

# Index

- Abouheif, E., 34  
Accretion, 246, 248  
ACT-R architecture, 333, 350  
Adami, C., 11  
Adams, C. C., 267  
Adamson, L., 154  
Adaptation, 18. *See also* Morphology; Mutation  
direct selection and, 36–43  
modifiers and, 37–39  
modular facilitation of, 42  
organ gain/loss and, 187–202  
pleiotropic effects and, 34, 36–37, 39–40  
quasi independence and, 51, 52  
Advertising, 285  
Agrafiotis, D. K., 104  
Agre, P. E., 3  
Alberch, P., 144, 146, 149, 155, 215, 230–231  
Albers, 262  
Alchian, A., 390  
Alexander, R. D., 86  
Allen, C., 66  
Alley, K. E., 155  
Allport, D. A., 333  
Altenberg, Lee, 6, 14, 31, 51–52, 190, 406, 435  
amphibians and, 144, 165  
evolutionary developmental biology and, 66, 69  
modularity issues and, 99–128  
morphology and, 221, 223–224, 228, 230, 232, 234  
natural selection and, 33–34, 36, 40  
RNA structure and, 129, 136  
Wagner-Altenberg model and, 55–56, 58–59  
Altenberg Workshop in Theoretical Biology, xv  
Amphibians  
cell types and, 162–163  
larvae and, 151–153  
lateral line system and, 159–162  
limb development and, 157–159  
metamorphosis and, 151–167  
neoteny and, 149–151  
urodeles and, 151–153  
*Amphioxus*, 191  
Amundson, R., 12, 213, 215  
*Anabaena*, 196  
Anatomy, 221  
Ancel Meyers, Lauren, 31, 33, 41, 46, 129–141, 435  
Anderson, Carl, 181–182, 435  
amphibians and, 162  
chunking and, 333, 350  
remodularization and, 185–205  
Ando, A., x  
Angola, 267  
*Anomalocaris*, 251–252  
Ants, 61, 195–197  
colony behavior and, 76–88, 198–199  
competition and, 83–88  
*Apis mellifera*, 81  
Archangeli, D., 428  
Aristotle, 383  
Arnold, S. J., 214  
Arnone, M. I., 66–67  
Art, 181  
ancient, 259, 269–274  
Bauhaus movement and, 285–286  
culture and, 259, 275–279  
dance and, 289–290  
dimension and, 262–267, 297–298  
eclectic basis for, 285–287  
golden section and, 288  
impossible figures and, 264–265, 267  
key patterns and, 269–274  
knots and, 266–269  
Koffka cubes and, 262–263  
models and, 294–296  
modular confines and, 283–285  
ornaments and, 275–279  
science and, 283–303  
self-organized hierarchical systems and, 296–302  
static concept and, 288  
symmetry and, 267, 269  
tiling and, 263–264, 269–274, 291, 295–296  
visual interpretation and, 259–267  
Arthropod segments, 35  
Arthur, W., 143, 191  
Articulation, 62, 64–65, 89–91  
Human Genome Project and, 69–70  
interactors and, 73–75  
kin selection and, 86–88  
replicators and, 73–75  
social insects and, 76–88  
stage of, 424–425  
Artificial life, xv, 11, 312–313  
Ascher, M., 278  
Atchley, W. R., 213  
Atran, S., 6  
Austin, J. L., 429  
Australian lungfish, 163  
Avery, L., 75  
Axelrod, R., 86  
Baatz, M., 37  
Babylon, 285  
Bain, G., 267, 270  
Baldwin, C. Y., 3  
Ballard, W. W., 162  
Banta, W. C., 195  
Barbuti, R., 11  
Bard, J., 209

- Barkow, J. H., 17, 322, 327  
 Barnes, M. D., 155  
 Barr, A., 334  
 Barrett, H. C., 6  
 Basin of attraction, 397  
 Bates, E. A., 415, 431  
 Bateson, W., 207–208, 217  
 Bauhaus movement, 285–286  
 Bechtel, W., 10–11  
 Behavior, 64–65  
     causal actors and, 225–226  
     evolutionary units and, 143–167  
     goal-directed systems and, 56–59  
     kin selection and, 72–73  
     mutualism and, 86  
     parental manipulation and, 86  
     social insects and, 76–88, 195–199  
 Behavioral inheritance system (BIS), 7  
 Beklemishev, W. N., 186, 195  
 Beldade, P., 215  
 Belew, R. K., 312  
 Bell, G., 197–198  
 Bely, A. E., 146, 148  
 Bengtson, S., 250  
 Bernstein, Nikolai A., 356–357, 361, 373–377  
 Berry, D. L., 155  
 Between-glance placements (BGP), 343  
 Big bang, x  
 Bihle, A. M., 373  
 Biology, 9–10. *See also* Evolutionary developmental biology  
     CHREST and, 333, 339–340  
     development modularity and, 12–13  
     morphology and, 13–14  
     research strategies and, 11–12  
 Black-boxing, 14–15  
 Blaxton, T. A., 365  
 Blenny fish, 69  
 B-matrix model, 113–114, 119–120  
 Boardman, R. S., 186  
 Böger, T., 152, 156  
 Bolker, J. A., 162  
     evolutionary developmental biology and, 66–67  
     modular ubiquity and, 9–10, 14  
     morphology and, 221, 223, 226  
     natural selection and, 33–34  
 Bolt, J. R., 149  
*Bombus empatiens*, 229  
 Bonner, John, 7, 12, 14, 30  
     evolutionary modules and, 52  
     jumping forms and, 213  
     lock-in and, 129  
     morphology and, 223, 231  
     natural selection and, 33  
     remodularization and, 186, 197  
 Bonnet, C., 414  
 Bornberg-Bauer, E., 41  
 Borromean rings, 264–265, 267  
 Bourke, A. F. G., 80, 84, 87  
 Bower, H., 364  
 Boxes-and-arrows diagrams, 309–310, 316–317, 322  
 Boyd, R., 222, 226  
 Brain. *See* Cognition  
 Brain, Russell, 16  
 Brändle, K., 160, 163  
 Brandon, Robert N., 30, 435  
     amphibians and, 145  
     evolutionary developmental biology and, 61, 70  
     evolutionary modules and, 51–60  
     modular ubiquity and, 6–7, 14, 19  
     natural selection and, 33  
     remodularization and, 186, 190  
 Bridgeman, B., 361  
 Broca, Pierre-Paul, 16  
 Brodbeck, D. R., 363  
 Brodmann's areas, 371  
 Brothers, D. J., 86  
 Brown, A. L., 367  
 Brown, D. D., 149, 152  
 Brutlag, D. L., 121  
 Buckingham, M., 145  
 Budd, G. E., 251–252  
 Buddhism, 285  
 Buhler, Karl, 355  
 Buller, D. J., 21  
 Burde, G., 267  
 Bürger, R., 111  
 Burgess Shale, 242, 244–245, 250–251  
 Buscalioni, Angela D., 183, 435  
     art/science modularity and, 283–304  
     jumping forms and, 209–210  
 Buss, L. W., 392  
     connectionism and, 322  
     evolutionary developmental biology and, 65, 71–76  
     modular ubiquity and, 9, 11  
     remodularization and, 186  
 Cabrera, J. L., 302  
 Cakaudrove patterns, 275  
 Calabretta, Raffaele, 29–30, 306, 435  
     connectionism and, 309–330  
     natural selection and, 33–49  
     robots and, 44–45  
 Callebaut, Werner, 3–28, 435  
 Callery, E. M., 149, 151, 154, 156–157

