

# Table of Contents

[Cover](#)

[Full contents](#)

[Preface](#)

[Acknowledgments](#)

[About the Companion website](#)

[Chapter 1: Paleontology as a science](#)

[INTRODUCTION](#)

[PALEONTOLOGY IN THE MODERN WORLD](#)

[PALEONTOLOGY AS A SCIENCE](#)

[STEPS TO UNDERSTANDING](#)

[FOSSILS AND EVOLUTION](#)

[PALEONTOLOGY TODAY](#)

[Further reading](#)

[References](#)

[Chapter 2: Stratigraphy](#)

[INTRODUCTION](#)

[HOW STRATIGRAPHY WORKS](#)

[NEW TECHNIQUES, NEW TOOLS](#)

[GEOLOGICAL TIME SCALE: A COMMON  
LANGUAGE](#)

[EXTRATERRESTRIAL STRATIGRAPHY](#)

[Further Reading](#)

[References](#)

[Chapter 3: Paleogeography and paleoclimates](#)

[PALEOBIOGEOGRAPHY](#)

[FOSSILS IN MOUNTAIN BELTS](#)

PALEOCLIMATES

THE ANTHROPOCENE

Further Reading

References

Chapter 4: Paleoecology.

INTRODUCTION

TAPHONOMIC CONSTRAINTS: SIFTING  
THROUGH THE DEBRIS

POPULATIONS: CAN GROUPS OF INDIVIDUALS  
MAKE A DIFFERENCE?

HABITATS AND NICHEs

PALEOCOMMUNITIES

EVOLUTIONARY PALEOECOLOGY

ECOLOGICAL RANKING OF MASS EXTINCTIONS

Further reading

References

Chapter 5: Taphonomy and the quality of the fossil  
record

INTRODUCTION

FOSSIL PRESERVATION

QUALITY OF THE FOSSIL RECORD

Further reading

References

Chapter 6: Fossil form and function

INTRODUCTION

GROWTH AND FORM

EVOLUTION AND DEVELOPMENT

INTERPRETING THE FUNCTION OF FOSSILS

Further reading

References

Chapter 7: Macroevolution and the tree of life

INTRODUCTION

EVOLUTION BY NATURAL SELECTION

EVOLUTION AND THE FOSSIL RECORD

TRENDS AND RADIATIONS

THE TREE OF LIFE

Further reading

References

Chapter 8: Biodiversity, extinction, and mass extinction

INTRODUCTION

THE DIVERSIFICATION OF LIFE

MASS EXTINCTIONS

THE “BIG FIVE” MASS EXTINCTION EVENTS

EXTINCTION THEN AND NOW

Further reading

References

Chapter 9: The origin of life

INTRODUCTION

THE ORIGIN OF LIFE

EVIDENCE FOR THE ORIGIN OF LIFE

LIFE DIVERSIFIES: EUKARYOTES

Further reading

References

Chapter 10: Protists

INTRODUCTION

PROTOZOA

MYSTERY PROTISTS OF THE PROTEROZOIC AND PALEOZOIC

PHYTOPLANKTON

Further reading

References

Chapter 11: Origin and expansion of the metazoans

ORIGINS AND CLASSIFICATION

INVERTEBRATE BODY AND SKELETAL PLANS

FIVE KEY FAUNAS

Further reading

References

Chapter 12: The basal metazoans: sponges and corals

INTRODUCTION

PORIFERA

CNIDARIA

Further Reading

References

Chapter 13:

INTRODUCTION

BRACHIOPODA

BRYOZOA

Further reading

References

Chapter 14: Lophotrochozoans 2: mollusks and annelids

MOLLUSKS

INTRODUCTION

EARLY MOLLUSKS

CLASS BIVALVIA

[CLASS GASTROPODA](#)

[CLASS CEPHALOPODA](#)

[CLASS SCAPHOPODA](#)

[CLASS ROSTROCONCHA](#)

[EVOLUTIONARY TRENDS WITHIN THE MOLLUSCA](#)

[ANNELIDS](#)

[Further reading](#)

[References](#)

[Chapter 15:](#)

[INTRODUCTION](#)

[EARLY ARTHROPOD FAUNAS](#)

[SUBPHYLUM TRILOBITOMORPHA \(ARTIOPODA\)](#)

[SUBPHYLUM CHELICERATA](#)

[SUBPHYLUM MYRIAPODA](#)

[SUBPHYLUM HEXAPODA](#)

[SUBPHYLUM CRUSTACEA](#)

[EXCEPTIONAL ARTHROPOD FAUNAS THROUGH TIME](#)

[Further reading](#)

[References](#)

[Chapter 16: Deuterostomes: echinoderms and hemichordates](#)

[INTRODUCTION](#)

[ECHINODERMS](#)

[HEMICHORDATES](#)

[Further reading](#)

[References](#)

[Chapter 17: Fishes and basal tetrapods](#)

[INTRODUCTION](#)

[ORIGIN OF THE VERTEBRATES](#)

[JAWS AND FISH EVOLUTION](#)

