vsnk$all.qxd 7/8/05 9:06 AM Page 603

Index

Page numbers in *italics* refer to illustrations.

aaATIII, 222
Abbott, A., 585*n*
Abbott, Larry, 170, 542*n*
Abbott Laboratories, 282
ABC News, 393
Abduljalil, A. M., 540*n*
Abeln, G. C., 562*n*, 563*n*
Abrams tanks, 332, 335
abstraction, 16, 175, 198
"Accelerating Change" conference, 504*n*
accelerating returns, law of, 3, 7–14, 29, 35–110, 371, 373, 432, 441, 457, 507*n*–26*n*
  communications and, 35, 48–50, *48–50,* 73, 76–77, *77,* 97, 102, 245–46, 511*n*–12*n*
  computer memory and, 57–58, *57, 58,* 59, 75–76, *75, 76,* 96, 102
  conservatism of social institutions and, 472–73
  DNA sequencing and, 73–74, *73, 74,* 514*n*
  economic growth and, 96–110, 433, 524*n*–26*n*
  ETI and, 344
  exponential growth in, 3, 7–14, 35, 40–46, 56–84, *57–65, 67, 69–71, 73–84,* 96–101, *98, 99, 101,* 106–10, *108,* 257, 498*n*
  farsighted evolution and, 47–50, *48–50*
  fractal designs and, 46–47
  information, order, and evolution and, 85–94, 516*n*–23*n*
  intelligence and, 265, 344, 349–51
  Internet and, 78–81, *78–81,* 95, 97, 516*n*
  life cycle of a paradigm and, 43–46
  life cycle of technology and, 51–56
  miniaturization and, 42–43, 45, 57–61, *57–60,* 73, 82–84, *82–84,* 96, 102, 227
  Moore's Law and, *see* Moore's Law
  nature of order and, 36–43
  principles of, 40–43
  revisiting of, 491–96, 504*n*
  second law of thermodynamics and, 39–40
  world hunger solution and, 224
  see also exponential growth
acceleration, 10, 165
actin, 175, 199–200, 383
Acura RL, 287
acute myeloblastic leukemia, 215
adenosine triphosphate (ATP), 118, 232, 234, 238, 306, 399
adenoviruses, 216
Adept Technologies, 285
Adleman, Leonard, 529*n*–30*n*
Adrian, E. D., 154, 539*n*
Afghanistan, 280, 332, 334
Africa:
  AIDS in, 95, 470
  GMO food in, 406, 414, 415
  natural nuclear reactor in, 139–40, 503*n*
  Web access in, 469
Age of Intelligent Machines, The (Kurzweil), 3, 24, 94, 275, 277, 279, 393, 497*n,* 518*n,* 519*n*
Age of Spiritual Machines, The (*ASM*) (Kurzweil), 3, 24, 113, 315–16, 361
  catching a fly ball examined in, 178–79
  molecular computing in, 121
  only-a-human cartoon in, 290–91, *291*
  promise vs. perils of technology in, 393–94, 427
AGEs (advanced glycation end-products), 220
aging, 100, 233
  of cells, 209
  slowing and reversal of, 28, 141, 206, 210–21, 253, 256–57, 259, 323, 371, 373, 377, 397
agriculture, *17, 18, 20,* 536*n*
  GMOs and, 414–15, 471

vsnk$all.qxd 7/8/05 9:06 AM Page 604

agriculture (*cont.*)
reduction in farm workforce and, 302, 340, 583*n*
AI, *see* artificial intelligence; narrow AI; strong AI
AIDS drugs, 95, 470
Air Force, U.S., 280, 335
Air Force Strategic Missiles Evaluation Committee, 401
airplanes, aviation, 138, 146, 246, 266, 397, 409, 420
Bernoulli's principle and, 265
guidance for, 8, 255, 276, 413, 435–36, 456
air pollution, 243
airports, 284
air pressure, 265
Akers, Nick, 247–48, 595*n*
alanine, 210
alcohol, 247–48
algebra, 283
algorithmic information content (AIC), 37, 38
algorithms, 5, 444, 445, 461, 522*n*
brain-modeling, 148–49
brain reverse engineering and, 147
Church-Turing thesis and, 454, 455
data compression, 516*n*–17*n*
decision or halting problem and, 601*n*
DNA computing and, 118
equivalence principle and, 136–37, 536*n*
learning, 156
minimax, 275–77
neural net, 269, 570*n*–74*n*
parallelizing of, 439
reversible computing and, 130–31, 132
self-organizing, 146, 439–40, 481, 538*n*; *see also* evolutionary (genetic) algorithms
software, 428, 438–42
Allan, Alasdair, 281
Allen, Paul, 343
Allen Telescope Array, 343, *343*
Allis, G., 561*n*
Allison, Graham, 596*n*
Allsop, A., 552*n*
alpha (fine-structure constant), 140, 356, 503*n*
ALT-711 (phenacyldimenthylthiazolium chloride), 220
aluminum, 245, 246
Alzheimer's disease, 549*n*
biotechnology and, 209, 220, 555*n*
brain reverse engineering and, 144, 188
Ameisen, J. C., 557*n*
amino acids, 483
nanotechnology and, 233, *233,* 234, 242
in proteins, 27, 47, 85, 148, 208–10, 309, 517*n,* 550*n*
amygdala, 541*n*
amyloid plaque, 220, 550*n*
analog, analog operations:
in brain, 71, 126, 147–51, 428, 442, 483
criticism from, 428, 442
digital vs., 14, 126, 147, 149–50, 308, 428, 442, 461, 519*n*
image sensors, 533*n*
Mead's use of, 89, 188
transistors' use of, 126, 149–50, 151, 188, 189, 442, 443
ANALOGY, 569*n*
Ananthaswamy, Anil, 553*n*
Andberg, Anders, 591*n*
Anderson, Mark K., 527*n*
Anderson, M. C., 544*n*
Anderson, W. French, 196, 548*n*
anger, 193, 379, 389, 477–78
Anger, Natalie, 551*n*
angiogenesis, blocking of, 218, 222
animal rights, 378
animals:
antiaging experiments in, 220–21
blood-brain barrier in, 163
brain of, 4, 129, 145, 169
cloning of, 221, 222, 555*n*–56*n*
consciousness of, 378, 466–68
defensive technologies tested on, 416
elimination of suffering of, 224, 379
gene therapy in, 215, 216
medical nanobots in, 254–55
memory in, 48
moratorium on transplantation of vascularized organs of, 418
motion detection in, 188
observation by, 47, 48
pattern recognition in, 16
pigmentation of, 90
SARS virus in, 402
transgenic, 215, 222
xenografts and, 418, 598*n*
see also specific animals
Anissimov, Michael, 10, 299, 320, 321
ant colonies, 151
Anthes, Gary H., 570*n*
Anthropic Cosmological Principle, The (Barrow and Tipler), 500*n*
anthropic principle, 15, 357, 359–64, 499*n*–501*n*
antibiotics, 306, 409

vsnk$all.qxd 7/8/05 9:06 AM Page 605

antibodies, 242, 255, 425
antigens, 218
antiparticles, 363, 486–87, 503*n,* 521*n*
antiviral medications, 511*n*
apes, 72, 191, 193, 387, 509*n*
  see also specific apes
apical dendrites, 191–92, *192*
Apo-A-I Milano (AAIM), 217
application-specific integrated circuits (ASICs), 125, 135, 276, 445
Arai, K. I., 584*n*
Arbib, Michael A., 190, 548*n*
arginine, 210
Argonne National Laboratory, 283
Aristotle, 154, 337, 539*n*
Aristov, V. V., 516*n*
arm:
  of kinematic constructor, 228, 229
  of nanobot, 229–30, 233
  of octopus, 181, 544*n*
Army, U.S., 280, 312, 331–32, 336
Army Science Advisory Group (ASAG), 331
Arndt, Michael, 580*n,* 581*n*
Arnold, Michael S., 527*n*
ARPANET, 78
art, *17, 18, 20,* 145, 191, 340, 498*n*
  as knowledge, 372, 375
  pattern and, 388
Artificial General Intelligence Research Institute, 599*n*
artificial intelligence (AI), 8, 111, 144, 240, 438
  Bayesian nets and, 267–68, 280
  combining methods in, 278–79, 293
  defined, 265
  development of, 497*n*
  divergence of human intelligence and, 146
  education of, 202–3, 294
  expert systems and, 266–67, 280, 282–83
  genetic algorithms and, *see* evolutionary (genetic) algorithms
  Lanier's views on, 441
  Markov models and, *see* Markov models
  narrow, *see* narrow AI
  neural nets and, *see* neural nets
  recursive search and, 272–73, 279, 576*n*–80*n*
  from simple rules, 91–94
  in software, 428
  strong, *see* strong AI
  toolkit of, 265–73, 278–79, 293, 435, 439, 456, 570*n*–80*n*
  winter of, 263–66, 289, 569*n*
  see also computers, computation; nonbiological intelligence; robots, robotics
art programs, recursive search and, 273, 577*n*–80*n*
Asaad, W. F., 542*n*
Ascent Technology, 284
Asia, 95, 469
  GMOs in, 471
  poverty in, 99, 470
  vitamin A deficiency in, 414
ASICs, *see* application-specific integrated circuits
Asilomar conference, 402, 418
Ask MSR (Ask MicroSoft Research), 286–87
Association of American Publishers, 497*n*
asteroids, *20,* 40, 281, 398, 405–6
astrocytes, 177
astrophysics, singularity in, 23, 486, 487, 503*n*
Atanassov, P., 595*n*
atherosclerosis, 212, 217, 257
At Home in the Universe (Kauffman), 509*n*
atomic bomb, 392–93, 404, 408, 594*n*
atomic-force microscope (AFM), 138, 237, 536*n*
atomic memory drive, 115
atoms, 5, 14, 85, 168, 198, 210, 383, 404, 499*n*
  computational capacity and, 131, 133, 138
  information in, 14, *15,* 119, 131, 134, 536*n*
  nanotechnology and, 226, 227, 228, 234, 240, 244, 251, 253
ATP, *see* adenosine triphosphate
atrasentan, 218
Audience, Inc., 530*n*
Audio Spotlight systems, 313
auditory cortex, 124
auditory nerve, 195
auditory system, human, 153, 165, 438, 530*n*
  scanning of, 165
  Watts's model of, 123–24, 147–48, 183–84, *185,* 443, 452, 530*n,* 545*n*–47*n*
auditory virtual reality, 105, 310, 312–13, 318, 472
Augarten, Stan, 513*n*
Augsburg, University of, 536*n*
Australia, 128, 398, 433
Australopithecines, 509*n*
Austria, Austrians, 2, 327
autoimmune reactions:
  biological, 223, 233, 255, 417, 426
  nanobot, 417

vsnk$all.qxd 7/8/05 9:06 AM Page 606

automation, 31, 65, 108, 340, 507*n*
in investing, 265, 435
with robots, 285
autonomic computing, 284, 437
autonomous, semi-intelligent observatories, 281
Autonomous Intelligent Network and Systems (AINS) program, 333
avastin, 218
Aviram, Avi, 115, 528*n*
Avouris, Phaedon, 527*n*
axons, 124, 145, 150, 154–55, 176, *192,* 428, 452

Babbage, Charles, 93–94
Babcock, Alpheus, 53
babies, 190
"designer," 215, 225–26, 553*n*
baboons, HIV-type xenoviruses in, 418
Bachand, George, 560*n,* 561*n,* 585*n*
backpropagation, 156
bacteria, 220, 282, 317, 367, 397
blood-brain barrier and, 163
cultivation of, 594*n*
in digestive system, 386
eukaryotic, *17, 18,* 450, 583*n*
flagellum of, 440
future of, 297–98
genetic engineering and, 393
nanotechnology and, 226, 233, 236, 248, 254, 255
protein synthesis and, 551*n*
Baguisi, A., 556*n*
Bai, Q., 584*n*
Bailey, Patrick, 562*n*
Baker, Andrew H., 216
Baker, Sue, 589*n*
balance, 179, 189
Balkenius, Christian, 538*n*
Ballard, D., 547*n*
balls, catching of, 178–79
bandwidth, 9, 96, 107, 337, 346, 432
of brain scanning, 25, 144, 161, 197, 292
of endocrine system, 200, 443
Internet, 81, *81,* 263, 312, 472, 516*n*
banking, 102, 289
Barel, Helit, 597*n*
Barlow, Horace, 154
Barrow, J. D., 502*n*
Barrow, John, 356, 500*n*
Bartol, Thomas M., Jr., 190
Barton, S. C., 595*n*
basal dendrites, *192*
Basel, University of, 115
Bashir, Rashid, 583*n*
basis functions, 179, 544*n*
batteries, 133, 246, 248
Bayes, Thomas, 267, 570*n*
Bayesian nets (belief networks), 267–68, 280
Bayles, Fred, 588*n*
"Be a Scientist, Save the World" (Smalley), 241
beauty, 310, 389, 476
Beethoven, Ludwig van, 378
Begley, Sharon, 542*n*, 543*n*
behavior, 378, 380, 385
Bekenstein, Jacob D., 593*n*
belief networks, *see* Bayesian nets
Bell, Anthony J., 169–70, 444–46, 448–51, 542*n,* 600*n*
Bell, Gordon, 328
Bellis, Mary, 515*n*
Bender, Eric, 589*n*
Benenson, Y., 530*n*
Bennett, Charles H., 130, 534*n*
Bennett, James, 598*n*
Benson, E., 542*n*
Bentley, Jon, 438, 600*n*
Berg, Paul, 418
Berger, Ted, 188, 195
Bergeron, Bryan, 328–29, 588*n*
Berndt, E. R., 512*n*
Bernoulli's principle, 265
Bernstein, Michael, 526
Bernstein, N., 544*n*
Berra, Yogi, 14
beta-carotene, 414
beta-catenin, 505*n*
Beveridge, W. I., 427
Bezos, Jeff, 96
Biever, Celeste, 516*n,* 530*n*
Big Bang(s), 14, 356, 361, 500*n*
Bilesch, Stanley, 547*n*
Bils, Mark, 100, 525*n*
Bingham, R., 539*n*
biochemists, skepticism of, 13
Biocosm vision, 361–62
biological age, 253, 257
test for, 210, 550*n*
biological assembler, nanotechnology and, 232–33
biological evolution, 522*n*
anthropic principle and, 15, 357, 359
asteroid and meteor collisions and, 398
complexity increases and, 36–38, 508*n*–9*n*
computational limits and, 137
continuance of, 47, 94, 511*n*
death and, 320, 321

vsnk$all.qxd 7/8/05 9:06 AM Page 607

digestive processes and, 301–2
disease and, 511*n*
diversity in, 45–46
in Epoch One, 14–15, *15*
in Epoch Two, *15,* 16, 47
in Epoch Three, *15,* 16, 47
incredulity about, 433
"inventions" of, 5
key events of, *see* key events, of biological and technological evolution
limitations of, 21, 26, 27, 148, 271, 309–10, 311, 321
local optimization and, 309
measurement of, 357
mutations and, 42, 92, 506*n*
as open system, 42
order increased by, 40
punctuated equilibrium theory of, 44–45, 510*n*–11*n*
survival purposes of, 38, 39, 41, 96
technological evolution as continuation of, 7, 42, 137
technological evolution compared with, 16–19, *17–19,* 94, 347, 441, 487
upending of, 374
water-based chemistry of, 239
wheels and roads and, 440
biological intelligence, 124, 128, 428
concerns about end of, 30
limits of, 8–9, 32, 316, 337, 340, 377
merger of nonbiological intelligence with, 4, 9, 24, 25, 47, 123, 128, 197, 296, 300, 316–17, 337, 340, 372, 375–76, 377, 424
technology merged with, 9, 28, 298
transcendence of, 375–76
Biological Micro Electronic Mechanical Systems, *see* BioMEMS
biology, 411, 412
emulating, three-dimensional molecular computing and, 112–13, 116–17, 519*n*
limits of, 206, 227, 234, 320, 321, 323, 325, 376, 381
models of, 168
nanotechnology compared with, 227, 232, 234
biomass, 243, 399–400, 425–26, 595*n*
BioMEMS (Biological Micro Electronic Mechanical Systems), 254, 303, 570*n,* 583*n*
biosphere, 33, 397
biotechnology, 27, 84, 95, 102, 210–27, 301, 323, 398, 549*n*–57*n,* 595*n*
availability of knowledge about, 398, 595*n*
dangers of, 206, 232, 395, 407, 408, 412
defensive technologies and, 408, 416–18
designer baby boomers and, 210–14, 551*n*
environmentalist campaign against, 391, 395, 414–15
ethical issues and, 221–22, 223, 224, 553*n*
gene chips and, 214–15, 552*n*
gene therapy and, 215–16, 219, 220, 256, 323, 416–17, 553*n*
guidelines for, 402, 418
nanotechnology compared with, 227, 232, 251, 256, 257, 412
regulation of, 416–17, 423
in reversal of aging, 28, 141, 206, 212–15, 218–21, 256, 257, 323, 371, 373, 396
in reversal of degenerative disease, 210, 217–21, 396, 553*n*–55*n*
RNA interference and, 12, 214, 256, 323, 417, 422, 551*n*
see also cloning; stem cells
bioweapons program, 393
Bird, Jon, 271
birth control, *see* contraception
Bissi, E., 541*n*
Black, Keith L., 541*n*
black holes, 23, 404, 503*n*
event horizon of, 7, 23, 29, 363, 486–87, 503*n*
as ultimate computer, 362–64
universe-generating, 360
Blakeslee, Sandra, 548*n*
Block, Steven, 157
blood:
nanobots in, 248, 253–57, 300, 303, 317, 377, 432, 472
programmable, 305–6
protein in, 282
blood-brain barrier (BBB), 163–65, 242
blood cells, 254, 276
mechanical red, *see* respirocytes
white, microbivores as replacements for, 254, 306
blood vessels, angiogenesis and, 218
blue goo, 416
Boahen, Kwabena, 530*n*
body, biological, 199, 257–58
emotions and, 193, 203
functional simulations of, 124
human longevity and, 325
identity and, 315, 383–87
limits of, 9, 27, 28, 29, 203, 325
nanotechnology problems and, 251
pattern of, 371, 383–84
reverse engineering of, 127

vsnk$all.qxd 7/8/05 9:06 AM Page 608

body, GNR impact on, 299–311, 583*n*–86*n*
brain and, 307–9, 585*n*
digestive system and, 301–5
heart and, 306–7
organ elimination and, 304–7, 310–11
programmable blood and, 305–6
body, virtual, 28–29, 199, 203, 319, 325
Boehm, T., 554*n*
Boese, Christine, 338, 589*n*
bombs:
atomic, 392–93, 404, 408, 594*n*
hydrogen, 391, 401, 404, 408
Bonds, A. B., 541*n*
Bone, 215
bone metabolism markers, 215
Bonner, John Tyler, 509*n*
bonobos, 192
Bostrom, Nick D., 259–60, 369, 401, 403, 404, 596*n*
Bouissou, Brigitte, 336, 589*n*
boundaries, of self, 387
bowel functions, 304
Boyer, Paul D., 501*n*
BP Amoco, 102
Bradbury, Robert, 350
Brader, Mark, 515*n*
brain, human, 4, 71–72, 120, 257–58
aesthetics and, 310
analog processes in, 71, 126, 147–51, 428, 442, 483
architecture of regions of, 152–53
cerebellum of, *see* cerebellum
chaos of, 148, 149, 151, 152, 178, 198, 440, 446, 449, 450, 452, 460, 462, 483
of children, 152, 177
Church-Turing thesis and, 454–55
complexity of, 89, 145, 147, 198, 200, 428–29, 430, 442–50, 463, 465, 475, 523*n*
computational efficiency of, 137–38
computer compared with, 149–53, 293, 444
computer's interfacing with, 194–95
contradictory views held by, 152
damage to, 173, 177
as deeply connected network, 152
design of, 46–47, 85, 147, 153, 317, 429, 442–43, 444, 446–49, 479, 517*n*
digital processes in, 71, 85, 126, 147–51, 442, 483, 519*n*
emergent properties of, 151, 463–64, 475, 477–78
evolution as learning paradigm of, 152
evolution of, 16, 27, 129, 143, 146, 505*n*–6*n,* 522*n*
experience beamers and, 316, 380
fractal nature of, 46–47, 68, 446–49
frontal lobe of, 505*n*
genome and, 89, 147, 180, 428–29, 440, 443–44, 523*n*
GNR age impact on, 307–9, 312–20, 564*n,* 586*n*–87*n*
gray-matter tissue in, 27, 505*n*–6*n*; *see also* cortex, cerebral
hippocampus of, *see* hippocampus
as holographic, 148, 152, 483
identity and, 383–87
imperfections of, 151–52
implants and, *see* neural implants
left prefrontal region of, 175
limitations of, 8–9, 20, 27, 143, 203, 227, 340, 445, 503*n*
music in, 519*n*
nanobots in, 28, 163–67, 201, 300, 316, 374
nonbiological intelligence in, 28, 201–2, 377, 472
parallelism of, 8, 25–26, 130, 148, 149, 150, 270, 439, 462, 483, 504*n*
parietal lobes of, 202
pattern recognition and, 8, 16, 25–26, 124, 143, 149, 150, 173, 441, 456, 501*n*
patterns of, 325, 371, 383–84, 463–64, 475, 477–78
plasticity of, 27, 151, 172–78, 202, 203, 445
quantum computing and, 450–52
quantum wave collapse in, 450–51
randomness of, 149, 151, 152, 153, 440, 443–44, 449
redesign of, 27, 307–9, 383
repetition and redundancy in, 146, 147, 428
self-organizing processes of, 25–26, 148, 152, 153, 293, 371, 440, 443–44, 446, 456, 460, 483, 501*n,* 523*n*
size of, 452
slow circuitry of, 150
spindle cells in, 191–94, *192,* 468
as "sub-critical," 259
surgery on, 315–16, 384
three-dimensional organization of, 68, 72
-to-brain communication, 316, 585*n*
uploading of, 166, 198–202, 324, 451, 548*n*–49*n*
virtual reality and, 487
weight of, 137
see also computational capacity of the human brain, achieving of
brain, of primates, 27, 152

vsnk$all.qxd 7/8/05 9:06 AM Page 609

brain cells, gene therapy and, 215, 216
brain models, 407, 443, 445
  analytic vs. neuromorphic, 146
  early attempts at, 154–57
  electronic neurons and, 173
  latest technology as, 458
  neuron, 4, 172–73, 428, 443, 446, 452, 455
  peeling the onion and, 148–49
  of regions, 177–94, 197, 265, 292–93, 428, 440, 443, 452, 479
  reverse engineering and, 4, 25, 143–49, 153, 167–94, 196, 197, 428, 439, 538*n,* 541*n*–47*n*
  right level for, 153, 167–69
  subneural, 169–72, 541*n*
  see also neuromorphic models
brain reverse engineering, 143–203, 265, 317, 377, 407, 435, 439, 446, 456, 485, 522*n,* 537*n*–49*n*
  accelerated pace of, 195–98, 293, 428
  brain compared with computer and, 149–53, 461, 463
  computational capacity and, 122, 127
  exponential growth of, 73, 144, 196–98
  GNR age and, 307–8
  neural nets and, 269–70, 574*n*
  at neuron level, 163–67, 440, 444, 530*n*
  overview of, 144–49, 537*n*–38*n*
  reverse engineering of computer compared with, 157–58
  self-understanding and, 4, 198
  sound localization and, 123–24
  strong AI and, 84, 93, 194–95, 293, 294, 407, 461
  tools for, 25, 144–45, 158–62, 197
  see also brain models; brain scanning; neuromorphic models
brain scanning, 73, 443
  bandwidth of, 25, 144, 161, 197, 292
  brain models and, 147, 171–74, 178, 292–93, 407
  destructive, 161–62
  exponential growth of, 25, 161, 197, 407
  fMRI and, 150, 158, 160–61
  imaging time and, 160, *160*
  noninvasive, 158, *159,* 162–63, 164, 197
  price-performance of, 144, 197, 265, 292
  resolution improved in, 25, 158, *159,* 160–63, 167, 175, 197, 265, 292, 407, 428
  reverse engineering and, 25, 144, 147, 158–67, 171–72, 175, 176, 254, 262
  tools for, 158–62, 197, 428
  uploading the brain and, 166, 198–202, 324, 548*n*–49*n*
  using nanobots, 163–67, 197, 200, 262, 293
brain simulations, 144, 145, 178, 196, 197, 265, 292, 293, 407, 428, 439, 445, 450, 452
  functional, 122–25, 148, 150, 527*n,* 529*n*
  neuromorphic, 122, 124–25, 438, 440, 527*n,* 530*n*
  University of Texas cerebellum, 182–83, *182,* 545*n*
brain stem, 172, 179, 181, 193, 203
Brain Tissue Scanner, 161–62
Brand, Stewart, 588*n*
Bray, Hiawatha, 535*n*
Bremermann, Hans J., 133, 535*n*
Brenner, Donald W., 562*n,* 563*n*
Brickell, Edie, 382
Bridis, Ted, 598*n*
Brigade Combat Teams (BCTs), 331–32
Bright, R. K., 554*n*
Brill, Eric, 287
British Columbia Cancer Agency, 514*n*
Britt, Robert Roy, 580*n*
broadband communication, 278
Broca, Paul, 173
Broderick, Damien, 24, 504*n,* 569*n*
Brody, Herb, 591*n*
Brooks, David, 601*n*
Brooks, Rodney, 263, 265, 300, 333
Brousseau, M. E., 554*n*
Browman, Steve, 597*n*
Brownian motion, 254, 388, 520*n,* 570*n*
Brumfiel, G., 585*n*
Brun, Todd, 140–41
bubonic plague, 398, 402
Buchan, Bruce, 286
Buchanan, Mark, 592*n*
Buckingham, Edgar, 536*n*
Buddha, 392
Buddhism, 380, 387, 388
Buechel, C., 543*n*
Büettrich, Sebastian, 533*n*
buildings, 250, 397
  as centralized technologies, 340, 409, 420, 421
Buonomano, Dean, 545*n*
Burch, Greg, 598*n*
Bureau of Labor Statistics, 100
Burenhult, G., 502*n*
Burke, Peter, 113–14, 115, 527*n*
Burkhard, Barbara, 542*n*
business, AI systems in, 271, 283–84, 287
Business Communication Company, 279

vsnk$all.qxd 7/8/05 9:06 AM Page 610

business cycles, 97
business models, 7, 103, 426
  intellectual property and, 339–40
  outdated, 96, 97
business-to-business (B2B) revenues, 103, *104*
business-to-consumer (B2C) revenues, 103, *104*
Busis, Neil A., 537*n*
busy-beaver problems, 455–56, 601*n*
Butler, Samuel, 96, 205, 549*n*
Byrne, John H., 505*n*