- Cambrian era, 239, 242, 244–245, 250–252  
CaMeRa model, 339–340  
Campbell, J., 189  
Cangelosi, A., 319–320, 322–323  
Cannatella, D. C., 149  
Canonical babbling, 421, 427  
Carrier tasks, 364  
Carroll, J. M., 17, 21, 207  
Catalano, Eduardo, 286, 295  
Caudron, A., 267  
Causal actors, 225–226  
Cecconi, F., 319, 321  
Celtics, 272–273  
Cezanne, Paul, 286  
Chain production, 425  
Challis, B. H., 363, 365–366, 368  
Chan, H. S., 41  
Changizi, M. A., 197  
Chaos, ix, 8, 283, 397  
Chaplin, Charlie, 285  
Chapman, R. E., 214  
Characters, 33  
animal skeletons and, 239–256  
causal actors and, 225–226  
direct selection and, 36–43  
evolutionary units and, 143–167  
jumping forms and, 207–218  
morphology and, 221–235 (*see also Morphology*)  
quantification of, 227–228  
rigor and, 221  
Charland, L., 17  
Chase, W. G., 340–341, 343, 347  
Cheetham, A. H., 186  
Chemical signals, 79  
Chengjiang, 250  
Chess, 340–348  
Cheverud, J., 33–34  
Chibon, P., 154  
Chiu, C-H., 29  
Chloroplasts, 193  
Chomsky, Noam, 306  
connectionism and, 311, 314, 327  
modular ubiquity and, 10–11, 16–17, 20  
natural logic and, 410, 412, 415, 418–419  
Christie, A., 259, 273  
Christoff, K., 371  
Chunk Hierarchy and REtrieval STructures (CHREST), 306–307, 331  
Attack and Defense relations, 343–347  
biological meaning and, 333, 339–340  
CaMeRa model and, 339–340  
chess and, 340–348  
chunk identification and, 342–347  
computer simulations and, 348–349  
concepts for, 332–334  
copy task and, 341  
discrimination net and, 336–337  
empirical studies of, 340–348  
EPAM and, 335–336, 338, 340, 350  
eye fixation and, 336, 343–345  
functional meaning and, 333, 340  
latencies and, 343–345  
learning and, 338  
linguistics and, 337  
links and, 337  
memory and, 335–336, 338, 340, 343, 348–349  
model overview, 335–336  
modularity in, 338–340  
nodes and, 336–337  
object representation, 337  
pattern recognition, 338  
recall task and, 341  
research examples of, 334–335  
Churchill, F. B., 89  
Churchland, P. S., 16, 331–333  
Cimino, C. R., 372  
Cisne, J. L., 201–202, 251, 254  
*Cis*-regulatory regions, 66–67  
Clade selection, 70  
Clark, K. B., 3, 15  
*Cloudina*, 244  
Cloutier, R., 149  
Coase, R. M., 388–392  
Coates, M. I., 159  
Cognition, xv, 10–11, 375–377  
artificial life and, 312–313  
CHREST and, 331–350  
communication and, 411–431  
connectionism and, 310–314, 318–328  
constraints and, 18–19  
distractor effect and, 358–359  
empiricism and, 311  
eye fixation and, 336, 343–345, 360–362  
form-oriented processing and, 358–362  
grand design and, 353  
knowledge representation and, 20–21  
learning studies and, 318–328  
linguistics and, 314–318  
massive modularity hypothesis (MMH) and, 17–18, 20–21  
modularity of mind and, 17–20  
multilevel method and, 355–358  
neural modularity and, 15–17  
neural networks and, 314–318  
phylogenetic growth and, 369–373  
processing and, 355–369  
psychology and, 354–355

- Cognition (cont.)  
 relevance effect and, 359  
 semantic categorization and, 363–369  
 theory of mind and, 19–21  
 Cohn, M. J., 158–159  
 Colectivo ETSAM, 286, 295  
 Collazo, A., 158, 160, 163  
 Collins, J. P., 149, 151  
 Colwell, R. K., 86  
 Comets, 4  
 Communication. *See also* Linguistics  
 canonical stage and, 421, 424–425, 427  
 capabilities for, 425  
 comfort sounds and, 420  
 constraints of, 417–418  
 expansion stage and, 424–425  
 extraterrestrial, 410  
 infants and, 419–431  
 mimicking, 417  
 phonation and, 419–431  
 poverty of stimulus and, 413  
 primitive articulation stage and, 424–425  
 quasivowels and, 422–423  
 rhythmicities and, 421  
 signal/value distinction and, 428–429  
 universal grammar and, 411–415  
 vocal development and, 419–431  
 Comparative anatomy, 221  
 Compartmentalization, 155  
 Competition, 30, 40–41  
 articulation and, 86–88  
 Coase theorem and, 388–392  
 interactors and, 61–63, 70–71  
 modular cooperation and, 63  
 modular deflection and, 63–64  
 multicellular organisms and, 70–71  
 partitioning and, 86–88  
 replicators and, 61–63, 70–71  
 social insects and, 83–88  
 theoretical perspective on, 88–91  
 Complexity, ix–xiii, 3, 201  
 disparity and, 232  
 goal-directed systems and, 56–59  
 hierarchical model of, 254  
 macroevolution and, 231–232  
 nearly decomposable (ND) systems and, 5–6  
 processing levels and, 355–369  
 self-organization and, 296–302  
 skeletons and, 239–256  
 solar system and, 4–6  
 Computation, ix, 18, 31  
 CHREST and, 331–350  
 cognition and, 315–316 (*see also* Cognition)  
 grand design and, 353  
 Conceptual structures, 358  
 Congruence principles, 46  
 Connectionism, 19, 68, 309–310, 314  
 artificial life and, 312–313  
 empiricism and, 311  
 evolutionary simulations and, 318–326  
 Conrad, M., 8  
 Contingency, 68  
 Conway Morris, S., 244, 251, 256, 267  
 Coombs, S., 160  
 Cooperation  
 articulation and, 62, 64–65, 69–70, 73–75, 78–80,  
 86–88  
 cell-lineage selection and, 71–76  
 fixation and, 73  
 modular defectors and, 71–76  
 partitioning and, 62, 64–65, 69–70, 73–75, 78–80,  
 86–88  
 social insects and, 76–88  
 Co-option, 8  
 Coordination mechanisms, 396  
 Copy task, 341  
 Cormidia, 195  
 Corning, P. A., 197  
 Corridor model, 111  
 Cortical areas, 315–316  
 Cosmides, L., 18, 310, 355  
 Covariation, 229–230  
 Cowan, N., 336, 340  
 Cox, E. C., 36  
 Coxeter, H. S. M., 267  
 Crabs, 196  
 Cracraft, J., 148  
 Craik, F. I. M., 353, 363–364, 368, 371  
 Crespi, B., 86  
 Critchlow, K., 273  
 Cromwel, Peter, 267  
 Crow, J. F., 115  
 Crowe, D. M., 259, 275, 278  
 Crozier, R. H., 84  
 Cryptic variation, 8  
 Dancing, 289–290  
 Darden, L., 221, 225  
 Darwin, Charles, 89, 216, 221  
 Darwinian modules, 18, 20–21  
 David, Paul, 3, 384–385  
 Davidson, E. H., 66–67, 234  
 Davies, N. B., 87  
 Da Vinci, Leonardo, 288  
 Dawkins, R., 14, 17, 61, 70, 72, 74–75, 87  
 Deacon, T. W., 355, 371  
 De Beer, G., 9–10, 143  
 Debrenne, F., 252

- Decomposability, 10, 406  
  basin of attraction and, 397  
  coordination and, 396  
  market selection and, 396–400  
  near, 400–402  
  preferred neighbor and, 396–397  
  scheme for, 394–400  
  search accuracy and, 402–405  
Degrees of freedom  
  dimension reduction and, 102–105  
  embeddings and, 102–105  
  environmental variation and, 112–113  
  evolvability and, 105–106  
  screening off and, 108–112  
  selection alignment and, 105–106  
  trait description and, 101–106  
  underlying, 106–113  
de Groot, A. D., 340–341, 349  
Dejoan, Anne, 183, 283–304, 435  
De la Coste-Lareymondie, M., 372  
de la Iglesia, Alicia, 183, 283–304, 435  
Delgado-Buscalioni, Rafael, 183, 283–304, 435  
Delta-Notch proteins, 145, 164  
Demsetz, H., 390  
Dennett, D. C., 8, 19  
Dent, J. N., 149, 152–153, 157  
Deoxyribonucleic acid (DNA), 66–67, 107, 305  
de Souza, S. J., 122  
Determinism, 70  
Deubel, H., 360  
Developmental couplings, 144–146  
Developmental Systems Theory, 15, 75  
de Villiers, C. G. S., 158  
Devonian era, 251  
Dewel, R. A., 186  
*Dickinsonia*, 242  
Di Ferdinando, A. R., 42, 46, 325, 328  
Dimension reduction, 102–105  
Dimmick, W. W., 149  
Direct selection, 124  
  adaptive traits and, 40  
  constructional selection and, 40–41  
  degrees of freedom and, 102–113  
  evolvability and, 36–39  
  for free, 122–123  
  modifiers and, 37–39  
  phenotypic stability and, 41  
  physiological adaptation and, 42  
  pleiotropic effects and, 39–40  
  screening off and, 108–112  
Disease, 70, 72  
Disparity, 230–232  
Dissociation, 8, 143, 146–149  
Distractor effect, 358–359  
Divergence, 8  
Dodd, M. H. I., 152–153  
Donald, Merlin, 16  
Dornhoefer, S., 361  
DPCS relations, 344–345  
Dreller, C., 199  
*Drosophila melanogaster*, 41, 229  
Duboule, D., 159, 207  
Ducibella, T., 152  
Duellmann, W. E., 149, 151–153, 158  
Dugatkin, L. A., 87  
Dünker, N., 158  
Duplication, 8  
Dürer, Albrecht, 288  
Eble, Gunther, J., 14, 182, 221–238, 435  
*Ecton burchelli*, 81  
Economics, xv, 3, 302, 307–308  
  accessibility and, 385–386  
  agency and, 390–393  
  Coase theorem and, 388–392  
  coordination mechanisms and, 396  
  decentralization and, 383  
  decomposition and, 394–406  
  definition for, 386  
  division of labor and, 383–392  
  efficiency and, 386–387  
  equilibrium and, 387  
  granularity and, 388–393  
  institutional contexts and, 387–388  
  interaction structures and, 387–388  
  market selection and, 396–400  
  NK model and, 383, 401  
  nonmonotonicity of marginal productivity and, 390  
  optimization issues and, 388–403  
  QWERTY system and, 384–385  
  search accuracy and, 402–405  
  Second Welfare Theorem and, 388  
  supply and demand, 387  
  transaction costs and, 392–393  
Eilers, R. E., 426  
Eisen, M. B., 148  
Eldredge, N., 63, 148  
Electroencephalograms (EEGs), 371  
Elementary Perceiver And Memorizer (EPAM), 335–336, 338, 340, 350  
Elinson, R. P., 151, 154, 156–158, 162  
Ellington, A. D., 132  
Elman, J. L., 312, 416–418  
Elowson, A. M., 420  
El-Said, I., 273  
Embedding, 102–105, 369–373  
Emerson, Alfred, 77