[TETRAPODS](#)

[REIGN OF THE REPTILES](#)

[Further reading](#)

[References](#)

[Chapter 18: Dinosaurs and mammals](#)

[INTRODUCTION](#)

[DINOSAURS AND THEIR KIN](#)

[BIRD EVOLUTION](#)

[RISE OF THE MAMMALS](#)

[THE LINE TO HUMANS](#)

[Further reading](#)

[References](#)

[Chapter 19: Fossil plants and fungi](#)

[INTRODUCTION](#)

[TERRESTRIALIZATION OF PLANTS](#)

[THE GREAT COAL FORESTS](#)

[SEED-BEARING PLANTS](#)

[FLOWERING PLANTS](#)

[Further reading](#)

[References](#)

[Chapter 20:](#)

[INTRODUCTION](#)

[UNDERSTANDING TRACE FOSSILS](#)

[TRACE FOSSILS IN SEDIMENTS](#)

[Further reading](#)

[References](#)

[Finale](#)

[Glossary](#)

[Appendix 1 Stratigraphic chart](#)

[Appendix 2 Paleogeographic maps](#)

[Index](#)

[End User License Agreement](#)

## List of Tables

Chapter 2

[Table 2.1 Naming the geological systems: systems, founders, and the original ...](#)

Chapter 4

[Table 4.1 Hierarchical levels of ecological change and their signals.](#)

[Table 4.2 Classification of the ecological impacts of a diversity crisis.](#)

Chapter 5

[Table 5.1 Mineralized materials in protists, plants, and animals.](#)

Chapter 6

[Table 6.1 The processes of heterochrony: differences in the relative timing a...](#)

Chapter 11

[Table 11.1 Key characteristics of the three main groups of animals.](#)

[Table 11.2 Some characteristics of the ecdysozoans, lophotrochozoans, and deu...](#)

[Table 11.3 Some possible causes for the Great Ordovician Biodiversification E...](#)

## Chapter 12

[Table 12.1 Features of the main coral groups.](#)

## Chapter 20

[Table 20.1 The main types of trace fossils, with definitions of the key terms...](#)

# List of Illustrations

## Chapter 1

[Figure 1.1 People love to collect fossils. Many professional paleontologists...](#)

[Figure 1.2 Paleontologists who are beginning their professional careers: \(a\)...](#)

[Figure 1.3 Important figures in the history of science: \(a\) Sir Francis Baco...](#)

[Figure 1.4 The colors of dinosaur feathers: \(a, b\) scanning electron microsc...](#)

[Figure 1.5 Some of the earliest reconstructions of fossil mammals. These out...](#)

[Figure 1.6 The world's largest dinosaur, a titanosaur from Argentina, as por...](#)

[Figure 1.7 Lying stones: two of the remarkable "fossils" described by Profes...](#)

[Figure 1.8 Nicolaus Steno's \(1667\) classic demonstration that fossils repres...](#)

[Figure 1.9 Proof of extinction: Cuvier's comparison of \(a\) the lower jaw of ...](#)

[Figure 1.10 The first dinosaur craze in England in the 1850s was fueled by n...](#)

[Figure 1.11 Statistical study of the Permian brachiopod \*Dielasma\*. Two measur...](#)

[Figure 1.12 Composition of a Middle Jurassic vertebrate fauna from England. ...](#)

[Figure 1.13 Finding the most complete titanosaur, \*Rapetosaurus\*, in Madagasca...](#)

## Chapter 2

[Figure 2.1 \(a\) Steno's series of diagrams illustrating the deposition of str...](#)

[Figure 2.2 The main types of biozone, the operational units of a biostratigr...](#)

[Figure 2.3 Behavior of ideal zone and facies fossils through a hypothetical ...](#)

[Figure 2.4 \(a\) Hypothetical and minimalist graphic correlation based on the ...](#)

[Figure 2.5 Approximate stratigraphic ranges through time of the main biostra...](#)

[Figure 2.6 Key concepts in the definition of stratotypes and parastratotypes...](#)

[Figure 2.7 Current status of the development of a new, internationally accep...](#)

[Figure 2.8 Stratigraphic case study: description and definition of the litho...](#)

[Figure 2.9 North American Phanerozoic sequences: the recognition of these la...](#)

[Figure 2.10 Sequences, system tracts, and stratigraphic surfaces defined in ...](#)

[Figure 2.11 DCA axis 1 sample scores plotted against the Frankfort composite...](#)

[Figure 2.12 \(a\) Illustration of Milankovitch frequencies showing the relatio...](#)

[Figure 2.13 \(a\) Litho-, magneto-, bio-, and chronostratigraphy of the Monte ...](#)

[Figure 2.14 The various methods currently available to construct the geologi...](#)

[Figure 2.15 New topographic map of the Moon, from Arizona State University i...](#)

[Figure 2.16 View, taken on May 22, 2015, from the Mast Camera \(Mastcam\) in N...](#)

### Chapter 3

[Figure 3.1 Modern biogeographic provinces of the World, based on the work of...](#)

