

Index

- |, Alternatives, 105
- &&, And, 51–52, 316–317
- @@, Apply, 135
- @@@, Apply at level one, 137
- _, Blank, 96
- ___, BlankNullSequence, 100, 123
- ___, BlankSequence, 96, 100
- ;, CompoundExpression, 12, 29
- /;, Condition, 102, 161
- ==, Equal, 51, 190
- <<, Get, 380
- ≥, GreaterEqual, 51
- >, Greater, 51
- ++, Increment, 169
- ?, Information, 16
- <, Less, 51
- ≤, LessEqual, 51
- /@, Map, 134
- ||, Or, 52
- %, Out, 9
- [[...]], Part, 24–25, 72
- ^, Power, 10
- .., Repeated, 105
- ..., RepeatedNull, 105
- ===, SameQ, 190
- =, Set, 43
- :=, SetDelayed, 44
- #, Slot, 176
- ;;, Span, 72
- ~~, StringExpression, 256
- <>, StringJoin, 248
- \t, (raw tab), 168
- ≠, Unequal, 51
- Abecedarian words, 268
- Aborting calculations, 15–16
- Abs, 35–36
- Accumulate, 32, 150
- Accuracy, 34
- Acyclic graphs, 189, 199
- Adjacency lists, 188
- Adjacency matrices, 144
- Adjacency structures, 188
- AdjacencyGraph, 65–66, 145
- AllTrue, 69
- Alternative input syntax, 13
- Alternatives (|), 105, 364
 - in string patterns, 259
- Amino acids, visualization of, 240, 302
- Anagrams, 252, 278, 280
 - efficiency of computations, 364
- And (&&), 51–52, 316–317

- AnyTrue, 69
- Append, 77
- Apply (@@), 135
- ArcLength, 119
- ArcTan, 329
- Area of triangles, 121, 332–333
- Arg, 36
- Argand diagram, 35
- ArrayPlot, 65
- Arrays
 - constant, ConstantArray, 66, 78, 346
 - creating, Array, 67
 - depth of, ArrayDepth, 71
 - in other languages, 90–91
 - operations on, 196
 - packed, 356
 - sparse, SparseArray, 66–67, 349
- Ascii characters, 244, 246
- Assignments, 43
 - compared with transformation rules, 111
 - delayed, 44
 - immediate, 43
 - parallel, 214
 - to list components, 78
- Associations
 - converting to lists, 85
 - creation of, 85
 - formatting values in, 173
 - keys, 85
 - looking up values, Lookup, 85
 - operating on, 87
 - sorting on keys, 87–88
 - sorting on values, 178
- Atomic expressions
 - graphs, 21–22
 - images, 22
 - numbers, 20–21
 - sparse arrays, 22
 - strings, 21
 - testing for, AtomQ, 20, 50
- Attributes, 55
 - clearing, ClearAttributes, 140
 - finding functions with, 184
 - Hold, 55
 - Listable, 55, 57
 - of mathematical constants, 36
 - Protected, 56
 - setting, SetAttributes, 56, 140, 356
- Autocorrelation, 230
- Auxiliary functions, 240
- Babbage, Charles, 57
- BaseForm, 37
- Begin, 383
- BeginPackage, 386
- Begriffsschrift, 19
- Benford's law, 82–83, 144
- BernoulliDistribution, 205, 216, 240
- Biased distributions, 41
- Bibliographies
 - creating with Association, 88
 - formatting values, 173
- Bigrams, 83–84, 255
- Binary exponentiation, 151
- Binary matrices, 199
 - computed in parallel, 367
- Binomial coefficients, 68
- Binomial, 348
- Bit operators, 53
 - BitOr, 53
 - BitXor, 53, 191
- Blanagrams, 277, 369
- Blank (_), 96
- BlankNullSequence (___), 96, 100, 123
- BlankSequence (_), 96, 100
- Blas routines, 355
- Block, 212
- Blokland, Frank, xvi
- Bond percolation, 240
- Boole, 66, 318
- Boolean operators, 51
- BooleanTable, 239
- Borges, Jorge L., 269
- Bounding boxes, points in plane and space, 144
- Bubble sort, 124
- C language
 - compared with Mathematica, 90–91
 - compilers, 375
 - pointers, 79
- Caenorhabditis elegans, 193
- Caesar, Julius, 250
- Calculations, interrupting or aborting, 15–16
- Calkins, Harry, 302
- Car Talk, 253
- Cartesian coordinates,
 - converting from polar angles to, 187

