MACMILLAN
DICTIONARY
OF

**GENETICS AND
CELL BIOLOGY**

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CELL BIOLOGY**

NORMAN MACLEAN

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MACMILLAN
REFERENCE
BOOKS

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Preface

Part of both the fun and frustration of the biological sciences over the last decade or so has been keeping up with the terminology. Many words borrowed from more general usage have been endowed with very special meanings, sometimes not obvious to the uninitiated. I refer to the use of words like amplification, and housekeeping as they apply to genes. Other terms, such as clone, have moved from biology into general journalism, but require understanding and precision in use. This book therefore sets out not just to define but to explain what certain words mean and what their relationship is to other terms in the same field. In this way it is hoped that those who use the dictionary frequently will, as they do so, expand their knowledge and understanding of the topics.

The fact that the dictionary combines two areas deserves comment. Both genetics and cell biology have changed greatly in recent years, since both have been greatly affected by the explosion in molecular biology, both technically and intellectually. This, to my mind, links them almost indissolubly. Thus, although it would be possible to have distinct volumes devoted to either topic, many, perhaps even most, of the words defined would be common to both disciplines. It is also noticeable that many who work in specialist areas of cell biology and genetics do encounter problems in keeping abreast of the terminology used in the alternative subject area. This book should do something to help.

As indicated in the opening pages, a number of colleagues helped in writing the entries for this dictionary and I am glad to acknowledge their specialist contributions. I tried to farm out to them words that were a little outside my area of expertise and relatively central to theirs. But lest my readers imagine that I am passing on responsibility for lapses in accuracy that they discover, let me acknowledge that I wrote approximately 80 per cent of the entries myself and tried to check most of the farmed out entries also.

I am also most grateful to many other colleagues who helped explain individual meanings, and to those who nobly agreed to check some of the material written. Mrs Sandra Wilkins, who has typed the greater part of it, also deserves special mention.

It is beyond doubt that mistakes and inaccuracies will be found in the definitions provided, and I would be most grateful if those who find them will let me know, so that they can be rectified.

Notes on use

Entries are arranged in alphabetical order; numerals used as prefaces in the naming of compounds have been ignored.

In the definitions, words appearing in small capitals (e.g., CORE ENZYME) indicate a reference to another entry which will provide further information and may be of some help. In addition, *See also* at the end of an entry refers the reader to another entry on a related topic which may be of use.

Appendices

Appendix 1

Common names and latin names of some key organisms in cell biology and genetics.

Bacteria	<i>Escherichia coli</i>
Gram-negative	<i>Serratia marcescens</i>
	<i>Proteus vulgaris</i>
	<i>Pseudomonas aeruginosa</i>
	<i>Rhizobium</i> spp.
	<i>Azotobacter</i> spp.
Gram-positive	<i>Staphylococcus aureus</i>
	<i>Streptococcus lactis</i>
	<i>Bacillus subtilis</i>
	<i>Streptomyces</i> spp.
	<i>Actinomyces</i> spp.
Protozoa	<i>Amoeba proteus</i>
	<i>Naegleria gruberi</i>
	<i>Paramecium aurelia</i>
	<i>Tetrahymena thermophila</i>
	<i>Spirostomum ambiguum</i>
	<i>Euglena gracilis</i>
	<i>Chlamydomonas reinhardtii</i>
	<i>Stentor coeruleus</i>
	<i>Euplotes eurytomas</i>
Mould	<i>Sordaria fimicola</i>
	<i>Penicillium notatum</i>
	<i>Aspergillus nidulans</i>
Acellular slime mould	<i>Physarum polycephalum</i>
Cellular slime mould	<i>Dictyostelium discoideum</i>
Common mould	<i>Mucor plumbeus</i>
Smut fungus	<i>Ustilago</i> spp.
Sac fungus	<i>Neurospora crassa</i>
Mushroom	<i>Agaricus campestris</i>
Baker's yeast	<i>Saccharomyces cerevisiae</i>
Fission yeast	<i>Schizosaccharomyces pombe</i>
Hydra	<i>Hydra viridis</i>
Common sea anemone	<i>Anemonia sulcata</i>
Planarian	<i>Planaria torva</i>
	<i>Dugesia</i> spp.
Nematode	<i>Rhabditis pellio</i>
	<i>Caenorhabditis elegans</i>
	<i>Ascaris lumbricoides</i>
Cat tapeworm	<i>Taenia pisiformis</i>
Sea squirt	<i>Ciona intestinalis</i>
Winkle	<i>Littorina</i> spp.
Fresh water snail	<i>Lymnaea peregra</i>
Banded snail	<i>Cepaea nemoralis</i>
Roman snail	<i>Helix pomatia</i>
Garden snail	<i>Helix aspersa</i>

