

Index

A

- Abundance of elements 2
 in the earth 12(fig), 13(fig), 16, 17(table)
 in the universe 3(fig)
- Acantharia 288
 strontium sulfate 288
- Acetylcholine 371
- Acritarchs 282(table)
- Acids and bases
 hard and soft 46, 47(table)
- Adrenaline 371
- Aerobes
 beginnings of aerobic environment 244
 direct use of oxygen 253
 evolution of non-metal chemistry 255–258
 handling of metals 159(fig)–262
 metallo-oxidases 259(table)
 new genetic features 266–268
- Albedo 99
- Allosteric changes 161, 228
- Alloys 42
- Amino-acids
 pathways 141(table), 143, 152(fig)
 types 144(table), 145(table), 146(table)
- Anaerobes
 and introduction of photosynthesis 244
 development 233–236, 234(table)
 energy capture 226(table)
 energy flow 225, 226
 evolution to aerobic organisms 273(fig)
 in deep-sea trenches 440, 441
 lithochemotrophic organisms 211
 major metal ions 233
 metabolism 202, 206, 224
 non-metal elements 233
 organisation 234(table)
 origins 195–197, 418, 419, 420
- range of redox potential 180
 use and rejection of elements 224, 225, 432(table)
 use of light 357, 432
- Anammox bacteria 220, 248, 284
- Animals
 classical division 128(table)
 evolution of multicellular 324–328
 growth from single cells 329–331
 hormones in mammals 346(table)
 immune system 358
 organs 327(table)
 origin in time 316(table), 317(fig)
 protection systems 357, 358
 use of light 357
- Apicoplasts 286
- Aplysia (sea slugs) 325
- Apoptosis 305, 309, 359, 360
 degradation activity 359, 360
- Archaea
 differences from bacteria 197, 198(table)
- Archaezoa 284
- Atmosphere
 composition 5–7, 8(table), 16, 416
 evolution of oxygen 26(fig), 31, 215(fig), 220, 221(fig), 235, 332(fig)
 hydrides 7, 28
 impact of mankind activity 406, 451(table)
 in solar system planets 4, 8(table)
 increase of O₂, *see* Dioxygen
 initial composition 5, 6(table), 16
 loss of CO₂ 6(table), 7
 nitric oxide 248
 ozone layer 90, 91(fig), 95, 333
- ATPases
 F₁F₀ 210
 P-type 372(fig)
 V-type 290

- ATP production 199(fig), 204, 213, 226(fig), 248, 256(fig)
 - intermediate proton gradients 226(table), 257(fig)
 - role of magnesium 226
- ATP-synthetase 187(fig)
- Autocatalysis 119, 194, 201
- Availability of elements
 - in the environment 27–30
 - in the sea 15, 17–20, 29(fig), 51, 52
 - increase in 18(table)
- Axons 371(fig)
- B
 - Bacteria
 - anammox 220, 248
 - cyanobacteria 213, 253, 264(fig)
 - differences from archaea 197, 198(table)
 - early species 243(table)
 - evolution of photosynthesis 213
 - genes sequences 342
 - green 213
 - green sulphur 199(fig), 213
 - protoaerobic 244, 246
 - purple 213, 243(table)
 - rhodopsin 213, 213
 - trading of genes 229
 - Bacteriorhodopsin 211, 213
 - Banded iron formation, BIF 22(fig), 245
 - Baryte 22, 23(fig)
 - Beginnings of life 418–420
 - Bénard cell 92
 - Bicarbonate
 - in photosystem II 220–221
 - Big Bang (ix), 2, 413
 - Binding and rate constants 72(table)
 - Biological systems
 - evolution drive and constraints 115(fig), 120, 121
 - Biominerals 306, 342, 342(table)
 - Biopolymers 155(fig), 196
 - in primitive cells 196, 227, 228
 - Black smokers 13, 136, 325, 440, 441
 - and tungsten 441(table)
 - hydrothermal vents 13, 441
 - Bone 328
 - calcium phosphate 328
 - Brain 374–381
 - and genetic structure 368, 369
 - and memory 374, 375
 - as an information store 374, 375, 379, 381(fig)
 - cerebrospinal fluid (CSF), 374
 - chemical elements composition 378, 379(table)
 - component parts 380(fig)
 - evolutionary states of chemical systems 380(table)
 - electrolyte balance of ions 374
 - glands 377, 378
 - glial cells 374, 375, 377
 - in nematodes 325, 373
 - main functional zones 377(table)
 - neurons 369–373
 - physical evolution 375, 376(fig), 377(table)
 - release of hormones 378
 - C
 - Calcium
 - advantages 355, 356
 - and filaments 435
 - as a messenger 303–305
 - biominerals 342(table)
 - classes of proteins 339(table)
 - communication network 305(fig)
 - currents 371
 - dependent cellulases 354
 - EF hand 210, 300, 336, 355
 - EGF domains 336
 - energised gradients 305
 - homeostasis 355
 - in photosystem 221(fig)
 - increasing functional significance 355
 - ion fluxes 302
 - message cascades 348
 - messages 350(fig), 351(table)
 - minerals 342(table)
 - protective codes 210
 - protein motifs 356(table)
 - pulses 302, 348
 - rejection 210
 - sequence of use in evolution 383, 384(table)
 - signalling 302(table)–305
 - Calvin cycle 248(fig)
 - Cambrian period 21(table), 22

