Index

anthropocentricity, 10
anthropologists
  Berger, Lee, 191
  Denning, Kathryn, 482
  Johanson, Donald, 186
  Leakey, Louis, 185
  Leakey, Mary, 185
  Weidenreich, Franz, 188, 395
are we alone?, 15
  fictional scenario, 17
  notion of 'now', 52
artificial intelligence
  computers and consciousness, 321
  critique, 323
  digital superintelligence, 317
  general, 316
  singularity, the, 318
  Turing test, 322
astronomy
  'Oumuamua, 485
  2 I/Borisov, 486
  advances in technology, 101, 102
  Alcubierre drive, 131
  Allen Telescope Array, 105
  Arecibo radio telescope, 483
  Aristarchus of Samos, 49
  Aristotle, 49
  Betelgeuse, 52
  biosignatures, 472
  Chandra X-ray Observatory, 103
  Compton Gamma Ray Observatory, 103
  Copernican Principle, The, 112
  Earth
    our position, 52
  Earth similarity index, 112
  European Space Agency, 102
  exoplanets
    astronomical art, 118
    basic types, 114
      gas giants, 114
      Neptune-like, 114
      super-Earths, 114
      terrestrial, 114
    classification, 114
    confirmed instances, 114
    criteria for 'Earth-like' exoplanets, 116
    discovery, 101
    Earth analogues, 109, 114
    Earth-like, 114
    Gliese 581 g, 117
    habitable zone, 108
    history of search, 115
    Kepler 22b, 108, 117
    methods for finding, 106
      direct imaging, 108
      gravitational microlensing, 108
      radial velocity method, 107
      transit method, 106
    Proxima Centauri b, 13, 117
    rogue planets, 109
    Ross 128b, 117
    search
      time factor, 16
    search for exoplanets, 115
    Trappist 1, 117
  Gaia space telescope, 103
  galaxies
    Andromeda, 55
    formation, 54
    Great Attractor, 55
    Laniakea Supercluster, 55
    Large Magellanic Cloud
      Tarantula Nebula, 58
    MACS0647-JD, 53
  galaxies, distant, 53
  Galilean moons, 49
  Habitable Exoplanet Observatory
      (HabEx), 105

astronomy (*cont.*)
habitable zone, 77
heliocentric and geocentric views, 49
history of astronomy, 48
Hubble Deep Field, 15, 53
Hubble Extreme Deep Field, 53
Hubble Space Telescope, 53, 102
Hubble Ultra Deep Field, 53
Hubble, Edwin, 53
James Webb Space Telescope, 15, 52
Jupiter, 26, 49, 60, 70, 82, 92, 107, 108, 115, 118, 119, 120
Jupiter Icy Moons Explorer, 120
Kepler Space Telescope, 104
Kuiper Belt, 485
light, speed of, 56
Mars, 5, 26, 92, 96, 124, 351, 391, 443, 485
Meerkat radio astronomy observatory, 106
Mercury, 36, 92, 116, 124, 391
METI (Messaging Extraterrestrial Intelligence International), 477, 583
Milky Way, 51
Eagle Nebula, 58
moons
Calisto, 120
Enceladus, 123
Europa, 120
exploration, 123
possible contamination, 123
possible habitat, 121
subglacial ocean, 123
exomoons
possible habitats, 125
Galilean moons, 118
Ganymede, 120
locus of microbial life, 125
potential habitats, 118
Titan, 124
Mount Wilson Observatory, 53
multiverse, 88
infinite extension?, 90
other bubble universes, 90
Nancy Grace Roman Space Telescope, 105
NASA (National Aeronautics and Space Administration), 102
National Science Foundation, 102
Neptune, 92, 391, 471
Oort Cloud, 143
Planetary Habitability Index, 112
planets
atmosphere, 78
axial tilt, 78
moons, 77
rocky planets, 77
Pluto, 133, 351
Proxima Centauri, 134
Ptolemy, 49
Rare Earth hypothesis, 110
Saturn, 26, 82, 92, 107, 123, 124, 126, 391
SETI (search for extraterrestrial intelligence), 105
size of universe
position of Earth, 48
Solar System
position, 51
space exploration
assessing probabilities, 135
distances involved, 133
Drake equation, 138
deconstruction, 138
exoplanetology, 139
Fermi paradox, 135
proposed solutions, 136
interstellar travel, 129
limits, 128
New Horizons spacecraft, 133
probes, 132
relative chronology, 132
Voyager I, 133
Golden Record, 134
Spitzer Space Telescope, 103
stars
Alpha Centauri, 59
black holes, 62
brown dwarfs, 60
constellations
Camelopardalis, 53
Libra, 60
Plough/Big Dipper, 54
formation, 58
gamma-ray bursts, 62
Gliese 581, 60
lifespan, 61
neutron stars, 62
origin of elements, 63
red dwarfs, 59
solar flares, 59

