Activity, 33-34, 130-132, 155, 264	conflict with internalist/structuralism,
cultural, 247, 273, 300	113
gene, 96–98, 102, 109, 110, 124, 135,	rejection by organic systems approach,
151, 265, 306n29, 309n41	25
and germlinedness, 306n28	widespread rejection, 27, 62, 62n2
group, 228	Autocatalytic network, 121–122, 269
modified by environment, 266	
variable of, 135–142	Bauplan, vii, 30, 48
Adaptation	Bickhard, Mark, 229, 230
constraints on, 158	Black-boxing
coupling with environmental factors,	cultural scaffolding, 245, 288, 294, 296,
133	299, 313n62
and entrenchment, 279, 288	development, 27, 227, 244, 266,
externalist view, 113	304n14
and homology, 206–208	inheritance, 58
lock-and-key model, 195	Boundary
and modularity, 202-205, 217	of culture, 239
according to population genetics, 16	of generations, 149, 159n4
rate, 153, 174	of modules, 175
reinterpretation by organic systems	of units of selection, 147
approach, 36, 42, 46, 50	Boundary condition, 42, 51, 115–116.
from the reproducer perspective, 267	See also Constraints
testing, 214	as constraints, 125-128, 156
Adaptationism, viii	Boyd, R., 252 253, 528n6, 312n59
Amundson, Ron, 4, 28, 58, 158, 210,	Brylski, P., viii
212	Buss, Leo, 55
Antiadaptationism, 209. See also Gould;	
Lewontin	Canalization, vii, 30, 102, 290
cultural support, 66n22	in cultural evolution, 254, 287, 288
within evo-devo, 191	significance for the organic systems
explanatory, 206–208	approach, 36, 46, 57

Capacity variable, 135-143, 151, 152, functional, 113-160 153 generative, 117-125, 135 Caporeal, Linnda R., 37, 244, 305n22 internal, 113, 125, 127 Cause probability, 143-145 proximate, 4, 9, 11, 17, 26, 41, 195, stability, 117–123 202, 215 Context-dependence, 94, 230, 245 ultimate, 4, 17, 26, 195 Context insensitivity, 152, 145, 160. See Central dogma, 4, 30, 38. See also Gene also Robustness Contingency, 57, 67n29, 68n30, 119, centricism: Gene selectionism Change. See also Stasis; Generative 158, 288 entrenchment; Variation continuous, Coupling, 115, 128-134, 137, 140-144, 54 149, 151, 158n9, 242 resistance to, 284, 285, 288, 312n59 Cultural transmission, 229, 236-238, revolutionary, 260, 282-284, 295 245, 247, 253-254, 258, 261-266, 270, 274-275 Chromosome, 15, 219n13, 245, 269-274 ideational, 234, 246, 261-263, 293, 296 Cis-regulatory region, 101, 132, 135, 153 symbolic, 236, 293, 300 Coevolution, 133, 135 Cultural virus. See Meme probability, 143-145, 153-157 Culture Cognitive development, 36, 227, 231, animal, 237, 266, 276 235, 258, 260 cultural modularity, 229, 242, 271, Comparative biology, 32, 35, 61, 204, 286, 287, 288, 290, 311n52 212, 216, 218n7, 219n14 cumulative nature of, 230-234, 250, Comparative method 260, 263, 282, 298 to support adaptation or genealogical of Darwinism, 29, 66n22 hypotheses, 207-209 of evo-devo, 18 Haeckel's, 7-8 sequestration and bundling, 261, 262, 264-266, 269, 270 as an investigation of constraints, 115, 154-156 thick versus thin and medium as a test for a unit of evolution, 155viscosity, description of, 227, 236-156 238, 242, 250, 276, 287, 302n6, Complexity 302n8, 303n9 of culture, 257, 259, 293, 297-298 emergence, 9, 154, 252 Darwin, Charles, 5-8, 10, 13-14, 32, 58, and self-organization, 35 206, 211-212 Constraints, 36, 45, 108, 191, 204, 235, Dawkins, Richard, vii, xi, 29-30, 34, 41, 253, 260, 294, 298. See also 43, 173, 206, 207, 212 Generative entrenchment on cultural evolution, 252, 262–269, developmental, viii, x, 3, 31, 52, 53, 275, 279 108, 113-160, 191 Deep change, 290, 295. See also Hopeful external, 124-126 monsters