[Figure 3.2 Carboniferous and Permian distributions of the \*Glossopteris\* flora...](#)

[Figure 3.3 Environmental controls on the distribution of Lower Paleozoic mar...](#)

[Figure 3.4 The emergence of the Isthmus of Panama promoted the Great America...](#)

[Figure 3.5 Oceanic dispersal of worm lizards \(\*Amphisbaenia\*\), see inset. Mult...](#)

[Figure 3.6 Schematic representation of the relationship between geographic d...](#)

[Figure 3.7 Changing ideas on the development of the Early Paleozoic Iapetus ...](#)

[Figure 3.8 Displaced faunas in terranes within the North American Cordillera...](#)

[Figure 3.9 Biogeography of cold-water Ordovician brachiopods. \(a\) Migration ...](#)

[Figure 3.10 Changing familial diversity of skeletal benthos through time \(a\)...](#)

[Figure 3.11 The Scandinavian Caledonides showing the pre-drift positions of ...](#)

[Figure 3.12 Distribution of Highland Border Complex rocks, showing how terra...](#)

[Figure 3.13 Fossils from the summit of Everest. \(a\) The stratigraphy of Ever...](#)

[Figure 3.14 Strained Cambrian trilobites from Himalaya.](#)

[Figure 3.15 Climate change through time, showing fluctuations in sea level, ...](#)

[Figure 3.16 Identifying ancient climates. \(a\) Some key indicators of climate...](#)

[Figure 3.17 Size changes in planktic foraminiferans from high and low latitu...](#)

[Figure 3.18 Climate change through time illustrated together with changes in...](#)

[Figure 3.19 Snowball Earth scenario. \(a\) Continents are near the equator, in...](#)

[Figure 3.20 Geological and historical timelines since the Miocene Epoch.](#)

## Chapter 4

[Figure 4.1 Life modes of marine organisms in a living offshore, muddy-sand c...](#)

[Figure 4.2 Tracking the transition from a living assemblage to a death assem...](#)

[Figure 4.3 \(a\) Comparison of the Cambrian seascapes of the Burgess Shale and...](#)

[Figure 4.4 Schematic size-frequency histograms: \(a\) right \(positively\) skewe...](#)

[Figure 4.5 Schematic survivorship curves: type I tracks, increasing mortalit...](#)

[Figure 4.6 Size-frequency histogram \(a\), polygon \(b\), cumulative frequency p...](#)

[Figure 4.7 Modern marine environments and their depth ranges, together with ...](#)

[Figure 4.8 The key marine lifestyles above, at the surface, within, and at t...](#)

[Figure 4.9 Epifaunal tiering of marine benthic communities; infaunal tiering...](#)

[Figure 4.10 Trophic groups, activity of members, and their life sites. 1, Pr...](#)

[Figure 4.11 Reconstructions of two food chains. \(a\) A community with a suspe...](#)

[Figure 4.12 The impact of fishing on a modern marine ecosystem. The diagram ...](#)

[Figure 4.13 \(a\) Trophic structures in and around a Late Carboniferous lake c...](#)

[Figure 4.14 Shoreline to basin transect showing the relative importance of d...](#)

[Figure 4.15 \(a\) Distribution of living organisms across a depth gradient; \(b...](#)

[Figure 4.16 Matching marine ecosystems to paleogeographic-depth zones. A bro...](#)

[Figure 4.17 Construction of a rarefaction curve based on data collected from...](#)

[Figure 4.18 The Devonian seafloor of the Ardennes; trilobite associations in...](#)

[Figure 4.19 Commensalism between \(a\) the gastropod \*Platyceras\* and a Devonian...](#)

[Figure 4.20 Encrusters \(a\), recent bivalve shell encrusted by bryozoans; \(b\)...](#)

[Figure 4.21 \*Duria antiquior\*, one of the earliest paleoecological reconstruct...](#)

[Figure 4.22 Selection of fossils from ancient hydrothermal vent sites. All s...](#)

[Figure 4.23 A cocktail of Jurassic environments. Early Jurassic: \(a\) sand, \(...](#)

[Figure 4.24 Mesozoic record of predator taxa, prey taxa with anti-predator a...](#)

[Figure 4.25 Bambachian megaguilds. A near full complement of lifestyles is p...](#)

[Figure 4.26 Shell beds through time. Thicknesses of shell concentrations dur...](#)

## Chapter 5

[Figure 5.1 How a dead bivalve becomes a fossil. The sequence of stages betwe...](#)

[Figure 5.2 The relative rates of decay and mineralization determine the kind...](#)

[Figure 5.3 The conditions for exceptional preservation. \(a\) The rate of buri...](#)

[Figure 5.4 Exceptional preservation of skin and chromatophores in a Miocene ...](#)

[Figure 5.5 The use of 3D digital reconstruction with the jawless galeaspid v...](#)

[Figure 5.6 An imaginary cross-section showing possible sites of exceptional ...](#)

[Figure 5.7 Processes of breakage and diagenesis of fossils. Dead organisms m...](#)

