EUROPE AND RUSSIA. The main countries of Europe (including Great Britain and European Russia from time to time) have followed a similar pattern in developing the sciences since the second half of the nineteenth century. The attitudes of the dominant churches and the rate of commercial and industrial development have variously affected the pace and intensity of the pursuit of natural knowledge in the several countries. But the ready exchange of information, people, and inventions; the similarity of institutions for the study and spread of science; and commercial competition, warfare, and colonial adventures coupled development in the main European countries. The surprising finding that in 1900 the number of academic physicists per unit of population, and the amount of investment per unit of national income, were virtually the same in Britain, France, and Germany suggests the tightness of the coupling. This equalization occurred despite considerable differences in the methods of funding and the operations of the universities in the different countries.

During the eighteenth century the chief institutions concerned with natural knowledge divided their work in the same way throughout Europe: the universities taught established science, the academies sought new knowledge. The larger observatories and botanical gardens, often associated with both universities and academies, taught, preserved, and developed their subject matters in the same way in Paris and Saint Petersburg. A flourishing book trade, expanding university libraries, and many review journals, some, like the *Göttingische gelehrte Anzeigen*, associated with universities, kept everyone interested abreast of the latest advances. European scholars saw themselves as inhabitants of a "republic of letters." The use of Latin and French as the languages of scholarly interchange, travel when war did not preclude it, the mobility of academicians (the moves of Leonhard *Euler from Switzerland to Saint Petersburg to Berlin to Saint Petersburg, and of Pierre de Maupertuis from Paris to Berlin and back, exemplify the traffic), and the institution of "corresponding members" of the learned societies further enforced the notion of a pan-European communion of philosophers. Immanuel Kant's *Idea for a universal history with a cosmopolitan purpose* (1784) made a "universal cosmopolitan existence . . . the highest purpose of nature." Ludwig Wachler, the author of a *History of history and art from the renewal of culture in Europe* (1812), taught that the cultivation of the sciences was a peculiarly European activity.

The sciences literally helped put Europe on the map. More exacting techniques for surveying and *geodesy were developed in national academies, and academy expeditions helped establish the topographic contours of Europe. European governments learned to appreciate that precision measurement increased state revenues, and they set about the laborious task of establishing common units recognized beyond provincial boundaries. Enlightened states supported natural sciences for their utility; not only technical subjects like astronomy and geodesy with obvious applications, but also natural philosophy, geography, meteorology, mining, forestry, and agriculture, whose study would prepare better civil servants and effective policing (*see* CAMERALISM).

Science unified more than knowledge and bureaucratic process. It helped constitute modern European states. Beginning in the early 1820s the Versammlung Deutscher Naturforscher und Ärzte brought together German-speaking physicians and naturalists from the patchwork of principalities, free cities, and palatinates that made up the region. The renowned explorer Alexander von *Humboldt called its meeting in Berlin in 1828 "a noble manifestation of scientific union in Germany; it presents the spectacle of a nation divided in politics and religion, revealing its nationality in the realm of intellectual progress." The German institution spread—the European system was above all one of parallel institutional forms. In 1831 "gentlemen of science" founded the British Association for the Advancement of Science, which, like its German model, had a wide membership and moved to meetings around the country. The French counterpart came into existence just after the Franco-Prussian war exposed the error of not staying closer to the practices of its rivals.

By spreading French science, which already gave the tone to European science, the French Revolution marked the acme of the Republic of Letters; by having its way by force of arms, the Revolution simultaneously disseminated a republicanism that many scholars judged to be inimical to the old cooperative scholarship. Auguste Comte may have envisioned the approach of a "scientific" stage of human civilization in which the intellectual elites of Europe would form ties across political boundaries and initiate a peaceful "European revolution" (*Cours de philosophie positive*, 1830–1842). But he was too late—and too early. From the Napoleonic wars to the unification of Germany, rivalry rather than cooperation dominated the development of European scientific institutions. The main growth occurred in the universities and higher schools. The foundation of the University of Berlin in 1810 and the restructuring of elementary and secondary curricula in Prussia gave a strong impetus to the entire educational system. Research gradually became a responsibility of the professoriate and of their students who aimed to be secondary school teachers. The rationale became ideology: only those who had contributed to knowledge, however small the contribution might be, could transmit to others the right mixture of information and enthusiasm. The Germans invented the teaching laboratory (*see* LIEBIG, JUSTUS VON), the research *seminar, the disciplinary *institute, and the Ph.D. After the middle of the nineteenth century, foreign students began to flock to the German universities, to profit from their professors and facilities and—helping to integrate the European system of science—to bring back home what they found useful and transportable. After their defeat in 1870–1871, the French sent a *mission to discover what made German universities so strong. In consequence, the French strengthened their provincial faculties of science and set up new higher technical schools like the École Supérieure d'Electricité (1884) and the École Supérieure de Physique et de Chimie (1882).

