasses and sedges are to be found, as also is bunchgrass (*Trachypogon*). Long-stemmed grass dominates the dry savanna and is mixed with carpet grass (*Axonopus affinis*), the only natural grass to provide green forage during the dry season.

The most conspicuous trees occur in the gallery forests along the rivers and in the narrower files of trees known as *morichales*, after the dominant moriche palm that follow minor water courses. Broadleaved evergreens originally occupied the high-rainfall zone in the Andean piedmont. There is a handful of xerophytic trees (*i.e.*, those adapted to arid conditions), including the *chaparro* (scrub oak) and the dwarf palm scattered on the open savanna.

The Llanos have few animals. Most mammals nest in the gallery forests and feed on the grassland. The only true savanna dwellers are a few burrowing rodents and more than 20 species of birds (among them the white and scarlet ibis, the *morichal* oriole, and the burrowing owl). There are several species of deer and rabbit, the anteater and armadillo, the tapir, the jaguar, and the largest living rodent, the capybara. Crocodiles, caimans (a crocodile-like amphibian), and snakes, including the boa constrictor, inhabit the rivers, which also teem with little-known varieties of fish. Insects include butterflies, beetles, ants, and mound-building termites.

Population and resources. Cattle raising remains the mainstay of the economy, the base of which was widened by the discovery of petroleum in the 1930s. Oil strikes in the eastern and central Venezuelan Llanos at El Tigre (1937) and Barinas (1948) initiated industrial and urban development. Several of the "boom towns" of that period, such as El Tigre, have grown into sizable cities.

The discovery of oil

An expansion of intensive agriculture has occurred with the settlement, which began in the 1950s, of pioneer farmers in the Andean piedmont and along the river valleys. Major concentrations of these small farms are located in the Barinas–Guanare–Acarigua district of Venezuela and the Ariari region in Colombia.

Population growth connected with these developments has been impressive. The population of Venezuela's Llanos states reached 1,800,000 (18 percent of Venezuela's population) in 1970. There is a high degree of urbanization; more than half of the people of the Venezuelan Llanos live in cities of more than 10,000 inhabitants. A few thousand Indians (of Carib and Arawak origin) are left on reservations in the Lower Orinoco area.

Population increase has been modest in the Colombian areas. In the Departmento del Meta, Colombia, the population expanded to 210,000 in 1970. Villavicencio, the department's capital, is the only city with more than 10,000 inhabitants (65,000 in 1970) in the Colombian Llanos. The rest of the area remains sparsely inhabited; the population of the Llanos Orientales numbers less than 2 percent of Colombia's total population of 22,000,000.

Prospects for the future. The Venezuelan Llanos benefit from Venezuela's continuing policy of exploiting the rich mineral and water-power resources of the Lower Orinoco and the Guiana Highlands. Flood-control schemes include the dams at Calabozo, San Carlos, and Guanare. Excellent trans-Andean roads, a highway along the Andes, and all-weather access routes to the Orinoco contribute to growing economic vitality.

Economic development in the Colombian Llanos is less promising. Agriculture is limited by the small proportion of cultivable land and by the low grazing capacity of the savanna. No mineral deposits had been found by 1970, but a road along the foot of the Andes has been planned.

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(Di.B.)

Lloyd George, David

For 16 years, from 1906 to 1922, English political life was dominated by the fiery personality of David Lloyd George. As leader of the radicals within the Liberal Party before World War I, he pushed through legislation that laid the foundation of the modern welfare state. A former pacifist, he headed a coalition government that guided Britain to victory in what then seemed the greatest of all wars. After 1922 he remained in the shadows of public life, but in the words of Winston Churchill, addressing the House of Commons after his death, "When the English history of the first quarter of the twentieth century is written it will be found that the greater part of our fortunes in peace and in war were shaped by this one man."

Lloyd George was born in Manchester on January 17, 1863. His father was a Welshman from Pembrokeshire and had become headmaster of an elementary school in Manchester. His mother was the daughter of David Lloyd, a Baptist minister. His father died in June 1864, leaving Mrs. George in poverty. She moved to Llanystumdwy in Carnarvonshire where her brother Richard, a shoemaker and Baptist minister, supported her and her children; and it was from him that David Lloyd George imbibed many of his formative beliefs. His uncle enabled him to embark at the age of 14 on the career of a solicitor; he became articled (1879) to a firm at Portmadoc, passing his final examination in 1884. In Wales, as in Ireland, an anglicized and Anglican Tory "ascendancy" class of landed gentry dominated a Celtic people of different race and religion. The cause of the Liberal Party, the Welsh nation, and Nonconformity were inseparable in the atmosphere in which Lloyd George was raised, and he first made his name by a successful battle in the courts to establish the right of Nonconformists to burial in the churchyard of their parish. Ironically, he who came to be the standard-bearer of the oppressed religious sects had lost his faith even as a boy.

As a young man, Lloyd George had the romantic, good

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Lloyd George, 1908.

looks that ensured success with women. After numerous love affairs, he was married in 1888 to Margaret Owen who bore him two sons and three daughters. It cannot be described as a happy marriage. Lloyd George was incapable of fidelity, and his affairs with other women were notorious. His wife stood by him on many occasions, but in the end his behaviour was too much for even her long-suffering tolerance.

Lloyd George entered Parliament in 1890, winning a by-election at Carnarvon Boroughs, the seat he retained for 55 years. He soon made a name for himself in the House of Commons by his audacity, charm, wit, and mastery of the art of debate. During the ten years of Liberal opposition that followed the election of 1895, he became a leading figure in the radical wing of the party. He bitterly and courageously opposed the South African War; and in 1901 was nearly lynched in Birmingham, the stronghold of Joseph Chamberlain and Conservative imperialism. With the arrival of peace, Lloyd George worked up a great agitation in Wales against tax-aided grants to church schools established by Balfour's Education Act (1902). This period saw him at the height of his reputation as the leader of Welsh nationalism. Cabinet office later somewhat reduced his fervour in this field, and with the passage of time his nationalism became cultural rather than political.

Pro-Boer sentiment

Arthur J. Balfour resigned in December 1905 and Sir Henry Campbell-Bannerman formed a Liberal administration, appointing Lloyd George to the Cabinet as president of the Board of Trade. In that office, he was responsible for important legislation: the Merchant Shipping Act (1906), improving seamen's living conditions, but also endangering their lives by raising the Plimsoll line on newly constructed ships; the Patents and Designs Act (1907), preventing foreign exploitation of British inventions; and the Port of London Act (1908), setting up the Port of London Authority. He also earned a high reputation by his patient work in settling strikes. He suffered a cruel bereavement in November 1907, when his daughter Mair died of appendicitis at the age of 17. Years afterward, the sight of her portrait could plunge him into tears.

CHANCELLOR OF THE EXCHEQUER

Campbell-Bannerman's health failed in 1908. He was succeeded as prime minister by the chancellor of the exchequer, Herbert Henry Asquith, who appointed Lloyd George to take his own place. This was a notable promotion and made him at least a very strong competitor for the premiership after Asquith. By this time, the Liberal Party's fortunes were beginning to languish. The House of Lords had blocked much of its social reform legislation, and the radical wing of the party was concerned that its thunder might be stolen by the nascent Labour Party unless the deadlock could be broken. At the same time, the demand for more battleships to match the German naval program threatened the finances available for social reform. It was to meet these difficulties that Lloyd George framed the famous "People's Budget" of 1909, calling for taxes upon unearned increment on the sale of land and on land values, higher death duties, and a supertax on incomes above £3,000. Moreover, it seemed for a time that the House of Lords' veto on progressive legislation would be bypassed, since the custom of the constitution forbade the upper house from interfering with the budget. In fact, however, the Conservative majority in the House of Lords, against the advice of some of its wiser members, decided to reject it. The consequences of this rejection were two general elections, a major constitutional crisis, and the ultimate passage of the Parliament Act of 1911, which severely curtailed the powers of the upper house. The principal burden of all this fell upon Asquith, but Lloyd George gave him vigorous support in a series of notable philippics against the aristocracy and the rich. The most famous of all was his speech at Limehouse, where he denounced the rapacity of the landlord class, especially the dukes, in unforgettable language.

