Index

The following index combines people, topics, techniques, and examples. Persons are cited by last name and one or two initials. References to figures are in **boldface**, preceded by **Pl**. if the figure also appears in the color insert. Entries pointing to footnotes go as page number followed by "n" and then footnote number, as with "74n1".

abduction (a principal mode of numerical inference), 13, 27, 85-100 in combination with consilience, 115, 289-290, 483-485 in complex systems, 305 definitions or characterizations of, xxviii, 5, 86-88 in discriminant analysis, as unlikely to arise, 392 examples of anthropogenicity of global warming, 88-89, PI.3.4 in biology, 99-100 continental drift, the graphical argument for, Pl.2.1 faulty, 463, 470 heart attacks in wives of smokers, 259 lung cancer in wives of smokers, 262 from maps, 122, 127 in mathematics, 95 in medicine, 204, 256-262 and pathological science, 210-211 in physics, 95-96 in public health, 96-97 Scorpion wreckage, discovery of, 8, 97-98 in social psychology, 270 in solar system science, 280-284 and the fate of two space shuttles, 99 in time-series data, 263-265 see also under examples, main grammar of the word, 86 intellectual precursors of, 86-87 in linear regression

for the intercept, 257-259 for the slope, 260-262 as the failure of the matrix formalism, 312 emphasis on selection, 290 in morphometrics, 405, 7.19, 7.20, 7.25 in multiple regression, as unlikely to arise, 244 the two polarities of, 286 psychological origin of, 91 this argument is transcendental, 92 surprise, the role of, 59-60, 88, 117, 259, 286 see also under surprise; plausible rival hypotheses added-variable plots, see under multiple regression, special cases additive conjoint measurement, 379-380, 6.16 agreement, reasonable, see under approximation, Kuhn's theory of AIC, Akaike Information Criterion, 104, 334-338, 5.19 example, the corpus callosum in schizophrenia, 338-344 formulas for, 335, 337, 340n14 alcohol dose, measurement of, 373 fetal exposure to, see fetal alcohol allometry, 308, 437-438, 6.9, 7.15 Alvarez, W., study of the cause of the Cretaceous-Tertiary extinction, 4, 11, 14, 34-35, 99, 117, 280-284, 285, 491 anatomical variants, 44 "and so on," see mathematical induction Andersen, P., 234

520

Index

Anderson, D., 244, 252, 331, 334, 337 Anderson, T., 322, 492 Anson, B., 44 anthrax, Sverdlovsk 1979 epidemic of, 3, 35, 127, 4.6 one-sentence summary of, 3 anthropogenic greenhouse gases, effect on global temperature of, Pl.3.4 apagoge, 86 approximations essential, 135-136 Kuhn's theory of, 37-38, 178, 181, 262, 493 mathematical notation for, 175 in Perrin's work, 178 arc length, index of a variable type, 360 arc-sine law, 46-48, 2.10 arithmetic into understanding (main theme of this book), xix, 497 Arrow, K., 279 asthma, epidemics of, in Barcelona, 129, 4.7, 200, 211 asymmetry, human facial, 455-456, 7.28 Atlantic Ocean, fit by E. Bullard to continents around, 19, Pl.2.1 atoms, existence and size of, see under Perrin Atwater, B., 97-98 autism, as thimerosal poisoning, 207 average definition, 131 as least-squares descriptor, 131 as maximum-likelihood, under a Normal assumption, 191-193 meaning of, as inseparable from theories about, 192 of nonnumerical quantities, 142-143 original sense of the word, 129 precision of, 132-135 weighted, 134-135 Millikan's modification according to expert knowledge of error, 148 regression slope as a weighted average of casewise slopes, 141 Avogadro's law, see under Perrin Bayes, T., scholium (fundamental question) of, 188 Bayesian inference, see under inverse probability Belmont Report, 271-272 bending energy, see thin-plate spline Benveniste, J., see under dilution, infinite Benzécri, B., 378-379

Berkeley Earth Study, analysis of global climate change by, 107–109, **3.9**

Berkeley Guidance Study, 240-241

Berry, W., xxviii beta weights (β), see multiple regression, coefficients in bilateral symmetry, see symmetry, bilateral billiards table, as substrate for Bayesian inference, 188, 4.24 binomial distribution, 151-152, 4.11 see also coin flips biology abduction, biological examples of, 99-100 numerical inference in, 13, 18 rhetoric of unification arguments in, 30 see also under anthrax, asthma, double helix, Fetal Alcohol Spectrum Disorder, Ramachandran plot, schizophrenia, Snow biplot (of an SVD), 353-354 in morphometrics, 362 Bloor, D., xxviii, 42 Bolhuis, J., 36 Boltzmann, L., 331 see also Maxwell-Boltzmann distribution Bookstein F email addresses of, xxiv and passive smoking trials, 254 worked or published examples by on brain damage in fetal alcohol disorders, 445-449, 7.22, 7.23, 7.24, 7.25 on brain damage in schizophrenia, 328-330, 338-343, 5.21, 443-445, 7.19 on fetal alcohol effects upon adult IQ profile, 372-375, 6.13, 6.14, 7.31, 461-463 on hominoid evolution, 362-364, 6.7 on human facial asymmetry, 455-456, 7.28 on human skull growth, 364-366, 6.9, 399, 6.26, 7.13, 7.15 on Pearson and his great folly, 466-471 on rodent skull growth, 398-399, 6.25, 7.5, 7.6, 7.9, 7.17, 7.18, 7.20 on strain statistics, see strain, statistics of on viremia in monkeys, 354-357 see also under thin-plate spline Bookstein coordinates, see under shape coordinates, two-point Boulding, K., 30-31, 71, 301-302, 498-499 Bowman, C., xxiv, 244, 377-378 "Boys have more" (Google search), 3-4 brain, human, damage to, from prenatal alcohol exposure, see under fetal alcohol Broadbent-Bolton data, 455 Brownian motion, 38, 49-50, 2.12, 4.19, 116, 179-182 certain origin of, see under Perrin

maximal disorder of, 4.19

Cambridge University Press 978-1-107-02415-1 - Measuring and Reasoning: Numerical Inference in the Sciences Fred L. Bookstein Index More information