- Carbon
 - deposits as organic compounds in soils 306
 - fossil fuels 306
 - mineralization as carbonates 306
 - reduced materials 311
- Carbon dioxide, CO₂
 - activation by Rubisco 247, 248(fig)
 - incorporation 254
 - increase in the environment 406
 - loss in atmosphere 6(table), 7
- Carbonaceous chondrites 4, 16
- Carbonate deposits 25
- Carotenoids 211, 212
- Catalase 246, 292
- Catalysis 24, 25, 39, 46, 55, 73(table), 86, 161, 162, 163(table), *see also Enzymes*
 - and energy transduction 167
 - catalytic sites 176, 177
 - condensation and hydrolysis 173, 174
 - constrained (entatic) states 162, 163(table)
 - elements of special value 73(table)
 - reduction and oxidation 163(table), 171, 172
 - selective action of metal complexes 46, 72–74
- Cells
 - apoptosis 305, 309
 - coded DNA / RNA 195
 - communication networks 179, 180
 - compartments 59, 60, 263, 264, 265(fig), 296
 - components of a bacterial cell 137(table)
 - conditions of viability 153, 198–200
 - cytoplasm elements 132(table), 134, 135(fig)
 - cytoplasm organic pathways 152(fig)
 - efficient growth and survival 419
 - element content 132(table), 133(fig), 134, 135(fig)
 - enzyme organisation 263
 - equilibrium constants 178, 179, 183–187
 - equilibrium in 418
 - equilibrium redox potential constants 186, 187
 - essence of 41(table)
 - export of proteins 299(fig)
 - informed systems 117(fig)
 - organic pathways 152(fig)
 - organisation and constraints 115–117, 178, 183–186
 - origins 417
 - periplasmic space 264, 265(fig), 296
 - proton gradients 198, 199
 - redox potential 197
 - reductive chemistry 194, 195, 196
 - storage in precipitates 263
 - thermodynamic characteristics 182(table)
 - walls 197
- Cells compartments 59, 60, 264, 265(fig), 296
- Cellulases 354
- Cerebrospinal fluid (CSF) 374, 378, 379(table)
- Chaperones 161
- Charge gradients
 - in bioenergetics 226
 - in uptake of nutrients 224, 235
- Chelatases 213
- Chemical and nuclear processes 38, 39(fig)
- Chemotaxis 232, 345
 - sensing and searching 232
- Chemotypes 93, 102, 120, 121, 127–131, 129(table), 130(fig), 233, 234, 443–449, 421(table)
 - and genotypes 443–449
 - animals with nerves and a brain 367
 - basic elements content 133(fig)
 - changes in messengers and organisation 437(table)
 - development of compartments and use of space 396(table)
 - distinguishing features 382
 - diversity 328, 329
 - evolutionary connections and interdependencies 130(fig), 440(fig)
 - evolutionary information 438(table)
 - fungi, plant and animals 328
 - human beings as novel 413
 - main groups 129(table)
 - messengers and organisation 437(table)
 - species 443
 - succession 421(table)
 - thermodynamic description 421, 435(table)
 - use of energy 435(table)
 - use of energy and degradation 434
 - use of space 436(table)

- Chitin 352–354(table)
- Chitinases 353, 354
- Chloride, Cl⁻ 199, 220, 348(table), 370, 383
- Chlorophylls 211, 212(fig)
 - synthesis 212(fig)
 - use of light to full advantage 218, 220
- Chloroplasts 287, 288, 289(table), 297
 - chlorophyll 212(fig)
 - pentose shunt 139, 143, 205, 288
 - synthesis of sugars from CO₂ 288
 - thylacoid 288
- Choanoflagelates 321(fig), 324
- Cholesterol 280, 293(fig)
 - in membranes 280
- Chromatin
 - condensation 359
- Chromista 287
- Chromosomes 447
- Citric-acid cycle
 - Krebs's (oxidising) 255(fig)
 - reversed 213, 214(fig)
- Clouds 83, 85, 89(fig), 95
- Cnidaria 325(fig)
- Cobalt
 - decreasing value 340
 - transfer of H and carbon fragments in prokaryotes 340
- Coccoliths 282, 288
- Coded control centres (DNA) 114
- Coded molecules (DNA, RNA) 156, 157
- Codons 148(table)
- Coenzymes 167
 - fixed 205, 222
 - fragments transfer 203
 - introduction of 202, 203
 - mobile 203, 204
 - primitive 203(table)
- Cofactors
 - fixed 205
 - FMN flavine 357
 - metal/organic 211–218
 - molybdenum 204–206, 222(fig)
 - porphyrins 212(fig), 216(table)
 - primitive 203(table)
- Collagen 336
- Colonies 324
- Compartments 59, 60, 261, 264, 265(fig), 296
 - and information transfer 106, 107
 - compartmental barriers 79(table), 84(table), 106(table)
- flow systems 107
- “kinetic” 220, 287
- Complexes, *see* Coordination compounds
- Cone of ecological evolution (ii), 33, 312, 362, 413, 458
- Connective tissues 330, 351–355
 - open cellular matrices 352
- Containment 154, 155
 - bilipid layer membrane 155(fig)
- Continents
 - appearance of land 24, 32
 - formation of 23, 24(fig)
 - plate tectonics 24
- Control
 - kinetic 179, 180(fig)
 - in prokaryotes 230, 232
- Cooperativity 310–312, *see also* Synergism
 - and Symbiosis
 - dependencies of human beings 397(table)
 - relationships between bacteria, fungi, plants and animals 384–387
 - relationships between plants and animals 386–387
- Coordination compounds
 - fast and slow exchanges 65(table), 71
 - ligands preferred 68(table)
 - order of affinity 67(fig), 68(table)
 - organic ligands with different donor atoms 64(table)
 - preferred geometries 68(table)
 - selective action in catalysis 72, 73(table)
 - selectivity 64(table), 65–69
- Copper 260–264
 - and zinc 354(table)
 - association with ethylene 339
 - functions 338, 339
 - in protection 353–357
 - oxidation outside cells 350
 - proteins and enzymes 338(table)
 - proteins in unicellular aerobes 265(table)
 - switch from iron functions 261, 262, 268
 - use in cross-linking 351–355
 - use in denitrification 260, 261(fig), 265(table)
- Creation ix, 413, 460
- Cristae 219, 220, 285(fig)
- Cross-linking 351–355, 353(table)
 - enzymes of external matrix 354(table)