- Empiricism, 311  
 Encoding  
     form-oriented, 358–362  
     multilevel, 355–358  
     semantic, 363–369  
 Endler, J. A., 46  
 Engelkamp, D., 59  
 Engels, W., 81  
 Environmental variation, 112–113  
 Epigenetic inheritance system (EIS), 7, 12  
 Epistasis, 36–37  
 Epistemology, 416–417  
 Epstein, A. N., 21  
 Equations  
     B-matrix model, 114  
     decomposition, 394–403  
     house-of-cards model, 115  
     maximum module number, 239  
     mutant genotype, 116  
     random-walk model, 115  
     Shannon, 239  
 Equilibrium, 39, 75, 269  
     economics and, 387  
     plasticity and, 130–135  
 Ericsson, K. A., 334  
 Ernst, B., 264  
 Erwin, D. H., 191, 234  
 Escher, M. C., 161, 262, 264, 269, 291  
 Ethologists, 420  
 Eukaryotic cells  
     organ gain and, 193–202  
     organ loss and, 187–193, 199–202  
*Eusthenopteron*, 252  
 Evans, J. D., 81–82  
 Evolution, x–xi, 8, 14–15  
     coherence and, 387  
     granularity and, 388–393  
     homologues and, 7, 9–11  
     human rationality and, 6  
     individuality and, 71–73  
     interaction structures and, 387–388  
     kin selection and, 71–73, 86–88  
     MMH and, 17–18  
     morphology and, 221–235 (*see also Morphology*)  
     mosaic, 143–167  
     natural selection and, 33–49  
     neo-Darwinian, 9  
     organ gain/loss and, 187–202  
     plasticity and, 14, 42  
     psychology and, 17–20  
     research strategies and, 11–12  
     scarcity and, 386  
     stochastic morphology and, 233–234  
     survival of fittest, ix  
     transcendental argument and, 52–53  
     units of, 143–167  
 Evolutionary developmental biology  
     amphibians and, 149–167  
     animal skeletons and, 239–256  
     articulation and, 73–75, 86–88  
     cell-lineage selection and, 71–76  
     competition and, 61–65, 70–71, 83–91  
     congruence principles and, 46  
     constructional selection and, 40–41  
     direct selection for, 36–43  
     evolvability and, 33, 36–39, 45–46  
     germ cells and, 71–72  
     individuality and, 63–65  
     integration and, 61–70 (*see also Integration*)  
     kin selection and, 71–88  
     lock-in and, 129–139  
     macroevolution and, 221–235  
     mechanisms of, 29–32  
     modular defection and, 71–76  
     partitioning and, 73–75, 86–88  
     phenotypes and, 34–35, 41  
     plasticity and, 14, 42, 57, 130–139  
     pleiotropic effects and, 39–40  
     repeated dissociated coevolution and, 143–144  
     research strategies and, 64–65  
     RNA-structure origins and, 129–139  
     social insects and, 76–88  
     units of, 143–149  
 Evolutionary modules, 11, 14–15, 34. *See also Modularity*  
     arguments for existence of, 51–53  
     conceptual analysis for, 54–59  
     empirical hypotheses for, 56–59  
     goal-directed systems and, 56–59  
     mammalian forelimbs and, 53  
     persistence and, 57  
     plasticity and, 57  
     transcendental argument and, 52–53, 56–59  
     unitary function and, 54–55  
     Wagner-Altenberg model and, 55–56, 58–59  
 Evolutionary psychology. *See Psychology*  
     “Evolution of Hierarchical Organization, The” (Buss), 72  
     *Evolution of Individuality, The* (Buss), 71–72  
 Evolvability, 33, 45–46  
     animal skeletons and, 239–256  
     B-matrix model and, 113–114, 119–120  
     degrees of freedom and, 105–106  
     direct selection and, 36–43  
     innovation and, 232–233  
     macroevolution and, 232–233  
     mutational kinetics and, 113–120

- plasticity and, 130–135  
selection alignment and, 105–106  
Exons, 122  
*Extended Phenotype, The* (Dawkins), 74
- Faivre, I. A., 334  
Fang, H., 154, 157, 162  
Feigenbaum, E. A., 334–335  
Fein, D., 334  
Feldman, M. W., 73, 86  
Felsenstein, J., 148  
Fiji, 275  
Findlay, J. M., 359  
Fink, W. L., 148, 230  
Fire ants, 84  
Fischer, B., 361  
Fisher, R. P., 363  
Fisichelli, R. M., 420  
Fixation, 73  
Fodor, Jerry, xv, 305, 307, 333  
cognition and, 355, 358–359, 373  
connectionism and, 309, 311, 315, 327  
modular ubiquity and, 10–11, 17–18, 20–21  
Fontana, Walter, 9, 11, 31, 435  
decomposability and, 392  
lock-in and, 129–131  
natural selection and, 33, 41, 46  
Foote, M., 214, 230, 233, 251  
Force, A., 36, 41, 124  
Ford, L. S., 149  
Form-oriented processing, 358–362  
Fox, H., 152  
Franken, K., xii  
Franks, N. R., 80, 84, 87, 195, 198  
Fristrup, K., 225  
Fritzsch, B., 149, 160–161  
Frogs. *See* Amphibians  
Frustration, 42–43, 118  
Functional magnetic resonance imaging (fMRI), 369–371  
Functions, 9–11, 14, 34, 66, 68  
AND, 418  
animal skeletons and, 239–256  
articulation and, 62 (*see also* Articulation)  
B-matrix model and, 113–114, 119–120  
causal actors and, 225–226  
CHREST and, 331–350  
cognition and, 318–328 (*see also* Cognition)  
communication and, 411–431  
connectivity and, 68  
context and, 227–228  
developmental couplings and, 144–146  
jumping forms and, 207–218  
levels of processing and, 355–369
- logical distinctions and, 409–411  
modular defectors and, 71–76  
morphology and, 223 (*see also* Morphology)  
nestedness and, 190–192  
OR, 418  
organ gain/loss and, 187–202  
partitioning and, 130–135 (*see also* Partitioning)  
poverty of stimulus and, 413  
remodularization and, 199–202  
reproductive, 71–76  
screening off and, 108–112  
social insects and, 76–88  
subfunctionalization and, 124–125  
unitary, 54–55  
Fungi, 187
- Gabrieli, J. D. E., 353, 369–371  
Gadagkar, R., 84  
Gale, E. A., 146, 155  
Galis, F., 36, 40  
Gallo, D., xv, 334, 356, 363, 368  
Gammaitoni, L., 302  
Gardiner, J. M., 364, 372  
Gardner, H., 291, 333  
Garfield, J. L., 17  
Geary, Valerie, xvi  
Gehling, J. G., 244  
Gellon, G., 145  
Gelman, S. A., 17  
Gene nets, 14, 30, 52  
Genes-D, 14–15, 30, 88  
Genes-P, 14–15, 30, 88  
Genetic inheritance system (GIS), 7  
Genetics, 67, 305  
amphibians and, 149–167  
articulators and, 61–63, 70–71, 73–75  
cell-lineage selection and, 71–76  
constructional selection and, 121–122  
degrees of freedom and, 101–113  
developmental modularity and, 12–13  
developmental regulatory genes and, 58–59  
epistemology and, 416–417  
evolutionary developmental biology and, 29, 61–65 (*see also* Evolutionary developmental biology)  
evolutionary units and, 143–167  
Human Genome Project and, 69–70  
jumping forms and, 207–218  
linguistics and, 410–411, 416  
modifiers and, 37–39  
modular defection and, 71–76  
morphology and, 13–15 (*see also* Morphology)  
mutation and, 36–43, 119–123 (*see also* Mutation)