Development	evolving, 180
of competencies, 229–235, 261, 288,	as external constituents, 122, 124–125
299	and gene selectionism, 266
conceptual separation from evolution,	imposing functional constraints, 124–
vii, 10, 11, 21, 26	125, 133–134
disciplinary, 232-235, 283, 285, 287	and novelties, 51
versus evolution (ambiguity in culture),	partial predictability of, 259–260
252, 277	persistence of, 266-267, 269
institutional, 230-232, 246, 264, 277,	problems determined by organisms,
281, 294	203–205 (See also Scaffolding)
professional, 230–235, 282	robustness to, 93, 269, 270
Developmental systems theory	and selection, 43, 48, 113, 114
(perspective), ix, 28, 37, 237, 260,	stability, 259–260
280, 289	uncertainty of, 260
Difference-makers, 263–266	Epigenesis, 9, 39, 41
Dissociated coevolution, 154–157	Epigenetics, 12, 33, 40
Double dissociation test, 197–202	Epistasis, 36, 138–147, 151, 156
Downstream dependencies. See	Evolution
Generative entrenchment	macro, 2, 3, 43
Drift, 52, 55, 59, 126–128, 156, 157, 290	micro, 2, 3, 101
F 1 44 100 100	Evolvability, viii, 31, 32, 36, 46, 153,
Eco-devo, 44, 189–190	173–175, 181–190
Embedding	Explanation, 36, 38, 39, 64n15, 66n24.
biological, 67n28, 94, 99, 152	See also Adaptationism
cultural, 246, 250, 261, 274, 285, 288, 297, 300	causal-mechanistic, 25, 28, 29, 41, 42, 52, 211
Emergence, 9, 25, 28, 40–44, 52–56, 196	complementary, 26, 127, 157, 159n8,
Cultural, 235, 237, 245, 250, 273, 279,	183
289, 297–298	contingency in evolutionary, 26,
Environment. See also Niche	67n29
as a product of cultural evolution, 228,	developmental evolutionary, 58
238, 247	equilibrium, 42
determining phenotype, 12, 26–30, 45,	evolutionary, 62n2
46, 95, 110, 265	functional (adaptive, selection,
and the dialectical account of biology,	Darwinian), 29, 114, 156, 207, 208,
36	211, 212
within dissociated coevolution, 155	genetic, 27, 64n15, 195, 305n19
dynamics and evolvability, 184, 185,	mechanical of development, 10
190 (see also Adaptation, lock and key	probabilistic, 126, 157
model)	
	proximate/ultimate (cognitive), 26,
entity-environment relations, 244, 245,	proximate/ultimate (cognitive), 26, 202, 215