structures
small-scale and large-scale, 91
underlying basis, 92
technosignatures, 472
Theia, 143
Titan, 124
Transiting Exoplanet Survey Satellite (TESS), 104
type of signal, 475
universe
Big Bang, 50
first second, 50
time of origin, 50
development, 50
Hubble volume, 54
observable universe, 54
organic compounds, 75
temperature question, 75
universe, size of, 47, 53
Uranus, 92, 391
Venus, 22, 42, 49, 92, 111, 119, 391
Very Large Array, 106

cephalopods, 156, 463
cetaceans, 23, 29, 179, 251, 253, 254, 527
cultural figures
Botticelli, 243
Caravaggio, 243
Cervantes, Miguel de, 243
da Vinci, Leonardo, 243
Goethe, Johann von, 343
Michelangelo, 243
Monteverdi, Claudio, 243
Raphael, 243
Shakespeare, William, 243
Titian, 243

Darwinian evolution, 10, 17, 21, 41, 42, 141, 146, 315, 332, 411, 437, 450, 581

Earth
dynamism of environment, 149
energy gradients, 150
epiphenomena, 95
exobeings
alternative phenotypes, 456
are they observing us?, 44
arrow of time, 469
attempted contact
language-independent messages, 483
Arecibo message, 484, 485, 583
Breakthrough Listen project, 487
predicting reactions, 491
behaviour, 453
biological rhythm, 9
biology, carbon-based, 8
characteristics, 8
brains, 27
cognition
limits, 281
common features with humans, 461
comparison with humans, 23
consciousness, 315
definition, 7
did they ever visit us?, 44
differences, possible, 42
energy intake, 220
energy regime, 147
events implying their existence, 584
evolutionary environment for intelligence, 254
existence, stage of their, 64
feelings, 457
first contact, 479
some scenarios, 479
free will and morality, 458
general preconditions, 581
interest in humans?, 478
language, 9
language faculty?, 380
lifespan, 279, 450
means for counting, 466
mental lives, 325
minimal requirements, 442
possible find scenario, 489
possible make-up, 461
further features, 463
possible sexual reproduction, 173
question of scale, 452
relative intelligence, 463
sense of time?, 467
technology, 8
use of oxygen, 203
weirdness, possible, 41
exolanguage, 583
acquisition, 421
airstream, use of ?, 369

exolanguage (*cont.*)
basic questions, 574
colour terms?, 353
common language, 424
complexity envelope, 362
design features, possible, 338
different types?, 368
hearing, 567
internal and external aspects, 332
internal organisation, 366
kinship terms?, 354
knowledge of language, 358
language faculty, 559
language impairment, 408
linguistic relativity, 348
media for conservation, 389
modality
sign language?, 387
names, 351
one per planet?, 395
possible comprehensibility, 568, 570
production, 566
reflection of world, possible, 350
relative loudness, 567
structure, 544
use of sound?, 527
exoplanets
alternative biologies, 454
alternative ecologies, 453
animal communication, 432
assumptions, detailed, 20
assumptions, general, 18
climate, 225
conditions, possible, 87
evolution, 21
exosocieties
art, existence of, 241
money, use of, 241
fictional search, 11
genetics, 241
geography, 227
linguistics, xxiii
mass extinction events, 84
mass extinctions, possible, 84
medicine, possible, 241
quantity in existence, 182
reverse implication scale for life, 488
societies, 232
space exploration, 491
telling time, 470
violence, question of, 233