Index

521

orderly scaling of, 183 specific observable properties of, 176-177 Bullard, E., see under Atlantic Ocean Bumpus, H., sparrow study of, 242-244, 4.39 principal finding, 4.40 Burnham, K., xxii, 331 Buss, D., 275-276, 4.52 ${}_{n}C_{k}$ ("enn choose kay"), symbol of counts of combinations, 151 cameras, consiliences of, as machines, 32-33, Pl.2.8 Campbell, D., 263-266 cancer biology, as fundamentally heterogeneous, 44 canonical variates analysis (CVA), 391-394 carbon dioxide, trend and circannual pattern of, 76, 3.2 Cargo Cult science, 212 caricature, 483 cases-by-variables matrix, 307 see also principal components analysis, SVD causation causal chains, correlations for, 223 common causes, correlations for, 223 Freedman and Weisberg on, 220-221 as one grand theme of statistics, 220 of multiple effects, 168 see also Partial Least Squares normal equations for, 229-230, 233 in the quincunx, 166, 220 and regression lines, 167, 7.34 see also multiple regression Ceccarelli, L., 30 centering matrix, 382 Central Limit Theorem, 159, 160 centrifugal force, 62 Centroid Size, 412, 418, 419-420, 424 see also Procrustes form distance; Procrustes shape distance ceteris paribus, see multiple regression, as counterfactual challenges, in multiple regression modeling, 252-262 Challenor, P., see Gulf Stream Chamberlin, T., 13, 101, 338 Chargaff, E., see under double helix Chicxulub (meteor crater), 60, 117, 284 chimpanzees, as skull data, 364, 6.7 χ^2 (chisquare), statistic, **4.20**, 253, 260, 315, 322 cholera, London epidemics of 1849, 1853, 1854, see under Snow Christmas tree, see meta-analysis

civic virtue, as mensurand of a Pearson study, 3, 466-471 one-sentence summary for, 3 classification, see discriminant analysis Clifford, W., xxviii, 471 cognitive neuroscience, 36 as having difficulties with consilience, 39 Cohen, J., 198-201 coin flips (model system), 132-135, 150-154 as actual data, 132n1 frequency falloff from its maximum, 153-154 see also mathematics, notes, Note 2 likelihood ratio tests for, 194-196 tie between heads and tails, chances of, 152 cold fusion (pathological science), 207 Collins, H., 41-42 complex organized systems, 14-15, 34, 291-478 advantages of, for both abduction and consilience, 483-485 complexity scale of Boulding for, 302 confirmatory statistical analyses for, as unlikely, 496 heterogeneity as a problem in, see under heterogeneity measurement types in, 71 morphometrics as a good example of analyses in, 405 organisms as, 71, 160 patterns in, 14, 289 reductionism and, 34-35 statistics of, as complement to the Gaussian model, 303, 316 computed tomography (CT) of the adult brain, 7.19 see also under Visible Female conic sections, 347 Connecticut speeding crackdown, see plausible rival hypotheses conservation equations, 162 consilience (a principal mode of numerical inference), 13, 27, 28, 29-37 in combination with abduction, 115, 289-290, 483-485 but temporally lags behind, 490, 493 in complex systems, 304, 490 emphasis on selection, 290 definition of, 17 examples of and anthrax, 4.6 and asthma, 4.7 and Avogadro's number, 178-179, 183-184 and the Cretaceous-Tertiary extinction, 284 and the effects of environmental tobacco smoke, 259, 262

522

Index

consilience (cont.) and Einstein's law of the photoelectric effect, 149-150. 4.10 between Kepler's laws and Newton's law of gravitation, 66, 68 and the Maxwell-Boltzmann distribution, 4.23 and Newton's apple, 28-30 and obedience behavior, 4.50 and Planck's constant, 148 in re the Scorpion sinking, 5-10 in seafloor spreading, 22-27, 2.5 and ulcers, 4.25 see also under examples, main in morphometrics, 405 in multiple regression, usually unavailable, 244 numbers, special role of, 30-31, 39-40 and pathological science, 210-211 in physics, 40, 57; see also Kuhn, Wigner quantifying, 36 requisites for visualization in, 28, 57-58 the slide rule, as a machine for, 219 trust in, as the foundation of the natural sciences, xxvii, 30, 186 Consilience (book), 29 continental drift, 18-27 magnetometer data and, 22 paleomagnetism and, 19-21 one-sentence summary for, 3 contrastive method (J. S. Mill), 86 Coombs, C., 279 coordinates for the double helix, 218, 4.28 Cartesian, 33, 410 polar, 62 copper, heat capacity, meta-analysis of, 4.41 Coriolis force, 60, 62-63, 2.20 corpus callosum, in human brain studies, 5.20, 7.21, 7.22, 7.23, 7.25, 8.1 details of permutation testing, 453 correlation formula for, 171, 222 Pearson's data as exemplifying, 4.17, 7.36 as product of two regression coefficients, 222 modified quincunx for, 4.29, 221-222 as a regression between standard scores, 4.29 correlation matrix, 320, 369, 373 not suited for principal components analysis of shape coordinates, 361, 362 Wright's modification of, 369 correspondence analysis, see under singular value decomposition covariance distance, 6.22, 394-399 pattern, for human skull growth, 6.26

pattern, for rodent skull growth, 6.25 explained by the uniform term of shape variation, 439 see also relative eigenanalysis covariance matrix, 357 rank, in PLS, 372 crease (morphometric features), 7.20, 444 Cretaceous-Tertiary extinction, see under Alvarez Crick, F., see under double helix Cromwell, O., skull of, 3, 464–466, 7.32 crud factor, see Meehl cudos ($\kappa \nu \delta o \varsigma$), "honor," acronym for a set of scientific norms, 41 curves, types of, 407 see also ridge curve, symmetry curve Darwin, C., 163, 185 DeHaene, S., studies of reading, 274 detective stories, as a model for numerical inference, 11, 91 determinantal rule, for intersections of lines, 140 diet, as confound in environmental tobacco studies, see under environmental tobacco smoke dihedral angles, 5.2 see also Ramachandran plot dilution, infinite, Benveniste study of, 208-210, 4.26 direct effect, direct path, see under multiple regression, as path model; path analysis discriminant analysis linear, 242-244, 6.18, 387, 6.19, 6.21, 387-391 example of, see under Bumpus's sparrows quadratic, 387, 6.20 examples of, 5.9, 8.4 unlikely to lead to surprise, 392 disorder 161 dissimilarity, see distance matrix distance matrix example of, 5.9 Procrustes shape distance, Procrustes form distance, see under Procrustes shape distance; Procrustes form distance see also principal coordinates analysis distances, commensurability of, as a principle of consilience, 28 distribution, see binomial distribution; Mardia-Dryden distribution; Normal distribution; prior distribution; random walk DNA (deoxyribonucleic acid), see under double helix

Cambridge University Press 978-1-107-02415-1 - Measuring and Reasoning: Numerical Inference in the Sciences Fred L. Bookstein Index More information