- Cyanobacteria 213, 253, 264(fig)
- Cycles
 - Calvin 248(fig)
 - Krebs's (forward citric acid) 255(fig)
 - of Fe^{3+} , SO_4^{2-} and carbon substrates 251(fig)
- Cyclic AMP, c-AMP 345
- Cyclic steady-state, *see* Steady-state
- Cytochrome P-450 262, 263, 346
 - protected oxidation in cytoplasm 262
- Cytoplasm
 - concentration of ions and molecules 132(table)
 - elements missing in early cells 134
 - free metallome 135(fig)
 - organic pathways 152(fig)
- D**
- Darwinism 468
 - and genes 425
 - approach to evolution 423–425, 424(fig) 459, 460
- Deep-sea trenches 441
- Degradation activity 359–360
- Dendrites 371(fig)
- Denitrification 260, 261(fig), 265(table)
- Design (intelligent) ix, 413
- Diatoms 287, 288
- Dioxygen, O_2
 - concentration signalling 260
 - evolution in the atmosphere 26(fig), 31, 220, 221(fig), 215(fig), 235, 332(fig)
 - geochemical effects 27, 28
 - input into the environment 29, 244, 245(table)
 - oxidation of elements and compounds 28(fig)
 - protection of reactions 162
 - recent evolution 332(fig)
 - rise of partial pressure with evolution 457(fig)
- Disorder 79, 80
- DNA
 - and i-RNAs 158–160, 309, 359, 448
 - and RNA machinery 149–153, 156–160
 - association to histones 228
 - axons 371(fig)
 - bacterial gene sequences 342
 - bases 147(fig), 148–149
 - chromosomes 309
 - coding 148(table)
 - conservative nature 194, 460
 - epigenetic mechanisms 229, 308, 309
 - exons 307
 - extensive and intensive properties 309
 - features 444
 - feedbacks to mutations 448
 - genes, *see* Genes and Genome
 - genetic code 148(table)
 - genotypes and chemotypes 443, 449
 - histones 228, 307, 308(fig)
 - in eukaryotes 307–310
 - in organic chemistry 309
 - in prokaryotes 228, 307–310
 - introns 307, 309
 - methylation 157
 - minicircular plasmids 307, 309
 - mutation trends 445, 446
 - nucleosomes 308(fig)
 - plasmids 229, 230(fig), 268, 307, 309
 - protection from offensive agents 445
 - satellite 229, *and see* Plasmids
 - strategic mutations 449(table)
 - telomeres 309, 444
 - transcription factors 228
 - transcription to RNA 308–310
 - transposons 309
 - Domains of life 195, 196(fig)
- E**
- Early cells, *see also* Cells
 - autocatalysed metabolism 201
 - chemotaxis 232
 - communication networks 202
 - conditions of viability 198–200
 - elements required 195, 196
 - energy sources 199
 - internal flows 232
 - metabolic pathways 201(table)
 - primitive enzymes 200(table)
 - proton gradients 198, 199
 - pumps 209(fig), 210
 - range of redox potential 197
 - reductive chemistry 194, 195, 196
 - size 198
- Earth
 - atmosphere 7, 8, *and see* Atmosphere

- basic chemical composition 417(table)
- composition 9(table), 11(fig), 12(fig), 17(table), 417(table)
- core 27(fig)
- crust 4, 12, 13(fig), 416
- distribution of elements 416
- ecosystem interactive flows 417(table)
- energy capture 422(fig)
- fissures in the surface 26
- formation of continents 23, 24(fig), *and see* Continents
- geochemistry 53–56
- geological processes 14(fig)
- hydrides 7, 28
- initial formation of minerals and gases 8–10, 11(table), 12(fig)
- major compounds 9(table), 12(fig)
- major zones 9, 10(fig)
- minority solids 12
- origin of water 15, 16
- oxides and sulfides 9, 11(table), 16, 17(table), 20(fig), 46(fig)
- physical characteristics 416
- physical effects on nature 4–7, 14, 15(table)
- singular nature 416(table)
- snow-ball times 7
- tectonic processes, *see* Continents
- temperature 5(fig), 6–7, 136
- Earth crust 4, 12, 13(fig), 416
- Ecological systems 87(fig), 118–121
 - cone of 459(fig)
- Ecosystems
 - and elements availability 457(fig)
 - approach to a fully cyclic condition 460
 - basic chemistry 74–75
 - biological chemotypes 382, 383, 421(table)
 - chemical changes in whole 331, 332
 - cone of ecological evolution 458(fig)
 - continuous gain and degradation of energy 434
 - cyclical 87(fig), 118–121, 93(fig)
 - design 455
 - driving force of evolution 197
 - ecological chemical systems 87(fig), 118–121
 - ecological principles for conserving processes 452(table)
 - flows 87(fig), 100(fig), 417(table)
- geological periods 21(table), 22, 23
- global 56, 74, 75
- inputs and impact of mankind activity 450–453
- interactive inorganic flows 417(table)
- sequence of events 456–460
- side effects of human activity 451(table)
- synergism, *see* Synergism
- uptake of energy 422(fig)
- wastes of human activity 405, 452, 453
- EF hand 210, 300, 336, 355
- Efficiency 153, 154, 187–190
 - overall efficiency of chemical organisation 105
 - survival of systems fitness 105, 153
- Efficiency and effectiveness 187–190
 - ATP-synthetase 188(fig), 187–190
 - of molecular machines 164, 187–190
- EGF domains 336
- Electron and proton transfer 70, 71, 176
- Electron-rich metal centres 171, 172
- Element biochemistry
 - after advent of O₂ 296(table)
- Elements
 - abundance 2, 3(fig), 13(fig), 40
 - availability 17, 51, 52, 245(fig), 417, 418
 - biochemistry after advent of O₂ 296(table)
 - biological functions 137, 138
 - cytoplasm metallome 336(fig)
 - distribution in planets 4, 8(table)
 - essential for life 417–422
 - formation 2–4
 - geochemical constraints on earth 136
 - in external fluids 335(table)
 - in medicine 405
 - in multicellular organisms 334(table)
 - involvement during evolution 433(fig)
 - metal ions 170–176
 - non-metals 168–170, 255–258
 - oxidation state 47, 48(fig)
 - periodic table 40(fig), 133(table), 416
 - spin state 49(table), 50(table)
 - stable nuclei 38(table)
 - successive oxidation potentials 241(table)
 - taken up by fungi and plants 334(table)
 - uses in compartments and signalling 342–355
- Endocrine glands 326(fig)