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Mud snail	<i>Ilyanassa obsoleta</i>
Mussel	<i>Mytilus edulis</i>
Slipper limpet	<i>Crepidula fornicata</i>
Sea hare	<i>Aplysia limacina</i>
Octopus	<i>Octopus vulgaris</i>
Squid	<i>Sepia officinalis</i>
Earthworm	<i>Lumbricus terrestris</i> and other species
Lugworm	<i>Arenicola marina</i>
Serpulid worm	<i>Pomatoceros triqueter</i>
Blood worm	<i>Tubifex rivulorum</i>
Medicinal leech	<i>Hirudo medicinalis</i>
Daphnia	<i>Daphnia pulex</i>
Fairy shrimp	<i>Artemia salina</i>
Large mayfly	<i>Ephemera danica</i>
House cricket	<i>Acheta domesticus</i>
Blowfly	<i>Calliphora vomitoria</i>
Fruitfly	<i>Drosophila melanogaster</i>
Monarch butterfly	<i>Danaus plexippus</i>
American cockroach	<i>Periplaneta americana</i>
Peppered moth	<i>Biston betularia</i>
Locust, migratory	<i>Locusta migratoria</i>
	<i>Schistocerca gregaria</i>
Honey bee	<i>Apis mellifera</i>
Fungus gnat	<i>Sciara coprophila</i>
Silk moth	<i>Bombyx mori</i>
Mosquito	<i>Aedes</i> spp.
	<i>Anopheles</i> spp.
	<i>Culex</i> spp.
Midge, non-biting	<i>Chironomus tentans</i>
Housefly	<i>Musca domestica</i>
Sea urchin	<i>Echinus esculentus</i>
	<i>Pacentrotus lividus</i>
	<i>Psammechinus miliaris</i>
Brook lamprey	<i>Lampetra planeri</i>
African lung fish	<i>Protopterus aethiopicus</i>
Killifish	<i>Aphyosemion scheeli</i>
American killifish	<i>Fundulus heteroclitus</i>
Brown trout	<i>Salmo trutta</i>
Brook trout	<i>Salvelinus fontinalis</i>
Rainbow trout	<i>Salmo gairdneri</i>
Atlantic salmon	<i>Salmo salar</i>
Guppy	<i>Lebistes reticulatus</i>
Common lancelet	<i>Branchiostoma lanceolatum</i>
	(<i>Amphioxus</i>)
Goldfish	<i>Carassius auratus</i>
Sturgeon	<i>Acipenser</i> spp.
Eel	<i>Anguilla anguilla</i>
Loach	<i>Missgurnis fossilis</i>
Carp	<i>Cyprinus carpio</i>
Salamanders and newts	<i>Salamandra</i> spp.
	<i>Triturus</i> spp.
	<i>Amphiuma means</i>
	<i>Necturus maculatus</i>
	<i>Xenopus laevis</i>
	<i>Xenopus borealis</i>
Clawed frog/toad	