- Genetics (cont.)  
 phenotypes and, 14–15, 29–31, 34–35, 41  
 pleiotropic effects and, 34, 36–43  
 replicator, 61–63, 70–71, 73–75  
 screening and, 108–112  
 social insects and, 76–88  
 Wagner-Altenberg model and, 55–56
- Gerdes, P., 269, 278
- Gerhart, J., 7, 36, 66–68, 145, 165, 242
- Germ cells, 71–72
- Germinal cytoplasm, 163
- Gerson, E. M., 64, 78, 89
- Ghiselin, M., 63
- Gibson, T. C., 36
- Gigerenzer, G., 17
- Gilbert, S. F., 209  
 amphibians and, 145, 159  
 evolutionary developmental biology and, 66, 68–69  
 modular ubiquity and, 9–10, 12  
 morphology and, 223–224  
 natural selection and, 34
- Gilbert, W., 70
- Gilligan, S. G., 364
- Gimbutas, M., 276
- Gitlin, D., 154
- Glaessner, M. F., 242
- Gluckman, B. J., 302
- Goal-directed systems, 56–59
- Gobet, Fernand, 20, 306–307, 331–351, 435
- Godfrey-Smith, S. F., 66, 87
- Goldberg, E., 371
- Golden section, 288
- Golgi apparatus, 192
- Golomb, S. W., 267
- Gombrich, E., 262
- Goodale, M. A., 323
- Goodnight, C. J., 64, 74–75
- Goodwin, B. C., 224, 226
- Gordon, Deborah M., 64–65, 79–80, 85, 90
- Gotz, M., 59
- Gould, S. J., 33, 63, 311, 322  
 amphibians and, 143–144  
 morphology and, 230–233  
 remodularization and, 188, 195
- Gradient, 358
- Grafen, A., 87
- Grand design, 353
- Grantham, T. A., 18
- Granularity, 388–393
- Gray, R. D., 13
- Grégoire, A., 420
- Gregory, R. L., 262
- Griesemer, J. R., 12, 64, 70, 75, 89
- Griffin, D., 409
- Griffiths, P. E., 13, 226
- Grobstein, P., 155
- Grotzinger, J. P., 244
- Gruppe  $\mu$ , 286, 291
- Gruss, P., 58
- Guillemot, F., 162
- Haddon, C., 161
- Hadfield, K. A., 148
- Haeckel, Ernst, 29, 89
- Haigh, J., 36
- Haley, M. C., 412
- Halkieria*, 251
- Hall, Brian K., 12, 29, 143, 156–157, 213
- Hallucigenia*, 252
- Hamburger, V., 158–159
- Hamilton, H. L., 72, 77, 83–88, 158
- Hanken, J., 149, 151–157, 162–163, 166, 198
- Hansen, T. F., 8
- Hardcastle, V. G., 21
- Harrison, R. G., 145, 159
- Hartfelder, K., 81
- Hartwell, L. H., 61, 129, 145
- Harvey, P. H., 148
- Hauser, M., 409, 420
- Hay, J. M., 149
- Hayashi, H., 155
- Hayes, T. B., 153
- Heanue, T. A., 145
- Heisenberg Principle, 300
- Heliocentric theory, xv
- Helicocidaris erythrogramma*, 68
- Hempel, C. G., 56
- Heterochrony, 33, 143
- Hetherington, T. E., 155
- Heyer, W. R., 151
- Heyes, C. M., 18
- Hill, M. E., 58
- Hillis, D. M., 149
- Hinchliffe, J. R., 145
- Hirschfeld, L. A., 17
- Hoff, K., 149
- Holistic information, 7
- Holland, J. H., 36, 312
- Hölldobler, B., 78–79, 81, 86
- Holloway, R. L., 372
- Homologues, 7, 12  
 evolutionary developmental biology and, 29  
 interaction and, 68–69  
 structure and, 9–11
- Homunculus, 414
- Hoskins, S. G., 155
- Houle, D., 33

- Hourdy, 155  
House-of-cards model, 115–118  
*H. tuberculata*, 68  
Huffman, D. A., 264  
Hughes, N. C., 154, 157, 232, 251, 328  
Hull, D. L., 3, 61, 63, 70, 186  
Human Genome Project (HGP), 69–70  
Hurley, S. L., 3  
Hurst, L. D., 85  
Hurwicz, L., 383  
Husken, M., 11
- Illocutionary force, 429  
Immune systems, 73  
Impossible figures, 264–265, 267  
Inclusive fitness, 87–88  
Individuality, 63–65, 67, 186  
    articulation and, 73–75  
    cell-lineage selection and, 71–76  
    cognition and, 318–328  
    modular defection and, 71–76  
    partitioning and, 73–75  
    social insects and, 76–88  
Information  
    chess and, 340–348  
    CHREST and, 331–350  
    cognition and, 357–358 (*see also* Cognition)  
    communication and, 419–431  
    encapsulation of, 17  
    eye fixation and, 336, 343–345  
    form-oriented processing and, 358–362  
    knowledge representation and, 20–21  
    latencies and, 343–345  
    modularity of mind and, 17–20  
    multilevel method and, 355–358  
    positivism and, 56  
    processing and, 355–369  
    robots and, 43–45  
    semantic categorization and, 363–369  
    theory of mind and, 19–21  
    transcendental argument and, 52–53, 56–59  
    transmission of, 7–8  
Infraphonology  
    development example for, 429–431  
    modularity and, 427–428  
    signal/value distinction and, 428–429  
    theoretical advances and, 426–427  
    vocal development and, 419–431  
Innovation, 232–233  
Insects, 195–196, 198–199  
    competition and, 83–88  
    integration and, 76–88  
Integration  
    animal skeletons and, 239–256  
    articulation and, 73–75, 78–80  
    cell-lineage defectors and, 71–76  
    description of, 61–65  
    disparity and, 230–231  
    economics and, 383–405  
    hierarchical, 239–256  
    jumping forms and, 207–218  
    kin selection and, 71–73  
    modular defection and, 71–76  
    multicellular organisms and, 66–70  
    partitioning and, 73–75, 78–80  
    processing levels and, 355–369  
    quantification of, 228–230  
    replicators and, 63  
    social insects and, 76–88  
    superorganismic, 76–88  
    theoretical perspective on, 88–91  
    vertical, 365  
Integration view, 30  
Intelligence quotients (IQs), 21  
Interaction, 12, 64–65  
    articulation and, 73–75  
    competition and, 70–71  
    covariation and, 229–230  
    evolutionary units and, 143–167  
    free, 122–123  
    homologues and, 68–69  
    mutation and, 122–123 (*see also* Mutation)  
    partitioning and, 73–75  
    protein function and, 68  
    three approaches to, 67–69  
Interactors, 61–63, 70–71, 73–75  
Ishizuya-Oka, A., 155  
Islets of Langerhans, 66  
Izpisua-Belmonte, 214  
Jablani, Slavik V., 183, 259–281, 435  
Jablonska, E., 7  
Jablonski, D., 234  
Jacob, François, 8  
Jacobs, R. A., 250, 256, 325  
Jacobson, A. G., 130, 163  
Jeffery, W. R., 148  
Jennings, D. H., 154, 156–157  
Johnson, R. L., 145, 159  
Jongh, H. J., 155  
Jordan, M. I., 325  
Juette, Astrid, xvi  
Juvenile hormone, 81–82  
Kaleidoscope embryology, 14  
Kalicz, N., 276  
Kanamadi, R. D., 153, 158  
Kant, Immanuel, xv

