



NetLogo 3.0.1 User Manual

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What is NetLogo?

NetLogo is a programmable modeling environment for simulating natural and social phenomena. It is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of independent "agents" all operating concurrently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals.

NetLogo lets students open simulations and "play" with them, exploring their behavior under various conditions. It is also an authoring environment which enables students, teachers and curriculum developers to create their own models. NetLogo is simple enough that students and teachers can easily run simulations or even build their own. And, it is advanced enough to serve as a powerful tool for researchers in many fields.

NetLogo has extensive documentation and tutorials. It also comes with a Models Library, which is a large collection of pre-written simulations that can be used and modified. These simulations address many content areas in the natural and social sciences, including biology and medicine, physics and chemistry, mathematics and computer science, and economics and social psychology. Several model-based inquiry curricula using NetLogo are currently under development.

NetLogo can also power a classroom participatory-simulation tool called HubNet. Through the use of networked computers or handheld devices such as Texas Instruments (TI-83+) calculators, each student can control an agent in a simulation. Follow [this link](#) for more information.

NetLogo is the next generation of the series of multi-agent modeling languages that started with StarLogo. It builds off the functionality of our product [StarLogoT](#) and adds significant new features and a redesigned language and user interface. NetLogo is written in Java so it can run on all major platforms (Mac, Windows, Linux, et al). It is run as a standalone application. Individual models can be run as Java applets inside a web browser.

Features

You can use the list below to help familiarize yourself with the features NetLogo has to offer.

- System:
 - ◆ Cross-platform: runs on MacOS, Windows, Linux, et al
- Language:
 - ◆ Fully programmable
 - ◆ Simple language structure
 - ◆ Language is Logo dialect extended to support agents and concurrency
 - ◆ Unlimited numbers of agents and variables
 - ◆ Many built-in primitives
 - ◆ Integer and double precision floating point math
 - ◆ Runs are exactly reproducible cross-platform
- Environment:
 - ◆ View your model in either 2D and 3D
 - ◆ Scalable and rotatable vector shapes
 - ◆ Turtle and patch labels
 - ◆ Interface builder w/ buttons, sliders, switches, choosers, monitors, text boxes

- ◆ "Control strip" including speed slider
- ◆ Powerful and flexible plotting system
- ◆ Info area for annotating your model
- ◆ HubNet: participatory simulations using networked devices
- ◆ Agent monitors for inspecting and controlling agents
- ◆ Export and import functions (export data, save and restore state of model)
- ◆ BehaviorSpace tool used to collect data from multiple runs of a model
- ◆ System Dynamics Modeler
- Web:
 - ◆ Models can be saved as applets to be embedded in web pages (note: some features are not available from applets, such as extensions and the 3D view)

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To reference this software in academic publications, please use: Wilensky, U. (1999). NetLogo. <http://ccl.northwestern.edu/netlogo/>. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

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For random number generation, NetLogo uses the MersenneTwisterFast class by Sean Luke. The copyright for that code is as follows:

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What's New?

Feedback from users is very valuable to us in designing and improving NetLogo. We'd like to hear from you. Please send comments, suggestions, and questions to feedback@ccl.northwestern.edu, and bug reports to bugs@ccl.northwestern.edu.

Version 3.0.1 (November 14, 2005)

- content:
 - ♦ improved models: Party (bugfix), Sound Machines (bugfix), Bug Hunt Camouflage (bugfix), Traffic Basic (bugfix)
 - ♦ assorted minor fixes to User Manual
- engine fixes:
 - ♦ fixed 3.0-only bug where the `repeat` and `foreach` commands didn't work in some recursive procedures
 - ♦ fixed 3.0-only bug where turtles could be mispositioned in the 2D view when the patch size wasn't an integer, or when zoomed
 - ♦ fixed 3.0-only bug that caused some models to run slowly when zoomed
 - ♦ fixed appearance of "line" and "line half" shapes in the 3D view
 - ♦ fixed bug in `import-drawing` that caused grayscale images to be lightened slightly
- System Dynamics Modeler fixes:
 - ♦ converters and stocks are now initialized in a well-defined order during `system-dynamics-setup`
 - ♦ fixed bug where NetLogo was sometimes unable to load saved system dynamics models
- interface fixes:
 - ♦ in buttons and monitors, the locations of syntax errors now are highlighted
 - ♦ fixed bug in shapes editor where "Rotate" button sometimes misbehaved
 - ♦ fixed bug in BehaviorSpace GUI where a results file could remain open even after the experiment was finished

Version 3.0 (September 2005)

- content:
 - ♦ new network models: Giant Component, Preferential Attachment, Small Worlds
 - ♦ new EvoLab evolution models: Bug Hunt Camouflage, Bug Hunt Speeds
 - ♦ new NIELS electromagnetism models: Electrostatics, Conductor
 - ♦ new MaterialSim materials science model: MaterialSim Grain Growth
 - ♦ new ProbLab probability model: 9-Block Stalagmite, Central Limit Theorem, Dice Stalagmite, Expected Value Advanced, ProbLab Genetics, Random Basic Advanced
 - ♦ new system dynamics models: Exponential Growth, Logistic Growth, Wolf Sheep Predation (System Dynamics), Wolf Sheep Predation (docked)
 - ♦ new biology models: Autumn, Algae, Moths, Disease Solo, Echo
 - ♦ new physics & chemistry models: GasLab Circular Particles, DLA Alternate, DLA Alternate Linear, Polymer Dynamics
 - ♦ new cellular automaton model: Life Turtle-Based
 - ♦ new computer science models: Vants, Merge Sort
 - ♦ new math model: Color Fractions
 - ♦ new art models: Sound Machines, Optical Illusions

- ◆ new games: Minesweeper, Lunar Lander
- ◆ new code examples: Neighbors–Nowrap Example, Halo Example, Perspective Example, 3D Shapes Example, GoGoMonitor
- ◆ new perspective demos section with alternate versions of Ants, Termites, Flocking, GasLab to demo new perspective features
- ◆ improved sample models: Rugby (bugfix), GasLab Gas in a Box (bugfix), Vector Fields (bugfix), Virus (bugfix), Turtles Circling (new look and controls), Pursuit (new look), Rebellion (new look), Reactor X–Section (new look), Sand (better colors), Virus (better colors), Shuffle Board, Traffic Basic, and most ProbLab models
- ◆ revamped code examples: Shape Animation Example (new look), Random Seed Example (now demonstrates `new-seed`), Image Import Example (now demonstrates `import-pcolors` and `import-drawing`)
- features:
 - ◆ you can now view any model in 3D (note though that the world remains 2D; for 3D worlds, use NetLogo 3D Preview 1)
 - ◆ new `follow`, `ride` and `watch` commands let you track the movements of a particular agent
 - ◆ new System Dynamics Modeler, found on Tools menu (includes sample models and section in User Manual)
 - ◆ new drawing layer on top of patches contains marks left by turtles, with their pens or by stamping their shapes
 - ◆ turtle pens may now vary in size; they draw in the drawing layer, rather than affecting patch colors as before
 - ◆ buttons take turns now (instead of interleaving their code with each other), so you can press `SETUP` during `GO` or press `GO` during `SETUP` and the right thing happens
 - ◆ find and replace in Information and Procedures tabs
 - ◆ new color palette is more muted and contains colors that harmonize better with each other
 - ◆ the Information tab is now displayed in a more attractive (but read–only) style; use the new Edit button to switch to the old view for editing
 - ◆ new GoGo extension allows interfacing NetLogo to physical devices
 - ◆ added Color Swatches, a dialog which helps you choose colors for your agents, to the Tools menu
 - ◆ improved user interface for reporting syntax errors (no more Errors tab)
 - ◆ turtle shapes now optionally wrap around the edges of the world
 - ◆ when you pick a turtle or patch with the mouse (by right–clicking or control–clicking), the selected turtle or patch is now highlighted
 - ◆ substantial improvements to BehaviorSpace:
 - ◇ BehaviorSpace experiments can now be run headless from the command line, using an experiment setup saved in the model or specified separately in XML
 - ◇ you can create multiple experiment setups and they are saved in your model for later reuse
 - ◇ there are now two output format options, spreadsheet and table; the latter is new, and is more suitable for use with statistics and database software
 - ◇ you can now use multiple reporters to measure each run; you can also use none, which is useful if you are recording the results some other way, such as with `export-world`
 - ◇ you can now vary the world size during an experiment, by varying `screen-edge/size-x/y` as if they were variables

- ◊ you can now vary the random seed during an experiment, by varying `random-seed` as if it were a variable
- ◊ you can now choose to measure runs only at the end, not every tick
- ◊ you can now vary no variables at all during an experiment; this is useful for doing many runs with the current settings
- language changes:
 - ◆ pen and drawing related changes:
 - ◊ turtle pens draw in the drawing layer, instead of changing patch colors as before
 - ◊ a turtle's pen, if it is down, now draws regardless of how the turtle moves (even if it's with `setxy` or `jump`)
 - ◊ a pen may also erase, using the new `pen-erase` (`pe`) command
 - ◊ the `stamp` command now stamps the turtle's shape on the drawing, rather than setting the patch color (use `set pcolor` to set the patch color)
 - ◊ added new commands `clear-drawing` (`cd`), `import-drawing`
 - ◊ added new turtle variables `pen-mode` and `pen-size`; removed old variable `pen-down?`
 - ◆ new `follow`, `watch`, `ride` (and `follow-me`, `watch-me`, `ride-me`) commands (and `subject reporter`) for focusing on individual agents
 - ◆ new `reset-perspective` command returns the observer to the default position and perspective.
 - ◆ the `clear-graphics` command no longer exists (in old models, it is automatically replaced with `cp ct`)
 - ◆ all other commands with "graphics" in the name now use "view" instead (e.g. `export-view`)
 - ◆ new `netlogo-version` reporter
 - ◆ new `import-pcolors` and `import-drawing` commands read image files (in a variety of formats) into the patch colors or drawing layer
 - ◆ new `in-cone` reporter lets you give a turtle a cone of vision
 - ◆ new `new-seed` reporter is useful for generating numbers to use as random seeds
 - ◆ new `mouse-inside?` reporter tells you whether the mouse pointer is in the view
 - ◆ renamed `get-and-date-time` to `date-and-time`
 - ◆ the constant `white` is now defined as 9.9, not 9.9999
- engine fixes:
 - ◆ fixed bug in `random-n-of` that favored earlier items in the list or `agentset`
 - ◆ fixed bug where `filter/map/foreach` didn't always work properly inside `run/runresult`
 - ◆ fixed bug in importing worlds where an `agentset` stored in a global variable could be imported incorrectly if the import caused the world size to change
 - ◆ the `export-view` and `export-output` commands now work even when running headless from the command line
 - ◆ when running headless from the command line, paths are now interpreted as relative to the location of the model, just as in the application
 - ◆ the `rgb` and `hsb` reporters are now better at choosing colors
 - ◆ fixed histogramming bug where sometimes a value was assigned to the bar one to the left of the correct bar
 - ◆ fixed bug that could cause a runtime error to be reported as happening in the wrong place in the code or to the wrong agent
 - ◆ fixed bug where `is-turtle?` and `is-agent?` sometimes returned true even if the input was nobody (if a turtle died)