CA-125, 282
Cacares, M., 505*n*
Cagin, Tahir, 563*n*
calcium, 121, 162, 399
calculus, theorem of, 519*n*
California, stem-cell research in, 471
California, University of, 113–14, 115, 138, 173, 174, 175, 505*n*–6*n,* 527*n*
California Institute of Technology (Caltech), 194, 195, 240
Callaway, E., 541*n*
Cambrian explosion, *17, 18, 20,* 38, 47, 441
cameras, 113, 162
Canada, gene therapy in, 216
cancer, 210, 212, 399, 544*n*
  bioengineered treatments for, 217–18, 409
  blood-brain barrier and, 165
  DNA mutations and, 219
  drugs for, 212, 303, 304
  evolution used by, 511*n*
  gene expression and, 214, 219, 422
  genetic profiling and, 215
  nanotechnology and, 233, 243, 255, 303, 306
  pattern recognition and, 282
  vaccines for, 217, 218
canonical milestones, 19, *20,* 502*n*–3*n*
capital, investment, 96, 106, 339, 395, 524*n*
capitalism, 394, 406
carbon, 230, 246, 251, 253
  in atomic-force microscope, 536*n*
  biological life and, 16, 207, 210, 360, 361, 500*n*
  in biomass, 399, 425, 595*n*
  in biosphere, 33
  black holes and, 360, 361
  in Epoch One, 14–15
  in nanobots, 164, 238, 352, 399, 400
  in nanotubes, 27, 113, 114, 229, 230, 234–35, 238, 246, 250, 375, 527*n*
  in synthesis of diamondoid material, 239–40, 563*n*
  three-dimensional shapes and, 15, 85
  in Zeus, 350
carbon dioxide, 244, 249, 252, 306, 400
carbon monoxide, 244
cardiovascular disease, 581*n*
Carducci, M. A., 554*n*
Carey, John, 580*n,* 581*n*
Carlisle, Brian, 285
Carnegie Mellon University (CMU), 275, 285
Carnivore e-mail snooping system, 413
Carroll, Lewis, 326
Carroll, Rory, 598*n*
cars, 100, 287, 288, 311
  nanotechnology and, 230, 246, 247, 252
case-based reasoning, 285
Caspari, Rachel, 218–19
Casseday, John, 545*n*
cassette tape, 53, 327
cataracts, 549*n*
cats, consciousness of, 467, 468
CD-ROMs, 54
celebrities, virtual, 318
C. elegans, 221
Celera Genomics, 216
Cell, 176, 543*n*
cell membranes, 232, 251, 256–57
cell phones, 100, 113, 282, 346, 406, 444, 473
  in clothing, 312
  cost of, 95, 338, 339
  mass use of, 42, 49, *49, 50,* 95, 469, 512*n*
cells, 148, 198, 208, 383, 483
  aging of, 209
  as computers, 221
  death of, 215, 218
  energy for, 219–20, 583*n*
  gene expression and, 213, 551*n*
  loss and atrophy of, 220
  toxic, 219
  transdifferentiation and, 222–23, 471, 556*n*–57*n*
  see also nucleus; *specific kinds of cells*
cell therapies, 214, 222–23, 471, 556*n*–57*n*
cellular automata, 85–91, 93, 359, 518*n*–22*n*
  class 4, 88–91, *88,* 93, 520*n*
  kinematic, 235
  predictability and, 88–89, 90, 519*n,* 521*n*–22*n*
  rule 110 and, 87–89, *88,* 523*n*
cellular gliders, 520*n*
cellular logic switch, 221
Centers for Disease Control (CDC), 514*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 611

centralized technologies, 340, 409, 420, 421
cerebellum, 68, 124, 125
  brain reverse engineering and, 144, 147, 169, 178–83, *180, 182*
  fiber cells of, 179, 180, *180,* 181, 545*n*
  genome and, 180
  muscles and, 179, 181, 260
  neuromorphic model of, 178–83, *180, 182*
  prediction and, 191
  skill formation and, 178–79, 194, 260
  wiring pattern of, 180, *180,* 449
cerebral palsy, 308
Cerf, V., 516*n*
Chaboyer, Brian, 590*n*
Chalmers, David J., 385, 594*n*
Chang, Kenneth, 567*n*
Chang, Xiao Yan, 561*n,* 562*n*
chaos, 198, 459–62
  of brain, 148, 149, 151, 152, 178, 198, 440, 446, 449, 450, 452, 460, 462, 483
  evolution and, 40, 41, 45–46, 509*n*
  GNR age and, 73
  pattern recognition and, 441
chaos theory, 89, 151, 271, 480
chaotic computing, 145, 173, 441, 475
character recognition, 97, 265, 294, 337
chat rooms, 272
chatterbot, 272, 294
Chaudhuri, Swades, 248
chemical energy, 230
chemical industry, 252
chemistry, 14–15, *15,* 167–68, 411
chemotherapy drugs, 511*n*
Cheng, J. C., 552*n*
Chenn, Anjen, 505*n*
chess, 126, 290
  computer, 8, 146, 274–78, *274,* 441, 459, 498*n*
  recursive search and, 272, 577*n*–80*n*
chickens, brain-stem neurons in, 172
Chiesa, G., 553*n*
children:
  brain of, 152, 177
  dyslexic, 175
  fears of, 241
  handwriting learned by, 181
  spindle cells in, 193–94
chimpanzees, *20*
  humans compared with, 5, 39, 192, 505*n,* 509*n*
  thumbs of, 39, 509*n*
China, 54, 99, 469
Chinese Room analogy:
  of author, 465–66
  of Searle, 430, 458–66
Chinnery, P. F., 555*n*
chips:
  design of, 122, 231
  gene (microarrays), 214–15, 552*n*
  hippocampal, 188
  manufacturing of, 42, 119, 122
  neural, 188, 195
  neural nets and, 270, 575*n*
  silicon, *see* silicon chips
chlorinated phenols, 252
Choi, Charles, 530*n,* 537*n,* 548*n*
cholesterol, 211, 217, 554*n*
Chomsky, Noam, 190
Chown, Marcus, 590*n*
chromosomes, 218, 219, 232, 510*n*
  evolution of, 42, 92
  parity errors and, 208
  X, 510*n,* 555*n*–56*n*
  Y, 42, 208
Church, Alonzo, 453–54, 601*n*
Churchill, Winston, 35, 320, 324
Churchland, Patricia, 473
Church-Turing thesis, criticism from, 429, 453–56, 601*n*
Ciccolo, Nate, 392–93
circle of empathy, 386
circulatory system, 442, 443
cities:
  as centralized technologies, 340, 409, 420, 421
  early, *17, 18*
civilization:
  destruction of, 345–46, 361
  search for intelligent, *see* SETI
  type II, 344, 348, 353
  type III, 344
civilization, human-machine, 26, 45
  destiny of, 3–4, 5, 128, 202, 299, 390
  nonbiological intelligence derived from, 317
  see also Singularity
civil liberties, 421–22
civil services model, 472
Civil War, U.S., 331
Clark, Gregory, 587*n*
Clarke, Arthur C., 4, 51, 427
Clinical Proteomics Program, 282
clock speed, microprocessor, *61,* 63, 66
cloning:
  human, 221–25, 556*n*
  therapeutic, 214, 220, 221, 222, 224, 256, 323
  transdifferentiation, 222–24, 556*n*–57*n*
closed systems, second law of thermodynamics and, 510*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 612

"closed timelike curve" (CTC), 140–41
coal, 243, 244, 246
cobalt, 119
cochlea, 184, *185,* 438
cochlear canal, 165
cochlear implants, 195, 384
cocktail-party effect, 184
codons, 16, 208, 517*n*
Cognex Corporation, 285
cognitive skills, *see specific skills*
colds, common, 402, 418
Cold Spring Harbor Laboratory, 171–72
cold war, 374, 396, 401
Colicos, Michael A., 175–76
Collas, P., 557*n*
colliculus cells, 184
Collier, C. P., 528*n*
Collins, Philip G., 527*n*
Colman, A., 556*n*
colon, 304
colonization, 352–53
colorectal cancer, 552*n*
Colton, Richard J., 563*n*
columnar structures, 160
comets, 281, 405–6
commerce:
  e-commerce, 13, 103–5, *104,* 263, 264
  fraud in, 269
common operating picture (COP), 332
commonsense knowledge, 177, 267, 292
communications, communications technologies, 3, 261, 308, 313, 347
  broadband, 278
  decentralization of, 396, 406
  exponential growth in, 35, 76–77, *77,* 102, 112, 245–46, 470
  mass adoptions of, 48–50, *48–50,* 97, 511*n*–12*n*
  military, 332–33
  nanotechnology and, 248–49, 434
  personalized customer, 103
  price-performance of, 77, *77,* 243
  radio transmissions, 344–49, 590*n*
  virtual reality and, 341
  wireless, *see* wireless communications
  see also telecommunications; telephones
compact discs, 53, 519*n*
complexity, 44–47, 198, 209
  of brain, 89, 145, 147, 198, 200, 428–29, 430, 442–50, 463, 465, 475, 523*n*
  of brain models, 4, 153, 168–69
  class 4 automata and, 89–90, 91, 522*n*
  of digestion, 301
  of emotion, 192
  exponential growth of, 20, 358
  failure rates and, 429, 456
  increase in, 15, 36–40, 44, 45, 47, 85, 91, 93, 359, 360, 389, 398, 476, 507*n*
  of neurons, 143–44, 153, 155, 197, 455
  order compared with, 38–40, 90, 372
  physics and, 86, 519*n*
  probabilistic fractals and, 46
  of rock vs. human, 37, 508*n*–9*n*
  of software, 428, 437–38
  of "super-critical" machines, 259
complexity theory, 89, 145, 151, 271, 480
computational capacity of the human brain, achieving of, 111–42
  bridge to 3–D molecular computing and, 112–15, 526*n*–28*n*
  estimates of, 70, 122–27, 150, 199, 452, 506*n*–7*n,* 527*n,* 529*n*–33*n*
  human memory capacity compared with, 126–27
  uploading of personality and, 124–25, 199
computational limits, 5, 72, 112, 113, 127–42, 300, 432, 485–86, 533*n*–36*n*
  Church-Turing thesis and, 453–56, 601*n*
  criticism from Malthus and, 427–28, 434–35
  error rate and, 132
  intelligence in the cosmos and, 349–51, 590*n*–91*n*
  memory and computational efficiency and, 136–38
  nanocomputing and, 133–35
  pico- and femtotechnology and, 138–39, 141, 351, 536*n*
  reversible computing and, 130–35, 428, 534*n*
  Singularity date setting and, 135–36
  speed of light and, 139–40
  time travel and, 140–41
  of universe-scale computer, 364–65, 485–86, 592*n*
computer-aided design (CAD), 231
computer-assisted instruction (CAI), 336–37
Computer History Museum, 327
computer-integrated manufacturing (CIM), 285
computerized physician order-entry (CPOE) system, 283
computers, computation, *17,* 36, 309, 375
  analog, 149–50, 442
  author's early experience with, 2–3, 64, 497*n*
  autonomic, 284, 437
  biological cells as, 221

vsnk$all.qxd 7/8/05 9:06 AM Page 613

biological evolution compared with, 47
brain compared with, 149–53, 293, 444
brain's interfacing with, 194–95
capacity of, 96, 127
chaotic, 145, 173, 441, 475
chess playing of, 8, 146, 274–78, *274,* 441, 459, 498*n*
consciousness of, 430, 458–69
decentralization of, 351
Dembski's views on, 474–77
design of, 40, 45, 62, 71, 434, 481, 499*n*
digital, 148–51, 442, 461
doubling of power of, 8, 16, 41–42, 56–66, *57–65,* 145, 261, 498*n,* 506*n*
dualism of, 444–45
efficiency of, 136–38, 362
exponential growth of, 25, 56–73, *57–65, 67, 69–71,* 75, *75,* 102, 112, 127, 128, 135, 276, 292, 432, 434, 436, 470, 498*n,* 514*n*
hacking into, 406, 426, 594*n*
invention of, *17, 18,* 38, 40, 45, 86, 93–94
invisible, 105, 136, 312
inward vs. outward expansion of, 351
mechanical, 93–94, 135, 228–29
memory of, *see* memory, computer
modular approach to, 481
Moore's Law and, 35–36, 41–42, 56–66, *57–65,* 434
nanotechnology and, 133–35, 139, 232–36, *233,* 248–49, 349, 412, 434
neuronal information processing compared with, 503*n,* 504*n*
new universe created for, 405
nonlinearity required by, 155
optimal level of, 21, 29
parallel processing in, 129–30, 135, 149, 150, 350, 461, 462
price-performance of, 12, 41–42, 45, 56–71, *57–65, 67, 69–71,* 100, 102, 125–28, 135–36, 142, 243, 261, 292, 432, 437, 506*n,* 514*n*
productivity growth and, 100
programmable, 445
quantum, *see* quantum computing
relay-based, 67, *67,* 127–28, 434
research budgets for, 25, 42, 259
reverse engineering of, 157–58
reversible, 130–35, 244–45, 350, 428, 534*n*
self-healing, 151
software programs for, *see* software
speed of, 127, 261, 276, 436
spread throughout entire universe, 45, 511*n*
star-scale, 350
symbolic, 460–61, 463–64, 468
three-dimensional molecular, *see* three-dimensional molecular computing
transistors in, 27, 42–43, 45, 63, *63,* 67, *67,* 150, 151, 153, 434, 498*n*
Turing test and, 25, 263, 286, 292, 504*n*–5*n*
typesetting on, 54
universal, 91, 94, 139, 228, 523*n*
universe-scale, 364–65
vacuum tubes in, 45, 56, 67, *67,* 434
viruses for, *see* software viruses
see also laptop computers; notebook computers; personal computers; supercomputers
conditioning, 182–83
Congress, U.S., 422, 594*n,* 599*n*
connectionism, 155–56
consciousness, 86, 190, 191, 326, 338, 369, 394
criticism from ontology and, 458–69
as emergent pattern, 463–64, 467–68
of nonbiological intelligence, 376–80, 385, 475
quantum computing and, 201, 429, 450–52
Singularity and, 374–82, 384
spindle cells and, 468
spirituality and, 388
subjectivity and, 378–80
of universe, 375, 388, 390
Consilience (Wilson), 195
"constructive destruction" process, 114
consumers, power of, 104
contact lenses, 312, 472
contraception, 321, 433
contradiction, 152
Cooley, J. W., 600*n*
Copernicus, Nicolaus, 433
Coren, R., 502*n*
coronary artery disease, 302
Correlogic Systems, 282
cortex, cerebral, 27, 157, 179, 189–94
architecture of, 68, 505*n*
auditory, 124
frontal, 176
frontoinsular, 193
inferotemporal, 186
insula regions of, 166, 193, 314
MEG and, 160
motor, 175
prefrontal, 170
spindle cells in, 191–94, *192*
tactile input and, 174

vsnk$all.qxd 7/8/05 9:06 AM Page 614

cortex, cerebral (*cont.*)
V5 region of, 156
visual, 156, 172, 176, 181, 530*n*
cosmological constant, 359, 361
Cossman, J., 552*n*
Coteus, Paul, 533*n*
Coull, J. T., 543*n*
Council of Europe, 471
"Countdown to Singularity" chart:
linear plot of, 18, *18,* 501*n*
logarithmic plot of, 17, *17,* 501*n*
Covey, Ellen, 545*n*
Cowan, W. M., 532*n,* 538*n*
CPEB protein, 176, 199–200, 543*n*
Craig, Arthur, 193
Cray 1 supercomputer, 535*n*
C-reactive protein, 211
creativity, 2, 128, 145, 476
in GNR age, 340, 341, 398
human intelligence and, 4, 9
love and, 485
recursive search and, 273, 577*n*–80*n*
Singularity and, 21, 389
credit-card fraud, 269, 276, 284
Crick, Francis, 206, 207, 549*n*
Cristofori, Bartolommeo, 53
criticisms, 427–83, 599*n*–602*n*
from analog processing, 428, 442
from the Church-Turing thesis, 429, 453–56
from the complexity of neural processing, 428–29, 442–50
from failure rates, 429, 456
from holism, 431, 479–83
from incredulity, 432–33
from likelihood of government regulation, 430–31, 470–73
from lock-in, 429–30, 457–58
from Malthus, 427–28, 433–35
from microtubules and quantum computing, 429, 450–52
from ontology, 430, 458–69
panopoly of, 427–33
from rich-poor divide, 430, 469–70
from software, 428, 435–42
from theism, 431, 473–78
Crosby, Alfred W., 595*n*
Crowley, Justin, 523*n,* 539*n*
cruise missiles, 255, 279–80, 335
cryonics, 384
Cuban missile crisis, 401
Cullen, Steve, 513*n*
cuneiform, 536*n*
curved surfaces, Bernoulli's principle and, 265
Cutcher-Gershenfeld, Joel, 472, 602*n*
cybermirror, 315
Cybernetics (Wiener), 86
cybernetic totalism, 380, 435
cyberwarfare, 333, 335
cyberweapons, 300
cyborgs, 309, 377
CYC (enCYClopedic), 267, 291–92
Cyclomatic Complexity Metric, 437–38
cystic fibrosis, 549*n*

Dahan, M., 586*n*
DAISI (Document and Image Storage Invention), 328, 329
Damasio, Antonio R., 193, 548*n*
Dana Farber Cancer Center, 218
Daptobacter bacteria, 297, 298, 583*n*
"Dark Winter," 398, 595*n*
Darnell, James, 549*n*
DARPA, *see* Defense Advanced Research Projects Agency
Darwin, Charles, 433
"Darwin, Charles," 31–33, 367, 381, 425–26
"Darwin Among the Machines" (Butler), 205
data-compression techniques, 36–38, 47, 507*n*–8*n*
redundancy and, 36, 508*n,* 516*n,* 517*n*
data mining, 265
Dautenhahn, Kerstin, 548*n*
Davis, Tamara M., 592*n*
Dawkins, Richard, 440, 600*n*
Dayan, Peter, 170, 542*n*
death, 7, 9, 320–23, 373, 398, 470
of author's father, 211, 326
biological evolution and, 320, 321
of cells, 215, 218
in gene-therapy trials, 416–17
from heart disease, 211, 217, 373, 413, 418
inevitability of, 320, 326
mutations and, 219
religious view of, 368, 372, 374
from SARS virus, 402
tragedy of, 329, 372
in war, 330–31, *331,* 409
decentralization, 396, 420–21, 473
of computation, 351
democratization and, 406, 408
of work, 105, 122, 340–41
decision making, 8, 190, 191
expert systems and, 266–67
by unmanned spacecraft, 280–81
decision (halting) problem, 453, 601*n*
Deep Blue, 274–77, 441, 459

vsnk$all.qxd 7/8/05 9:06 AM Page 615

deep brain stimulation, 195, 585*n*
Deep Fritz software, 274–78, 441
Deep Space One, 280–81
Deep Thought machine, 275
Defense Advanced Research Projects Agency (DARPA), 194, 284, 328, 333, 334, 588*n*
Defense Department, U.S., 312, 331, 594*n*
Defense Ministry, British, 594*n*
defensive technologies for GNR age, 408–10, 416–26, 598*n*–99*n*
deflation, 65, 101–8, 245
DeGaspari, J., 584*n*
de Grey, Aubrey, 212–13, 219–21, 321, 587*n*
dehydrogenase, 247
Dekker, Cees, 527*n*
Delio, Michelle, 582*n*
Dembski, William A., 431, 473–78, 483, 602*n*
democracy, *20,* 152, 395, 396, 406, 408, 498*n*
dendrites, 145, 153, 170–73, 178, 180, 197, 202, 383, 428, 452, 530*n*
  apical, 191–92, *192*
  basal, *192*
  defined, 124
  morphology of, 155
  nonlinearities in, 124, 137, 148, 151
  spines of, 171–72, 173, *174*
dendritic cells, cancer and, 217–18
Dennett, Daniel, 191, 467, 473, 548*n*
Denning, Peter J., 167
Denton, Michael, 431, 479–83, 599*n,* 602*n*
depressions, 99, 102
Derocher, Robert J., 582*n*
DeRose, James, 515*n*
Desai, T. A., 584*n*
Desai, Tejal A., 568*n*
Descartes, René, 173
Desert Storm campaign, 284
De Silva, H., 560*n*
desktop cold fusion, 250, 567*n*
developing countries, *see* underdeveloped countries
development stage, 52
De Vos, Alexis, 566*n*
DeWan, George, 597*n*
Dewey, David, 600*n*
diabetes, 212, 303, 549*n*
  type 1, 223, 255, 557*n*
  type 2, 210, 211, 225, 302
Diamond, M. C., 549*n*
diamondoid assembler, 229–30, 234, 238, 239–40
DiCarlo, James, 194
Dickens, Charles, 396
Diehl, Michael R., 528*n*
digestive system, 234, 238, 301–5, 307, 386
digital, digital operations:
  analog operations vs., 14, 126, 147, 149–50, 308, 428, 442, 461, 519*n*
  in author's archive, 327
  in brain, 71, 85, 126, 147–51, 442, 483, 519*n*
  cameras, 113
  disks and tapes, 327–28, 588*n*
  pianos, 53
  as theory of physics, 86–87, 518*n*–22*n*
Digital Biology Interest Group, 288
digital divide, 95
Dijkstra, E. W., 56
Dingel, B. B., 516*n*
dinosaurs, 222
diodes, light-emitting, 245
dioxins, 253
disabled, 189, 195
disaster zones, 286
discount rate, 109–10, 526*n*
disease, 100, 116, 209
  biological evolution and, 511*n*
  brain damage and, 177
  brain reverse engineering and, 144
  degenerative, reversal of, 210, 217–21, 553*n*–55*n*
  elimination of, 205, 206, 241, 259, 396, 424
  see also specific diseases
disks, digital, 327–28
disorder, 38, 40, 510*n,* 520*n*
Dittmer, W. U., 560*n*
diversity, 152, 225, 424
  chaos and, 40, 41, 45–46
  genetic, 402
DNA, 11, *20,* 45, 86, 218–23, 378, 386, 483, 551*n*
  complementary (cDNA), 551*n*
  computing with, 112, 117–18, 119, 529*n*–30*n*
  damaged, 397, 552*n*
  in Epoch Two, *15,* 16, 47
  in Epoch Three, 16
  errors in, 207–8, 233, 254, 256, 300, 471
  fetal, 168
  in gene therapy, 215–16, 553*n*
  information in, *15,* 16, 38, 40, 117, 207, 232, 518*n*
  junk, 510*n,* 516*n,* 517*n*–18*n*
  as life's computer, 207–10
  military uses of, 334
  mutations of, 208, 219