Index

double-centered data, see principal coordinates analysis double helix, 72, 214-220, 285 Chargaff's rule for base-pair counts in DNA, 99, 216-217, 219 discovery, as an abduction, 219 discovery, as a consilience, 215, 219 one-sentence summary for, 3 X-ray crystallographic image of, 215, 4.27 Double Helix, The (book), 116, 214 Duncan, O., xxii, 278 e, Euler's constant, the base of natural logarithms, passim E, expectation operator, 168 earthquakes in Seattle, xxii, 97-98 worldwide, 2.2 question posed by this figure, 22 economics, 278 Edgewarp (computer program), Pl.2.8, Pl.7.14, 425 Edgeworth, F., 141, 248 Edwards, A., 193-201 see also under Interocular Trauma Test effects, direct, indirect, and total, in multiple regression, 229, 233 effect sizes, in analysis of complex systems, 337 eigenanalysis, 309 Einstein, A., 3, 84, 96, 143-145, 179-180, 218n11, 490 elasticity, 45 ellipses in geometry, 60-61 in gravitational physics, 69 in statistical data analysis, 171-73, 4.18 ellipsoids in geometry, 6.6 in principal-components analysis, 322-324 variation of the principal axes of, 357-359 Elsasser, W., 13, 21, 42-43, 70, 160 empty space, as dominant feature of multivariate patterns for complex systems, 294-296, 5.1, 5.3 abductions deriving from, 296 endophrenology, 447 entropy (physical concept) relative, Gibbs's inequality regarding, 331 maximized by a Normal distribution, 161, 315 environmental tobacco smoke, 3, 116, 251, 253-262 and heart attack risk, 256-259 and lung cancer risk, 260-262 one-sentence summary for, 3

523

epidemiology, role of multiple regression in, 244 - 252equation, error in the, in linear regression, 137 linear regression as the minimization of the mean square of these, 139-140, 4.8 equipoise, 201 Euler, L., see e; mathematics, Note 7.1 EVAN (European Virtual Anthropology Network), xxiii. 426 Eve, see Visible Female evolution, hominoid, 362-364, 6.7 evolutionary psychology, limits of abduction and consilience in, 213, 274-276 Ewald, P., contemporary version of Koch's postulates by, 205-206 examples, main, of this book, see under Alvarez, anthrax, asthma, corpus callosum, double helix, environmental tobacco smoke, evolution, Fetal Alcohol Spectrum Disorder, growth, Hertzsprung-Russell diagram, IPCC, Livingstone, Millikan, obedience, Perrin, Ramachandran plot, schizophrenia, Scorpion, seafloor spreading, Snow, Tetrahymena, ulcers, viremia see also under Bookstein, examples by excursion statistics, see random walk expected value of log likelihood, see AIC "explained" variance via correlations, 222-223 see also under multiple regression extrapolation, of a shape change, 445n6 see also crease extremes, rhetoric and risks of, 75-76 fact, scientific, see under Fleck factor, 162, 396 general role in epidemiological studies, 252 Wright's method for extracting, 369 special, 369 factor analysis, 368-370 Guttman's models for, 472-473 factorial function (n!)definition of, 151 Stirling's approximation for, 152, 173-175 FASD, see under fetal alcohol Feller, W., 46 Felsenstein, J., xxii, xxiv fetal alcohol effects of exposure to, at low doses, 15, 372-375, 461-463 Fetal Alcohol Spectrum Disorder (FASD)

524

Index

fetal alcohol (cont.) in the adult brain, 3, 7.21, 7.22, 7.23, 7.25, 491 legal and forensic aspects, 449-451, 5.9, 7.25 behavior in, 5.6, 5.7 corpus callosum in, 5.9, 7.21, 7.22, 7.23, 7.25 in relation to executive function, 448, 7.24 discovery of, 97 the face in, 296, 5.4 in the infant brain, 3, 485-489 one-sentence summary form for, 3 test scores in, 5.5 Feynman, R., 62-63, 484 on pathological science, 212 Fisher, R., 96, 242, 310 Fleck, L., xxviii, 14, 42, 93, 185, 301, 481, 490 Flury, B., 362, 398 force gravitational, see under Newton's law of gravitation as metaphor, xxvii, xxviii, 272, 468-470 see also centrifugal force, Coriolis force forensic neurology, see fetal alcohol spectrum disorders, legal and forensic aspects fractals, random walks as, 4.19, 184 Franklin, R., 215, 219, 493 Freedman, D., xxi, 122, 220 scale of practicality of regression of, 233-234 Friedrich, C., see under Wanderer fruitcake, as metaphor for social measurement, xxii Galton, F., 46, 404, 466-471 averaged photography by, 34 breadth of work by, 163 Pearson and, 466-467 quincunx machine of, 46, 162, 4.13 invention of, in holograph, 4.15 relation to coin flips, 163-164 regression, discovery of, 4.14 Gauss, K. the average of a Normal distribution is the likeliest mean, 193 if the average is the likeliest value, the data must be Normal, 314 see also Normal distribution Gauss-Laplace synthesis, 191-193 general systems theory, 301-302, 499 Generalized Procrustes Analysis (GPA), 412-413, 7.3 the Procrustes shape coordinates it produces, 413-414, 7.4

geodesy, 33 geologists, relative cognitive nonclosure of, 19 geometric morphometrics (GMM), see morphometrics geometry, 1.1, 11 of covariance matrices, 397-398 of multiplication, see hyperbolic paraboloid of scientific visualization, 57-58 Gerard, R., 13, 71 Gesamtkunstwerk, see rules of morphometrics, first Gibbs, J., 315 Gibbs's inequality, 331 GMM, see morphometrics Goldstein, I. and H., 129, 4.7 Google 3-4 Gould, S., 51 Gower, J., 382 Granger causality, 89n5 Green, W., xxiv, Pl.2.8, 338, Pl.7.14, 402 greenhouse gases, anthropogenic forcing of, see IPCC Greenwald, A., propaganda study of, 272-273, 4.51 grids examples, see rules of morphometrics, fourth random fields over, 326-328, 5.15 as representations of shape patterns, see thin-plate spline simplifications of, 439-443 see also partial warps see also rules of morphometrics, fourth growth, analysis of by added-variable plots, 240, 4.37 by grids, 366, 6.9 examples, see under Bookstein, examples, human skull growth and rodent skull growth growth axis, of the human skull, 438 Guillemin, J., see anthrax Gulf Stream, risk of collapse of, 110-111 Guttman, L., 472-473 Hagen's hypothesis (Normality of psychophysical variables), 139n2, 160-161 Hansen, J., approach to climate change of, 106-107 see also NOAA hat matrix, 233 heart attacks, risk of, from environmental tobacco smoke, 3, 256-259, 285 platelet aggregation as explanation of, 259, 4.44

Helicobacter pylori, see under ulcers helix, double, see under double helix

Index

Herrnstein, R., 276-277 Hertzsprung-Russell diagram (astronomy), 291-293, 5.1, 492 heterogeneity of cancer biology, 44 hidden, 160 in high-exposure groups, 247 interferes with consilience in the rhetoric of biology, 43 as a mechanism for generating correlation, 227 of random walks, when analyzed inappropriately, 51 of strain, see under thin-plate spline, bending energy "hockey stick" (overstated statistical model of global warming), 76-78 hominid evolution, as example of principal component analysis, 362-366 Huff, D., 4 hyperbolic paraboloid, 15, 346-349, 6.1, 6.2 alternating fourfold rotational symmetry of, 349 as the blend of two oppositely opening parabolas at 90°, 348-349 for depicting individual terms of an SVD, see singular value decomposition as the finding, in a low-dose fetal alcohol study, 6.13 as the surface z = xy, 347 hypotheses, scientific a-priori choice of, as unhelpful for studies of complex systems, 482 discriminant analysis as testing, 385 the kinetic theory as, see under Perrin likelihood of, see under likelihood ratios multiplicity of, as a strength of morphometrics, 482 null, as lacking a role in most competent numerical inferences, 200 ignorance, assumptions about in Bayes's scholium, 188 as justification for the Normal distribution, 315 in morphometrics as justification for the isotropic Mardia-Dryden distribution, 417 as justification for the thin-plate spline, 403 indirect effect, indirect path bounds on, from a meta-analysis, 260-261 Wright's equations example, 368 and PLS, 368-369

see also under multiple regression, as path model; path analysis individuality, 16