Fitness, 120, 123, 124, 248. <i>See also</i> Adaptation; Evolvability	Gene centricism (central dogma), 25, 30, 42,
of cultural elements, 252, 257, 300,	65
312n60	circuits, 51, 56
epistasis, 138–147, 151, 152, 157,	network, 56, 154, 155
159n9	regulation, 35, 51, 57, 94
in explanation, 26	selectionism, vii, xi, 34, 35, 40-45,
of genes, vii, 16, 40, 252, 257	189, 195–196, 263–265
heritable variation in, 43, 113, 125–	selfish, vii, 40, 43, 263 (see also
128, 134	Dawkins)
landscape, 61, 66n22, 102, 104, 106-	Generative entrenchment (GE), 37, 60,
107, 146	143, 177–181, 252, 254, 270, 272
Fontana, W., 36, 55	as a cause of stasis, 284–287
Frame problem (of artificial	in culture, 227-230, 238, 244-246,
intelligence), 297	274, 277–284
Function, 96, 123, 210n14, 280. See also	cumulative entrenchment, 232
Coupling	developmental lock model, 68n34
categorization of organisms and traits,	of scaffolding, 278, 293-301
206–208	in sciences and study of culture, 287-
and causal depth, 213–217 (see also	290
Adaptation; Adaptationism;	Genetic determinism, 38, 44, 62, 304n29
Scaffolding)	Genetics
context, 94	developmental, viii, 3, 11, 17, 18, 32-
delineation, of 189–190	34, 94
distributed, 197	molecular, 12, 16, 32, 35
emergence, 43	population, 12, 16, 17, 27, 126, 237,
epistemic demand, 206–213	254, 257
equivalents, 296	quantitative, 2, 16, 99, 143
functional biology, 26, 62n3, 65n15	Genotype, 16, 107
functional genomics, 145	Genotype phenotype relationship
functionalism, 113–114, 125	and the builder perspective of culture,
functional morphology, 131	247, 249
functional novelty, 50, 51	according to developmental genetics,
functional organization, 124, 157, 175,	34
176	evolution of, 47–48, 56
functional redundancy, 123, 144	interactionist consensus, 28
maintaining functionality, 124–125, 144	modularity of, 153
mapping function, 93	according to organic systems approach,
multiplexing, 287	45–46, 52
polyfunctional, 294	according to population genetics, 2,
of scaffolding, 229	15, 26, 27, 29, 30, 62n3
specialization of neural subsystems,	structural modeling of, 36, 54, 93–111
197–202	and thin models of culture, 237, 300

Induction (in embryology), 133, 197, Germ line, vii, 1, 10, 123, 135, 149–151, 262, 264 217 Gilbert, Scott, 19, 27, 28, 35, 68n33 Information Goldschmidt, Richard, 11, 12, 16, 184 accounts of ontogeny, 26-30, 62n3, Gould, Stephen J., vii, 17, 41, 43-44, 68, 64n14 184, 191 biological (for identifying homology), Grain problem, 203-205 211 Griessemer, James, ix, 36, 38, 41, 43, 58, channels, 229, 258, 286, 291, 294, 297-301 64, 122 Group cultural, 258, 286, 291, 307n36, development, 37, 245, 253, 272, 282 311n53 inheritance, 215 disembodied transmission, 229 reproduction, 245, 251 encapsulation in brain modules, 198, 200 selection, 43, 189, 212, 296 environmental, 68n34 Haeckel, Ernst, 2, 5, 7, 9-11, 18, 32 inherited, 8-15, 122, 270 Hall, Brian, viii, 3, 26, 65n18, 195, Infrastructure, 271, 276, 278-281, 206 294 Hierarchical levels, 36 material, 246, 271, 272, 278 of constraints, 141 social, 281, 282 of coupling, 128, 138 Ingold, T., 236, 237, 266 Inheritance, 1-5, 11-14, 48, 56, 58, 64, of evolution, 43, 148 of gene networks, 55 122, 214, 302n6. See Hopeful of mechanism, 34, 65n19 monsters; Inherency; Lamarckianism; in models of culture, 261, 278, Reproducers; Weismannism 304n17, 306n27 conceptual separation from of modules, 148, 197 development, 10, 17 of natural selection, 38, 43, 189 cultural, 227-229, 235, 252-261, 265, of organization, 36, 244 279 of cultural artifacts, 271, 274 of phenotype (development, organism), 44, 121 cultural channels of, 253, 287, 297 Homology definition of (as type of reproduction), in evolutionary psychology, 196, 206-267, 268 217 dual inheritance model according to used to define novelty, 50 the reproducer perspective, 36, 252, organizational, 53 64n10 Von Baer's explanation of, 210–211 dual inheritance models, 227, 236, Wagner's definition and examples of, 227, 248, 249, 252 epigenetic, 306n26 Homoplasy (homoplasies), 54, 155–156 role of scaffolding in cultural Hopeful monsters, 184-186. See also inheritance, 244, 245 Punctualism selection for accuracy of, 186-189 Hull, David, 43, 58, 304n18 Inherency, 31, 57, 61, 67n28

