

## Index

Locators followed by 'n' refer to notes. Locators followed by 'g' refer to the glossary.

- acidity (pH), 38  
 active causation (efficient cause), 169,  
     177–178, 189  
 adaptability driver (Baldwin effect),  
     222–224, 233  
 adaptive improvisation, 209n  
 ageing, 117  
 altruism, 260–261  
 amoeba  
     aggregation in *Dictyostelium*, 51–52  
     movement, 97–98  
 anthropic principle, 263  
 antibiotic resistance, 118–119n  
 antibodies and antigens, 61–62, 195  
 apoptosis (cell death), 117–118  
 Archaea, 103, 106  
 Aristarchus, 7  
 astronomy, 1–12, 22–24  
     *see also* cosmology  
 atomic number, 36  
 atoms, 35–39  
 attractors, 76, 179–180  
 axons, 59–60
- bacteria, 33, 102–105, 107  
     evolution in, 103–105, 196  
     in the gut, 206  
 Baldwin effect (adaptability driver),  
     222–224, 233  
 Bangham, Alex, 41  
 behavioural transmission of epigenetic  
     markers, 221  
 Bernard, Claude, 163, 193–194  
 Beurton, Peter, 201  
 big bang theory, 74–75, 262
- Big Dipper (*Ursa Major*), 3  
 Biological Relativity, 181–182, 269  
     and the author's autobiography,  
     161–165  
     components constrained by the  
     whole, 167–168, 174  
     and evolution, 190–206, 232–238  
     levels and emergent properties,  
     64–65, 176  
     no privileged level of causation,  
     34–35, 160–161, 163–164, 168–173  
     organisms as open systems, 63–64,  
     173–174, 256–260  
     Spinoza's influence, 164–168  
     stochasticity, 174–176, 185n  
 'blind chance', 131, 249  
 'blueprint', as a metaphor, 132, 148–149  
 'Book of Life', 149–150  
 boundary conditions, 170  
 brain, 90  
 Brownian motion, 135  
 Buddhism, 254–255
- Caenorhabditis elegans* (nematode), 220  
 calcium ions, 50, 52–53, 101–102  
 Cambrian explosion, 108, 230, 245n  
 canalisation, 216–217  
 cancer, 119n  
 cardiovascular system, 56–57, 68n  
     cardiac rhythm, 83–86, 90, 214–215  
 Cartesian philosophy, 165–166, 261  
 catastrophism, 124  
 causality/causation  
     circular, 49–50, 63–64, 163–164  
     feedback loops, 80–81, 84–86

- and genes, 145–146, 150  
 no privileged level, 34–35, 160–161, 168–173  
 forms of, 169, 176–181, 189  
 in neo-Darwinism, 140–142, 189–190  
 and the time dilation effect, 19
- cells, 32, 48–51, 97–98, 171  
 compartmentalisation, 50–51, 98–99  
 death (apoptosis), 117–118  
 evolution, 113–114, 204–205  
 lipid membranes, 40–41, 50, 60  
 movement, 97, 99–102  
 polarity 88  
*see also* eukaryotes; prokaryotes
- Central Dogma, 127, 136–137, 197–200
- chaos theory, 75–76
- chemical elements, 35–39
- chloroplasts, 204–206
- chromatin, 202
- chromosome replication, 109–110
- cilia, 60–61
- circadian rhythm, 78–83, 147–148
- circular causality/causation, 49–50, 63–64, 163–164  
 feedback loops, 80–81, 84–86  
 and genes, 145–146, 150  
 no privileged level, 34–35, 160–161, 168–173
- circulatory system, 56–57, 68n
- classical (Newtonian) mechanics, 12–15
- ‘clock’ genes (*period*), 79–83, 147–148
- clones, 148
- closed systems, 173–174
- code, genetic, 136–137, 145–146
- coding, as causation, 180
- Coen, Enrico, 147
- common sense, 252–253
- complexity, 46, 73–76
- computers, early, 146, 162
- Comte, August, 252
- conditioned arising, 75–76, 176, 210n
- conjugation, bacterial, 103, 104–105
- connexins, 114–115
- consciousness, 68n, 257–258
- contextual logic, 256–260
- Copernicus, Nicolaus, 7–9
- cosmological constant, 26n, 263
- cosmology, 74–75, 262–263  
 in history, 1–12  
 number of particles in the universe, 23–24
- creative purposiveness (spirituality), 247–248, 251–252, 255–256
- Crick, Francis, 35, 197
- Cuvier, Georges, 124, 229
- cyclins, 110–111
- cytoskeleton, 99–102
- Darwin, Charles, and Darwinism, 121–126, 241–242n, 271g
- Darwin, Erasmus, 153n
- Darwin’s finches, 122, 226–227
- Dawkins, Richard, 208n  
*Selfish Gene*, 131, 261  
*Voices from Oxford* debate, 132, 138, 204, 205–206
- death, of cells, 117–118
- Denoth, Christoph, 187
- Descartes, René, 165–166, 261
- developmental biology, 132, 133–134, 217
- Dictyostelium discoideum* (slime mould), 51–52
- DiFrancesco, Dario, 214–215
- digestive system, 58–59
- DNA  
 as an aperiodic crystal, 91, 134–135  
 as a blueprint, 132, 148–149  
 in the Central Dogma, 136–137, 197–200  
 centrality/non-centrality of, 35, 53, 91–92, 150–152  
 as a code, 136–137, 145–146