- Kapur, S., 371  
 Karmiloff-Smith, A., 19–20, 305, 311–312, 354  
 Kauffman, S. A., 100, 122, 383, 401  
 amphibians and, 158  
 animal skeletons and, 256  
 art/science modularity and, 267  
 evolutionary developmental biology and, 64, 90  
 morphology and, 232  
 Kawecki, T. J., 41  
 Keller, E. F., 70, 162  
 Keller, L., 86  
 Kelsø, S. J. A., 302  
 Kelvin-Helmholtz instability, 294  
 Kemp, A., 159  
 Kepler, Johannes, 4  
 Kerr, B., 87  
 Kim, J., 33, 212, 227, 233–234  
 Kim, M., 33, 212, 227, 233–234  
 Kimmel, C. B., 162–163  
 Kimura, M., 115  
 Kinetic constraint, 100, 113–120  
 King, J. W., 359  
 Kingman, J. F. C., 115  
 Kin selection  
     cell-lineage selection and, 71–76  
     modular defectors and, 72–73  
     social insects and, 76–88  
 Kintner, C., 154, 158  
 Kirk, D. L., 195  
 Kirkpatrick, M., 118  
 Kirschner, M., 7, 36, 66–68, 145, 165, 242  
 Kitcher, P., 12  
 Klee, P., 283  
 Klemm, T., 353, 371  
 Klepper, S., 391  
 KLI, 285, 287, 294  
 Klingenberg, C. P., 207, 228–229  
 Kluge, A. G., 148  
 Klymkowsky, M. W., 154, 156–157  
 Knots, 266–269  
 Knouff, R. A., 160, 163  
 Knowledge. *See* Information  
 Koenig, O., 16–17, 333  
 Koffka, K., 262–263, 415  
 Kollros, J. J., 155  
 Konrad Lorenz Institute for Research on  
     Evolution and Cognition, xvi  
 Kosslyn, S. M., 16–17, 333  
 Krebs, J. R., 87  
 Kruse, P. D., 244  
 Kufic writing, 273–274  
 Kulpa, Z., 264  
 Kutatas, M., 359  
*La constante* (Catalano), 295  
 Lamborghini, J. E., 155  
 Landacre, F. L., 163  
 Lande, R., 157  
 Langeland, J. A., 162  
 Langendoen, D. T., 428  
 Langlois, R., 391  
 Larsen, E. W., 67  
 Larson, A., 146, 148–149, 153  
 Lashley, K. S., 332  
 Latencies, 343–345  
 Lateral line system, 159–162  
 Laubichler, M. D., 8, 29  
 Lauder, G. V., 224  
*L'Aventure des figures impossibles* (Ernst), 264  
 Layzer, D., 239, 252, 254  
*Leanchoilila*, 252  
 Le Corbusier, Charles, 286  
 Leibniz, Wilhelm Gottfried, xv  
 Leigh, E. G., Jr., 186  
 Le Moli, F., 193  
 Lena River region, 244–245  
 Lenneberg, E., 427  
 Leont'ev, A. N., 364  
 Leroi, A. M., 36, 40  
 Leslie, A. M., 19–20  
 Lessios, H. A., 68  
 Levels of processing (LOP)  
     ambient/focal, 360–361  
     conceptual structures and, 358  
     distractor effect and, 358–359  
     form-oriented, 358–362  
     metacognitive coordinations and, 358  
     multilevel, 355–358  
     object actions and, 357  
     paleokinetic regulations and, 357  
     personal sense and, 364  
     phylogenetic growth and, 369–373  
     retrieval volition and, 364  
     semantic categorization and, 363–369  
     spatial field and, 357  
     synergies and, 357  
 Levelt Sengers, J. M. H., 302  
 Levin, S., 100, 328  
 Levins, R., 64  
 Levinson, P., 6  
 Levy-Schoen, A., 359  
 Lewis, M. M., 420  
 Lewontin, Richard, 51–52, 225, 322  
 amphibians and, 144  
 evolutionary developmental biology and, 64, 70, 78  
 modular ubiquity and, 7, 14, 30

- Liem, K. F., 36, 40  
Limb development, 157–159  
*Linepithema humile*, 198–199  
Linguistics, xv, 10, 16–17, 314–318, 356  
chain production and, 425  
CHREST and, 337  
comfort sounds and, 420  
genetics and, 410–411, 416  
logical distinctions and, 409–411  
phonation and, 419–424  
poverty of stimulus and, 413  
quasivowels and, 419–424  
semantic categorization and, 363–369  
syllabicity and, 423  
universal grammar and, 411–415  
vocal development and, 419–431  
Links, 337  
Linksvayer, Timothy, 86  
Linström, B., 264  
Livingston, C., 267  
Lloyd, E. A., 21, 61, 63, 70, 75, 86  
Lobopods, 251  
Localization, 10  
Locke, John, 331  
Lockhart, R., 356, 363–364  
Locomotion, 211–212  
Lofsvold, D., 118  
Logsdon, J. M., 122  
Long-term memory (LTM), 335–336, 343  
Looren de Jong, H., 21  
Lumsden, A., 155  
Lunda designs, 278  
Lunsford, R. F., 412  
Luria, Alexander, 356, 371  
Lutz, B., 149, 151, 154  
Lynch, M., 124  
Lynn, W. G., 149, 151–154, 156–157, 160  
  
Mabee, P. M., 148  
McCaskill, J. S., 130  
McClelland, J. L., 309, 323  
McGhee, G. R., 214  
McGinnis, W., 145  
McKay, S. R., 100  
McKinney, M. L., 143, 195  
McLaughlin, H. M. G., 67  
MacLean, Paul, 356  
McNamara, K., 143  
Macroevolution  
complexity and, 231–232  
evolvability and, 232–233  
innovation and, 232–233  
stochastic morphology and, 233–234  
trends in, 234–235  
  
McShea, Daniel W., 83, 181–182, 252, 435  
morphology and, 223–224, 227–228, 231  
remodularization and, 185–205  
Maculae, 195  
MacWhinney, B., 415  
Maddison, W. P., 148  
Magic module, 16  
Makovicky, E., 259  
Mamedov, K. H., 273  
Mantegna, R. N., 302  
Marcus, G. F., 328  
*Marella*, 252  
Marengo, Luigi, xii, 307, 383–408, 435  
Markets. *See* Economics  
Marks, S. B., 158  
Marr, David, 354  
Massive modularity hypothesis (MMH), 17–18, 20–21  
Mathematics, xv, 72  
art and, 259–279, 288  
golden section and, 288  
knots and, 266–269  
*N*-dimensional problem, 383–384  
Matsuda, R., 156  
Mavilya, M., 427  
May, C. L., 190, 284  
Maynard-Smith, J., 36, 123, 186  
amphibians and, 144, 165  
evolutionary developmental biology and, 72–74, 86  
Mayr, Ernst, 51, 57–59  
Mecham, J. S., 149, 158  
Mechanisms, 10, 20–21  
art and, 291 (*see also* Art)  
congruence principles and, 46  
coordination, 396  
degrees of freedom and, 102–113  
direct selection and, 36–43  
division of labor and, 388–392  
dynamical side effects and, 43–45  
epigenetic specification and, 221–222  
evolutionary developmental biology and, 29–32  
integration and, 228–239 (*see also* Integration)  
interactors and, 63  
Kelvin-Helmholtz instability and, 294  
module origins and, 35–45  
morphology and, 221–235 (*see also* Morphology)  
mutational kinetics and, 113–120  
mutualism and, 86  
parental manipulation and, 86  
plurality and, 46–47  
replicators and, 63

- Mechanisms (cont.)  
 robustness and, 33  
 speciation, 46–47
- Meier, S., 163
- Memory  
 CHREST and, 335–336, 338, 340, 343, 348–349  
 long-term, 335–336, 343  
 phylogenetic growth and, 369–373  
 processing levels and, 355–369  
 short-term, 335–336, 338, 340, 348–349
- Mendel, 85, 221
- Mental chemistry, 331
- Metacognitive coordinations, 358, 373
- Mezey, Jason, 29–30, 435  
 evolutionary developmental biology and, 69  
 modular ubiquity and, 33–49  
 morphology and, 223, 228–229, 234
- Miall, D. S., 364
- Michelson, A., 214
- Michener, C. D., 86
- Michod, R. E., 73, 75–76, 85, 186, 328
- Microstates, 239
- Miller, R. L., 225, 230
- Millikan, Ruth G., 19, 108
- Milner, A. D., 323
- Milo, R., 212
- Mind, 305–308. *See also* Cognition; Neurology  
 communication and, 411–431  
 connectionism and, 309–314, 318–328  
 linguistics and, 314–318  
 neural networks and, 314–318
- Minelli, A., 13
- Minimalism, 418–419
- Minsky, M., 333
- Minsuk, S. B., 162
- Mirsky, M., 376
- Mishkin, M., 323, 371
- Mishler, B. D., 186
- Misof, B. Y., 222
- Mitman, G., 78
- Mitochondria, 72, 82, 193
- Mitteldorf, Joshua, 46
- Mittenthal, J. E., 34, 190
- Miyake, T., 163
- Modern Synthesis, 12, 17, 392
- Modern Times* (Chaplin), 285
- Modifiers, 37–39
- Modular cooperation, 63
- Modular defection, 63–64, 71–76
- Modularity, xv–xvi  
 as adaptive constraint escape, 40  
 animal skeletons and, 239–256  
 art and, 259–303 (*see also* Art)  
 bottom-up research and, 11–12
- as causal actor, 225–226
- CHREST and, 331–350
- cognition and, 17–20, 353–381 (*see also* Cognition)  
 concept basis for, 33–34  
 congruence principles and, 46  
 connectionism and, 309–314  
 constructional selection and, 40–41  
 defining, 29, 208–209  
 developmental, 12–13, 34, 66, 68, 221, 291–294  
 dimensions of, 8–12  
 direct selection and, 36–43, 124  
 as dynamical side effect, 43–45  
 eclectic, 285–287  
 evolutionary developmental biology and, 29–32, 61–65 (*see also* Evolutionary developmental biology)  
 evolvability and, 33, 36–39, 45–46  
 for free, 122–123  
 from frustration, 42–43  
 functional, 9–11, 34, 335 (*see also* Functions)  
 horizontal, 355–358  
 inclusive, 123–124  
 infraphonology and, 427–428  
 integration and, 61–70  
 interactor, 61–63, 70–71, 73–75  
 jumping forms and, 207–218  
 kinds of, 8–12, 33–35, 66–67  
 macroevolution and, 231–235  
 massive modularity hypothesis (MMH) and, 11, 17–18, 20–21  
 maturation and, 319–323  
 of mind, 15–21, 305–314  
 modern science and, 3–6  
 morphological, 13–14 (*see also* Morphology)  
 multilevel method and, 355–358  
 nearly decomposable (ND) systems and, 5–6, 22n6, 225  
 necessity of, 7–8  
 organizational modules and, 224  
 origin mechanisms and, 35–45  
 physiological, 42, 66, 68  
 plasticity and, 14, 42, 57, 130–139  
 pleiotropic effects, 34, 36–43, 67, 136–139, 149–167, 223  
 plurality and, 46–47  
 presupposition and, 409–432  
 process and, 9–11  
 replicator, 61–63, 70–71, 73–75  
 RNA-structure origins and, 129–139  
 robots and, 43–45  
 self-organized hierarchical systems and, 296–302  
 simplicity and, 4–6  
 social insects and, 76–88