[Figure 5.8 \(a\) Numerous examples of deformation of the brachiopod \*Eoplectodo...\*](#)

[Figure 5.9 Different modes of plant preservation. \(a\) Permineralization, a s...](#)

[Figure 5.10 Stemward slippage of the features of early vertebrate fossils. N...](#)

[Figure 5.11 Four controls on fossil occurrence within sedimentary basins, in...](#)

[Figure 5.12 Mean scores of the stratigraphic consistency index \(SCI\), the re...](#)

[Figure 5.13 Clade-stratigraphic metrics. Calculation of the three congruence...](#)

[Figure 5.14 Is the fossil record controlled by the rock record? The rock rec...](#)

[Figure 5.15 Paleontological knowledge has improved by about 5% in the 26-yea...](#)

## Chapter 6

[Figure 6.1 Variation in the Early Silurian brachiopod species \*Dicoelosia bil...\*](#)

[Figure 6.2 Sexual dimorphism in ammonites, the Jurassic \*Kosmoceras\*. The larg...](#)

[Figure 6.3 Adult female \*Ichthyosaurus\* \(a\) from the Lower Jurassic of Somerse...](#)

[Figure 6.4 Tests of allometry in the ichthyosaur \*Ichthyosaurus\*. \(a\) Plot of ...](#)

[Figure 6.5 Positive allometry in the antlers of the giant Irish deer \*Megaloc...\*](#)

[Figure 6.6 The null expectation is that diversity and disparity are coupled ...](#)

[Figure 6.7 Evolution of form in the trilobite family Pterocephaliidae, from ...](#)

[Figure 6.8 Hints of ancestry in modern animals. \(a\) Extra toes in a horse, a...](#)

[Figure 6.9 Heterochronic evolution in the Cenozoic brachiopods \*Tegulorhynchi...\*](#)

[Figure 6.10 Heterochronic evolution in the Triassic rhynchosaurs. The skull ...](#)

[Figure 6.11 \*Hox\* genes and the development of the tetrapod limb. \(a\) The sequ...](#)

[Figure 6.12 The use of a modern analog to interpret a mysterious fossil. \(a\)...](#)

[Figure 6.13 Basic mechanical models for biological structures. There are dif...](#)

[Figure 6.14 Finite element analysis of the skull of \*Tyrannosaurus rex\*. The s...](#)

[Figure 6.15 The running stride of \*Tyrannosaurus rex\*. \(a\) The main components...](#)

[Figure 6.16 Evidence for a rodent-plant interaction from the Eocene. \(a\) See...](#)

## Chapter 7

[Figure 7.1 Charles Darwin \(1809-1882\), a portrait made by George Richmond in...](#)

[Figure 7.2 Branching diagram of phylogeny, the only illustration in \*On the O...\*](#)

[Figure 7.3 Allopatric speciation models, occurring either symmetrically \(a\)...](#)

[Figure 7.4 Two models of speciation and lineage evolution. \(a\) Phyletic grad...](#)

[Figure 7.5 Fine-scale evolution in freshwater snails and bivalves in Lake Tu...](#)

[Figure 7.6 Examples of the three main models of evolution, representing dire...](#)

[Figure 7.7 Phyletic gradualism and speciation in the planktonic diatom \*Rhizo...\*](#)

[Figure 7.8 Punctuated evolution and speciation in the bryozoan \*Metrarabdotos\*](#)

[Figure 7.9 The evolution of the horses has been interpreted as a simple one-...](#)

[Figure 7.10 A classic example of a radiation, the pattern of diversification...](#)

[Figure 7.11 A classic example of competitive replacement? Articulate brachio...](#)

[Figure 7.12 Reconstructing the phylogeny of vertebrates by cladistic methods...](#)

[Figure 7.13 Swimming forepaddles of a variety of reptiles \(a-d\) and mammals ...](#)

[Figure 7.14 The relationships of the major groups of vertebrates, tested usi...](#)

[Figure 7.15 Relationships of the woolly mammoth based on nuclear DNA \(nDNA\)....](#)

[Figure 7.16 The number of unique trees for three \(a\) and four \(b\) taxa. Thes...](#)

[Figure 8.1 An image of the dodo from another era. Lewis Carroll introduced t...](#)

[Figure 8.2 Paleozoic life was replaced by Modern evolutionary faunas during ...](#)

[Figure 8.3 Sepkoski's three-phase coupled logistic model for diversification...](#)

[Figure 8.4 Two models for the diversification of marine invertebrate life ov...](#)

[Figure 8.5 The diversification of four groups of multicellular organisms dur...](#)

[Figure 8.7 Mass extinctions through the past 600 myr include the enormous Pe...](#)

[Figure 8.6 Theoretical models for the diversification of life plotted as if ...](#)

[Figure 8.8 \(a\) The classic collector curve showing the sigmoid \(or logistic\)...](#)

[Figure 8.9 Patterns of extinction of foraminifera in a classic KPg section s...](#)