Innovation, 25, 31-32, 44, 49-52, 54-Lineage. See also Legacy 57, 239 of cell, 11, 44 in cultural infrastructure, 239, 243, 280 complexity of cultural, 262 in culture, 238, 253, 260, 272, 290, evolvability, 31 295, 313n62 types of, 187-189 Input-output-transformation (IOT), 111, units within, 148-149, 154-158 135, 149-152 Integration, 31, 46, 53, 56, 153, 175, Maintenance 181 - 186of culture, 228, 232, 272, 281-282, 288, 294 Kauffman, Stuart, 35, 58, 59 of function, 124-125, 144 Keller, Evelyn Fox, 36, 61 of organism, 121, 133, 267 Kluge, 285, 289, 303n9 of phenotype, 27, 48 self-maintainance, 54, 121-123, 128, Lamarckianism, 12, 17, 26, 36 159n4, 308n41 of cultural infrastructure, 237, 292, 298 Material Language overlap in cultural inheritance, 36, 37, Evolution, 280, 281 228, 251, 263, 266, 267, 272, 278, oral versus written, 280 288, 297-300, 309n43 origins of, 237, 253 propagules, 123, 245, 261-262, 266-Legacy, 187-191, 192n6, 192n10 267, 270-275, 278-280, 293, 298-Levels 299 of inheritance, 245 transfer, 229, 247, 250, 270, 272 Maynard Smith, John, 40 multilevel organization, 271, 276, 290-296, 303n9, 308n37 (see also Mayr, Ernst, 7, 26, 62n3 Hierarchy) Meme organization, 27, 36, 43-44, 51, 55, 56, as account of cultural evolution, 227, 196, 245, 246, 251, 270 228, 248, 262-264, 291 failures of, 252, 252, 257, 262-264, selection, 40, 43-44 270-274, 291, 297, 305n23 Lethality 134, 229 Lewontin, Richard, 191 Mendelianism, 16, 47, 48, 58, 258, criticism of genetic determinism, 27-270 28 Model organism, 12, 16, 18, 154, 155, definition of evolution, 43 281 on metaphor in science, 37 Modern synthesis, vii-viii, 2, 12, 16, on niche construction, 192n11, 218n6 25-27, 43, 60, 214 on limits of population genetics, 63n6 Module, modularity. See also Quasion quasi-independence, 175, 178, 180, independence and adaptivity, 175-184, 202-205, 216-217 Life cycle, 122–128, 132–134, 141, 148– 154, 157, 158n3, 236, 270, 283 developmental, x, 31, 51, 148-158, cultural, 252-261, 277 175-184, 216-217 and cultural evolution, 227-278 environmental, 192n11

within evo-devo, viii, 20, 31, 36, 54, 175 - 184evolutionary (modules of evolutionary transformation), 115, 148-158 functional, 175-184, 190, 191, 196-199, 216-217 of genotype-phenotype map, 152 mental, 153, 199-205, 216-217 virtual functional, 196, 199-201, 216 Molecular biology, 16-19, 28-30, 36, 60, 214 Morgan, Thomas Hunt, 12, 14-17, 270, 307n32 Morphospace, 61, 116, 117 Mosaic evolution, 148, 153 Mutation. See also Constraints; Hopeful monsters; Punctualism; Variation difference between biological and cultural, 290, 292, 295 genetic, 135-141, 149-153, 159n4 to genetic code, 314n69 gradual, 173-186, 198, 201 according to neo-Darwinism, 55 according to organic systems approach, quantitative mathematical modeling, 95-101, 107-110 rate, 113, 127, 290 studies, 16, 33, 34