- solar system and, 4–6  
structural, 9–11, 66  
top-down research and, 11–12  
transformations and, 291–294  
ubiquity of, 3–4, 6–8  
varieties of, 9  
vertical, 355–358  
Wagner-Altenberg model and, 55–56  
weak, 16–17, 333  
*Modularity of Mind, The* (Fodor), 305, 315  
“Modularity: Understanding the Development and Evolution of Complex Natural Systems,” xvi  
Modular voice, 365  
Moebius strip, 263  
Moholy-Nagy, Laszlo, 286  
Molecular developmental systems, 12  
Molting, 246, 248  
Mondrian tree, 283–284  
Montague, Richard, 410  
Mooers, A. O., 197–198  
Mori, A., 193  
Morphology, xv, 12–14  
amphibians and, 151–167  
causal actors and, 225–226  
comparative, 214  
constraints and, 69  
context and, 232–233  
direct selection and, 36–43  
economics and, 405–406  
epigenetic specification and, 221–222  
evolutionary developmental biology and, 61–65  
(*see also* Evolutionary developmental biology)  
interaction and, 67–69  
intermediate-level parts and, 194–196  
jumping forms and, 207–218  
macroevolution and, 231–235  
modifiers and, 37–39  
module identification and, 223–226  
module space and, 214–216  
morphospace logic and, 212–214  
natural selection and, 33–49  
organ gain/loss and, 187–202  
organizational modules and, 221, 224  
overlap and, 224  
quantification of, 226–231  
skeletons and, 211–212, 239–256  
stochastic, 233–234  
systemization of, 221–235  
thyroid hormone and, 152–153, 156–157  
variational modules and, 225  
Morriss-Kay, G., 163, 363  
Moser, H., 156  
Moss, Lenny, 8–15, 30, 88, 302  
Motor composition, 377  
Mountcastle, 315  
Moury, J. D., 163  
Müller, Gerd B., xvi, 9, 12–14, 146  
Multicellularity. *See also* Evolutionary developmental biology  
gain of organisms and, 193–202  
jumping forms and, 207–218  
loss of organisms and, 187–193, 199–202  
Multilevel selection, 86–88  
Multiplicity, 99–101  
Munro, E. M., 11–12, 33, 66, 145, 207  
Murre, J. M. J., 319  
Mutation, 35. *See also* Morphology  
amphibians and, 149–167  
B-matrix model and, 113–114  
constraints and, 99–101  
constructional selection and, 121–122  
degrees of freedom and, 102–113  
direct selection and, 36–43  
disparity and, 231  
finite models for, 114–118  
fitness sensitivity and, 41  
germ cells and, 71–72  
infinitesimal models for, 114–118  
kinetics of, 31, 113–120  
modular defectors and, 71–76  
multiplicity and, 99–101  
phenotypic stability and, 41  
plasticity and, 14, 42, 57, 130–139  
recombination and, 36–37  
selection gradient alignment and, 119–120  
subfunctionalization and, 124–125  
Mutualism, 86  
Myron, 288  
Nagel, E., 51, 56–59  
Nagy, D., 33, 35, 275  
*Namacalathus*, 244  
*Namapoikia*, 244  
National Center for Biotechnology Information, 305  
Nativism, 18  
Natural complex systems. *See* Complexity  
Natural logic, 409–410  
communication systems and, 411–415  
general theory for, 432  
infant communication and, 419–424  
infrastructural roots of, 415–424  
nature/nurture dichotomy and, 411, 418–419  
universal grammar and, 411–415  
vocal development and, 419–431  
Naumann, E., 369  
*N*-dimensional problems, 383–384

- Nearly decomposable (ND) systems, x–xiii, xvi, 5–6, 22n6, 225  
 Needham, J., 6, 143, 213  
 Neighbor, 396–397  
 Neo-Darwinian views, 9, 385  
 Nestedness, 190–192  
 Neuroscience, 12–13, 16–17, 375–377  
   boxes-and-arrows diagrams and, 309–310, 316–317, 322  
   Brodmann's areas, 371  
   CHREST and, 331–350  
   cognition and, 363–369 (*see also* Cognition)  
   communication and, 419–431  
   connectionism and, 310–314, 318–328  
   cortical structures and, 315–316  
   direct selection and, 36–43  
   imaging techniques and, 369–371  
   levels of processing and, 355–369  
   maturation and, 319–323  
   modular defection and, 71–76  
   neural networks and, 310–328  
   phylogenetic growth and, 369–373  
   semantic categorization and, 363–369  
   simulation studies and, 318–328  
   theory of mind, 19–21, 373  
 Newell, A., 309, 333, 355  
 Newman, S., 9, 12, 209  
 Newmeyer, F. J., 412–413  
 Newton, Isaac, 4, 23n9, 300  
*New Webster's Dictionary and Thesaurus of the English Language*, xv  
 Ng, J. K., 145, 159  
 Nichols, S., 18  
 Nicoll, C. S., 153  
 Niehrs, C., 148  
 Nielsen, M. G., 68  
 Nieuwkoop, P. D., 163  
 Nishikawa, A., 155  
 NK model, 383, 401  
 Noble, G. K., 149, 153, 158  
 Nodes, 336–337  
 Nolfi, S., 44  
 Noll, F. B., 145, 193  
 Northcutt, R. G., 148, 160, 163  
*Notonecta*, 196  
 Nunney, L., 76  
 Nussinov, R., 130  
 Object actions, 357  
 Obler, L. K., 334  
 Oculomotor reflex, 359  
 Odors, 354–355  
 Ohno, S., 124, 328  
 Oller, D. Kombrough, 308, 409–435  
 Olson, E. C., 12, 163, 225, 230  
 Omerza, F. F., 155  
*On Growth and Form* (Thompson), 294  
*On the Construction of Movements* (Bernstein), 374–377  
*Opabinia*, 251  
 Ordovician era, 251  
 Organelles, 187  
 Organisms. *See also* Modularity  
   animal skeletons and, 239–256  
   cellular-level tests and, 192–193  
   complexity and, 231–232  
   evolutionary developmental biology and, 61–65  
     (*see also* Evolutionary developmental biology)  
   gain of higher-level, 193–202  
   intermediate-level parts and, 194–196  
   jumping forms and, 207–218  
   loss of lower-level, 185, 187–193, 199–202  
   morphology and, 221–235 (*see also*  
     Morphology)  
   multicellularity and, 185–186  
   nature/nurture dichotomy and, 411  
   nestedness and, 190–192  
   part definition and, 189–190  
   remodularization of, 185–202  
   selection levels and, 190–192  
   structural hierarchy and, 190–192  
 Organizational modules, 223–224  
 Organizers, 146  
 Orton, G. L., 149, 153, 158  
 Orwell, George, 353  
 Oster, G. F., 78–79, 90, 193, 197  
 Otte, D., 46  
 Overlap, 224, 273  
 Oyama, S., 12, 15, 70, 75  
 Pagel, M. D., 148  
 Paleokinetic regulations, 357  
 Paleontology, xv, 221  
 Paleozoic era, 228  
 Pamilo, P., 84  
 Panksepp, J., 18, 21, 353, 355  
 Panksepp, J. B., 18, 21, 353, 355  
 Pannasch, S., 358  
 Parental manipulation, 86  
 Parichy, D. M., 161  
 Parisi, Domenico, 306, 309–330, 435  
 Park, Thomas, 77  
 Parman, A., 273  
 Partee, B. H., 410  
 Partitioning, 62, 64–65, 89–91  
   decomposability and, 394–406  
   Human Genome Project and, 69–70  
   interactors and, 73–75