- ◆ fixed Windows—only problem where the sound extension didn't always work on some Java VM's newer than 1.4.2_05
- ◆ import and export world now include the observer perspective and contents of the output area
- ◆ the sizing and positioning of turtle shapes in 2D, especially very small ones, is now more accurate, and more consistent cross-platform
- interface fixes:
 - ◆ right/control-clicking to pick a turtle in the 2D view is now much easier because it takes the size and position of the turtle into account
 - ◆ removed now useless checkbox for turning off "Exact turtle positions & sizes"
 - ◆ smaller changes in turtle heading are now visible onscreen, particularly when the patch size is large
 - ◆ turtle sizes 1.5 and 2.0 are now accelerated graphically in the 2D view (before, only size 1.0 was accelerated)
 - ◆ improved some error messages, and improved the pinpointing of runtime error locations
 - ◆ you can now use the keyboard shortcuts for undo and redo when editing the code in a button or monitor
 - ◆ fixed bug where if a chooser had lots of choices, some would disappear off the edges of the screen
 - ◆ fixed bug where deleting a button or monitor with a syntax error halted the model
 - ◆ in saved applets, you can now copy from an output area on all web browsers (as far as we know)
 - ◆ fixed bug where a generated movie file could disappear when you quit NetLogo
 - ◆ editing a slider, switch, or choice no longer halts the model (unless you change the variable name)
 - ◆ general miscellaneous improvements to look and feel
- HubNet changes:
 - ◆ new activity: Dice Stalagmite
 - ◆ improved activity: Beer Game Alternate 2
 - ◆ in computer HubNet, the "Graphics Window" tag for receiving mouse events from clients has changed to "View"; existing activities that use this feature must be updated in order to work
 - ◆ `hubnet-message-waiting?` sleeps, so HubNet activities don't hog the CPU
- Java API changes:
 - ◆ controlling API can now run BehaviorSpace experiments
 - ◆ controlling API now includes new `resizeWorld()`, `getDrawing()`, `getGraphics()`, `halt()` methods
 - ◆ fixed bug in extensions API where the `unload()` method was not being called
 - ◆ the `LogoList` and `LogoException` classes have been relocated to the `org.nlogo.api` package
 - ◆ in the extensions API, the `runOnce()` method in the `ClassManager` now takes an `ExtensionManager` which allows the extension to specify that it uses HubNet and also to store an `Object` that is kept even across multiple loads of the extension
- system:
 - ◆ on Windows, bundled Java version is now 1.4.2_08 (was 1.4.2_05)

Version 2.1 (December 2004)

- much larger and higher quality library of turtle shapes

- runs models "headless", with no GUI, from the command line
- editor now highlights matching parentheses and brackets
- "action keys" let buttons be triggered by keypresses
- makes Quicktime movies of models
- redesigned Command Center for greater usability
- optional "output area" in models
- greatly improved shapes editor
- easy capture of images from Interface tab
- multilevel "Undo" in editor
- new `let` command for easy creation of local variables
- new `carefully` command for trapping runtime errors
- computer HubNet:
 - ◆ substantially improved reliability
 - ◆ "server discovery" is now fully supported
 - ◆ you may serve multiple activities simultaneously from the same computer
 - ◆ improved client interface and Control Center

Version 2.0.2 (August 2004)

- new, experimental "extensions" API lets users write new commands and reporters in Java
- NetLogo can now make sounds and music; this is done with a new, experimental sound extension that is also an example of how to use the extensions API
- new "controlling" API lets users control NetLogo from external Java code (such as for automating multiple runs)

Version 2.0 (December 2003)

- full support for Mac OS X; improved Linux support
- minimum Java version is now 1.4.1; Windows 95, MacOS 8, MacOS 9 no longer supported
- increased overall reliability
- improved look and feel throughout the application
- faster and more flexible graphics (labels, turtle sizes, exact turtle positions all now fast, reliable, and flicker-free)
- suite of primitives for reading and writing external files
- "strict math" mode now always on, for reproducible results
- export graphics window or interface tab as image file
- revamped BehaviorSpace (various improvements made; some old features are missing)
- Mersenne Twister random number generator
- many new primitives
- computer HubNet:
 - ◆ improved reliability; no longer alpha or beta
 - ◆ improved graphics window mirroring features and performance

Version 1.3 (June 2003)

- graphics window control strip
- choosers
- strict math mode so results are identical on all platforms (requires Java 1.3 or higher)
- new primitives including `run/runresult` and `map/foreach/filter/reduce`

- some primitives now accept a variable number of inputs

Version 1.2 (March 2003)

- alpha release of computer HubNet: formerly HubNet required the TI Navigator calculator network to operate; now you can use it over TCP/IP with networks of laptop or desktop computers
- new primitives and other language improvements
- display of coordinates when mousing over plots

Version 1.1 (July 2002)

- "Save as Applet" lets you embed your model in any web page
- printer support
- Procedures menu
- scrollable Interface tab
- contextual menus in Interface tab
- new primitives

Version 1.0 (April 2002)

- initial release (after a series of betas)

System Requirements

NetLogo is designed to run on almost any type of computer, but some older or less powerful systems are not supported. The exact requirements are summarized below. If you have any trouble with NetLogo not working on your system, we would like to offer assistance. Please write bugs@ccl.northwestern.edu.

System Requirements: Application

On all systems, approximately 25MB of free hard drive space is required.

Windows

- Windows NT, 98, ME, 2000, or XP
- 64 MB RAM (or probably more for NT/2000/XP)

You can choose to include a suitable Java Virtual Machine when downloading NetLogo. If you want to use a JVM that you install separately yourself, it must be version 1.4.1 or later. 1.4.2 or later is preferred.

Windows 95 is no longer supported by the current version of NetLogo. Windows 95 users should use NetLogo 1.3.1 instead. We will continue to support NetLogo 1.3.1.

Mac OS X

- OS X version 10.2.6 or later (10.3 or later is recommended)
- 128 MB RAM (256 MB RAM strongly recommended)

On OS X, the Java Virtual Machine is supplied by Apple as part of the operating system. OS X 10.3 includes an appropriate JVM. OS X 10.2 users must install Java 1.4.1 Update 1, which is available from Apple through Software Update.

For OS X 10.3 users, installing Java 1.4.2 Update 1 is recommended, for improved application reliability. The update is available from Apple through Software Update.

Mac OS 8 and 9

These operating systems are no longer supported by the current version of NetLogo. MacOS 8 and 9 users should download NetLogo 1.3.1 instead. We will continue to support NetLogo 1.3.1.

Other platforms

NetLogo should work on any platform on which a Java Virtual Machine, version 1.4.1 or later, is available and installed. Version 1.4.2 or later is preferred. If you have trouble, please contact us (see above).

System Requirements: Saved Applets

NetLogo models saved as Java applets should work on any web browser and platform on which a Java Virtual Machine, version 1.4.1 or later, is available. If you have trouble, please contact us (see above).

On Mac OS X, the Internet Explorer browser does not make use of the 1.4.1 JVM, so it cannot run saved applets. We suggest using Apple's Safari browser instead, or another web browser which uses the newer JVM.

Note that the 3D view is not available in applets.

System Requirements: 3D View

NetLogo's 3D view is a new feature, and hasn't been tested on every configuration. Below is information about configurations that we have tested so far.

Operating Systems

We've tested the 3D view on:

- Linux 2.6.8 (Debian i386)
- Linux 2.6.8 (Debian amd64)
- Mac OS X 10.3.8, 10.4.0, and 10.4.1
note: Java 1.4.2 is required
- Windows 2000
- Windows XP

If you use the 3D view on an operating system that we haven't tested, we'd like to hear about it. Please let us know at feedback@ccl.northwestern.edu. Please include the information in the System section of About NetLogo.

Graphics Cards

We've tested the 3D view on many different graphics cards and controllers, including:

- ATI Radeon 7500
- ATI Radeon 9200
- ATI Radeon 9600
- ATI Radeon 9800 XT
- ATI Radeon IGP 345
- ATI Radeon Mobility
- ATI FireGL V3100
- Intel 82830M
- nVidia GeForce MX
- nVidia GeForce FX 5200
- nVidia GeForce FX Go5650
- nVidia Quadro NVS

If you use the 3D view with a graphics card that we haven't tested, we'd like to hear about it. Please let us know at feedback@ccl.northwestern.edu. Please include the information in the System section of About NetLogo.

Fullscreen mode

Fullscreen mode does not work with some graphics cards and controllers, including the ATI Radeon IGP 345 and the Intel 82845.

Some users with older computers, especially laptops, have reported that entering fullscreen mode caused NetLogo to crash. If you experience this problem, please let us know.

Library Conflicts

NetLogo includes JOGL version 1.1.0 for the 3D View.

On Mac OS X and Windows, NetLogo uses the version of JOGL that comes with NetLogo, even if you have a different version of JOGL on your computer. If for some reason NetLogo is unable to find and use the correct version, it will warn you. If you get such a warning, you may need to remove your separate JOGL installation in order for NetLogo's 3D View to work.

On a Linux machine, if NetLogo is finding the wrong version of JOGL, trying running with the `-Djava.ext.dirs=` command line option, like this:

```
java -Djava.ext.dirs= -jar NetLogo.jar
```

That should fix the problem. If it doesn't, try removing your JOGL installation.