Common frog	<i>Rana temporaria</i>
Leopard frog	<i>Rana pipiens</i>
Common toad	<i>Bufo bufo</i>
Axolotl	<i>Ambystoma mexicanum</i>
Quail	<i>Coturnix japonica</i>
Pigeon	<i>Columba livia domestica</i>
Chicken	<i>Gallus domesticus</i>
Chinese goose	<i>Cygnopsis cygnoid</i>
Grey lag goose	<i>Anser anser</i>
Turkey	<i>Meleagris gallopova</i>
Guinea-pig	<i>Cavia cobaya</i>
Mouse	<i>Mus musculus</i>
Golden hamster	<i>Mesocricetus auratus</i>
Chinese hamster	<i>Cricetulus griseus</i>
Rat	<i>Ratus norvegicus</i>
Dog	<i>Canis familiaris</i>
Rabbit	<i>Oryctolagus cuniculus</i>
Sheep	<i>Ovis aries</i>
Cat	<i>Felis catus</i>
Horse	<i>Equus caballus</i>
Cow	<i>Bos taurus</i>
Goat	<i>Capra hircus</i>
Pig	<i>Sus scrofa</i>
Rhesus monkey	<i>Macaca mulatta</i>
Chimpanzee	<i>Pan troglodytes</i>
Human	<i>Homo sapiens</i>
Green alga	<i>Acetabularia mediterranea</i>
Ginko tree	<i>Ginko biloba</i>
Autumn crocus	<i>Colchicum autumnale</i>
Saffron crocus	<i>Crocus sativus</i>
Pea	<i>Pisum sativum</i>
Flax	<i>Linum usitatissimum</i>
Maize	<i>Zea mays</i>
Evening primrose	<i>Oenothera lamarckiana</i>
Cabbage	<i>Brassica oleracea capitata</i>
Cucumber	<i>Cucumis sativus</i>
Carrot	<i>Daucus carota sativa</i>
Primrose	<i>Primula vulgaris</i>
English ivy	<i>Hedera helix</i>
Tobacco	<i>Nicotiana tabacum</i>
Snapdragon	<i>Antirrhinum majus</i>
Potato	<i>Solanum tuberosum</i>
Tomato	<i>Lycopersicon esculentum</i>
Onion	<i>Allium cepa</i>
Broad bean	<i>Vicia faba</i>
Alfalfa (lucerne)	<i>Medicago sativa</i>
Beet	<i>Beta vulgaris</i>
Broomcorn (sorghum)	<i>Sorghum vulgare technicum</i>
Millet	<i>Setaria italica</i>
Rice	<i>Oryza sativa</i>
Rye	<i>Secale cereale</i>
Soybean	<i>Glycine max</i>
Sunflower	<i>Helianthus annuus</i>
Wheat	<i>Triticum aestivum</i>
Barley	<i>Hordeum vulgare</i>

Appendix 2
Chromosome numbers in various species.

<i>Common name</i>	<i>Latin name</i>	<i>Diploid number</i>
Mould	<i>Penicillium</i>	8
Mould	<i>Neurospora crassa</i>	14
Mould	<i>Aspergillus nidulans</i>	16
Slime mould	<i>Dictyostelium discoideum</i>	14
Paramecium	<i>Paramecium aurelia</i>	60–126
Alga	<i>Chlamydomonas reinhardtii</i>	32
Yeast	<i>Saccharomyces cerevisiae</i>	18 approx.
Alga	<i>Acetabularia mediterranea</i>	20 approx.
Onion	<i>Allium cepa</i>	16
Barley	<i>Hordeum vulgare</i>	14
Rice	<i>Oryza sativa</i>	24
Maize/corn	<i>Zea mays</i>	20
Rye	<i>Secale cereale</i>	14
Emmer wheat	<i>Triticum turgidum</i>	28
Bread wheat	<i>Triticum aestivum</i>	42
Pine	<i>Pinus ponderosa</i>	24
Pea	<i>Pisum sativum</i>	14
Broad bean	<i>Vicia faba</i>	12
Bean	<i>Phaseolus vulgaris</i>	22
Sweet pea	<i>Lathyrus odoratus</i>	14
Snapdragon	<i>Antirrhinum majus</i>	16
Tomato	<i>Lycopersicon esculentum</i>	24
Potato	<i>Solanum tuberosum</i>	48
Tobacco	<i>Nicotiana tabacum</i>	48
Cabbage	<i>Brassica oleracea</i>	18
Radish	<i>Raphanus sativus</i>	18
Cucumber	<i>Cucumis sativus</i>	14
Nematode	<i>Caenorhabditis elegans</i>	11/12
Hydra	<i>Hydra vulgaris</i>	32
Planarian	<i>Planaria torva</i>	16
Starfish	<i>Asterias forbesi</i>	36
Hermit crab	<i>Eupagurus ochotensis</i>	254
Silk moth	<i>Bombyx mori</i>	56
Housefly	<i>Musca domestica</i>	12
Fruitfly	<i>Drosophila melanogaster</i>	8
Mosquito	<i>Culex pipiens</i>	6
Cockroach	<i>Blatta germanica</i>	23/24
Goldfish	<i>Carassius auratus</i>	100
Platy	<i>Platypoecilus maculatus</i>	48
Carp	<i>Cyprinus carpio</i>	104
Frog	<i>Rana pipiens</i>	26
Xenopus	<i>Xenopus laevis</i>	36
Toad	<i>Bufo bufo</i>	22
Turkey	<i>Meleagris gallopova</i>	82
Chicken	<i>Gallus domesticus</i>	78
Rat	<i>Ratus norvegicus</i>	42
House mouse	<i>Mus musculus</i>	40
Guinea-pig	<i>Cavia cobaya</i>	64
Golden hamster	<i>Mesocricetus auratus</i>	44

Rabbit	<i>Oryctolagus cuniculus</i>	44
Cat	<i>Felis domesticus</i>	38
Dog	<i>Canis familiaris</i>	78
Pig	<i>Sus scrofa</i>	38
Cow	<i>Bos taurus</i>	60
Horse	<i>Equus caballus</i>	64
Donkey	<i>Equus asinus</i>	62
Rhesus monkey	<i>Macaca mulatta</i>	48
Chimpanzee	<i>Pan troglodytes</i>	48
Human	<i>Homo sapiens</i>	46

Appendix 3

DNA content of haploid genomes expressed in picograms per cell (1 pg = 10^{-12} g). 1 picogram of DNA is equivalent to approximately 1×10^9 base pairs.