Promulgation of the "People's Budget"

In 1913 he faced one of the gravest personal crises in his career. In April 1912, along with Rufus Isaacs, the attorney general, he had purchased shares in the Marconi Wireless Telegraph Company of America at a rate well below that available to the general public. The American Marconi company was legally independent of the British concern, but the two companies were closely connected, and the latter's shares had recently boomed as a result of the government's decision to accept its proposal to construct a chain of radio stations throughout the empire, Lloyd George and Isaacs unluckily denied, in somewhat ambiguous language, any transactions in the shares of "the Marconi company," a denial that technically referred only to the British company but was generally assumed to cover the American as well. A select committee of the House of Commons revealed the facts and, although by a party majority it acquitted the ministers of blame, Lloyd George's reputation for integrity was damaged.

Social reform and the outbreak of war. Lloyd George's major achievement during the years immediately before the war was in the field of social insurance. Inspired by a visit to Germany (1908), where he studied the Bismarckian scheme of insurance benefits, Lloyd George decided to introduce health and unemployment insurance on a similar basis in Britain. This he did in the National Insurance Act of 1911. The measure inspired bitter opposition and was even unpopular with the working class who were not convinced by Lloyd George's slogan "ninepence for fourpence," the difference in these two figures being the employer's and the state's contribution. Lloyd George, undeterred, piloted his measure through Parliament with great skill and determination. He thus laid the foundations of the modern welfare state and, if he had done nothing else, would deserve fame for that achievement.

Though much of the government's time during these years was occupied by the Irish question, Lloyd George played little part in it and, on the whole, left foreign policy to his colleagues. It was, therefore, something of a surprise when, in July 1911, after careful consultation with Asquith and Sir Edward Grey, he issued a formidable warning to Germany over the Moroccan crisis. When the question of entry into the war convulsed the Cabinet in late July and early August 1914, he seemed at first to incline to the isolationist section. For a brief moment he contemplated retirement. But the tide of events swept him to the other side. As chancellor, he plunged into the financial problems posed by the war.

Minister of munitions and secretary of state for war. Throughout the remainder of 1914 and the early months of 1915, Lloyd George was a vigorous advocate of increased munitions production. Here he came into sharp conflict with Lord Kitchener in the War Office. The resignation of Admiral Fisher in 1915 forced Asquith to reconstruct the government on a coalition basis and admit the Conservatives. In the new administration, Lloyd George became minister of munitions. In this capacity, he made one of the most notable contributions to the victory of the Allies. His methods were unorthodox and shocked the civil service, but his energy was immense. He imported able assistants from big business and used his eloquence to induce the cooperation of organized labour. When, in the summer of 1916, the great Battle of the Somme began, supplies were forthcoming.

Lloyd George acquired definite views on war strategy at an early stage. He doubted the possibility of breaking through on the Western front and advocated instead a flank attack from the Near East. He was thus at loggerheads with the view of the official military hierarchy, cogently pressed by Sir Douglas Haig and Sir William Robertson, that the war could only be won in the West. On June 5, 1916, Kitchener was drowned on his way to Russia, when his ship struck a German mine. A last-minute accident—acute developments in the Irish situation—alone had prevented Lloyd George from travelling with him. After some hesitation, Asquith appointed him to the vacant position at the War Office.

Disagreement with military leaders

Lloyd George held the post for five months, but Robertson as chief of the imperial general staff possessed nearly all the really important powers of the war minister. Lloyd George chafed under these restrictions, the more so because he profoundly disagreed with Robertson on vital

issues of strategy. Thus frustrated, he began to survey the whole direction of the war with increasing skepticism; and he did not conceal his doubts from his friends who, by the end of November, had become convinced that Asquith should delegate the day-to-day running of the war to a small committee whose chairman should be Lloyd George. There was undoubtedly widespread uneasiness at Asquith's conduct of affairs, particularly in the Conservative Party. Asquith was manoeuvred into resigning on December 5 and was replaced two days later by Lloyd George. He was supported by the leading Conservatives, Bonar Law becoming chancellor of the exchequer, leader of the house, and second in command of the government, and Balfour becoming foreign secretary. But the most prominent Liberal ministers resigned with Asquith, and, although about half the rank and file of the party supported the new government, Lloyd George was never forgiven by the old guard of his party for having jockeyed Asquith out of office.

PRIME MINISTER

Lloyd George was now 54 and at the height of his powers. His energy, eloquence, and ability had already made him the leading statesman of the day, and his accession to the premiership was highly popular in the country generally. A sense of renewed vigour, of "push and go," was given to the war effort. He immediately substituted a small War Cabinet of five, which was to be in constant session, for the unwieldy body of 23 that had hitherto conducted affairs. The result was a general speeding up of decisions and the disappearance of the procrastination that had marred the previous government.

War cabinet reorganized

One of Lloyd George's most notable efforts was in combatting the submarine menace which, in the early months of 1917, threatened to starve Britain into submission. He achieved this by forcing the adoption of the convoy system upon a reluctant admiralty. The food shortage resulting from the submarine war was acute. Drastic action had to be taken to step up agricultural production, and eventually a system of food rationing had to be introduced (1918). In these matters Lloyd George was at his best, contemptuous of red tape, determined to take action and to make his will prevail.

It was in the field of grand strategy that he was least successful. Lloyd George remained profoundly skeptical of the ability of the British high command to conduct even a "Western" strategy successfully. Without warning Haig or Robertson in advance, he confronted them at the Calais Conference of February 1917 with a plan to place the British Army under French command for Gen. Robert-Georges Nivelle's forthcoming offensive. Haig and Robertson deeply distrusted Lloyd George from that moment onward. The Nivelle offensive was a total failure, and Lloyd George was, as a result, on shaky ground when he endeavoured to resist Haig's proposals for a major British campaign in Flanders in the summer. After much hesitation, he gave way, and on July 31, 1917, the ill-fated Passchendaele offensive began. Although it may have forestalled a possible German attack on the French, Passchendaele, with enormous loss of life, achieved none of its main objectives. He was now convinced of the incompetence of the British high command.

He still dared not take action against them openly. Instead, he began what Sir Winston Churchill calls "a series of extremely laborious and mystifying maneuvers," with the object of creating a unified command under someone other than Haig. In February 1918, Robertson offered his resignation, which Lloyd George accepted, but Haig remained as commander in chief. Such was Lloyd George's distrust of Haig that, during the winter of 1917-18, he had deliberately kept him short of troops for fear that he might renew the attack. The result was that the Germans came near to launching a successful offensive. The emergency caused a unified command under Marshal Foch to be established (April), and by May the situation became stabilized. Out of these events arose the famous Maurice debate. Maj. Gen. Sir Frederick Maurice, who was in the War Office, published a letter claiming that Lloyd George had given incorrect figures in reply to a question about manpower on the Western front. Lloyd George made a brilliant speech at the subsequent debate in Parliament, though later evidence shows that Maurice was undoubtedly right. The Asquithian Liberals pressed the matter to a division and were heavily beaten.

The Armistice of November 1918 faced Lloyd George with a dilemma. Should he allow a return to peacetime party politics or continue the coalition? There was little doubt of the answer. Bonar Law was willing to cooperate. A somewhat perfunctory offer to include Asquith was declined. The ensuing election in December gave the coalitionists an overwhelming victory. Many of those who followed Asquith at the Maurice debate were not granted the "coupon," the joint letter from Lloyd George and Bonar Law that certified the candidate as a coalitionist. Nearly all, Asquith included, lost their seats. The rift in the Liberal Party became wider, and Lloyd George was now largely dependent on Conservative support.

The "coupon election"

As one of the three great statesmen at Versailles, Lloyd George must bear a major responsibility for the peace settlement. He pursued a middle course between Georges Clemenceau and Woodrow Wilson. But, throughout, Lloyd George was under strong pressure at home to pursue the more draconian policy. It is to his credit that the final settlement was not far worse than it was. The treaty was well-received in Britain, and in August 1919 the king conferred on him the Order of Merit.