Removing an old JOGL

If NetLogo tells you you need to remove your JOGL installation, here's how to do it. You need to remove the `jogl.jar` file and one or two native library files:

- Remove `jogl.jar` from `lib/ext` in your Java home directory.
- On Mac OS X, remove `libjogl.jnilib` from `/Library/Java/Extensions` or `~/Library/Java/Extensions`.
- On Windows, remove `jogl.dll` and `jogl_cg.dll` from `jre/bin` in your Java home.
- On Linux, remove `libjogl.so` from your always-checked Java native libraries directory.

Known Issues

If NetLogo malfunctions, please send us a bug report. See the ["Contact Us"](#) section for instructions.

Known bugs (all systems)

- Integers in NetLogo must lie in the range `-2147483648` to `2147483647`; if you exceed this range, instead of a runtime error occurring, you get incorrect results
- Out-of-memory conditions are not handled gracefully
- The `stop` and `report` commands do not work properly if used inside `without-interruption` (we are already working on fixing this)
- If you use "Export World" to suspend a model run and then resume it later with "Import World", this may change the outcome of the model run if your model involves turtles dying and new turtles being born, because the export/import may change what who numbers get assigned to new turtles (we are already working on fixing this)
- "Export World" does not include the contents of plots (we are already working on fixing this)
- Extensions don't work from models saved as applets (we are already working on fixing this)
- The 3D View doesn't work on some graphics configurations; on others the 3D View works but 3D full screen mode doesn't
- A bug in Java causes patch colors imported using `import-pcolors` to be brighter than the original if the original image has a grayscale palette. To work around this issue, convert the image file to an RGB palette.

Windows-only bugs

- The "User Manual" item on the Help menu does not work on every machine (Windows 98 and ME are most likely to be affected, newer Windows versions less so)
- On some laptops, the Procedures and Info tabs may become garbled when you scroll them. To avoid this bug, reduce the size of the NetLogo window and/or reduce the color depth of your monitor (e.g. change from 32-bit to 16- or 8-bit color). This is a bug in Java itself, not in NetLogo per se. For technical details on the bug, see <http://developer.java.sun.com/developer/bugParade/bugs/4763448.html> (free registration required). NetLogo users are encouraged to visit that site and vote for Sun to fix this bug.

Macintosh-only bugs

- On Mac OS X 10.4 only, the "Copy View" and "Copy Interface" items may not work: the resulting image is distorted. The workaround is to use the "Export View" and "Export Interface" items instead.
- On versions of Mac OS X prior to 10.4, when opening a model from the Finder (by double-clicking on it, or dragging it onto the NetLogo icon), if NetLogo is not already running, then the model may or may not open; the bug is intermittent. (If NetLogo is already running, the model always opens.) The bug does not occur on OS X 10.4.
- On versions of Mac OS X prior to 10.4, it is possible for NetLogo's menus to get confused so that the "Quit" item does not work. If this happens, you can quit NetLogo by pressing the red close button on the left end of the NetLogo's title bar.
- On Mac OS X 10.2 only, the "User Manual" item on the Help menu will sometimes launch a web browser other than your default browser

- On Mac OS X 10.2 only, opening the Models Library can trigger an error if you have malformed fonts installed. If this happens you should determine which fonts in /System/Library/Fonts and other font directories are causing the problem and remove them.

Linux/UNIX-only bugs

- User Manual always opens in Mozilla, not your default browser. One possible workaround is to bookmark the file docs/index.html in your favorite browser. Another workaround is to make a symlink that's called "mozilla" (that's the command name NetLogo tries to run), but actually runs a different browser.
- We have discovered a problem on Linux where the "exp" reporter sometimes returns a slightly different answer (differing only in the last decimal place) for the same input. According to an engineer at Sun, this should only happen on Linux kernel versions 2.4.19 and earlier, but we have observed the problem on more recent kernel versions. We assume the problem is Linux-specific and does not happen on other Unix-based systems. We are not sure if the problem ever occurs in practice during actual NetLogo model runs, or only occurs in the context of our testing regimen. The bug in the Sun's Java VM, and not in NetLogo itself. We hope that only the "exp" reporter is affected, but we can't be entirely certain of this. NetLogo users are encouraged to visit <http://developer.java.sun.com/developer/bugParade/bugs/5023712.html> (free registration required) and vote for Sun to fix this bug.
- If NetLogo cannot find the font Lucida, menus will be illegible. This has been known to happen on Fedora Core 3, after upgrading packages. Restarting the X Font Server (xfs) has resolved the problem in all reported cases.

Known issues with computer HubNet

See the [HubNet Guide](#) for a list of known issues with computer HubNet.

Unimplemented StarLogoT primitives

The following StarLogoT primitives are not available in NetLogo. (Note that many StarLogoT primitives, such as `count-turtles-with`, are intentionally not included in this list because NetLogo allows for the same functionality with the new `agentset` syntax.)

- `maxint`, `minint`, `maxnum`, `minnum`
- `import-turtles`, `import-patches`, `import-turtles-and-patches` (note that NetLogo adds `import-world`, though)
- `bit`, `bitand`, `bitneg`, `bitor`, `bitset`, `bitstring`, `bitxor`, `make-bitarray`, `rotate-left`, `rotate-right`, `shift-left`, `shift-right`
- `camera-brightness`, `camera-click`, `camera-init`, `camera-set-brightness`
- `netlogo-directory`, `project-directory`, `project-name`, `project-pathname`, `save-project`

Contacting Us

Feedback from users is very valuable to us in designing and improving NetLogo. We'd like to hear from you.

Web Site

Our web site at ccl.northwestern.edu includes our mailing address and phone number. It also has information about our staff and our various research activities.

Feedback, Questions, Etc.

If you have general feedback, suggestions, or questions, write to feedback@ccl.northwestern.edu.

If you need help with your model, you should also consider posting to the NetLogo users group at <http://groups.yahoo.com/group/netlogo-users/>.

Reporting Bugs

If you would like to report a bug that you find in NetLogo, write to bugs@ccl.northwestern.edu. When submitting a bug report, please try to include as much of the following information as possible:

- A complete description of the problem and how it occurred.
- The NetLogo model or code you are having trouble with. If possible, attach a complete model.
- Your system information: NetLogo version, OS version, Java version, and so on. This information is available from NetLogo's "About NetLogo" menu item. In saved applets, the same information is available by control-clicking (Mac) or right-clicking the white background of the applet.
- Any error messages that were displayed.

Sample Model: Party

This activity is designed to get you thinking about computer modeling and how you can use it. It also gives you some insight into the NetLogo software. We encourage beginning users to start with this activity.

At a Party

Have you ever been at a party and noticed how people cluster in groups? You may have also noticed that people do not stay within one group, but move throughout the party. As individuals move around the party, the groups change. If you watched these changes over time, you would notice patterns forming.

For example, in social settings, people tend to exhibit different behavior than when they are at work or home. Individuals who are confident within their work environment may become shy and timid at a social gathering. And others who are quiet and reserved at work may be the "party starter" with friends.

The patterns may also depend on what kind of gathering it is. In some settings, people are trained to organize themselves into mixed groups; for example, party games or school-like activities. But in a non-structured atmosphere, people tend to group in a more random manner.

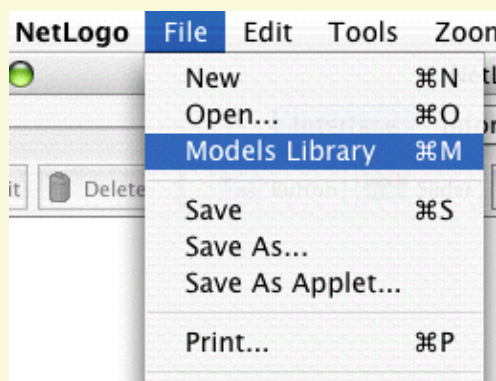
Is there any type of pattern to this kind of grouping?

Let's take a closer look at this question by using the computer to model human behavior at a party. NetLogo's "Party" model looks specifically at the question of grouping by gender at parties: why do groups tend to form that are mostly men, or mostly women?

Let's use NetLogo to explore this question.

What to do:

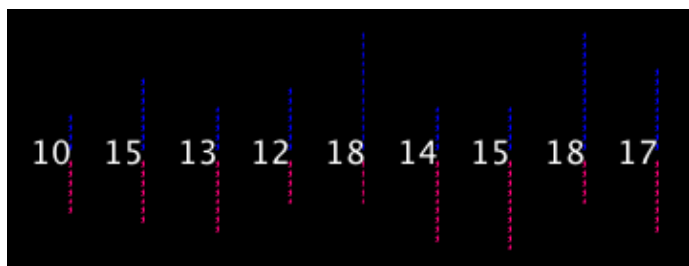
1. Start NetLogo.
2. Choose "Models Library" from the File menu.



3. Open the "Social Science" folder.
4. Click on the model called "Party".

5. Press the "open" button.
6. Wait for the model to finish loading
7. (optional) Make the NetLogo window bigger so you can see everything.
8. Press the "setup" button.

In the view, you will see pink and blue lines with numbers:



These lines represent mingling groups at a party. Men are represented in blue, women in pink. The numbers are the total number of people in each group.

Do all the groups have about the same number of people?

Do all the groups have about the same number of each sex?

Let's say you are having a party and invited 150 people. You are wondering how people will gather together. Suppose 10 groups form at the party.

How do you think they will group?

Instead of asking 150 of your closest friends to gather and randomly group, let's have the computer simulate this situation for us.

What to do:

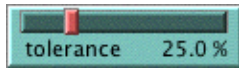
1. Press the "go" button. (Pressing "go" again will stop the model manually.)
2. Observe the movement of people until the model stops.
3. Watch the plots to see what's happening in another way.

Now how many people are in each group?

Originally, you may have thought 150 people splitting into 10 groups, would result in about 15 people in each group. From the model, we see that people did not divide up evenly into the 10 groups -- instead, some groups became very small, whereas other groups became very large. Also, the party changed over time from all mixed groups of men and women to all single-sex groups.

What could explain this?

There are lots of possible answers to this question about what happens at real parties. The designer of this simulation thought that groups at parties don't just form randomly. The groups are determined by how the individuals at the party behave. The designer chose to focus on a particular variable, called "tolerance":



Tolerance is defined here as the percentage of people of the opposite sex an individual is "comfortable" with. If the individual is in a group that has a higher percentage of people of the opposite sex than their tolerance allows, then they become "uncomfortable" and leave the group to find another group.

For example, if the tolerance level is set at 25%, then males are only "comfortable" in groups that are less than 25% female, and females are only "comfortable" in groups that are less than 25% male.