Common name	Latin name	DNA amount (pg)
Bacteriophage lambda		0.00005
Bacteriophage T4		0.00017
SV40 virus		0.000005
Single-stranded DNA phage ϕ X174		0.000002
Bacterium	<i>Escherichia coli</i>	0.004
Bacterium	<i>Bacillus subtilis</i>	0.003
Yeast	<i>Saccharomyces cerevisiae</i>	0.024
Fungus	<i>Neurospora crassa</i>	0.017
Fungus	<i>Aspergillus nidulans</i>	0.044
Slime mould	<i>Dictyostelium discoideum</i>	0.036
Slime mould	<i>Physarum polycephalum</i>	0.50
Paramecium	<i>Paramecium aurelia</i> (polyploid)	160.00
Alga	<i>Chlamydomonas reinhardtii</i>	0.06
Maize	<i>Zea mays</i>	3.9
Onion	<i>Allium cepa</i>	16.8
Onion sp.	<i>Allium globosum</i>	37.6
Lily	<i>Lilium longiflorum</i>	36.1
Scilla	<i>Scilla campanulata</i>	22.0
Broad bean	<i>Vicia faba</i>	24.0
Rye grass	<i>Secale cereale</i>	9.0
Rye	<i>Lolium perenne</i>	4.8
Pea	<i>Pisum sativum</i>	4.5
Lupin	<i>Lupinus albus</i>	1.2
Flax sp.	<i>Linum usitatissimum</i>	0.7
Nematode	<i>Caenorhabditis elegans</i>	0.062
Silk moth	<i>Bombyx mori</i>	0.52
Fruitfly	<i>Drosophila melanogaster</i>	0.18
Cricket	<i>Gryllus domesticus</i>	0.5
Crab	<i>Cancer borealis</i>	1.7
Squid	<i>Sepia officinalis</i>	4.5
Sea urchin	<i>Paracentrotus lividus</i>	0.7
African lung fish	<i>Protopterus aethiopicus</i>	50.0
Brook trout	<i>Salvelinus fontinalis</i>	3.5
Rainbow trout	<i>Salmo gairdneri</i>	2.5
Pike	<i>Esox lucius</i>	2.5

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Tench	<i>Tinca tinca</i>	0.9
Goldfish	<i>Carassius auratus</i>	2.0
Carp	<i>Cyprinus carpio</i>	1.7
Sturgeon	<i>Acipenser sturio</i>	1.6
Killifish	<i>Fundulus heteroclitus</i>	1.5
Eel	<i>Anguilla rostrata</i>	1.4
Pufferfish	<i>Tetradon fluviatilis</i>	0.5
Siamese fighting fish	<i>Betta splendens</i>	0.7
Salamander	<i>Amphiuma means</i>	84.0
Frog	<i>Rana esculenta</i>	8.4
Frog	<i>Rana pipiens</i>	7.6
Clawed frog/toad	<i>Xenopus laevis</i>	3.15
Toad	<i>Bufo bufo</i>	6.0
Toad	<i>Bufo regularis</i>	4.5
Tree frog	<i>Hyla arborea</i>	5.8
Newt	<i>Triturus alpestris</i>	38.4
Newt	<i>Triturus vulgaris</i>	36.1
Alligator	<i>Alligator mississippiensis</i>	2.5
Green turtle	<i>Chelonia mydas</i>	2.6
Black racer snake	<i>Coluber constrictor</i>	1.4
Chicken	<i>Gallus domesticus</i>	1.25
Grey lag goose	<i>Anser anser</i>	1.4
Pigeon	<i>Columba livia</i>	1.1
Pheasant	<i>Phasianus colchicus</i>	0.8
Ox	<i>Bos taurus</i>	3.2
Mouse	<i>Mus musculus</i>	2.5
Rabbit	<i>Oryctolagus cuniculus</i>	2.6
Horse	<i>Equus caballus</i>	2.9
Human	<i>Homo sapiens</i>	3.0