A major domestic problem was Ireland, where the Sinn Fein refused to recognize the British Parliament, and from 1919 to 1921 a civil war of massacre and reprisal raged. In the summer of 1921, Lloyd George, with full agreement of his Conservative colleagues, reversed the policy of repression in Ireland and initiated the negotiations that culminated in Irish independence in December 1921. The more rigid Tories never forgave this "surrender," as they deemed it. In 1922 Lloyd George ran into further trouble over the so-called honours scandal, when accusations against the coalition were made in both houses of Parliament that peerages and other honours were being regularly sold for large campaign contributions. Tory discontent was rife, when, from a wholly unexpected quarter, a crisis occurred that drove Lloyd George from power forever. This was the Çanak incident (see OTTOMAN EMPIRE AND TURKEY, HISTORY OF), when it seemed to critics that the reckless foreign policy of the government had led Britain to the verge of an unnecessary war with Turkey. When the Conservative leaders decided to appeal to the country on a coalition basis once again, a party revolt ensued. Bonar Law returned to the political scene; and on October 19 a two-to-one majority of Conservative members of Parliament endorsed his and Stanley Baldwin's plea to fight as an independent party. Lloyd George at once resigned.

Later years and assessment. The long twilight of Lloyd George's career was a melancholy anticlimax. The feud with the Asquithians was never healed, and from 1926 to 1931 he headed an ailing Liberal Party. He devoted himself thereafter to writing his *War Memoirs* (1933–36) and *The Truth About the Peace Treaties* (1938). Lengthy, yet supremely readable and interspersed with brilliant pen portraits, these volumes are an exercise in the forensic, rather than the historian's, art. He seldom admits error, and the endless diatribes against his opponents carry little conviction. In 1936 he visted Germany and met Hitler and was temporarily taken in by him; but in 1938 and 1939 he was a leading opponent of appeasement. In 1940 Churchill invited him to join his war cabinet, but Lloyd George declined, ostensibly on grounds of age and health. On January 1, 1945, he was elevated to the peerage as Earl Lloyd-George of Dwyfor. He died on March 26, 1945.

Publication of his memoirs

Lloyd George's personality is something of an enigma to the historian. It is easy to list his qualities: his eloquence; his extraordinary charm and persuasiveness; his sense of wit and fun; his capacity to see the heart of problems whose complexity baffled lesser men; his profound sympathy with oppressed classes and races; his genuine hatred of those who abused power, whether that power was based on wealth or caste or military might. But there

was an obverse side to these virtues: his love of devious methods; his remarkable, albeit temporary, gullibility in the face of Hitler and the Nazis; his carelessness and want of discretion—some would use severer words—over appointments and honours; his defeatism in World War II, which contrasted so sadly with his earlier courage.

Lloyd George, for all his greatness, aroused in many persons a profound sense of mistrust, and it was in the upper-middle class, represented in politics by Stanley Baldwin and Neville Chamberlain, that he inspired the most acute misgivings. They were both determined to exclude him from office, and it would be wrong to ascribe his long years in the political wilderness solely to the declining fortunes of the Liberal Party. It is perhaps significant of his defects that Lloyd George, though possessing a host of acquaintances, never had a really intimate friend. There was in him a streak of ruthlessness that left little room for the cultivation of personal friendship. For these and other reasons, he was never able to recover the position he had lost in 1922. It was one of the tragedies of the interwar years that, in an era not notable for political talent, the one man of genius in politics should have had to remain an impotent spectator. But his earlier achievements make his place in history secure.

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(B.)

Lobachevsky, Nikolay Ivanovich

Nikolay Ivanovich Lobachevsky, Russian mathematician, is, with his Hungarian contemporary János Bolyai, the founder of non-Euclidean geometry. This geometry is not based on Euclid's parallel postulate, according to which one and only one line can be drawn through a point in a plane parallel to a given line in the plane. First announced in 1826 and published in 1829, Lobachevsky developed it further in subsequent publications. By showing that a non-Euclidean geometry (*q.v.*) was logically possible, he and Bolyai (who published his theory in 1832) discovered the final solution of a problem—whether Euclid's parallel postulate could be deduced as a consequence of his other postulates—that had baffled mathematicians for 2,000 years. Their discovery that it could not would profoundly influence the mathematics, physics, and philosophy of the 20th century.

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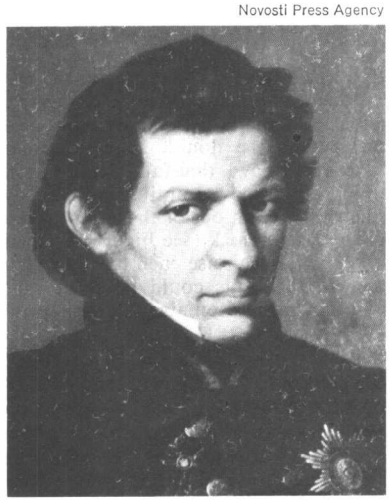

Lobachevsky, detail of a portrait by an unknown artist.

Lobachevsky was born on December 1 (November 20, old style), 1792, in Nizhny Novgorod (now Gorky), the son of an impecunious government official. His entire life centred around the University of Kazan, beginning at age 14, when he entered as a student. In 1811 he received the M.A. degree and then taught, from 1816 as extraordinary professor and from 1822 as ordinary professor.

His administrative talents were soon recognized; in 1820 he became dean of the faculty of mathematics and physics, in 1825 university librarian, and in 1827 rector of the university, a position he held, with repeated reelections, until 1846. In all of his duties, he exercised remarkable organizing and educational skill in rescuing the university from the chaotic conditions into which it had drifted. The previous administration had reflected the spirit of the later years of Tsar Alexander I, who was distrustful of modern science and philosophy, particularly that of the German philosopher Immanuel Kant, as evil products of the French Revolution and a menace to orthodox religion. The results at Kazan during the years 1819–26 were factionalism, decay of academic standards, dismissals, and departure of some of the best professors, including Johann Martin Christian Bartels, friend of the German mathematician Carl Friedrich Gauss, and Lobachevsky's teacher of mathematics.

Academic career

In 1826, a more tolerant period was inaugurated with the accession of Tsar Nicholas I, and Lobachevsky became the leading innovator at the university, restoring academic standards and faculty harmony. He was active in saving lives during the cholera epidemic of 1830, in rebuilding several university buildings after a devastating fire in 1842, and in popularizing science and modernizing primary and secondary education in the region of Kazan. Although burdened with this work, in addition to a heavy administrative teaching load, he still found time for extensive mathematical research.

Lobachevsky's ideas were rooted in his opposition to Kant's transcendental Idealism, which maintains that such ideas as space, time, and extension, are a priori, and that the mind imposes order on sense experience. For him space was an a posteriori concept, derived by the human mind from external experience.

Opposition to Kant

In addition to geometry, Lobachevsky also did distinguished work in the theory of infinite series, especially trigonometric series, integral calculus, and probability; in algebra he found, in 1834, a method for approximating the roots of algebraic equations, often called after the Swiss mathematician Carl Heinrich Gräeffe (1837).

His fame, like that of Bolyai, was posthumous. During his lifetime, few were impressed by his geometry, and the leading Russian mathematician of his day, Mikhail Vasilevich Ostrogradsky, who was well-known in western Europe, could not appreciate it. Moreover, Lobachevsky's first publications, in Russian—in 1829 in a local general periodical and in 1835–39 in the Kazan academic transactions—were little known abroad. But Lobachevsky, in contrast to Bolyai, refused to be discouraged. With characteristic perseverance he continued the publication of his ideas not only in Russian but also in French and German. In 1837 his "Géométrie imaginaire" ("Imaginary Geometry") appeared in *Crelle's Journal* (Berlin), and in 1840 his book *Geometrische Untersuchungen zur Theorie der Parallellinien (Geometrical Researches on the Theory of Parallels*, 1891) was published. There was no general recognition of his work, despite the praise bestowed on it by Gauss, the leading mathematician of Europe, who had reached, but never published, the same conclusions.

Toward the end of his life, nearly blind and grieved by domestic losses, Lobachevsky in 1855 once more presented his theory in French in the book *Pangéométrie*, also appearing in Russian.