vsnk$all.qxd 7/8/05 9:06 AM Page 616

DNA (*cont.*)
nanotechnology and, 232, 233, 235–36, 237, 242, 251, 397, 412
physical constants compared with, 362
RNA interference and, 214
of SARS virus vs. HIV, 398
self-replication of, 16, 47, 116, 117, 118, 207–8, 235, 529*n*
sequencing, 73–74, 85, 470, 514*n*
structure and behavior of, 207–8, 549*n*
transdifferentiation and, 223, 471
2–bit base pairs of, 85, 207, 209–10, 516*n,* 517*n*
Doctorow, Cory, 271–72
dogs, consciousness of, 467, 468
Dolly the Sheep, 221
Dombeck, Daniel, 163
Domjan, Michael, 542*n*
Donovan, 300
dopamine, 303
dorsal pathway, 175
Dorus, Steve, 506*n*
Doyle, Arthur Conan, 570*n*
Drake, Frank, 344, 590*n*
Drake equation, 342, 344–49, 590*n*
DRAM (dynamic random access memory), *57,* 58, *58,* 59, 66
Drexler, K. Eric, 111, 141, 236–40, 242, 245, 535*n,* 558*n*, 559*n,* 560*n,* 561*n,* 563*n,* 564*n,* 568*n,* 595*n,* 598*n*
as founder of nanotechnology, 139, 228–31, 395
on MNT manufacturing safeguards, 400
molecular assembler idea of, 228–31, 234, 236–37
nanocomputer design of, 135, 228–29
drugs, 371
for AIDS, 95, 470
antiangiogenic, 218, 222
antirejection, 223, 557*n*
antiviral, 417, 422
biological evolution and, 511*n*
cancer, 212, 303, 304
cholesterol-lowering (statin), 217
development of, 209, 213, 259, 282
genetic profiling and, 214–15
as information technology, 470
nanotechnology and, 242–43, 303, 583*n*
to prevent weight gain, 11–12, 303
to promote neurogenesis, 177
to reverse atherosclerosis, 217
smart, 100, 212–15, 251, 256, 303–4, 323
Dubois, Charles, 196
Dudley, Gary, 538*n*
Duke University, 117, 118, 194–95
Dulberger, E. R., 512*n*
Dumé, Belle, 536*n*
Dutta, A. K., 516*n*
DVDs, 54
dynamite, 404
dyslexia, 175, 337, 589*n*
Dyson, Freeman, 350, 359, 591*n*
Dyson Sphere, 350
Dzegilenko, Fedor N., 562*n,* 563*n*

ear, 123, 165
Earth:
asteroid collisions with, *20,* 40, 398, 405–6
biomass of, *see* biomass
as center of universe, 342, 433
comet collision with, 405–6
hot core of, 246
magnetic field of, 281
mass of, 349
meteor collisions with, 398
NTT model of, 113
water chemistry on, 239
eating, 301–5, 307
eavesdropping, 333, 354
Eberhart, Russell C., 589*n*
Echelon system, 280
E. coli, 236, 551*n*
e-commerce, 13, 103–5, *104,* 263, 264
economy, economic growth, 128
GNR age and, 98, 230–31, 396–97, 406, 410
information technology and, 65, 107, *107,* 525*n*
law of accelerating returns and, 96–110, 433, 524*n*–26*n*
in World Bank report, 99, 338, 396, 470
Edelman, G. M., 532*n,* 540*n*, 538*n*
Edelman, Gerald, 201
Edgar, B., 502*n*
Edison, Thomas, 52, 53
education, 202, 294, 336–37
of AI, 202–3, 294
exponential growth of, 108, *108,* 525*n*
software for, 175, 337, 341, 589*n*
see also learning
egg cells, 221–22, 553*n*
Eighth Day of Creation, The (Judson), 550*n*
Einstein, Albert, 133, 355, 361, 388, 521*n,* 570*n*, 592*n*
general relativity theory of, 341, 355, 378, 500*n,* 503*n,* 520*n*
parietal lobes of, 202
on simplicity, 39, 519*n*
special relativity theory of, 341, 354, 520*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 617

Einstein-Rosen bridges, 355
Eisenach, J. A., 600*n*
Eisenhower, Dwight D., 72
Eldering, C., 600*n*
Eldredge, Niles, 510*n*–11*n*
electricity, *17, 18,* 244
  nanotechnology and, 114, 230, 248, 249, 250, 252
  prions and, 116–17
  from solar power, 249, 250
electrocardiograms (ECGs), diagnosing of, 8, 276, 281–82
electromagnetic-coupling constant, 499*n*
electromagnetic fields, 131
electromagnetic force, 140
electromagnetic radiation, communication with (radio transmission), 344–49, 590*n*
electromagnetic technologies, 76, 434
electromechanical paradigm, 67, *67,* 127–28, 434
electron-beam lithography, 113
electronic circuits, 27, 71, 503*n,* 504*n*
electronic neurons, 172
electronics, 3, 53, 54–55, 73, 227, 242, 245, 347, 444
  communications bridge between biological information and, 308, 313
  contemporary process of, 122
  democratization and, 406
  disposal problems and, 251
  nanotechnology and, 227, 407
  portable, 56, 113, 247
  price-performance of, 111–12, 526*n*
  value of, 339
Electronics, 111
electrons, 114, 141, 355, 499*n*
  in atoms, 14, 85, 131
  computing with spin of, *see* spintronics
  as digital vs. analog phenomena, 519*n*
  movies of movement of, 138
  quantum effects and, 119, 238
  transistor travel times of, 56, 61
elements, 14–15
  see also specific elements
elimination process, 304–5
Ellis, Havelock, 376
e-mail, 30–31, 78, 255–56
  FBI snooping on, 413
  spam filters for, 267–68
embryos, cloning and, 222, 555*n*–56*n*
Emerson, J. J., 510*n*
emotional intelligence, 8, 28, 124, 389
  machine, 28–29, 145, 377–79, 385
  spindle cells and, 191–94, *192*
emotions, 300, 310, 315–16, 319, 341, 475
encryption codes, 121, 354, 412, 419
encryption trapdoor, 413, 422
encyclopedias, 54, 363
endangered species, preservation of, 222
endocrine (hormonal) system, 163, 257, 325, 475
  artificial, 243, 306–7
  bandwidth of, 200, 443
  circulatory system and, 442, 443
endostatin, 218
endothelial cells, 163, 165, 210, 216
energy, 32, 33, 243–50, 339, 407
  black holes and, 7, 363, 503*n*
  cell aging and, 209, 552*n*
  cellular, 219–20, 583*n*
  centralized, 420, 421
  computational limits and, 72, 113, 128–34, *129,* 136, 300, 349–51, 427–28, 432, 434–35, 533*n*
  cost of, 96, 243, 246, 249–50
  as digital vs. analog, 14
  distributed, 421
  Dyson Sphere and, 350
  efficiencies in the use of, 243, 244, 248–49, 566*n*
  fossil fuels as source of, *see* coal; oil, oil industry
  information's relationship with, 86, 87, 243, 457, 522*n*
  lock-in and, 429, 430, 457
  for nanotechnology, 230, 238, 244, 245, 352
  nanotechnology-based, 133, 243–50, 340, 395, 397, 430, 434, 457
  nonbiological intelligence's saturating of, *15,* 21, 29, 45, 364, 375, 389, 511*n*
  patterns of, 325, 383, 385, 431, 474
  potential, 133
  recycling of, 249
  renewable, 243, 244, 251, 372, 395, 421, 434, 457
  for smart-dust systems, 334
  solar, *see* solar energy
  spintronics and, 118
  storage of, 246, 247, 248, 421, 434, 457
  total metabolic output of, 249
  transmission of, 246–47
  transportation of, 246, 247, 340
  utilization of, 244–46
  wind, 243, 244, 334
  worldwide requirements for, 243–44
  wormholes and, 355, 356
Energy Department, U.S., 247, 567*n*
Enger, John, 524*n*

vsnk$all.qxd 7/8/05 1:14 PM Page 618

engineered negligible senescence, 213
Engines of Creation (Drexler), 111, 139, 228
enhancers, 551*n*
ENIAC, 56
Enough (McKibben), 410
entertainment, 259, 288, 339–40
entropy, 39–40, 130, 134, 510*n,* 520*n*
entropy rate, 508*n*
"Entscheidungsproblem," *see* decision (halting) problem
environment:
  cleaning up of, 241, 249, 251, 372, 397, 410
  complexity of, 449, 475
  computing distributed in, 105, 136, 312
  diversity and, 45–46
  energy and, 243, 246, 249
  entropy and, 130
  exponential growth and, 44, 128, 433
  factory farming and, 224
  gene expression and, 551*n*
  nanotechnology and, 229, 230, 250–53, 259
  survival and, 39
  virtual-reality, 105, 312, 314, 337, 340, 341
  voxel (three-dimensional pixel) maps of, 285
environmentalists, 391, 395, 414–15
enzymes, 147, 207, 208, 217, 218, 238, 301, 306, 482, 550*n*
  digestive, 168
  DNA computing and, 117, 530*n*
  as molecular machines, 231–32
  nanotechnology and, 238–39, 247
  see also specific enzymes
epigenetic information, 16, 147
epilepsy, 188, 216
epithelium, 165
Epoch One, 14–15, *15*
Epoch Two, *15,* 16, 47
Epoch Three, *15,* 16, 47
Epoch Four, *15,* 16–20, *17–20,* 47
Epoch Five, 14, *15,* 20–21, 40, 47, 205, 367
Epoch Six, 14, *15,* 21, 32, 367, 390
equity markets, *see* stock, stock market
equivalence principle, 136–38, 536*n*
esophagus, upper, 307
ethanol, 247
ethical issues:
  biotechnology and, 221–22, 223, 224, 553*n*
  consciousness and, 379
  defensive technologies and, 416
  genetic engineering and, 402
  nanotechnology and, 229, 418, 423
  SETI and, 348
  xenografts and, 418, 598*n*
"Ethical Issues in Advanced Artificial Intelligence" (Bostrom), 260
"Ethics for Intelligent Machines" (Bostrom), 369
ETI, *see* extraterrestrial intelligence; SETI
eukaryotic evolution, *17, 18,* 450, 583*n*
Eumenes II, 54
Europe:
  bubonic plague in, 398, 402
  GMOs in, 471
European Commission, 414
Evans, Thomas, 569*n*, 570*n*
event horizon, 7, 29, 486–87
  gravity in, 23, 363, 486, 503*n*
Everett, Hugh, 500*n*–501*n*
evolution:
  complexity increases and, 36–39, 44, 45, 47, 389, 476, 507*n*
  farsighted, 47–50
  indirection and, 14, *15,* 16, 30, 40–41, 92, 94
  of language, 190
  law of accelerating returns and, *see* accelerating returns, law of
  as learning paradigm, 152
  as open system, 40, 41, 42
  order and, 14, 15, 20, 36–45, 47, 509*n*
  patterns and, 14–21, 389
  positive feedback in, 40, 41
  as runaway phenomenon, 32
  self-replicating nanotechnology and, 418
  six epochs of, 14–21, *15, 17–20*
  of universes, 360, 361
  see also biological evolution; technology evolution
evolutionary (genetic) algorithms, 38–39, 42, 91–93, 270–72, 405, 455, 480–81
  in AI applications, 280, 281, 284, 288
  basic schema for, 575*n*–76*n*
  defined, 539*n*
  evaluation function for, 272
  neural nets combined with, 271, 278–79
  order in, 38–39
  pattern recognition and, 92, 152, 271, 461
Evolution of Complexity by Means of Natural Selection (Bonner), 509*n*
existential risks, 400–408, 422, 495*n*–96*n*
exomuscle, 332
experience beamers, 316, 379
expert systems, 266–67, 280, 282–83
exponential growth, 425, 486

vsnk$all.qxd 7/8/05 9:06 AM Page 619

of brain reverse engineering, 73, 144, 196–98
of brain scanning, 25, 161, 197, 407
of communications, 35, 76–77, *77,* 102, 112, 245–46, 470
of complexity, 20, 358
of computing, 25, 56–73, *57–65, 67, 69–71,* 75, *75,* 102, 112, 127, 128, 135, 276, 292, 432, 434, 436, 470, 498*n,* 514*n*
criticism from Malthus and, 427–28, 433–34
in DNA sequencing, 74, *74,* 470, 514*n*
double, 12, 25, 27, 28, 41–42, 56, 506*n*
of education, 108, *108,* 525*n*
GNR and, 73, 227, 245–46
of information technologies, 3, 9, 25, 35, 72, 84, 85, 109, 245–46, 265, 377, 385, 429, 433–35, 457, 469, 470, 491–96, 504*n*
"knee of the curve" and, 9, *10,* 97, 154
of knowledge, 9, 73, 105, 302, 396
limits of, 128, 433–34
linear growth vs., 8, 10–14, *10,* 97–98, 108, 109, 137
Moore's Law and, *see* Moore's Law
nearly vertical phase of, 24
of nonbiological intelligence, 257, 300, 316, 377, 407
of order, 20, 45
paradigms and, 42–46, *43, 44,* 263–64
in productivity, 98–101, *98, 99, 101*
of quantum computing, 121
rabbits in Australia and, 128, 433
see also accelerating returns, law of
"Exponential Growth of Computing" chart, 70, *70,* 125, 135
extinction, 222, 409, 511*n*, 588*n*
extracellular aggregates, 220
extraterrestrial intelligence (ETI), 372, 406
search for, *see* SETI
eyeglasses, 105, 312, 472
eyes, 130, 186–87, *187,* 482

facial animation, 294–95
factoring large numbers, 121, 354, 530*n*
factory farming, 224, 379
famine, 406
Fandel, D., 512*n*
Fantastic Voyage (Kurzweil and Grossman), 210, 217, 323
Fantastic-Voyage.net, 490
Faraday, Michael, 326
Fast ForWord, 175
fat cells, 12, 219, 303
fat insulin receptor (FIR) gene, 12, 303
FATKAT (Financial Accelerating Transactions by Kurzweil Adaptive Technologies), 569*n*
fats, dietary, 301
Fay, R., 545*n*
FBI, 392, 413, 421
FDA, *see* Food and Drug Administration
fear, 241, 541*n*
Feder, Barnaby J., 564*n*
Federal Reserve Board, 97
feedforward sequence, 154, 170, 186, 574*n*
Feigenbaum, Edward A., 295–96, 582*n*
Feigenbaum test (FT), 295–96
Feinstein Amendment, 594*n*
Feldham, Jim, 591*n*
Felsenfeld, Gary, 549*n*
femtotechnology, 138–39, 351
Fenniri, Hicham, 528*n*
Feringa, Ben, 234
Fermi, Enrico, 348
Fermi Paradox, 348, 357–59
ferromagnetic metallic alloys, 119
fetuses, cloning of, 221
Feynman, Richard P., 86, 226, 227, 228, 320, 558*n*
Feynman Gate, 534*n*
fiber cells:
climbing, 180, *180,* 181
mossy, 179, *180, 182,* 545*n*
fiber optics, 76, 346
field-emission displays (FEDs), 253
fimbriae, 236
finance, 413, 449
AI systems in, 283, 284, 287, 294
see also stock, stock market
fine-structure constant, *see* alpha
fingers, 174
see also thumbs
Finkel, Leif H., 162, 164, 530*n*, 541*n*
Finn, O. J., 554*n*
firewalls, 256, 257
firmware, 444
First Union Home Equity Bank, 284
Fitch, Tecumseh, 190
flash memory, 54, 113, 115, 116
Fleischman, Martin, 567*n*
Florence, University of, 288
flu, 398, 402
flying machines, 457–58
FocalPoint, 282–83
Focus, 309, 586*n*
Fodor, Jerry A., 387, 594*n*
Fogg, D. K., 552*n*
foglets, 28, 29, 33, 310, 325, 506*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 620

Foiles, P., 555*n*
Foley, E. T., 562*n*
food, food supply, 301, 339
  cloning of, 224
  in digestive tract, 386
  genetically modified, 406, 414–15, 471
  nanotechnology and, 251
  spybots and, 406
food additives, 215
Food and Drug Administration (FDA), 12, 195, 217, 282, 412, 416, 585*n*
foreign languages, translation of, 288, 292, 313, 337
Foresight Institute, 558*n,* 584*n*
  guidelines of, 229, 395, 411, 418–19, 598*n*
forgetting, 176–77, 543*n*
Forró, László, 526*n*
Fortran, 89
forward internal models, 179
fossil fuels, *see* coal; oil, oil industry
Founds, H., 555*n*
Fountain, Henry, 536*n*
four-dimensional network, 520*n*
Fourier transforms, 438
Foveon, 533*n*
Fox, Armando, 284
fractals, 89, 522*n*
  brain and, 46–47, 68, 446–49
  defined, 68, 447
Francis of Assisi, Saint, 382
Franklin, Benjamin, 382–83
Franks, Tommy, 334
Frantz, Gene, 533*n*
fraud, detection of, 269, 276, 283, 284
Fredkin, Edward, 86, 87, 127, 518*n*–19*n*, 533*n,* 534*n*
  reversible computing and, 130, 131–32
Freeman, Walter J., 538*n*
free will, 382, 521*n*–22*n*
Freitas, Robert, Jr., 133, 230, 238, 403, 506*n,* 535*n,* 536*n,* 537*n,* 541*n,* 548*n,* 557*n*–60*n,* 561*n,* 562*n,* 563*n,* 566*n,* 568*n,* 584*n,* 585*n,* 587*n,* 591*n,* 595*n,* 596*n,* 597*n,* 600*n*
  on biological age, 253
  brain scanning and, 164–66
  on brain-uploading system, 548*n*–49*n*
  on energy, 249, 566*n*
  on life expectancy, 323
  on nanobot problems, 399, 400, 411–12, 425
  nanomedicine and, 254, 255, 305–6, 584*n*
  robotic probes advocated by, 591*n*
  sentience quotient of, 536*n*
  vasculoid design of, 306
Fremouw, Thane, 545*n*
French, Robert M., 569*n*
Freud, Sigmund, 176
"Freud, Sigmund," 202, 203, 317–18, 381, 458, 475
Friedman, Scott, 547*n*
Frisch, Max, 341
Friston, K. J., 143, 537*n,* 543*n*
Fromherz, Peter, 586*n,* 587*n*
Frontier Medical Institute, 550*n*
frontoinsular cortex, 193
fructose, 248
fuel cells, 133, 230, 238, 244, 246, 247–48, 334, 340, 397
  energy storage in, 247, 421, 434, 457
Fuerth, Leon, 470, 471–72
Fujishima, Akira, 567*n*
Fulford, Benjamin, 526*n*
functional magnetic-resonance imaging (fMRI), 150, 156, 158, 160–61, 175, 176, 193
fundamentalism, 498*n*
  environmentalist, 414–15
  GNR impact and, 338, 340–41
  humanist, 415, 471
  religious, 414
Fuster, J. M., 542*n*
future, 3–4, 5, 7, 299
  misunderstanding of, 10–14, 240–41
  prediction of, 432
Future Combat System (FCS), 331–33
FutureGen, 244
Future of Life conference (2003), 11–12, 499*n*
Future Route, 284

Gabriel, Richard, 569*n*
Gabrieli, John, 175, 176–77
Gage, Fred H., 177, 544*n*
galaxies, 357, 390
  Hubble distance and, 354
  Milky Way, 342–48, 590*n*
  stars vs., 281
Gall, W. E., 532*n,* 538*n*
Gallant, J., 547*n*
Gallaway, J., 595*n*
gallium arsenide, 119, 138, 251
game-playing programs:
  for chess, 274–78, 441, 459
  recursive search and, 272–73, 577*n*–80*n*
Gan, Wen-Biao, 172
Ganer, Alan G., 599*n*
ganglion cells, 187
Gardner, James, 359, 361–62, 366, 592*n,* 602*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 621