525

see also heterogeneity inference, numerical abduction. see under abduction arithmetic and, 105, 289 Bayesian, see under prior distributions and complex systems studies, 300-301, 494-498 deduction, 86, 92 detective stories and, 10, 91, 99 the double helix, as the best biological example ever, 219-220 examples of, in one sentence each, 3 induction, 86, 92 see also mathematical induction and Koch's postulates, 205-206 norms of, 12 apparently incongenial to the psychological and social sciences, with some exceptions, 272-280 rhetorical form of, 3-5 strong, see under strong inference as the subject of this book, xix, 16, 494, 499 visualization and, 1.1, 57-58, 3.3, Pl.3.4, 85 see also under Latour inference, statistical, 491-492 information, Shannon's quantification of, 331-332, 5.18 information matrix in bioinformatic PLS, 377-378 Fisher's, 310 integers and continua, see mathematics, Note 4.5 the Pythagorean epiphany, xxvii, 152 sum of the squared reciprocals of the, see mathematics, Note 7.1 integration, 439 interaction, in causal reasoning, 252, 302, 311, 337, 462-463, 7.31, 498 intercept, of a regression line, 135, 142, 145, 148, 238, 285, 335-336, 5.19 Intergovernmental Panel on Climate Change, see **IPCC** Interocular Trauma Test (ITT), xxvii, 76, 129, 260, 292 interrupted time series design, 263-265 inverse probability, 188-191 prior distributions and, 178, 189 see also likelihood ratios Ionian enchantment, 30 IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report, 74n1 Fourth Assessment Report (FAR), 74-90 anthropogenicity of global warming, Pl.3.4, 13, 74-85

Cambridge University Press 978-1-107-02415-1 - Measuring and Reasoning: Numerical Inference in the Sciences Fred L. Bookstein Index More information

526

Index

IPCC (cont.) as a classic abduction, 88-90, 95 global temperature change contributors to, 75 treatment by, 76-77, 3.2, 3.3 see also hockey stick greenhouse gases, treatment by, 3.1 methodology of not explaining events, 89-90 refutation by Hansen, 106-107 policy implications of, 84-85, 3.6 visualizations, quality of, 85 IQ, 370n5, 372-375, 461-463 iridium, anomalous concentrations of, 281-283 ischaemic heart disease, see heart attacks Ising model (for binary images), 328 Jaynes, E., xxi, 289, 314, 315, 331 Jeffreys, H., 26, 193-201, 289, 314 Jeffreys's paradox, with increasing sample size, 196-197 Josephson, B., on variations in the strength of abductions, 90 Juan de Fuca Ridge, see seafloor spreading Kahneman, D., xx, 279, 493 Keeling, C., and the Keeling curve, 76, 3.1, 94 see also IPCC Kepler's laws, 64-65 as abductions from Newton's law of gravitation, 66 68 see also Newton's law of gravitation kinematic quantities, 132 kinetic theory, use by Perrin, 176-177 Koch's postulates, 205; see also Ewald, P. Konrad Lorenz Institute for Evolution and Cognition Research, xx, xxiii, 70 Krantz, D., 379 Krieger, M., on the craft of physics, 96 Krzanowski, W., xxi Kuhn, T., xxvii, 12, 13, 15-16, 35, 38-40, 71, 93, 94, 101, 262, 286, 359, 484, 495 argument for the centrality of strong inference, 100-101 normal science, concept of, 39 persistent anomalies, analysis of, 39-40 as abductions, 93-94 limits of, in the historical natural sciences, 491 Kullback-Leibler (K-L) divergence, 333-334, 5.18 Lagemaat, R. van de, xxi landmarks, in morphometrics, 404, 406-409, 7.1, 464 see also rules of morphometrics, first Langmuir, I., 207

Laplace, P., see under likelihood ratios Gauss-Laplace synthesis, 191-193 latent variable scores, see Partial Least Squares, two-block, interpretation in terms of scores Latour, B., 31-33, 484 laws, physical auxiliary assumptions underlying, 136, 180, 200 and consilience, 179 see also under Perrin often are linear, 137, 181-182, 4.21 fit by linear regression, as weighted averaging, 4.8 significance testing in, 199 see also under Newton's law of gravitation; Millikan; Wigner least-squares methods average as, 131 Gauss-Laplace synthesis of, 191-193 straight-line fits (linear laws) as, 135-142 see also Millikan; multiple regression LeGrand, H., narrative of continental drift of, 19 - 26Letvin, N., 354 lever, as example of consilience, 29 likelihood ratios, 116, 193-198 and the AIC, 338, 340 -2 times the log of, distributed as a chisquare, 315 in Hansen's approach to global warming, 107 in Jeffreys' approach to hypothesis testing, 193-196 Laplace's theorem, 189 maximum likelihood, principle of, 190 average as maximum likelihood, under a Normal assumption, 191-193 are not to be found in NHSST, 196, 198-201 as corrected for number of parameters, see AIC on the quincunx, 166-167 see also inverse probability linear multivariate analysis, 290 not conducive in general to abduction or consilience, 311-312 Lipton, P., on "inference to the best explanation," 87, 94, 96 Livingstone, F., 34, 212-213, 276, 491 logarithm as the function for which f(xy) = f(x) + f(y), 159, 332,395-396 as the geometry of the slide rule, 395-396 of the likelihood function in discriminant analysis, 242, 387 see also likelihood ratios, AIC of a Normal distribution. 4.12