[Figure 8.10 Gaps and missing data can make gradual extinction events seem su...](#)

[Figure 8.11 The end-Permian mass extinction in China. \(a\) The pattern of ext...](#)

[Figure 8.12 The possible chain of events following the eruption of the Siber...](#)

[Figure 8.13 The KPg boundary at Gubbio, Italy. \(a\) Luis \(left\) and Walter Al...](#)

[Figure 8.14 The KPg impact site identified. Location of the Chicxulub Crater...](#)

[Figure 8.15 Evidence for a KPg impact in the Caribbean. \(a\) Shocked quartz. ...](#)

[Figure 8.16 Disaster taxa after the end-Permian mass extinction: the brachio...](#)

[Figure 8.17 Explaining extinction: paleontological data can provide definiti...](#)

[Figure 8.18 The sum of extinctions that have been documented historically by...](#)

## Chapter 9

[Figure 9.1 The biochemical theory for the origin of life, as proposed by A.I...](#)

[Figure 9.2 The model behind "RNA world," where an RNA replicase and a self-r...](#)

[Figure 9.3 Time scale and oxygen curves, showing major events in the history...](#)

[Figure 9.4 Postulated prokaryotes from the Apex Chert of Western Australia \(...\)](#)

[Figure 9.5 Evidence for the oldest life on Earth? \(a\) Tubular fossils, measu...](#)

[Figure 9.6 Stromatolites, a Neoproterozoic example from the Vazante Formatio...](#)

[Figure 9.7 The oldest microfossils on Earth? Chains of lenticular \(a\) and sp...](#)

[Figure 9.8 Prokaryote fossils from the Gunflint Chert of Ontario, Canada \(c....\)](#)

[Figure 9.9 The universal tree of life, based on molecular phylogenetic work....](#)

[Figure 9.10 Eukaryote characters: a typical prokaryote cell \(a\) differs from...](#)

[Figure 9.11 Diagram showing the evolutionary relationships and divergence ti...](#)

[Figure 9.12 The oldest fossil eukaryotes. \(a\) \*Tappania plana\* Yin, 1997, and ...](#)

[Figure 9.13 A filamentous alga from the Lakhanda Formation, Siberia \(c. 1000...](#)

[Figure 9.14 The oldest multicellular eukaryote, \*Bangiomorpha\*, from the 1.2 G...](#)

[Figure 9.15 Multicellular eukaryotic fossils of early Neoproterozoic age. \(a...](#)

[Figure 9.16 Overview of major events and fossil diversity in the Proterozoic...](#)

## Chapter 10

[Figure 10.1 Stratigraphic ranges of the main protist groups.](#)

[Figure 10.2 Main types of foraminiferan test walls: \(a\) the composition and ...](#)

[Figure 10.3 Main types of foraminiferan chamber construction.](#)

[Figure 10.4 Some genera of foraminifera: \(a\) \*Textularia\*, \(b\) \*Cribrostomoides\*](#)

[Figure 10.5 Three-dimensional reconstruction of the growth sequence of the f...](#)

[Figure 10.6 Foram test and environments: distribution of test types and gene...](#)

[Figure 10.7 Stratigraphic ranges of the main foraminiferan groups.](#)

[Figure 10.8 Descriptive morphology of the radiolarians.](#)

[Figure 10.9 Some radiolarian morphotypes: \*Lenosphaera\* \(×100\), \*Actinomma\* \(×24...](#)

[Figure 10.10 Haeckel's radiolarians: plate 12 from \*Die Radiolarien \(Rhizopod...\*](#)

[Figure 10.11 Descriptive morphology of the acritarchs.](#)

[Figure 10.12 Some acritarch morphotypes: \*Multiplicisphaeridium\* \(×800\), \*Baiom...\*](#)

[Figure 10.13 Acritarch and invertebrate diversity through Cambrian and Ordov...](#)

[Figure 10.14 Chitinozoan apparatus: a large cluster of \*Desmochitina nodus\* in...](#)

[Figure 10.15 Descriptive morphology of the chitinozoans: \(a\) Operculatifera ...](#)

[Figure 10.16 Some chitinozoan morphotypes: \*Sphaerochitina\* \(×160\), \*Urnochitin...\*](#)

[Figure 10.17 Comparison of evolving sea level through the Mesozoic and Cenoz...](#)

[Figure 10.18 Descriptive morphology of \(a\) a dinoflagellate, and \(b\) a dinof...](#)

[Figure 10.19 A prasinophyte \(a\) and some dinoflagellate taxa \(b-h\): \(a\) \*Tasm...\*](#)

[Figure 10.20 Morphology of some tintinnids in cross-section from limestones ...](#)

[Figure 10.21 The AutoMorph pipeline, showing the image stack of a single for...](#)

[Figure 10.22 Some coccolith morphotypes: \(a\) coccospheres of the living \*Emil...\*](#)

[Figure 10.23 Descriptive morphology of the diatoms.](#)

[Figure 10.24 Some diatom morphotypes: \*Coscinocoanus\* \(×250\), \*Asterolampra\* \(×40...](#)