As individuals become "uncomfortable" and leave groups, they move into new groups, which may cause some people in that group to become "uncomfortable" in turn. This chain reaction continues until everyone at the party is "comfortable" in their group.

Note that in the model, "tolerance" is not fixed. You, the user, can use the tolerance "slider" to try different tolerance percentages and see what the outcome is when you start the model over again.

How to start over:

1. If the "go" button is pressed (black), then the model is still running. Press the button again to stop it.
2. Adjust the "tolerance" slider to a new value by dragging its red handle.
3. Press the "setup" button to reset the model.
4. Press the "go" button to start the model running again.

Challenge

As the host of the party, you would like to see both men and women mingling within the groups. Adjust the tolerance slider on the side of the view to get all groups to be mixed as an end result.

To make sure all groups of 10 have both sexes, at what level should we set the tolerance?

Test your predictions on the model.

Can you see any other factors or variables that might affect the male to female ratio within each group?

Make predictions and test your ideas within this model. Feel free to manipulate more than one variable at a time.

As you are testing your hypotheses, you will notice that patterns are emerging from the data. For example, if you keep the number of people at the party constant but gradually increase the

tolerance level, more mixed groups appear.

How high does the tolerance value have to be before you get mixed groups?

What percent tolerance tends to produce what percentage of mixing?

Thinking With Models

Using NetLogo to model situations like this party scenario allows you to experiment with a system in a rapid and flexible way that would be difficult to do in a real world situation. Modeling also gives you the opportunity to observe a situation or circumstance with less prejudice -- as you can examine the underlying dynamics of a situation. You may find that as you model more and more, many of your preconceived ideas about various phenomena will be challenged. For example, a surprising result of the Party model is that even if tolerance is relatively high, a great deal of separation between the sexes occurs.

This is a classic example of an "emergent" phenomenon, where a group pattern results from the interaction of many individuals. This idea of "emergent" phenomena can be applied to almost any subject.

What other emergent phenomena can you think of?

To see more examples and gain a deeper understanding of this concept and how NetLogo helps learners explore it, you may wish to explore NetLogo's Models Library. It contains models that demonstrate these ideas in systems of all kinds.

For a longer discussion of emergence and how NetLogo helps learners explore it, see "[Modeling Nature's Emergent Patterns with Multi-agent Languages](#)" (Wilensky, 2001).

What's Next?

The section of the User Manual called [Tutorial #1: Running Models](#) goes into more detail about how to use the other models in the Models Library.

If you want to learn how to explore the models at a deeper level, [Tutorial #2: Commands](#) will introduce you to the NetLogo modeling language.

Eventually, you'll be ready for [Tutorial #3: Procedures](#), where you can learn how to alter and extend existing models to give them new behaviors, and build your own models.

Tutorial #1: Models

If you read the [Sample Model: Party](#) section, you got a brief introduction to what it's like to interact with a NetLogo model. This section will go into more depth about the features that are available while you're exploring the models in the Models Library.

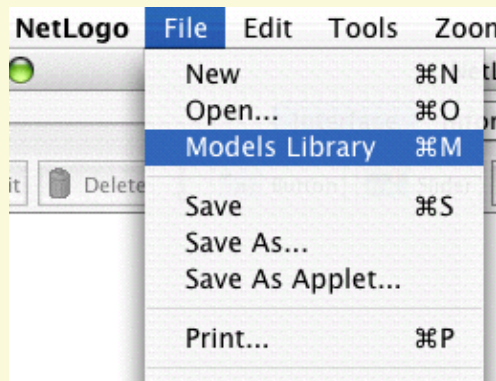
Throughout all of the tutorials, we'll be asking you to make predictions about what the effects of making changes to the models will be. Keep in mind that the effects are often surprising. We think these surprises are exciting and provide excellent opportunities for learning.

Some people have found it helpful to print out the tutorials in order to work through them. When the tutorials are printed out, there's more room on your computer screen for the NetLogo model you're looking at.

Sample Model: Wolf Sheep Predation

We'll open one of the Sample Models and explore it in detail. Let's try a biology model: Wolf Sheep Predation, a predator–prey population model.

- Open the Models Library from the File menu.



- Choose "Wolf Sheep Predation" from the Biology section and press "Open".

The Interface tab will fill up with lots of buttons, switches, sliders and monitors. These interface elements allow you to interact with the model. Buttons are blue; they set up, start, and stop the model. Sliders and switches are green; they alter model settings. Monitors and plots are beige; they display data.

If you'd like to make the window larger so that everything is easier to see, you can use the zoom menu at the top of the window.

When you first open the model, you will notice that the view is empty (all black). To begin the model, you will first need to set it up.

- Press the "setup" button.

What do you see appear in the view?

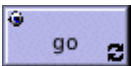
- Press the "go" button to start the simulation.

As the model is running, what is happening to the wolf and sheep populations?

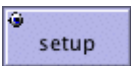
- Press the "go" button to stop the model.

Controlling the Model: Buttons

When a button is pressed, the model responds with an action. A button can be a "once" button, or a "forever" button. You can tell the difference between these two types of buttons by a symbol on the face of the button. Forever buttons have two arrows in the bottom right corners, like this:



Once buttons don't have the arrows, like this:



Once buttons do one action and then stop. When the action is finished, the button pops back up.

Forever buttons do an action over and over again. When you want the action to stop, press the button again. It will finish the current action, then pop back up.

Most models, including Wolf Sheep Predation, have a once button called "setup" and a forever button called "go". Many models also have a once button called "go once" or "step once" which is like "go" except that it advances the model by one time step instead of over and over. Using a once button like this lets you watch the progress of the model more closely.

Stopping a forever button is the normal way to stop a model. It's safe to pause a model by stopping a forever button, then make it go on by pressing the button again. You can also stop a model with the "Halt" item on the Tools menu, but you should only do this if the model is stuck for some reason. Using "Halt" may interrupt the model in the middle of an action, and as the result the model could get confused.

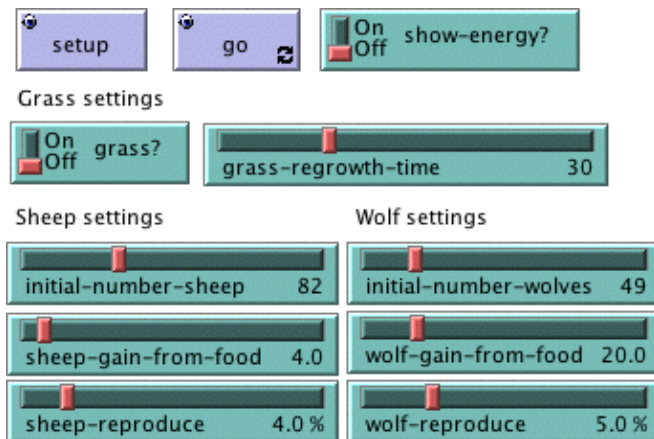
- If you like, experiment with the "setup" and "go" buttons in the Wolf Sheep Predation model.

Do you ever get different results if you run the model several times with the same settings?

Adjusting Settings: Sliders and Switches

The settings within a model give you an opportunity to work out different scenarios or hypotheses. Altering the settings and then running the model to see how it reacts to those changes can give you a deeper understanding of the phenomena being modeled. Switches and sliders give you access to a model's settings.

Here are the switches and sliders in Wolf Sheep Predation:



Let's experiment with their effect on the behavior of the model.

- Open Wolf Sheep Predation if it's not open already.
- Press "setup" and "go" and let the model run for about a 100 time-ticks. (Note: there is a readout of the number of ticks right above the plot.)
- Stop the model by pressing the "go" button.

What happened to the sheep over time?

Let's take a look and see what would happen to the sheep if we change one of the settings.

- Turn the "grass?" switch on.
- Press "setup" and "go" and let the model run for a similar amount of time as before.

What did this switch do to the model? Was the outcome the same as your previous run?

Just like buttons, switches have information attached to them. Their information is set up in an on/off format. Switches turn on/off a separate set of directions. These directions are usually not necessary for the model to run, but might add another dimension to the model. Turning the "grass?" switch on affected the outcome of the model. Prior to this run, the growth of the grass stayed constant. This is not a realistic look at the predator-prey relationship; so by setting and turning on a grass growth rate, we were able to model all three factors: sheep, wolf and grass populations.

Another type of setting is called a slider.

Sliders are a different type of setting than a switch. A switch has two values: on or off. A slider has a range of numeric values that can be adjusted. For example, the "initial-number-sheep" slider has a minimum value of 0 and a maximum value of 250. The model could run with 0 sheep or it could run with 250 sheep, or anywhere in between. Try this out and see what happens. As you move the marker from the minimum to the maximum value, the number on the right side of the slider changes; this is the number the slider is currently set to.

Let's investigate Wolf Sheep Predation's sliders.

- Read the contents of the Information tab, located above the toolbar, to learn what each of this models' sliders represents.

The Information tab is extremely helpful for gaining insight into the model. Within this tab you will find an explanation of the model, suggestions on things to try, and other information. You may want to read the Information tab before running a model, or you might want to just start experimenting, then look at the Information tab later.

What would happen to the sheep population if there was more initial sheep and less initial wolves at the beginning of the simulation?

- Turn the "grass?" switch off.
- Set the "initial-number-sheep" slider to 100.
- Set the "initial-number-wolves" slider to 20.
- Press "setup" and then "go".
- Let the model run for about 100 time-ticks.

Try running the model several times with these settings.

What happened to the sheep population?

Did this outcome surprise you? What other sliders or switches can be adjusted to help out the sheep population?

- Set "initial-number-sheep" to 80 and "initial-number-wolves" to 50. (This is close to how they were when you first opened the model.)
- Set "sheep-reproduce" to 10.0%.
- Press "setup" and then "go".
- Let the model run for about 100 time ticks.

What happened to the wolves in this run?

When you open a model, all the sliders and switches are on a default setting. If you open a new model or exit the program, your changed settings will not be saved, unless you choose to save them.

(Note: in addition to sliders and switches, some models have a third kind of setting, called a chooser. The Wolf Sheep Predation doesn't have any of these, though.)

Gathering Information: Plots and Monitors

A purpose to modeling is to gather data on a subject or topic that would be very difficult to do in a laboratory situation. NetLogo has two main ways of displaying data to the user: plots and monitors.