- Cartesian products,
 - using transformation rules, 115
- Cases
 - basic examples, 97, 197
 - level specification of, 101–102
- Cells
 - initialization, 388
 - printing, `CellPrint`, 89
- Center of mass, of random walk, 227
- `CentralMoment`, 228
- Centroids,
 - of clustered data, 201–204
 - of triangles, 179
 - visualizations of, 286
- Champernowne constant, 49
- Chandah-sutra*, 151
- `CharacterRange`, 244
- Characters, 249–250
- Chemicals
 - data for, `ChemicalData`, 325
 - positions of atoms, 325
 - radius of atoms, `VanDerWaalsRadius`,
 - 325–326
 - space-filling plots, 324, 342
- `ChiSquareDistribution`, 39
- Church, Alonzo, 133
- Ciphers
 - Caesar, 250
 - ciphertext, 250
 - mixed-alphabet substitution, 254
 - permutation, 251–252
 - substitution, 250
 - transposition, 254
 - XOR, 40, 247
- Circumcenter of triangles, 292, 342
- Circumsphere, 338
- Clearing
 - attributes, `ClearAttributes`, 140
 - attributes, messages, or options,
 - `ClearAll`, 140–141
 - values, 43
- Clipping, amplitudes in data, 173
- `CloseKernels`, 367
- Clustering data, 201
 - visualization of, 207
- Coleman, Ornette, 14
- Collatz sequences, 109, 173
 - package for, 392
- Collinear points, 291
- Collocation of words, 280
- Color wheel, 291
- `ColorData`, 203
 - CPK model, 326
- Comments, 14
- Compilation
 - autocompiling, `CompileOptions`, 361
 - of functions, `Compile`, 373
 - output of, `CompiledFunction`, 373
 - parallelizing, 374
 - runtime options for, 374
 - to C, `CompilationTarget`, 375
 - to listable functions, 374
 - to virtual machine, 373
 - tools for, `CompilePrint`, 375
- Complement, 80
- Complex numbers, 35
 - Argand diagram for, 35
 - conjugate, `Conjugate`, 35
 - converting to polar form, 40
 - imaginary part, `Im`, 35
 - length of, `Abs`, 35
 - phase angle, `Arg`, 35
 - random, 38
 - real part, `Re`, 35
 - visualization of, 339
- Composite numbers, 129, 185
- Compound expressions, 29
- Compound functions, 45
- Computation
 - symbolic vs. numeric, 353
 - threading, 368
- Computational geometry
 - convex hull, 312–313
 - point in polygon, 332
- Condition numbers, 215, 241
- Conditional expressions, `Condition (/;)`, 161
- Conditional functions
 - `If`, 159
 - nested, 163
 - `Piecewise`, 162
 - `Switch`, 164–165
 - `Which`, 164
- Conditional patterns, `Condition`, 102
- `Conjugate`, 11, 35–36
- `ConjugateTranspose`, 30–31

- ConnectedGraphQ, 50
- ConstantArray, 66, 78, 346
- Constants
 - attributes of, 36
 - localizing, With, 212
 - mathematical, 36
 - sorting, 124
- Contexts
 - current, \$Context, 383
 - exiting current, End, 384
 - global, 383
 - nested, 385
 - of symbols, Context, 383
 - path for, \$ContextPath, 383
 - private, 386–387
 - starting new, Begin, 383
- Contractions, 264
- Control objects
 - PopupMenu, 301
 - setter bars, 301
 - two-dimensional slider, Slider2D, 302–303, 377
- ControlType, 301
- Converting
 - associations to lists, Normal, 85
 - between number bases, 37, 186
 - character codes to strings,
 - FromCharacterCode, 245
 - complex numbers to polar form, 40
 - contractions in strings, 264
 - date formats, 126, 216
 - expressions to strings, ToString, 244
 - list of digits to number, FromDigits, 37
 - lists to associations, Association, 85
 - polar angles to Cartesian coordinates, 187
 - sparse arrays to lists, Normal, 67
 - strings to binary codes, 40
 - strings to character codes,
 - ToCharacterCode, 246
 - strings to expressions, ToExpression, 244
 - to packed arrays,
 - Developer`ToPackedArray, 360
 - True/False to os and is, Boole, 66
- Convex hulls
 - boundary mesh region for,
 - ConvexHullMesh, 313
 - ConvexHull, 312
 - to compute diameter of point set, 365
- Convex polygons, 332
- CoordinateBoundsArray, 69
- CoprimeQ, 54
- Count, 70, 108
- Counting
 - approaches, efficiency of, 348
 - binary matrices, 199, 367
 - change, 116, 129, 204
 - characters in strings, 254
 - iterations in loops, 171
 - nucleotides in sequences, 259
 - number of multiplies, MultiplyCount, 115
 - steps inside looping constructs, 352
- CPK model, for coloring atoms, 326
- Cross products, 121
- CSV file format, 118, 193, 219
- Cylinder, 288
- Darwin, Charles, 249
- Data
 - adding headers to tabular, 80–81
 - autocorrelated, 230
 - clipping values, 173
 - clustering, 201, 207
 - displaying tabular, Grid, 63
 - filtering, 117, 129
 - finding convex hull for, 312–313
 - fitting with linear model, 124–125
 - historical differences from mean, 130
 - missing, Missing, 126
 - nonnumeric values in, 108–109, 196
 - operating on arrays of, 196
 - removing outliers from, 108–109, 110, 117
 - scraping from web pages, 257
 - smoothing noise in, 371
 - spikes in, 180–181
 - visualizing, ArrayPlot, 65

Data sets

- avian influenza A (National Center for Biotechnology Information), 319
- beam deflection (NIST), 231–232
- C. elegans* (Dana-Farber Cancer Institute), 193
- historical land temperatures (NASA Goddard Institute for Space Studies), 219
- power grid (University of Florida sparse matrix collection), 65
- sea and land surface temperatures (Goddard Institute for Space Studies), 130
- serotonin (PubChem, National Center for Biotechnology Information), 325
- sunspot activity (Royal Observatory of Belgium), 125, 232
- text transcripts and tagged texts (British Academic Spoken English), 266–267
- water reservoirs (CA Dept. of Water Resources), 118

Dataset, 87

Dates

- conversion of, 126, 216
- difference between, `DateDifference`, 128
- list of, `DateList`, 126

Declarative style of programming, 6

Default values, 183

Defer, 28–29, 43

Definitions

- multiple, 47
- of variables, 41

Delayed assignments, `SetDelayed` (`:=`), 44Delayed rules, `RuleDelayed` (`:->`), 112

Delete, 74

DeleteCases, 98, 108

DeleteDuplicates, 80

Density of graphs, 54

Deploying packages, 388

Diameter of point sets, 144, 185

- computational efficiency, 365

Dice, visualization using transformation rules, 115

DictionaryLookup, 187, 268–269

Digit roots, 175

Digit sums, 175

`DigitCharacter`, 257

Dimensions, 70–71, 193, 289

Directive, 316

Directives, for graphics, 286

`DistanceFunction`, 240`DistributeDefinitions`, 370

Divergence, of vector field, 146

DNA

- bases used in random strings, 269
- computing GC ratios, 272
- displaying sequences of, 275
- sequence analysis, 272