- DNA (*cont.*)  
 junk, 89, 228–229  
 as a programme, 146–148  
 recombination, 112  
 replication, 102  
 transcription, 110  
 transposition, 120n, 201–204, 206, 231  
   mobile genetic elements, 196,  
   200–201, 274g  
   in prokaryotes, 103, 104–105, 106  
   in symbiogenesis, 204–205, 231  
 dogmatism, a bad thing, 127, 164, 236  
 downward causation, 80–81, 169  
*Drosophila* (fruit fly), 196  
 drug discovery, 215  
 Dupré, John, 158n
- Earth, position in the cosmos, 5–12,  
 17–18
- Eckhart von Hochheim (Meister  
 Eckhart), 265n
- efficient cause (active causation), 169,  
 177–178, 189
- Einsteinian relativity, 17–23, 26n
- electron microscopy, 30–31, 42
- electrons, 37–38
- emergent properties, 64–65, 176, 274g  
   cardiac rhythm, 83–86  
   circadian rhythm, 78–83  
   metronome synchronisation, 89–90  
   molecular level, 42–46
- endocrine system, 62
- environmental interactions, 49–50,  
 250  
   organisms as open systems, 63–64,  
   173–174, 256–260  
   *see also* epigenetics
- enzymes, 71–72
- epicycles, 26n
- epigenetics, 231–232, 273–274g  
   in the evolution of Darwin's finches,  
   226–227  
   modern, 219–222  
   Waddington's work, 169, 216–219
- epistemology  
   relativity of, 262–264  
   science vs religion debate, 247–256
- eukaryotes, 107–108  
   cell cycle, 108–112  
   evolution, 107–108, 117, 204–206  
   horizontal DNA transfer, 120n, 206  
   meiosis, 112  
   organelles, 47–48, 99
- evolution, 73, 88  
   bacteria, 103–105, 196  
   Darwinism, 121–126, 241–242n, 271g  
   epigenetics, 216–222, 226–227,  
   231–232  
   eukaryotes, 107–108, 117, 204–206  
   genomic re-organisation *see*  
   transposition  
   Lamarckism, 123–125, 256, 270–271g  
   neo-Darwinist view of, 126–128,  
   132, 236  
   neo-Darwinism and the Modern  
   Synthesis, 126–152, 268–269,  
   271–272g  
   criticisms of, 189–190, 199–200,  
   205–206, 222–224, 236  
   extensions to the theory, 133–134,  
   233–236  
   origin of life, 48–49, 86, 113–114  
   relativistic theory, 190–206, 232–238,  
   269  
   speed of, 229–232  
   tree of life, 103, 115–117
- evolutionary developmental biology  
   (evo-devo), 133–134
- evolvability, 234
- excretory system, 58