- kin selection and, 86–88  
replicators and, 73–75  
RNA structure and, 130–135  
social insects and, 76–88  
Pasquali, Corrado, 307, 383–408, 435  
Pastels, J. M., 162  
Patil, N. S., 153, 158  
Patterns, 181  
Pauli's Principle of Exclusion, 300  
PCS relations, 344–345  
Peadon, M., 156–157  
Pelvis, 211–212  
Penrose, L. S., 262  
Penrose, Roger, 262, 291  
Perlstein, W. M., 359  
Persistence, 57  
Personal sense, 364  
Peterson, I., 263  
Pettersson, M., 190  
*Pheidole pallidula*, 195  
Phenotypes, 14–15, 34–35, 88–91, 385  
B-matrix model and, 113–114  
direct selection and, 41  
evolutionary developmental biology and, 29–31  
fitness map and, 114  
genotype map and, 114, 122–124, 227, 305  
modular defectors and, 71–76  
morphology and, 223 (*see also* Morphology)  
mutational kinetics and, 113–120 (*see also* Mutation)  
plasticity and, 42  
RNA and, 41–42  
stability and, 41–42  
Philosophy, xv, 17–19, 383  
natural logic and, 409–432 (*see also* Natural logic)  
transcendental argument and, 52–53, 56–59  
Phonation, 419–424  
Phrenology, xv, 10, 334  
Physics, xv, 4–6  
Physiology, 66  
Piaget, Jean, 19, 416  
*Pikaia*, 245  
Pinker, Steven, 17, 311, 314, 317  
Piranesi, 262  
Pittendridge, 57  
Plasticity, 14, 42, 57  
congruence and, 133–135  
RNA structure and, 130–139  
Simpson-Baldwin Effect and, 132  
Plato, 217, 383  
Platt, J. B., 163  
Pleiotropic effects, 34, 67, 223  
amphibians and, 149–167  
direct selection and, 36–43  
plasticity and, 136–139  
Plurality, 46–47  
*Pogonomyrmex barbatus*, 79  
Pollet, N., 148  
Polycliteitos, 288  
Polyploidy, 107  
Pomplun, M., 361  
Popper, A. N., 11  
Portoghesi, Paolo, 286  
Positivism, 56  
Positron emission tomography (PET) scans, 369, 371  
Poverty of stimulus, 413  
Pragmatism, 19, 332  
Predictive project, 18–19  
Price, G. R., 83–88  
Prince, A., 314  
Principal component analysis (PCA), 102  
Prior, Robert, xvi  
Process, 9–11  
Processing. *See* Levels of processing (LOP)  
Proprioceptive reflex, 376  
Proteins, 208  
Proterozoic era, 244  
Psychology, xv, 10, 354–355  
CHREST and, 331–350  
cognition and, 17–20 (*see also* Cognition)  
connectionism and, 310–314, 318–328  
distractor effect and, 358–359  
evolutionary, 17–20  
knowledge representation and, 20–21  
levels of processing and, 355–369  
massive modularity hypothesis (MMH) and, 17–18, 20–21  
phylogenetic growth and, 369–373  
processing levels and, 355–369  
theory of mind and, 19–21, 373  
Purcell, S. E., 162  
Quantification, 226  
disparity and, 230–231  
integration and, 228–230  
number of characters and, 227–228  
Quasi independence, 14, 30, 51–52  
Quasivowels, 422–423  
Queller, D. C., 73, 84, 86–87, 198–199  
Quine, W. V., 222, 226  
QWERTY keyboards, 3, 384–385  
Raff, Rudolph A., 191, 207  
amphibians and, 143, 148, 165–166  
evolutionary developmental biology and, 61, 66–69, 83

- Raff, Rudolph A. (cont.)  
 modular ubiquity and, 6–7, 9, 12, 14  
 morphology and, 221, 223–224, 228  
 natural selection and, 33–35
- Ragsdale, J., 86
- Random-walk model, 115–118
- Rasmussen, Jens, 356
- Rasskin-Gutman, Diego, 8, 182, 207–219, 229, 435
- Raup, D. M., 214, 233
- Rauschenbach, B. V., 264
- Raynaud, A., 158
- Recall task, 341
- Reductionism, 70
- Reeve, H. K., 86–87
- Reidemeister, K., 267
- Reif, W.-E., 240, 242, 250, 252
- Reingold, E., 359, 361
- Reitner, J., 252
- Relaix, F., 145
- Relevance effect, 359
- Remodeling, 247, 249
- Remodularization, 182, 199–202
- Replicators, 61–63, 70–71, 73–75
- Representations, 20–21
- Reproducer systems, 75
- Republic* (Plato), 383
- Research strategies, 11–12, 64–65
- Rethinking Innateness: A Connectionist Perspective on Development* (Elman), 417
- Retrieval volition, 364
- Reusability, 13
- Rhythmicities, 421
- Ribonucleic acid (RNA)  
 folding and, 31, 129–130, 136–139  
 modularity origins and, 129–139  
 partitioning and, 130–135  
 phenotypic stability and, 41–42  
 plasticity and, 130–139
- Rice, Sean, 33, 39, 42–43
- Richardson, R. C., 10–11, 154, 157–158
- Richman, H. B., 335
- Ridley, M., 9
- Riedl, R., 13, 213, 223
- evolutionary developmental biology and, 100, 105–106, 118, 121
- modular ubiquity and, 13
- natural selection and 35–36
- remodularization and, 191
- Rieppel, O. C., 213, 221
- Rigby, J. K., 244
- Riley, B. B., 161
- Robbins, Lionel, 386
- Robert, J. S., 12
- Robertson, D. R., 391
- Robinson, G. E., 81–82
- Robinson, J., 267
- Robots, 43–45
- Roediger, H. L., III, 356, 363, 368
- Rohani, P., 302
- Rohwer, J. M., 34
- Rolfsen, D., 267
- Roman mazes, 271–273
- Rose, M. R., 21, 152–153, 155–157
- Rosenkilde, P., 152
- Roth, V. L., 69, 143, 148, 153–158, 160–161
- Roweis, S. T., 102, 104
- Roy, K., 230
- Roze, D., 73
- Rozin, P., 17, 19
- Rueckl, J. G., 323, 325, 361
- Rumelhart, D., 309, 323
- Runnegar, B., 250
- Saariluoma, P., 335
- Sadaghiani, B., 163
- Safi, R., 152
- Salamanders. *See* Amphibians
- Salthe, S. N., 149, 151, 158, 186, 191
- Samuels, R., 18, 20–21
- Sanquist, T. F., 369
- Sarkar, Sahotra, 90
- Saul, L. K., 102, 104
- Schacter, D. L., 365
- Schank, J. C., 15, 239
- Scharloo, W., 41
- Schattschneider, D., 278
- Schilling, T. F., 163
- Schlemer, Oskar, 286
- Schlenoff, D. H., 358
- Schlosser, Gerhard, 31–33, 143–179, 435
- Schmidt, 152–153, 156–157
- Schmitz, A., 163
- Schneirla, T. C., 81
- Scholl, B. J., 18–20
- Schroeder, T. E., 163
- Schumpeter, Joseph, 392
- Schwartzman, R. A., 155
- Schwenk, K., 34, 144, 146, 148, 164, 223–224
- Science  
 art and, 283–303  
 CHREST and, 331–350  
 hierachical levels in, 332  
 misunderstanding and, 373  
 simplicity and, 4–6  
 solar system and, 4–6