- Endocytosis 285, 286(fig)
- Endoplasmic reticulum 287, 288
- Energy 77, 78, 121–123, 406–408
 - and group transfer 172, 173
 - available 121
 - charge gradients and 226
 - degradation 85, 86, 87, 104
 - driving force of life and evolution 197
 - effective 85, 86
 - efficiency of use 407
 - flows 79, 91, 100(fig), 151
 - forms 78(table), 111(table)
 - generation by inorganic reactions 135, 199
 - inorganic sources from gases 135, 199
 - nuclear power 406, 407
 - radiant 93–95
 - rates of conversion and retention 95–96
 - reserves 54
 - sources 111(table)
 - storage in compartments 79(table)
 - storage in non-equilibrium inorganic systems 53, 54
 - thermodynamics 121–123
 - use and degradation 434
- Entatic (constrained) state 162, 163(table)
- Enthalpy 122
- Entropy 81, 86, 87, 122
 - of information 113
 - statistical 112–114
 - thermal disorder 85, 86, 87
 - thermodynamic 11–114
- Environment
 - and information 381(fig)
 - as an open system 426
 - chemical changes 331–333, 420
 - chemical sequence 429–431
 - effect of progressive oxidation 244, 245(table)
 - flows of energy and materials 387–389
 - impact of dioxygen 29, 244, 245(table)
 - impact of mankind 450–453, 451(table)
 - increase of pollution 405, 406
 - information effect 329, 381(fig)
 - ozone layer 333
 - possibilities for life 440–442
 - progressive oxidation 244–246, 312
 - reduction of non-metal compounds 247–251
- sequence of adaptation 245, 246
- structuring fields 84(table)
- Environmental change
 - and evolution 312
- Enzymes, *see also* by name and metals
 - constrained (entatic) states 162, 163(table)
 - primitive metabolic pathways 201(table)
 - primitive using metals 200(table)
 - specific metal ion catalysts 163(table)
- Epigenetics 229, 308, 309, 426, 448
- Epithelial cells 355
- Equilibrium binding 115
- Equilibrium constants 115, 121–123, 178, 179, 183–186
- Equilibrium constraints in cell systems 183–186
- Ethylene
 - and copper 339
- Eukaryotes
 - advantages and disadvantages over prokaryotes 288, 310(table)
 - cells 279(fig)
 - characteristics 277
 - compartmental oxygen metabolism 294
 - compartments of 59, 60, 264, 265(fig), 279(fig), 280, 289(fig)(table), 290, 296
 - connections to prokaryotes 283(fig)
 - cooperativity 310–312
 - development from the earliest anaerobic ancestors 273(fig)
 - distribution of elements 296(table)
 - evolution 278(table), *and see* Evolution
 - form 291
 - gene regulation and development 306–310
 - growth 291
 - interactions between 282
 - membrane 284, 15(fig)
 - messengers in single cells 301–315
 - metabolome 297
 - metallome 294(fig), 336(fig)
 - minerals in unicellular plants and animals 306, 341, 342(table)
 - multicellular *see* Multicellular organisms
 - mutual dependence of prokaryotes 310–312
 - novel features 281(table)
 - optimal energy capture 310

- organelles 280, 285(fig), 286, 287, 288, 297
- origin time of plants and animals 316(table), 317(fig)
- protection from dioxygen 292, 293
- proteins for metal ions 298(table), 299, 300
- proteome 297, 298(table)
- reproduction 291
- sexual reproduction 309
- size 277–280
- unicellular (protista) 282(table), 291
- use of elements 137, 138, 334(table), 417, 422
- Evolution
 - and environmental oxidation 244–246, 312
 - and increase of information transfer 383(table)
 - cone of ecological development 458, 459(fig)
 - cone-like tunnel of increasing variety 442
 - direction of 389, 390, 427
 - elements and materials usage 400, 401(table), 433(fig)
 - epigenetics 425, 426, 448
 - exploitation of available elements 120, 387, 388(table), 389
 - geological periods 21(table), 23(table)
 - growth of single cells 329–331
 - increase of information transfer 383(table)
 - maintained pathways 141(table), 143–149
 - of carriers of material and energy 408(table)
 - of codes 394(table)
 - of constrains 402(table)
 - of eukaryotes 278(table)
 - of flow 98, 99(table)
 - of message systems 409(table)
 - of multicellular animals 324–328
 - of multicellular fungi 323, 324
 - of multicellular plants 317–322(table)
 - of non-metal chemistry in aerobes 255–258
 - of organised systems 119–120
 - of prokaryotes 195–197, 269(table)
 - of species 425, 426, 427–429
- F
 - Faint young Sun paradox 6
 - Feedback control 108, 109(fig), 110(fig)
 - FeMoco 249(fig)
 - Ferritin 263
 - Fields of forces 84(table)
 - Filaments 435
 - requirement of copper and zinc 435
 - Fitness of chemical systems 420(table), 421
 - Flagella 232, 284
 - Flow 118–120
 - barriers 85(fig)
 - chemical thermodynamics of flowing systems 435(table)
 - evolution 98, 99(table)
 - gradients causing 102(table)
 - in Earth ecosystem 87(fig), 100(fig), 417(table)
 - in multicellular organisms 327(table)
 - of chemicals 151, 152(fig)
 - of energy 387, 389, 434
 - of materials 387, 389
 - Flowing systems 83(fig), 85(fig), 99(table), 435(table)
 - FMN flavin cofactor 357
 - FNR proteins 259
 - Form and information 103–105
 - Formation of atoms 37, 38(table), 39(fig)
 - Fossil deposits 306, 406
 - Burgess shale 306
 - Free radicals 445
 - Free-energy 121–123
 - Fully cyclic ecosystem