He died in Kazan on February 24 (February 12, O.S.), 1856. Acceptance of non-Euclidean geometry had to wait until, under the influence of the German mathematician Bernhard Riemann's ideas on the principles underlying geometry in 1866, the Italian mathematician Eugenio Beltrami in 1868 and the German mathematician Felix Klein in 1871 demonstrated the consistency and general applicability of this geometry.

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(D.J.S.)

Lock

A lock is a mechanical device for securing a door or receptacle so that it cannot be opened except by a key or by a series of manipulations that can be carried out only by a person knowing the secret or code.

EARLY HISTORY

The lock originated in the Near East; the oldest known example was found in the ruins of the palace of Khorsabad near Nineveh. Possibly 4,000 years old, it is of the type known as a pin-tumbler or, from its widespread use in Egypt, an Egyptian lock. It consists of a large wooden bolt, which secures the door, through which is pierced a slot with several holes in its upper surface. An assembly attached to the door contains several wooden pins positioned to drop into these holes and grip the bolt. The key is a large wooden bar, something like a toothbrush in shape; instead of bristles it has upright pegs that match the holes and the pins. Inserted in the large keyhole below the vertical pins it is simply lifted, raising the pins clear and allowing the bolt, with the key in it, to be slid back (Figure 1A). Locks of this type have been found in Japan, Norway, and the Faeroe Islands, and are still in use in Egypt, India, and Zanzibar. An Old Testament reference, in Isaiah, "And I will place on his shoulder the key of the house of David," shows how the keys were carried. The falling-pin principle, a basic feature of many locks, was developed to the full in the modern Yale lock (see below).

In a much more primitive device used by the Greeks, the bolt was moved by a sickle-shaped key of iron, often with an elaborately carved wooden handle. The key was passed through a hole in the door and turned, the point of the sickle engaging the bolt and drawing it back. Such a device could give but little security. The Romans introduced metal for locks, usually iron for the lock itself and often bronze for the key (with the result that keys are found more often today than locks). The Romans invented wards—*i.e.*, projections around the keyhole, inside the lock, which prevent the key from being rotated unless the flat face of the key (its bit) has slots cut in it in such a fashion that the projections pass through the slots. For centuries locks depended on the use of wards for security, and enormous ingenuity was employed in designing them and in cutting the keys so as to make the lock secure against any but the right key (Figure 1B). Such warded locks have always been comparatively easy to pick, since instruments can be made that clear the projections, no matter how complex. The Romans were the first to make small keys for locks—some so small that they could be worn on the fingers as rings. They also invented the padlock, which is found throughout the Near and Far East, where it was probably independently invented by the Chinese.

Use of wards

In the Middle Ages, great skill and a high degree of workmanship were employed in making metal locks, especially by the German metalworkers of Nürnberg. The moving parts of the locks were closely fitted and finished, and the exteriors were lavishly decorated. Even the keys were often virtual works of art. The security, however, was solely dependent on elaborate warding, the mechanism of the lock being developed hardly at all. One refinement was to conceal the keyhole by secret shutters, another was to provide blind keyholes, which forced the lock picker to waste time and effort. The 18th-century French excelled in making beautiful and intricate locks.

After F.P. Gillman

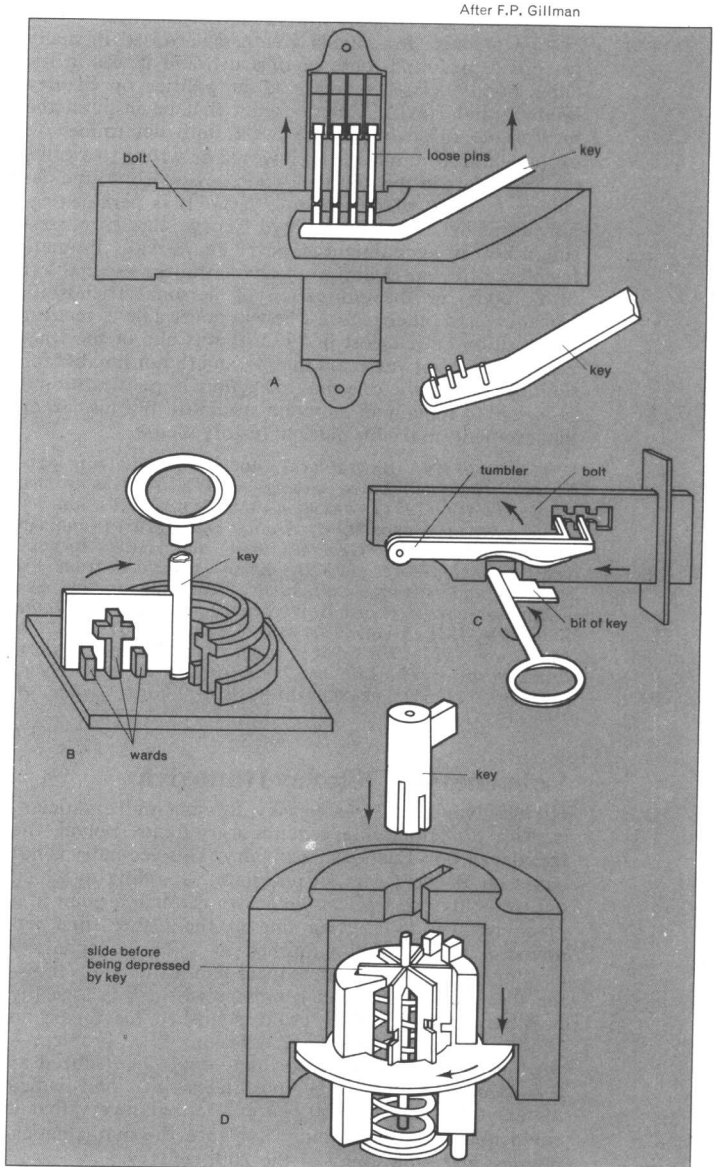

Figure 1: *Early lock types.*
(A) Ancient Egyptian lock. (B) Warded lock and key. (C) The Barron tumbler lock, 1778. (D) The Bramah lock, 1784.

DEVELOPMENT OF MODERN LOCK TYPES

The Barron lock. The first serious attempt to improve the security of the lock was made in 1778 when Robert Barron, in England, patented a double-acting tumbler lock. A tumbler is a lever, or pawl, that falls into a slot in the bolt and prevents it being moved until it is raised by the key to exactly the right height out of the slot; the key then slides the bolt. The Barron lock (see Figure 1C) had two tumblers and the key had to raise each tumbler by a different amount before the bolts could be shot. This enormous advance in lock design remains the basic principle of all lever locks.

The Chubb lock. But even the Barron lock offered little resistance to the determined lock picker, and in 1818 Jeremiah Chubb of Portsmouth, England, improved on the tumbler lock by incorporating a detector, a retaining spring that caught and held any tumbler which, in the course of picking, had been raised too high. This alone prevented the bolt from being withdrawn and also showed that the lock had been tampered with.

The Bramah lock. In 1784 (between Barron's lock and Chubb's improvements on it) a remarkable lock was patented in England by Joseph Bramah. Working on an entirely different principle, it used a very small light key, yet gave an unprecedented amount of security. Bramah's locks are very intricate (hence, expensive to make), and for their manufacture Bramah and his young assistant Henry Maudslay (later to become a famous engineer) constructed a series of machines to produce the parts mechanically. These were among the first machine tools designed for mass production. The Bramah key is a small metal tube that has narrow longitudinal slots cut in its end. When the key is pushed into the lock, it depresses a number of slides, each to the depth controlled by the slots. Only when all the slides are depressed to exactly the right distance can the key be turned and the bolt thrown (Figure 1D). So confident was Bramah of the security of his lock that he exhibited one in his London shop and offered a reward of £200 to the first person who could open it. For over 50 years it remained unpicked, until 1851 when a skilled American locksmith, A.C. Hobbs, succeeded and claimed the reward.

Tube-like key of the Bramah lock

Lockmaking in the mid-19th century. The lock industry was in its heyday in the mid-19th century. With the rapidly expanding economy that followed the Industrial Revolution, the demand for locks grew tremendously.

