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Not to be confused with History of evolutionary thought. For more systematic coverage, see History of life. Life timelineThis box: viewtalkedit−4500 ——–−4000 ——–−3500 ——–−3000 ——–−2500 ——–−2000 ——–−1500 ——–−1000 ——–−500 ——–0 — Water Single-celled life Photosynthesis Multicellular life Plants Arthropods MolluscsFlowersDinosaurs MammalsBirdsPrimatesHadeanArcheanProterozoicPhanerozoic ←Earth formed←Earliest water←LUCA←Earliest fossils←Atmospheric oxygen←Sexual reproduction←Earliest fungi←Greening of Earth←Ediacaran biota←Cambrian explosion←Earliest tetrapods←Earliest hominoid(million years ago) The timeline of the evolutionary history of life represents the current scientific theory outlining the major events during the development of life on planet Earth. Dates in this article are consensus estimates based on scientific evidence, mainly fossils. In biology, evolution is any change across successive generations in the heritable characteristics of biological populations. Evolutionary processes give rise to diversity at every level of biological organization, from kingdoms to species, and individual organisms and molecules, such as DNA and proteins. The similarities between all present day organisms imply a common ancestor from which all known species, living and extinct, have diverged. More than 99 percent of all species that ever lived (over five billion)[1] are estimated to be extinct.[2][3] Estimates on the number of Earth's current species range from 10 million to 14 million,[4] with about 1.2 million or 14% documented, the rest not yet described.[5] However, a 2016 report estimates an additional 1 trillion microbial species, with only 0.001% described.[6] There has been controversy between more traditional views of steadily increasing biodiversity, and a newer view of cycles of annihilation and diversification, so that certain past times, such as the Cambrian explosion, experienced maximums of diversity followed by sharp winnowing.[7][8] Main article: Extinction event Visual representation of the history of life on Earth as a spiral Species go extinct constantly as environments change, as organisms compete for environmental niches, and as genetic mutation leads to the rise of new species from older ones. At long irregular intervals, Earth's biosphere suffers a catastrophic die-off, a mass extinction,[9] often comprising an accumulation of smaller extinction events over a relatively brief period.[10] The first known mass extinction was the Great Oxidation Event 2.4 billion years ago, which killed most of the planet's obligate anaerobes. Researchers have identified five other major extinction events in Earth's history, with estimated losses below:[11] End Ordovician: 440 million years ago, 86% of all species lost, including most[12] graptolites Late Devonian: 375 million years ago, 75% of species lost, including most trilobites End Permian, The Great Dying: 251 million years ago, 96% of species lost, including tabulate corals, and most trees and synapsids End Triassic: 200 million years ago, 80% of species lost, including all conodonts End Cretaceous: 66 million years ago, 76% of species lost, including all ammonites, mosasaurs, plesiosaurs, pterosaurs, and nonavian dinosaurs Smaller extinction events have occurred in the periods between, with some dividing geologic time periods and epochs. The Holocene extinction event is currently under way.[13] Factors in mass extinctions include continental drift, changes in atmospheric and marine chemistry, volcanism and other aspects of mountain formation, changes in glaciation, changes in sea level, and impact events.[10] In this timeline, Ma (for megaannum) means "million years ago," ka (for kiloannum) means "thousand years ago," and ya means "years ago." Moon Main article: Hadean 4540 Ma – 4031 Ma Date Event 4540 Ma Planet Earth forms from the accretion disc revolving around the young Sun, perhaps preceded by formation of organic compounds necessary for life in the surrounding protoplanetary disk of cosmic dust.[14][15] 4510 Ma According to the giant-impact hypothesis, the Moon originated when Earth and the hypothesized planet Theia collided, sending into orbit myriad moonlets which eventually coalesced into our single Moon.