The strength of the French educational system since the Revolution had been its technical schools. The École Polytechnique trained scientists and engineers in a great deal of higher mathematics combined with physics and chemistry. Its students, selected by competition, graduated to enter specialized engineering schools—for mining, civil engineering, artillery, and so on. They then practiced as state employees, civil or military. Along with the centralized École Polytechnique the Revolution created an École Normale Supérieure, which supplied the teachers for the new system of state secondary schools (the *lycées*). The excellence of the Parisian technical schools and the scientific culture they supported made France the mecca of European natural philosophers and mathematicians until the 1830s and 1840s. As late as 1845 William *Thomson chose Paris as the best place to complete his education in physics.

Thomson had been educated in old British universities (Glasgow and Cambridge). By the time he went to Paris, a new sort of university, which emphasized modern languages and science, had begun to grow. The University of London was put together from University College and King's College, founded in 1826 and 1831, respectively; later other colleges were added. Provincial manufacturing centers supported the creation of "redbrick" universities, which trained practical scientists of the second industrial revolution. Beginning in the 1850s committees of Parliament forcibly brought Oxford and Cambridge into the nineteenth century by establishing professorships in science and reducing the power of the humanistic dons.

As rivalry and war propagated the stronger institutional forms from one country to another (the Germans borrowed from the École Polytechnique for their *Technische Hochschulen*), pressures from science and its applications forced the invention of new means of cooperation. Some, like the famous meeting in Karlsruhe in 1860 where chemists came to settle their differences over atomic weights, were fleeting. Others, like the International Bureau of Weights and Measures, established near Paris in 1875, have endured. The need for agreement over measures made an irresistible force for internationalism.

The push toward standardization, the increasing mobility of students, the ever more efficient distribution of scientific journals, the remarkable expansion of the applied sciences that marked the second industrial revolution—all of these factors contributed to a pan-European identity for science even as imperial rivalries reached their peak. In *A History of European Thought in the Nineteenth Century* (1896–1914), John Theodore Merz, a German with a doctorate on Hegel who ran a chemical factory in Britain, gave voice to the growing conviction that "in the course of our century Science at least has become international.... [W]e can speak now of European thought, when at one time we should have had to distinguish between French, German, and English thought."

Around 1900 the reconstruction of the Republic of Letters was cemented by the foundation of the International Association of Academies, with headquarters in Berlin; the International Catalogue of Scientific Literature, a retrospective inventory of periodical literature run from the Royal Society of London; and, outlasting both, the Nobel Institution and its prizes. On the nationalist level, the *Kaiser-Wilhem Gesellschaft (founded 1911) copied in its own way the Royal Institution of Great Britain (founded 1799) and the Carnegie Institution of Washington (founded 1902), both examples of the use of private money for scientific research, then contrary to German practice. Alarmed British scientists pointed to Germany's expenditures on higher education to try to obtain, without much luck, greater resources from a stingy government. German scientists pointed to British trade schools and to the large expenditures on big research institutions made by the United States. French scientists pointed everywhere.

World War I shattered the growing internationalism. It replaced the International Association of Academies, headquartered in Berlin, with the International Research Council (IRC), dominated by the Belgians, French, British, and Americans, which did not admit the former Central Powers until 1926. The war also led to the creation of the Soviet Union, which was to spend most of the twentieth century outside the Western concert of science, and, indirectly, Nazi Germany, which would soon be ostracized for its hounding of Jewish academics. Still, World War I consolidated parallels among the belligerents: closer cooperation between science and the military and industry in the various countries, and, among the Allies, creation of equivalent institutions for the channeling of government money into academic science. The international *Rockefeller philanthropies set up to support the exchange of researchers and to help build scientific institutes in Europe (France, Germany, Denmark, and Sweden were among the recipients) also helped the advanced scientific nations progress together.