The Newell lock. In this period lock patents came thick and fast. All incorporated ingenious variations on the lever or Bramah principles. The most interesting was Robert Newell's Parautoptic lock made by the firm of Day and Newell of New York. Its special feature was that not only did it have two sets of lever tumblers, the first working on the second, but it also incorporated a plate that revolved with the key and prevented the inspection of the interior, an important step in thwarting the lock picker. It also had a key with interchangeable bits so that the key could be readily altered. Newell displayed an example in London in the Great Exhibition of 1851. Despite many attempts, there is no record that it has ever been picked.

The Yale lock. In 1848 a far-reaching contribution was made by an American, Linus Yale, who patented a pin tumbler lock working on an adaptation of the ancient Egyptian principle. In the 1860s his son Linus Yale, Jr., evolved the Yale cylinder lock, with its small, flat key with serrated edge, now probably the most familiar lock and key in the world. Pins in the cylinder are raised to the proper heights by the serrations, making it possible to turn the cylinder. The number of combinations of heights of the pins (usually five), coupled with the warding effect of the crooked key and keyhole, give an almost unlimited number of variations (see Figure 2). It has come to be almost universally used for outside doors of buildings and automobile doors, although in the 1960s there was a trend toward supplementing it on house doors with the sturdy lever lock.

After F.P. Gillman

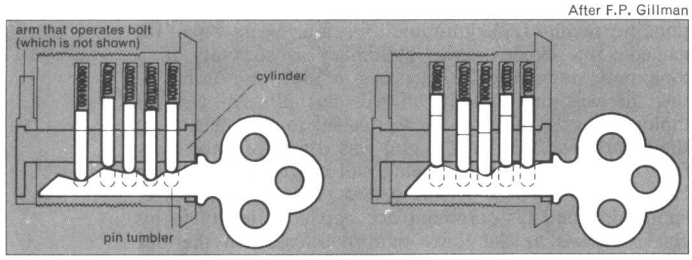

Figure 2: Contemporary version of the Yale lock, patented in the 1860s: (Left) Correct key lifts all pins to proper height and key can be turned. (Right) Wrong key lifts pins to incorrect height and lock will not open.

Time locks. In the 1870s a new criminal technique swept the United States: robbers seized bank cashiers and forced them to yield keys or combinations to safes and vaults. To combat this type of crime, James Sargent of Rochester, New York, in 1873 devised a lock based on a principle patented earlier in Scotland, incorporating a clock that permitted the safe to be opened only at a preset time.

Combination locks. The keyless combination lock derives from the "letter-lock," in use in England at the beginning of the 17th century. In it a number of rings (inscribed with letters or numbers) are threaded on a spindle; when the rings are turned so that a particular word or number is formed, the spindle can be drawn out because slots inside the rings all fall in line. Originally, these letter locks were used only for padlocks and trick boxes. In the last half of the 19th century, as developed for safes and strong-room doors, they proved to be the most secure form of closure. The number of possible combinations of letters or numbers is almost infinite and they have no keyholes into which an explosive charge can be placed. Furthermore, they are easy to manufacture.

A simple combination lock with four rings (tumblers, in the U.S.) and 100 numbers on the dial (*i.e.*, 100 positions for each ring) presents 100,000,000 possible combinations. Figure 3 shows how the single knob can set all the wheels; in this case the lock has three rings, or wheels, giving 1,000,000 possible combinations. If, for example, the combination is 48, 15, 90, the knob is turned counterclockwise until the 48 comes opposite the arrow for the fourth time, a process that ensures that there is no play between the other wheels. The slot on the first wheel (on the left in the diagram) is then in the correct position for opening and it will not move in subsequent operations. The knob is then turned clockwise until the 15 is opposite the arrow for the third time; this sets the slot of the middle wheel in line with the first. Finally, the knob is turned counterclockwise to bring the 90 for the second time to the arrow. All three slots are then in line and a handle can be turned to withdraw the bolts. The combination can easily be changed, for the serrations shown on each wheel enable the slot to be set to a different position relative to the stud for that wheel.

Possible combinations in multiple-ring locks

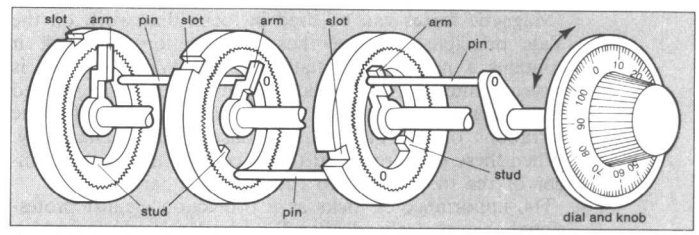

Figure 3: Combination safe lock. The lock cannot be opened until the slots of the three wheels are in line. The movement of the dial is transmitted to each wheel by a system of pins (in practice much shorter than shown), arms, and studs.

Master keys. It is frequently necessary, particularly in hotels and office buildings, for a manager or caretaker to have a master key that will open all the locks in the building. To design a set of single locks each of which can be opened by its own key, and also by the master key, requires a coordinated arrangement of the warding. The master key is so shaped as to avoid the wards of all the locks. Another method involves two keyholes, one for the normal key, the other for the master key, or two sets of tumblers or levers, or in the case of Yale locks, two concentric cylinders.

Electronic elements. In the 1960s an electronic cash dispenser for banks was introduced. This system allows a customer to withdraw money when the bank is closed. The customer has a personal card that is coded with magnetic and other markings. He inserts the card into the machine, located in the wall of the bank. The card is drawn inside and automatically checked for genuineness. The customer then sets up his personal account number (not marked on the card) by pressing a series of numbered buttons. This is also checked electronically and, if correct, a fixed amount of cash is ejected. The card remains within and is later returned to the customer by mail. The whole device constitutes a lock, but it is not a mechanical device, since all the information given by the card, which constitutes the key, is sorted by electronic circuits. Other electronic devices are being increasingly used in connection with security systems (see POLICE TECHNOLOGY).

Present status of locks and safes. Over the years, locks have been constructed with many specialized functions. Some have been designed to resist being blown open, others to shoot or stab intruders or to seize their hands. Locks have been made that can be opened or closed by different keys but can be unlocked only by the key that closed them. So-called unpickable locks are usually devised to prevent a thief from exploring the positions of the lock parts from the keyhole or from sensing with his picking tool slight changes of resistance when pressure is applied to the bolt. The basic types, however, remain the Bramah, lever, Yale, and combination locks, though innumerable variations have been made, sometimes combining features of each. The Swiss Kaba lock, for example, employs the Yale principle but instead of having a serrated-edge key, the flat sides of the key are marked with deep depressions into which four complete sets of pin-tumblers are pressed. The Finnish Abloy lock is a compact combination lock, but the rings, instead of being turned separately by hand, are moved to the correct positions by a single turn of a small key.

Basic types remaining in use

Magnetic forces can be used in locks that work on the Yale principle. The key has no serrations; instead, it contains a number of small magnets. When the key is inserted into the lock, these magnets repel magnetized spring-loaded pins, raising them in the same way that the serrations on a Yale-type key raise them mechanically. When these pins are raised to the correct height, the cylinder of the lock is free to rotate in the barrel.

The importance of locks as a protection against professional thieves declined after World War II, during which the knowledge and use of explosives had become widely disseminated. Most safe locks and strong-room locks became almost unpickable, and criminals tended to use explosives to blow them off. An attempt to blow up the mechanism of a lock by detonating an explosive in the keyhole can be foiled by introducing a second series of bolts, not connected to the lock mechanism, but automatically inserted by springs when an explosion occurs; the safe then cannot be opened except by cutting through the armour.

Another method used by criminals is to burn away the plating or hinge of a safe with an electric arc or an oxy-acetylene flame, an operation requiring many hours' work. To resist this type of entry, safe makers produced even more resistant materials and new methods of construction to carry away the heat of the cutting flame.