Gardner, Timothy, 221
Garfinkel, S. L., 555*n*
Gargini, Paolo, 112, 526*n*
Gartner, John, 567*n,* 582*n*
gas:
  curved surfaces and, 265
  energy from, 243, 244, 247, 250, 252, 420
  prediction of properties of, 168, 432
gates, 111
  logic, *see* logic gates
"Gates, Bill," 374–76
Gell-Mann, Murray, 37, 38, 508*n*
gender, change in, 318–19
gene chips (microarrays), 214–15, 552*n*
gene expression, 16, 147, 213–16, 283, 551*n*–53*n,* 556*n,* 557*n*
  nanobots and, 232–33
  peptides and, 213, 223, 232
  RNA interference and, 12, 214, 256, 323, 417, 422, 551*n*
  suppression of, 219, 323, 422
General Dynamics, 235
General Electric, 271
General Problem Solver (GPS) program, 264, 273, 569*n*
general relativity theory, 341, 355, 378, 500*n,* 503*n,* 520*n*
genes, genetics, 16, 27, 107, 168, 282, 482–83
  of chimpanzees vs. humans, 5, 505*n*
  defective, 214, 553*n*
  as disposition, 225
  fat insulin receptor (FIR), 12, 303
  mutations and, *see* mutations
  protection of, 42
  regulatory sequences of, 551*n*
  revolution in, 73, 84, 205–27, 299–300, 549*n*–57*n*; *see also* biotechnology
  in sexual reproduction, 46
  "suicide," 219
gene splicing, 418, 423, 482
gene therapy, 215–17, 219, 220, 256, 323, 553*n*
genetic algorithms (GAs), *see* evolutionary (genetic) algorithms
genetically modified organisms (GMOs), 406, 414–15, 471
genetic disorders, 553*n*
genetic engineering, 28, 301
  environmentalist campaign against, 391
  viruses and, 206, 393, 398, 402–3
genetic errors, cloning and, 221, 556*n*
genetic modification, 116–17, 171
genetic profiling, uses of, 214–15
genome, human, 13, 145, 225, 600*n*
  aging and, 221
  brain and, 89, 147, 180, 428–29, 440, 443–44, 523*n*
  compression of, 89, 147, 206–7, 443, 448, 449, 482, 508*n,* 516*n*–17*n,* 523*n,* 538*n*
  DNA sequencing and, 73–74, *73, 74,* 85, 514*n*
  fractal designs and, 46, 47
  information content of, 46, 47, 206–7, 516*n*–17*n,* 522*n*
  proteins and, 42, 225, 510*n,* 517*n*
  reverse engineering of, 517*n*
genome, virus, 553*n*
genomics, 323
geothermal technologies, 243, 244, 246
Gerberding, Julie, 514*n*
Gerla, Mario, 589*n*
Germany, Germans, 2, 138, 188, 195, 308, 536*n*
Gianaro, Catherine, 506*n*
Gilbert, S. F., 551*n*
Gilder, George, 370, 394, 497*n*
Giorelli, Giulio, 369
giraffe, brain of, 4, 169
Gisin, Nicolas, 353–54
Glenn, Jerome C., 565*n*
glial cells, 195
Glickstein, M., 544*n,* 545*n*
glucose, 124, 230, 232, 399, 530*n*
  blood-brain barrier and, 163, 165
  in fuel cells, 230, 238, 248, 306
  nanomedicine and, 238, 243, 307
  as nutrient, 301
glycogen, 305
GMOs, *see* genetically modified organisms
GNR (Genetics, Nanotechnology, Robotics) age, 205–98, 407, 549*n*–83*n*
  defensive technologies for, *see* defensive technologies for GNR age
  economic growth from, 98, 230–31, 396–97, 406, 410
  existential risks of, 406–7, 422
  exponential growth and, 73, 227, 245–46
  impact of, *see* impacts, GNR
  information and, 84, 206–7, 210, 231, 245–46, 261
  intertwined benefits and dangers of, of, 396–400
  Joy's concerns about, 391, 394–95
  peril vs. promise of, 391–426, 427, 594*n*–99*n*
  relinquishment of, 12, 395, 406, 407–8, 410–16, 423
  synergy and, 73

vsnk$all.qxd 7/8/05 9:06 AM Page 622

GNR (Genetics, Nanotechnology, Robotics) age (*cont.*)
wealth creation from, 13, 107, 338, 396–97, 410
see also biotechnology; nanotechnology; robots, robotics; strong AI
goats, transgenic, 222
God, 15, 360, 375, 389–90, 474, 476, 477
"playing," 299
Goda, Yukiko, 176
Goddard, William A., III, 563*n*
Gödel, Kurt, 453–54, 601*n*
Godling's Glossary (Transend), 198
God parameters, 92
Goertzel, Ben, 279, 580*n,* 599*n*
Golden Rice, 414–15
Goldman-Rakic, P. S., 543*n*
Goldstein, C. D., 535*n*
Golgi cells, 182, 545*n*
Golub, T. R., 552*n*
Gompers, Paul, 524*n*
Good, Irving John, 22, 23
Goodall, Randall, 512*n*
Google, 286
Gorbachev, Mikhail, 406
Gordon, Theodore J., 565*n*
gorillas, 192
Gosney, John, 58*n*
Gould, Stephen Jay, 487, 510*n*–11*n*, 602*n*
Graham, S., 555*n*
grandfather paradox, 140–41
grandmother hypothesis, 218–19, 302
granule cell, *180,* 181, *182,* 544*n*
graphics programs, 46
gravitational constant, 499*n*
gravity, 356, 362, 486
body's sensations of, 165
event horizon and, 23, 363, 486, 503*n*
general relativity theory and, 520*n*
overcoming of, 364
quantum, 14
gray dust scenario, 400
gray goo, 399–400, 416
gray lichens scenario, 400
gray plankton scenario, 400
Grayson, A., 584*n*
Grayson, Richards, 564*n*
Great Depression, 99, 102
"Great Principles of Computing" (Denning), 167
Greeks, ancient, 458
Greenpeace, 391, 414–15
Greten, T. F., 554*n*
Grey, Aubrey D. N. J. de, 551*n,* 555*n*
Grossberg, S., 545*n*
gross domestic product (GDP), 65, 98, *98,* 99, *99*
Grossman, Terry, 210–12, 217, 323, 550*n*–51*n*, 593*n*
growth hormone, *see* human-growth hormone
Grutzendler, J., 542*n*
Gulde, Stephan, 121, 531*n*
Gulf War, *331*
Gurdon, J. B., 556*n*
Gustafsson, Marie, 538*n*
Gutenberg, Johannes, 54

Hackett, John, 581*n*
hacking, 406, 426, 594*n*
Hahnlose, R. H., 540*n*
hair cells, 165
Håkelien, Anne-Mari, 557*n*
Haldane, J. B. S., 342
Hall, J. Storrs, 310, 506*n,* 516*n*
halting (decision) problem, 453, 601*n*
Hameroff, Stuart, 450–52, 600*n*
Hammarström, Per, 550*n*
hands, *see* fingers; thumbs
handwriting, 181, 269
haptic (tactile) interfaces, 105
Harcourt, Brace, and World, 497*n*
hard drive, 115, 119
hardware, 259
for artificial neural networks, 574*n*–75*n*
deflation and, 102
to emulate human intelligence, 25, 126, 127, 145
files installed on, 324–25
self-organization in, 151
software vs., 102, 428, 435, 438, 439, 445
specialized, 275–76
for strong AI, 261
Harper, Jack, 515*n*
harpsichords, 53
Harrison, J. A., 563*n*
Harry Potter and the Prisoner of Azkaban (Rowling), 4–5
Hart, S., 586*n*
Harvard University, 116, 162–63, 308, 471
Hauser, Marc D., 190, 548*n*
Havenstein, Heather, 569*n*
Hawking, Stephen, 309, 363–64, 487, 503*n,* 586*n,* 592*n*
Hawking radiation, 363–64, 487, 503*n*
HDL (high-density lipoprotein) cholesterol, 211, 217, 554*n*
heart, replacement of, 223, 302, 306, 373
heart cells, 214, 220
heart disease, 212, 303

vsnk$all.qxd 7/8/05 9:06 AM Page 623

death from, 211, 217, 373, 413, 418
reversal of, 210, 217
see also atherosclerosis
heat generation:
computational limits and, 129–32, 350, 351, 428, 434
energy and, 245, 249, 566*n*
Hebb, Donald O., 156–57, 170–71, 176, 542*n*
Hebbian reverberatory memory, 156–57, 170–71
Heidmann, J., 502*n*
Heisele, Bernd, 547*n*
Heisenberg, Werner, 138
Heller, A., 565*n*
hemoglobin, 209
Henry, Thomas, 400
Hersam, C., 563*n*
Hess, K., 562*n*
heuristic methods, 454, 455
Hidden Order (Holland), 509*n*
hippocampus, 171, 175, 176, 177, 188
history:
Dembski's view of, 476–77
human, rupture of, 9, 23
"singularity" in, 486
HiTech, 275
Hitler, Adolf, 327
HIV virus, 74, 398, 402, 514*n*
Ho, Wilson, 561*n,* 562*n,* 564*n*
Hobbes, Thomas, 338, 590*n*
Hochberg, David, 356, 592*n*
Hodgkin, A. L., 154–55, 539*n*
Hodgkin's disease, 552*n*
Hofstadter, Douglas R., 4, 169, 198, 497*n*, 498*n,* 568*n,* 582*n,* 600*n*
Hogan, Jenny, 560*n*
holism, criticism from, 431, 479–83
Holland, John, 509*n*
Holmes, Bob, 552*n*
Holocaust, 1, 2
holographic processes, 163, 325
of brain, 148, 152
memory retention and, 172
of universe, 365–66, 486
hominids, 193
evolution of, *17, 18, 20,* 39, 509*n*
see also chimpanzees; humans
homocysteine, 211
Homo Faber (Frisch), 341
Homo genus, *17, 18,* 509*n*
Homo sapiens, 17, 18, 20, 42, 47, 195
Honda Odyssey, 287
hormones, *see* endocrine (hormonal) system
Hornbeck, Larry J., 516*n*
Horowitz, B., 143, 537*n*
hospitals, intensive-care units in, 255, 413, 435, 456
House of Representatives, U.S., Science Committee of, 599*n*
"How Long Before Superintelligence?" (Bostrom), 259
H. pylori, 282
H-scan test, 550*n*
Hubble distance, 354
Hubble Space Telescope, 590*n*
Hubel, D. H., 173, 542*n*
Huehn, Rebecca, 567*n*
Huffet, H., 512*n*
Hughes, James, 396
Human Genome Project, 510*n*
human-growth hormone, 212, 215
human intelligence, 264, 342, 407, 440
Church-Turing thesis and, 429, 454–56
complexity of, 482
as emergent property, 151
nonbiological portion of, 9, 28, 201–2, 296, 300, 310, 316, 317, 356
personal computers' emulating of, 25, 70, 125–26, 441–42, 533*n*
plasticity of, 27, 203
self-understanding and, 4, 198
software of, *see* brain reverse engineering
as suboptimal, 151–52
supercomputers' emulating of, 25, 70, *70,* 71, *71,* 125, 150, 196, 530*n*–33*n*
technology merged with, *15,* 20–21
see also biological intelligence
humanism, fundamentalist, 415, 471
humanity, 136, 476
ascent vs. descent of, 387
fear of loss of, 9, 310–11
goal of, 373
human rights, 471
humans:
brain of, *see* brain, human; cortex, cerebral
chess playing of, 274–75, 277
chimpanzees compared with, 5, 39, 192, 505*n,* 509*n*
Church-Turing thesis and, 429, 454–56
cloning of, 221–25, 556*n*
complexity of rock compared with, 37, 508*n*
divergence from great apes by, 509*n*
duration of observation by, 48
dysfunction of, 202
enhanced, 200
jaws of, 506*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 624

humans (*cont.*)
migration and colonization patterns of, 352
mirrors used by, 190
order and, 90–91
robotic searches for, 286
as "second-class robots," 205–6
teams of, 261
technology's merger with, 374, 377
uniqueness of, 4, 226, 311, 433
human somatic-cell engineering, *see* transdifferentiation
Humayun, M. S., 546*n*
hunger, overcoming, 224, 371, 406
Hunt, J. M., 595*n*
Huxley, A. F., 154–55, 539*n*
hydrocarbons, 252
hydroelectricity, 243
hydrogen, 119, 131, 210, 244–47, 251, 349, 365, 592*n*
in fuel cells, 133, 230, 244, 246, 247, 306
nuclear fusion of, 250, 567*n*
storage capacity of, 134
hydrogen abstraction, 239–40, 563*n*
hydrogen bomb, 391, 401, 404, 408
Hypersonic Sound technology, 313
hypertension, pulmonary, 216
hypsithermal limit, 249, 566*n*

IBM, 114, 287
autonomic computing and, 284, 437
Blue Gene/L supercomputer of, *71,* 125, 482, 533*n*
Blue Gene/P supercomputer of, 71, *71*
computer chess and, 275, 276, 441, 459
nanotube fabrication at, 114, 527*n*
self-assembling nanoscale circuits and, 116, 529*n*
IBM 360 Model 91, 2–3
IBM 1620 ("minicomputer"), 2
IBM 7000 series, 2
IBM 7094, 64–65
ICBM arsenals, 401
ideas, power of, 1–5, 497*n*–98*n*
identity, 142, 201, 315
boundaries and, 387
cloning and, 224–25
copies and, 383–84, 389
human longevity and, 325–26, 329
"me" vs. "not me" and, 386
Singularity and, 369, 382–87
If Aristotle Ran General Motors (Morris), 485
iHex, 284
Illinois, University of, 115, 255, 335
image processing, 123, 187–88, 279, 445
imagination, 299, 318
imaging reporter genes, 216
imaging technology, 138, 163, 164
imitation, 190
immortality, 320, 324–25, 330, 370, 474
immune system, human, 217–20, 223, 255, 418, 425
immune system, technological, 241, 413
nanotechnology-based, 400, 411–12, 417, 425–26
Immune Tolerance Network, 557*n*
impacts, GNR, 299–368, 583*n*–93*n*
on body, 299–311, 583*n*–86*n*
on brain, 307–9, 312–20, 586*n*–87*n*
on human longevity, 320–30
on intelligent destiny of the cosmos, 342–68, 590*n*
on learning, 335–37, 589*n*
panoply of, 299–300
on play, 341–42
on warfare, 330–35
on work, 337–41
implants:
neural, *see* neural implants
pancreas, 124, 307, 530*n*
to regulate insulin, 124, 243, 307, 530*n*
retina, 185, 308, 585*n*
incompleteness theorem, 453–54, 601*n*
individuality, 375
industrialization, 28, 95, 122
industrial products, 215, 231, 245, 339
industrial revolution, *17, 18, 20,* 340, 409, 410
infant mortality, 321
infection, infectious disease, 165, 306, 335, 581*n*
MYCIN system and, 266–67
RNA interference and, 422, 552*n*
inferotemporal cortex, 186
Infineon chip, 195
information:
accessibility of, 327–29, 338, 469
alternation between analog and digital representations of, 519*n*
in atomic structures, 14, *15,* 119, 131, 134, 536*n*
biology's intersection with, *see* biotechnology
black holes and, 503*n*
in brain and nervous systems, *15,* 16, 127, 148, 152, 179, 325, 440, 449
caring for, 329–30
cellular automata and, 85–91
complexity and, 15, 36–40, 437

vsnk$all.qxd 7/8/05 9:06 AM Page 625

in DNA, *15,* 16, 38, 40, 117, 207, 232, 518*n*
epigenetic data as, 147
evolution and, 14–16, *15*
fractal designs and, 46–47
in genome, 46, 47, 206–7, 516*n*–17*n,* 522*n*
GNR age and, 84, 206–7, 210, 231, 245–46, 261
in hardware and software, *15,* 16, 38
in holograms, 148, 152, 172
importance of, 85
improvements in recording of, 40
knowledge vs., 372, 375, 386
limits on transfer of, 21
longevity of, 325–30
matter and energy's relationship to, 86, 87, 522*n*
in "mesh" computing, 125
military communications and, 332–33
order as, 38–42
patterns of, 5, 258, 460, 522*n*
physical world's intersection with, *see* nanotechnology
value determined by, 231, 245, 339
Information Mechanics (Kantor), 518*n*
information technologies (IT), 8, 41
acceleration of, *see* accelerating returns, law of
boom-and-bust cycles in, 13, 97, 103
decline in cost of, 338, 469, 472
demand for, 65, *65*
economic share of, 65, 107, *107,* 525*n*
energy as, 243, 457
exponential growth of, 3, 9, 25, 35, 72, 84, 85, 109, 245–46, 265, 377, 383, 429, 433–35, 457, 469, 470, 491–96, 504*n*
paradigm shifts in, 429–30
power (price-performance, speed, capacity, and bandwidth) of, 25, 27, 41, 84, 101, 102, 224, 377, 429, 432, 469, 470, 504*n*
prediction and, 432
principles of Singularity and, 25–29
reduction in adoption lag time for, 469, 472
see also computers, computation; Internet
Ingber, Donald, 163
initiator (single design element), 46
innovation, *see* paradigm shifts; technology evolution
Innsbruck, University of, 121
insects, 415
swarms of, 333
insider trading, 284
instinct, 293–94, 378
Institute for Advanced Study, 498*n*–99*n*
Institute for Creative Technologies, 312
Institute for Molecular Manufacturing (IMM), 598*n*
Institute Workshop on Molecular Nanotechnology Research Policy Guidelines, 598*n*
insula, right and left, 166, 193, 314
insulin, 168, 221, 255
fat receptor gene and, 12, 303
implantable devices for regulating of, 124, 243, 307, 530*n*
insulinlike growth factors (IGFs), 215
integrated circuits, 56, 67, 71
application-specific (ASICs), 125, 135, 276, 445
nanotube-based, *see* nanotubes and nanotube circuitry
as paradigm, 67, *67,* 75, *75,* 127–28, 434
transistors on, 42–43, 56, 71, 76, 111–12, 114, 157, 351, 434
Integrated Fuel Cell Technologies, 247
integrator neurons, 166
Intel, 434
intellectual property (IP), 96, 105, 107, 339–40
patents, 84, *84,* 106, 146, 525*n,* 533*n,* 537*n*
intelligence, 4, 370, 372
artificial, *see* artificial intelligence; narrow AI; strong AI
biological, *see* biological intelligence
emotional, *see* emotional intelligence
extraterrestrial, *see* SETI
human, *see* human intelligence
military, 280, 281
moral, 8, 192
nonbiological, *see* nonbiological intelligence
intelligence quotient (IQ), 505*n*
intelligent design, 360, 480–81
Intel processors:
chip problems for, 456
single-chip vs. dual-core, 129–30, 533*n*–34*n*
transistors in, 63, *63,* 66
intensive-care units, 255, 413, 435, 456
Interaction Gate, 534*n*
interaural level difference (ILD), 184
interaural time difference (ITD), 123, 184
interferometry, 344
international cooperation, 423

vsnk$all.qxd 7/8/05 1:14 PM Page 626

International Society for BioMEMS and Biomedical Nanotechnology, 584*n*
International Technology Roadmap for Semiconductors (ITRS), 57, 112, 126, 292
International Xenotransplantation Authority (IXA), 598*n*
Internet, 261, 279
  access to knowledge via, 26, 32, 261, 286
  adoption of, 13, 95, 97, 264
  bandwidth of, 81, *81,* 263, 312, 472, 516*n*
  bank transactions on, 102
  brain compared with, 152
  complexity and, 38
  dangerous information on, 392–93, 395, 594*n*
  data traffic on, 80, *80,* 516*n*
  decentralization and, 396, 406, 420
  education and, 336
  hosts, 78–79, *78, 79*
  lock-in and, 430, 457
  nodes (servers) of, 13, 152, 263, 499*n*
  skepticism about, 13, 263
  software viruses and, 255–56
  surveillance and, 413
  unused computational power of devices on, 125–26, 135, 278
  wireless communications and, 312, 346
  see also World Wide Web
Internet bubble, 13, 97, 263
Internet Software Consortium, 499*n*
interneuronal connections, 163, 184, 430
  brain models and, 147–48, 174, 178, 428, 446
  complexity of, 428
  defined, 145
  growth in, 174
  information and, 47
  limits of, 26, 27, 129, 265, 270, 337, 445
  memory and, 126–27, 137, 329, 523*n*
  nanobots and, 313, 316
  in newborns, 152
  number of, 8, 27, 129, 150, 440, 600*n*
  patterns of, 260, 317, 337, 445, 463
  plasticity of, 175, 176
  reset time for, 124, 503*n,* 504*n*
  simulations of, 122, 428, 530*n*
  see also axons; dendrites
intracellular aggregates, 220
intracellular surgery, 162–63
inventions:
  of author, 1, 2–3, 370, 497*n*
  of biological evolution, 5
  mass use of, *50,* 512*n*
  textile automation, 507*n*
  see also specific inventions
invention stage, 51–52
inverse internal models, 179
investment, investing:
  automated, 265, 435
  capital for, 96, 106, 339, 395, 524*n*
  in defensive technologies, 408, 417, 418, 422
  lock-in and, 429–30, 457–58
in vitro fertilization, 340
Iraq, Desert Storm campaign in (1991), 284
Iraq war, 280, *331,* 332
I-Robot, 333
irreversible computing, 130, 132, 245
Ishiyama, Kazushi, 304, 584*n*
islet cells, pancreatic, 124, 168, 213, 223, 255, 557*n*
isogenic replacement cells, 556*n*

Jacobi, C. T., 535*n*
Jacobstein, Neil, 598*n*
Jacoby, Mitch, 536*n*
Jaffee, E. M., 554*n*
Jahnke, A., 575*n*
Jaiswal, J. K., 586*n*
Jansen, Jac J., 587*n*
Japan, life expectancy in, 408
Jefferson Airplane, 300, 315
Jenkins, D. E., 342
Jensen, R. J., 585*n*
jet engines, design of, 270, 271
jet propulsion, 138
Jobling, Mark A., 549*n*
Johanson, D., 502*n*
Johns Hopkins University, 398
Johnson, M., 553*n*
Johnson, R. Colin, 528*n,* 586*n*
Johnston, M. V., 539*n*
Joint Forces Command, U.S., Project Alpha of, 333
Jones, Douglas, 515*n*
Jones, Tanya, 598*n*
Joy, Bill, 12, 391, 394–95, 409, 411, 417, 595*n,* 598*n*
Joyce, Gerald F., 235–36
Judson, Horace F., 550*n*
Jung, Carl, 382
Jupiter, 280, 349
Justice Department, U.S., 284
Juvenile Diabetes Foundation, 557*n*

Kaczynski, Ted, 32, 410, 411, 597*n*
Kahle, Brewster, 588*n*
Kahn, Ron, 303
Kalaugher, Liz, 528*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 627

Kamat, Prashant V., 567*n*
Kandel, Eric R., 544*n*
Kanellos, Michael, 526*n,* 529*n*
Kanerva, Pentti, 172
Kant, Immanuel, 335
Kantor, Frederick W., 518*n*
Kapor, Mitch, 295
Kardashev, N. S., 344, 590*n*
Kasparov, Gary, 8, 275, 277–78, 292
Kass, D. A., 555*n*
Kass, Leon, 470
Katz, Lawrence, 523*n,* 539*n*
Kauffman, Stuart, 509*n*
Keklak, John, 580*n*
Keller, Helen, 341
Kelly, Jeffrey W., 550*n*
Kelly, T. Ross, 234, 560*n*
Kempermann, G., 177, 544*n*
Kempf, Karl, 513*n*
Kennedy, James, 589*n*
Kennedy, John F., 1, 401
Kennedy, Robert, 596*n*
Kentucky, University of, Institute for Molecular Manufacturing at, 240
Kephart, Thomas W., 356, 592*n*
Kevlar, 332
key events, of biological and technological evolution, 16–20, *17–20,* 36, 501*n*–3*n*
  canonical milestones, 19, *20,* 502*n*
  in "Countdown to Singularity" charts, 17–18, *17, 18,* 501*n*
  increase-in-complexity criteria for, 36–40, 507*n*
  paradigm shifts for fifteen lists of, 18, *19,* 501*n*–2*n*
  punctuated equilibrium and, 44–45, 510*n*–11*n*
Kharif, Olga, 586*n*
kidneys, 223, 305, 418
Kim, J. J., 545*n*
Kim, Seong-Gi, 540*n*
kinematic cellular automata, 235
kinematic machine replication, 228, 229, 558*n*–59*n*
kinesthetic sensory management, 166
King, Neil, Jr., 598*n*
Klar, H., 575*n*
Kleiner, Perkins, Caufield & Byers, 395
Klenow, Peter, 100, 525*n*
Klibanov, A. M., 239, 562*n*
Klimov, V. I., 566*n*
Kling, Ross D., 581*n*
Knapp, Louise, 565*n*
"knee of the curve," 9, *10,* 97, 154
Knight, Will, 528*n,* 530*n,* 534*n,* 589*n*
knowledge, 25, 341, 358, 375, 498*n*
  backing up of, 323
  brain limits and, 9
  commonsense, 177, 267, 292
  creation of, 300
  downloading of, 300, 337
  economy and, 96, 97
  exponential growth of, 9, 73, 105, 302, 396
  human learning of, 26, 293–94
  information technologies' encompassing of, 8, 85
  information vs., 372, 375, 386
  innate (instinct), 293–94
  Internet access to, 26, 32, 261, 286
  limits on pursuit of, 391
  loss of, 372, 386
  medical, 282, 283, 396
  number of expert "chunks" of, 126
  as pattern, 323, 386
  personality uploading and, 124
  respect for, 424
  technology's sharing of, 20, 26, 145, 202–3, 260
Koch, Christof, 194, 450, 532*n*, 538*n*, 600*n*
Koehler, Kenneth R., 505*n*
Kokinov, Boicho, 569*n*
Konarka, 250
Korean War, 330, *331*
Kortum, Samuel, 524*n*
Koumura, N., 560*n*
Krag, Tomas, 533*n*
Kramer, Peter D., 169, 541*n*
Kramnik, Vladimir, 274–75, 277–78
Krauss, Lawrence, 590*n*
Krazit, Tom, 526*n*
Kristula, Dave, 516*n*
Kurzweil, Allen, 319, 587*n*
Kurzweil, Fredric, 1, 211
  archive of, 326–27
  as musician, 327, 339, 497*n*
Kurzweil, Hannah, 1, 2, 497*n*
Kurzweil, Ray (author), 504*n,* 505*n,* 544*n,* 548*n,* 550*n*, 580*n,* 582*n,* 592*n,* 593*n,* 594*n,* 595*n,* 599*n*
  biochemical programming of, 211–12
  biological age of, 211
  childhood of, 1–3
  Chinese Room of, 465–66
  congressional testimony of, 422
  as cybernetic totalist, 380–81, 435
  daughter of, 315
  health of, 211, 225
  information collecting of, 326–28
  as inventor, 1, 2–3, 370, 497*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 628