## Chapter 11

[Figure 11.1 Time scale and tempo of early animal evolution: the key metazoan...](#)

[Figure 11.2 Some putative animals and animal traces from the Ediacaran: \(a\)](#)

[Figure 11.3 Putative trace fossils from the Precambrian of Australia, showin...](#)

[Figure 11.4 Animal embryos from the Doushantou formation, China. \(a\) Surface...](#)

[Figure 11.5 Main invertebrate body plans and larvae: upper and lateral views...](#)

[Figure 11.6 Comparison of the animal fossil record and molecular divergence ...](#)

[Figure 11.7 Phylogenetic relationships among the main invertebrate groups....](#)

[Figure 11.8 Macroecological steps in the evolution of Paleozoic marine ecosp...](#)

[Figure 11.9 Evolution of the oceans through the Ediacara-Early Cambrian inte...](#)

[Figure 11.10 Different groups of Ediacara organisms; \(a\) twofold \*Yorgia\*; \(b\)...](#)

[Figure 11.11 An Ediacaran community including a fixed and mobile tiered bent...](#)

[Figure 11.12 The calcareous tube \*Cloudina\* displaying indications of predatio...](#)

[Figure 11.13 Proterozoic calcareous tubes: field photograph of concentration...](#)

[Figure 11.14 Components of the Tommotian-type or Small Shelly Fauna from Sou...](#)

[Figure 11.15 An integrated model for the Cambrian Explosion invoking biotic ...](#)

[Figure 11.16 Comparison of Ediacara and Cambrian landscapes: \(a\) fitness lan...](#)

[Figure 11.17 Diversifications of the main groups of planktonic, nektonic, an...](#)

[Figure 11.18 The construction of the first marine Eltonian trophic pyramid. ...](#)

[Figure 11.19 The Nekton Revolution. Source:](#)

## Chapter 12

[Figure 12.1 Basic sponge morphology.](#)

[Figure 12.2 Main grades of sponges.](#)

[Figure 12.3 Main categories of spicule morphology. Magnification approximate...](#)

[Figure 12.4 Living sponges. \(a\) \*Xestospongia\*, the giant barrel sponge. \(b\) A...](#)

[Figure 12.5 Some examples of the main groups of common sponges in the fossil...](#)

[Figure 12.6 Relationship of sponges \(Porifera\) to other metazoan and non-met...](#)

[Figure 12.7 Crescentic and circular holes in vase-shaped microfossils from t...](#)

[Figure 12.8 Stratigraphic distribution of reef-building sponges and related ...](#)

[Figure 12.9 Stromatoporoid morphology.](#)

[Figure 12.10 Stromatoporoid growth modes.](#)

[Figure 12.11 The Archaeocyatha: \(a\) morphology and \(b\) classification, funct...](#)

[Figure 12.12 Some archaeocyaths from the Lower Cambrian of Western Mongolia,...](#)

[Figure 12.13 Archaeocyathan reef structures which, when preserved, become \(a...](#)

[Figure 12.14 Modeling the functional morphology of the archaeocyaths.](#)

[Figure 12.15 Paleogeographic range of Early Cambrian archaeocyathid reefs. \(...](#)

[Figure 12.16 Evolutionary trends within the archaeocyaths; modular forms, ap...](#)

[Figure 12.17 \*Namapoikea\*: \(a\) nodular individual perpendicular to a fissure w...](#)

[Figure 12.18 Morphology of \*Hydra\*: \(a\) general body plan, and \(b\) detail of t...](#)

[Figure 12.19 Cnidarian life cycle, showing alternation between the polyp and...](#)

[Figure 12.20 Main cnidarian body plans: \(a\) generalized scleractinian polyp,...](#)

[Figure 12.21 Terminology for the main modes of solitary growth in corals....](#)

[Figure 12.22 Terminology for the main modes of colonial growth in corals....](#)

[Figure 12.23 Ternary plot of colonial growth modes based on the shape of the...](#)

[Figure 12.24 \(a\) Septal and tabular development in solitary rugose corals wi...](#)

[Figure 12.25 Rugose solitary life strategies displaying attached, fixosessil...](#)

[Figure 12.26 Some rugose corals: \(a, b\) cross and longitudinal sections of A...](#)

[Figure 12.27 Tabulate morphology: \(a\) transverse and \(b\) longitudinal sectio...](#)

[Figure 12.28 Some tabulate corals: \(a, b\) cross and longitudinal sections of...](#)

[Figure 12.29 \*Aulopora\* morphology: computer-generated reconstructions of \(a\) ...](#)

[Figure 12.30 Scleractinian morphology: \(a\) longitudinal and \(b\) mode of sept...](#)

[Figure 12.31 Some typical scleractinian corals: \(a\) \*Hydnophora\* \(Recent\); \(b\)...](#)

[Figure 12.32 \(a\) \*Kilbuchophyllum\* - an Ordovician scleractiniomorph coral \(ap...](#)