Appendix 4
The Greek alphabet

<i>Letters</i>		<i>Name</i>
<i>Capital</i>	<i>Small</i>	
A	α	alpha
B	β	beta
Γ	γ	gamma
Δ	δ	delta
E	ε	epsilon
Z	ζ	zeta
H	η	eta
Θ	θ	theta
I	ι	iota
K	κ	kappa
Λ	λ	lambda
M	μ	mu
N	ν	nu
Ξ	ξ	xi
O	ο	omicron
Π	π	pi
P	ρ	rho
Σ	σ	sigma
T	τ	tau
Υ	υ	upsilon
Φ	φ	phi
X	χ	chi
Ψ	ψ	psi
Ω	ω	omega

Appendix 5

Classification of living organisms

Classification: the subdivision of organisms into an evolutionary hierarchy of groups. The formal hierarchy proceeding from the largest to the smallest group is Kingdom, Phylum, Class, Order, Family, Genus, and Species. To allow further subdivisions the names Grade or Division are sometimes placed between Kingdom and Phylum, the name Branch is placed between Phylum and Class, the name Cohort between Class and order, and the name Tribe between Family and Genus. In addition the prefixes Super- and Sub- may be added to any group name.

SUPERKINGDOM Prokaryotes

KINGDOM 1 Monera

- PHYLUM Aphragmabacteria (*Mycoplasma*)
- PHYLUM Fermenting bacteria (*Diplococcus*, *Streptococcus*)
- PHYLUM Spirochaetae (*Spirochaeta*)
- PHYLUM Thiophnetues (sulphur-reducing bacteria, *Desulfovibrio*)
- PHYLUM Methaneocreatrices (methane-forming bacteria, *Methanobacillus*)
- PHYLUM Anaerobic photosynthetic bacteria (*Rhodospirillum*)
- PHYLUM Cyanobacteria (blue-green algae, *Anabaena*)
- PHYLUM Chloroxybacteria (*Prochloron*)
- PHYLUM Nitrogen-fixing aerobic bacteria *Rhizobium*)
- PHYLUM Pseudomonads (*Pseudomonas*)
- PHYLUM Aeroendospora (aerobic endospore-forming bacteria, *Bacillus*)
- PHYLUM Micrococci (*Staphylococcus*)
- PHYLUM Chemoautotrophic bacteria (*Nitrobacter*)
- PHYLUM Omnibacteria (*Escherichia*, *Haemophilus*, *Salmonella*, *Serratia*, *Shigella*)
- PHYLUM Actinobacteria (*Actinomyces*, *Streptomyces*)
- PHYLUM Myxobacteria (*Myxococcus*)

SUPERKINGDOM Eukaryotes

KINGDOM 2 Protocista

- PHYLUM Caryoblastea (*Pelomyxa*)
- PHYLUM Dinoflagellata (*Gonoyaulax*)
- PHYLUM Rhizopoda (*Amoeba*)
- PHYLUM Chrysophyta (*Ochromonas*)
- PHYLUM Haptophyta (*Prymnesium*)
- PHYLUM Euglenophyta (*Euglena*)
- PHYLUM Cryptophyta (*Cyathomonas*)
- PHYLUM Zoomastigina (animal flagellates, *Trypanosoma*)
- PHYLUM Xanthophyta (*Vaucheria*)
- PHYLUM Eustimatophyta (*Vischeria*)
- PHYLUM Bacillariophyta (diatoms, *Diatoma*)
- PHYLUM Phaeophyta (brown algae, *Fucus*, *Nereocystis*)
- PHYLUM Rhodophyta (red algae, *Polysiphonia*)
- PHYLUM Gamophyta (conjugating green algae and desmids, *Spirogyra* and *Micrasterias*)
- PHYLUM Chlorophyta (green algae forming flagellated gametes, *Acetabularia*, *Chlamydomonas*, *Volvox*)
- PHYLUM Actinopoda (radiolarians and heliozoans, *Acanthocystis*, *Sticholonche*)
- PHYLUM Foraminera (*Fusulina*, *Globigerina*)
- PHYLUM Ciliophora (ciliates, *Paramecium*, *Tetrahymena*)
- PHYLUM Apicomplexa (sporozoans, *Plasmodium*)
- PHYLUM Cnidosporidia (microsporidians, *Nosema*)