[16][17] The Moon's gravitational pull stabilised Earth's fluctuating axis of rotation, setting up regular climatic conditions favoring abiogenesis.[18] 4404 Ma Evidence of the first liquid water on Earth which were found in the oldest known zircon crystals.[19] 4280–3770 Ma Earliest possible appearance of life on Earth.[20][21][22][23] Main article: Archean Fragment of the Acasta Gneiss exhibited at the Museum of Natural History in Vienna The cyanobacterial-algal mat, salty lake on the White Sea seaside Halobacterium sp. strain NRC-1 4031 Ma – 2500 Ma Date Event 4100 Ma Earliest possible preservation of biogenic carbon.[24][25] 4100–3800 Ma Late Heavy Bombardment (LHB): extended barrage by meteoroids impacting the inner planets. Thermal flux from widespread hydrothermal activity during the LHB may have aided abiogenesis and life's early diversification.[26] Possible remains of biotic life were found in 4.1 billion-year-old rocks in Western Australia.[27][28] 4000 Ma Formation of a greenstone belt of the Acasta Gneiss of the Slave craton in northwest Canada - the oldest known rock belt.[29] 3900–2500 Ma Cells resembling prokaryotes appear.[30] These first organisms are believed to have been chemoautotrophs, using carbon dioxide as a carbon source and oxidizing inorganic materials to extract energy. 3800 Ma Formation of a greenstone belt of the Isua complex in western Greenland, whose isotope frequencies suggest the presence of life.[29] The earliest evidence for life on Earth includes: 3.8 billion-year-old biogenic hematite in a banded iron formation of the Nuvvuagittuq Greenstone Belt in Canada;[31] graphite in 3.7 billion-year-old metasedimentary rocks in western Greenland;[32] and microbial mat fossils in 3.48 billion-year-old sandstone in Western Australia.[33][34] 3800–3500 Ma Last universal common ancestor (LUCA):[35][36] split between bacteria and archaea.[37] Bacteria develop primitive photosynthesis, which at first did not produce oxygen.[38] These organisms exploit a proton gradient to generate adenosine triphosphate (ATP), a mechanism used by virtually all subsequent organisms.[39][40][41] 3000 Ma Photosynthesizing cyanobacteria using water as a reducing agent and producing oxygen as a waste product.[42] Free oxygen initially oxidizes dissolved iron in the oceans, creating iron ore. Oxygen concentration in the atmosphere slowly rises, poisoning many bacteria and eventually triggering the Great Oxygenation Event. 2800 Ma Oldest evidence for microbial life on land in the form of organic matter-rich paleosols, ephemeral ponds and alluvial sequences, some bearing microfossils.[43] Detail of the eukaryote endomembrane system and its components Blepharisma japonicum, a free-living ciliated protozoan Dickinsonia costata, an iconic Ediacaran organism, displays the characteristic quilted appearance of Ediacaran enigmata. Main article: Proterozoic 2500 Ma – 539 Ma. Contains the Palaeoproterozoic, Mesoproterozoic and Neoproterozoic eras. Date Event 2500 Ma Great Oxidation Event led by cyanobacteria's oxygenic photosynthesis.[42] Commencement of plate tectonics with old marine crust dense enough to subduct.[29] 2023 Ma Formation of the Vredefort impact structure, one of the largest and oldest verified impact structures on Earth. The crater is estimated to have been between 170–300 kilometres (110–190 mi) across when it first formed.[44] By 1850 Ma Eukaryotic cells, containing membrane-bound organelles with diverse functions, probably derived from prokaryotes engulfing each other via phagocytosis. (See Symbiogenesis and Endosymbiont). Bacterial viruses (bacteriophages) emerge before or soon after the divergence of the prokaryotic and eukaryotic lineages.[45] Red beds show an oxidising atmosphere, favouring the spread of eukaryotic life.[46][47][48] 1500 Ma Volyn biota, a collection of exceptionally well-preserved microfossils with varying morphologies.[49] 1300 Ma Earliest land fungi.[50] By 1200 Ma Meiosis and sexual reproduction in single-celled eukaryotes, possibly even in the common ancestor of all eukaryotes[51] or in the RNA world.[52] Sexual reproduction may have increased the rate of evolution.[53] By 1000 Ma First non-marine eukaryotes move onto land. They were photosynthetic and multicellular, indicating that plants evolved much earlier than originally thought.