Kurzweil, Ray (author) (*cont.*)
as materialist, 388, 394, 431, 473–74
as patternist, 5, 386, 388, 474
religious upbringing of, 1, 2
as Singularitarian, 368, 370–73
technology models of, 3
as technology optimist, 393, 395
virtual-reality persona experienced by, 314–15
as writer, 3, 370, 497*n*; *see also specific books*
KurzweilAI.net, 279, 489–90, 497*n,* 580*n*
Kurzweil Applied Intelligence (KAI), 570*n,* 599*n*
Kurzweil Computer Products, 97, 570*n*
Kurzweil Education Systems, 337, 589*n*
Kurzweil Technologies, 282
Kurzweil Voice, 599*n*
Kurzweil Voice Report, 570*n*
Kwong, K. K., 540*n*

labor productivity, 100, 101
La Cerra, P., 539*n*
Lahn, Bruce T., 506*n,* 510*n*
Laino, Charlene, 581*n*
Lamina 1 neurons, 193, 314
laminar structures, 160
Lamm, Dick, 321
Lamoreaux, Steve K., 139–40, 537*n*
Landauer, Rolf, 130, 534*n*
language, 26, 260, 276
AI applications for, 286–88
brain region for, 173, 175, 190
evolutionary algorithms and, 92
origin of, 190
Rosetta Disk and, 588*n*
translation of, 288, 292, 313, 337
Turing test and, 272, 286, 288, 292, 295, 461, 464
written, *17, 18, 20,* 36, 44, 48, 286, 338, 536*n*
see also Chinese Room analogy; speech recognition
Lanier, Jaron, 380, 386, 456, 469
criticism from software and, 435, 436, 440–41
on lock-in, 457
Lanza, R. P., 557*n*
laptop computers, 133–36, 337, 349, 362
laser light, computing with, 113, 119–20
Lasota, Jean-Pierre, 503*n*
Lassiter, L. K., 554*n*
Latif, Sajid, 336
Lauhon, L. J., 561*n,* 562*n*
Laurent, Gilles, 168
law, legal system, 374–75, 379, 416
law enforcement organizations, 413, 421
Lawrence Berkeley National Laboratory, 235
Lawrence Livermore National Laboratory, 307, 533*n,* 585*n*
LDL cholesterol, 554*n*
learning, 120, 143, 152, 202, 260, 293–94, 317
AI and, 294
basis functions and, 179
computer, 146
GNR impact on, 335–37, 589*n*
of handwriting movements, 181
neural, Hebb's theories of, 156–57, 170–71
neural, Svoboda's research on, 171–72
online, 300
to read, 175, 337, 589*n*
by robot scientists, 283
synaptic plasticity and, 169, 541*n*
of visual-spatial relationships, 175
"Leary, Timothy," 31, 318, 368
LeDoux, Joseph, 169, 541*n*
Lee, Hyojune, 563*n,* 564*n*
Lee, San-Hee, 218–19
Leibniz, G. W., 167, 376, 458
Lenat, Doug, 267
Lenslet, 120
Lerner, Josh, 524*n*
leukemia, 215
Lewis, J. D., 554*n*
Li, Chao, 529*n*
Liao, Shiping, 235, 560*n*
Liao, Yihau, 575*n*
liberty, 421–22, 424
Libet, Benjamin, 191
libido, 318
libraries, 279, 393, 594*n*
Lie, Dieter C., 544*n*
Lieber, Charles M., 528*n*
Lien, Hsing-Lung, 567*n*
life, 86, 377, 501*n*
evolution of, *17, 18, 20,* 47, 207–10
fragility of, 408
length of, 9, 13, 98, 141, 205, 210–15, 218–21, 241, 259, 302, 323–24, 338, 371, 372, 383, 408, 415
meaning of, 7, 311, 372, 470, 485
origins of, *15,* 16, *17*
purpose of, 370, 372
Life (game), 520*n*
light:
black hole and, 23, 486, 503*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 629

computing with, 113, 119–20
foglets' control of, 310
nanotechnology-based, 245, 252
light, speed of, 26, 41, 119, 133, 351–57, 520*n*
superseding of limit of, 21, 29, 139–40, 300, 353–56, 366, 503*n,* 511*n*
wormholes and, 354–56
Lindquist, Susan, 117, 176
linear growth:
of evolution, 18, *18,* 501*n*
exponential growth vs., 8, 10–14, *10,* 97–98, 108, 109, 137
Lineweaver, Charles H., 592*n*
Linux, 533*n*
Lipitor, 217
liposomes, 216
Lisberger, S. G., 545*n*
literature, 375, 498*n*
see also poetry
liver, 307
liver cells, 223, 557*n*
liver disease, 418
liver metastases, 552*n*
Llinas, Rodolfo, 189, 544*n,* 545*n*
Lloyd, Seth, 133–34, 342, 435, 451, 535*n,* 590*n,* 593*n*
on universe-scale computer, 364–65, 592*n*
Loan Arranger, 284
local optimization, 309
lock-in, criticism from, 429–30, 457–58
Loebner Prize contest, 294
logic, 119, 309, 481
limits to, 453–54
logic gates, 112, 121, 245, 530*n,* 538*n*
brain compared with, 446, 449–50
nanotubes as, 113, 114
reversible, 131–32, 244, 249, 434, 534*n*
Lohn, Jason, 281, 580*n*
Long, R. Q., 567*n*
longevity, human, 320–30, 371
Long Now Foundation, 328, 588*n*
Los Alamos National Lab, 139, 503*n*
love, 189, 389, 476, 485
boundaries and, 387
falling in, 26, 142, 382
remembering, 376
spindle cells and, 193, 194
Lovett, R., 553*n*
Lovley, Derek R., 248
Lowel, S., 176, 543*n*
Lucas, J. R., 259, 376
Lucent Technologies, Bell Labs of, 157
Lucy (*Australopithecine*), 509*n*
Ludd, Ned, 507*n*
"Ludd, Ned," 31–33, 225–26, 298, 319, 367, 426
Luddites, 338, 341, 415, 507*n*
Ludwig Maximilians University, 235
lungs, 209, 216, 306
Lurie, Karen, 565*n*
Lyding, J. W., 562*n,* 563*n*
Lyman, Peter, 588*n*
lymph nodes, 217

macaque monkeys, 186, 193
McCabe, Thomas, 437, 600*n*
McCallum, John C., 515*n*
McCool, Joe, 582*n*
McCormick, Bruce H., 540*n*
McCrea, Keith, 567*n*
McCulloch, W. S., 155, 539*n*, 539*n*
McCulloch-Pitts neural-net model, 155, 170
Macer, Darryl, 267
McGill University, 242
McKibben, Bill, 391, 395, 410, 594*n,* 597*n*
McLuhan, Marshall, 14
MacRobert, Alan M., 590*n*
macrophages, robotic (microbivores), 254, 306
mad-cow disease, 116, 224, 543*n,* 549*n*
magic, 4–5, 388
magnetic field, 118, 119, 160, 161, 281
magnetic (disk-drive) memory, 76, *76*
magnetic resonance imaging (MRI), 308
magnetic tape, 325
magnetoencephalography (MEG), 150, 158, 160, 186
magnetoresistance, 119
Magueijo, Joao, 592*n*
Maher, M. P., 548*n*
Mahowald, M. A., 547*n*
Makeig, Scott, 172, 542*n*
Malthus, Thomas, 427–28, 433–35
mammals, *17, 18, 20*
brain matter added to, 16
embryos of, 556*n*
nervous system evolution in, 506*n*
spindle cells in, 192
see also specific mammals
Man and Superman (Shaw), 96
Mandelbrot set, 447–49, *450*
MANIAC (Mathematical Analyzer, Numerical Integrator, and Computer), 499*n*
Mann, David J., 562*n*
mannitol, 165
Mano, N., 565*n,* 585*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 630

manufacturing, 250–51
law of accelerating returns and, 243
molecular, *see* molecular manufacturing
productivity growth and, 100–101, *101*
robotics and, 276, 285–86
of silicon chips, 42, 119, 122
transistor, *60*
Mao, F., 565*n*
Marcikic, I., 591*n*
Margolus, Norman, 518*n*
Markov, Andrei Andreyevich, 268
Markov chains, 268
Markov models, 89, 151, 152, 461, 481, 570*n*
defined, 539*n*
speech recognition and, 153, 268, 278
Mars, 280
Marshall, E., 552*n*
Marshall, Matt, 566*n*
Martin, Mike, 566*n*
Martinville, Léon Scott de, 52
Marx, Karl, 475
"Mass Use of Inventions" chart, *50,* 512*n*
Masuoka, Fujio, 113
materialism, 388, 394, 431, 473–76
mathematics, 453–54
chaotic systems and, 151, 198, 449, 450
of complexity theory, 145, 151
existential risks and, 404
proofs in, 264, 283
singularity in, 22–23, *23,* 485, 486
Mathematica (program), 89
Matick, Richard E., 515*n*
Matrioshka brain, 350–51
Matrix Semiconductor, 113
matter, 32, 33
black hole's effect on, 7, 363
computational limits and, 72, 113, 128, 131, 133–34, 136–38, 300, 349–51, 427–28, 432, 434–35
as digital vs. analog, 14
information's relationship with, 86, 87, 522*n*
nonbiological intelligence's saturating of, *15,* 21, 29, 45, 364, 375, 389, 511*n*
observed density of, 365, 592*n*
patterns of, 325, 383, 385, 431, 474
pico- and femtotechnology and, 138–39, 351
Matthews, Stephen, 539*n*
maturity stage, 52
Mauk, Michael D., 182–83, 545*n*
Max Planck Institute, 188, 195, 308, 313
Maya (illusion), 388
Maysinger, D., 564*n*
Mazur, Eric, 162–63
MCM-41, 252
Mead, Carver, 183, 440, 533*n*
analog-emulation-of-brain work of, 18, 126, 151, 189, 442, 533*n,* 538*n,* 545*n,* 547*n*
meaning:
as emergent pattern, 463–64
parity and, 190
meat, 224
mechanical devices, decrease in size of, 82, *82,* 407
media:
technology controversy and, 393
war coverage by, 330, 331
medical diagnostic systems, 266–67
medical informatics, 265
medicine, 126, 214
AI applications in, 8, 276, 281–82
knowledge and, 282, 283, 396
nanotechnology and, 238, 242–43, 251, 253–55, 259, 300, 303–5, 377, 407
progress in, 411
regulation of, 373, 412–13, 416–17, 423
warfare compared with, 331
see also drugs; *specific biotechnology practices*
Medina, Javier F., 182–83, 545*n*
Medtronic MiniMed, 307, 530*n,* 585*n,* 586*n*
MEG, *see* magnetoencephalography
Melton, H. Keith, 580*n*
Meltzer, Martin I., 596*n*
Melymuka, Kathleen, 580*n*
memory, 48, 86, 316
brain and, 48, 126, 137, 138, 176, 523*n*
computational capacity compared with, 126–27
efficiency of, 136–38
Hebbian reverberatory, 156–57, 170–71
human longevity and, 329
learning vs., 541*n*
long-term, 157, 172, 175–76, 188, 543*n,* 544*n*
repression of, 176–77, 544*n*
short-term (working), 170, 175
in soma, 170–71
storage device for, 176
synapses and, 169, 170–71, 175–76, 200, 541*n,* 543*n,* 544*n*
of threatening stimuli, 541*n*
uploading of, 199
memory, computer, 3, 26, 135, 261, 481–82
cost of, 126
law of accelerating returns and, 57–58, *57, 58,* 59, 64–65, 75–76, *75, 76,* 96, 102, 436

vsnk$all.qxd 7/8/05 9:06 AM Page 631

long-term, 158–59
magnetic (disk-drive), 76, *76*
molecular computing and, 115
nanotubes in storage of, 113–15
random access, *see* RAM
spintronics and, 118–19
storage issues and, 327–29, 588*n*
memory, flash, 54, 113, 115, 116
memory banks, 312
memory cells, based on atoms, 121
MEMS (Micro Electronic Mechanical Systems) technology, 133, 238, 247, 306, 421
Mencken, H. L., 369
meritocracy, 472
Merkle, Ralph, 229, 230, 240, 400, 412, 559*n,* 560*n,* 561*n,* 562*n,* 563*n,* 595*n,* 598*n*
Merzenich, Michael, 174, 542*n*
mesh (peer-to-peer, many-to-many, and "multihop") networks, 125, 280, 533*n*
Mesopotamia, 536*n*
"MEST" (matter, energy, space, and time) compression, 24
meteors, 398
methane (CH_4), 400
methanol, 247
Meyerson, Bernard, 519*n*, 529*n*
mice:
beta-catenin overproduction in, 505*n*
brain-scanning experiments in, 161–62, 171–72
neurogenesis in, 177
robustly rejuvenated, 213
weight gain prevented in, 11–12, 303
microarrays (gene chips), 214–15, 552*n*
microbivores (robotic macrophages), 254, 306
microbots, 333
MicroCHIPS, 242–43
microfluidic devices, 242
microprocessors, 116, 119
clock speed of, *61,* 63, 66
cost per transistor cycle of, 62, *62,* 66
performance in MIPS of, 64–65, *64,* 66
transistors per, 63, *63,* 498*n*
microscopes, 47–48, 163
atomic-force (AFM), 138, 237, 536*n*
scanning probe (SPM), 237, 240
Microsoft, 284, 286–87
Microsoft Word, 147, 538*n*
microtubules, 383, 429, 449–52
Microvision, 586*n*
microwaves, 165, 247, 250, 343
midbrain, 193
Miles, J. B., 515*n*
military:
AI used by, 259, 279–80, 281, 284
development times reduced in, 334
nanobots used by, 300, 333, 400
robots, 189, 280, 285, 331–32, 333
virtual reality used by, 312, 335, 586*n*
warfare and, 330–35
see also weapons
military manuals, 594*n*
Milky Way galaxy, 342–48, 590*n*
Miller, Arthur, 376, 593*n*
Miller, E. K., 542*n*
Miller, Mark, 598*n*
Miller, Max, 21
Miller, Steve, 175
MIMD (multiple instruction multiple data) architectures, 120
mind, 143, 444
Church-Turing thesis and, 454
expansion of, 316–17
growth of, 324
longevity of, 325, 329
Mind Children (Moravec), 24
"Minds, Brains, and Science" (Searle), 458
"Minds, Machines, and Gödel" (Lucas), 259, 376
miniaturization, 245, 407, 411
law of accelerating returns and, 42–43, 45, 57–61, *57–60,* 60, 73, 82–84, *82–84,* 96, 102
military and, 332, 334, 335
price-performance of electronics and, 111–12, 526*n*
shrinking transistors and, 42–43, 45, 61, 76, 111–12, 113, 351, 434
see also nanobots; nanotechnology
minimax algorithm, 275–77
Minsky, Marvin, 156, 177, 189, 202, 203, 228, 260, 289, 473, 497*n,* 539*n,* 570*n,* 582*n*
Minteer, Shelley, 565*n*
mirror system hypothesis, 190
missiles, 423
cruise, 255, 279–80, 335
guidance for, 255, 276, 279–80
MIT, 157, 285, 337
Artificial Intelligence Laboratory of, 264
Institute for Soldier Nanotechnologies at, 332
Media Lab, 113, 221
Open Courseware of (OCW), 336
visual processing studies at, 186, 194
mitochondria, 219–20, 583*n*
Mobile Robot Laboratory, 529*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 632

model constraints, 152
modernity, 387
Modis, Theodore, 19, 501*n*–3*n,* 507*n*
Mohan, Anuj, 547*n*
molecular assemblers, 228–31, 261
molecular circuits, 27
molecular computing, *see* three-dimensional molecular computing
molecular manufacturing, 11, 13, 226–31, 242, 250, 258, 422, 434, 457, 557*n*–58*n*
  body changes and, 310, 324, 372
  cost of, 230–31, 338–39, 340
  energy efficiency of, 245, 340
  Foresight guidelines for, 418–19
  goal of, 234
  molecular assemblers and, 228–31, 261
  safeguards for, 400
  software design for, 231
molecular photography technique, 119
molecules, 14, 16, 85, 131, 383, 499*n*
  AGEs and, 220
  brain uploading and, 199–200
  "chaperone," 209
  design of, 483
  in gas, 168
  in ice chips vs. cup of water, 510*n*
  nanobots and, 28
money, 478
monkeys, 186, 193
Montemagno, Carlo, 234, 516*n,* 560*n,* 561*n,* 585*n*
moon, energy harvesting on, 246
Moore, Gordon E., 56, 111–12, 485, 512*n,* 513*n,* 526*n*
Moore, Patrick, 391, 414, 415, 598*n,* 601*n*
Moore, T. B., 552*n*
Moore's Law, 35–36, 41–42, 56–72, 76, 114
  criticism of, 66, 111–12
  as fifth paradigm, 41, 66–72, *67,* 72, 112
  semiconductor feature size reduction and, 57–66, *57–65,* 434
moral intelligence, 8, 192
morality, 369, 374–75, 379
Moravec, Hans, 148, 290, 464, 504*n,* 513*n,* 514*n,* 531*n,* 547*n,* 582*n,* 601*n*
  brain computational capacity estimated by, 123, 529*n*
  on evolution of computer power/cost, 68, *69,* 122
  image processing and, 123, 187–88
  robotics and, 24, 122, 123, 187–88, 205, 285
More, Max, 262, 369, 371, 373, 510*n*, 569*n,* 593*n,* 596*n*
Moreau, René, 513*n*
Morgenstern, Oskar, 499*n*
Morris, Michael S., 355–56, 592*n*
Morris, Tom, 485
mortgage applications, 284
Moshfegh, Allen, 333, 589*n*
motion, 145
  Brownian, 254, 388, 520*n,* 570*n*
  detection of, 123, 156, 188, 547*n*
  digital basis for, 86
  of nanobots, 254
motor cortex, 175
motor neurons, 166, 180–81
motor skills, brain region for, 173
Mottaghy, F. M., 540*n*
mousepox, 398
movies:
  downloading of, 339–40
  eye's extraction of, 186–87, *187*
  see also specific movies
Moving Object and Transient Event Search System (MOTESS), 281
MP3 files, decoding of, 276
MP3 players, 312
MRAM (magnetic random-access memory), 119
MT (visual area), 185
Muggeridge, Malcolm, 372
multielectrode recording, 163
multiple sclerosis, 308, 555*n*
multiple universes (parallel multiverses; "bubbles"), 15, 360, 362, 390, 499*n*–500*n*
multiplication, neurons' performing of, 155–56
Mumford, D., 547*n*
Murakami, Shuichi, 530*n*
muscles, 191, 210, 232, 552*n*
  cerebellum and, 179, 181, 260
  virtual reality and, 314
Musgrave, Charles B., 562*n,* 563*n*
music, musician(s), 145, 191, 194, 202, 498*n*
  as analog vs. digital phenomenon, 519*n*
  author's father as, 327, 339, 497*n*
  of bands of cells, 297
  brain plasticity and, 174, 176
  downloading of, 100, 339
  imagining of, 379
  as knowledge, 372, 375
  live performances by, 340
  pattern and, 388
  virtual reality and, 312
music players, 473
Mussa-Ivaldi, Ferdinando, 189
mutations, 46, 219
  genetic algorithms and, 270, 539*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 633

in human evolution, 42, 92, 208, 506*n,* 539*n*
mitochondrial, 219–20
protein and, 553*n*
Mutschler, Ann Steffora, 526*n*
mutual assured destruction, 402, 421
MYCIN system, 266–67
MYH1 gene, 506*n*