- extended evolutionary synthesis,  
 233–236
- eye colour, 129
- facilitated variation, 208n
- feedback loops  
 cardiac rhythm, 84–86  
 circadian rhythm, 80–81, 147–148
- final cause, 178–179
- Fischer, Paul, 187–189
- flat Earth model, 5, 6
- formal cause, 177
- fractal structures, 57
- free will, 257–258
- fruit fly, 196
- function, 178–179, 273g
- Galileo Galilei, 9–11
- gastrointestinal system, 58–59
- 'gemmules', 125, 241–242n
- General Theory of Relativity, 20–23,  
 27n
- genes  
 definitions, 140–143, 159n, 189, 228,  
 229, 273g  
 Mendelian genetics, 129–130  
 non-centrality of, 35, 91–92, 150–152  
 variation in expression patterns,  
 87–89, 175, 198, 219
- genetic assimilation, 217–218, 231, 233
- genetic code, 136–137, 145–146
- genetic drift, 133, 223–224
- genetic 'programmes', 146–148
- genome re-organisation *see*  
 transposition
- geocentric model, 5–6, 7
- geothermal vents, 114
- glycolytic pathway, 72
- goal-directedness *see* teleology
- gravitational lensing, 22–23
- gravity, 20–23, 27n
- greenish warbler, 224–225
- guitar manufacture, 187–189
- Hampshire, Stuart, 164–165
- Harold, Franklin, 116, 172
- Harvey, William, 56–57
- heart and circulatory system, 56–57, 68n  
 cardiac rhythm, 83–86, 90, 214–215
- heliocentric model, 7–10
- Hodgkin Cycle, 84–86, 164
- Holarctic redpoll finch, 244n
- holism, 274g
- horizontal DNA transfer, 103, 104–105,  
 106, 120n, 206
- hormones, 62
- Hubble telescope, 22–24
- Human Genome project, 149–150
- Huxley, Hugh, 30–31
- hydrogen ions, 38
- immune system, 61–62, 195
- inheritance of acquired characteristics  
 in bacteria, 103–105, 124–125, 196  
 epigenetics, 216–222, 226–227,  
 231–232  
 genetic assimilation, 217–218, 231, 233
- Lamarckism, 123–125, 256, 270–271g  
 neo-Darwinist view of, 126–128,  
 132, 236
- mobile genetic elements, 196,  
 200–201, 274g
- in plants, 153n
- symbiogenesis, 138, 206, 231
- integrationism, 274g  
*see also* emergent properties
- integuments, 62–63
- ions, 37–38, 39
- isolation of the germ cell line, 104, 127,  
 132  
 Weismann Barrier is not absolute,  
 191–194

- Jacob, Francois, 147  
 Johannsen, Wilhelm, 140, 141  
 ‘jumping genes’ (mobile genetic elements), 196, 200–201, 274g  
 junk DNA, 89, 228–229  
 Jupiter (planet), 10
- Keller, Evelyn Fox, 158n  
 Kelvin, William Thomson, 1st Baron, 14  
 Kimura, Motoo, 133
- Lamarck, Jean-Baptiste, and  
   Lamarckism, 123–125, 256,  
   270–271g  
   epigenetics, 216–219, 226–227,  
   231–232  
   neo-Darwinist view of, 126–128, 132,  
   236
- landscape concept, 75–76, 217, 258–259  
 Laplace, Pierre-Simon, 14, 166  
 Leeuwenhoek, Antony van, 48  
 levels in biology, 32–56, 64–65  
   and function/purpose, 54, 176,  
   222–223, 250  
 light, speed of, 18–20  
 light microscopy, 48, 56, 97  
 lipids, 40–41  
 lock and key model, 62, 71  
 Lorentz transformation, 28n  
 LUCA (last universal common ancestor), 117  
 lungs, 57  
 lymphocytes, 195
- Malpighi, Marcello, 56  
 Margulis, Lynn, 138, 204, 205–206  
 Martiensson, Robert, 241–242n  
 material cause, 177  
 mathematics, 14, 193  
   and reductionism, 163  
 Mattick, John, 201
- Mayr, Ernst, 132, 140  
 McClintock, Barbara, 200–201  
 meiosis, 112  
 Meister Eckhart, 265n  
 membranes, cellular, 40–41, 50  
   in early evolution, 114  
   insulation of nerve cells, 60  
 Mendel, Gregor, 129–130  
 metabolic networks (pathways), 69–72  
 metaphysics, 1–5, 11, 248–249, 262–264  
 metronomes, synchronisation, 89–90  
 Michelson–Morley experiment, 18, 28n  
 microscopes, 30–31, 42, 48, 56, 97  
 microtubules, 99–102  
 mitochondria, 204–206  
 mitosis, 108–112  
 mobile genetic elements, 196, 200–201,  
   274g
- Modern Synthesis *see* neo-Darwinism  
   and the Modern Synthesis  
 modularity, 82–83  
 molecules, 39–46  
 movement of/within cells, 97, 99–102  
 movement of organisms, 60–61, 97  
 muscle filaments, 30–31  
 musculoskeletal system, 61  
 mutations, variable effects, 92, 216
- natural genetic engineering, 274g  
   *see also* transposition  
 natural purposiveness, 111–112, 190,  
   194–197, 223, 249  
 natural selection, 122, 125–126, 132,  
   154n
- neo-Darwinism and the Modern  
   Synthesis, 126–152, 268–269,  
   271–272g  
 criticisms of, 189–190, 199–200,  
   205–206, 222–224, 236  
 extensions to the theory, 133–134,  
   233–236