Do, 166

- counting steps inside loop, 352

Documentation Center, 17

Dot plots, 317

- labeling, 341

- window (or block) size, 320, 340–341

Dot product, `Dot`, 141

Drop, 74

Duchamp, Marcel, 302

Dynamic, 297

Dynamic expressions

- constraining movement of, 303
- control objects for, 294
- locators, 294
- saving state, 300
- scoping of, `DynamicModule`, 299–300
- setting control type, `ControlType`, 301
- updating values within, 298

Dynamic programming, 155

`DynamicModule`, 299, 337

EdgeCount, 54

Eigenvalues, 30–31, 200

Eigenvectors, visualization of, 229, 342

`ElementData`, `VanDerWaalsRadius`, 325–326

Elements of lists, 60

Ellipsoids, 301

Encoding, text, 250

`EndPackage`, 387–388

Entropy, 41

Epicycloids, 341

Equal (`==`), 35, 51, 190

Equality

- of strings, 245
- testing for, `Equal` vs. `SameQ`, 35, 70

- Equilateral triangles, 216
- Eratosthenes, Sieve of, 223, 351–352
- Error messages, 220
- Errors, syntax coloring of, 14–15
- Euclidean algorithm,
 - for greatest common divisor, 174
- Euclidean plane, quadrants, 175
- Euler, Leonhard, 342, 371
- Euler lines, 342
- Eulerian numbers, 158–159
- Evaluate, 56
- Evaluation
 - deferring, `Defer`, 28–29, 43
 - of arguments to functions, 28
 - preventing, `HoldForm`, 29
 - releasing held, `ReleaseHold`, 29
 - sequence of, 28
 - tracing of, 30
- EvaluationMonitor, 170–171
- EvenQ, 50
- Except, 98, 197
- ExponentialMovingAverage, 187
- Exponentiation, notation for, $^$, 10
- Expressions, 20
 - atomic, 20
 - compound, 29
 - deferring evaluation of, 28–29
 - display of, 27
 - evaluation of, 8, 28
 - extracting parts of, 122
 - getting dimensions of, `Dimensions`, 70–71
 - head of, 20
 - internal form for, `FullForm`, 23
 - length of, `Length`, 23
 - levels of, `Level`, 26
 - mapping functions over, 134
 - nesting of, 30
 - normal, 22
 - parts of, 25, 72
 - structure of, 22
 - visualizing with `TreeForm`, 26
- FaceGrids, 288
- Factoring
 - integers, 145
 - large integers, 366
- FASTA file format, 318, 319, 341
 - importing, 273
- Fibonacci, Leonardo, 152
- Fibonacci numbers
 - computed iteratively, 174
 - defined recursively, 152
 - defined using dynamic programming, 155
 - definition, 104
 - fast computation with matrices, 172
 - leading digits of, 82–83, 144
 - negative integer indices, 158
 - speeding up computation of, 158
- Fibonacci words, 255
- Filtering data
 - removing nonnumeric elements, 108, 129
 - removing outliers, 117, 142
 - removing spikes, 181
 - using Gaussian kernel, `GaussianFilter`, 127
- FindClusters, 202
- FindFile, 382
- FindPeaks, 127–128
- FindShortestTour, 303, 331
- First, 74
- Fitting data, `LinearModelFit`, 125
- FixedPoint, 148
- Flatten, 77
- Fold, 150
- FoldList, 150
- For, 168, 224
- FreeQ, 69
- Frege, Gottlob, 19
- FromDigits, 37
- FullForm, 23
 - of strings, 244
- Function, 176
- Functions
 - alternate syntax for, 13
 - applying, `Apply`, 135
 - applying to lists, 74
 - argument checking, 165
 - auxiliary, 240
 - composition of, 30
 - compound, 45
 - definitions for, 41
 - evaluation of arguments, 28
 - indexed, `MapIndexed`, 182

- (Functions continued)
 - information about, 16
 - iterating, 146
 - listing all in System` context, 184
 - mapping of, 134
 - multiple definitions for, 47
 - nesting of, 30
 - piecewise-defined, 49, 162, 175
 - private, 237, 379
 - public, 237, 379, 387
 - pure, Function, 176
 - syntax of, 13
- Galileo Galilei, 125
- GaussianFilter, 127
- Gavioli, Anselmo, 19
- GC ratios, 259, 272
 - visualization of, 275
- GenBank file format, 277
- GenomeData, 271
- Get (<<), 380
- Global context, Global`, 383
- Golden ratio, as fixed point, 148–149
- Graphics
 - cached values in, 310
 - color wheels, 291
 - Directive, 316
 - directives, scope of, 286
 - displayed with Show, 290, 322–323
 - displaying, 285
 - efficient representation of, 303
 - internal box representation, 309
 - lighting of three-dimensional, 326–327
 - multi-objects, 303
 - numeric vs. symbolic values, 309
 - options, 287
 - primitives, 284
 - reflection of lights, Specularity, 326–327
 - reflection transforms, 290
 - representing with GraphicsComplex, 306
 - rotating, 147–148
 - space-filling plots, 324
 - structure of built-in, 122–123, 288
 - three-dimensional, 288
 - translation of, 148
 - used to visualize roots of functions, 314
- Graphics, 285
- Graphics3D, 288
- GraphicsComplex, 306
- Graphs
 - adjacency, 65–66
 - adjacency matrix of, 144
 - adjacency structures, 188
 - counting edges incident to vertex, VertexDegree, 194
 - deleting self-loops, 195
 - density of, 54
 - directed acyclic (DAGs), 189, 199
 - highlighting parts of, HighlightGraph, 68, 189, 240
 - neighborhood of vertex, NeighborhoodGraph, 188–189
 - power grid as, 65–66
 - protein–protein interactions, 193
 - random, $G(n, m)$, 40–41
 - random, $G(n, p)$, 205–206, 216
 - random walk on, 205
 - regular, 204
 - test for connected, ConnectedGraphQ, 50
- Greater (>), 51
- GreaterEqual (\geq), 51
- Greatest common divisor, 174
- Grid, 63
 - displaying DNA sequences, 276
 - inheriting options from, 276
- GridGraph, 68, 240
- Hamming distance, 190, 204
 - efficiency issues, 364
- Hamming (regular) numbers, 188
- Hamming weight, 48
- HASKELL programming language, 133
- Head, 20
- Heron's formula for triangle area, 143
- Hexadecimal values, 246
- Hexagonal lattice, 312
- HighlightGraph, 68, 189, 240
- Hilbert matrices, HilbertMatrix, 14, 215
- Hold attributes, 55
 - HoldAll, 369
 - HoldForm, 29
- Hollerith, Herman, 19
- Horner's method,
 - for polynomial multiplication, 186