After the opening of the IRC to the former Central Powers and the foundation of various international unions for pure and applied science, cosmopolitanism had a brief renewal. Just before the Nazi takeover, for example, the staff of sixty chemists at Fritz *Haber's Kaiser Wilhelm Institut für Physikalische Chemie included seven Hungarians, four Austrians, three Russians, two Czechs, two Canadians, and one each from the United States, England, France, Poland, Ireland, Lithuania, Mexico, and Japan. During the late 1920s, international meetings increased in frequency. The Nazis and fascists then promoted internationalism in their special way by forcing some of the greatest European scientists to flee, particularly to Great Britain or the United States. At the same time, the Soviet Union drew in on itself. It had recruited left-leaning European scientists regardless of passport to help build up scientific research institutes in the People's Commissariat of Heavy Industry. The successive political purges of 1936–1938 expelled many visiting scientists, and the remainder left at the earliest opportunity.

World War II damaged the material infrastructure of European science and, together with the emigrations of the 1930s, made the United States by far the world's dominant scientific power. Soviet scientists who until the mid-1930s had played a lively part in multilateral European exchanges were sorely disappointed to find themselves further isolated by Cold War politics. Science remained an engine of prestige for the Soviet social experiment, however, and the growth in the Soviet Academy of Sciences in particular reflected its members' ability to turn the geopolitical insecurities of Soviet leaders into massive infusions of support for scientific research.

Two differences between Soviet and western European scientific institutions are especially notable. In Russia funding for individual programs of research did not come through formal independent peer review, but rather from large block grants to their host institutions. This practice exaggerated the discretionary powers of institute directors, who seldom resisted the temptation to cultivate huge patronage networks as the addition of classified research swelled the staffs of some institutes to a thousand or more. The Soviet Academy of Sciences also far outstripped its European counterparts in the control of institutional resources. In collective terms, it could thus dispense both resources and status, a function usually performed by separate institutions elsewhere.

Cold War rivalries and incipient European integration aided the rise of *multinational laboratories. High-energy physics, with its unprecedented concentration of material and human resources on the search for the ultimate constituents of matter, took the lead. If the popular rationales for these expenditures often made reference to bilateral geopolitics, each new generation of *accelerators still fostered increasingly complex multilateral collaborations. The best known institution in the western half of the continent was the European Center for Nuclear Research (*CERN in its French abbreviation), founded outside Geneva in 1954 after arduous negotiations involving twelve sponsor nations. On the other side of the Iron Curtain, members of the Warsaw Pact nations joined Soviet physicists in building a rival accelerator at Dubna, outside Moscow, at an analogous institute—the Joint Institute for Nuclear Research.

Large-scale collaborations came to the life sciences with the founding of the European Molecular Biology Laboratory (EMBL) in the 1970s. Based in Heidelberg, it boasted four affiliated facilities elsewhere in Europe, and more than a dozen member nations. Where the lengthy lead times for particle experiments dictated a large permanent staff along with a steady stream of visiting researchers at CERN, EMBL had few permanent staff and visiting appointments lasting several years at most before the researcher returned to a home institution. It aimed not so much to transcend national boundaries by means of a single institution as to ensure steady cross-fertilization among the scientific communities of its member nations. Other initiatives like the European Synchrotron Radiation Facility (Grenoble), EURATOM, and the European Space Agency have been launched as well, with varying degrees of success.

The collapse of the Soviet Union and the increasing federalization of the European Union have reshaped the playing field for science in Europe. Scientists from EU nations are among the primary beneficiaries of employment mobility across borders, and continuing economic disparities have also made it attractive for Russian, Czech, or Hungarian scientific elites to pursue careers further west on the continent. Science in Russia, though financially impoverished in general, shows modest signs of stabilizing after the "brain drain" of the early 1990s, with a pronounced shift toward grant-based research funded by private (both foreign and domestic) and government foundations.