Naam, Ramez, 299
Nagaosa, Naoto, 118–19, 530*n*
nanobots, 28, 32, 33, 201, 232–38, 252
in biomass, 399–400, 425–26
in blood, 248, 253–57, 300, 303, 317, 377, 432, 472
blood-brain barrier and, 163–65
as brain extenders, 317
brain scanning with, 163–67, 197, 200, 262, 293
colonies of, 352–53
control of, 255, 406–7
defined, 163
in digestive system, 303–5
DNA, 236
in Drexler's molecular assembler, 229–30, 231, 236–38
energy and, 246, 248, 249
fat and sticky fingers problem and, 236–38
foglets, 28, 29, 33, 310, 325, 506*n*
GNR age impact and, 302–7, 352–53, 358, 398–400, 403, 409
human longevity and, 325
military's use of, 300, 333, 400
programmable, 317
self-replication of, 232, 237, 256, 352, 398–400, 403, 409, 411–12, 416, 425–26
software viruses and, 406–7
strong AI and, 261–62
virtual reality and, 28, 29, 310, 313–17, 319, 377
wireless communications used by, 163, *233,* 303, 304, 316
nanocatalysts, 246, 252
nanocomputing, 139, 232–36, *233,* 412
limits of, 133–35, 349
nanoelectromechanical systems (NEMS), 309
nanofactories, 245, 340, 425
nanofilters, 246, 252
nanogrids, 117
nanolayers, 251
Nano Letters, 113–14
nanoparticles, 242–43, 250–53
military's use of, 332, 335
with recognition proteins, 583*n*
nanostructures, 251
Nanosys, 250
Nanosystems (Drexler), 228, 229–30, 234
nanotags, magnetic, 242
nanotechnology, 4, 27, 28, 84, 111, 141, 205, 206, 221, 226–59, 299–300, 323, 558*n*–68*n*
biological assembler and, 231–32
biotechnology compared with, 227, 232, 251, 256, 257, 412
dangers of, 11, 206, 229, 230, 237, 241, 249, 251, 256, 334, 395, 398–400, 403, 408–19, 423
early adopters of, 242–43
economic effects of, 102, 245–46, 249–50, 257
energy based on, 133, 243–50, 340, 395, 397, 430, 434, 457
energy required for, 230, 238, 244, 245, 352
environment and, 229, 230, 250–53, 259
ethical issues and, 229
exponential growth and, 27, 73, 227, 396, 407, 558*n*
fat and sticky fingers problem and, 236–38
foundations of, 139, 227–31
limits of, 133–35, 138
medicine and, 238, 242–43, 251, 253–55, 259, 300, 303–5, 377, 407
military use of, 300, 332–35
patents for, 84, *84*
relinquishment of, 395, 411
in reversal of aging, 372, 373, 397
science citations of, 83, *83*
self-replication and, *see* self-replicating nanotechnology
strong AI and, 261–62, 412, 426
technology hype cycle for, 263–64
thermal effects and, 238
threshold of, 60, 112
transportation and, 230, 246, 247, 252, 457–58
wealth creation from, 13, 107, 396–97
see also molecular manufacturing
Nanotherapeutics, 243
nanotubes and nanotube circuitry, 27, 112–15, 122, 247, 248, 526*n*–28*n,* 558*n*
carbon, 27, 113, 114, 229, 230, 234–35, 238, 246, 250, 375, 527*n*
environmental applications of, 251, 253
self-assembly in, 112–13, 115–16, 528*n*
nanoweapons, 300, 334–35

vsnk$all.qxd 7/8/05 9:06 AM Page 634

nanowires, 117, 121
Nantero, 114–15
narrow AI:
  applications for, 276, 279–89, 293
  defined, 92, 264
NASA, 24, 116, 235, 250, 280–81, 333
NASDAQ, 284
Nash, Ogden, 391
Nathanson, H. C., 516*n*
National Cancer Institute, 282
National Nuclear Security Agency, 307, 533*n,* 585*n*
natural selection, 21–22, 127, 195
nature:
  molecular machines in, 231–32
  technology's emulating of, 146, 149, 479–83
  transcendence and, 388, 389
Nedervelde, Philippe Van, 598*n*
Nehaniv, Chrystopher L., 548*n*
Nelson, David, 502*n*
neocortical neurons, 171
Neumann, John von, 10, 227–28, 401, 498*n*–99*n*, 558*n*
  kinematic constructor of, 29, 228
neural chips, 188, 195
neural clusters, 168, 197
neural diseases, 304
neural implants, 28, 201, 374, 377, 443, 483
  challenge in connection of, 195
  nanobots compared with, 317
  for Parkinson's disease, 195, 255, 308, 384, 585*n*
  for retinas, 185, 308, 585*n*
neural nets, 89, 149, 173, 268–70, 288, 428, 442, 446, 481
  algorithmic description of, 269, 570*n*–74*n*
  backpropagation and, 156
  biological, 269–70
  business use of, 283
  connectionism and, 155, 156
  defined, 539*n*
  genetic algorithms combined with, 271, 278–79
  McCulloch-Pitts model of, 155, 170
  pattern recognition and, 151, 152, 156, 268–69, 271, 461
  Perceptron, 574*n*
neural precursor cells, 177
neural processing, criticism from complexity of, 428–29, 442–50
neurogenesis, 177
neuromorphic electronic systems, 533*n*
neuromorphic models, 178–94, 197, 308, 316, 440
  of auditory regions, 123–24, 147–48, 183–84, *185,* 529*n,* 545*n*–47*n*
  of cerebellum, 178–83, *180, 182*
  of hippocampus, 188
  of neural regions, 452
  of olivocerebellar region, 189
  of visual system, 185–88, *187*
neuromorphic simulations, 122, 124–25, 438, 440, 527*n,* 530*n*
neurons, nervous system, 46, 85, 145, 202, 223, 468–69, 474, 475, 600*n*
  in auditory cortex, 124
  biological limitations to, 27, 127, 144
  blood flow and, 161
  brain modeling and, 4, 172–73, 428, 443, 452, 455
  brain reverse engineering and, 163–67, 440, 444, 530*n*
  building of, 111
  change of, 325, 383
  chaotic computing and, 173
  chip compared with, 530*n,* 538*n*
  complexity of, 143–44, 153, 155, 197, 455
  damage to, 173, 308
  design of, 153
  early models of, 154–57, 169
  electronic, 173
  excitatory vs. inhibitory, 157
  feedforward sequence of, 154, 170
  firing of, 147, 150, 155, 162, 170, 173, 176, 269, 313, 446
  formation of, 177
  Hebb's learning theories for, 156–57, 170–71
  of human vs. nonhuman primates, 506*n*
  information in, *15,* 16, 127
  information processing times and, 8–9, 26, 27, 71, 503*n,* 504*n,* 505*n*
  loss of, 152, 293
  measurement of electrical output of, 154
  membrane of, 442–43
  motor, 166, 180–81
  nanobots' interaction with, 28, 165–66, 300, 319, 377
  personality and, 200
  plasticity of, 171–72
  quantum computing and, 429, 450–52
  response time of, 172
  in retina, 123
  as self-organizing, 151, 538*n*
  simplicity of, 143–44
  simulation of, 268–69, 455
  stabilization time of, 150

vsnk$all.qxd 7/8/05 9:06 AM Page 635

subcellular components vs., 169–70
virtual reality from within, 28, 29, 165, 300, 377
see also axons; dendrites; soma; spines; synapses
neuron transistors, 308, 313
neuroscience, 154, 168–69
neurotransmitters, 153, 163, 199, 257, 378, 430
in analog domain, 147, 149
defined, 145
information and, 47
memory and, 127, 137, 329, 523*n*
patterns of, 260, 317, 337, 440, 445, 463
in synapses, 145, 147, 153, 170
neutrons, 14
newborns, 152, 193
Newburger, Eric C., 511*n*
Newell, Allen, 264, 273, 569*n*
New Kind of Science, A (Wolfram), 85, 90, 519*n*
Newton, Isaac, 473, 485
Newtonian physics, 520*n*
Ng, Y. Jack, 342, 590*n*
Nicolaescu, Roxana, 567*n*
Nicolelis, Miguel, 194–95
Niehaus, Ed, 598*n*
Nietzsche, Friedrich Wilhelm, 373, 374, 475
911 emergency systems, 255, 413
Ningaraj, Nagendra S., 541*n*
Nippon Telegraph and Telephone Corporation (NTT), 113
Nishizawa, Matsuhiko, 565*n*
Nissen, S. E., 554*n*
nitric oxide, transmembrane diffusion of, 170, 446
nitrogen, 551*n*
Nixon, Richard M., 391
NMDA receptors, 383
Nobel, Alfred, 404
noise, 38
Nomad for Military Applications, 586*n*
nonbiological experience, transformation to, 324–26
nonbiological intelligence:
change in meaning of, 311
concern about, 30
consciousness of, 376–80, 385, 475
design and architecture freedom of, 26, 27, 31
emotional, 28–29, 145, 377–79, 385
energy and matter saturated by, *15,* 21, 29, 45, 364, 375, 389, 511*n*
exponential growth of, 257, 300, 316, 377, 407
feedback cycle of, 28
as human, 3, 317, 409
in human brain, 28, 201–2, 377, 472
knowledge sharing and, 20, 26, 145, 202–3, 260
merger of biological intelligence with, 4, 9, 24, 25, 47, 123, 128, 197, 296, 300, 316–17, 337, 340, 372, 375–76, 377, 424
prevalence of, 226, 309, 335, 350, 352, 375, 377
silicon vs. carbon, 375
speed of, 26, 27
spiritual experiences of, 377
strengths of, 26, 27
Turing test and, *see* Turing test
see also artificial intelligence
nonlinearity:
in neuronal information processing, 124, 137, 138, 148, 150–51, 155, 197, 428, 442, 452, 503*n,* 527*n*
as requirement for self-organizing system, 155
nonsexual reproduction, 46
"nor" gate, 94, 523*n*
notebook computers, 64–65, 247
Notebooks (Butler), 96
"Note for Physicists" (Wolfram), 519*n,* 521*n*
Novamente architecture, 279
Nowatzyk, Andreas, 161
nuclear energy, *20*
natural, 139–40, 503*n*
nuclear reactors, 243, 252
power plants, 255, 420
nuclear war, 401
nuclear-waste management, 252
nuclear weapons, 397–98, 401–2, 423
atomic bomb, 392–93, 404, 408, 594*n*
proliferation of, 393, 401–2, 426
nucleic acids, 47, 423
nucleotides, 207
nucleus, 198, 208, 219
cloning and, 221–22, 556*n*
cochlear, 184
genes inserted into, 215, 220, 323
nanotechnology in upgrading of, 232–36, 412
posterior ventromedial (VMpo), 193, 314
nurture (experience), 225
nutrients, 301, 303, 304
nutritional supplements, 211, 303, 371
Nuttin, B., 585*n*

obesity, 221, 302
objectivity, 378, 380, 385, 388, 467, 468

vsnk$all.qxd 7/8/05 9:06 AM Page 636

O'Brien, R. J., 542*n*
observation, 47–48, 358
obsolescence stage, 52, 53
Och, Franz Josef, 288
O'Craven, K. M., 539*n*
octopus, arms of, 181, 544*n*
Odlyzko, Andrew M., 511*n,* 516*n*
Oellette, Jennifer, 581*n*
Oeppen, Jim, 597*n*
Oertel, D., 545*n*
Office of Naval Research, U.S., Autonomous Intelligent Network and Systems (AINS) program of, 333
Ó hAnluain, Daithí, 540*n*
Ohio State University Health System, 283
Ohm's Law, 118
oil, oil industry, 102, 243, 244, 252, 420
Oklahoma, University of, 119, 131, 134
Oklo nuclear reactor, 139–40, 503*n*
oligodendrocytes, 177
oligonucleotides, 552*n*
olive cells, 184
olivocerebellar region, artificial, 189
Omnidirectional Search System, *343,* 344
oncogenesis, 552*n*
oncology, 581*n*
O'Neal, D. Patrick, 564*n*
"One Half a Manifesto" (Lanier), 380
ontology, criticism from, 430, 458–69
Open Courseware (OCW), 336
optical character recognition (OCR), 97
optical coherence imaging (OCI), 163
optical computers, 119–20
optical fibers, 53
optical imaging, 161
optical switching, 76
optic nerve, 154, 166, 170, 186–87, 188
optimism, 374
order, 38–41, 198, 389
  class 4 automata and, 88–91
  complexity compared with, 38–40, 90, 372
  defined, 90
  evolution and, 14, 15, 20, 36–45, 47, 509*n*
  exponential growth of, 20, 45
  information as, 38–42
  nature of, 36–43
organ transplants, 418, 598*n*
Osborne, Lawrence, 540*n*
oscillator circuit, 271
ovarian cancer, 282
Overbye, Dennis, 503*n*
overpopulation, 13
oxidants, 252
oxygen, 161, 163, 209, 305, 399
  in fuel cells, 230, 238, 247, 248
  respirocytes and, 305, 306
Oyabu, Noriaki, 561*n*

Pacino, Al, 315
Page, David C., 510
Page, Michael, 563*n*
Paine, R. W., 545*n*
Pakistan, 336
Palmer, Brett, 587*n*
Palo Alto Research Center (PARC), 240, 286
pancreas:
  artificial, 124, 243, 307, 530*n*
  modeling of, 168
pancreas cells, 223, 557*n*
  islet, 124, 168, 213, 223, 255, 557*n*
Panov, A. G., 567*n*
Papageorgiou, Constantine, 547*n*
paper documents, 327, 328, 588*n*
Papert, Seymour, 156, 177, 497*n*, 539*n,* 544*n*
Pap-smear slides, 282–83
paradigm, 42–46, 127–28
  asymptote of, 44, 45, 231, 244
  fifth, *see* Moore's Law
  life cycle of, 43–46, *43, 44,* 67, 72
  of self-organizing chaotic processes, 459–62
  sixth, *see* three-dimensional molecular computing
paradigm shifts, 16, 30, 43, 47, 94, 323, 434
  acceleration of, 9, 11, 17–20, *17–20,* 25, 28, 36, 42, 44, 48–50, *48–50,* 264, 324, 334, 432, 511*n*–12*n*
  complexity and, 38
  defined, 36
  doubling rate for, 50, 56, 338, 469, 512*n*
  economic cycles and, 106
  exponential growth of RAM capacity over, 75, *75*
  for fifteen lists of key events, 18, *19,* 501*n*–2*n*
  lock-in vs., 429–30
  mistakes during, 13
  punctuated equilibrium vs., 44–45, 510*n*–11*n*
  technology hype cycle for, 263–64
paralysis, 173, 195, 308–9
parietal lobes, 202
parity, 190, 208
Parker, Pat, 598*n*
Parkinson's disease, 303, 549*n*
  biotechnology and, 216
  brain reverse engineering and, 144, 195

vsnk$all.qxd 7/8/05 9:06 AM Page 637

neural implants for, 195, 255, 308, 384, 585*n*
Parmentola, John A., 331, 588*n*
particle accelerators, high-energy, 403–4
particles, 120, 134, 168, 355, 520*n,* 521*n*
in event horizon, 363, 486–87, 503*n*
Lloyd's estimates on, 364–65
quantum-entangled, 353–54, 363, 487
Pascual-Leone, Alvaro, 175, 543*n*
passivity, 373
past, 7, 11, 408, 409–10, 436
Pasteur, Louis, 226
patents, 106, 525*n,* 533*n*
brain reverse engineering and, 146, 537*n*
nanorelated, 84, *84*
pathogens, 282, 371
bioengineered, 407, 409, 417
"enhanced intelligence" cells and, 221
gene sequences of, 395
microbivores and, 254, 306
nanobots and, 300, 303, 397
self-replicating, 423–24
software, *see* software viruses
see also specific pathogens
"pathogen sentinel" program, 423
patternists, 5, 385, 388, 474
pattern recognition, 135, 260–61, 309, 316, 435, 438, 439, 480, 482
brain and, 8, 16, 25–26, 124, 143, 149, 150, 173, 441, 456, 501*n*
chaotic computing and, 173, 441, 475
computer chess and, 274, 277, 278, 441, 459
evolutionary algorithms and, 92, 152, 271, 461
"hypothesis and test" in, 186–87, *187*
irreversible computing and, 130
Markov models and, 151, 152, 278, 461
in medical diagnosis, 281–83
memory and, 126
military software and, 279–80, 335
neural nets and, 151, 152, 156, 268–69, 271, 461
by robots, 286
patterns:
of body, 371, 383–84
of brain, 325, 371, 383–84, 463–64, 475, 477–78
copies of, 383–84
emergent, 463–64, 467–68, 475, 477–78, 480
of energy and matter, 325, 383–84, 385, 431, 474
evolution and, 14–21, 388
of information, 5, 258, 460, 522*n*
of interneuronal connections, 260, 317, 337, 445, 463
knowledge as, 323, 386
of neurotransmitters, 260, 317, 337, 440, 445, 463
self as, 383, 386
of special cells, 297
transcendence and, 388
uploading of, 377
PCBs, 253
PDAs (personal digital assistants), 125
Pearson, Helen, 560*n*
Peng, Jinping, 562*n*
Penn, Anna, 523*n,* 539*n*
Pennisi, Elizabeth, 510*n*
Pennsylvania, University of, Neuroengineering Research Laboratory of, 162, 530*n*
Penrose, Roger, 201, 450–52, 600*n*
Pentium processors, 276
Peploski, James, 561*n,* 562*n*
peptides, 217, 233, 308
gene expression and, 213, 223, 232
perception, 190, 191, 194
feedforward sequence and, 154, 186, 574*n*
see also visual systems
Perceptron, 156
Perceptrons (Minsky and Papert), 156
Perry, Jason K., 563*n*
Perry, Martin, 561*n,* 562*n*
personal computers, *17, 18,* 406, 473
changing of, 324–25
human intelligence emulated by, 25, 70, 125–26, 441–42, 533*n*
IBM 7094 compared with, 64–65
laptops, *see* laptop computers
mass use of, *50,* 512*n*
MIPS provided by, 64–65, 122
notebook, *see* notebook computers
spam messages on, 255–56
speed of, 276
personality, 225
backing up of, 323
location of, 200
uploading of, 124–25, 166, 199–201, 429, 451
in virtual reality, 29, 314–16, 587*n*
personal services, 340
pesticides, 224, 253, 415
Peters, James A., 549*n*
Peterson, Christine, 229, 395, 558*n*, 598*n*
Petricoin, Emanuel F., III, 282, 581*n*
pharmaceutical companies, 303
Philipkoski, Kristen, 514*n*, 570*n,* 581*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 638

Phoenix, Chris, 400, 595*n*
phonautographs, 52
phone books, information in, 90
phonemes, 268
phonetics, 268, 278
phonographs, 52–53, 55
photolithography, 45, 116, 122
photons, 119, 141, 162, 353
photoreceptor neurons, 166, 547*n*
photovoltaics, 246, 249
physical reality, 9
  nanotechnology in manipulation of, 4, 28
  spirituality and, 388
physician-patient relationship, 104
physics, *20,* 168, 320, 411, 454
  constants of, 139–40, 356, 359–62, 365, 499*n,* 592*n*
  digital theory of, 86–87, 518*n*–22*n*
  in Epoch One, 14–15, *15*
  intelligence compared with, 364
  Newtonian, 520*n*
  singularity in, 23*n,* 486, 487, 503*n*
  virtual reality and, 319
phytochemicals, 301, 304
pianos, 53, 55
Picasso, Pablo, 202
Pick Best Next Step program, 272–73, 577*n*–80*n*
picotechnology, 138–39, 141, 351, 536*n*
piercing, body, 310
pigs, HIV-type xenoviruses in, 418
piracy, intellectual, 339
Pirsig, Robert M., 392
Pitts, W., 155, 539*n*
plague, 398, 402, 409
Planck constant, 133–34, 359, 360, 365, 592*n*
planets, 280, 342, 349, 357
  in Drake equation, 345, 346, 347
  see also Earth
planning, 190, 191, 194
"Plastic Fantastic Lover" (song), 300
plastics, self-healing, 335
plastic surgery, 310
Plato, 326
play, 300, 341–42
pleasure:
  of breathing, 306
  eating and, 301, 304
  sex and, 301, 307, 315, 319
Plus, Mark, 498*n*
plutonium, 393
pocket computers, 444
Poe, Edgar Allan, 312
poetry, 202
  recursive search and, 273, 577*n*–80*n*
Poggio, Tomaso, 166, 179, 532*n,* 541*n,* 544*n,* 546*n,* 547*n*
  on neuron as chip, 530*n,* 538*n*
  visual processing and, 186, 194
polarization, 344
political issue(s):
  biotechnology and, 223, 224
  encryption trapdoor and, 422
  nanotechnology and, 423, 426
  preemptive action as, 423–24
political patron model, 472
pollution, 28, 243, 251–53
Polsson, Ken, 513*n*
polyethylene glycol, 332
polymerase chain reaction (PCR), 117, 530*n*
polymer (or hydrogel) particles, 583*n*
polymers:
  biodegradable, 243
  electrically actuated, 583*n*
polynucleotides, 207
Pons, Stanley, 567*n*
Pontil, M., 547*n*
pool, software for, 288
Popper, A., 545*n*
population growth, 99, 321, 433
Port, Otis, 580*n,* 581*n*
portable electronics, 56, 113, 247
positron-emission tomography (PET), 160–61
Posner, M. I., 540*n*
posterior inferior-temporal cortex cells, 175
posterior parietal-cortex cells, 175
posterior ventromedial nucleus (VMpo), 193, 314
Postma, Henk W. Ch., 527*n*
post-Singularity period, as posthumanism, 374
Pouget, Alexandre, 179
poverty, 241, 259, 372, 397, 410, 424
  in World Bank report, 99, 338, 396, 470
power loom, invention of, 507*n*
power plants, 255, 409, 420
power relationships, access to knowledge and, 104
Prater, Corwyn, 320
precautionary principle, 403, 404
precursor stage, 51
Predator, 280, 332, 335
predictions:
  as brain feature, 190–91
  cellular automata and, 88–89, 90, 519*n,* 521*n*–22*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 639

computational processes and, 93
of future, 432
of materialism, 431, 473–75
of properties of gas, 168, 432
as test of theory of physics, 519*n*
prefrontal cortex, 170
Preskill, John, 363
Preston, Richard, 595*n*
price-performance, 432
of brain scanning, 144, 197, 265, 292
of computing, 12, 41–42, 45, 56–71, *57–65, 67, 69–71,* 100, 102, 125–28, 135–36, 142, 243, 261, 292, 432, 437, 506*n,* 514*n*
of electronics, 111–12, 526*n*
exponential growth of, 430, 469, 470
of Internet, 263
of software, *103,* 436, 438
of wireless communications, 77, *77*
primates, *17, 18,* 190, 433
brain in, 27, 152
duration of observation in, 48
nervous system evolution in, 506*n*
suffering of, 379
visual system of, 574*n*
see also specific primates
Primo Posthuman, 302
Principia Mathematica (Whitehead and Russell), 453
"Principles of Extropy" (More), 369
printing, printing press, *17, 18, 20,* 42, 44, 54
prions, 116–17, 176, 224, 232, 254, 543*n*
privacy, 407, 413, 422
proactionary principle, 403, 495*n*–96*n*
probabilistic fractals, 46–47, 449
probes, nanobots as, 352, 591*n*
problem solving, 8, 42, 296, 372–73, 499*n*
Church-Turing thesis and, 429, 453–56, 601*n*
evolutionary algorithms in, 38–39, 92
Perceptron and, 156
speed of, 21–22
swarms and, 333
Proceedings of the National Academy of Sciences, 116
productivity:
exponential growth in, 98–101, *98, 99, 101*
manufacturing, 100–101, *101*
of software, 428, 437
progress, 96, 321, 370, 391, 408
break in the continuity of, 24
defined, 41
intertwined sciences and, 411
in nanotechnology, 227
rate of, 10–13, 16, 41, 50, 102, 108, 510*n,* 512*n*
relinquishment of idea of, 407
risks of, 417
Project Alpha, 333
promoters, 551*n*
property, destruction of, 375
prostate cancer, 282
prostate-specific antigen (PSA), 282
prostitution, virtual, 318
proteins, 234, 239, 383, 423
AGEs and, 220
amino acids in, 27, 47, 85, 148, 208–10, 309, 517*n,* 550*n*
beta-catenin, 505*n*
blood-brain barrier and, 163–64, 165
CPEB, 176, 199–200, 543*n*
DNA self-assembly and, 117
epigenetic data in, 147
folding of, 27, 209, 234, 482–83, 550*n*
as food, 224, 301
gene expression and, 16, 147, 213, 214, 223, 552*n*
genome and, 42, 225, 510*n,* 517*n*
misformed, 209, 220, 254, 397, 550*n*
mitochondrial function and, 220
nanotechnology and, 235–36, 412, 425
pattern recognition and, 282
prions, 116–17, 176, 224, 232, 254, 543*n*
recognition, 583*n*
RNA interference and, 214
synthesis of, 47, 208–10, 213, 378, 550*n,* 551*n,* 552*n*
wheel-like, 440
proteome, 225
proteomics, 323
proteosome, 209
protofibrils, 209, 254, 397, 550*n*
protons, 14, 85, 119, 131
Ptolemies, 54
public awareness, 423
pulmonary hypertension, 216
punch cards, 327
punctuated equilibrium (PE), 44–45, 510*n*–11*n*
Purdue University, 115–16, 118, 528*n*
Purkinje, Johannes, 181
Purkinje cells, *180,* 181, *182,* 545*n*
Putnam, H., 596*n*
Putnam, Sarah, 588*n*

quadriplegics, 308
quanta, 14
quantum coherence, 446, 451

vsnk$all.qxd 7/8/05 9:06 AM Page 640

quantum computing, 113, 119, 120–21
consciousness and, 201, 429, 450–52
factoring large numbers and, 121, 354
quantum decoherence, 120, 121
quantum disentanglement, 353–54
quantum dots, 242, 245, 308, 313, 586*n*
quantum entanglement, 119, 353–54, 363, 487
quantum gravity, 14
quantum mechanics, 85, 380, 450, 486, 499*n,* 522*n*
continuous levels and, 85, 518*n*
Copenhagen interpretation of, 500*n*
"hidden variables" interpretation of, 431, 521*n*
"many worlds" or multiverse theory and, 500*n*–501*n*
randomness in, 353–54, 363, 474–75, 481, 521*n,* 522*n*
spintronics and, 118, 119
uncertainty, 138, 238, 353, 486
wormholes and, 355
quantum theory, 382, 503*n,* 519*n*
quantum wave function, collapse of, 450–51, 500*n,* 521*n*
quarks, 85, 486
quasars, 356
qubits, 119, 120, 121, 450
Quintana, J., 542*n*