Plots

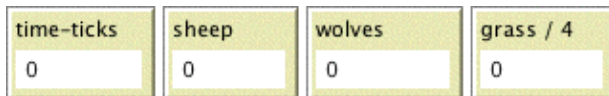
The plot in Wolf Sheep Predation contains three lines: sheep, wolves, and grass / 4. (The grass count is divided by four so it doesn't make the plot too tall.) The lines show what's happening in the model over time. To see which line is which, click on "Pens" in the upper right corner of the plot window to open the plot pens legend. A key appears that indicates what each line is plotting. In this case, it's the population counts.

When a plot gets close to becoming filled up, the horizontal axis increases in size and all of the data from before gets squeezed into a smaller space. In this way, more room is made for the plot to grow.

If you want to save the data from a plot to view or analyze it in another program, you can use the "Export Plot" item on the File menu. It saves this information to your computer in a format that can be read back by spreadsheet and database programs such as Excel. You can also export a plot by control-clicking (Mac) or right-clicking (Windows) it and choosing "Export..." from the popup menu.

Monitors

Monitors are another method of displaying information in a model. Here are the monitors in Wolf Sheep Predation:



The monitor labeled "time-ticks" tells us how much time has passed in the model. The other monitors show us the population of sheep and wolves, and the amount of grass. (Remember, the amount of grass is divided by four to keep the plot from getting too tall.)

The numbers displayed in the monitors update continuously as the model runs, whereas the plots show you data from the whole course of the model run.

Note that NetLogo has also another kind of monitor, called "agent monitors". These will be introduced in Tutorial #2.

Controlling the View

If you look at the view, you'll see a strip of controls along the top edge. The control strip lets you control various aspects of the view.

Let's experiment with the effect of these controls.

- Press "setup" and then "go" to start the model running.
- As the model runs, move the slider in the control strip back and forth.

What happens?

This slider is helpful if a model is running too fast for you to see what's going on in detail.

- Move the speed slider all the way to the right again.
- Now try pressing and unpressing the red arrowhead in the control strip.
- Also try pressing and unpressing the on/off switch in the control strip.

What happens?

The shapes button and the freeze button are useful if you're impatient and want a model to run faster. When shapes are turned off, turtles are drawn as solid squares; it takes less work for NetLogo to draw squares than special shapes, so the model runs faster.

The freeze button "freezes" the view. The model continues to run in the background, and plots and monitors still update; but if you want to see what's happening, you need to unfreeze the view by turning the switch back on. Most models run much faster when the view is frozen.

The size of the view is determined by three separate settings: Screen Edge X, Screen Edge Y, and Patch Size. Let's take a look at what happens when we change the size of the view in the "Wolf Sheep Predation" model.

- Experiment with the three sets of black arrows on the left of the control strip.

What happens the first time you press one of them?

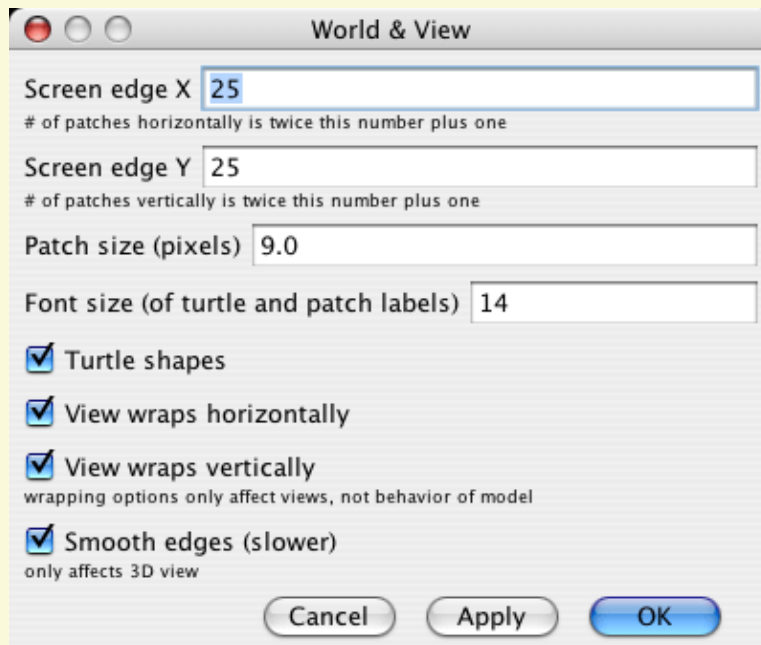
What happens after that? Try all three sets of arrows.

The arrows give you a convenient way of changing the number of patches in the world. NetLogo can't change the number of patches without starting the model over from the beginning, so that's why it warns you the first time you press an arrow.

There are more world and view settings than there's room for in the control strip. The "Edit..." button lets you get to the rest of the settings.

- Press the "Edit..." button in the control strip.

A dialog box will open containing all the settings for the view:



What are the current settings for Screen Edge X, Screen Edge Y, and Patch Size?

- Press "cancel" to make this window go away without changing the settings.
- Place your mouse pointer next to, but still outside of, the view.

You will notice that the pointer turns into a crosshair.

- Hold down the mouse button and drag the crosshair over the view.

The view is now selected, which you know because it is now surrounded by a gray border.

- Drag one of the square black "handles". The handles are found on the edges and at the corners of the view.
- Unselect the view by clicking anywhere in the white background of the Interface tab.
- Press the "Edit..." button again and look at the settings.

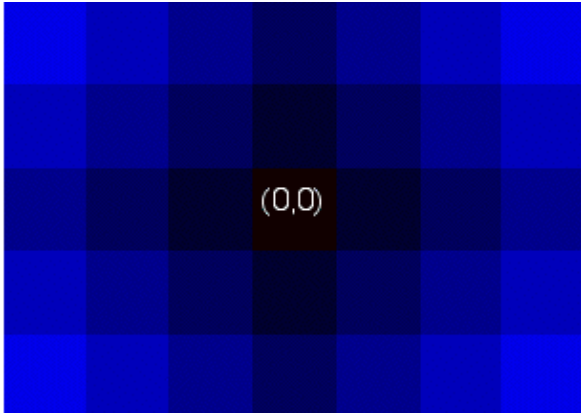
What numbers changed?

What numbers didn't change?

The NetLogo world is a two dimensional grid of "patches". Patches are the individual squares in the grid.

In Wolf Sheep Predation, when the "grass?" switch is on the individual patches are easily seen, because some of them are green, while others are brown.

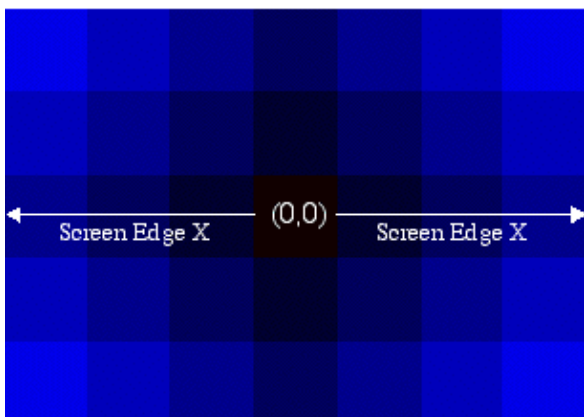
Think of the patches as being like square tiles in a room with a tile floor. Exactly in the middle of the room is a tile labeled (0,0); meaning that if the room was divided in half one way and then the other way, these two dividing lines would intersect on this tile. We now have a coordinate system that will help us locate objects within the room:

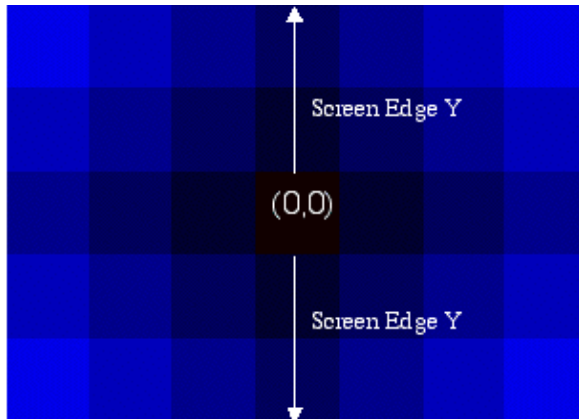


How many tiles away is the (0,0) tile from the right side of the room?

How many tiles away is the (0,0) tile from the left side of the room?

In NetLogo, the distance the middle tile is from the right or left edge of the room this is called Screen Edge X. And the distance the middle tile is from the top and bottom edges is called Screen Edge Y:





In these diagrams, Screen Edge X is 3 and Screen Edge Y is 2.

When you change the patch size, the number of patches (tiles) doesn't change, the patches only get larger or smaller on the screen.

Let's look at the effect of changing Screen Edge X and Screen Edge Y.

- Using the Edit dialog that is still open, change Screen Edge X to 30 and Screen Edge Y value to 10.

What happened to the shape of the view?

- Press the "setup" button.

Now you can see the new patches you have created.

- Edit the view again.
- Change the patch size to 20 and press "OK".

What happened to the size of the view? Did its shape change?

Editing the view also lets you change other settings, including the font size of labels and whether the view uses shapes. Feel free to experiment with these and other settings as well.

Once you are done exploring the Wolf Sheep Predation model, you may want to take some time just to explore some of the other models available in the Models Library.

The Models Library

The library contains five sections: Sample Models, Curricular Models, Code Examples, HubNet Calculator Activities, HubNet Computer Activities.

Sample Models

The Sample Models section is organized by subject area and currently contains more than 180 models. We are continuously working on adding new models to it, so come visit this section at a later date to view the new additions to the library.

Some of the folders in Sample Models have folders inside them labeled "(unverified)". These models are complete and functional, but are still in the process of being reviewed for content, accuracy, and quality of code.

Curricular Models

These are models designed to be used in schools in the context of curricula developed by the CCL at Northwestern University. Some of these are models are also listed under Sample Models; others are unique to this section. See the info tabs of the models for more information on the curricula they go with.

Code Examples

These are simple demonstrations of particular features of NetLogo. They'll be useful to you later when you're extending existing models or building new ones. For example, if you wanted to put a histogram within your model, you'd look at "Histogram Example" to find out how.

HubNet Calculator & Computer Activities

This section contains participatory simulations for use in the classroom. For more information about HubNet, see the [HubNet Guide](#).

What's Next?

If you want to learn how to explore models at a deeper level, [Tutorial #2: Commands](#) will introduce you to the NetLogo modeling language.

In [Tutorial #3: Procedures](#) you can learn how to alter and extend existing models and build your own models.