- Fungi
 - association with plants 323
 - evolution 323, 324
- FUR proteins 259

- G

- Gaia hypothesis 254, 461, 462
- Genes
 - and nervous system 381, 382
 - changes in eukaryotes 447
 - loss of 447
 - plasmids 229, 230(fig), 246, 268, 307
 - regulation and development 306–310
 - rejection of useless 447
 - shuffling 448
 - transposons 309, 448
- Genetic apparatus
 - features 444
- Genetic code
 - message systems 149, 153
 - triplet codons 148(table)
- Genetic structures
 - changes in 358, 359
- Genome 130, 131
- Genotypes and chemotypes 443–449
- Geochemical thermodynamic constraints of the elements on earth 136
- Geological periods
 - chemicals and fossil records 21(table), 23(fig), 25
 - isotope dating 23, 25
 - occurrence of deposits of minerals 23(fig)
- Giant stars 2–4, 37
- Giardia 280
- Gibbs free energy 48, 49, 121–123
- Glands 346, 377, 378
- Glial cells 374, 375, 377
- Global ecosystem 56, 74–75
 - basic chemistry 74
- Glutamate 372, 373(table), 377
- Glutathione peroxidase 340
- Glycolysis 340
- Glycosylation 336, 340
- Golgi apparatus 288, 336
- G-protein receptors 348, 356(table)
- Gradients, *see also* Charge gradients
 - calcium 266, 305
 - causing flow 102(table)
 - Na^+/K^+ 210, 370, 371, 438(table)
 - proton 178, 198, 199, 210, 226, 235
- Growth and differentiation 291, 329–331, 342, 343
 - control of sizes and shapes 329–331
 - of plants and animals 329–331
- Grypania 282(table)

- H

- Hard and soft acids and bases 47(table)
- Heme peroxidases 339
- Heme-dependent chitinases 354
- Heme-dependent ligninases 354
- Histone code 447
- Histones 228, 307, 308(fig)
- Homeostasis
 - calcium 355
 - of cell chemistry 419
 - pH 177
 - steady-states 151
- Homo sapiens 382, 454
 - distinguishing features as a chemotype 382
- Hormone-like messengers 344, 346
- Hormones 346(table), 347(table)
 - animals with nerves and a brain 346(table)
 - brain 378
 - glands 377, 378
 - plant 347(table)
- Human beings, *see also* Mankind
 - culture 410, 413
 - dependence on symbiotic internal organisms 396, 397
 - dependencies 397(table)
 - development of external message systems 398, 399, 409
 - evolution 388(table), 389(table), 398(table), 399(table)
 - genome 411, 412
 - increase of pollution 405, 406
 - internal ecosystem 397
 - language and development 400, 410
 - learning 410
 - message systems 409(table), 410
 - novel use of chemical elements 403–406
 - organisation of social life 410, 411
 - requirement of essential chemicals 396

self-consciousness 411
 storage and transmission of information 438(table)
 usage of elements and applications 400, 401(table), 403–406
 understanding of science 401–403
Humankind, *see* Mankind
 Hydrides 7, 28
 Hydrogen
 biological properties 177, 178
 special nature 73, 74
 Hydrogen bonding 165(fig)
 Hydrogen peroxide removal 246, 292
 Hydrogen sulfide 7, 18, 28
 in the atmosphere 18
 in the sea 18(table), 20, 30, 51
 Hydrogenases 200
 active site 200, 208(fig)
 nickel in 200, 207
 Hydrogenosomes 280
 Hydrolysis 17
 Hydrothermal vents 13, 441

I

Immune system 358
 Information
 and brain 394
 and environment 381(fig)
 and form 103–105
 definitions 112
 development of codes 393, 394(table), 437, 48(table)
 external 114, 115(fig)
 feedback 108, 109(fig), 110(fig), 117
 from the environment 329
 human externally coded 394(table), 404, 408, 453
 informed cellular systems 117(fig)
 intensity 374
 organic messages produced by oxidation 349(table)
 reproducibility 453
 small information transmitters 348(table)
 statistical and thermodynamic 113, 118
 storage of 438(table)
 transfer 105, 106, 149
 transmition and reception 105, 149, 345–351

Information transfer and reproducibility 453
 Initial formation of mineral and gases 8–10, 11(table), 12(fig)
 Inorganic compounds 41, 42
 barriers to change 52, 53
 energy storage in systems 53, 54
 Inositol triphosphate 350(fig)
 Intelligent design ix, 413, 450
 Intensive and extensive factors 130, 447, 448
 Interdependence of organisms, *see*
 Cooperativity
 Interfering RNA 158–160, 309, 359, 448
 Intron transcription 448
 Introns 307–309, 448
 Invertebrates
 evolution 324, 325
 sponges and medusa 325(fig)
 Iodine 51, 355
 Ionic assemblies 42(fig)
 Ionic compounds 42(fig)
 Iron
 and aerobic / anaerobic changes 259
 banded formations BIFs 22(fig) 245
 FNR 259
 FUR 259
 hydroxilases 339(table)
 oxidases 350
 regulation 259–260
 scavengers for 259
 storage in ferritin 263
 storage in magnetite 263
 uptake 259
 Iron / sulfur clusters 207, 208(fig)
 Irving-Williams series 45, 66, 67(fig), 73, 115, 175, 183, 216
 Isomers 60, 61

K

K^+ ion 199, 207, 348(table), 383
 Kinases 202, 348
 Kinetic constraints 116
 Kinetic controls 179, 180(fig)
 Kinetic energy 78(table)
 directional motion 79
 random motion 79, 80
 Kinetic stability 37, 43
 Kinetics of reactions 72

L

Language 400, 410
 Laws of Nature (ix), 413
 Life
 as a catalyst for energy degradation 428
 autocatalysed metabolism 201(table),
 204
 capture of energy 422(fig)
 domains 420(table), 424(fig)
 elements required 170, 225
 fitness of chemical systems 420(table),
 421
 fossil records 25
 major biopolymers 227, 228
 origins and development trends 4, 18,
 25, 136, 419, 420
 universal tree 424(fig)
 Life in deep-sea vents 440, 441
 Ligands, *see* Coordination compounds
 Light absorption 211–215, 218–220
 Light switches in plants and animals 357
 Lignin 340
 Ligninase 340
 Lipids 155(fig)
 LOV proteins 357