rabbits:
cerebellar lesions in, 183
exponential growth of, 128, 433
Rabiner, Lawrence, 570*n*
radiation, 165
electromagnetic, 344–49, 590*n*
Hawking, 363–64, 487, 503*n*
radioactive isotopes, from Oklo reactor, 139–40, 503*n*
radio circuits, 271
radios, *17, 18,* 338
mass use of, *50,* 512*n*
portable, 45
radio-transmitting civilization, search for, *see* SETI
radix-2 Cooley-Tukey algorithm, 438
radix-4 method, 438–39
Radman, Morislav, 549*n*
Rado, Tibor, 455, 601*n*
Raff, Lionel M., 561*n,* 562*n*
railroads, 13, 263–64, 420
Rainer, G., 542*n*
RAM (random access memory), 64, 65, 75, *75,* 115
dynamic, *see* DRAM
magnetic (MRAM), 119
Ramona project, 315, 587*n*
randomness, 92, 131, 132, 362, 388, 474
class 4 automata and, 89, 90, 520*n,* 521*n*
deterministic processes and, 89
of neural net, 269
of neurons and brain, 149, 151, 152, 153, 440, 443–44
quantum, 353–54, 363, 474–75, 481, 521*n,* 522*n*
Rao, R., 547*n*
Rao, Tata N., 567*n*
Rappaport, N. J., 512*n*
Ratner, Mark A., 115, 528*n*
rats, 188, 255
Rauch, Jonathan, 524*n*
Ray, Thomas, 429, 442–44, 446, 456, 600*n,* 601*n*
RayandTerry.com, 490
Ray Kurzweil's Cybernetic Poet, 273, 580*n*
Raymond, J. L., 545*n*
reading, 175, 337, 589*n*
real-estate industry, 105
reality:
analog vs. digital nature of, 519*n*
mental models of, 198
see also physical reality; virtual reality
reasoning, 120, 143, 285
recessions, 99, 106
high-tech (2000–2003), 97, 524*n*
records, recording industry, 53, 327, 339
recursion, 190
recursive search, 272–73, 279
algorithmic description of, 273, 576*n*–80*n*
red-blood cells, mechanical, *see* respirocytes
Rediscovery of Mind, The (Searle), 459–60
reductants, 252
"Reduction in Watts per MIPS" chart, 128–29, *129*
Reed-Sternberg cell, 552*n*
Rees, Martin, 361, 500*n,* 597*n*
Regan, Chris, 235
regional cerebral blood flow (rCBF), 161
regulation, 430–31, 470–73
medical, 373, 412–13, 416–17, 423
Reil, Torsten, 288, 582*n*
Reilly, B. D., 554*n*
"Relative State Formulation of Quantum Mechanics" (Everett), 500*n*–501*n*
relativity theory:
general, 341, 355, 378, 500*n,* 503*n,* 520*n*
special, 341, 354, 520*n*
relays, 67, *67,* 127–28, 434

vsnk$all.qxd 7/8/05 9:06 AM Page 641

religion:
author's upbringing in, 1, 2
death as viewed by, 368, 372, 374
fundamentalism and, 414
Singularity compared with, 370, 374
Rensselaer Polytechnic Institute, Center for Gigascale Integration at, 113
repetition, mechanical, 26
repression, of memory, 176–77, 544*n*
reproduction:
of bacteria, 248
of cells, 218
in vitro fertilization and, 340
nonsexual, 46
sex separated from, 301, 367
sexual, *see* sexual reproduction
research, 279, 407
computer, budgets for, 25, 42, 259
Internet, 392–93, 594*n*
paradigm shifts and, 45
stem-cell, 222, 431, 471
respirocytes (mechanical red-blood cells), 28, 227, 305, 306, 506*n*
effectiveness of, 254, 558*n*
retina, 166, 187, 530*n*
feedforward sequence and, 154, 170
image processing in, 123, 187–88
implants of, 185, 308, 585*n*
of toad, 154
virtual reality and, 312, 472
retirement, 98
Rettig, Duane, 569*n*
Reuter, A., 560*n*
reverse engineering, 127, 146, 213, 323
of blood, 305–6
of computers, 157–58
of human brain, *see* brain reverse engineering
of primate visual system, 574*n*
of products, 231
reversible computing, 130–35, 244–45, 350, 428, 534*n*
Reynolds, Glenn, 598*n*
Rhea, John, 589*n*
rhesus macaques, humans compared with, 505*n*
Rhodoferax ferrireducens bacterium, 248
ribosomes, 16, 147, 198, 207–10, 213
design of, 483
nanotechnology and, 232–35, 238–39, 412
Rich, Elaine, 265, 266
Richards, Jay W., 593*n*
Richards, Mark A., 438, 439, 600*n*
rich-poor divide, 95, 430, 469–70
Riesenhuber, Maximilian, 186
Riley, James, 588*n*
Rilke, Rainer Maria, 299
Rizzolatti, Giacomo, 190 548*n*
RNA, 47, 216, 441
gene expression and, 16, 213
messenger (mRNA), 207, 208, 214, 412, 552*n*
nanotechnology and, 232
transfer (tRNA), 207, 208, 233
RNA interference (RNAi), 12, 214, 256, 323, 417, 422, 552*n*
Roach, John, 591*n*
roads, biological evolution and, 440
Robitaille, P-M. L., 540*n*
Robot (Moravec), 24
robotic telescopes, 281
robots, robotics, 24, 122
disabled assisted by, 189, 195
household, 292
kinematic constructor, 228, 229, 558*n*
manufacturing and, 276, 285–86
military, 189, 280, 285, 331–32, 333
at molecular level, *see* nanobots
monkeys' control of, 194–95
nanotechnology and, 228–33, 246
as probes, 352, 591*n*
revolution in, 73, 84, 205, 206, 259–300, 570*n*–83*n*; *see also* strong AI
search-and-rescue, 286
vision systems for, 123, 187–88, 285–86, 529*n*
rock:
complexity of, 37, 508*n*–9*n*
computation in, 131, 137, 362
information in, 37, 137, 508*n*–9*n*, 536*n*
Rodgers, Peter, 592*n*
rogue nations, 423
Roninson, I. B., 554*n*
Rosamond, J., 552*n*
Roscheisen, Martin, 250
Rosen, Nathan, 355, 592*n*
Rosenblatt, Frank, 156, 539*n*
Rosetta Disk, 588*n*
Roska, Boton, 187, 547*n*
rotaxane, 115
Roth, U., 575*n*
Rothblatt, Martine, 379, 418, 593*n*, 598*n*
Roush, Wade, 580*n*
Rowling, J. K., 4–5
Roy, C. S., 540*n*
Rubel, E. W., 542*n*
Rueckes, Thomas, 114
Rukeyser, Muriel, 5
rule 110, 87–89, *88*, 522*n*, 523*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 642

Rupley, Sebastian, 533*n*
Russell, Bertrand, 264, 321, 453, 514*n*, 600*n*
Russia, ICBM arsenal of, 401

Sabatini, B. L., 541*n*
Sagan, Carl, 18, 35, 346, 355, 501*n,* 590*n*
Sahlins, Marshall, 387
"Sailing to Byzantium" (Yeats), 301
Saini, Subhash, 562*n,* 563*n*
St. Louis University, 247–48
Sakamoto, K. M., 552*n*
Salinas, E., 539*n*
Samonds, Jason M., 541*n*
Sandberg, Anders, 134, 144, 350–51, 356, 535*n*
Sandhana, Lakshmi, 589*n*
Sandia National Laboratories, 304
Sandvik, Haavard Bunes, 592*n*
sanitation, 409
San Jose AI conference (2004), 286
Santa Fe Institute, 509*n*
SARS (Severe Acute Respiratory Syndrome) virus, 74, 398, 402–3, 423, 514*n*
satellites, 413
  Space Solar Power, 250
  Space Technology 5, 281
  spy, 281
Sato, Hisahiko, 517*n*
Sato, K.-I., 516*n*
Sato, M., 553*n*
Savoy, R. L., 539*n*
scaffolds, nanoscale, 242
Scalaidhe, S. P., 543*n*
Scalise, George M., 525*n*
scanning-probe microscope (SPM), 237, 240
ScanSoft (formerly Kurzweil Computer Products), 570*n*
Schafer, Ron, 588*n*
Schaller, R. D., 566*n*
Scheibel, Thomas, 529*n*
Schewe, Phillip F., 586*n*
Schmidt, Bob, 283
Schneider, Frank, 550*n*
Schoenauer, T., 575*n*
Schopenhauer, Arthur, 7
Schönenberger, Christian, 526
Schopf, J. W., 502*n*
Schwartz, Jeffrey M., 542*n*
Schwarzschild, Kurt, 503*n*
science, 335, 372, 373, 375, 498*n*
  AI applications in, 283
  human grasp of, 261
  inflated self-significance corrected by, 487
  objectivity and, 378, 380
  simplicity as driving force in, 39
  technology's enabling of advances in, 143
  see also specific sciences
Science, 114, 117, 176, 215, 505*n*
science fiction, 271–72, 569*n*
Scientific American, 51, 101, 236–38, 254
scientific models, right level for, 167–68
scientist's pessimism, 12
Scripps Research Institute, 235–36, 556*n*
S-curves:
  energy and, 244
  in paradigm life cycle, 43–44, *43, 44,* 67, 72
  of technology as expressed in its life cycle, 51–56
  transportation and, 457
search-and-retrieve methods, 328
search engines, 100, 150, 286–87, 336, 436
Searle, John R., 394, 458–69, 474, 475, 477, 601*n*
second-harmonic generation (SHG) microscopy, 163
Securities Observation, News Analysis, and Regulation (SONAR) system, 284
security issues:
  defensive technologies and, 417
  law enforcement organizations and, 413, 421, 424
  spybots and, 406–7
"Seed AI," 569*n*
Seegrid, 285
Seeing Machines, 285
Seeman, Nadrian C., 235, 236, 560*n*
Seitz, C. L., 535*n*
Select computer program, 2–3, 497*n*
self-assembly, 121, 227
  in nanotube circuits, 112–13, 115–16, 528*n*
self-organizing system(s), 89, 225, 265, 435, 459–62
  algorithms, 146, 439–40, 481, 538*n*; *see also* evolutionary (genetic) algorithms
  biopolymers, 252–53
  brain as, 25–26, 148, 152, 153, 293, 371, 440, 443–44, 446, 456, 460, 483, 501*n,* 523*n*
  communication networks as, 125, 533*n*
  connectionism and, 155–56
  design and, 479–83
  knowledge and, 126
  mesh networks, 125, 280, 533*n*
  military's use of, 332–33
  nonlinearity as requirement for, 155
  see also Markov models; neural nets

vsnk$all.qxd 7/8/05 9:06 AM Page 643

self-replicating nanotechnology, 230, 235–36, 346, 352
broadcast architecture and, 232, 235, 400, 409, 412, 419
Foresight guidelines for, 229, 395, 411, 418–19, 598*n*
immune system and, 400, 411–12, 417
need for, 352, 400, 411–12, 425–26
probes and, 352, 412
safety concerns about, 11, 206, 229, 232, 237, 256, 395, 398–400, 403, 409, 411–12, 425–26
von Neumann's model of, 228
weapons and, 334
self-replication:
of computer viruses, *see* software viruses
of computing resources, 116–17, 139
of DNA, 16, 47, 116, 117, 118, 207–8, 235, 529*n*
GNR defense and, 423–24
immune system and, 417
intelligent destiny of the cosmos and, 346, 352, 356
power of patterns vs., 388
Selkoe, D. J., 555*n*
Sematech, 57
semiconductors, semiconductor industry, 119, 153, 253
deflation in, 102
feature-size reduction in, 57–61, *57–60,* 113, 434
growth in, 65, 102
International Technology Roadmap for, 57, 112, 126, 292
nanotubes as, 114
quantum effects in, 429
spintronics and, 119
see also silicon; silicon chips; transistors
Sendoh, M., 584*n*
sensorimotor skills, formation of, 178–79
sensory data:
brain's processing of, 120
in Epoch Three, 16
virtual reality and, 319
sensory disabilities, 144
sensory signals, nanobots' monitoring of, 165–66
sentience quotient (SQ), 536*n*
September 11, 2001, terrorist attacks, 280, 397
serial endosymbiosis theory, 583*n*
Serre, Thomas, 547*n*
Chinese Room analogy of, 430, 458–66
serum monitoring, 423
SETI (Search for Extraterrestrial Intelligence), 342–53
biological vs. nonbiological intelligence and, 350, 352, 358
computational limits and, 349–51
Drake equation and, 342, 344–49, 590*n*
Fermi Paradox and, 348, 357–59
scope of, 342–43, *343*
Severe Acute Respiratory Syndrome, *see* SARS (Severe Acute Respiratory Syndrome) virus
sex, sexual activity:
contraception and, 321
desire and, 193
pleasure and, 301, 307, 315, 319
reproduction separated from, 301, 367
virtual, 318–19
sexual reproduction, 46, 92, 207, 301, 402, 441
genetic algorithms and, 270*n,* 539*n*
Shachtman, Noah, 588*n*
Shah, P. K., 553*n*
Shakespeare, William, 126, 196
shale oil, 244
Shane, Scott, 597*n*
Shannon, Claude, 507*n*–8*n*
Shapiro, Ehud, 118
Shaw, Gary A., 438, 439, 600*n*
Shaw, George Bernard, 96
Shaw, J. C., 264, 273, 569*n*
Shay, Mary-Ellen, 557*n*
Shenderova, O. A., 563*n*
Shepherd, Gordon M., 184, 545*n*
Sherman, William, 236, 560*n*
Sherrington, Sir Charles S., 458, 540*n*
Shi, Yuhui, 589*n*
Shoham, S., 586*n*
Shostak, Seth, 346, 358, 422, 590*n*
Si, K., 543*n*
signal-processing techniques, 279, 438–39, 445
silicon, 442
in BioMEMS, 583*n*
in photovoltaic cells, 249
silicon chips, 113, 119, 122
number of, 351, 591*n*
number of components on, 41–42, 111–12, 351, 526*n*
three-dimensional, 113
silicon intelligence, 376
silicon lithography, 113
Silk, J., 502*n*
Silva, R. A., 560*n*
SIMD (single instruction multiple data) architecture, 118, 119–20, 229

vsnk$all.qxd 7/8/05 9:06 AM Page 644

Simmel, F. C., 560*n*
Simon, Herbert A., 264, 273, 569*n*–70*n*
Simon, S. M., 586*n*
Simone (movie), 315
simplicity:
  brain design and, 446–49
  Einstein's views on, 39, 519*n*
  equivalence principle and, 136–38, 536*n*
  of neurons, 143–44
Simpson, Michael, 236
Sims 2 game, 341
simulations:
  brain, *see* brain simulations
  existential risks and, 404–5
Singer, Maxine, 418
Singer, W., 176, 543*n*
Singularitarian, 369–90, 593*n*–94*n*
  alienation and loneliness of, 370–71
  meaning of being, 371–73
  understanding and, 370
  use of term, 7, 370, 498*n*
Singularitarian Principles, The (Yudkowsky), 498*n*
Singularity:
  concept of, 5, 7–9, 498*n*
  consciousness and, 374–82, 384–85
  countdown to, 17, *17,* 18, *18*
  death and, 326
  as economic imperative, 96–110, 524*n*–26*n*
  Epoch Five and, 14, *15,* 20–21, 205
  Epoch Six and, 14, *15,* 21
  GNR age and, 205, 206
  goal of, 364
  history of use of word, 22–24, 485–87
  identity and, 382–87
  meaningful statements about the nature of life after, 29–33
  passivity and, 374
  powering of, 243–50
  principles involved in, 25–29
  religion compared with, 370, 374
  time frame for, 123, 135–36, 226
  as transcendence, 373, 375, 387–90
  von Neumann's views on, 10
Singularity.com, 489
Singularity Institute for Artificial Intelligence (SIAI), 598*n*–99*n*
Sinnott, Susan B., 563*n*
Skaletsky, Helen, 549*n*
Skarda, Christine A., 538*n*
skeleton, 307
skepticism, 12–13, 263
skills:
  backing up of, 323
  downloading of, 300
  formation of, 178–79, 194, 202, 260–61, 309
  human longevity and, 329
skin, 242, 307
skin cells, 213, 214, 223
  transdifferentiation and, 223, 471, 557*n*
Sky & Telescope, 342–43, *343*
Slack, Jonathan M. W., 557*n*
Smalley, Richard E., 234, 236–41, 246, 254, 432, 559*n,* 560*n,* 561*n,* 564*n*
smallpox, 398, 402
Smart, John, 24, 35, 358, 370, 504*n*, 507*n,* 592*n*
Smart-Airport Operations Center (SAOC), 284
smart dust, 334
Smith, Huston, 387, 594*n*
Smith, K. R., 553*n*
Smith, Quentin, 500*n*–501*n*
Smith, Tony, 565*n*
Smolin, Lee, 360, 361, 362, 364, 592*n*
Smoller, Joel, 504*n*
snails, consciousness of, 466, 467
Snider, S., 586*n*
snowflakes, 93
Snyder, Allan, 161
Snyder, Lawrence H., 179
Sobel, Dava, 590*n*
soccer, software for, 288
social institutions, conservatism of, 472–73
Social Security, 97–98
software, 5, 100, 259
  AI systems' monitoring of, 284
  algorithms, 428, 438–42
  auditory, 148
  for chess, 274–78, *274,* 441, 459
  complexity of, 428, 437–38
  as composing universe, 86
  consumer power and, 104
  criticism from, 428, 435–42
  deflation and, 102–3
  development of, 97, 107, 437, 534*n*
  for dyslexic students, 175, 337, 589*n*
  genetic algorithms and, 271
  genome compared with, 206–7
  hardware vs., 102, 428, 435, 438, 439, 445
  human intelligence modeled by, 25, 126, 127; *see also* brain reverse engineering
  irreversible, 130
  longevity of, 325–30
  military uses of, 279–80
  for molecular manufacturing, 231
  price-performance of, *103,* 436, 438
  productivity of, 428, 437

vsnk$all.qxd 7/8/05 9:06 AM Page 645

responsiveness of, 436
self-organization in, 151
for space exploration, 280–81
for speech recognition, 5, *103,* 146, 153, 184, 268, 436, 438, 529*n,* 570*n*
sports, 288
stability of, 435–36
for strong AI, 261–62
of universal computer, 91, 523*n*
viability of, 325
software viruses, 241, 255–56, 333, 423
biological viruses compared with, 413–14, 416
dealing with, 413–14, 416, 417–18, 426
Internet information on, 594*n*
nanobots and, 406–7
self-modifying, 416
solar cells, 397, 457
solar energy, 234, 243, 244, 246–51, 340, 434
calculation of, 248, 566*n*
cost of, 249–50
Matrioshka shells and, 351
solar panels, 246, 248, 249, 250, 251, 421, 434, 457
solar system:
computational limits and, 349–51, 435
expansion beyond, 351–53
intelligence in, 374
mass of, 349, 350–51, 590*n*–91*n*
solvents, halogenated organic, 253
soma (cell body), 124, 155, *192,* 208
memory function in, 170–71
somatic gene therapy, *see* gene therapy
Sommer, Fritz, 160
Somorjai, Gabor A., 567*n*
Soros, George, 394
sound:
foglets' control of, 28, 310
localizing of, 123–24, 148, 184
patterns of, 297
in phonemes, 268
processing of, 123–24, 172, 530*n*
virtual reality and, 105, 310, 312–13, 318
Southern California, University of, 116, 188
Soviet Union, bioweapons program in, 393
space, 23, 520*n*
curvatures in, 520*n*
empty, 355
energy generating in, 246, 247, 250
expansion of, 354
exploration of, 280–81, 352–53, 412
general relativity and, 500*n*
quantum gravity and, 14
special relativity and, 520*n*
Space Elevator, 250
Space Solar Power satellite, 250
Space Technology 5 satellites, 281
space-time, wormhole in, 140
SpamBayes, 268
spam filters, 267–68
special relativity theory, 341, 354, 520*n*
species, extinction of, 222, 409, 511*n*
"Speculations Concerning the First Ultraintelligent Machine" (Good), 22
speech recognition, 122, 265, 286–88, 337
author's work with, 268, 278, 294, 570*n,* 599*n*
Markov models and, 153, 268, 278
neural nets and, 268
search engines and, 286–87
software for, 5, *103,* 146, 153, 184, 268, 436, 438, 530*n,* 570*n*
sperm cells, genetic information altered in, 552*n*
Spike, The (Broderick; 1997), 24
Spike, The (Broderick; 2001), 24
spikes, 161, 169–70, 445–46, 530*n*
defined, 154
growth of, 171
spike trains, 170
spinal cord, 163, 171, 181, 193, 203
injury to, 308
spindle cells, 191–94, *192,* 468
spines, 151, 162, 171–72, 180, 197
defined, 171
growth of, 173, *174,* 202
spintronics, 112–13, 116–17, 119, 529*n*
spiral ganglion, 165
spirituality:
Dembski's views on, 475–77
of nonbiological intelligence, 377
in the physical world, 387
transcendence and, 387–90, 475–76
Sporns, O., 540*n*
sports, 288, 341
spybots, 406–7
spy satellites, 281
squid neurons, 155
SRI International, 282
Srivastava, Deepak, 562*n,* 563*n*
standard of living, 106
Stanford University, 114, 176
Staring into the Singularity (Yudkowsky), 35
stars, 281, 342, 344
collapsed, 141
in Drake equation, 345, 346, 347
Dyson Sphere and, 350
formation of, 360
sun, 349–51, 591*n*
Vega, 355–56

vsnk$all.qxd 7/8/05 9:06 AM Page 646

Star Trek, 348
Stein, Ben, 586*n*
stem cells:
  adult, 223, 556*n,* 557*n*
  autologous, 216
  controversy over, 222, 431, 471
  neural, 177
Stenger, Victor, 499*n*
Stenner, M., 591*n*
Sterling, Bruce, 588*n*
Stix, Gary, 529*n*
stock, stock market, 103, 525*n*–26*n*
  AI applications in, 284
  price of, 13, 108, 109–10
stories:
  as composing universe, 5
  principles of fields as, 167
Störmer, Horst, 253
strawberry genes, 551*n*
stream separation, 123
string theory, 359, 360
stroke, 144, 173, 188, 210, 212
strong AI, 259–63, 289–300, 422
  brain reverse engineering and, 84, 93, 194–95, 293, 294, 407, 461
  Church-Turing thesis and, 454
  criticism from ontology and, 430, 458–69
  dangers of, 206, 403, 409
  defined, 92, 260
  friendly, 409, 420, 424, 598*n*–99*n*
  at human levels, 260, 262
  nanotechnology and, 261–62, 412, 426
  runaway, 24, 262–63, 569*n*
  skepticism about, 292
  wealth creation from, 13, 396–97
Strout, Joseph, 326
student matching program, 2–3, 497*n*
subatomic particles, 85, 133, 198, 355
  computing with, 138–39, 141, 351
  transformed energy states in, 403–4
subconscious, 318
subjective experience, 378–80, 386, 388, 467
subneural models, 169–72, 541*n*
subtraction paradigm, 161
sucrose, 248
suffering, 321, 373, 374–75, 423
  alleviation of, 224, 311, 379, 406, 409–10
  of animals, 224, 379
sugar, 220, 248
  see also glucose
sun, 349–51, 591*n*
Sung, J. C., 552*n*
Sung, Kah-Kay, 546*n*
Sun Tzu, 105
supercomputers, 231, 261, 312, 535*n*
  Blue Gene/L, *71,* 125, 482, 533*n*
  Blue Gene/P, 71, *71*
  human intelligence emulated by, 25, 70, *70,* 71, *71,* 125, 150, 196, 533*n*
  protein folding and, 209
superconducting, superconductors, 119, 451
superconducting wires, 246
superintelligence, 259–60
  runaway AI and, 262, 569*n*
supernova explosion, 23
supply chains, optimizing of, 271
surgery, 307, 317
  brain, 315–16, 386
  intracellular, 162–63
  optical imaging and, 161
  plastic, 310
  transplant, 418, 598*n*
surveillance:
  by law enforcement organizations, 413, 421, 424
  military, 281, 334
  spybots and, 406–7
survival, 90, 152, 325, 396
  digestive system and, 301–2
  economic imperative as, 96
  as evolutionary purpose, 38, 39, 41, 96
  family size and, 433
  grandmother hypothesis and, 218–19
  terrorism and, 421
  of virus outbreaks, 402
  in warfare, 330–31, *331,* 334
Susskind, Leonard, 360, 361, 362, 364
Svoboda, Karel, 171–72, 541*n,* 542*n*
swarm intelligence, 333
swarm weapons, 335
Sweden, life expectancy in, 408
Sylla, M. L., 600*n*
symbolic computing, 460–61, 463–64, 468
synapses, 155, 166, 169–74, 269, 383, 430
  backpropagation and, 156
  blood flow and, 161
  brain scanning and, 161, 162, 166, 171–75, 197
  in cerebellum, 180, *180,* 181, 182
  in cerebral cortex, 190
  CPEB protein in, 176, 199–200, 544*n*
  criticism from the complexity of neural processing and, 428, 445–46
  defined, 124
  formation of, 170, 171, 173–74, *174,* 176, 202, 446
  Hebb's neural learning theory and, 156, 157, 170–71
  in hippocampus, 175