[54] 750 Ma Beginning of animal evolution.[55][56] 720–630 Ma Possible global glaciation[57][58] which increased the atmospheric oxygen and decreased carbon dioxide, and was either caused by land plant evolution[59] or resulted in it.[60] Opinion is divided on whether it increased or decreased biodiversity or the rate of evolution.[61][62][63] 600 Ma Accumulation of atmospheric oxygen allows the formation of an ozone layer.[64] Previous land-based life would probably have required other chemicals to attenuate ultraviolet radiation.[43] 580–542 Ma Ediacaran biota, the first large, complex aquatic multicellular organisms.[65] 580–500 Ma Cambrian explosion: most modern animal phyla appear.[66][67] 550–540 Ma Ctenophora (comb jellies),[68] Porifera (sponges),[69] Anthozoa (corals and sea anemones),[70] Ikaria wariootia (an early Bilaterian).[71] Main article: Phanerozoic 539 Ma – present The Phanerozoic Eon (Greek: period of well-displayed life) marks the appearance in the fossil record of abundant, shell-forming and/or trace-making organisms. It is subdivided into three eras, the Paleozoic, Mesozoic and Cenozoic, with major mass extinctions at division points. Main article: Paleozoic This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed.Find sources: "Timeline of the evolutionary history of life" – news · newspapers · books · scholar · JSTOR (September 2022) (Learn how and when to remove this message) 538.8 Ma – 251.9 Ma and contains the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian periods. With only a handful of species surviving today, the Nautiloids flourished during the early Paleozoic era, from the Late Cambrian, where they constituted the main predatory animals.[72] Haikouichthys, a jawless fish, is popularized as one of the earliest fishes and probably a basal chordate or a basal craniate.[73] Ferns first appear in the fossil record about 360 million years ago in the late Devonian period.[74] Synapsids such as Dimetrodon were the largest terrestrial vertebrates in the Permian period, 299 to 251 million years ago. Date Event 535 Ma Major diversification of living things in the oceans: arthropods (e.g. trilobites, crustaceans), chordates, echinoderms, molluscs, brachiopods, foraminifers and radiolarians, etc. 530 Ma The first known footprints on land date to 530 Ma.[75] 520 Ma Earliest graptolites.[76] 511 Ma Earliest crustaceans.[77] 505 Ma Fossilization of the Burgess Shale 500 Ma Jellyfish have existed since at least this time. 485 Ma First vertebrates with true bones (jawless fishes). 450 Ma First complete conodonts and echinoids appear. 440 Ma First agnathan fishes: Heterostraci, Galeaspida, and Pituriaspida. 420 Ma Earliest ray-finned fishes, trigonotarbid arachnids, and land scorpions.[78] 410 Ma First signs of teeth in fish. Earliest Nautilida, lycophytes, and trimerophytes. 488–400 Ma First cephalopods (nautiloids)[79] and chitons.[80] 395 Ma First lichens, stoneworts. Earliest harvestmen, mites, hexapods (springtails) and ammonoids. The earliest known tracks on land named the Zachelmie trackways which are possibly related to icthyostegalians.[81] 375 Ma Tiktaalik, a lobe-finned fish with some anatomical features similar to early tetrapods. It has been suggested to be a transitional species between fish and tetrapods.[82] 365 Ma Acanthostega is one of the earliest vertebrates capable of walking.[83] 363 Ma By the start of the Carboniferous Period, the Earth begins to resemble its present state. Insects roamed the land and would soon take to the skies; sharks swam the oceans as top predators,[84] and vegetation covered the land, with seed-bearing plants and forests soon to flourish. Four-limbed tetrapods gradually gain adaptations which will help them occupy a terrestrial life-habit. 360 Ma First crabs and ferns. Land flora dominated by seed ferns. The Xinhang forest grows around this time.[85] 350 Ma First large sharks, ratfishes, and hagfish; first crown tetrapods (with five digits and no fins and scales). 350 Ma Diversification of amphibians.[86] 325-335 Ma First Reptiliomorpha.[87] 330-320 Ma First amniote vertebrates (Paleothyris).[88] 320 Ma Synapsids (precursors to mammals) separate from sauropsids (reptiles) in late Carboniferous.