- Hyperlinks, creating from associations, 88
- Hypocycloids, 320, 341
 - dynamic visualization of, 323–324
- IdentityMatrix, 235
- If, 159
- Im, 35
- Images
 - convolving, ImageConvolve, 297–298
 - dimensions of, ImageDimensions, 160
- Immediate assignment, Set (=), 43
- Imperative style of programming, 5–6
- Importing
 - CSV files, 118, 193, 219
 - FASTA files, 273, 318, 341
 - SDF files, 325
 - spreadsheets (.xlsx), 202
 - time series data, 125, 130, 219, 232
- Incenter of triangles, 292
- Indexed functions, MapIndexed, 182
- InfiniteLine, 338
- Infix notation, 13
- Information
 - about built-in functions, 16
 - documentation, 17
- Information theory, 41
- Initialization cells, 388
- Inner products, Inner, 141
- InputForm, 27
 - of plots, 122, 289
 - of strings, 244
- Insert, 77
- Installing packages, 388
- Integer lattice, 69
- IntegerDigits, 3
- Integers, 34
 - extracting digits of, IntegerDigits, 3, 37
 - random, RandomInteger, 38
 - reversing digits of, 3
 - testing for, IntegerQ, 50
- Interactomes, 193
- InterpolatingFunction, 362
- Interpolation, 362
- Interpreted languages, 6
 - Interrupting calculations, 15–16
 - Intersection of lists, Intersection, 80
 - Iteration
 - convergence problems, 149
 - fixed point, FixedPoint, 148
 - functions of two arguments, Fold, 150
 - graphics objects, 147
 - of functions, 146
 - of symbolic expressions, 147
 - Sierpiński triangle, 151
 - with conditions, NestWhile, 149
 - Iterator lists, 61
 - Iterators, multiple, 62
 - Jacobian matrix, 146
 - Jacquard loom, 19
 - JAVA programming language, 6, 133
 - compared with Mathematica, 90
 - Join, 80
 - Josephus, Flavius, 191
 - Josephus problem, 191, 204
 - Julia, Gaston, 378
 - Julia sets, 376
 - Kashi Vishwanath, 157
 - Keys, 85
 - KeySort, 87
 - Klee, Paul, 284
 - Knuth, Donald E., 345
 - Lag plots, 230
 - Languages
 - C, 6, 90
 - comparisons between, 90
 - domain-specific, xii
 - FORTRAN, 6
 - HASKELL, 133
 - interpreted, 6
 - JAVA, 6, 90, 133
 - LISP, 133, 208
 - PERL, 6, 261
 - PYTHON, 6, 133
 - SCHEME, 133
 - Last, 74

Lattices

- hexagonal, 312
- random walk on, 234
- three-dimensional, 312
- visualizing integer, 69

LaunchKernels, 366

Leading digits problems, 82–83, 144

Length

- of data, 193
- of expressions, Length, 23
- of lists, Length, 70

Less (<), 51

LessEqual (\leq), 51

LetterCharacter, 256

LetterQ, 245

Levels of expressions, Level, 26

Lighting, 326–327

LinearModelFit, 125

LISP programming language, 133, 208

Listability, 55, 139, 355

- of built-in functions, 74
- of compiled functions, 374
- setting attribute, 57, 160, 356

Listable, 55

ListLinePlot, 64

ListPlot, 64

Lists

- applying functions to, 74
- compared with arrays in other languages, 90–91
- comparison with pointers in C, 79
- complement of, Complement, 80
- component assignment, 78, 83, 214
- constructing, 60
- converting to associations, 85
- counting frequency of elements in, 70
- deleting duplicates, DeleteDuplicates, 80
- depth of, ArrayDepth, 71
- display of, 63
- dropping elements, Drop, 74
- elements of, 60
- flattening, Flatten, 77
- inserting elements, Insert, 77
- internal representation, 60