M

Magnesium
 association to nucleotide triphosphates
 205, 226
 condensation and hydrolysis reaction
 173, 174
 role in ATP 226
 Man, *see* Mankind and Human beings
 Manganese
 and glycosylation 340
 and lignin 340
 In cells 220, 221(fig)
 In oxidation reactions 213, 261
 In photosystem II 220, 221(fig)
 storage and use 295
 Mankind, *see also* Human beings
 changes in use of environment 395, 405,
 406
 culture 410, 413
 development of external activities 398
 energy and external machines 406, 407

exploitment of external organisation and
 information 394, 395
 humans as a new chemotype 306(table),
 397, 413, 422
 industrialised society 449, 450
 interference with the ecosystem 451–453
 Medical use of elements 405
 Membrane, biological 155(fig)
 Memory 374, 375
 Message cascades 346, 348, 350(fig)
 kinases and phosphatases 346, 348, 351
 Message systems
 evolution 409(table)
 first central coordination 325
 nerve system appearance 325
 Messengers 105, 107, 108, 345–351,
 372–374
 and glands 378
 and organisation in chemotypes
 437(table)
 between cells 345
 between cells in the brain 373(table)
 calcium messages 303–305
 cascades 348
 cyclic-AMP 345
 evolution 437(table), 438(table)
 evolution of message systems 409(table)
 feedback and controls 108, 109(fig),
 110(fig)
 hormone-like 344, 346
 humankind message systems 409(table),
 410
 in eukaryote single cells 301–315
 in nervous systems 370(fig), 371(fig)
 order of use in evolution 373(table)
 phosphate 302, 304
 primitive 231(table)
 produced by oxidation 349(table)
 production of chemical 345–351
 Metabolic pathways
 in prokaryotes 201(table), 202, 204
 Metabolism 175
 Metabolome 131, 204
 steps of synthesis of small molecules
 139, 140
 Metal clusters 207, 208(fig)
 Metal insertion 214, 215, 216
 chelatases 213
 Metal ions 170–176

- condensation and hydrolysis reactions 173, 174
- control by pumps 209(fig)
- controls of metabolism 175
- energy and group transfer 172, 173
- irreversible insertion 213, 214, 215, 216
- metallome 131, 135(fig), 336(fig)
- osmotic and electrolytic balance in cells 174
- oxygen transfer 173
- primitive roles 230, 231(table)
- reaction centres 176, 177
- reduction and oxidation catalysts 163(table), 171, 172
- rejection 175, 176
- release from sulfides 260, 261
- requirements for life 170
- stabilisation of structures 174
- Metallo-porphyrins 212(fig), 216(table)
 - advantages 216–218
- Metal reaction centres
 - irreversible metal insertion 214, 215, 216
 - primitive 206
- Metallome 131, 135(fig)
 - of advanced plants and animals 336(fig)
- Meteorites 4, 15(table), 26, 27, *and see* Carbonaceous chondrites
- Methane 6, 7, 243
- Methanogens 243(table)
- Mg-ATP production 199(fig), 204, 226(table), 248, 256(fig)
- Mineralization 341
- Minerals in unicellular plants and animals 341, 342(table)
- Minority solids 12
- Mitochondria 280, 285(fig)
 - cristae 285(fig)
 - synthesis of iron/sulfur and heme units 287
- Molecular machines 164, 187–190
- Molecular shapes 44(fig)
- Molecules 44(fig), 60, 61
 - motion 80
 - steps of biosynthesis of small 139, 140
- Molybdenum 50, 51, 52, 74
 - and cyanobacteria 253
 - and tungsten 441(table)
 - FeMoco 208(fig), 247, 249(fig)
 - major enzymes 252(table)
- Moco 222(fig)
- nitrogenase 253
- O-transfer 204, 205, 251
- reduction of acids to aldehydes 248
- reduction of NO_3^- 250
- Molybdenum cofactors 208(fig), 222(fig), 247, 249(fig)
- Moon 14, 15(table)
- Morphogens 347
- Multicellular animals
 - advantages of evolution 361(table)
- Multicellular cross-linking 351–355, 353(table)
 - by boron, silica and calcium 353
 - degradation by zinc metalloproteases 354
 - in animal tissues 353
 - involvement of non-metals (halogens, selenium and sulfur) 355
- metal enzymes of the external matrix 354(table)
- polysaccharides 352
- requirements 352
- role of copper and iron enzymes 353
- Multicellular eukaryotes
 - flow in 327(table)
 - morphological nature 317
- Multicellular organisms
 - chemical changes 333–335
 - cooperativity 361, 362
 - dependence on external supplies 361(table)
 - distribution of elements 334(table), 335
 - elements in extracellular fluids 335(table)
 - evolution 317, 341
 - metallome 336(fig)
 - new functional use of elements 333–342, 334(table), 336(fig)
 - new proteins 335–337
 - novel elements and organisation 383(table)
- Muscles 344
- Mutations 445, 446, 449(table)
- N
- NADH and NADPH
 - functions 205
- Nerves 369–373

- dendrites 371(fig)
- messages 370(fig), 371(fig)
- Na^+ K^+ gradients 370(fig), 371
- organisation of circuits 381(fig)
- synapses 371(fig)
- transfer of ions across membranes 370(fig)
- Nervous system 369–373, 381(fig)
- Networks of messages 202
- Neurons 371(fig)
- Nickel
 - and cellulose digestion 328
 - binding 293
 - reductive use in cells 171
 - in some bacteria 246
- Nickel and cobalt
 - decreasing value 340
 - transfer of H and carbon fragments in prokaryotes 340
- Nitric oxide (NO) 248
 - anammox bacteria 220, 248
 - in the atmosphere 248
 - planctomycetes 248, 264
 - sensing proteins 250
 - signalling 346
 - use before O_2 (?) 248
- Nitrogen fixation 247
 - energy cost 247
- Nitrogenase 253
- Non-metals
 - chemistry 255–258
 - function in cells 168–170
 - overall incorporation in life 138, 139(table), 140(fig)
 - primitive pathways 201(table)
 - reduction of environmental compounds 247
- Nootypes 454
- NOX proteins 250
- Nucleosomes 307, 308(fig), 447
- Nucleotide triphosphates
 - different uses 205, 206
- O
- Occurrence of biological elements in simple forms 45(table)
- Oceans, *see also* Sea
 - ridges 27(fig)
- Optical isomers 61
- Order 79, 80
- Order / Disorder 79, 80
 - and organisation 84, 108–110
 - changes of state of water 80(fig)
 - equilibrium 81
 - in polymers 81
 - motion of molecules 80(fig), 81
 - structuring fields 84(table)
 - thermal 85, 86, 87
- Organelles
 - chloroplasts 287, 288, 289(table), 297
 - mitochondria 280, 285(fig)
- Organic chemicals
 - acid-base reactions 60, 65, 71
 - in cells 58(table)
 - compounds of ecological relevance 57–58
 - informed systems 149–153
 - pathways 152(fig)
 - rates of organic reactions 62, 63
 - redox reactions 60, 65, 71, 116
 - retention of energy 97
 - stability and reactivity 58, 59, 60
 - stereochemistry 60, 62
 - thermodynamic and kinetic stability 58
- Organisation 84, 108–110
 - and compartments 105–108
 - messengers feedback and codes 108–110
- Organised systems
 - shape 96–98
 - steady-states, *see* Steady-states
 - structuring fields 84(table)
- Organisms, *see also* Multicellular organisms, Prokaryotes and Eukaryotes
 - animal-like 282–291
 - basic life cycle 240(fig)
 - classification 127–131
 - evolution of information 438(table)
 - fungi like 282–291
 - generalized element content 131, 132(table), 133(table), 134
 - plant-like 291
 - times of origin of major groups 25(table)
 - uptake of energy 422(fig)
 - use of space 436(table)
- Organo-metallic chemistry 63
- Organs
 - in animals 327(table)
 - in plants 330