- Science* magazine, 70  
Scientific Revolution, xv, 4  
Screening, 108–112  
Sea urchins, 228  
Second Welfare Theorem, 388  
Seeley, T. D., 187  
Segal, G., 17  
Sejnowski, T. J., 16, 331–333  
Self-organization, 16–17, 296–302  
Semantic categorization, 363–369  
Sengers, J. V., 302  
Sepkoski, J. J., 254  
Shaffer, H. B., 151–152  
Shammi, P., 373  
Shannon's formula, 239  
Shapere, D., 6  
Shapiro, I., 21  
Shi, Y. B., 153, 155–156  
Shifting Balance Theory, 77  
Short-term memory (STM), 335–336, 338, 340, 348–349  
Shubin, N., 143–146, 159, 230  
Signal systems, 428–429  
Simms, M. J., 251  
Simon, Herbert A., ix–xiii, xvi, 309, 383, 435  
animal skeletons and, 242, 254  
art/science modularity and, 283, 296  
chunking and, 332, 335–336, 338, 340–343, 345, 347, 349  
cognition and, 354–355  
jumping forms and, 216  
modular ubiquity and, 3–6, 22n1  
morphology and, 221  
remodularization and, 189  
Simons, R. F., 359  
Simplicity, 4–6  
Simpson, G. C., 132, 213  
Skeletons  
accretion and, 246, 248  
*Anomalocaris* and, 251–252  
Cambrian explosion of, 239  
characterization of, 240–242  
*Cloudina* and, 244  
complexity increase and, 252–254  
*Dickinsonia* and, 242  
*Eusthenopteron* and, 252  
*Halkieria* and, 251  
*Hallucigenia* and, 252  
Layzer model and, 239–240, 252, 254  
*Leanchoilia* and, 252  
*Marella* and, 252  
modularity role in, 250–252  
molting and, 246, 248  
morphospace exploitation and, 242–250  
*Namacalathus* and, 244  
*Namapoikia* and, 244  
*Opabinia* and, 251  
remodeling and, 247, 249  
space and, 13–14  
unit constructions and, 247, 249  
Slack, J. M. W., 145, 209  
Sly, B. J., 68, 221, 223  
Smith, Adam, 197, 386, 405  
Smith, K. K., 148  
Smith, Neil, 412, 418  
Smith, S. C., 161  
Snails, 196, 242  
Sneath, P., 214  
Soar, 333  
Sober, E., 73, 86, 187, 226  
Society of mind, 333  
Sokal, R., 214  
Sokolov, E. N., 359  
Solar system, 4–6  
Soviet Revolution, 285  
Spatial field, 357  
Spelke, E. S., 311  
Sperber, D., 12, 17–18  
Sponges, 244–245  
Stadler, P. F., 107, 363, 385  
Stampe, D., 359, 361  
Stanley, H. E., 302  
Star, L. S., 10  
Stearns, S. C., 41  
Stephenson, W. G., 153, 160  
Sterelny, K., 13, 21, 201  
Sterr, A., 355  
Stewart, G. W., 154, 156–157  
Stiegler, P., 130  
Stock, D. W., 33, 35  
Stone, J. W., 160–161, 163, 214  
Stotz, K., 6  
Strassman, J. E., 84  
Strauss, R. E., 148  
Strogatz, S. H., 212  
Structural hierarchy, 9–11, 190–192  
Stuss, D. T., 373  
Su, Y., 153, 155  
Subfunctionalization, 124–125  
Subspace constraint, 100  
Sudd, J. H., 195  
Summers, C. H., 152, 156  
Sutasurya, L. A., 163  
Sutton, D., 420  
Swalla, B. J., 148  
Swedmark, B., 198

- Syllabicity, 423  
 Symbolic inheritance system (SIS), 7  
 Symmetry, 267, 358  
   breaking, 279  
   tilings and, 269–274 (*see also* Art)  
 Synergies, 357  
 Systematic asymmetries, 358  
 Szathmary, E., 73–74, 186
- Tabachnek-Schijf, H. J. M., 339–340  
 Tabin, C. J., 145, 159  
 Tamil designs, 267  
 Tan, S. S., 163  
 Tata, J. R., 152–153  
 Taxonomy, 107, 149, 221  
 Taylor, P. D., 195  
 Tchikalenko, L., 275–276  
 Tchokwe sand drawings, 267  
 Teeth, 242  
 “Teleology Revisited” (Nagel), 57  
 Teleconomy, 57  
 Tell Halaf, 275  
 Tenenbaum, J. B., 102–103  
 Termites, 77  
 Teuber, M. L., 262  
 Thelen, E., 421  
 Theory of mind, 19–21, 373  
 Thiébaud, C. H., 163  
 Thieffry, D., 145  
 Thomas, Roger D. K., 13, 182–183, 214, 239–258,  
   435  
 Thompson, D’Arcy, 214, 239, 294  
 Thyroid hormone, 152–153, 156–157  
 Tickle, C., 158  
 Tiling, 263–264, 269–274, 291, 295–296  
*Tilings and Patterns* (Grunbaum & Shephard),  
   269  
 Titus, T. A., 149, 153  
 Todd, P. M., 17  
 Tommotian era, 245  
 Tooby, J., 310, 355  
 Townsend, D. S., 154, 156–157  
 Transaction costs, 392–393  
 Transcendental argument, 52–53, 56–59  
 Transcription factors, 66  
 Trbuhovich, V., 276  
 Trevarthan, C., 360  
 Trilobites, 251  
 Trivers, R. L., 86  
 Trophallaxis, 77  
 Truchet tile, 273  
 Trueb, L., 149, 151–153, 158  
 Tulving, E., 365, 368, 372  
 Turner, J. S., 17, 196, 267
- Turney, P. D., 39–40  
 “Two Watchmakers, The” (Simon), x–xi
- Ukraine, 269, 275  
 Unema, P., 358  
 Ungerleider, L. G., 323  
 Unitary function, 54–55  
 Unit constructions, 247, 249  
 Universal grammar, 411–415  
 University of Chicago, 77–78  
 Urodeles, 151–153  
 U.S. National Institutes of Health, 305  
 Ussing, A. P., 152  
 Uyenoyama, M., 72–73, 86
- Valente, Marco, xii, 307, 383–408, 435  
 Valentine, J. W., 190–191, 202, 232, 251, 284  
 van de Griend, P., 267  
 Van der Steen, W. J., 21  
 van Nimwegen, E. J., 100  
 van Oostrom, C. G., 163  
 van Valen, L. M., 80  
 Variational modules, 223, 225–227  
 Vasiljevich, V., 276  
 Velichkovsky, Boris M., 307, 333, 353–381, 435  
 Venit, E. P., 190, 192–193, 223–224, 227–228  
 Verbeek, J. J., 104  
 Vermeij, G. J., 36  
 Verwoerd, C. D. A., 163  
 Vincent, A., 369  
 Vocal development  
   infants and, 419–431  
   stages of, 424–431  
 Vogel, K., 239  
 Vogt, W., 162  
*Volvox*, 195–196  
 von Baer’s laws, 234  
 Von Dassow, G., 11–12, 33, 66, 90, 145, 207, 210  
 Voss, S. R., 151–152  
 Vrba, E. S., 63, 311
- Waddington, C. H., 102  
 Wade, Michael, 64, 70, 73–75, 77, 85, 87  
 Wagner, Gunter P., 99, 111, 406, 435  
   amphibians and, 144–146, 148, 164–165  
   B-matrix model and, 113–114  
   evolutionary developmental biology and, 29–30,  
   33–49, 51–52, 61, 66–69, 83  
   jumping forms and, 216  
   lock-in and, 129, 136  
   modular ubiquity and, 6–9, 13–14, 21  
   morphology and, 221–224, 226, 228, 230, 232–  
   234  
   natural selection and, 33–49

- remodularization and, 190  
Wagner-Altenberg model and, 55–56, 58–59  
Wahnshafffe, U., 155, 161  
Wakahara, M., 149, 152–153, 163  
Wake, D. B.  
amphibians and, 144, 146, 148, 151, 153, 155, 160–161  
remodularization and, 198  
Wake, M. H., 149, 153  
Walker, R., 359  
Walther, C., 58  
Warren, E., 158  
Waschmann, Konrad, 286  
Washburn, D. K., 259, 278  
Wasserman, S., 75  
Wassersug, R. J., 149, 151  
Waterman, M. S., 130  
Watson, J. D., 69  
Watters, W. A., 244  
Weber, H., 361  
Websites, xvi, 285, 287, 291, 294  
Webster, G., 224, 226  
Weinberger, E. D., 100  
Weintraub, H., 162  
Weismann, A., 89  
Weiss, K. M., 35, 207  
Wen, X., 148  
Wenzel, J., 83  
Wernicke, Carl, 16  
Werren, J. H., 71, 85  
West-Eberhard, M. J., 12, 80  
Westheide, W., 198  
Westhof, E., 129  
Westoll, T. S., 254  
Wheeler, D. E., 15, 81–82  
Wheeler M. A., 357, 373  
Wheeler, William M., 77, 187  
White, B. A., 153  
Whittington, H. B., 251  
Wiesenfeld, K., 302  
Wilbur, H. M., 149, 151  
Wiley, E. O., 148  
Wilkins, A. S., 207  
Williams, George C., 17, 33, 35, 74, 77  
Williamson, O., 390  
Wills, M. A., 230  
Wilson, D. S., 73, 186–187  
Wilson, D. W., 86  
Wilson, Edward O., 64, 78–79, 86, 90, 193, 196–197  
Wimsatt, W. C., 15, 64, 74, 89, 186, 190–191, 215, 239  
Winther, Rasmus G., 30, 61–97, 435  
Within-glance placements (WGP), 343  
Woese, C. R., 254  
Wolf, J. B., 75  
Wolpert, D., 66  
Wood, R. A., 244  
Wray, C. G., 34, 143, 146, 148  
Wright, Frank Lloyd, 286  
Wright, Sewall, 77, 99, 214  
Wuchty, S., 130  
Wynn, K., 311  
Xu, H., 104  
Yamaguchi, M., 152–153  
Yang, A. S., 232  
Yao, X., 319  
Yaoita, Y., 152  
Yoshizato, K., 155  
Zambia, 267  
Zelditch, M. L., 230  
Zetterström, R., 264  
Zhang, G., 336  
Zieschang, R., 267  
Zigler, Kirk, 68  
Zooids, 195  
Zuker, M., 130