[89] 305 Ma The Carboniferous rainforest collapse occurs, causing a minor extinction event, as well as paving the way for amniotes to become dominant over amphibians and seed plants over ferns and lycophytes. First diapsid reptiles (e.g. Petrolacosaurus). 280 Ma Earliest beetles, seed plants and conifers diversify while lepidodendrids and sphenopsids decrease. Terrestrial temnospondyl amphibians and pelycosaurs (e.g. Dimetrodon) diversify in species. 275 Ma Therapsid synapsids separate from pelycosaur synapsids. 265 Ma Gorgonopsians appear in the fossil record.[90] 251.9–251.4 Ma The Permian–Triassic extinction event eliminates over 90-95% of marine species. Terrestrial organisms were not as seriously affected as the marine biota. This "clearing of the slate" may have led to an ensuing diversification, but life on land took 30 million years to completely recover.[91] Main article: Mesozoic This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed.Find sources: "Timeline of the evolutionary history of life" – news · newspapers · books · scholar · JSTOR (September 2022) (Learn how and when to remove this message) Utatsusaurus is the earliest-known ichthyopterygian. Plateosaurus engelhardti Cycas circinalis For about 150 million years, dinosaurs were the dominant land animals on Earth. From 251.9 Ma to 66 Ma and containing the Triassic, Jurassic and Cretaceous periods. Date Event 250 Ma Mesozoic marine revolution begins: increasingly well adapted and diverse predators stress sessile marine groups; the "balance of power" in the oceans shifts dramatically as some groups of prey adapt more rapidly and effectively than others. 250 Ma Triadobatrachus massinoti is the earliest known frog. 248 Ma Sturgeon and paddlefish (Acipenseridae) first appear. 245 Ma Earliest ichthyosaurs 240 Ma Increase in diversity of cynodonts and rhynchosaurs 225 Ma Earliest dinosaurs (prosauropods), first cardiid bivalves, diversity in cycads, bennettitaleans, and conifers. First teleost fishes. First mammals (Adelobasileus). 220 Ma Seed-producing Gymnosperm forests dominate the land; herbivores grow to huge sizes to accommodate the large guts necessary to digest the nutrient-poor plants.[citation needed] First flies and turtles (Odontochelys). First coelophysoid dinosaurs. First mammals from small-sized cynodonts, which transitioned towards a nocturnal, insectivorous, and endothermic lifestyle. 205 Ma Massive Triassic/Jurassic extinction. It wipes out all pseudosuchians except crocodylomorphs, who transitioned to an aquatic habitat, while dinosaurs took over the land and pterosaurs filled the air. 200 Ma First accepted evidence for viruses infecting eukaryotic cells (the group Geminiviridae).[92] However, viruses are still poorly understood and may have arisen before "life" itself, or may be a more recent phenomenon. Major extinctions in terrestrial vertebrates and large amphibians. Earliest examples of armoured dinosaurs. 195 Ma First pterosaurs with specialized feeding (Dorygnathus). First sauropod dinosaurs. Diversification in small, ornithischian dinosaurs: heterodontosaurids, fabrosaurids, and scelidosaurids. 190 Ma Pliosauroids appear in the fossil record. First lepidopteran insects (Archaeolepis), hermit crabs, modern starfish, irregular echinoids, corbulid bivalves, and tubulipore bryozoans. Extensive development of sponge reefs. 176 Ma First Stegosaurian dinosaurs. 170 Ma Earliest salamanders, newts, cryptoclidids, elasmosaurid plesiosaurs, and cladotherian mammals. Sauropod dinosaurs diversify. 168 Ma First lizards. 165 Ma First rays and glycymeridid bivalves. First vampire squids.[93] 163 Ma Pterodactyloid pterosaurs first appear.[94] 161 Ma Ceratopsian dinosaurs appear in the fossil record (Yinlong) and the oldest known eutherian mammal: Juramaia. 160 Ma Multituberculate mammals (genus Rugosodon) appear in eastern China. 155 Ma First blood-sucking insects (ceratopogonids), rudist bivalves, and cheilostome bryozoans. Archaeopteryx, a possible ancestor to the birds, appears in the fossil record, along with triconodontid and symmetrodont mammals. Diversity in stegosaurian and theropod dinosaurs. 131 Ma First pine trees. 140 Ma Orb-weaver spiders appear. 