Index

as a useful transform for growth data, 237, 4.36 log-likelihood, see under likehood ratios, AIC London, England, cholera epidemics in, see under Snow longitudinal analysis, see under Berkeley Growth Study; Vilmann lung cancer, risk of from environmental tobacco smoke, 3, 260-262, 285 from smoking, 96-97 machines Alvarez's, 281-283 the astronomers', 19, 291 Galton's, 163-165 for the Maxwell-Boltzmann distribution, 4.22 Millikan's, 145 and PLS analysis, 372 the slide rule, as a machine for abduction, 219 Wigner's characterization of, 6, 31, 33 Maddox, J., on the infinite dilution experiment, 208-210 magnetic resonance (MR) images of the brain, 7.19 magnetic reversals, see under seafloor spreading magnetometer data, see under continental drift malaria, evolution of, 212-213 Mandelbrot, B., 46, 184 mandible, template for the morphometrics of, 433-436, Pl.7.14 Mardia, K., xxiii, 294, 402, 454 Mardia-Dryden distribution, of shapes, 417 Margenau, H., 55-57, 2.18 Marshall, B., 116, 490; see also under ulcers Martens, H., xxi, 377, 405n1 Martin, R., 406, 464, 7.1 mathematical induction, 95, 175 mathematics appearance of brilliance in, 175; see also under Wigner obscurity of, in the reader's youth, xxii notes, mathematical Note 4.1, on extended equalities, 131-132, 141 Note 4.2, on coin models, 134 Note 4.3, on what a step in a derivation is, 151-152 Note 4.4, on clever tricks, 156 "Interlude," on the geometry of the regression line and the ellipse, 171-173 Note 4.5, on the interplay between integers and continua, 174-175

Note 4.6, maximum likelihood: symbols or reality?, 192

527

Note 5.1, derivation of the precision matrix, 321-322 Note 5.2, why does the arithmetic mean exceed the geometric mean?, 324-326 Note 7.1, A wonderful identity of Euler's, 474-476 power of, xxvii relation to scientific understanding, xix, 4 role in natural philosophy, xxvii role in scientific training, xxii as a set of stratagems for symbol manipulation, 66 unreasonable effectiveness of, in the physical sciences, see under Wigner matrix (mathematics) arithmetic of $(+ \text{ and } \times)$, 307 labels of rows and columns, 15, 309-310 general nature of, 306-307 notation, failure of, as grounds for abduction, 312 notation of multiple regression in, 233 rank, 350, 372 shift matrix, 310 subordination of, in complex systems analysis, 15.311 incompatible with most forms of feature selection, 300 adding more subscripts, 310 varieties of, in statistical data analysis, 5.9 covariance structure, 307-308 data structure, 308 gridded surface, 307 operator, 307 pattern of distances, 309 quadratic form, 308-309 see also cases-by-variables matrix, correlation matrix, covariance matrix, distance matrix, hat matrix, image matrix, information matrix, precision matrix, singular value decomposition Maxwell, J. (British physicist), 37, 144, 294 Maxwell-Boltzmann distribution, 37, 328 derivation by Maxwell, 158 as the most disordered distribution, 161 experimental confirmation of, 186-188, 4.23 mean centering, 141 mean square, 132; see also least squares measurement, measurements additive conjoint, see additive conjoint measurement in biology, 43-44 regarding the double helix, 215 design of, 183, 184-185 for complex adaptive systems, 360-362 in developmental psychology, 37

Cambridge University Press 978-1-107-02415-1 - Measuring and Reasoning: Numerical Inference in the Sciences Fred L. Bookstein Index More information

528

Index

measurement, measurements (cont.) foundations of, 36 in physics, 37 indirect, via regression, 140 for questions with one principal explanandum, Chapter 4 passim repetition with variation, importance of in Alvarez's study, 281-283 in Milgram's study, 4.50 in Perrin's study, 177-178, 183 see also under Collins in science in general, xxviii, 40 in the context of theory confirmation, 40, 101, 188 cannot precede understanding, in Kuhn's view, 495 medial axis, 5.23, 343-344 medical images as consiliences, 33 multiple approaches for organizing, 343 as provoking a renaissance in biometrics, 72 as a variable type, 360 see also computed tomography, magnetic resonance Meehl, P., 199, 303n4 Meiland, J., xx Merton, R., 12, 41 meta-analysis, 41, 256, 259, 4.45 Christmas tree (type of plot), 260, 4.45 metrological chain, the Alvarez example of, 35 Michelson and Morley, experiment of, 96, 143 microstates, as unsuited for biological measurement, 44 microwave background radiation, 5.8 midsagittal plane, 362, 434, Pl.7.14 Milgram, S., 14, 117, 491; see also under obedience Mill, J., 85 Millikan, R., study of the photoelectric effect by, 14, 115, 143-150, 285, 490 measurements, design of, 145, 4.9, 4.10 overruling of linear regression by, 145-148 Planck's constant, estimates of, 148 skepticism of, 144 overruled by data, 150 one-sentence summary of, 3 as an example of the "unreasonable effectiveness of mathematics," 150 Mills, C., 279-280 Mitteroecker, P., 394-399, 419 Mladeč (archaic human skull), 364 modularity, 439 molecular magnitudes, see under Perrin Moon, orbit of the, 27, 2.7

moral reasoning, contemporary experimental approaches to, 272 morphometrics, 402-461 as exemplar of analyses of complex organized systems, 15, 44, 482 shape coordinates as structured variables, 360 data flow in, 403; see also rules of morphometrics brief history of, 404-405 the unusually broad role of hypotheses in, 482 permutation testing and, 453 principal components analysis in, see rules of morphometrics, second principal coordinates analysis in, see rules of morphometrics, second rules of, see rules of morphometrics templates and, Pl.7.14 examples, see under human skull growth, rodent skull growth, schizophrenia Mosteller, F., 239-241 "Mrs. Ples" (hominoid skull), 363 multiple regression assumptions of, in epidemiological studies, 226-227, 244-252 plausibility of, Freedman's scale for, 233-234 predictable failures of, 252 adjustment for bias, 250 biological plausibility, 247-248 confounders, assumptions regarding, 251 dose-response relationships, 248-249 breadth of evidence, 249-250 for challenging models that are otherwise plausible, 252 coefficients of, as direct effects, 229 examples artificial example: Success on IQ and SES, 224, 4.31, 4.32 in studies of environmental tobacco smoke, 116, 253-262 indirect effects, meta-analytic estimates of, 257, 4.43, 260-261 as part of linear discriminant analysis, see under Bumpus malaria in West Africa, see under Livingstone as incapable (by itself) of driving numerical inferences, 251-252, 497 the three interpretations of causal and least-squares analyses are arithmetically the same, 232-233 as counterfactual, 227-231, 4.32, 233 "holding constant," 206, 230-231 as path model, 231, 4.33, 233, 6.10 direct and indirect effects, 229

as least-squares fit, 231-233

Cambridge University Press 978-1-107-02415-1 - Measuring and Reasoning: Numerical Inference in the Sciences Fred L. Bookstein Index More information