Natural selection, 101–115, 127–128, 212, 215, 219n14, 255. *See also* Adaptationism; Constraints on brain structure, 199, 202–206 cultural selection, 258, 292–294 in Darwin's definition of evolution, 6 equations, 126 for heritability, 48 internal selection, 125, 127, 159n7 against lethal variants, 134 and novelty, 51–56 and self-organization, 59

stabilizing selection, 178, 180 tweaking functional joints, 181, 184 Neo-Darwinism. See also Gene centricism; Gene selectionism cultural support, 66n22 commitment to externalism/ selectionism, 57, 62n5, 63n9, 206 commitment to genetic program, 28, 46, 62n5, 63n9 omissions by, 54, 55, 64n13, 114, 195, 217n1 Niche, 49, 190. See also Niche construction Niche construction, 34, 192n11, 209, 218n6, 203-204, 209, 302n6, 304n14, 318n15 by cultural evolution, 229, 244, 260, 264, 278–280, 285 Nonlinearity, 105 gene interactions, 93-100 interactions within culture, 258 contrast with linearity, 42, 44, 100 phenotypic surfaces, 102-107

Ontogeny and phylogeny conceptual separation of, 2 ontogeny creates phylogeny, 25-26 ontogeny recapitulates phylogeny, 7-8 Organic Systems Approach (OSA), 25, 44 - 45use of equilibrium explanations, 42 explanation of generation, 45-49 explanation of innovation (novelty), 49 - 52explanation of organization, 52-54 compatibility with philosophical naturalism, 41 Organization, 25, 27, 34, 36, 45, 52-54, 56, 57, 64n13 determining constraints, 117-118, 121-128, 133 homology of, 53

and punctuated equilibrium, 54

Organization (cont.) Process-oriented view, 116, 128, 149 levels and orders of, 27, 36, 43-44, 51-Process structuralism, 35, 39 56, 196, 245, 246, 251, 270 Progeneration, 122, 267, 268 multilevel organization, 44, 271, 276, Propensity, 31, 121, 124, 139 290-296, 303n9, 308n37 (see also Punctualism (Punctuated equilibrium), Hierarchical levels) 54-55. See also Hopeful monsters origination of, 25, 55 Quasi-independence. See also Semidecomposability; Module, **Packaging** bracketing, 229, 261 modularity bundling, 261, 269 of cultural channels, 298 and coordination, 231, 242, 274, 293, mutations, 175-186 298, 308n37 units of evolution, 147, 148 and modularity, 287 (see also Module, modularity) Raff, Elizabeth, 7 and organization, 288, 244, 245, 261-Raff, Rudy, 7, 19 270, 281 Recombination, 146, 147 Recurrent artifacts, 271, 273 sequestration, 261, 269, 287, Persistence Redeployment, 51, 155 of agents, 229 Reductionism, 65n19, 263, 303n9 of artifacts, 229, 250, 271, 272, 273, Redundancy, 46, 123, 191n2, 287, 290, 278, 279, 285 295, 296, 311n52 of infrastructure, 229, 243, 271, 272, functional, 123, 144 278, 285, 286 Reference groups, 251, 264 of stable states, 121 Regulatory region. See Cis-regulatory Phenotypic evolution, 17, 25-28, 33, 36, 44, 49-57, 205 Replication, 41, 121–122, 228, 263–269, Phylogeny, 33, 55, 154, 155, 215, 281. See also Ontogeny and phylogeny Replicators, 43, 262–272, 279, 306n28 Plasticity, 36, 45, 46, 65n16, 110, 204, Reproducers 281 biological, ix, 36, 41, 43, 267 Pleiotropy, 31, 50, 152, 153. See also cultural, 228, 244, 249-252, 261, 271-Constraints; Nonlinearity, phenotypic 279, 283, 287, 304n17 surfaces versus replicators, 266–271 Pluralism Reproduction, 7, 8, 55, 173-174. See of multilevel selection, 40, 43-44 also Reproducers of theories, 60-62, 66n24 recurrent reproduction of a state, 122-Population genetics, 12, 16, 17, 27, 127, 130-133, 139-151, 157, 158n2, 63n6, 126 158n3, 236 and thin models of culture, 237, 254, Resources cultural, 244, 246, 258, 246, 258, 282 Population size, 119, 126, 127, 128, developmental, 28, 196, 198, 228, 238,