genetics
epigenetics, 540
haplogroup, 190
mitochondrial DNA, 190
Y chromosome, 190
geology
Chibanian period, 186
Pleistocene epoch, 186
Pliocene epoch, 186
Great Filter hypothesis, 66

history
Anthropocene, 126
Archaean Era, 144
Cambrian 'explosion', 151
Devonian period, 152
extinction events, 83
Great Oxygenation Event, 85
K–Pg extinction event, 81, 144
Late Cretaceous extinction event, 85
Late Devonian extinction event, 85
Late Ordovician extinction events, 85
Late Permian extinction event, 85
Late Triassic extinction event, 85
Toba eruption, 149
future of the Earth, 65
future of the universe, 68
geologic timescale, 144
Göbekli Tepe, 65
Hadean Era, 144
Late Heavy Bombardment, 144
humans
animals
cognitive tradeoff hypothesis, 428
communication across species, 430
comparison with humans, 425
joint attention, 428
language analogues, 430
relative intelligence, 426
artefacts, 164
brain, 313
aging, 278
brain waves, 262
cognition, 280
'Cartesian theatre', 285

communication, 282
limits, 281
notion of object, 283
notion of self, 283
patterns, our love of, 287
theory of mind, 283
working memory, 282
world we perceive, the, 286
cognitive gap to higher primates, 226
consciousness, 290
attention, role of, 306
awareness, 302
determinism and free will, 297
emotions, origin of, 293
emotions, role of, 292
explanations, proposed, 295
fundamentalism, 314
hard problem, the, 294
ideas, origin of, 299
information integration, 298
location, possible, 305
memory, 309
memory, working, 306
metaphors used, 301
metaphysical reality?, 300
panpsychism, 314
personal identity, 300
quantum origins?, 308
reductionism, 314
relation to brain size, 304
relation to unconsciousness, 307
energy regime, 262, 269
energy requirements, 207
evolution (Wallace's puzzle), 252
extending the mind, 465
feedback loops, role of, 252
flexibility, 263
hearing, 266
language and aging, 278
necessity for survival, 255
neuroplasticity, 312
proliferation of neurons, 273
relative size, 251
senses, 264
binding problem, 268
sight, 265
smell, 267
structure, 256
basal ganglia, 258
brain stem, 257
cerebellum, 257
cerebrum, 259
glia, 261
limbic system, 258
amygdala, 259
cingulate cortex, 258
hippocampus, 259
hypothalamus, 259
thalamus, 258
neurons, number of, 260
taste, 268
touch, 267
brain-to-body weight, 206
childhood and puberty, 274
consciousness
sentio ergo sum, 324
cultural evolution, 239
culture and technology, 242
embryogenesis, 271
energy regime, 147
homeostasis, 204
lifespan and aging, 276
societies, 228
cultural buffering, 239
farming, advent of, 237
origins, 229

immune system, 545
innate and adaptive, 545
organisation, 547
information and knowledge, 31, 36

language
acquisition, 330
abduction and ambiguity, 418
characteristics, 415
exposure to language, 414
language transmission, 419
logical problem, 420
native language, 413
pidgins and creoles, 420
stages, 416
triggering, 411
unconscious knowledge, 412
anatomical foundation, 330
anatomy and cognitive evolution, 371
characterisation, 330