Index

see also normal equations modeled as geometry, 4.31 special cases of analysis of covariance, 234-239, 4.34 ecological fallacy in, 4.35, 237 added-variable plots, 239-240, 4.37, 4.38 linear discriminant analysis, 242-244, 4.40 variance, "explained" and "unexplained," language of, 223 with uncorrelated predictors, 224-227, 4.32 see also additive conjoint measurement multiplication geometrization of, see hyperbolic paraboloid and rank-one matrices, see singular value decomposition "multivariate statistics," see linear multivariate analysis N (Avogadro's number), 179, 186 see also under Perrin Nash, L., 29 Nature, assumptions regarding, see ignorance; law, physical Nature (journal), 208-210 Neanderthals, skull data of, 364, 6.7 Nebelmeer, Der Wanderer über dem, see Wanderer Netflix Prize, won by an SVD algorithm, 354 network diagrams, 5.11 Newton's law of gravitation, 28, 2.7, 58-70, 143 as both mathematics and physics, 68-70 relevance of the inverse-square formulation, 59 NHSST, see significance testing Nisbett, R., studies of culture, 273-274 NOAA (National Oceanographic and Atmospheric Administration), approach to climate change of, 107, 3.8 Nobel prizes, see under Alvarez, Arrow, Crick, Einstein, IPCC, Kahneman, Marshall, Millikan, Perrin, Warren, Watson nomogram, 380 Normal distribution, 14, 46, 2.10, 116, 154-163 in biology, only an idealization, 160 no longer a requisite for using textbook statistics, 162 ignorance, as Jaynes's justification for its use, 315 in mathematical statistics, 161-163 its two independently measureable and interpretable parameters, 183 as characterized by the linearity of all regressions, 169 the reproducing characterization, 314 sums of Normals are again Normal, 161, 162, 166

529

as "most disorderly" for given mean and variance, 161, 315 see also entropy notation and properties, 154 "width" at the inflections is 2 standard deviations, 156 "bell curve" as exponential of a parabola, 4.12 origin of the normalizing constant $1/\sqrt{2\pi}$ of, 156 origins distribution of shots at a target, 159 evenly spaced increments of a Brownian motion, 159 see also under Perrin inhomogeneity is possible, 163, 166 see also Umpire-bonus model appropriately scaled limit of binomials, 153, 4.11, 4.12 Galton's quincunx, 163, 4.15 in scientific sampling and survey research, 160, 161 and temperature change, at continental scale, 106-107, 3.7 normal equations, in least squares, 140, 230, 233, 6.10 as weighted sums of the errors-in-equations, 139 null-hypothesis statistical significance testing (NHSST), see significance testing numbers, role in science of, xxvii obedience, Milgram's experiment on, 266-272, 285 "authority of the experimenter," 270 calibration as consilience, 267-270, 4.50 basic dramaturgy, 266-267 ethical issues, 270-272 choice of a mensurand, 4.49, 269-270 observer-expectancy effect, 277 off-diagonal entries of a correlation matrix, see under factor analysis of the inverse of a covariance matrix, see under precision matrix Olson, E., 72 On the Mode of Communication of Cholera, see Snow organisms, as complex organized systems, 160, 402 Ornstein-Uhlenbeck process, 316n7 "orphan tsunami," see Seattle, earthquakes near Oxnard, C., xxiv

paleoanthropology, limits of abduction and consilience, in, 213, 301

More information

530

Index

paleomagnetism, see under continental drift Pangæa, Panthalassa, 19 paraboloid, 348-349, 6.2 see also hyperbolic paraboloid parapsychology, as pathological science, 207-208 Partial Least Squares (PLS), 366-372 and additive conjoint measurement, 379 by count of separate measurement blocks two-block as a path analysis, 6.11 as an SVD, 371 iterative algorithm for, 375-376, 6.15 interpretation in terms of scores, 371 example from fetal alcohol psychology, 6.14 example from endophrenology, 448-449, 7.24 three-block algorithm for, 376-377, 6.15 multiblock ("domino PLS"), 377 and passive smoking, according to the U.S. Surgeon General, 254 for strain energy against shape change, 7.30 structured variables in, 372, 402 see also shape coordinates styles of, 366-367 partial warps, 423, 439, 7.7, 7.17, 7.18 passive smoking, see environmental tobacco smoke path analysis, path coefficients, 140, 162, 367-368 see also under multiple regression, as path analysis pathological science, 42, 116, 203, 206-212 Feynman's views on, 212 Langmuir's and Rousseau's criteria for, 207 pattern languages, 306n5 patterns, see complex organized systems Pauling, L., 214-215, 219 PCA, see principal components analysis PCO, see principal coordinates analysis Pearl, J., xxi, 220, 353 Pearson, K., xxi, xxvii, 15, 34, 53-55, 2.17, 315, 361, 443, 476, 499 and civic virtue, 466-471 and Cromwell's skull, 463-466 and the inheritance of human height, 168-171, 4.16, 4.17, 7.34, 7.36 see also under correlation, formula for; principal components; chisquare; civic virtue Peirce, C. S., xxviii, 4, 12, 13, 85-86, 91-92, 150, 303, 405, 491

periodic table of the elements, 18, 52–53, **2.14**, **2.15**, **2.16**

permutation testing, 451-452, 7.26 Perrin, J., study of molecular magnitudes, 4, 11, 14, 37–38, 40–41, 116, 175–186, 284, 285, 490 abductive in form, 179 atmosphere, rarefaction of the, 177 consilience as explicit goal of, 176 as achieved, 183-184 the kinetic hypothesis, 176 measurements, design of, 177-178, 185-186 origins of, in Brownian motion, 176-177 verified as regards both slope and uncertainty, 181 - 182Einstein's equipartition law for, 182 random walk, as one component of the study, 179-182, 4.19 one-sentence summary of, 3 variations of experimental conditions, 178, 181 around a line, themselves lawful, 182 weight of a particle, as measureable intermediary, 177 photoelectric effect (physics), see under Millikan photography, averaged, see under Galton physics, as a domain specialized for abduction, 96 role of abduction and consilience in, 143-144 physiognomy, 34, 5.3 π (pi), unexpected appearances of, 156, 474–476 Planck's constant (h), precision of Millikan's estimate of, 148 plasticity (of organismal form), 44-45 plate tectonics, see continental drift Platt, J., xxiii, 13, 101-104, 482, 491 on mathematics, 103 on the social sciences, 103-104 plausible rival hypotheses, 263-266 PLS, see Partial Least Squares Pólya, G., 87-88, 95, 159, 173n8, 324 Popper, K., 477 power laws, for biological growth, 237 pragmatism (American school of philosophy), as context of abduction, 100 precision matrix, 318-321, 369 principal components analysis characterizations of as uncorrelated extrema of variance, 358 low-rank least-squares fits to data, see singular value decomposition for dimension reduction prior to covariance distance analysis, 398-399 common, 362 examples hominid evolution, 362-366, 6.7, 6.8, 6.9 rodent skull growth, 7.5, 7.16