[Figure 12.33 Pioneer \(a\) and climax \(b\) reef communities in Silurian and Dev...](#)

[Figure 12.34 Devonian banded coral, \*Heliophyllum halli\* \(×3\).](#)

[Figure 12.35 Over the past 500 myr, the diversity of species in coral reefs ...](#)

[Figure 12.36 Global proportion of staghorn coral occurrences among zooxanthe...](#)

## Chapter 13

[Figure 13.1 Brachiopod morphologies: \(a\) internal features of a lingulate; \(...](#)

[Figure 13.2 Classification and stratigraphic distribution of the Brachiopoda...](#)

[Figure 13.3 Disentangling the origins of brachiopods. \(a\) Stem groups and th...](#)

[Figure 13.4 Brachiopod larvae. \(a\) Ventral and \(b\) dorsal valves of the brac...](#)

[Figure 13.5 Morphological variation in \*Terebratalia\* from the San Juan island...](#)

[Figure 13.6 Shell secretion at the margins of \*Notosaria\*.](#)

[Figure 13.7 Representatives of the main orders of non-articulates and articu...](#)

[Figure 13.8 Teeth of articulated brachiopods: \(a\) deltidiodont and \(b\) cyrto...](#)

[Figure 13.9 Brachiopod lifestyles.](#)

[Figure 13.10 Lifestyles and tiering in Cambrian brachiopod communities. \(a\) ...](#)

[Figure 13.11 Lower Silurian depth-related paleocommunities developed across ...](#)

[Figure 13.12 Mesozoic palaeocommunities developed across Alpine Europe. Numb...](#)

[Figure 13.13 Brachiopod predation: boring of \*Oichnus paraboloides\* in the con...](#)

[Figure 13.14 Tethyan brachiopods in East Greenland: \*Pygope\* and the proto-Nor...](#)

[Figure 13.15 \(a\) \*Gigantoproductus elongatus\* from Once a Week Quarry \(Mississ...](#)

[Figure 13.16 Morphology of two living bryozoans: \(a\) a stenolaemate and \(b\) ...](#)

[Figure 13.17 The modular construction of a colony using Lego blocks: complex...](#)

[Figure 13.18 \(a\) Stratigraphic ranges and phylogeny of the main bryozoan gro...](#)

[Figure 13.19 Some bryozoan genera: \(a\) \*Bythopora\* \(Ordovician trepostome\); \(b...](#)

[Figure 13.21 Typical post-mortem histories of bryozoans with different colon...](#)

[Figure 13.22 Distribution of \(a\) cyclostome and \(b\) cheilostome bryozoans ac...](#)

[Figure 13.20 Competitive overgrowth interactions: fossil and Recent. \(a\) \*Val...\*](#)

## Chapter 14

[Figure 14.1 Mollusk phylogeny. A summary mollusk tree based on molecular phy...](#)

[Figure 14.2 The early mollusks \(a\) \*Kimberella\*, \(b\) \*Odontogriphus\*, and \(c\) ph...](#)

[Figure 14.3 Stem-group mollusks looked like shelly slugs. \(a\) Model of the m...](#)

[Figure 14.4 Theoretical morphospace created by the computer simulation of sh...](#)

[Figure 14.5 Bivalve morphology based on a living bivalve: \(a\) internal featu...](#)

[Figure 14.6 \(a\) Main gill types in the bivalves. \(b\) Main types of bivalve d...](#)

[Figure 14.7 Bivalve molluscs, external and internal views. \(a\) \*Venericardia\*;...](#)

[Figure 14.8 Morphology and adaptations of the main ecological groups of biva...](#)

[Figure 14.9 Life modes of bivalve mollusks: \(a\) shallow and deep burrowers i...](#)

[Figure 14.10 Plot of scores on principal component axes of shell shape based...](#)

[Figure 14.11 Rudist growth strategies: encrusters \(a, b, h, and i\), elevator...](#)

[Figure 14.12 Gastropod morphology: \(a\) annotated reconstruction of a living ...](#)

[Figure 14.13 Gastropod shell shapes.](#)

[Figure 14.14 Planktotrophic gastropod larvae: Measured protoconch parameters...](#)

[Figure 14.15 Gastropod and scaphopod molluscs. \(a\) \*Patella\*; \(b\) \*Bellerophon\*...](#)

[Figure 14.16 \(a\) Features of the shell and \(b\) internal morphology of a livi...](#)

[Figure 14.17 Life attitudes and external morphologies of the nautiloids.](#)

[Figure 14.18 Morphology and shape terminology of the ammonoids: \(a\) external...](#)

[Figure 14.19 Evolution of suture patterns: the five main types; arrows point...](#)

[Figure 14.20 Some heteromorph ammonites.](#)

[Figure 14.21 Stratigraphic ranges of the main ammonite taxa together with th...](#)

[Figure 14.22 Cephalopod molluscs. \(a\) nautiloid \*Aturia\*; \(b\) agoniatite \*Agoni...\*](#)

[Figure 14.23 Life attitudes and buoyancy of the ammonites. \(a\) Supposed life...](#)