intersection of, Intersection, 80

iterators for, 61

joining, Join, 80

measuring length of, Length, 70

nested, 62

operations compared with strings, 249

partitioning, Partition, 76

permuting elements of, 174

position of elements in, 70

removing elements of, Delete, 74

replacing parts of, ReplacePart, 77

reversing order of, Reverse, 76

rotating elements, RotateLeft, 76

sorting, Sort, 75–76

sorting, with rules, 123

syntax of, 11, 60

taking sublists, Take, 73

testing for, ListQ, 50

testing for membership in, MemberQ, 69

transposing elements, Transpose, 77

union of, Union, 80

visual representation, TreeForm, 71

Loading packages

Get, 380

Needs, 380

Localization of

constants, With, 212

names, Module, 210

values, Block, 212

Location of packages, 381

Locators

create on click, LocatorAutoCreate, 295

Locator, 295

panes for, LocatorPane, 300

Logarithm, properties of, 49

Logical operators, 52

Venn diagrams, 316, 339–340

Lookahead/lookbehind constructs, 263

Lookup, 85

Loops

counting iterations, 171

deleting in graphs, 195

Do, 166

Do vs. Table, 174–175

- Loops (continued)
 - efficiency issues, 351
 - For, 166, 224
 - printing intermediate values, 168, 171
 - While, 169
- LowerCaseQ, 245
- Lucas, Édouard, 157
- Lucky numbers, 239
- Machine numbers, 34
- Mandelbrot set, 372
- Manipulate, 293
- Map (/@), 134
- MapCompileLength, 362
- MapIndexed, 182
- Mapping
 - at different levels, 136–137
 - over expressions automatically,
 - Listable, 139
 - pure functions, 177
- MapThread, 137, 190
- Markov models, 205
- MatchQ, 96
- Matrices
 - adjacency, 144–145
 - binary, 199, 367
 - column means of, 196–198
 - condition number of, 215, 241
 - conjugate transpose, 30–31
 - displaying with MatrixForm, 63
 - Hilbert, 14, 215
 - inserting columns and rows, 83
 - Jacobian, 146
 - multiplication of, 144
 - nilpotent, 189
 - Pascal's, 68
 - powers of, 14
 - spectral norm of, 30–31
 - swapping rows and columns, 83, 214
 - testing for square, 102, 143
 - testing for symmetry,
 - SymmetricMatrixQ, 50, 65
 - transition probability, 205
 - triangular, 66, 172, 213
 - Vandermonde, 146
 - visualizing, MatrixPlot, 64
- MatrixForm, 63
- MaxRecursion, 339
- Median, 173, 204
- MemberQ, 69, 184
- Merge sort, 125
- Mersenne prime numbers, 142
 - computed using prime exponents, 146
- Mesh, 314–315
- MeshFunctions, 314–315
- MeshPrimitives, 313
- Messages
 - error and warning, 220
 - in packages, 387
 - issuing, Message, 221
 - multiple associated with symbol, 222
 - switching on and off, 358
 - templates for, 220
- Midpoints, of triangle sides, 179
- Missing data, 126
- Module, 210
 - compared to With, 213
- Monte Carlo algorithms
 - used to approximate π , 207, 365, 371–372
- Most, 74
- Moving averages, 143, 371
 - exponential, 187
- Multi-objects, 303
- Multi-threaded computation, 368
- Multiplication, by binary exponentiation, 151
- N-grams, 84, 255
- Named patterns, 107
- Names, 184, 381
- Natural language processing
 - comparing punctuation in corpora, 280
 - converting contractions, 264
 - distribution of sentence length, 260
 - distribution of word length, 260
 - energy content in, 41
 - finding unique words in corpora, 260
 - letter frequency analysis, 254
 - measuring complexity of texts, 260
 - n-grams, 84, 255
 - pluralizing words, 266
 - stop words, 267
 - text comparison, 371
 - word collocation, 280
- Natural numbers, 54
- Nearest neighbor algorithm
 - used to solve TSP, 207

- Needs, 380
- Nested lists, 62
- Nesting functions
 - Nest, 146
 - NestList, 146
 - NestWhile, 149, 183
- Networks
 - power grid, 65
 - protein–protein interaction, 193
- Newton's method for finding roots, 166, 183
- Nilpotent matrices, 189
- Norm, 31, 185
- Normal expressions, 22
- NormalDistribution, 39
- Normality of digit sequences, 40
- Notebook interface, 8
- Nucleotide sequences
 - aligning, 318
 - analyzing frequency in DNA, 143–144
 - bases used in, 269
 - displaying, 275
 - GC ratios, 272
 - n*-grams in, 255
 - visualizing with dot plots, 317
 - window (or block) size, 274
 - word length, 143–144
- NumberForm, 40
- NumberQ, 36
- Numbers
 - binary representation, 48
 - Champernowne, 49
 - complex, 35
 - composite, 129, 185
 - concatenating, 49
 - constants, 36
 - controlling display of digits in, 40
 - converting between bases, 186
 - display of approximate, 27
 - Eulerian, 158–159
 - explicit vs. implicit, 36–37
 - extracting digits of, 37
 - Fibonacci, 82, 152
 - Hamming (regular), 188
 - Hamming weight of, 48
 - integers, 34
 - leading digits of Fibonacci, 144
 - lucky, 239
 - machine, 34
 - Mersenne, 142
 - Mersenne prime, 146, 371
 - natural, 54
 - perfect, 50–51, 143, 216, 371
 - periodicity of digits in, 41
 - rational, Rational, 34, 48, 57
 - real, 34
 - relatively prime, CoprimeQ, 54
 - rep units, 186
 - Smarandache–Wellin, 49, 253
 - Smith, 240
 - square, 54, 185
 - square palindrome, 365
 - square pyramidal, 84
 - square triangular, 54
 - triangular, 54, 363
 - weighted random, 71
- NumberString, 257
- NumericQ, 36–37
- OddQ, 50
- Off, 358
- On, 358
- Opacity, 288
- Operators
 - bit, 53
 - infix notation for, 13
 - logical, 52
 - postfix notation for, 13
 - precedence of, 51
 - prefix notation for, 13
- Options, 217
 - argument structure, OptionsPattern, 218
 - defined in packages, 387
 - extracting values of, OptionValue, 218
 - finding all functions with given, 188
 - for graphics, 287
 - inheriting, 276, 315, 341
 - syntax of, 217
- Or (||), 52
- OrderedQ, 268
- Orthocenter of triangles, 292
- Outer products, Outer, 141
- Outliers, removing from data, 108–109, 110, 117
- Output, how to refer to, %, 9
- OutputForm
 - of numbers, 27
 - of strings, 244