293

147, 254, 305n19, 113

Richardson, Michael K., 18, 59 Soma Richerson, P. J., 252, 253, 528n6, cultural, 247, 304n17, 306n28 312n59 distinction from germ line, vii, 1, 135, Robustness, 32, 93-98, 153, 284, 297, 149-151, 158 311n52 Stasis, 154-156, 253 generative entrenchment as a cause, 284-287 Scaffolding accumulating adaptation, 244, 292, recognizing, 282-284 293 Sterelny, Kim, 279 artifactual, 276-278 and chunking or black-boxing, 45, Transcription factor, 129, 132, 135, 139, 288, 294, 296, 299, 313n62 140, 153. See also Gene circuits; Gene and making deep changes, 290, 295 network; Gene regulation definition, 229 developmental agent, 276, 281-282 Unity of type, 206-209 functions, 229, 230 as generative, 233-236, 250, 251, 272, Variability, 29, 48, 114, 124, 260, 261. 284 See also Variation infrastructural, 276, 278-281 Variance/covariance matrix, 109, 143. internalized, 245, 269, 270 See also Nonlinear phenotypic surfaces and niche construction, 244, 260, 266 Variation, 16, 27-29, 36, 45-46, 55-56, 65n16, 110-115. See also Constraints; parent-offspring, 248, 261, 265-274 as reproducer, 244, 246, 249, 250, 261-Coupling 279, 283 between genotypes and phenotypes, self, 230, 244, 269 93 - 110as shaping, 228, 231, 238, 266, 274, heritable, 13, 124-125, 134-135, 139-299 144, 149-157 according to the organic systems increasing speed of evolutionary change, 290-292, 297 approach, 49-52 as supporting differential in population genetics, 2 specialization, 234, 235 Von Baer, Karl Ernst Schank, J. C., 177, 178, 180, 181 explanation of homology, 210-211 Selective constraints. See Functional laws explained by generative entrenchment, 68n34, 177-178 constraint Self-maintenance, 54, 121-123, 128, laws as influences on Darwin, 6 159n4, 308n41 Semidecomposability, 198 Waddington, C. H. Sexual reproduction, 123, 146, 147, 187, anticipation of genetic integration, 56 evo-devo renegade, 17, 27 Signaling cascades, 97–98, 129, 135, "Waddingtonian microevolution," 101 143, 197 Wagner, Günter Simon, H. A., 288, 311n55 the causal link between molecular and Sober, Elliot, 42, 62n5 phenotypic evolution, 32-33

Wagner, Günter (cont.) development, 65n17 evolution of modularity, 186, 203 evolvability, 173 the nature of evo-devo, 19, 31 definition and examples of novelty and homology, 51, 211, 219n12 Weismann, vii, 1-5. See also Weismannism and the disintegration of generation, 9-10 Weissmannism, 26, 38 62n3 hierarchical multilevel Weismannism, 261, 304n17, 306n27 models of culture, 237, 247-248 Williams, George C., 40, 41, 57, 62n2 Wilson, E. B., 12-15, 40, 66n24 Wimsatt, William, 42, 60, 68n34, 158n11, 177, 178, 180, 181 Wray, Greg, 18