- PHYLUM Labyrinthulamyxota (slime nets, *Labyrinthula*)
- PHYLUM Acrasiomycota (cellular slime molds, *Dictostelium*, *Polysphondylium*)
- PHYLUM Myxomycota (plasmodial slime molds, *Echinostelium*)
- PHYLUM Plasmodiophoromycota (*Plasmodiophora*)
- PHYLUM Hypochytridiomycota (*Hypochytrium*)
- PHYLUM Chytridiomycota (*Blastocladiella*)
- PHYLUM Oomycota (*Saprolegnia*)
- KINGDOM 3 Fungi
 - PHYLUM Zygomycota (conjugating fungi, *Mucor*, *Phycomyces*, *Pilobolus*, *Rhizopus*)
 - PHYLUM Ascomycota (sac fungi, *Neurospora*, *Saccharomyces*)
 - PHYLUM Basidiomycota (club fungi, *Agaricus*, *Schizophyllum*, *Ustilago*)
 - PHYLUM Deuteromycota (*Aspergillus*, *Penicillium*)
 - PHYLUM Mycophycophyta (lichens, *Cladonia*)
- KINGDOM 4 Animalia
 - SUBKINGDOM Parazoa
 - PHYLUM Placozoa (*Trichoplax*)
 - PHYLUM Porifera (sponges, *Euplectella*)
 - SUBKINGDOM Mesozoa
 - PHYLUM Mesozoa (*Dicyema*)
 - SUBKINGDOM Eumetazoa
 - GRADE Radiata
 - PHYLUM Cnidaria (Coelenterates)
 - CLASS Hydrozoa (hydroids, *Hydra*)
 - CLASS Scyphozoa (true jelly fish, *Physalia*)
 - CLASS Anthozoa (corals and sea anemones, (*Metridium*))
 - PHYLUM Ctenophora (comb jellies, *Mnemiopsis*)
 - GRADE Bilateria
 - SUBGRADE Protostomia
 - SUPERPHYLUM Acoelomata
 - PHYLUM Platyhelminthes (flatworms)
 - CLASS Turbellaria (planarians)
 - CLASS Trematoda (flukes, *Schistosoma*)
 - CLASS Cestoda (tapeworms)
 - PHYLUM Nemertina (Rhynchocoela) (ribbon worms)
 - SUPERPHYLUM Pseudocoelomata
 - PHYLUM Acanthocephala (spiny-headed worms)
 - PHYLUM Entoprocta (entoprocts)
 - PHYLUM Aschelminthes
 - SUBPHYLUM Rotifera (rotifers)
 - SUBPHYLUM Gastrotricha (gastrotrichs)
 - PHYLUM Loricifera (loriciferans)
 - SUBPHYLUM Kinorhyncha (kinorhynchs)
 - SUBPHYLUM Priapulida (priapulids)
 - SUBPHYLUM Nematoda (round worms, *Ascaris*, *Caenorhabditis*)
 - SUBPHYLUM Nematomorpha (Gordiacae) (horsehair worms)
 - SUPERPHYLUM Coelomata
 - DIVISION Tentaculata
 - PHYLUM Phoronida (phoronids)
 - PHYLUM Ectoprocta (bryozoa)
 - PHYLUM Brachiopoda (brachiopods)
 - DIVISION Inarticulata
 - PHYLUM Sipunculoidea (sipunculids)
 - PHYLUM Mollusca (molluscs)
 - CLASS Amphineura (chitins)
 - CLASS Scaphopoda (tooth shells)