BIBLIOGRAPHY. G. PRICE, *A Treatise on Fire and Thief-Proof Depositories, and Locks and Keys* (1856); and C. TOMLINSON (ed.), *Rudimentary Treatise on the Construction of Locks* (1853, 1868), are the classic books on the history of locks and their mechanisms up to the mid-19th century (fully illustrated). For a great variety of types of locks, especially U.S. locks, see A.A. HOPKINS, *The Lure of the Lock* (1928), a catalogue of the Mossman collection in New York that includes historical notes. V.J.M. ERAS, *Sloten en Sleutels door de eeuween Heen* (1941; Eng. trans., *Locks and Keys Throughout the Ages*, 1957, reissued 1975), is an account of the Lips collection of locks at their factory in Dordrecht, The Netherlands. It also contains illustrations and descriptions of locks from many other collections throughout the world. E.A. SLOANE, *The Complete Book of Locks, Keys, Burglar and Smoke Alarms, and other Security Devices* (1977), is an extensively illustrated manual that describes the operation and installation of many types of locks; C.A. ROPER, *The Complete Handbook of Locks and Locksmithing* (1976), covers all aspects of the modern locksmith's craft. For descriptions of the latest developments in locks and the announcement of new varieties, see the weekly London journals *The Engineer* and *Engineering*.

(G.B.L.W.)

Locke, John

John Locke was an English philosopher who was expert in many fields, particularly epistemology (theory of knowledge), politics, education, and medicine. His chief contributions were, first, a clear and emphatic formulation of the social and political principles that, in his opinion, emerged from the turbulence of 17th-century Britain and, second, an account of human knowledge, including his examination of the "new science" of his day—*i.e.*, modern science.

Locke, oil painting by Sir Godfrey Kneller (1646/49–1723). In Christ Church, Oxford.

By courtesy of the Governing Body of Christ Church, Oxford

Early life. Locke was born in Wrington, Somerset, on August 29, 1632, and reared in Pensford, six miles south of Bristol. His family was Anglican with Puritan leanings. His father was a country attorney of modest means who fought on the Parliamentarian side in the Civil War—a fact that later helped him to find a place for his son in Westminster School, then controlled by a Parliamentarian committee (though its headmaster, Dr. Richard Busby, was a Royalist). The training there was thorough, but Locke later complained of the severity of its discipline. In 1652 Locke entered Christ Church, Oxford. Although the Puritans, led by the eminent John Owen, had introduced some reforms into Oxford life, they had made little change in the traditional curriculum of rhetoric, grammar, moral philosophy, geometry, and Greek, and Locke found the course of study insipid. Nonetheless, this link with traditional Scholastic methods was not wholly valueless. He graduated B.A. in 1656 and M.A. two years later.

Student years

During his student years Locke interested himself in studies not in the traditional curriculum; in particular, he was drawn to experimental science (brilliantly taught at Oxford by John Wilkins) and to medicine. In 1660, the year of the restoration of the monarchy, Locke was appointed a tutor in Christ Church. He remained a student (i.e., a fellow) with rooms in the college until 1684; but, not wishing to make teaching his permanent vocation, he taught undergraduates for four years only. He gained some experience in diplomacy as secretary to a diplomatic mission to Brandenburg in 1665, and on his return he was immediately offered, but refused, another diplomatic post. Nor did he feel called to the ministry of the Church, a fact that for him was definitive since entry into holy orders without being called would have been culpable. His papers of this period (1656-66), his correspondence, and his commonplace books all testify to his chief interests at the time: natural science, on the one hand, and the study of the underlying principles of moral, social, and political life, on the other. In the latter connection, his "Essays on the Law of Nature," which he wrote in 1663-64 but never published, indicate how far this study had then proceeded. In order to remedy the narrowness of his education he read contemporary philosophy, particularly that of René Descartes, the father of modern philosophy. But more than anything else, experimental science engaged his interest. He collaborated with his close friend Robert Boyle, one of the founders of modern chemistry, and, toward the end of the period, with another friend, Thomas Sydenham, an eminent medical scientist.

Association with Shaftesbury. It was as a physician that Locke first came to the notice of the statesman Lord Ashley (later to become the 1st earl of Shaftesbury), who at once recognized his worth and in 1667 invited him to

become part of his household staff serving as physician. Locke accepted the invitation and very soon was Ashley's personal adviser not merely on medical matters but on his general affairs as well. Ashley was a forceful, aggressive politician who had many enemies (some of them men of letters—for instance, Locke's schoolfellow, the poet laureate John Dryden). It is doubtful, however—if only in view of Locke's respect for him—whether Ashley was as evil as his enemies sometimes made him out to be. It is known that he stood firmly for a constitutional monarchy, for a Protestant succession, for civil liberty, for toleration in religion, for the rule of Parliament, and for the economic expansion of Britain; and that he continued to make this stand when many influential men were working against these aims. Since these were already aims to which Locke had dedicated himself, there existed from the first a perfect understanding between the statesman and his adviser, one that meant much to both. Ashley entrusted Locke with the task of negotiating his son's marriage with the daughter of the Earl of Rutland; he also made him secretary of the group that he had formed to increase trade with America, particularly with the southern colonies.

Private studies and discussions

During the following decades, Locke persevered in his private studies, and many of his social meetings were in effect meetings with friends to discuss philosophical and scientific problems. As early as 1668 he had become a fellow of the newly formed (1663) Royal Society, which kept him in touch with scientific advances. It is known, too, that groups of friends met in his rooms (Lord Ashley; John Mapletoft; Thomas Sydenham; Sydenham's physician colleague, James Tyrrell, who was also a divine; and others), for one of its meetings is mentioned in the preface of his *Essay Concerning Human Understanding*, in which he reports that, because of the difficulties that beset the participants, they resolved to devote their next meeting to discussing the powers of the mind in order, as they said, "to examine our own abilities and see what objects our understandings were, or were not, fitted to deal with." Locke himself opened the discussion and, following the meeting, set out his view of human knowledge in two drafts (1671), still extant, which show the beginnings of the thinking that 19 years later would blossom into his famous *Essay*. In these London years, too, Locke encountered representatives of Cambridge Platonism, a school of Christian humanists, who, though sympathetic to empirical science, nonetheless opposed Materialism because it failed to account for the rational element in human life. They tended to be liberal both in politics and religion. Insofar as they taught a Platonism that rested on belief in innately known Ideas, Locke could not follow them; but their tolerance, their emphasis on practical conduct as a part of the religious life, and their rejection of Materialism were features that he found most attractive. This school was closely related in spirit to another school that influenced Locke at this time, viz., that of Latitudinarianism. For the latter school, if a man confessed Christ, that alone should be enough to entitle him to membership in the Christian Church; conformity in nonessentials should not be demanded. These movements prepared Locke for the antidogmatic, liberal school of theology that he would later encounter in Holland, a school in revolt against the narrowness of traditional Calvinism.

In 1672 Ashley was raised to the peerage as the 1st Lord Shaftesbury and at the end of that year was appointed lord high chancellor of England. Though he soon lost favour and was dismissed, he did, while in office, establish the Council of Trade and Plantations, of which Locke was secretary for two years. Locke, however, who suffered greatly from asthma, found the London air and his heavy duties unhealthful; and in 1675 he had to return to Oxford.

Intellectual contacts in France

Six months later he departed for France, where he stayed for four years (1675–79), spending most of his time at Paris and Montpellier. In France during the 1670s, Locke made contacts that deeply influenced his view of metaphysics (the nature of being) and epistemology, viz., with the Gassendist school, and particularly with its leader, François Bernier. Pierre Gassendi, a philosopher and scientist, had rejected overspeculative elements in Descartes's philosophy and had advocated a return to Epicurean doctrines—*i.e.*, to empiricism (stressing sense experience), to hedonism (holding pleasure to be the good), and to corpuscular physics (with reality made of atomic particles). Knowledge of the external world, Gassendi held, depends upon the senses, though it is through reasoning that man may derive much further information from empirically gained evidence.

Upon Locke's return to England, he found the country torn by dissension. The heir to the throne, James (the brother of Charles II), was a Catholic, whom the Protestant majority led by Shaftesbury wished to exclude from the succession. For a year Shaftesbury had been imprisoned in the Tower, but by the time Locke returned he was back in favour once more as lord president of the Privy Council. When he failed, however, to reconcile the interests of the King and Parliament, he was dismissed; in 1681 he was arrested, tried, and finally acquitted by a London jury. A year later he fled to Holland, where, in 1683, he died.

Later life. No one of Shaftesbury's known friends was now safe in Britain; and Locke himself, who was being closely watched, crossed to Holland in September 1683.