135 Ma Rise of the angiosperms. Some of these flowering plants bear structures that attract insects and other animals to spread pollen; other angiosperms are pollinated by wind or water. This innovation causes a major burst of animal coevolution. First freshwater pelomedusid turtles. Earliest krill. 120 Ma Oldest fossils of heterokonts, including both marine diatoms and silicoflagellates. 115 Ma First monotreme mammals. 114 Ma Earliest bees.[95] 112 Ma Xiphactinus, a large predatory fish, appears in the fossil record. 110 Ma First hesperornithes, toothed diving birds. Earliest limopsid, verticordiid, and thyasirid bivalves. 100 Ma First ants.[96] 100–95 Ma Spinosaurus appears in the fossil record.[97] 95 Ma First crocodilians evolve.[98] 90 Ma Extinction of ichthyosaurs. Earliest snakes and nuculanid bivalves. Large diversification in angiosperms: magnoliids, rosids, hamamelidids, monocots, and ginger. Earliest examples of ticks. Probable origins of placental mammals (earliest undisputed fossil evidence is 66 Ma). 86–76 Ma Diversification of therian mammals.[99][100] 70 Ma Multituberculate mammals increase in diversity. First yoldiid bivalves. First possible ungulates (Protungulatum). 68–66 Ma Tyrannosaurus, the largest terrestrial predator of western North America, appears in the fossil record. First species of Triceratops.[101] Main article: Cenozoic This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed.Find sources: "Timeline of the evolutionary history of life" – news · newspapers · books · scholar · JSTOR (September 2022) (Learn how and when to remove this message) Mount of oxyaenid Patriofelis from the American Museum of Natural History The bat Icaronycteris appeared 52.2 million years ago Grass flowers Reconstructed skeletons of flightless terror bird and ground sloth at the Museu Nacional, Rio de Janeiro Diprotodon went extinct about 40,000 years ago as part of the Quaternary extinction event, along with every other Australian creature over 100 kg (220 lb). 50,000 years ago several different human species coexisted on Earth including modern humans and Homo floresiensis (pictured). American lions exceeded extant lions in size and ranged over much of North America until 11,000 BP. Cenozoic era (66 Ma – present) Date Event 66 Ma The Cretaceous–Paleogene extinction event eradicates about half of all animal species, including mosasaurs, pterosaurs, plesiosaurs, ammonites, belemnites, rudist and inoceramid bivalves, most planktic foraminifers, and all of the dinosaurs excluding the birds.[102] 66 Ma Rapid dominance of conifers and ginkgos in high latitudes, along with mammals becoming the dominant species. First psammobiid bivalves. Earliest rodents. Rapid diversification in ants. 63 Ma Evolution of the creodonts, an important group of meat-eating (carnivorous) mammals. 62 Ma Evolution of the first penguins. 60 Ma Diversification of large, flightless birds. Earliest true primates,[who?] along with the first semelid bivalves, edentate, carnivoran and lipotyphlan mammals, and owls. The ancestors of the carnivorous mammals (miacids) were alive.[citation needed] 59 Ma Earliest sailfish appear. 56 Ma Gastornis, a large flightless bird, appears in the fossil record. 55 Ma Modern bird groups diversify (first song birds, parrots, loons, swifts, woodpeckers), first whale (Himalayacetus), earliest lagomorphs, armadillos, appearance of sirenian, proboscidean mammals in the fossil record. Flowering plants continue to diversify. The ancestor (according to theory) of the species in the genus Carcharodon, the early mako shark Isurus hastalis, is alive. Ungulates split into artiodactyla and perissodactyla, with some members of the former returning to the sea. 52 Ma First bats appear (Onychonycteris). 50 Ma Peak diversity of dinoflagellates and nannofossils, increase in diversity of anomalodesmatan and heteroconch bivalves, brontotheres, tapirs, rhinoceroses, and camels appear in the fossil record, diversification of primates. 40 Ma Modern-type butterflies and moths appear. Extinction of Gastornis. Basilosaurus, one of the first of the giant whales, appeared in the fossil record. 38 Ma Earliest bears. 37 Ma First nimravid ("false saber-toothed cats") carnivores — these species are unrelated to modern-type felines. First alligators and ruminants. 