vsnk$all.qxd 7/8/05 9:06 AM Page 647

hormones and, 443
learning and, 179
memory and, 169, 170–71, 175–76, 200, 541*n,* 543*n,* 544*n*
models of, 144, 169–71
neurotransmitters in, 145, 147, 153, 170
nonlinearities in, 137, 148
plasticity of, 151, 156, 169, 171, 173, 541*n*
resetting of, 124, 150
synaptic scaling, 171
system-on-a-chip concept, 533*n*

tactical autonomous combatants (TACs), 333
tags and labels, nanoparticles as, 242
Talbot, David, 569*n*
Tale of Two Cities, A (Dickens), 396
Taleyarkhan, R. P., 567*n*
Tallal, Paula, 175, 543*n*
Tammany Hall, 472
Tanaka, K., 547*n*
tanks, Abrams, 332, 335
tape recordings, 53, 327
tapes, digital, 327–28, 588*n*
Tasmanian tiger, DNA of, 222
tattoos, 310
Taub, Edward, 174
Taylor, J. G., 143, 537*n*
T cells, 217–18, 417, 557*n*
"Technological Singularity, The" (Vinge), 22
technology, 372, 375, 498*n*
author's interest in trends in, 3, 370
brevity and, 5
centralized, 340, 409, 420, 421
Clarke's third law and, 4
communications, *see* communications, communications technologies; telecommunications; telephones
decentralized, *see* decentralization
decline in cost of, 64–65, 95, 338, 469, 472
failure rates of, 429, 456
in GNR age, *see* biotechnology; GNR (Genetics, Nanotechnology, Robotics) age; nanotechnology; robots, robotics; strong AI
human intelligence merged with, *15,* 20–21
information, *see* information technologies
life cycle of, 51–56
magic compared with, 4–5
opposable thumb and, 16, 39, 41
relinquishment of, *see* GNR, relinquishment of
shrinking of, *see* miniaturization; nanotechnology
three stages of impact of, 408
transcendence of, 389
as unified system, 411
see also specific topics
technology evolution:
biological evolution compared with, 16–19, *17–19,* 94, 347, 441, 487
complexity increases and, 38
as continuation of biological evolution, 7, 42, 137
in Epoch Four, *15,* 16–20, *17–20,* 47
in Epoch Five, *15,* 20–21, 40, 47
in Epoch Six, *15,* 21
farsighted, 47–50, *48–50*
key events of, *see* key events, of biological and technological evolution
order increased by, 40
theory of, *see* accelerating returns, law of
TED (technology, entertainment, design) conference (2001), 314–15, 587*n*
Tegmark, Max, 500*n*
telecommunications:
adoption of, 97, 264
bubble in (1997–2000), 13, 97, 264
technology hype cycle for, 263–64
teleconferencing, 123
telephones, *17, 18,* 317–18, 438
as auditory virtual reality, 318
mass use of, 48, *48, 50,* 512*n*
speech recognition over, 287
surveillance and, 413
telephones, cellular, *see* cell phones
telepresence, 123
Telescom conference (1998), 394
telescopes, 47
Hubble Space Telescope, 590*n*
robotic, 281
television, 330, 338
mass use of, *50,* 512*n*
Telford, Ric, 528*n*
telomerase, 218
telomeres, 218, 219, 221, 223–24, 323
Temple, Blake, 504*n*
10% Solution for a Healthy Life, The (Kurzweil), 211
termites, 151, 466
terrorism, 247, 280
civil liberties and, 421–22
GNR age and, 395, 397, 400, 401–2, 414, 421, 423–24
nuclear, 401–2

vsnk$all.qxd 7/8/05 9:06 AM Page 648

terrorism (*cont.*)
preemptive action and, 423–24
suicide, 402, 421
Tesla, Nikola, 1
Texas, University of, 124, 248
cerebellum model and simulation of, 182–83, *182,* 544*n*
Texas A&M University, Brain Networks Laboratory at, 162
Theis, Thomas, 114
theism, criticism from, 431, 473–78
Theory of Games and Economic Behavior (von Neumann and Morgenstern), 499*n*
therapeutic cloning, 214, 220, 221, 222, 224, 256, 323
"There's Plenty of Room at the Bottom" (Feynman), 227, 228
thermodynamics:
laws of, 130, 168, 432
second law of, 39–40, 509*n*–10*n,* 520*n*
thermonuclear explosion, 134
Thier, P., 539*n*
thinking, thought, 86, 144, 167, 316, 386–87, 390, 445
about body, 193, 203
Church-Turing thesis and, 454
cortex and, 190, 191
expansion of, 316–17, 325
incredulity and, 432–33
at its best, 379
pattern recognition and, 149, 309
physical action vs., 175
robots controlled by, 194–95
slowness of, 8–9, 309
understanding, 154–57, 198
see also consciousness; intelligence; mind
Thomas, Dylan, 326
Thompson, Donald L., 561*n,* 562*n*
Thompson, J. N., Jr., 555*n*
Thompson, Larry, 598*n*
Thompson, R. F., 545*n*
Thorne, Kip S., 355–56, 363, 592*n*
Thorpe, S. J., 574*n*
threatening stimuli, 541*n*
three-dimensional molecular computing, 27, 45, 67, 111–22, 128, 133, 292, 434, 526*n*–33*n*
bridge to, 112–22, 526*n*–33*n*
computing with light and, 113, 119–20
DNA computing and, 113, 117–18, 119, 529*n*–30*n*
emulating biology and, 112–13, 116–17, 519*n*
fractal dimensions and the brain and, 68
nanotubes and nanotube circuitry and, 112–15, 526*n*–28*n*
quantum computing and, 113, 119, 120–21
self-assembly in nanotube circuits and, 112–13, 115–16, 528*n*
spintronics and, 112–13, 116–17, 529*n*
three-dimensional shapes:
carbon and, 15, 85
of proteins, 209, 234, 482–83, 550*n*
Through the Looking Glass (Carroll), 326
thumbs:
of humans vs. chimpanzees, 39, 509*n*
opposable, 4, 16, 39, 41, 47, 152, 433, 487, 509*n*
time, 23
digital basis for, 86
general relativity and, 500*n*
problem solving and, 296
quantum gravity and, 14
reversal of, 4–5
special relativity and, 520*n*
subjective, 31–32, 33
travel in, 140–41
Time, Future of Life conference of (2003), 11–12, 499*n*
Tipler, Frank, 500*n*
titanium dioxide, 252
titanium-oxide nanoparticles, 250
toad, Adrian's experiments with, 154
Tobias, Phillip, 502*n*
Toffoli, Tommaso, 130, 518*n,* 534*n*
tolerance, 424
Tomlin, Lily, 189
Tom Swift Jr. book series, 1–2, 497*n*
Tononi, G., 540*n*
toolmaking, *17, 18, 20,* 72, 213
Torcetrapib, 217
Torgerson, Justin R., 139–40, 537*n*
Toshiba, 247
totalitarianism, 471, 498*n*
relinquishment and, 395, 406, 407–8
Toth-Fejel, Tihamer, 560*n*
Townes, C. H., 590*n*
toxic cells, 219
toxins, 371
Internet information on, 594*n*
nanotechnology and, 251, 252, 253, 256, 300
testing for, 215
in viruses, 402
Trachtenberg, J. T., 542*n*
traditional cultures, 387
trains, *see* railroads
Trajtenberg, Manuel, 540*n*

vsnk$all.qxd 7/8/05 9:06 AM Page 649

transcendence, 373, 387–90, 475–76
of biological intelligence, 375
patterns and, 388
use of term, 388, 390
transcension scenario, 358
transcranial magnetic stimulation (TMS), 161
transdifferentiation, 222–24, 471, 556*n*–57*n*
Transend, David Victor de, 198
Transhumanists, 498*n*
transistors, *20,* 45, 59–63, 71, 116, 151, 153, 271, 519*n*
analog-mode use of, 126, 149–50, 151, 188, 189, 442, 443
digital-mode use of, 150, 442
on integrated circuit, 42–43, 56, 71, 76, 111–12, 114, 157, 351, 434
in Intel processors, 63, *63,* 66
manufacturing of, *60*
microprocessor cost per cycle of, 62, *62,* 66
molecular computing and, 115, 528*n*
nanotube, 27, 114, 230, 527*n*
nanowire field-effect, 116
neuron, 308, 313
as paradigm, 67, *67,* 75, *75,* 127–28
per microprocessor, 63, *63,* 498*n*
price of, 59, *59,* 62, 66
shorter electron travel times in, 56, 61
shrinking of, 42–43, 45, 61, 76, 111–12, 113, 351, 434
single-molecule, 121
stacked, 113
tunneling in, 429, 451
transition-state theory, 240
translation, of languages, 288, 292, 313, 337
translation process, 208–9
transportation, 289, 347, 434
of energy, 246, 247, 340
flying machines, 457–58
lock-in and, 429, 430, 457–58
nanotechnology and, 230, 246, 247, 252, 457–58
railroads, 13, 263–64, 420
see also airplanes, aviation; cars; vehicles
transterrestrial community, 361–62
traveling-salesperson problem, 529*n*–30*n*
Travis, John, 554*n*
Treder, Mike, 400, 595*n*
Trezise, A. E., 553*n*
Trinity College, 288
TriPath Imaging, 282–83
Trosch, Rick, 308
truth, many paths to, 1
Tryk, Donald A., 567*n*
Tseng, Yu-Chih, 527*n*
tuberculosis, 282
Tukey, J. W., 600*n*
tumorigenesis, 215
tungsten, 536*n*
turbulence, 90, 522*n*
Turing, Alan M., 94, 155, 259, 286, 295, 453–54, 504*n,* 505*n,* 600*n*, 601*n*
Turing machine, 94, 523*n*
problem solving and, 429, 453–56
Turing test, 25, 200, 201, 263, 294–96, 473, 504*n*–5*n*
copies and, 383, 443
language and, 272, 286, 288, 292, 295, 461, 464
"Ray Kurzweil," 383, 429
variations of, 294–96
Turkle, Sherry, 338, 497*n*, 506*n*
Turner, Linda, 236
turnover pulse, 511*n*
Turrigiano, G. G., 542*n*
two-photon laser scanning microscopy (TPLSM), 162–63, 164, 166
Tyler-Smith, Chris, 549*n*
type II civilization, 344, 348, 353
type III civilization, 344
typography, 54

UAVs, *see* unmanned aerial vehicles
ubiquitin, 209
Ueland, T., 553*n*
Ulam, Stanislaw, 498*n*
ulcers, 282
Ullman, Shimon, 547*n*
ultrasonic beams, 313
Unbounding the Future (Drexler and Peterson), 558*n*
uncertainty, 267
probabilistic fractals and, 46
quantum, 138, 238, 353, 486
uncertainty principle, 138
underclass, disappearance of, 338
underdeveloped countries:
criticism from the rich-poor divide and, 469–70
economic growth in, 99
education in, 336, 396
family size in, 433
life expectancy in, 338
uniforms, army, 332
Unitarianism, 1, 382
United Nations, 525*n*–26*n*
United Therapeutics, 216, 282, 581*n*
universal assembler, use of term, 228

vsnk$all.qxd 7/8/05 9:06 AM Page 650

universe(s), 342–68
  age of, 347, 590*n*
  anthropic principle and, 15, 357, 359–64, 499*n*–501*n*
  cellular automata and, 85–91, 518*n*–22*n*
  closed, 500*n*
  computational limits of, 364–65, 485–86, 592*n*
  computing of, 342
  consciousness of, 375, 389, 390
  as deterministic, algorithmic system, 85–86
  Earth-centered view of, 342, 433
  in Epoch Six, 14, *15,* 21, 367, 390
  evolution of, 360, 361
  existence of, 389–90
  expansion of, 354, 357, 360, 361
  holographic, 365–66, 486
  inflationary period of, 357, 360
  multiple (parallel multiverses; "bubbles"), 15, 360, 362, 390, 499*n*–500*n*
  new, 358, 405
  purpose of, 374
  search for extraterrestrial intelligence in, *see* SETI
  spreading of intelligence through, *15,* 21, 29, 45, 300, 361–68, 372, 375, 389, 486, 511*n*
  stories vs. atoms in, 5
  wormholes in, 354–56
University College, 288
unmanned aerial vehicles (UAVs), 280, 332, 333, 335
unsolvable problems, Church-Turing thesis and, 453–56
Upper Paleolithic era, 219
Uranos, 350–51
usr/bin/god (Doctorow), 271–72
Utah, University of, 308
Utility Fog, 506*n*
utility function, 39, 362, 364

V1 (visual area), 185
V5 (cortical region), 156
vaccines:
  Alzheimer's disease and, 220, 555*n*
  cancer and, 217, 218
  mousepox, 398
  smallpox, 398, 402
vacuum tubes, 45, 56
  as paradigm, 67, *67,* 75, *75,* 127–28, 434
Valdes, Francisco, 591*n*
values, 323, 424
vampire bot, 248
Van Essen, D., 547*n*
Vangelova, Luba, 556*n*
van Praag, Henriette, 177, 544*n*
variant Creutzfeldt-Jakob disease (vCJD), 116, 224
Vasan, S., 555*n*
vasculoid, 306
Vaupel, James W., 597*n*
vectors, 553*n*
Vega, 355–56
vehicles, 245, 246, 250
  fuel cells for, 247
  robot-driven, 285–86, 292
  unmanned aerial (UAVs), 280, 332, 333, 335
  see also cars
Venter, Craig, 216
ventral pathway, 175
venture-capital investment, 395, 524*n*
vestibular system, 314
video games, 125, 276, 319–20, 341
video graphics array (VGA) computer screens, 55
Vietnam War, *331*
Vince, Gaia, 528*n*
Vinci, Leonardo da, 2, 51, 473
Vinge, Vernor, 22, 23, 24, 324, 328, 504*n*
virtual bodies, 28–29, 199, 203, 319, 325
virtual people, 105, 287, 313, 318, 473
virtual reality, 4, 9, 28–29, 203, 312–20, 340, 397, 487
  auditory, 105, 310, 312–13, 318, 472
  body changes and, 310
  concerns about, 318, 319–20
  e-commerce and, 105
  foglets and, 28, 29, 310
  full-immersion, 105, 315, 340, 341, 457, 472
  military use of, 312, 335, 586*n*
  nanobots and, 28, 29, 310, 313–17, 319, 377
  from within the nervous system, 28, 29, 165, 300, 377
  personality in, 29, 314–16, 587*n*
  social change and, 473
  visual, 105, 310, 472
virtual-reality environment designers, 314
viruses, 226, 418, 423, 511*n*
  gene therapy and, 215, 216
  genetic engineering and, 206, 393, 398, 402–3
  HIV and AIDS, 74, 95, 398, 402, 470, 514*n*
  Internet information on, 594*n*
  nanotechnology and, 233, 235–36, 255

vsnk$all.qxd 7/8/05 9:06 AM Page 651

SARS, 74, 398, 402–3, 423, 514*n*
smallpox, 398, 402
synthetic, 216
as vectors, 553*n*
viruses, software, *see* software viruses
Visser, Matt, 356, 592*n*
visual cortex, 156, 172, 176, 181, 530*n*
visual-spatial relationships, learning of, 175
visual systems, 130, 265
modeling of, 185–88, *187*
of primates, 574*n*
robotic, 123, 187–88, 285–86, 529*n*
visual virtual reality, 105, 310, 472
vitamin A, 414
vitamins, 301
Vita-More, Natasha, 302, 583*n,* 589*n*
Vlastos, Gregory, 51
Vogel, Viola, 236
voice over Internet protocol (VOIP), 473
voice synthesis, 294–95
Voogd, J., 544*n,* 545*n*
voxel (three-dimensional pixel) maps, 285
VPNs (private networks), 256
Vrba, Elisabeth, 511*n*

Wade, Nicholas, 510*n*
Wagner, Richard, 549*n*
Waisman, D. M., 552*n*
Walch, Stephen P., 562*n,* 563*n*
Wales, University of, 283
Walker, John, 515*n*
Wal-Mart, 283
Walsh, Christopher, 505*n*
Wang, Chuan-Bao, 567*n*
warfare, 300, 330–35, 398, 401, 409
civil liberties and, 421–22
death in, 330–31, *331,* 409
see also specific wars
war-game simulation, 398, 595*n*
Warner Bros., 315
Warwick, Kevin, 194
water, 239, 240, 406
pattern of, 383
pollution of, 243
purification of, 252
spirituality and, 388
Waterston, Robert, 206*n*, 549*n*
Watson, Arthur H., 599*n*
Watson, James, 11, 206, 207, 549*n*
Watts, Lloyd, 143, 440, 531*n*–32*n,* 537*n,* 545*n*
auditory system model of, 123–24, 147–48, 183–84, *185,* 443, 452, 530*n,* 545*n*–47*n*
waves, cellular gliders and, 520*n*
wealth, 341, 372, 391
creation of, 13, 107, 338, 396–97, 410
weapons, 8, 330–35
bioweapons, 393
guidance of, 255, 276, 279–80, 413, 435
of mass destruction, 423–24
nanotechnology-based, 300, 334–35
nuclear, *see* nuclear weapons
simulations of, 280, 334
smart, 335, 435
weather patterns, 449
Weaver, Kimberly, 503*n*
weavers, destruction of cottage industry of, 507*n*
Webb, John K., 356, 592*n*
Web browsers, 473
Weibel, Peter, 549*n*
Weiershausen, W., 516*n*
weight gain, prevention of, 11–12, 303
Weinberg, Steven, 500*n*
Weiner, H. L., 555*n*
Weir, Laila, 586*n*
Weis, R., 587*n*
Weiss, Rick, 556*n*
Weiss, Ron, 221, 555*n*
Weizenbaum, Joseph, 312
Weizmann Institute of Science, 118
Welsh, J. P., 544*n*
Werblin, Frank S., 186–87, 547*n*
Westphal, Sylvia, 553*n*
"what-if" experiments, 26
wheel, biological evolution and, 440
Wheeler, John A., 355, 503*n*, 592*n*
"When Will Computer Hardware Match the Human Brain?" (Moravec), 122
White, Carter T., 563*n*
White, S. R., 589*n*
white blood cells, 305
microbivores as replacement for, 254, 306
Whitehead, Alfred North, 72, 189, 410, 453, 514*n*, 601*n*
Whitesides, George, 254, 568*n*
Whitfield, John, 541*n*
"Why the Future Doesn't Need Us" (Joy), 391, 394–95, 409, 427
Wiener, Norbert, 86, 268, 382, 518*n*, 593*n*
Wiesel, T. N., 173, 542*n*
will, freedom of, 382, 521*n*–22*n*
Williams, Brian, 281
Williams, Sam, 576*n,* 581*n*
Wilson, Arthur, 437
Wilson, D., 584*n*
Wilson, E. O., 195
Wilson, Frank A., 509*n*, 543*n*
Wimax standard, 346, 432

vsnk$all.qxd 7/8/05 9:06 AM Page 652

wind energy, 243, 244, 334
Winerman, Lea, 561*n*
Winston, Patrick, 284
Winter, J. O., 587*n*
Wired, 394, 427
wireless communications, 221, 282, 346, 432
  between brains, 316, 585*n*
  to Internet, 312, 346
  nanobots' use of, 163, *233,* 303, 304, 316
  price-performance of, 77, *77*
Wisconsin, University of, 115
wisdom, 330, 335, 369
  grandmother hypothesis and, 219, 302
Wise, Kensall, 304, 584*n*
Wittgenstein, Ludwig, 312
Wolfram, Stephen, 93, 481, 518*n*
  cellular automata and, 85–91, 93, 359, 448, 519*n*–22*n*
Woodruff, R. C., 555*n*
Woods, C. Geoffrey, 523*n,* 539*n*
work, 259
  automation and, 108
  call-center, 287
  categories of, 302, 314
  decentralization of, 105, 122, 340–41
  farm, decline in, 302, 340, 583*n*
  GNR impact on, 337–41
  intellectual property and, 339–40
  meaningful, 396
  mental vs. physical, 302
  personal services as, 340
  play vs., 300, 341–42
  role of, 300
World Bank, 2004 report by, 99, 338, 396, 470
World Health Organization, 423
World War I, 330, *331,* 374
World War II, 330, 374, 396, 442
  deaths in, 331, *331*
World Wide Web, *17,* 78, 100, 102, 261, 436, 441
  access to, 338, 469
  dangerous information on, 392–93, 395, 594*n*
  eBay on, 104
  education and, 336, 337
  experience beamers and, 316
  human longevity and, 325
  mass use of, 20, 42, *50,* 512*n*
  virtual environments of, 314, 337, 472
  as worldwide mesh, 312
wormholes, 140, 354–56
Wright, John, 548*n*
Wright, Robert, 86–87, 518*n*
writing, *17, 18, 20,* 36, 44, 48, 286, 338, 536*n*
Wu, L., 553*n*
Wurman, Richard Saul, 315

X chromosome, 510*n,* 556*n*
xenografts, 418, 598*n*
xenoviruses, HIV-type, 418
Xerox, 570*n*
  Palo Alto Research Center of, 240, 286
Xerri, C., 542*n*
Xiao, Y., 584*n*
X inactivation, 510*n*
X-ray scattering, 138
Xu, Kaixin, 589*n*
xylose, 248

Yamada, T., 564*n*
Yan, Hao, 117, 529*n*
Yang, R. T., 567*n*
Y chromosome, 42, 208
yeast, gene expression in, 283
Yeats, William Butler, 301
Yeltsin, Boris, 406
Yin, Tom, 545*n*
Young, E., 184, 545*n*
Young, Mike, 283
Young, Richard, 509*n*
Young, S. R., 542*n*
Yovits, M. C., 535*n*
YRUU (Young Religious Unitarian Universalists), 382
Yu, V., 570*n*
Yudkowsky, Eliezer S., 35, 498*n,* 597*n*
  friendly AI and, 409, 420, 598*n*–99*n*
Yurtsever, Uri, 355–56, 592*n*
Yuste, R., 541*n*

Zakon, Robert, 516*n*
Zaks, A., 562*n*
Zeck, Günther, 586*n*
Zen and the Art of Motorcycle Maintenance (Pirsig), 392
Zen parable, 312
zeolites, 252
Zeus (Earth-sized computational object), 350, 351
Zhang, L., 552*n*
Zhang, Shoucheng, 118–19, 530*n*
Zhang, Wei-xian, 567*n*
zinc oxide, 252
Zita, Karen, 542*n*
zonulin, 163–64
zot, 163–64
Zuse, Konrad, 86, 518*n*