- problems with terminology, 138–152  
 view of Lamarckism, 126–128, 132, 236
- nervous system, 59–60, 63, 90
- networks, 46–47  
 complexity, 46, 73–76  
 gene expression patterns, 87–89, 198, 215–216  
 interactions between levels, 46–47, 72, 80–81  
 metabolic, 69–72  
 no privileged level of causality, 168–173  
 oscillators and attractors, 76–86, 89–90, 179–180
- neutral theory of molecular evolution, 133
- Newton, Isaac, 12, 14
- Newtonian mechanics, 12–15
- niche construction, 222–224, 233
- Nicholas of Cusa, 8–9
- Noble, Denis, autobiography, 161–165
- Noble, Raymond, 162, 207n
- Nottale, Laurent, 29n
- nucleotides, 40
- nucleus, 47, 98
- Occam's razor (law of parsimony), 132–133, 138, 249
- ocelloid, 212n
- Oldenburg, Henry, 166–167
- open systems, 63–64, 173–174, 256–260
- Oresme, Nicole, 8
- organelles, 47–48, 99  
 evolution by symbiogenesis, 204–206, 231
- organisms as open systems, 63–64, 173–174, 256–260
- organs as systems, 54–55
- origin of life, 48–49, 86, 113–114
- Origin of Species* (Darwin), 121–123, 125–126
- oscillators, 76–86  
 cardiac rhythm, 83–86, 90  
 circadian rhythm, 78–83  
 synchronisation, 89–90
- paradigm shifts in science, 7, 131
- parsimony, 132–133, 138, 249
- particle–wave duality, 15–16
- period* gene, 79–83, 147–148
- periodic table, 36
- Perutz, Max, 35, 65–66n
- pH, 38
- phylogenetic tree, 103, 115–117
- physics, 12–24, 38–39, 135–136
- physiological (whole body) systems, 55–63, 97–98
- plants, inheritance in, 153n
- plastids, 204–206
- Plough (*Ursa Major*), 3
- Polaris (pole star), 3
- Popper, Karl, 65–66n, 199–200, 222, 223
- prime mover, 174, 177–178
- 'programme', as a metaphor, 146–148
- prokaryotes, 33, 102–107  
 evolution in, 103–105, 196  
 gut bacteria, 206
- protons, 35–36  
 hydrogen ions, 38
- pseudopodia, 60–61, 97
- Ptolemaic model of the universe, 5–6, 7
- punctuated equilibrium, 229–230
- purposefulness (teleology), 45, 54–55, 249–250  
 final cause, 178–179  
 natural purposiveness, 111–112, 190, 194–197, 223, 249
- purposive creativity (spirituality), 247–248, 251–252, 255–256
- quantum computers, 16–17
- quantum mechanics, 15–17, 135–136