- $\mathcal{P} = N\mathcal{P}$, 343
- Packages
 - beginning, `BeginPackage`, 386–387
 - built-in, 380
 - deployment/installation of, 388
 - displaying names of functions in, `Names`, 381
 - distributing across kernels, `ParallelNeeds`, 370
 - ending, `EndPackage`, 387
 - finding location of (`FindFile`), 382
 - framework for, 382, 386
 - loading, `Get` vs. `Needs`, 380
 - location of, 381
 - location of initialization file for, 382
 - messages defined in, 387
 - options defined in, 387
 - search path for (`$Path`), 381
 - testing of, 391
 - tips for developing, 388
- Packed arrays, 356
 - converting to, `Developer`ToPackedArray`, 360
 - size of, 357
 - testing for, `Developer`PackedArrayQ`, 357
 - unpacking, 358
- Padé approximants, 378
- Palindromes, 2
 - words of length n , 260
 - square, 365
 - string, 253
- Panel, 299
- Parallel assignments, 214
- Parallel computation, 5, 366
 - closing kernels, `CloseKernels`, 367
 - computations that do not parallelize, 368
 - distributing definitions, `DistributeDefinitions`, 370
 - distributing package definitions, `ParallelNeeds`, 370–371
 - graphical user interface for, 367
 - launching kernels, `LaunchKernels`, 366
 - methods for, 368
 - with compiled functions, 374
 - `$ProcessorCount`, 366
- `Parallelize`, 368
- `ParallelMap`, 368
- `ParallelTable`, 377
- `ParametricPlot`, 321
- Partitioning
 - lists, `Partition`, 76
 - lists of vertices, 334
 - strings, 270
- Parts of expressions, `Part`, 24–25
 - shorthand notation, `[[...]]`, 72
- Pascal's matrix, 68
- Password generator, 270
- Pattern matching, efficiency of, 348
- Patterns, 96
 - alternatives in, `|`, 105
 - conditional, 102
 - finding expressions that match, `Cases`, 97
 - function arguments as structured, 270
 - in function definitions, 42, 98
 - labeled in transformation rules, 112
 - matching, `MatchQ`, 96
 - matching deeply nested expressions, 101
 - matching sequence of expressions, 100
 - named, 107
 - regular expressions, 261
 - repeated, 105
 - string, 255
 - structured, 98
 - syntactic vs. semantic matching, 99, 105
- Percolation, bond, 240
- Perfect numbers
 - searching for, 143, 216
 - searching for in parallel, 371
 - tests for, 50–51
- Perimeter, triangle, 118
- PERL programming language, 261
- Permutation ciphers, 251–252
- Permutations, 174
 - inverse, 174
 - of strings, 251
- Permutations, 252

- Pi(π)
 approximating by Monte Carlo
 simulation, 207, 365, 371–372
 finding sequence of digits in, 258
 normality of digits of, 40
 playing digits of, 189
 random walks on digits of, 291, 313
- Pick, 142, 195
- Piecewise, 162
- Piecewise-defined functions, 49, 175
- Player pianos, 19
- Plot
 adaptive sampling used in, 289
 structure of, 122, 288
- Points
 collinear, 291
 in polygons, 332
 multi-objects, 303
- Polar angles,
 converting to Cartesian coordinates, 187
- Polygons
 convex, 332
 in hexagonal lattice, 312
 nonconvex, 335
 points in, 332
- Polynomials
 fast multiplication with Horner's
 method, 186
 plotting complex solutions of, 339
- Position, 70, 108
- Postfix operators, 13
- Power grid, as graph, 65
- Precedence of operators, 51
- Precision
 fixed, 212
 in numbers, Precision, 34
- Predicates, 49
 as pure functions, 180
 creation of, 50–51
 for filtering data, 142
 multiple tests with, 104
 two-argument form, 50
- Prefix operators, 13
- Prepend, 77
- Prime numbers
 gaps in, 71
 less than a number, PrimePi, 82, 225
 Prime, 82
 sieving, 223, 351
 testing for, PrimeQ, 50
- Print, 6, 171
- Private context (Private`), 387
- Private functions, 237, 379, 387
- Profiling, 354, 368
- Programming
 comparing styles of, 5, 346
 declarative style of, 6
 dynamic, 155
 functional, 133
 history, 19
 imperative style of, 6
 modularity in, 196
 tasks in, 7
- Programs
 adding comments to, 14
 bad input in, 3, 221
 choosing efficient approaches, 346
 computational complexity, 124–125
 evaluation of, 6
 parallel, 366
 parallelizing, 5
 profiling, 354, 368
 testing efficiency of, 4, 345
- Protected, 56
- Proteins
 interaction networks, 193, 205
 visualizing with dot plots, 317, 341
- Public functions, 237, 379, 387
- Pure functions
 built-in, 362
 efficiency of, 361
 listable, 356
 mapping, 177
 multiple arguments, 179
 predicates, 180
 syntax of, 176