[Figure 14.24 Ammonoid evolution in relation to body chamber length \(BCL\), ap...](#)

[Figure 14.25 Coleoid morphology: \(a\) reconstruction of a hypothetical living...](#)

[Figure 14.26 Evolution of belemnite diversity, disparity, and size patterns ...](#)

[Figure 14.27 Belemnite battlefields and their possible origin: \(a\) post-spaw...](#)

[Figure 14.28 \(a\) Scaphopod morphology and \(b\) rostroconch morphology.](#)

[Figure 14.29 Stratigraphic range of the main mollusk groups.](#)

[Figure 14.30 Key stages in cephalopod evolution \(top\) compared to biodiversi...](#)

[Figure 14.31 Cambrian annelids \(a\) \*Phragmochaeta\* and \(b\) \*Canadia\*; \(c\) summar...](#)

[Figure 14.32 The machaeridian \*Plumulites\* from the Lower Ordovician \(Upper Tr...](#)

[Figure 14.33 Scolecodont morphology. Reconstruction of the polychaete jaw ap...](#)

[Figure 14.34 The most terrifying worm. \(a\) CT scans of jaw elements of \*Webst...\*](#)

## Chapter 15

[Figure 15.1 Arthropod diversity and evolution. \(a\) Some of the main arthropo...](#)

[Figure 15.2 Relationships between the extant groups of arthropods; terrestri...](#)

[Figure 15.3 Exceptionally preserved Cambrian arthropods. \(a\) Nervous and vis...](#)

[Figure 15.4 \*Tamisiocaris\* from Sirius Passet, North Greenland; the animal, ne...](#)

[Figure 15.5 Trilobite morphology: \(a\) external morphology of the Ordovician ...](#)

[Figure 15.6 Facial sutures: the tracks of the proparian, gonatoparian, and o...](#)

[Figure 15.7 Molt phases of the Bohemian trilobite \*Sao hirsuta\* Barrande. Magn...](#)

[Figure 15.8 Outline phylogeny and stratigraphic distribution of the main tri...](#)

[Figure 15.9 Vision in trilobites and an anomalocaridid: \(a\) lateral view of ...](#)

[Figure 15.10 Variation in trilobite morphology. \(a\) \*Paradoxides\*; \(b\) \*Parabol...\*](#)

[Figure 15.11 Trilobite ecomorphs: pelagic \(a, b\), illaenomorph \(c, d\), margi...](#)

[Figure 15.12 Lifestyles of the trilobites: a mosaic of selected Lower Paleoz...](#)

[Figure 15.13 Eight lineages of trilobites show gradual changes in numbers of...](#)

[Figure 15.14 Landmark analysis of \*Aulacopleura\*. \(a\) Measurements, \(b\) landma...](#)

[Figure 15.15 Pathological trilobites: \(a\) \*Onnia superba\* - the fringe in the ...](#)

[Figure 15.16 Chelicerate morphology displaying features of \(a\) dorsal and \(b...](#)

[Figure 15.17 Giant arthropods from the fossil record compared with the avera...](#)

[Figure 15.18 Eurypterid functional morphology showing \(a\) swimming and \(b, c...](#)

[Figure 15.19 Insects trapped in a Cretaceous spider's web: \(a\) actual specim...](#)

[Figure 15.20 Early millipedes: \(a\) \*Archidesmus\* \(Lower Devonian\), \(b\) \*Cowiede...\*](#)

[Figure 15.21 Spindle diagram showing family richness of the major insect gro...](#)

[Figure 15.22 Origins of insect flight. \(left\). Simplified insect phylogeny, a...](#)

[Figure 15.23 Carboniferous shrimp-like crustaceans: \(a\) \*Tealliocaris woodwar...\*](#)

[Figure 15.24 \(a\) Cluster of the very abundant \*Agnostus pisiformis\* from the A...](#)

[Figure 15.25 Descriptive terminology of the ostracode animal \(a\), including ...](#)

[Figure 15.26 Some ostracode genera: \(a\) left valve of a male living \*Limnocytt...\*](#)

[Figure 15.27 Exceptionally preserved arthropods. \(a\) Clockwise from top left...](#)

[Figure 15.28 Insects from the Mo-Clay, Jutland, Denmark. a, Crane fly, approx...](#)

## Chapter 16

[Figure 16.1 Life modes of the main echinoderm body plans.](#)

[Figure 16.2 Phylogeny of the early echinoderms.](#)

[Figure 16.3 Some crinoid ossicle types. \(a\) Articular facet of a columnal of...](#)

[Figure 16.4 \(a\) Morphology of the Ordovician \*Dictenocrinus\*. \(b\) Two main cri...](#)

[Figure 16.5 Phylogenetic relationships between major crinoid clades. Monobat...](#)

[Figure 16.6 Diversity of Early Carboniferous crinoids; the curves compare da...](#)

[Figure 16.7 Colony of \*Traumatocrinus\*, from the Upper Triassic \(Carnian\) blac...](#)