Index

531

interpretation as patterns, 361 scores as weighted averages of structured variable lists, 359-360 for the patterns of small variance, 361 for multidimensional random walks, 50-51, 2.13, 289, 473-474 and principal cooordinates analysis, 384 power method for, 376 statistical aspects variation of the principal directions of, Anderson's formula, 359 Anderson's statistic for meaningfulness of, 322-324, 5.12, 328, 363n4 contraindicated when showing clusters known a-priori, 364 see also singular value decomposition principal coordinates analysis, 381-384, 6.17 and principal components analysis, 384 examples, using covariance distance, 398-399 relative warps as principal coordinates of Procrustes shape distance, 415 see also singular value decomposition; rules of morphometrics, second prior distribution, 192-193 in Perrin's study, 178, 184 see also under inverse probability principal warps, see partial warps Procrustes (mythical Greek), 410n1 Procrustes average shape as coefficient matrix in the projection notation, 419 as nuisance parameter, 416-417 Procrustes distance algorithms for, 411-412, 7.2 has no biological content, 404 as common metric for shape variables, 361, 402, 414, 419 Procrustes form distance, 419-420 Procrustes form space, 6.7, 420, 424 see also rules of morphometrics, third Procrustes registration, 338, 344, 412-414, 7.4 restoring the Centroid Size component, 419-420 see also shape coordinates Procrustes shape distance, 410-412, 7.2 Procrustes shape space, 289 as projection down from digitizing space, 417-419 subspaces of, 418, 7.17 proof "decisive," 178, 179, 286 "incontrovertible," 122, 126 see also mathematics, notes on Prossinger, H., xxiv

proteomics, see Ramachandran plot psychology, see evolutionary psychology, social psychology psychophysics, see Hagen's hypothesis quadric surfaces, see ellipsoid; hyperbolic paraboloid; discrimination, quadratic quasi-experimental designs, 265 Queteletian fallacy, 162 quincunx, see Galton Raff, A., see under Zebra Diagram Ramachandran plot (proteomics), 293-296, 5.2, 5.3, 491, 492 randomness, 14, 312-331 as a null, vs. clinical inutility, 204 random walk, 45-51, 316-318 distribution of an excursion statistic, 317-318, 5.10 intuitive inaccessibility of, 48-50 and the Guttman scale model, 473 in Perrin's study of Avogadro's number, see under Perrin principal components of, 7.37 rank, of a matrix, 350 of Procrustes shape coordinates, 414n5 Rao, C., 158 regression and the AIC, 5.19 and climate change, see Berkeley Earth elliptical geometry of, 168, 171-173, 4.18 typical Victorian example of, 4.16, 4.17 intercept of the line on the ellipse, 173 Freedman's scale of practicality of, 233-234 intercept, see under intercept on the quincunx, 165-167, 4.14 regression line, as prediction or explanation, 167 not necessarily causal, 238 limits of the linear argument, 262 the case of multiple regression, 231 as one of a pair of lines, 169, 4.17, 223 see also under correlation slope, see under slope see also laws, physical, ofter are linear "regression to the mean," 173, 223 relabeled reflection, 454 relative eigenanalysis, 6.22 see also covariance distance relative warps, 362, 416 see morphometrics, principal components in replication, see Collins rete mirabile, as metaphor for complex systems analysis, 495

532

Index

retroduction, 92n9 see abduction Reyment, R., xxi, xxiv, 405n1 ridge curve, 407 examples, on the human mandible, 434-436, Pl.7.14 Rohlf, F. J., xxiv, 402 Rosenthal, R., 277-278 Rothman, K., xxi Rousseau, D., 42, 207 Ruhla, C., 186-187 rules of morphometrics, 15 first, 407 examples, 6.8, 6.25, 6.26, 7.1, 7.14, 7.19, 7.22, 8.1 second, 415 examples, 5.9, 5.20, 5.21, 6.7, 7.5, 7.13, 7.19, 7.22, 7.30, 8.3 third, 420 examples, 6.7, 7.6, 7.13 fourth, 426 examples, 6.9, 7.9, 7.13, 7.15, 7.16, 7.17, 7.18, 7.19, 7.23, 7.24, 7.28, 8.4 Russell, B., xxvii sample size, and significance testing, see under Jeffreys Saturday Review, xxii scaling of shape data, see Centroid Size of variables, 132 see also under correlations schizophrenia, morphometric examples on, 328, 5.16, 5.17, 443-445, 7.19 sciences, unity of the, 30 scientific fact, definition of, see under Fleck scientific paper, format of, xx Scorpion, a sunken submarine, 3, 5-11, 204 finding it as an abduction, 97-98 as the closure of a numerical inference, 10 visualization and, 18 seafloor spreading, 3, 18-27, 2.6, 211 as an abduction, 98 the Juan de Fuca ridge map and, 22, 2.4 magnetic reversals and, 22, 26, 2.3, 2.4, 2.5 Seattle, earthquakes in or near, xxii, 98-99 Seidler, H., xxiii selection of biometric data, 43 eigenanalysis as, 309 emphasis upon, in numerical inference for complex systems, 290

rules for, in typical complex systems studies, 300 semilandmarks, Pl.7.10, Pl.7.14, 426-437, 456-459 and bilateral symmetry, 457-458, 7.29 examples of human brain images, 5.20, Pl.7.10 human skull growth, 7.13 formula for, 427 interpretation, 431-432 as an additional parameter for the relabeling group, 427 single-point prototype for, 428-429, 7.11 informal statistic for, 340 on surfaces, 432 working from a template, 433-437, Pl.7.14 see also thin-plate spline Semmelweis, I., principal discovery of, as an abduction, 86-87 Shannon, C., 331 shape coordinates Procrustes, 410-415 see also rules of morphometrics, second two-point, 439-443, 491n2 see also under variables, structured sickle-cell anemia, evolution of, 212-213 significance testing the Bayesian replacement, 193-198 and health bureaucracies, 201 domains of unsuitability for studies of coin-flipping, 195 see under Jeffreys paradox for studies of complex systems, 304 replacement by extended distributions, 492 see under singular value decomposition as an impediment to the development of morphometrics, 405 as responsible for parapsychology, 208 in a linear multivariate context, 311 null-hypothesis statistical (NHSST) as deplorable, xxii, 83, 116, 198-201, 211 with the exception of the "strong form," 199, 284 single-factor model, 396; see also factor, general singular value decomposition (SVD), 14, 289, 349-354, 375-376, 482 as decomposition of the sum of squared matrix entries, 352 formula for, 351 associated identities, 352 interpretation of second and higher singular vectors, 361

Cambridge University Press 978-1-107-02415-1 - Measuring and Reasoning: Numerical Inference in the Sciences Fred L. Bookstein Index More information