- QuantityMagnitude, 326
- Quitting the kernel, Quit, 391
- Radius of gyration tensor, 226
 - symbolic vs. numeric, 353
 - visualization of, 229, 342
- Random graphs
 - $G(n, m)$, 40–41
 - $G(n, p)$, 205–206, 216
- Random musical notes, 206
- Random numbers
 - biasing distributions of, 41
 - creation of, 38
 - from distributions, 38–39
 - weighting choices, 71
- Random sampling
 - with replacement,
 - RandomChoice, 32, 39, 83, 269
 - without replacement,
 - RandomSample, 39, 269
- Random strings, 269
 - weighted, 279
- Random walks, 233
 - animation of, 302
 - center of mass, 226
 - characterization of, 226–227
 - dynamic interfaces for, 302
 - full package for, 389
 - off-lattice, 237, 240
 - on digits of π , 291, 313
 - on graphs, 205
 - on integer lattice, 216, 233
 - one-dimensional, 32
 - two-dimensional lattice, 186
 - visualization of, 32, 106, 110
- RandomChoice, 32, 39, 83, 269
- RandomComplex, 38
- RandomInteger, 38
- RandomReal, 38
- RandomSample, 39, 269
- RandomVariate, 38–39
- Range, 60
- Rational numbers, 34, 48, 57
- Re, 35
- Real numbers, 34
- RealDigits, 37
- Reciprocals, 48, 57
- Recursion, 152
 - dynamic programming, 155
 - limiting levels of in computations,
 - \$RecursionLimit, 156–157, 212
 - multiple arguments in functions defined
 - with, 154
 - tail, 153
- ReflectionTransform, 290
- RegionMemberFunction, 363
- RegionPlot, 316–317
- Regions
 - centroids, RegionCentroid, 180, 287
 - centroids of clustered data, 201–204
 - efficiency of RegionMember, 362–363
 - finding boundary of, RegionBoundary, 120
 - measuring arc length in,
 - RegionMeasure, 120
 - membership in, RegionMember, 335–336
 - point closest to line, RegionNearest, 338
 - polygonal, 335
- Regular expressions, 261
 - classes of characters in, 262
 - lookahead/lookbehind, 263
 - mixing with string patterns, 262
 - referring to patterns in, 263
 - RegularExpression, 261
- Regular graphs, 204
- Relational operators, 51
- ReleaseHold, 29
- Rep units, 186
- Repeated (.), 105
- RepeatedNull (..), 105
- ReplacePart, 77, 113
- Rest, 74
- Reverse, 76, 135
- Root finding
 - Newton's method, 166
 - secant method, 174
- Root plots, 314
 - complex values in, 339
- Rotate, 147
- RotateLeft, 76, 192
- RotateRight, 76
- Rotoreliefs, 302
- Row, 64, 89
- Rows of matrices, swapping, 214
- Rules, delayed, RuleDelayed (:>), 112

- SameQ (===), 35, 190
- Sapir–Whorf hypothesis, *xii*
- Scatter plots, 116
- SCHEME programming language, 133
- Schwabe, Samuel Heinrich, 131
- Scoping, 210
 - graphics directives, 286
 - localization of constants, `With`, 212
 - localization of names, `Module`, 210
 - localization of values, `Block`, 212
- SDF file format, 325
- Select, 142, 195
- Selectors, 35
- Semantic vs. syntactic pattern matching, 99, 105
- Semantics, definition of, 20
- Semordnilaps, 260
- Sentences, length of, 260
- Sequences, 100
 - finding subsequences within, 130, 216, 258
- Serotonin, 325
- SessionTime, 305
- Set (=), 43
- SetAttributes, 56, 140
- SetDelayed (:=), 44
- SetSystemOptions, 358, 362
- Shannon, Claude, 41
- Short, 289
- Shortest path problems, 331
- Shorthand notation
 - `&&`, And, 51–52
 - `@@`, Apply, 136
 - `@@@`, Apply at level one, 137
 - `/;`, Condition, 102
 - `&`, Function, 176
 - `/@`, Map, 135
 - `||`, Or, 52
 - `;;`, Span, 72
 - `~~`, StringExpression, 256
 - `<>`, StringJoin, 248
 - `[[...]]`, Part, 25, 72
- Show, 290, 322–323
- ShowStringCharacters, 89
- Sierpiński triangle, 151
- Sieving algorithms
 - Eratosthenes, 223
 - improving efficiency of, 351–352
 - used to find lucky numbers, 239
- Sign function, `Sign`, 172, 348
- Signal processing
 - Hamming distance, 190
 - removing spikes, 181
 - smoothing noise, 371
- Signed area, of triangles, 121, 333
- Simple closed paths, 328, 341, 342
- Sin, dynamic visualization of, 302
- Sinc, 185
- Slider, 298
- Slider2D, 294, 377
- Smarandache–Wellin numbers, 49, 253
- Smith numbers, 240
- Software development, 7
- Sort, 75–6, 124, 135
- SortBy, 75–76, 194
- Sorting
 - associations, 87–88
 - basic algorithm for lists, 123
 - bubble sort, 124
 - canonical order for, 75
 - computational complexity of, 124–125
 - elements of nested lists, 135
 - lists, 75–76
 - mathematical constants, 124
 - merge sort, 125
 - points in plane by polar angle, 329–330
- Space-filling plots, 324, 342
- Span (; ;), 72
- Sparse arrays, 22
 - converting to normal form, 67
 - creating, `SparseArray`, 67
 - efficiency issues, 349
- Spectral norms, 30–31
- Specularity, 326–327
- Sphere, 288
- Sphere stacking, 84
- Spikes, removing in data, 180–181
- Square matrices, 102–103, 143
- Square numbers, 54, 185
- Square palindromic numbers, 365
- Square pyramidal numbers, 84
- Square triangular numbers, 54
- Standard deviation, 186
 - visualization of, 292
- Stem plots, 218–219
 - package for, 393