language (*cont.*)
cognitive categories, 349
complexity envelope, 360
constructed languages, 422
Basic English, 423
Esperanto, 422
Interlingua, 423
Volapük, 422
definitions, 333
design features, 333
general, 334
physical, 336
semantic, 337
digital infinity, 543
English, sounds of, 570
environment and culture, 352
evolution, 330, 503
'mother tongues' hypothesis, 517
beginning, 504
brain, 560
neural oscillations, 561
chronology, possible, 496
computational models, 495
contact calls, 507
conventionalisation, 522
deception, 514
direct to symbolic reference, 515
discontinuity hypothesis, criticism of the, 539
early triggers, 505
externalisation or internalisation, 541
from the concrete to the abstract, 518
geographical origin, 498
gestures, 507
gossip, 506
grammar and compositionality, 529
grammaticalisation, 522
grooming, 505
holistic or atomistic, 520
increase in complexity, 499
independence of the here and now, 518
innateness, 557
iterated learning, 530
just once?, 500
language and inner speech, 553
language and introspection, 552
language and memory, 562
types, 564
language and thought, 549, 551
language as an instinct, 557
language faculty, 554
levels of language, 523
lexical proto-language, 521
mirror neurons, 509
morphology, 532
differences across languages, 533
gender, 534
niche construction, 504
Out of Africa, 499
pointing, 509
primacy of spoken language, 550
proto-language, 515
Proto-World, 395
qualitative leaps, 518
relative complexity, 554
rise of complex structures, 520
ritualistic language, 513
role of music, 511
role of sexual selection, 512
role of song, 510
sound systems, 524
stress differences, 526
use of tone, 526
sources of structure, 555, 564
syntax, 535
Merge operation, 537
outside language, 542
non-temporal word order, 541
origin, 536
recursion, 537
system expansion, 524
words and meanings, 528
gene for language?, 421
language change, 396
language faculty, 378
constraints and conditions, 379
externalisation modality, 380
haptic, 384
sign languages, 382
nature, assumed, 379
receptive modality, 384
relation to childhood, 380
levels of language, 362
bottom-up approach, 364
lexis, 365
morphology, 365
phonetics

possible sound sequences, 355
phonetics/phonology, 364
pragmatics, 366
semantics, 365
syntax, 365
well-formedness, 357
names, 350
primary purpose, 331
production, 368
consonants, 372
types, 374
convergent evolution, 377
tongue and throat, 369
vowels, 372
formants, 375
production, 374
reading, 408
recognising shapes, 409
reception
hearing, 371
reflection of world, 348
colour terms, 352
kinship terms, 353
relation to cognition, 330
relation to writing, 387
speakers' intuitions, 357
structure, 330
talking about language, 343
unconscious knowledge, 354
without writing?, 389
written documents, 388
language and the brain, 399
arcuate fasciculus, 403
areas, 399
binding problem, the, 403
Broca's area, 402
primary auditory cortex, 403
primary motor cortex, 403
primary visual cortex, 403
Wernicke's area, 403
language groups
Afro-Asiatic, 394
Caucasian, 394
Celtic, 572
Dravidian, 394
Germanic, 313, 572
Indo-European, 351, 394, 572
Nostratic, 394
Sanskrit, 572
language pathology, 404
aphasia, types of, 405
specific language impairment, 407
Williams syndrome, 408
languages
Akrikaans, 556
Arabic, 367, 387, 556
Bantu-Nguni
Xhosa, 499
Zulu, 499
Basque, 340
Caucasian languages, 361
Chinese, 313, 323, 354, 362, 388, 510, 519, 526, 556
click sounds, 499
diversity on Earth, 390
Dutch, 351, 388, 397, 421
effect of geography, 391
Finnish, 350, 362, 367, 388, 534, 556
French, 334, 387
Georgian, 556
German, 313, 331, 340, 345, 351, 354, 362, 534
Gothic, 572
Greek, 340, 387, 572
Hawaiian, 361, 556
Hebrew, 387, 556
Hindi, 331
Hittite, 572
Hungarian, 362, 534, 556
Irish, 355, 556
Italian, 345, 387, 510, 534
Japanese, 268, 313, 331, 387, 388
Korean, 388
Latin, 555, 572
linguistic dominance, 392
Malay, 556
Old English, 355
original language?, 393
Persian, 387
polysynthetic, 521
Quechua, 390
Rotokas, 499
Russian, 313, 331, 334, 340, 345, 355, 362, 387, 534, 555, 556
San languages, 499
Silbo Gomero, 528
Spanish, 348, 388, 390, 421, 423, 528, 534, 559