Exile in Holland. Locke remained in Holland for over five years, until James II, who had become king in 1685, was overthrown. As an exile Locke's sojourn in Holland was happier than he had expected it to be: his health improved, he made many new friends, and he found the leisure that enabled him to bring his thoughts on many subjects to fruition. Locke spent his first winter in Amsterdam and soon became friendly with a distinguished Arminian theologian, Philip van Limborch, pastor of the Remonstrants' church there—a friendship that lasted till Locke's death. The companionship of Philip and other friends made it easier to bear bad news from home: at Charles II's express command, Locke (in 1684) was deprived of his studentship at Christ Church. The next year his name appeared on a list sent to The Hague that named 84 traitors wanted by the English government. Locke went into hiding for a while, but soon was able to move freely over Holland and became familiar with its different provinces.

Return to England and retirement to Oates. In the autumn of 1688, William left for England; and Locke himself in February 1689 crossed in the party that accompanied the Princess of Orange, now to be crowned Queen Mary II of England. The triumph was complete; Locke was home again, although not without a nostalgia for the Holland that he had come to love. He now took little part in public life. He refused ambassadorial posts but accepted a membership in the Commission of Appeals. (Much later, in 1696, he was appointed a commissioner in the resuscitated Board of Trade and Plantations, however, and for four years played a leading part in its deliberations.) But the London air again bothered him, and he was forced to leave the city for long visits to his friends in the country. In 1691 he retired to Oates in Essex, to the house of his friends Sir Francis and Lady Masham, and subsequently made only occasional visits to London. Nonetheless, he was not without influence in these last years of his life (1689–1704), for he was the intellectual leader of the Whigs. Their principal parliamentarians were frequently old friends of Locke, and the younger generation—particularly the ablest of them all, John Somers, who soon became lord chancellor—turned to him constantly for guidance. In "the glorious, bloodless revolution," the main aims for which Shaftesbury and Locke had fought were achieved—even though in William's reign strong Tory pressures limited the extent of the reform. First and foremost, England became a constitutional monarchy, controlled by Parliament. Second, real advances were made in securing the liberty of the subject in the law courts, in achieving a greater (though far from complete) measure of religious toleration, and in assuring freedom of thought and expression. Locke himself drafted the arguments that his friend Edward Clarke used in the House of Commons in arguing

Influence during retirement

for the repeal of the restrictive Act for the Regulation of Printing. The act was abolished in 1695 and the freedom of the press secured. These were major reforms.

Publication of his works. The main task of this last period of his life, however, was the publication of his works, which had been the product of long years of gestation. The *Epistola de Tolerantia* (Eng. trans., *A Letter Concerning Toleration*, 1689) was published anonymously at Gouda in 1689. Locke had been reflecting on this topic from his early days at Oxford. Though his correspondence and a paper that he wrote in 1667 show his support for toleration, in 1660–61 he wrote two tracts on this theme (published in 1967), which are surprisingly conservative. How he came to write them is rather mysterious. The 1667 paper is very much in line with the 1689 *Letter* in its demand for toleration of religion: (1) No man has such complete wisdom and knowledge, he held, that he can dictate the form of another man's religion; (2) each individual is a moral being, responsible before God, and this presupposes freedom; and (3) no compulsion that is contrary to the will of the individual can secure more than an outward conformity. *Two Treatises of Government* (1690) was also the fruit of years of reflection upon the true principles in politics, a reflection resting on Locke's own observations. Government, Locke held, is a trust; its purpose is the security of the citizen's person and property; and the subject has the right to withdraw his confidence in the ruler when the latter fails in his task. Government and political power are necessary, but so is the liberty of the citizen; and in a democratic, constitutional monarchy, a type of government is possible in which the people are still free.

In all of these social and political issues, Locke saw that the ultimate factor is man's nature. To understand man, however, it is not enough to observe his actions; one must also inquire about his capacities for knowledge. Locke had been conscious of this point in writing his paper on the *Law of Nature* as early as 1663. In 1671, as has been seen, he set out to write a book about human knowledge, the *Essay*, which was not published, however, until 1690—nor was it wholly completed even then, for Locke made changes, sometimes substantial ones, in three of the four following editions.

Ideas of sense and of reflection

Development of his epistemology. Epistemology was a main concern in the last 30 years of his life. Human knowledge, he argued, rests (1) on the experience of the external world acquired through the senses, and (2) on that of the inner world of psychical happenings achieved through introspection (or, in Locke's terminology, "reflection"). The empirical knowledge derived from these sources is uncertain and never provides more than probability, whereas the ideal of knowledge is certainty. In Locke's opinion, this ideal is in fact attainable in some fields—for instance, in mathematics. Though knowledge originates in sensory and introspective experience, this is only the beginning; for many other factors are to be attended to as well—factors such as the reasoning that enables a person to derive, from empirically based propositions, more general conclusions about the world, both physical and mental. Such reasoning may be inductive (resting on the assumption that what usually happens always happens) or it may be deductive. Mathematical reasoning, for example, is deductive; and this kind of knowledge is only to be understood, Locke believed, in terms of an intellectual intuition of relations between ideas, which, though empirically derived, have the status of defined archetypes of such a nature that their empirical reference is irrelevant. In addition, the knower, by means of intuition, can discern the relations between statements that warrant the drawing of inferences. Through such intellectual intuitions, necessary and universal knowledge is possible. To facilitate his presentation of this theory, Locke considered the nature of (1) idea and (2) language. He concluded that, in the case of human beings, intuitive knowledge is limited in extent; for the most part, knowledge is only probable, and Locke examined the degrees of probability and the nature of evidence. He acknowledged that the natural sciences cannot give complete certainty: nonetheless, careful reasoning, with the application of mathematical reasoning wherever possible, will heighten the probability of attaining true knowledge in these fields. In the *Essay*, Locke set down the foundations of an epistemology of modern science.

Last years. Locke's last years were spent in the peaceful retreat of Oates. His hostess was a woman with whom he had been acquainted for many years, viz., Lady Masham, or Damaris, the daughter of Ralph Cudworth, one of the Cambridge Platonists, by whom Locke had been significantly influenced. He found friendship and comfort in this household, for which he never ceased to be thankful. Many of his friends visited him here: Sir Isaac Newton, who came to discuss the Epistles of Saint Paul, a subject of great interest to both; his nephew and heir Peter King, destined to become lord high chancellor of England; and Edward Clarke with his wife and children, Edward and Elizabeth, for whom Locke had great affection (as he had, too, for the children of the Oates household). Locke had written a series of letters to Edward Clarke from Holland, advising him on the best upbringing for his son. These letters formed the basis of his influential *Some Thoughts Concerning Education* (1693), setting forth new ideals in that field. He wrote and published pamphlets on matters of economic interest, on rates of interest, on the coinage of the realm, and more widely on trade (defending mercantilist views). In 1695 he published a dignified plea for a less dogmatic Christianity in *The Reasonableness of Christianity*. It is, finally, interesting to note that Locke never produced a book on morals, though this subject was possibly his greatest interest: for in this field he never succeeded in working out a coherent theory that would reconcile differences within his thinking.

Later writings

John Locke died on October 28, 1704, and was buried in the parish church of High Laver. "His death," wrote Damaris Cudworth, "was like his life, truly pious, yet natural, easy and unaffected." This account of his character by one who knew him well seems singularly appropriate. There is adequate evidence of his piety, as there is of his natural simplicity, grace, and unaffectedness. He was orderly, careful about money, occasionally parsimonious, abstemious, and, though naturally emotional and hot-tempered, controlled and disciplined. He had a great love of children, and friendship was for him a necessity. Both in his books and in his life are found the marks of the prudence and wisdom for which he was famed.

MAJOR WORKS

PHILOSOPHY AND RELIGION: *Essays on the Law of Nature* (eight essays written *c.* 1662–64 in Latin with various Latin titles; first published, with Eng. trans., in 1954); *An Essay Concerning Human Understanding* (1690); *Epistola de Tolerantia* (1689; *A Letter Concerning Toleration*, 1689); *A Second Letter Concerning Toleration* (1690); *A Third Letter for Toleration* (1692); *The Reasonableness of Christianity* (1695); *Some Thoughts on the Conduct of the Understanding in the Search of Truth* (1762).