- Stop words, 267
- StringCases, 256
- StringCount, 248
- StringDrop, 84, 248
- StringExpression (~~), 256
- StringInsert, 84, 248
- StringJoin (<>), 84, 248
- StringMatchQ, 256
- StringPosition, 248, 257
- StringReplace, 114, 249
- StringReplacePart, 277–278
- StringReverse, 84, 248
- Strings, 243
 - alternatives in patterns, 259
 - binary representation, 40
 - character codes, 245
 - characters in, Characters, 249
 - codes for non-English languages, 246
 - concatenating, StringJoin, 248
 - converting to Ascii, ToCharacterCode, 246
 - digits in, DigitCharacter, 257
 - encoding, 250
 - internal algorithms, 249–250
 - length of, StringLength, 249
 - n-grams, 255
 - naming patterns in, 257
 - numbers in, NumberString, 257
 - operations compared with lists, 249
 - operations on, 248
 - output form, 27, 244
 - padding, 255
 - partitioning, 270
 - patterns for, 255
 - random, 269
 - random (weighted), 279
 - regular expressions for, 261
 - rotating, 253
 - splitting into words, TextWords, 83–84
 - tallying character counts, 254
 - testing for, StringQ, 50
 - tests on, 245
 - transposing, 253
 - trimming, 249
 - Unicode of, 246
- StringSplit, 258
- StringTake, 248
- StringTrim, 249
- Structured patterns, 99–100, 270
- Sturmian words, 255
- Style, 88–89
- Subsets, 179, 338, 365
- Sum, 347–348
- Sunspot activity, 125, 232
- Surfaces, visualizing intersection of, 339
- SwatchLegend, 219
- Switch, 164–165
- Symbolic computation,
 - compared with numeric, 309
- SymmetricMatrixQ, 50, 65
- Syntax
 - alternate forms, 13
 - definition of, 19
- SystemOptions, 357–358

- Table, 61
 - creating nested lists with, 62
- TableForm, 63
- Tabs, in strings (\t), 168
- Take, 73
- Tao, Terrence, 93
- Templates, for messages, 220
- Text analysis
 - cleaning transcribed audio, 267
 - punctuation counts in, 280
 - stop words, 267
- TextCell, 89
- TextSentences, 260
- TextWords, 84, 260
- Thread, 137
- Time series
 - changing window, TimeSeriesWindow, 127
 - converting expressions to, 126
 - creating from data, 232–233
 - differences from mean in, 130
 - finding peaks, FindPeaks, 127–128
 - importing data as, 125, 130, 219, 232
 - lag plots, 230
 - plotting, DateListPlot, 127
 - TimeSeries object, 126
 - visualizing autocorrelation in, 230

- Timing
 - different measures of, 363
 - granularity, `$TimeUnit`, 305
 - kernel vs. front end, 305
 - measuring on multi-threaded machines, 355
- `ToBoxes`, 309
- `ToUpperCase`, 249
- Tower of Hanoi, 157
- Tracing
 - evaluation, 30, 192
 - localized variables, 210–211
 - recursive computation, 153
- Transformation rules, 111
 - applied repeatedly, 113
 - Cartesian product example, 115
 - compared with assignments, 111
 - counting change example, 116
 - delayed, 112
 - dice visualization example, 115
 - evaluation order of, 265
 - labeled patterns with, 112–113
 - syntax of, 111
 - with strings, `StringReplace`, 114
- Transformations, geometric in graphics, 290
- Transition probability matrix, 205
- Translations, of graphics, `Translate`, 148
- Transposing
 - expressions, `Thread`, 137
 - lists, `Transpose`, 77
 - procedural definitions for, 174–175
 - strings, 253
- Traveling salesman problems, 207, 303, 331, 343
- `TreeForm`, 25–26, 71
- Triangles
 - altitude of, 342
 - area of, 121, 333
 - center of mass (centroid), 179
 - centers of, 292, 337
 - circumcenter, 292, 342
 - dynamic, 295
 - equilateral, 216
 - Euler line, 342
 - graphics primitive, `Triangle`, 284
 - Heron's formula to find area of, 143
 - incenter, 292
 - medians, 179, 286
 - midpoints of sides, 179
 - orthocenter, 292
 - perimeter of, 118
 - perpendicular bisectors, 338
 - signed area, 121, 333
- Triangular numbers, 54, 363
- Truth tables, 52, 206, 239
- Tryptophan, 327
- Turing, Alan, 215
- Unicode, 246
- `Unequal`, `#`, 51
- Union, 80
- Units, `QuantityMagnitude`, 326
- `Unprotect`, 56
- Upper-triangular matrices, 172
 - efficient generation of, 349–350
- Usage messages, 220,
 - in packages, 387
- Values, 85
- van der Waals radius, 325–326
- Vandermonde matrix, 146
- Variables, definitions for, 41
- Vectors
 - testing for, `VectorQ`, 50
 - visualization of arithmetic on, 302–303
- Venn diagrams, 316, 339–340
 - dynamic interface for, 340
- `VertexCoordinates`, 325
- `VertexCount`, 54
- `VertexDegree`, 194
- `VertexTypes`, 325
- Virtual machine, compilation to, 373
- Vowels, finding words containing, 266
- Warning messages, 220, 387
- Web pages, scraping data from, 257, 266
- Weisstein, Eric, 199
- West, Mae, 284
- Which, 162
- While, 169

- With, 212
 - compared to Module, 213–214
- Wolfram Language, xv
- Word games
 - anagrams, 252, 280, 364
 - blanagrams, 277, 369
 - palindromes, 253
 - semordnilaps, 260
- Word length, in nucleotide sequences, 143–144
- Words
 - abecedarian, 268
 - collocation of, 280–281
 - finding unique in text, 260
 - in dictionary, 187
 - length of, 260
 - pluralizing, 266
 - stop, 267
 - Sturmian, 255
 - vowels in, 266
- Xor ($\underline{\vee}$), 52–53
- Xor cipher, 40, 247
- Zhang, Yitang, 93
- \$BaseDirectory, 381
- \$Context, 383
- \$MaxPrecision, 212
- \$MinPrecision, 212
- \$Path, 381
- \$ProcessorCount, 366
- \$UserBaseDirectory, 381