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- CLASS Gastropoda (snails, *Cepaea*, *Lymnea*)
- CLASS Pelecypoda (bivalves, *Crassostrea*, *Mytilus*)
- CLASS Cephalopoda (squids, octopuses)
- DIVISION Articulata
- PHYLUM Echiuroidea (echiuroids)
- PHYLUM Annelida (segmented worms)
 - CLASS Polychaeta (marine worms)
 - CLASS Oligochaeta (earthworms)
 - CLASS Hirudinea (leeches)
- PHYLUM Tardigrada (water bears)
- PHYLUM Onychophora (peripatus)
- PHYLUM Pentastomida (tongue worms) (parasites)
- PHYLUM Arthropoda
 - BRANCH Chelicerata
 - CLASS Merostomata (king crabs)
 - CLASS Pycnogonida (sea spiders)
 - CLASS Arachnida (scorpions, opilionids, mites, spiders)
 - BRANCH Mandibulata
 - CLASS Crustacea
 - ORDER Branchiopoda (shrimps)
 - ORDER Ostracoda (ostracods)
 - ORDER Copepoda (copepods)
 - ORDER Cirripedia (barnacles)
 - ORDER Malacostraca (lobsters and crabs)
 - CLASS Myriapoda
 - ORDER Diplopoda (millipedes)
 - ORDER Chilopoda (centipedes)
 - CLASS Hexapoda
 - SUBCLASS Entognatha
 - ORDER Collembola (springtails)
 - ORDER Protura (proturans)
 - ORDER Diplura (campodeans)
 - SUBCLASS Insecta
 - COHORT Apterogota (primitively wingless insects)
 - ORDER Archaeognatha (machilids)
 - ORDER Zygentoma (silverfish)
 - COHORT Pterygota (winged insects)
 - SUBCOHORT Paleoptera (extended wing)
 - ORDER Ephemeroptera (mayflies)
 - ORDER Odonata (dragonflies)
 - SUBCOHORT Neoptera (hinged wing)
 - SUPERORDER Hemimetabola (no pupal stage)
 - ORDER Embioptera (embiids)
 - ORDER Phasmida (stick insects)
 - ORDER Orthoptera (grasshoppers)
 - ORDER Grylloblattaria (grylloblatids)
 - ORDER Dictoptera (roaches, *Blattella*)
 - ORDER Dermaptera (earwigs)
 - ORDER Psocoptera (booklice)
 - ORDER Phthiraptera (sucking lice)
 - ORDER Hemiptera (true bugs)
 - ORDER Plecoptera (stone flies)
 - ORDER Thysanoptera (thrips)
 - SUPERORDER Holometabola
 - ORDER Coleoptera (beetles, *Tribolium*)

- ORDER Raphidioptera (snakeflies)
- ORDER Megaloptera (alder flies)
- ORDER Neuroptera (lacewings)
- ORDER Hymenoptera (*Apis*, *Mormoniella*, *Habrobracon*)
- ORDER Trichoptera (caddis flies)
- ORDER Lepidoptera (moths, *Bombyx*, *Ephestia*)
- ORDER Mecoptera (scorpion flies)
- ORDER Siphonaptera (fleas)
- ORDER Diptera (*Aedes*, *Anopheles*, *Chironomus*, *Culex*, *Drosophila*, *Glyptotendipes*, *Lucilia*, *Musca*, *Rhynchosciara*, *Sciara*)
- SUBGRADE Deuterostomia
- PHYLUM Echinodermata
 - ORDER Crinoidea (sea lilies)
 - ORDER Asteroidea (starfish)
 - ORDER Ophiuroidea (brittle stars)
 - ORDER Echinoidea (sea urchins)
 - ORDER Holothuroidea (sea cucumbers)
- PHYLUM Chaetognatha (arrow worms)
- PHYLUM Pogonophora (beard worms)
- PHYLUM Chordata (notochord-bearing animals)
- SUBPHYLUM Acraniata
 - COHORT Hemichordata (acorn worms and pterobranchs)
 - COHORT Urochordata (tunicates)
 - COHORT Cephalochordata (lancelets)
- SUBPHYLUM Craniata
 - COHORT Agnatha (jawless vertebrates)
 - CLASS Cyclostomata (lampreys)
 - COHORT Gnathostoma (jawed vertebrates)
 - CLASS Chondrichthyes (elasmobranchs)
 - CLASS Osteichthyes (bony fish)
 - SUBCLASS Palaeopterygii (ancient fish)
 - ORDER Acipenseriformes (sturgeons)
 - ORDER Semionotiformes (gars)
 - SUBCLASS Neopterygii (modern fish)
 - ORDER Salmoniformes (trouts)
 - ORDER Anguilliformes (eels)
 - ORDER Cypriniformes (*Oryzias*)
 - ORDER Cyprinodontiformes (*Fundulus*, *Lebistes*)
 - ORDER Perciformes (*Tilapia*)
 - ORDER Siluriformes (catfish)
 - ORDER Elopiformes (tarpons)
 - ORDER Clupeiformes (herrings)
 - ORDER Gasterosteiformes (sea horses)
 - ORDER Pleuronectiformes (flounders)
 - SUBCLASS Crossopterygii (coelacanth, *Latimeria*)
 - CLASS Amphibia
 - ORDER Apoda (caecilians)
 - ORDER Urodela (salamanders, *Ambystoma*, *Triturus*, *Pleurodeles*)
 - ORDER Anura (frogs and toads, *Rana*, *Xenopus*)
 - CLASS Reptilia (turtles, alligators, lizards, snakes)
 - CLASS Aves (birds)
 - SUBCLASS Palaeognathae (flightless birds, ostriches, emus)
 - SUBCLASS Neognathae (modern birds)
 - ORDER Anseriformes (ducks)
 - ORDER Galliformes (quail, turkeys, *Gallus*)