Tutorial #2: Commands

In Tutorial #1, you had the opportunity to view some of the NetLogo models, and you have successfully navigated your way through opening and running models, pressing buttons, changing slider and switch values, and gathering information from a model using plots and monitors. In this section, the focus will start to shift from observing models to manipulating models. You will start to see the inner workings of the models and be able to change how they look.

Sample Model: Traffic Basic

- Go to the Models Library (File menu).
- Open up Traffic Basic, found in the "Social Science" section.
- Run the model for a couple minutes to get a feel for it.
- Consult the Information tab for any questions you may have about this model.

In this model, you will notice one red car in a stream of blue cars. The stream of cars are all moving in the same direction. Every so often they "pile up" and stop moving. This is modeling how traffic jams can form without any cause such as an accident, a broken bridge, or an overturned truck. No "centralized cause" is needed for a traffic jam to form.

You may alter the settings and observe a few runs to get a full understanding of the model.

As you are using the Traffic Basic model, have you noticed any additions you would like to make to the model?

Looking at the Traffic Basic model, you may notice the environment is fairly simple; a black background with a white street and number of blue cars and one red car. Changes that could be made to the model include: changing the color and shape of the cars, adding a house or street light, creating a stop light, or even creating another lane of traffic. Some of these suggested changes are cosmetic and would enhance the look of the model while the others are more behavioral. We will be focusing more on the simpler or cosmetic changes throughout most of this tutorial. ([Tutorial #3](#) will go into greater detail about behavioral changes, which require changing the Procedures tab.)

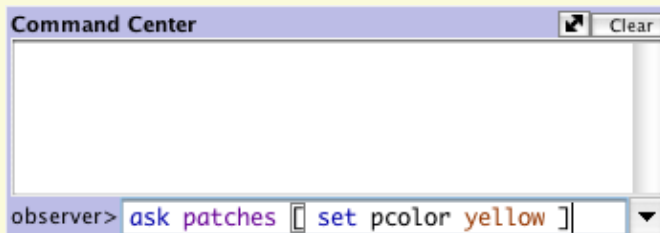
To make these simple changes we will be using the Command Center.

The Command Center

The Command Center is located in the Interface Tab and allows you to enter commands or directions to the model. Commands are instructions you can give to NetLogo's agents: turtles, patches, and the observer. (Refer to the [Interface Guide](#) for details explaining the different parts of the Command Center.)

In Traffic Basic:

- Press the "setup" button.
- Locate the Command Center.
- Click the mouse in the white box at the bottom of the Command Center.
- Type the text shown here:



- Press the return key.

What happened to the View?

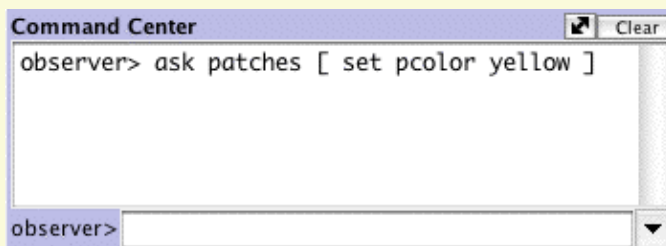
You may have noticed the background of the View has turned all yellow and the street has disappeared.

Why didn't the cars turn yellow too?

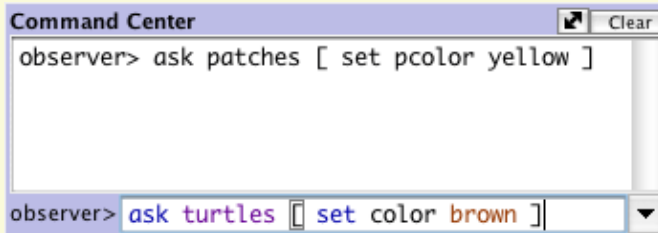
Looking back at the command that was written, we asked only the patches to change their color. In this model, the cars are represented by a different kind of agent, called "turtles". Therefore, the cars did not received these instructions and thus did not change.

What happened in the Command Center?

You may have noticed that the command you just typed is now displayed in the white box in the middle of the Command Center as shown below:

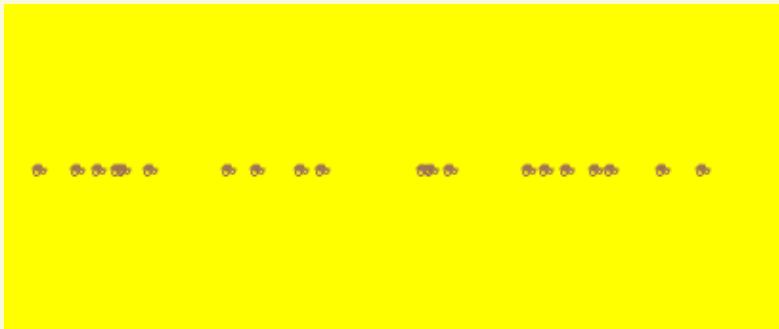


- Type in the white box at the bottom of the Command Center the text shown below:



Was the result what you expected?

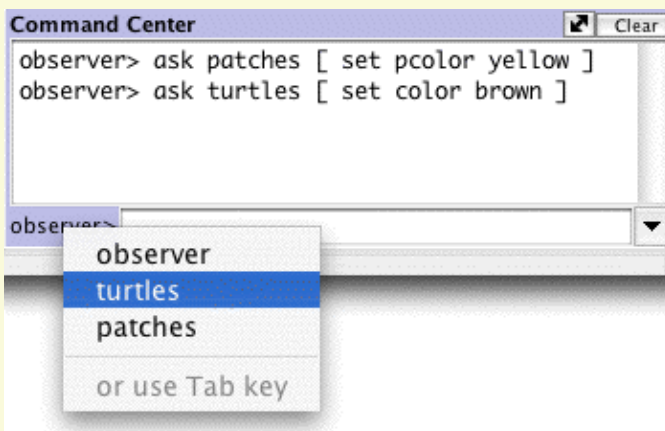
Your View should have a yellow background with a line of brown cars in the middle:



The NetLogo world is a two dimensional world that is made up of turtles, patches and an observer. The patches create the ground in which the turtles can move around on and the observer is a being that oversee everything that is going on in the world. (For a detailed description and specifics about this world, refer to the [NetLogo Programming Guide](#).)

In the Command Center, we have the ability to give the observer a command, the turtles a command, or the patches a command. We choose between these options by using the popup menu located in the bottom left corner of the Command Center. You can also use the tab key on your keyboard to cycle through the different options.

- In the Command Center, click on the "O>" in the bottom left corner:



- Choose "Turtles" from the popup menu.
- Type `set color pink` and press return.
- Press the tab key until you see "P>" in the bottom left corner.
- Type `set pcolor white` and press return.

What does the View look like now?

Do you notice any differences between these two commands and the observer commands from earlier?

The observer oversees the world and therefore can give a command to the patches or turtles using `ask`. Like in the first example (`O>ask patches [set pcolor yellow]`), the observer has to ask the patches to set their `pcolor` to yellow. But when a command is directly given to a group of agents like in the second example (`P>set pcolor white`), you only have to give the command itself.

- Press "setup".

What happened?

Why did the Graphic Window revert back to the old version, with the black background and white road? Upon pressing the "setup" button, the model will reconfigure itself back to the settings outlined in the Procedures tab. The Command Center is not often used to permanently change the model. It is most often used as a tool to customize current models and allows for you to manipulate the NetLogo world to further answer those "What if" questions that pop up as you are investigating the models. (The Procedures tab is explained in the next tutorial, and in the [Programming Guide](#).)

Now that we have familiarized ourselves with the Command Center, let's look at some more details about how colors work in NetLogo.

Working With Colors

You may have noticed in the previous section that we used two different words for changing color: `color` and `pcolor`.

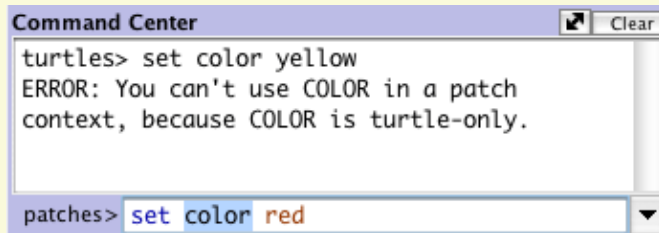
What is the difference between `color` and `pcolor`?

- Choose "Turtles" from the popup menu in the Command Center (or use the tab key).
- Type `set color blue` and press return.

What happened to the cars?

Think about what you did to make the cars turn blue, and try to make the patches turn red.

If you try to ask the patches to `set color red`, an error message occurs:



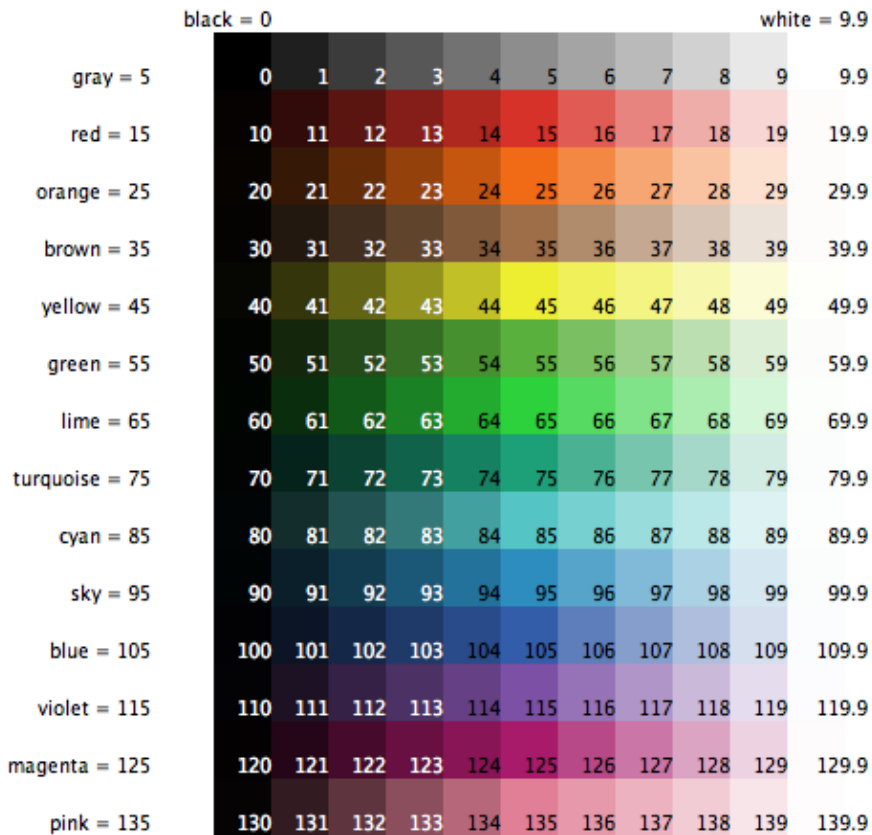
- Type `set pcolor red` instead and press return.