Origins of life 418, 419, 420, *see also* Life
 Osmotic balance 174, 175
 Out of equilibrium conditions
 in the atmosphere 52
 of minerals of earth 54
 Oxyanions 46
 Oxidases 259(table)
 NO and O₂ based 267(fig)
 Oxidation of elements 28(fig)
 Oxidation states of elements 47, 48(fig)
 Oxidation-reduction potentials 68, 69(table),
 241(table)
 Oxides and sulfides 9, 11(table), 46(fig)
 Oxygen, *see also* Dioxygen, O₂
 transfer reactions 204, 205
 Ozone 90, 91
 Ozone layer 90, 91(fig), 95, 333

P

Pathways
 in cells cytoplasm 152(fig)
 and efficiency 153
 major primitive 201(table)
 maintained in evolution 141(table)
 Pentose shunt 139, 205
 Peptide hormones 346(table), 347
 Periodic table 40(fig)
 arrangement of electron shells 38, 39
 distinction between metals and non-metals 40–44
 of the biological elements 133(table)
 Periplasmic space 209(fig), 264, 265(fig), 296
 and oxidative metabolism 264
 Peroxisomes
 as defence mechanisms 289(table), 290
 Phagocytosis 285, 286(fig)
 Phosphatases 202
 Phosphate
 critical role 202
 messengers 302, 304
 uptake 140, 151
 Photosynthesis
 evolution in bacteria 213
 Photosystems 215(fig)
 Planetary systems 4, 7, 88
 Plants
 advantages of evolution 360(table)
 and animals 386, 387
 association with fungi 323
 capture of energy 319(fig)
 classical division 128(table)
 cooperativity 318, 319
 development 322(table)
 evolution of multicellular
 317–322(table), 360(table)
 growth from single cells 329–331
 hormones 347(table)
 morphology 319–320(fig)
 organs 330
 origin in time 316(table), 317(fig)
 protection from external damage 318,
 357, 358
 protection systems 318, 357, 358
 time of origin 316(table), 317(fig)
 tubular form 320(fig)
 use of light 357
 Plants and animals relationship 386, 387
 Plasmids 229, 230(fig.), 268, 307, 309
 genes 246
 Polymers, *see* Biopolymers
 Polynucleotides, *see* DNA and RNA
 Polysaccharides 169(fig)
 Porphyrins 216(table)
 synthesis 212(fig), 216(table)
 Primitive metabolic pathways 201(table)
 Prokaryotes
 advantages and disadvantages
 272(table)
 anaerobic, *see* Anaerobes
 as sources of materials and energy 311
 chemotaxis 232, 345
 chemotypes 269(table)
 classes of early 195, 196(fig), 197
 coenzyme and cofactors 202, 203(table),
 204, 205
 controls 230–232
 development 243(table), 268–274
 elements concentration in the cytoplasm
 207(fig)
 elements selection 224, 225
 energy flow in 225–227
 gene responses 228, 229
 metabolism 201(table), 202, 204
 metabolome 204
 metal reaction centres 206–211
 organisation 234(table)
 origins of anaerobes 195–197, 418, 419,
 420
 possible progression 269(table)

- primitive enzymes using metals 199, 200(table)
- primitive messengers 231(table)
- primitive roles of metal ions 231(table)
- proteome 161
- protoaerobes 244–246
- redox range of activity 243(table)
- redox range of activity of some chemo-types 180, 243(table)
- rejection of ions 235
- role of the elements 227(fig)
- sequence of development 268–274
- shapes and sizes 198
- steps of evolution 196, 197, 235, 236, 268–274
- transcription factors 228
- Protection systems 161, 162, 318, 357, 358
 - in animals 357, 358
 - in plants 318, 357, 358
- Proteins 164, 165(fig)
 - and energy transduction 167
 - antibodies 358
 - as biological machines 164, 166(fig), 187–190
 - calcium 356(table)
 - chaperones 161
 - copper 338(table)
 - enzymes, *see* Enzymes and catalysts
 - eukaryotes proteome 297, 298(table)
 - FMN flavin cofactor 357
 - FNR 259
 - folded 162(fig)
 - FUR 259
 - G-proteins 348, 356(table)
 - in membranes 161, 162(fig), 165, 166(fig), 167, 262, 263
 - in multicellular organisms 335–337
 - LOV 357
 - metal centres 176, 177
 - NOX 250
 - pumps 165, 166(fig), 167
 - secondary structure 165(fig)
 - SIR 248
 - ZUR 260
- Proteome 131
- Protoaerobes 244–246, 280
 - early anaerobic and proto-aerobic species 243(table)
 - handling of sulfate 247
- protection of cytoplasm 246, 247
- sensing systems 150
- use of metal ions 251–253, 259–262
- Protocells
 - fossil evidence 195
- Proton gradients 198, 199
- Pumps 166(fig), 209(fig), 210
 - evolutionary links between P-type ATPases 372(fig)
- Pyrite 12, 49, 55, *see also* Sulfides
- Pyrophosphate 54, 114, 116, 132, 136
- Q**
- Quanta of radiation 93, 94
- Quinones 167
 - membrane carriers 204
- R**
- Radiant energy 93–96
 - conversion 94, 95, 96
 - effect of earth 100(fig)
 - optimal rate 95, 96
- Radiolaria 306
- Rate constants 52, 53(fig), 71, 72(table)
- Rates of exchange 52, 53(fig), 71
 - idealised binding and rate constants 72(table)
 - Rates of water exchange 52, 53(fig)
- Red-bands 22(fig), 245
- Redox reactions 60, 65, 71, 116
- Redox potential controls 186
- Reductive reactions 194
- Reproducibility of information 453
- Reproduction
 - coded molecules 104
 - eukaryotes 29, 309
 - sexual 309
- Retinoic acid 346
- Ribosomes 158(fig)
- RNA
 - interfering 158–160, 309, 359, 448
 - life 159(fig)
 - messenger 157, 158
 - ribosomal 158(fig)
 - short 309
 - transfer 159(fig)
 - world 157–160
- Rock cycle 14(fig)