languages (*cont.*)
structural complexity, 361
Swahili, 331
Swedish, 510, 534
Tagalog, 367
Thai, 354
the first language?, 393
Turkish, 367
Urdu, 387
Vietnamese, 313, 362, 510, 556
life
abiogenesis, 438
alternative biologies, 98
assumptions about exolife, 438
asteroid strikes, 84
basic preconditions, 70
beginnings, 151
being out of sync, 445
carbon and water availability, 72
definitions of life, 145
devices and organisms, 165
emergence, 93
criticism, 94
limits to complexity, 95
strong and weak, 93
evolution
'design' from below, 162
analogous and homologous structures, 180
basic questions, 25
bipedality, rise of, 81, 208
bodily adaptations (hard tissue), 180
control from above or below, 160
convergent evolution, 177
cultural evolution, 158
dinosaurs
demise, 80
divergent evolution, 176
ears, 212
from sea to land, 80, 82
genes and phenotypes, 159
genesis of organic structure, 161
genetic mutation, 175
hands
development of, 211
power and precision grip, 211
kinds of evolution, 157
macroevolution, 158
marine life, 177
marine life in the air, 178
microbes, rise of, 79
microevolution, 158
our history, 143
post-biological, 27
profusion in nature, 181
prokaryotes to eukaryotes, 82
setbacks, 223
climate fluctuations, 224
evolution and design, 166
exolife, appearance of, 448
extremophiles, 41
fine-tuning problem, 88
from cell to organism, 169
functions of the whole, 167
habitat independence, 441
health and disease, 176
key developments, 79
issues, 82
likelihood, 69
likelihood of exolife, 441, 443
meiosis and crossing over, 174
origin in sea, 152
panspermia hypothesis, 438
photosynthesis, 74, 455
post-biological, 446
post-human, 446
principles and realisation, 154
questions of scale, 168
range of search for exoplanets, 437
research into basis, 147
rise of predators, 155
role of chance, 96
search for life, 100
serendipity, role of, 444
sexual reproduction, 170
cost, 172
single occurrences, 97
variation and evolution, 174
linguistics
Critical Period Hypothesis, 276
deciphering language, 571, 572, 573
Linear B, 572
Rosetta Stone, 572
historical background, 359
language typology, 367, 534
word order, 367
linguistic relativity, 346
linguistic relativity hypothesis, 348

minimalist program, the, 539
onomatopoeia, 344
structural notions, 338
arbitrariness, 340
competence, 339
diachrony, 339
iconicity, 345
language, 339
open and closed classes, 341
paradigm, 340
parole, 339
performance, 339
processes, 342
rules, 342
signifiant, 339
signifié, 339
sound symbolism, 344
synchrony, 339
syntagm, 340
Voynich Manuscript, 572
linguists, 338
Atkinson, Quentin, 395, 499
Bickerton, Derek, 497, 498, 504, 529, 551
Bloomfield, Leonard, 410
Chomsky, Noam, 39, 331, 333, 339, 378, 536, 537, 538, 539, 540, 541, 542, 543, 550
Curtiss, Susan, 415
Dolgopolsky, Ahron, 394
Fitch, W. Tecumseh, 332, 370, 425, 431, 496, 497, 503, 511, 514, 517
Greenberg, Joseph, 394
Hockett, Charles, 334, 518, 552
Hrozný, Bedřich, 572
Hurford, James, 515
Jespersen, Otto, 423
Johansson, Sverker, 507
Jones, Sir William, 572
Pinker, Steven, 329, 493, 560
Sapir, Edward, 347
Tomasello, Michael, 428, 429, 459, 551
Trombetti, Alfredo, 393
Ventris, Michael, 572
Whorf, Benjamin Lee, 347

paleoanthropology, 185
Afar Triangle, 186
anatomically modern humans, 200
brain size, 200
tongue shape, 201
Ardipithecus ramidus, 207, 210
Australopithecus, 193
Australopithecus afarensis, 207
Blombos Cave, 200
consciousness, development of, 199
Cradle of Humankind, 191
Denisova cave, 188
Denisovans, 198
divergence of *Homo* and *Pan* genera, 81
Divje Baba Cave, 512
fire, management of, 81
Flores island, 188
Fuyan Cave, 188
Great Rift Valley, 186
Hadar region, 186
Hominid No. 7, 186
hominids, 192
hominins, 95, 156, 183, 192, 225
hominoids, 192
Homo erectus, 17, 195
Homo ergaster, 207
Homo floresiensis, 191
Homo habilis, 17, 194
Homo heidelbergensis, 207
Homo longi (?), 198
Homo naledi, 191
Homo sapiens, 111, 149, 184, 186, 190, 191, 196, 197, 199, 200, 202, 205, 208
anatomy and physiology, 208
classification, 192
clothes, 213, 221
use of shoes, 222
controlling fire, 213, 216
cooking, 213, 217
gain in time, 220
nutrients, 217
social effect, 220
Cro-Magnon, 494
cultural definition, 213
food intake, 218
loss of fur, 221
tool production, 213
Homo species, 194
brain size, 205
energy intake, 202
increase in brain size, 207
Jebel Irhoud, 188
Kenyathropus platyops, 190