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- ORDER Columbiformes (pigeons)
- ORDER Psittaciformes (parrots)
- ORDER Passeriformes (song birds)
- CLASS Mammalia
- SUBCLASS Protheria (egg-laying mammals)
- SUBCLASS Metatheria (marsupials)
- SUBCLASS Eutheria (placental mammals)
- ORDER Insectivora (moles, shrews)
- ORDER Chiroptera (bats)
- ORDER Edentata (sloths)
- ORDER Rodentia (rodents, *Cavia*, *Chinchilla*, *Mesocricetus*, *Mus*, *Peromyscus*, *Rattus*)
- ORDER Lagomorpha (rabbits, *Oryctolagus*)
- ORDER Cetacea (whales)
- ORDER Proboscidea (elephants)
- ORDER Pinnipedia (seals)
- ORDER Perissodactyla (odd-toed ungulates, *Equus*)
- ORDER Artiodactyla (even-toed ungulates, *Bos*, *ovis*)
- ORDER Primates (lemurs, tarsiers, monkeys, apes, *Homo sapiens*)

KINGDOM 5 Plantae

- PHYLUM Bryophyta
- SUBPHYLUM Hepaticae (liverworts)
- SUBPHYLUM Anthocerotae (hornworts)
- SUBPHYLUM Musci (mosses)
- PHYLUM Tracheophyta (vascular plants)
- SUBPHYLUM Psilophyta (*Psilotum*)
- SUBPHYLUM Lycopodophyta (clubmosses and quillworts)
- SUBPHYLUM Sphenopsida (horsetails)
- SUBPHYLUM Pteropsida (ferns and seed plants)
- SUPERCLASS Filicinae (ferns)
- SUPERCLASS Gymnospermae (cone-bearing, seed plants)
- CLASS Pteridospermophyta (seed ferns)
- CLASS Cycadophyta (cycads)
- CLASS Ginkophyta (ginkgos)
- CLASS Coniferophyta (conifers)
- CLASS Gnetophyta (gnetophytes)
- SUPERCLASS Angiospermae (flowering plants)
- CLASS Dicotyledoneae
- ORDER Magnoliales (magnolias)
- ORDER Rosales (rose, apple, plum, strawberry, etc.)
- ORDER Leguminales (*Pisum*, *phaseolus*)
- ORDER Salicales (willows)
- ORDER Fagales (beech, oak, etc.)
- ORDER Geraniales (geranium, flax, citrus fruits)
- ORDER Cactales (cactuses)
- ORDER Scrophulariales (*Antirrhinum*, *Collinsia*)
- ORDER Ranales (buttercups, water lilies)
- ORDER Myrtales (myrtle, eucalyptus, *Oenothera*)
- ORDER Cruciales (cabbage, turnip, etc.)
- ORDER Cucurbitales (*Cucurbita*, *Cucumis*)
- ORDER Caryophyllales (carnations)
- ORDER Gentianeales (gentians, olives, lilacs)
- ORDER Primulales (*Primula*)
- ORDER Malvales (*Gossypium*, linden, elm, hemp)
- ORDER Rubiales (coffee, quinine)
- ORDER Saxifragales (current, gooseberry)

- ORDER Umbrellales (carrot, parsnip)
- ORDER Sapindales (horse chestnut, maple)
- ORDER Solanales (*Datura*, *Lycopersicon*, *Nicotiana*)
- ORDER Celastrales (grapes, ivy)
- ORDER Personales (snapdragons, etc.)
- ORDER Boraginales (heliotrope, etc.)
- ORDER Lamiales (lavendar, mint, etc.)
- ORDER Asterales (composites, *Haplopappus*)
- CLASS Monocotyledoneae
- ORDER Palmales (palms)
- ORDER Graminales (grasses, *Hordeum*, *Oryzea*, *Triticum*, *Zea*)
- ORDER Liliales (lilies, tulips, amaryllis, iris)
- ORDER Commelinales (*Tradescantia*)
- ORDER Arales (callas, taros)
- ORDER Zingiberales (bananas)
- ORDER Orchidales (orchids)
- ORDER Bromeliales (pineapple)

Adapted from Lynn Margulis (1974) *The Classification and Evolution of Prokaryotes and Eukaryotes. Handbook of Genetics 1*: 1–41, Plenum Press, and Lynn Margulis and Karlene V. Schwartz (1982) *Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth*, W. H. Freeman.