France and Germany continue to fund large systems of institutes for pure research with few rivals elsewhere in the world, but more and more of the money for academic research passes through Brussels. Since proposals seem to have a better chance of success the larger the spectrum of collaborators, EU grants make a powerful force for the integration of European science. Nonetheless, the entire enterprise may be regarded as underfunded, particularly in Britain. Both Japan and the United States spend half again as large a percentage of their gross domestic products on research and development compared to the average EU member. The increasing autonomy of European Council members vis-à-vis their national state bureaucracies, however, offers further opportunities for the scientists of Europe to cement broader institutional alliances that constrain national policy makers. European political union remains anything but certain, yet most scientists continue to claim "Europe" as one of the surest means (whether directly or indirectly) for the local advancement of science on a global stage.

See also Academics and Learned Societies; Associations for the Advancement of Science; Nobel Prize; Standardization; University; World War II and Cold War.

Alexander Vucinich, *Science in Russian Culture* (1963). Paul Forman, J. L. Heilbron, and Spencer Weart, "Physics around 1900: Personnel, Funding, and Productivity of the Academic Establishments," *Historical Studies in the Physical And Biological Sciences* 5 (1975): 1–185. Brigitte Schröder-Gudehus, *Scientifiques et la paix. La communauté scientifique internationale au cours des années* 20 (1978). Spencer Weart, *Scientists in Power* (1979). Charles Paul, *Science and Immortality: The Éloges of the Paris Academy of Sciences, 1699–1791* (1980). Alexander Vucinich, *Empire of Knowledge: The Soviet Academy of Sciences 1917–1970* (1984). James E. McClellan III, *Science Reorganized. Scientific Societies in the 18th Century* (1985). Harry Paul, *From Knowledge to Power. The Rise of the Science Empire in France, 1860–1939* (1985). Christa Jungnickel and Russell McCormmach, *Intellectual Mastery of Nature: Theoretical Physics from Ohm to Einstein*, 2 vols. (1986). Daniel J. Kevles. *The Physicists, The History of a Scientific Community in Modern America*, rev. ed. (1995). John Krige and Dominique Pestre, eds., *Science in the 20th Century* (1997).

Karl Hall

EVOLUTION. What we now call evolution in biology—the notion that organisms are related by descent—was first debated within the life sciences during the second half of the eighteenth century. The word "evolution," however, had been used in the seventeenth and eighteenth centuries to denote individual, embryonic development, not descent. "Evolution" (from Latin *evolvere*, "to unroll") then meant typically the unfolding of parts preexisting in the embryo, as conceived by the supporters of "preformation" in *embryology. Occasionally, supporters of epigenesis used evolution to denote what they regarded instead as the successive addition of new parts in individual development (*see* Epigenesis and Preformation).

From the mid-eighteenth century—both jointly with earlier embryological speculations (*see* Biogenetic Law) and independently of them—a number of natural philosophers formulated hypotheses implying a dynamic conception of the history of the universe, the earth, and life, as opposed to a static conception of nature. Stasis was then increasingly regarded, and occasionally attacked, as typical of the major western religious traditions (*see* Religion and Science). The Enlightenment produced new or renewed dynamic conceptions of nature: in astronomy, by attempts aimed at extending Newtonian concepts to explain the history of the planetary system as well as its functioning (Georges-Louis de Buffon, Immanuel Kant, Pierre-Simon de *Laplace); in the earth sciences, by evidence pointing at a formerly unthought of antiquity of the earth (Buffon, James *Hutton); and in the life sciences, by speculations on a possible temporalization of the traditionally static system of classification of living beings (Charles Bonnet, Jean-Baptiste Robinet), by attempts at formulating materialistic explanations of the origin of life, *generation, heredity, development, and change of organic structures (Benoît de Maillet, Pierre de Maupertuis, Erasmus Darwin), by the occasional observation of variability in species (Carl *Linnaeus), and by the transposition of the notion of embryonic development to the entire history of life on Earth (Carl Friedrich Kielmeyer).

Between 1802 and 1820, Jean Baptiste *Lamarck combined several of these themes to produce the first systematic, if not always clear, theory of organic change (in those years "evolution" in its present meaning is documented only in the works of Julien-Joseph Virey). Around 1830, Étienne and Isidore Geoffroy Saint-Hilaire developed and circulated Lamarck's notions further. Charles *Lyell discussed Lamarck's views from a critical perspective in his authoritative geological work of the early 1830s, where he