We call `color` and `pcolor` "variables". Some commands and variables are specific to turtles and some are specific to patches. For example, the `color` variable is a turtle variable, while the `pcolor` variable is a patch variable.

Go ahead and practice altering the colors of the turtles and patches using the `set` command and these two variables.

To be able to make more changes to the colors of turtles and patches, or shall we say cars and backgrounds, we need to gain a little insight into how NetLogo deals with colors.

In NetLogo, all colors have a numeric value. In all of the exercises we have been using the name of the color. This is because NetLogo recognizes 16 different color names. This does not mean that NetLogo only recognizes 16 colors. There are many shades in between these colors that can be used too. Here's a chart that shows the whole NetLogo color space:



To get a color that doesn't have its own name, you just refer to it by a number instead, or by adding or subtracting a number from a name. For example, when you type `set color red`, this does the same thing as if you had typed `set color 15`. And you can get a lighter or darker version of the same color by using a number that is a little larger or a little smaller, as follows.

- Choose "Patches" from the popup menu in the Command Center (or use the tab key).
- Type `set pcolor red - 2` (The spacing around the "-" is important.)

By subtracting from red, you make it darker.

- Type `set pcolor red + 2`

By adding to red, you make it lighter.

You can use this technique on any of the colors listed in the chart.

Agent Monitors and Agent Commanders

In the previous activity, we used the `set` command to change the colors of all the cars. But if you recall, the original model contained one red car amongst a group of blue cars. Let's look at how to change only one car's color.

- Press "setup" to get the red car to reappear.
- If you are on a Macintosh, hold down the Control key and click on the red car. On other operating systems, click on the red car with the right mouse button.
- From the popup menu that appears, choose "inspect turtle 0"

A turtle monitor for that car will appear:

turtle 0	
who	0
color	15.0
heading	90.0
xcor	6.772186068086915
ycor	0.0
shape	"car"
label	
label-color	9.9999
breed	turtles
hidden?	false
size	1.0
pen-size	1.0
pen-mode	"up"
speed	6.1
speed-limit	1
speed-min	0

Taking a closer look at this turtle monitor, we can see all of the variables that belong to the red car. A variable is a place that holds a value that can be changed. Remember when it was mentioned that all colors are represented in the computer as numbers? The same is true for the agents. For example, turtles have an ID number we call their "who" number.

Let's take a closer look at the turtle monitor:

What is this turtle's who number?

What color is this turtle?

What shape is this turtle?

This turtle monitor is showing a turtle who that has a who number of 0, a color of 15 (red — see above chart), and the shape of a car.

There are two other ways to open a turtle monitor besides right-clicking (or control-clicking, depending on your operating system). One way is to choose "Turtle Monitor" from the Tools menu, then type the who number of the turtle you want to inspect into the "who" field and press return. The

other way is to type `inspect turtle 0` (or other who number) into the Command Center.

You close a turtle monitor by clicking the close box in the upper left hand corner (Macintosh) or upper right hand corner (other operating systems).

Now that we know more about Agent Monitors, we have three ways to change an individual turtle's color.

One way is to use the box called an Agent Commander found at the bottom of an Agent Monitor. You type commands here, just like in the Command Center, but the commands you type here are only done by this particular turtle.

- In the Agent Commander of the Turtle Monitor for turtle 0, type `set color pink`.

What happens in the View?

Did anything change in the Turtle Monitor?

A second way to change one turtle's color is to go directly to the color variable in the Turtle Monitor and change the value.

- Select the text to the right of "color" in the Turtle Monitor.
- Type in a new color such as `green + 2`.

What happened?

The third way to change an individual turtle's or patch's color is to use the observer. Since, the observer oversees the NetLogo world, it can give commands that affect individual turtles, as well as groups of turtles.

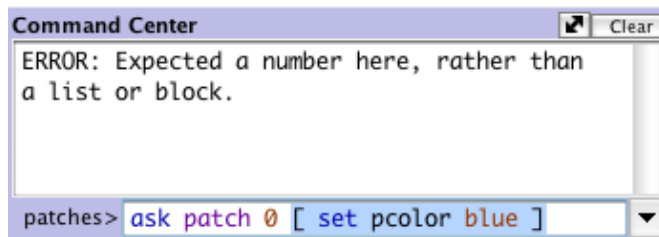
- In the Command Center, select "Observer" from the popup menu (or use the tab key).
- Type `ask turtle 0 [set color blue]` and press return.

What happens?

Just as there are Turtle Monitors, there are also Patch Monitors. Patch monitors work very similarly to Turtle Monitors.

Can you make a patch monitor and use it to change the color of a single patch?

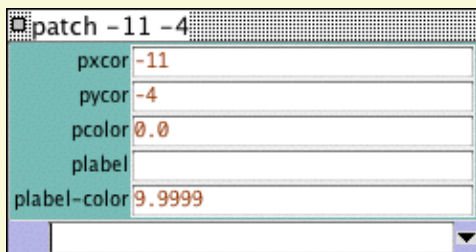
If you try to have the observer ask `patch 0 [set pcolor blue]`, you'll get an error message:



To ask an individual turtle to do something, we use its `who` number. But patches don't have `who` numbers, therefore we need to refer to them some other way.

Remember, patches are arranged on a coordinate system. Two numbers are needed to plot a point on a graph: an `x`-axis value and a `y`-axis value. Patch locations are designated in the same way as plotting a point.

- Open a patch monitor for any patch.



The monitor shows that for the patch in the picture, its `pxcor` variable is -11 and its `pycor` variable is -4. If we go back to the analogy of the coordinate plane and wanted to plot this point, the point would be found in the lower left quadrant of the coordinate plane where $x=-11$ and $y=-4$.

To tell this particular patch to change color, use its coordinates.

- Type `ask patch -11 -4 [set pcolor blue]` and press return.

What are the two words in this command that "tip you off" that we are addressing a patch?

What's Next?

At this point, you may want to take some time to try out the techniques you've learned on some of the other models in the Models Library.

In [Tutorial #3: Procedures](#) you can learn how to alter and extend existing models and build your own models.

Tutorial #3: Procedures

In Tutorial #2, you learned how to use command centers and agent monitors to inspect and modify agents and make them do things. Now you're ready to learn about the real heart of a NetLogo Model: the Procedures tab. This tutorial leads you through the process of building a complete model, built up stage by stage, with every step explained along the way.

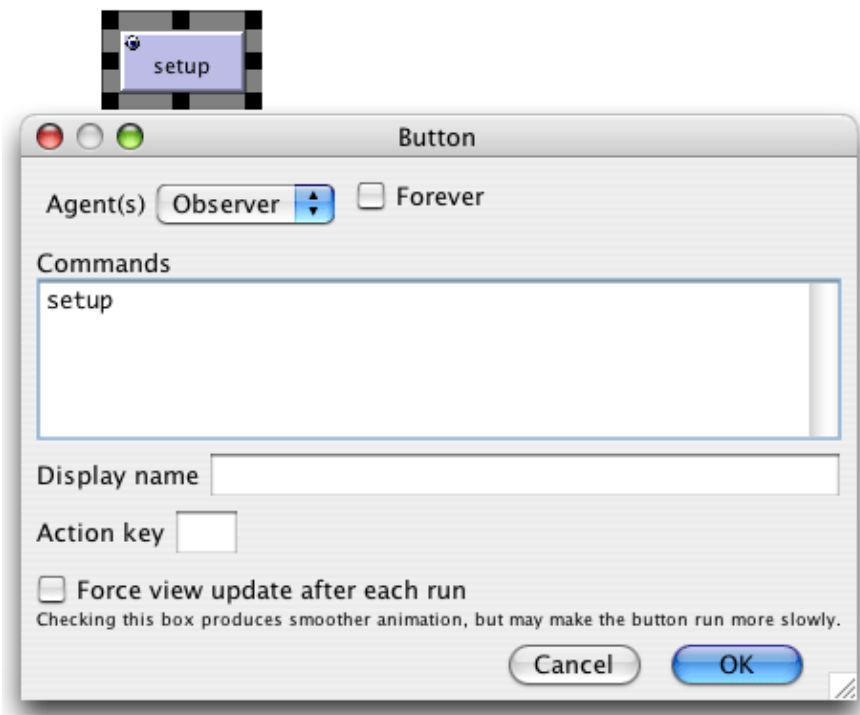
You've already been exposed to the three types of agents you can give commands to in NetLogo: turtles, patches, and the observer. As you start to write your own procedures, it'll be helpful to keep in mind how people usually think of these three different kinds of agents. The turtles and patches usually don't use information about the whole world. They mostly use information about what's close to them. The observer, on the other hand, typically uses and accesses the whole world. Also, while patches can't move and often represent some sort of environment, turtles can move around in the world.

Setup and Go

To start a new model, select "New" from the the File menu. Then begin making your model by creating a once button called 'setup'.