35 Ma Grasses diversify from among the monocot angiosperms; grasslands begin to expand. Slight increase in diversity of cold-tolerant ostracods and foraminifers, along with major extinctions of gastropods, reptiles, amphibians, and multituberculate mammals. Many modern mammal groups begin to appear: first glyptodonts, ground sloths, canids, peccaries, and the first eagles and hawks. Diversity in toothed and baleen whales. 33 Ma Evolution of the thylacinid marsupials (Badjcinus). 30 Ma First balanids and eucalypts, extinction of embrithopod and brontothere mammals, earliest pigs and cats. 28 Ma Paraceratherium appears in the fossil record, the largest terrestrial mammal that ever lived. First pelicans. 25 Ma Pelagornis sandersi appears in the fossil record, the largest flying bird that ever lived. 25 Ma First deer. 24 Ma First pinnipeds. 23 Ma Earliest ostriches, trees representative of most major groups of oaks have appeared by now.[103] 20 Ma First giraffes, hyenas, and giant anteaters, increase in bird diversity. 17 Ma First birds of the genus Corvus (crows). 15 Ma Genus Mammut appears in the fossil record, first bovids and kangaroos, diversity in Australian megafauna. 10 Ma Grasslands and savannas are established, diversity in insects, especially ants and termites, horses increase in body size and develop high-crowned teeth, major diversification in grassland mammals and snakes. 9.5 Ma[dubious – discuss] Great American Interchange, where various land and freshwater faunas migrated between North and South America. Armadillos, opossums, hummingbirds Phorusrhacids, Ground Sloths, Glyptodonts, and Meridiungulates traveled to North America, while horses, tapirs, saber-toothed cats, jaguars, bears, coaties, ferrets, otters, skunks and deer entered South America. 9 Ma First platypuses. 6.5 Ma First hominins (Sahelanthropus). 6 Ma Australopithecines diversify (Orrorin, Ardipithecus). 5 Ma First tree sloths and hippopotami, diversification of grazing herbivores like zebras and elephants, large carnivorous mammals like lions and the genus Canis, burrowing rodents, kangaroos, birds, and small carnivores, vultures increase in size, decrease in the number of perissodactyl mammals. Extinction of nimravid carnivores. First leopard seals. 4.8 Ma Mammoths appear in the fossil record. 4.5 Ma Marine iguanas diverge from land iguanas. 4 Ma Australopithecus evolves. Stupendemys appears in the fossil record as the largest freshwater turtle, first modern elephants, giraffes, zebras, lions, rhinoceros and gazelles appear in the fossil record 3.6 Ma Blue whales grow to modern size. 3 Ma Earliest swordfish. 2.7 Ma Paranthropus evolves. 2.5 Ma Earliest species of Arctodus and Smilodon evolve. 2 Ma First members of genus Homo, Homo Habilis, appear in the fossil record. Diversification of conifers in high latitudes. The eventual ancestor of cattle, aurochs (Bos primigenus), evolves in India. 1.7 Ma Australopithecines go extinct. 1.2 Ma Evolution of Homo antecessor. The last members of Paranthropus die out. 1.0 Ma First coyotes. 810 ka First wolves 600 ka Evolution of Homo heidelbergensis. 400 ka First polar bears. 350 ka Evolution of Neanderthals. 300 ka Gigantopithecus, a giant relative of the orangutan from Asia dies out. 250 ka Anatomically modern humans appear in Africa.[104][105][106] Around 50 ka they start colonising the other continents, replacing Neanderthals in Europe and other hominins in Asia. 70 ka Genetic bottleneck in humans (Toba catastrophe theory). 40 ka Last giant monitor lizards (Varanus priscus) die out. 35–25 ka Extinction of Neanderthals. Domestication of dogs. 15 ka Last woolly rhinoceros (Coelodonta antiquitatis) are believed to have gone extinct. 11 ka Short-faced bears vanish from North America, with the last giant ground sloths dying out. All Equidae become extinct in North America. Domestication of various ungulates. 10 ka Holocene epoch starts[107] after the Last Glacial Maximum. Last mainland species of woolly mammoth (Mammuthus primigenus) die out, as does the last Smilodon species. 8 ka The giant lemur dies out. Evolutionary history of plants (timeline) Geologic time scale History of Earth Sociocultural evolution Timeline of human evolution

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