Index

533

central role in the pattern analysis of organized systems, 350, 483 regarding abduction, 483-484 regarding consilience, 484-485 rank-1 example, 351, 6.3 iterative algorithm for, 375-376, 6.15 rank-2 example (viremia in monkeys), 354-357 salience of the findings, vis-á-vis a PCA, 357 regression coefficients, singular vector elements as, 353 see also under its special cases: Partial Least Squares, principal components analysis, principal coordinates analysis SIV (simian immunodeficiency virus), example of an SVD, 354-357 skull, human, in midsagittal section, Pl.7.10 Slice, D., xxiv slide rule, 4.28, 219, 6.23, 396 sliding landmarks, see semilandmarks slope (in regression analysis) abduction on, 260-262 in biology, 100 consilience on, 148, 178, 4.21 formula for in simple regression, 140 in multiple regression, see multiple regression, as path model as weighted average of casewise slopes, 141 small multiples, principle of (visualization), 81, 3.5 89 Snow, J., on the mode of "communication" (dissemination) of cholera, 14, 115, 117-126, 211, 249, 284, 285, 490 abduction and, 118, 123, 126 Broad Street pump, role of, in this inference interpretation of the 1854 epidemic near, 118 map of. 4.1 natural experiment, logic of the, 122, 200 counterfactual summary of, 126 shoe leather, as characterization of his methodology, 97, 122 one-sentence summary for, 3 water companies of London, role of, in inference, 118-126 death rates by neighborhood in 1853, 4.2 death rates by neighborhood by water company in 1854, **4.4**, **4.5** map of. Pl.4.3 vis-á-vis the Marshall-Warren ulcer studies, 204 social class as confound, in studies of fetal alcohol damage, 15, 461-463 as a consideration in Pearson's studies of inheritance, 169n7, 7.34, 468-470

social psychology, abduction and consilience in, 272-274, 276-278 social sciences abduction and consilience in, 15-16 critiques of numerical inferences in, various examples, 272-280 Kuhn's comments on, 41 types of measurement, 278 Wilson's comments on, 36 sociobiology, 36, 274-276 sociology, limits of abduction and consilience in, 278-280 space, Euclidean models for, 28 spacetime Galilean models of, 28 role in visualizations, 57-58 sparrows, effect of a snowstorm upon, see under Bumpus spectrum, index of one type of variable list, 360 splenium intercept point, 8.1, 8.2, 8.3 spline, thin-plate, see thin-plate spline standard deviation, 132 standard error of the mean, 134 standard scores (in correlational analysis), 221 statistics inutility of standard courses in, xxii a 20th-century curriculum for, 302-303 a 21st-century curriculum for, 494, 496-500 role in physics, 54-57 Stirling's approximation for n!, 152, 174, 196; see also factorial Stoppard, T., Rosencrantz and Guildenstern are Dead, 93 strain, statistics of, 459-461, 7.30 strain energy, relation to bending energy, 425, 7.30 Streissguth, A., xxiii, 296, 5.4, 5.7, 372-375 strong inference, 13, 100-103, 211, 280-284 in complex organized systems, 334, 338 definition of, 5 Platt's characterization of, 101 studentized residuals (in multiple regression), 233 subitizing (direct apprehension of small counts), 178 submarine, see Scorpion "Suddenly I became aware" (comment of J. Watson), 217, 491 sum of squares, 131, 132; see also least squares as an energy term, in interpreting an SVD, 361 surprise, 117, 144, 210, 217, 247, 296, 296n2, 300, 303–304, 312, 394, 481, 484, 496 as a component in the definition of abduction, xxviii, 86 in a grid, 326, 5.14 in an image, 330

534

Index

surprise (cont.) in an investigation of random walk, 318 Alvarez's iridium anomaly, 281, 4.53 arguing against surprise where it is unwanted, 259 see also plausible rival hypotheses SVD, see singular value decomposition swept area (in gravitational physics), 64 Switzerland, 2003 summer temperatures in, 90 symmetry, 26, 158, 190, 226, 361 bilateral, 454-456, 7.27, 7.28 reductionism vs. holism as an example of, 35 of semilandmarks, 456-458 substituting the reflection plane for a landmark, 459 symmetry curve, 407, 445, 7.21 Taleb, N., xxi template (algorithmic schematic of a semilandmark scheme), 433-436, PL 7.14 tensor, as a report of a uniform shape change, 443 teratology, see epidemiology; fetal alcohol Tetrahymena (protist), 237-239, 4.36 thin-plate spline, 403, 421-426 lack of any biological basis for, 425 bending energy of, 423 construction of, 7.8, 424 kernels, in 2D and 3D, 425 prototypes, 7.7 visual processing of, 425 see also rules of morphometrics, fourth Thompson, Sir W., xxvii, 403 time series, patterns of, after an intervention, 4.46 as index of a variable type, 361 see also viremia total effect, see under multiple regression, as path model trigonometric functions (sine, cosine), 28, 61-62, 473 tsunami, orphan, see Seattle, earthquakes near Tufte, E., 81, 253 Tukey, J., 201 formula of, for approximating regression coefficients, 226, 231 twins, identical, see under Weiss ulcers, 3, 201-205, 211, 491 the main abduction in, 204 two types of graphics for, 4.25 one-sentence summary for, 3

ultrasound, neonatal intracranial, 485–488 "Umpire-bonus model," 162 *see also under* Galton, F., quincunx machine of unicorns, and abduction, 210 uniform term, in Procrustes shape space, 418, 7.17. 7.18. 457 see also partial warps validity and invalidity, see plausible rival hypotheses variables, structured, varieties of, 360, 372 variance, 132; see also least squares "explained" and "unexplained," 222-223 variances of independent processes add, 133 varilocal superpositions, 340 Varmus, H., xxviii, 35-36 Vilmann, H., rodent skull data of, 398-399 see also Bookstein, examples, rodent skull growth viremia, SIV-related (example of the SVD), 354-357 Visible Female (NIH avatar), hidden consilience in, Pl.2.8, 493 visualization, and numerical inference, see inference, numerical, visualization and Waals, van der, J., estimates of molecular magnitudes by, 175-176 Wanderer über dem Nebelmeer, Der (painting by C. D. Friedrich), front and back covers, 43, 45, 70, 296, 312-313, 484 as metaphor for multiscale representation of complex processes, 313 warps, see principal warps, partial warps, relative warps Warren, R., 116 see also under ulcers water companies of London, see under Snow Watson, J., 4, 14, 99, 116 see also under double helix Weaver, W., 302 Wegener, A., 19-22, 42, 491 see also Atlantic Ocean weighted average, see average, weighted Weisberg, S., regression textbook of, 169, 220-221, 233, 240 Weiss, P., xxvii, 18, 45, 70-71 Whewell, W., 17 Wigner, E., xxvii, 6, 12, 28, 29, 33, 51, 69, 84, 92, 149, 184–185, 293, 492 Millikan's study as illustration of, 149-150 Wilkinson skull, see Cromwell Williams, R., 72 Wilson, E. B., xxi Wilson, E. O., xxvii, 12-13, 15, 17, 29-37, 405 Wilson, J. T., 22, 2.4, 2.5 wind direction, as a mappable variable, 127, 4.6

Index

Winn, J., xxiv
Wold, H. and S., 367
Worsley, K., Markov models for images of, 328–330
Wright, S., 59, 72, 160, 229, 231, 367
leghorn chicken data, correlation matrix of, 319–320

535

Yucatán, see Chicxulub

Zebra Diagram, 22, **2.3** Ziliak, S., 198–201 Ziman, J., xxi z-scores (standardized variables), unsuitability for consilient reasoning, 361