paleoanthropology (*cont.*)
last common ancestor, 185
Liang Bua Cave, 191
Mislaya Cave, 188
Neanderthals, 112, 184, 196
Olduvai Gorge, 186
Orrorin tugenensis, 207, 210
Out of African hypothesis, 190
Paranthropus, 193
Paranthropus aethiopicus, 190
Paranthropus boisei, 185, 190
Paranthropus robustus, 190
Peking Man, 188
primates, first, 80
Rising Star cave complex, 187
Dinaledi Chamber, 191
Sahelanthropus chadensis, 207
Skhul Cave, 188
Solo Man, 186
tools, 215
Acheulean (Mode II), 195, 205, 215
Mousterian (Mode III), 215
Oldowan (Mode I), 195, 200, 215
palaeontologists
Shubin, Neil, 152
palaeontology
Tiktaalik, 152
philosophers
Churchland, Patricia, 459
Dennett, Daniel, 285
Descartes, René, 324
Fodor, Jerry, 549
Grice, Herbert Paul, 517
McGinn, Colin, 282
Occam, William of, 33
Putnam, Hilary, 281
Searle, John, 322
Wittgenstein, Ludwig, 410
pinnipeds, 253
predation, 12, 21, 155, 191, 229, 254, 266, 444
prerequisites for scientific development, 243
probability of exolife, 4
basic questions, 5
proof, nature of, 34
psychologists
Baddeley, Alan, 282
Vygotsky, Lev, 553
scholars
Ogden, C. K., 423
Schleyer, Johannes Martin, 422
Zamenhof, Ludwig, 422
science
exceptions, nature of, 40
facts, 37
unexplained, 38
problems and mysteries, 39
weird life, 40
science and zeitgeist, 35
science fiction, 245
scientists
Alcubierre, Miguel, 13, 131, 480
Bohr, Niels, 280
Broca, Paul, 402
Cavalli-Sforza, Luigi, 394
Copernicus, Nicholas, 49
Crick, Francis, 149
Darwin, Charles, 148, 157, 176, 193, 268, 280, 329, 458, 495, 512, 513, 551
Dawkins, Richard, 156
Dehaene, Stanislas, 409
Diamond, Jared, 482
Drake, Frank, 483
Einstein, Albert, 13, 32, 33, 36, 57, 100, 131, 280
Faraday, Michael, 280
Fraknoi, Andrew, 486
Franklin, Rosalind, 149
Galileo, Galilei, 49, 50, 118, 243
Gliese, Wilhelm, 351
Gould, Stephen Jay, 497
Hawking, Stephen, 482
Hoyle, Fred, 50
Huttner, Wieland, 273
Huygens, Christiaan, 124
Kardashev, Nikolai, 137
Kepler, Johannes, 49
Kirby, Simon, 530
Leibniz, Gottfried, 280
Loeb, Avi, 486
Maxwell, James Clerk, 280
Mendel, Gregor, 148
Messier, Charles, 483
Morgan, Thomas Hunt, 148
Newton, Isaac, 280
Planck. Max, 280

Rees, Martin, 33
Sagan, Carl, 483, 486
Schrödinger, Erwin, 145
Semon, Richard, 563
Turing, Alan, 322
von Neumann, John, 486
Watson, James, 149
Wernicke, Carl, 403
Wilkins, Maurice, 149
Williams, John C. P., 408
Zackrisson, Erik, 64
'set of one' issue, 3
sociologists
Durkheim, Émile, 339
speculation, informed, 24, 32

technosignature
conclusions from one, 7

Voynich, Wilfrid, 573