- randomness (stochasticity), 91–92,  
 174–176, 185n, 272g  
 of genetic change  
   not random, 194–197, 203  
   random, 131, 133, 223–224, 249  
 in physics, 135–136  
 reductionism, 63, 65–66n, 73, 163,  
 247–249, 251–252, 274g  
   Cartesian 165–166  
   *see also* neo-Darwinism  
 relativity, 24–25  
   in astronomy, 6, 7–9  
   Einstein's theories, 17–23  
   in Newtonian mechanics, 13  
   *see also* biological relativity  
 religion vs science, 247–256  
   in astronomy, 8–9, 10–11  
 Replicator theory, 234  
 respiratory system, 57  
 retrotransposons, 201  
 reverse transcription, 198–199  
 ring species, 224–225  
 RNA  
   inheritance of sRNA in *C. elegans*,  
     220  
   reverse transcription, 198–199  
   transcribed from 'junk' DNA, 229  
 RNA world, 113–114  
 Romanes, George, 126  
 rotifers, 206  
 saltatory evolution, 230–232  
 scale  
   in biology, 30–33, 65, 171–172  
   of spiral waves, 76–77  
 scale relativity, 29n  
 Schrödinger, Erwin (*What is Life?*),  
   91–92, 134–136  
 science vs religion, 247–256  
   in astronomy, 8–9, 10–11  
 sea slug, 206  
*Selfish Gene* (Dawkins), 131, 261  
 selfish gene theory, 67n, 143–145, 208n,  
   228–229  
 sexual reproduction  
   in bacteria, 103, 104–105  
   in eukaryotes (meiosis), 112  
 sinus node, 90  
 skeleton, 61  
 skin, 62–63  
 Skinner, Michael, 226–227  
 sky at night, 1–4  
 slime mould, 51–52  
 Smith, John Maynard, 155n, 236  
 space-time, 20–23  
 Special Theory of Relativity, 17–20  
 speciation, 224–227  
   speed of, 229–232  
   *see also* evolution  
 spherical Earth model, 5–6  
 Spinoza, Bernard de, 164–168, 174  
 spiral formations, 76–77  
 spirituality (creative purposiveness),  
   247–248, 251–252, 255–256  
 squid, 53  
 stochasticity (randomness), 91–92,  
   174–176, 185n, 272g  
   of genetic change  
     not random, 194–197, 203  
     random, 131, 133, 223–224, 249  
   in physics, 135–136  
*Strategy of the Genes* (Waddington), 169,  
   216, 218, 247  
 subatomic particles, 38–39  
 sun, heliocentric model, 7–10  
 suprachiasmatic nucleus (SCN), 79  
 symbiogenesis, 138, 204–206, 231  
 symbiosis, 51  
 symmetry, breaking, 75–76, 88  
 synchronisation of oscillators, 89–90

- teleology, 45, 54–55, 249–250  
   contextual logic, 256–260  
   final cause, 178–179  
   natural purposiveness, 111–112, 190,  
     194–197, 223, 249  
 teleonomy, 45  
 temperature, 38  
 Third Way of Evolution (website), 245n,  
   250  
 time dilation effect, 19  
 tissues, 51–53, 114–115  
 trace elements, 37, 114  
 transcription, 110  
 transcription factors, 198, 219  
 transposition, 120n, 201–204, 206,  
   231  
   mobile genetic elements, 196,  
     200–201, 274g  
   in prokaryotes, 103, 104–105, 106  
   in symbiogenesis, 204–205, 231  
 tree of life, 103, 115–117  
  
 uncertainty principle, 16  
 unicellular organisms, 124–125  
   physiology, 58, 59, 60–61, 97–98  
   *see also* bacteria  
 University College London (UCL) in  
   the 1950s/1960s, 161  
  
 urinary system, 58  
*Ursa Major* (Plough), 3  
  
 vacuoles, 48  
 vascular system, 56–57, 68n  
 viruses, 115  
 vital energy, 41–42, 255–256  
*Voices from Oxford* (videoed debate),  
   132, 138, 204, 205–206  
  
 Waddington, Conrad, 169, 216–219,  
   247  
 Wallace, Alfred Russel, 123  
 water, properties of, 43–44  
 Watson, James, 65, 207n  
 wave–particle duality, 15–16  
 weather systems, 75–76  
 Weismann, August, 126–128, 194  
 Weismann Barrier, 104, 127  
   not absolute, 191–194  
 West-Eberhard, Mary Jane, 133–134  
*What is Life?* (Schrödinger), 91–92,  
   134–136  
 white blood cells, 195  
 Wilkins, Adam, 147  
 Woese, Carl, 102, 106  
  
 yeast, knockout mutations, 92, 216