S

- Saccharides 169(fig), 352
- Sea
 - availability of elements 17, 51, 52
 - composition 18(table), 29(fig)
 - concentration of ions and molecules in early 132(table)
 - hydrolysis 17
 - initial formation 15–17
 - mid-ocean ridges 27(fig)
 - sulfate levels 30, 31, 51
 - sulfides 18, 20, 30, 51
- Sea water composition 18(table), 29(fig)
- Selection of elements 64(table), 65
- Selectivity of complexation and precipitation 64(table), 65
- Selenium 51, 170, 340, 347, 355
 - gluthatione peroxidase 340
- Self-consciousness 414
- Senses
 - and nervous system 368
 - order of development 367, 368(table), 369
- Sexual reproduction 309
- Shapes of molecules
 - stereochemistry 60, 61
 - structures 44(fig)
- Shells
 - calcium carbonate 328
- Siderophores 259
- Signalling
 - calcium 302(table)–305
- Silica
 - in flowering plants 304
 - uptake 328, 342(table)
- SIR proteins 248
- Small information transmitters 348(table)
- Snow-ball earth times 7
- Sodium
 - gradients 224, 235
- Sodium and potassium gradients, Na^+ K^+ 224, 235, 370, 371, 383, 438(table)
- Solar nebula 3, 4
- Solar system 4, 7
- Solubility products 18, 20(fig)
- Species 423–425, 443
 - and chemotypes 443
 - Darwin's approach 447
- emergence of novel 446(fig)
- Spirogyra 318(fig)
- Sporulation 210
- Stability and reactivity of organic chemicals 58, 59, 60
- Stability 78–79
- Stability constants 65, 115, 121, 183
- States of matter, water 80(fig)
- Statistical entropy 112–114
- Steady-states
 - anaerobic cyclic steady-state 180
 - and organisation 83, 84
 - clouds 83, 85, 98(fig), 95
 - cyclical 82, 85, 86, 87, 88, 90, 93(fig), 95, 96, 97
 - homeostasis 151
 - optimal 194, 322
 - ozone layer 90, 91(fig), 95
 - planetary systems 88
 - structuring fields 84(table)
- Steroid hormones 346(table)
- Sulfation in Golgi 288, 336
- Sulfides 11(table), 20(fig), 30, 46(fig), 56, 135, *see also Sea*
 - and evolution 55
 - as sources of energy 55
 - solubility products of 20(fig)
- Sulfur
 - PAPS 205
 - transfer 205
- Sun
 - faint young Sun paradox 6
 - formation 3
 - luminosity 6
 - radiant energy 6, 93–95
- Superoxide dismutase 246
 - CuZn 292–295, 339, 358
 - FeMn 292
- Survival fitness 153, 423
- Symbiosis 286, 310–312, 439, 440(fig)
 - coral banks 311
- Synapses 371(fig)
- Synergism 318, 319, 319(fig), 361, 362, 366, 367, 384–387, *see also Cooperativity*
- Systems
 - conditions 82(table), 85(fig)
 - ecological 87(fig)
 - equilibrium 81, 87

flowing 83(fig), 85, 98–103

isolated 87

metastable state 82

multicomponent 103–105

out-of-equilibrium inorganic 53, 54

stationary states 85, 85(fig), 86(fig)

T

Telomeres 309, 444

Temperature on earth 5(fig), 6–7, 136

Thermodynamic entropy 112–114, 115(fig)

Thermodynamic equilibrium 121–123

Thermodynamic and kinetic stability 37, 43

Thermodynamic description of chemotypes
421

Thermodynamic view of evolution
427–429

Thermodynamics

in flowing systems 435(table)
second law 427

Thylacoids 220, 284

Thyroxin 346(table), 355

Transcription factors

and allosteric switches 228
in prokaryotes 228
zinc 260, 309, 334, 344

Transition metal compounds 44, 46(fig), 49

Transmitters 371, 372, 348(table)

Transport

carriers of materials and energy
408(table)

Transposons 309, 448

Tree of life 424(fig)

Trenches, deep-ocean 441

Trichomonas 280

Triplet codons 148(table)

Trypanosome 282

Tungsten 50, 51, 223, 253, 441(table)

and molybdenum 134, 223, 441(table)

U

Ulva lactuca 318(fig)

Understanding of science by mankind
401–403

V

Vanadium 50, 51, 52, 253

accumulation in organisms 341

early uses 223(table)

handling of halides 340

nitrogenase 253

oxidation states 253

value in oxidising conditions 340

Vitamin B₁₂ 206

Volvox 321(fig)

W

Wall, bacterial 197, 209

Waste 240–242, 405, 428

derived from mankind activity 405, 452,
453

effect of O₂ 235

importance in material cycles 235

production 240(fig)–242

recycling 324

re-employment 311

rejection of ions 235

Water

changes of state 80(fig)

oxidation of 213, 215(fig)

Winds 89

Work 78

Z

Zinc 294, 295

as a master hormone 344, 347

cytoplasm content 333

early uses 223(table)

effects of deficiency 330

fingers 295, 297, 300, 309

functions 337, 338

in aerobic bacteria 260

in anaerobic prokaryotes 210, 223(table)

LIM homeobox domains 349

protein classes 337(table)

protein p-53 and cancer 349

transcription factors 260, 309, 334

Zinc-fingers 295, 297, 300, 309, 344