POLITICAL PHILOSOPHY AND ECONOMICS: *Two Treatises of Government* (1690); *Some Considerations of the Consequences of the Lowering of Interest, and Raising the Value of Money* (1692); *Short Observations on a Printed Paper, Intituled "For Encouraging the Coining of Silver Money in England"* (1695); *Further Considerations Concerning Raising the Value of Money* (1695).

EDUCATION: *Some Thoughts Concerning Education* (1693).

BIBLIOGRAPHY. HANS O. CHRISTOPHERSEN, *A Bibliographical Introduction to the Study of John Locke* (1930). At present, no modern standard edition of Locke's works exists, but the first volume of the Oxford edition is expected to appear soon.

Biography: PETER KING, *The Life of John Locke* (1829, fuller edition 1830), a poor biography, but King possessed and quoted from what is now known as the Lovelace Collection of Locke papers, and this gives the book great value; H.R. FOX BOURNE, *The Life of John Locke* (1876), an excellent study, still indispensable though not now definitive; MAURICE W. CRANSTON, *John Locke: A Biography* (1957), the best and most up-to-date biography, very readable and most illuminating.

On Locke's philosophy: RICHARD I. AARON, *John Locke*,

3rd ed. (1971), a general study, with bibliography; SAMUEL ALEXANDER, *Locke*, "Philosophies Ancient and Modern Series" (1908), brief, but a jewel; D.J. O'CONNOR, *John Locke* (1952), a concise, enlightening, and well-written introductory commentary; J. GIBSON, *Locke's Theory of Knowledge and Its Historical Relations* (1917), a thorough study of the topic; J.W. YOLTON, *John Locke and the Way of Ideas* (1956), much information on Locke's sources and early critics.

(R.Aa.)

Locomotion

Animals are, by definition, motile organisms. Large or small, their locomotor ability is expressed by their structural organization, from external shape to tissue and cell morphology. A fusiform (tapering) body, for example, suggests speed and a high level of activity, whether this shape is possessed by a protozoan (one-celled animal), molluskan (*e.g.*, squid), insect, or vertebrate. In contrast, a globular body enclosed in a protective shell, such as a clam, indicates slow or sedentary habits. Animals, however, are not machines; each individual is a precisely blended and balanced amalgamation of structures that enable it to perform the many functions necessary for its survival and reproduction. The fact that an animal's structure clearly reflects locomotor habits indicates the importance of mobility in all phases of its life.

GENERAL CONSIDERATIONS ABOUT LOCOMOTION

To locomote, all animals require both propulsive and control mechanisms. The diversity of animal propulsive mechanisms, all of which involve a contractile structure —muscle in most cases—to generate a propulsive force, are dealt with in the sections that follow. The quantity, quality, and position of contractions are initiated and coordinated by the nervous system: through this coordination, rhythmic movements of the appendages or body produce locomotion. Control of locomotion by the nervous system, locomotion as a learned behaviour, and physiological problems associated with locomotion, such as temperature control, metabolism, nutrition, and respiration, are described elsewhere in the articles NERVES AND NERVOUS SYSTEMS; BEHAVIOUR, ANIMAL; MUSCLE SYSTEMS; and MUSCLE CONTRACTION.

Physical restraints to movement. Animals successfully occupy a majority of the vast number of different physical environments (ecological niches) on earth; in a discussion of locomotion, however, these environments can be divided into four types: aerial (including arboreal), aquatic, fossorial (underground), and terrestrial. The physical restraints to movement—gravity and drag—are the same in each environment: they differ only in degree. Gravity is here considered as the weight and inertia (resistance to motion) of a body, drag as any force reducing movement. Although these are not the definitions of a physicist, they are adequate for a general understanding of the forces that impede animal locomotion.

Gravity. To counteract the force of gravity, which is particularly important in aerial, fossorial, and terrestrial locomotion, all animals that live in these three environments have evolved skeletal systems to support their body and to prevent the body from collapsing upon itself. The skeletal system may be internal or external, and it may act either as a rigid framework or as a flexible hydraulic (fluid) support.

To initiate movement, a sufficient amount of muscular work must be performed by aerial, fossorial, and terrestrial animals to overcome inertia. Aquatic animals must also overcome inertia; the buoyancy of water, however, reduces the influence of gravity on movement. Actually, because many aquatic animals are weightless—*i.e.*, they possess neutral buoyancy by displacing a volume of water that is equal in weight to their dry weight —little muscular work is needed to overcome inertia. But not all aquatic animals are weightless. Those with negative buoyancy sink as a result of their weight; hence, the greater their weight, the more muscular energy they must expend to remain at a given level. Conversely, an animal with positive buoyancy floats to and rests on the surface, and must expend muscular energy to remain submerged.

Buoyancy

Drag. In water, the primary force that retards or resists forward movement is drag, the amount of which depends upon the animal's shape and how that shape cleaves the water. Drag results mainly from the friction of the water as it flows over the surface of the animal and the adherence of the water to the animal's surface (*i.e.*, the viscosity of the water). Because of the water's viscosity, its flow tends to be lamellar; *i.e.*, different layers of the water flow at different speeds, with the slowest layer of flow being the one adjacent to the body surface. As the flow speed increases, the lamellar pattern is lost, and turbulence develops, thereby increasing the drag.

Another component of drag is the retardation of forward movement by the backward pull of the eddies of water behind the tail of the animal. As they flow off an animal, the layers of water from each side meet and blend. If the animal is streamlined (*e.g.*, has a fusiform shape), the turbulence is low; if, however, the water layers from the sides meet abruptly and with different speeds, the turbulence is high, causing a strong backward pull, or drag, on the animal.

Aerial locomotion also encounters resistance from drag, but, because the viscosity and density of air are much less than those of water, drag is also less. The lamellar flow of air across the wing surfaces is, however, extremely important. The upward force of flight, or lift, results from air flowing faster across the upper surface than across the lower surface of the wing. Because this differential in flow produces a lower air pressure on the upper surface, the animal rises. Lift is also produced by the flow of water across surfaces, but aquatic animals use the lift as a steering aid rather than as a source of propulsion.

Lift and drag

Drag is generally considered a negligible influence in terrestrial locomotion; and, in fossorial locomotion, the friction and compactness (friability) of soils are the two major restraints. If the soil is extremely friable, as is sand, some animals can "swim" through it. Such fossorial locomotion, however, is quite rare; most fossorial animals must laboriously tunnel through the soil and thereafter depend upon the tunnels for active locomotion.

Axial and appendicular locomotion. Movement in animals is achieved by two types of locomotion, axial and appendicular. In axial locomotion, which includes the hydraulic ramjet method of ejecting water (*e.g.*, squid), production of a body wave (eel), or the contract–anchor–extend method (leech), the body shape is modified, and the interaction of the entire body with the surrounding environment provides the propulsive force. In appendicular locomotion, on the other hand, special body appendages interact with the environment to produce the propulsive force.

There are also many species of animals that depend upon their environment for transportation, a type of mobility that is called passive locomotion. Some jellyfish, for example, develop structures called floats that extend above the water's surface and act as sails. A few spiders have developed an elaborate means of kiting; when a strand of their web silk reaches a certain length after being extended into the air, the wind resistance of the strand is sufficient to lift and carry it away with the attached spider. In one fish, the remora, the dorsal (top) fin has moved to the top of the head and become modified into a sucker; by attaching itself to a larger fish, the remora is able to ride to its next meal.

AQUATIC LOCOMOTION

Micro-organisms. Most motile protozoans, which are strictly aquatic animals, move by locomotion involving one of three types of appendages: flagella, cilia, or pseudopodia. Cilia and flagella are indistinguishable in that both are flexible filamentous structures containing two central fibrils (very small fibres) surrounded by a ring of nine double fibrils. The peripheral fibrils seem to be the contractile units and the central ones, neuromotor (nervelike) units. Generally, cilia are short and flagella long, although the size ranges of each overlap.

Flagellar locomotion. Most flagellate protozoans possess either one or two flagella extending from the anterior (front) end of the body. Some protozoans, however,