Here's how to make the button:

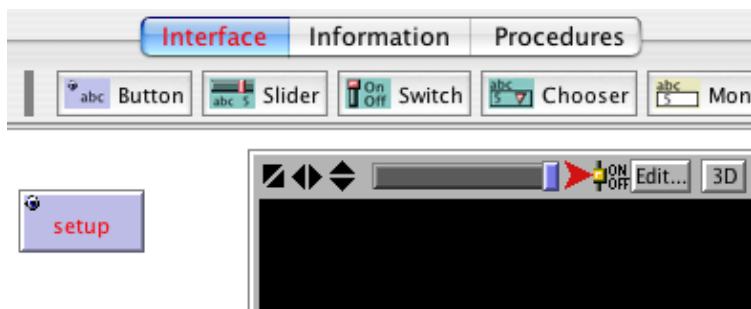
1. Click on the button icon in the Toolbar
2. Click where you want the button to be in the empty white area of the Interface tab
3. When the dialog box for editing the properties of the button opens, type `setup` in the box labeled "Code"



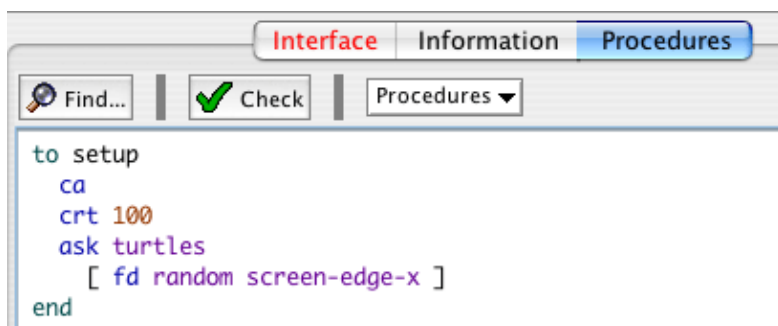
4. Press "OK" to dismiss the dialog box

Now you have a button called 'setup'. It will execute the procedure 'setup' when pressed, which once we define it, will do just that — set up the NetLogo world.

At this point, both the new button and the Interface tab have turned red. That's because there is no procedure called 'setup'! If you want to see the actual error message, click on the button:



Now switch to the Procedures Tab and create the 'setup' procedure shown below. Notice that the lines are indented different amounts. A lot of people find it very helpful to indent their code in a way at least similar to how it's done here. It helps them keep track of where they're at inside of a procedure and makes what they write easier for others to read as well.



One line at a time:

to setup begins defining a procedure named "setup".

ca is short for **clear-all** (you can also spell it out if you want). This command will blank out the screen, initialize any variables you might have to 0, and remove all turtles. Basically, it wipes the slate clean for a new run of the project.

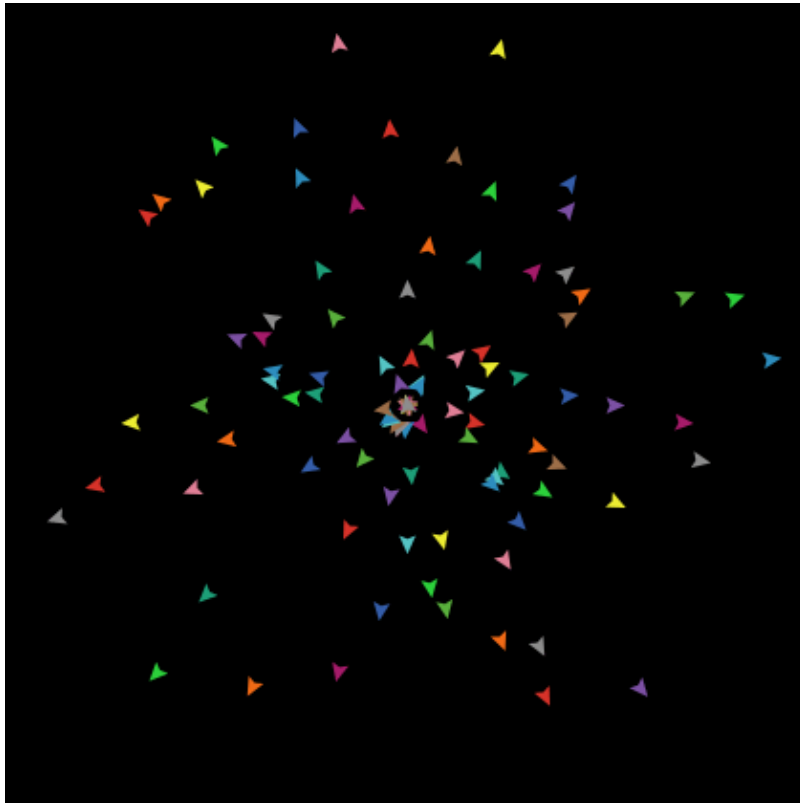
crt 100 will then create 100 turtles. (**crt** is short for **create-turtles**.) If the turtles didn't move after this command is given, each of these turtles would begin on the center patch (at location 0,0). You would only see what looks like one turtle on the screen; they'd all be on top of each other — lots of turtles can share the same patch. Only the last turtle to arrive on the patch would be visible. Each of these newly-created turtles has its own color, its own heading. All of the turtles are evenly distributed around the circle.

ask turtles [...] tells each turtle to execute, independently, the instructions inside the brackets. Note that **crt** is not inside the brackets. If the agent (observer, turtle, or patch) is not specified using **ask**, the observer runs it. Here the observer runs the ask, but the turtles run the commands inside the ask.

fd (random screen-edge-x) is a command that also uses "reporters". Reporters, as opposed to commands, are instructions that report a result. Each turtle will first run the reporter **random screen-edge-x** which will report a random integer at least 0 but less than 'screen-edge-x' (the dimension from the center to the edge of the screen along the x-axis). It then takes this number, and goes **fd** (short for **forward**) that number of steps, in the direction of its heading. The steps are the same size as the patches.

end completes the definition of the "setup" procedure.

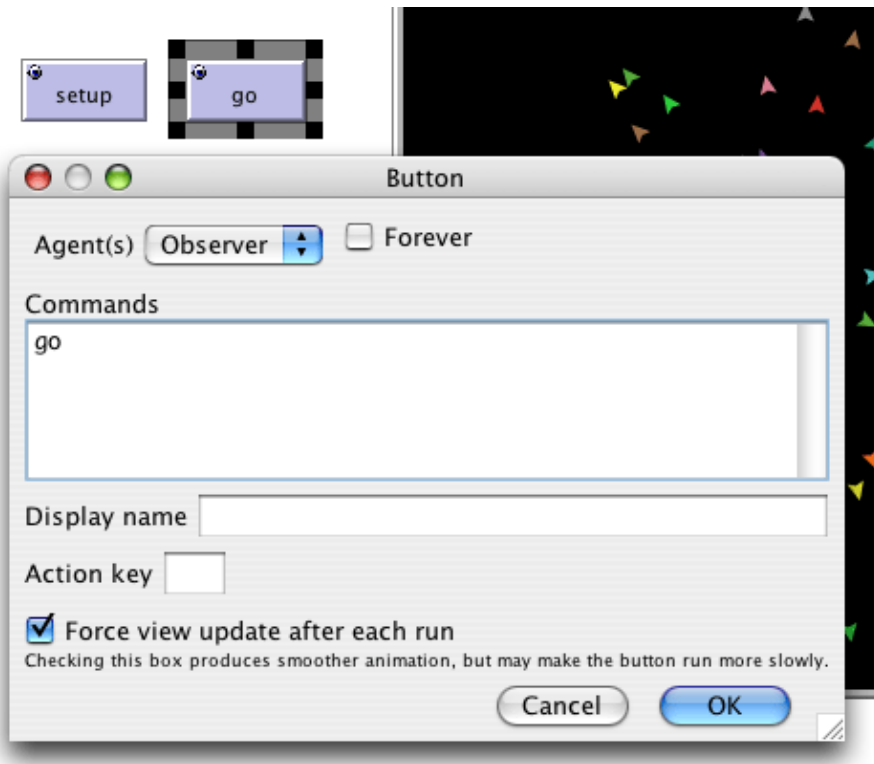
When you're done typing in the code, switch to the Interface tab and press your 'setup' button . You will see the turtles quickly spread out in a rough cluster:



Notice the density distribution of the turtles in the view. Press 'setup' a couple more times, and watch how the turtles' arrangement changes. Keep in mind that some turtles may be right on top of each other.

Can you think of other ways to randomly distribute the turtles over the screen? Note that if a turtle moves off the screen, it "wraps", that is, comes in the other side.

Make a forever button called 'go'. Again, begin by creating a button, but this time check the "forever" checkbox in the edit dialog.



Then add its procedure to the Procedures tab:

```
to go
  move-turtles
end
```

But what is **move-turtles**? Is it a primitive (in other words, built-in to NetLogo), like **fd** is? No, it's a procedure that you're about to write, right after the **go** procedure:

```
to move-turtles
  ask turtles [
    set heading (random 360)
    fd 1
  ]
end
```

Be careful of the spacing around the "-". In Tutorial #2 we used `red - 2`, with spaces, in order to subtract two numbers, but here we want `move-turtles`, without spaces. The "-" combines 'move' and 'turtles' into one word.

Line by line:

ask turtles [commands] says that each turtle should execute the commands in the brackets.

set heading (random 360) is another command that uses a reporter. First, each turtle picks a random integer between 0 and 359 (**random** doesn't include the number you give it as a possible result). Then the turtle sets its heading to the number it picked. Heading is measured in degrees, clockwise around the circle, starting with 0 degrees at twelve o'clock (north).

fd 1: Each turtle moves forward one step in the new direction it just set its heading to.

Why couldn't we have just written that in **go**? We could, but during the course of building your project, it's likely that you'll add many other parts. We'd like to keep **go** as simple as possible, so that it is easy to understand. Eventually, it could include many other things you want to have happen as the model runs, such as calculating something or plotting the results. Each of these sub-procedures could have its own name.

The 'go' button you made in the Interface tab is a forever button, meaning that it will continually execute its code until you shut it off (by clicking on it again). After you have pressed 'setup' once, to create the turtles, press the 'go' button. Watch what happens. Turn it off, and you'll see that all turtles stop in their tracks.

We suggest you start experimenting with other turtle commands. You might try typing **turtles> pendown** into the Command Center and then pressing go. Another thing to try is changing **set heading (random 360)** to **rt (random 360)** inside of **move-turtles**. ("rt" is short for "right turn".) Also, you can try changing **set heading (random 360)** to **lt (random 45)** inside of **move-turtles**. Type commands into the Command Center (like **set color red**), or add them to **setup**, **go**, or **move-turtles**. Note that when you enter commands in the Command Center, you must choose **turtles>**, **patches>**, or **observer>** in the popup menu on the left, depending on which agents are going to execute the commands. You can also use the tab key, which you might find more convenient than using the popup menu. **turtles>commands** is identical to **observer> ask turtles [commands]**, and **patches>commands** is identical to **O> ask patches [commands]**.

Play around. It's easy and the results are immediate and visible -- one of NetLogo's many strengths. Regardless, the tutorial project continues...

Patches and Variables

Now we've got 100 turtles aimlessly moving around, completely unaware of anything else around them. Let's make things a little more interesting by giving these turtles a nice background against which to move. Go back to the 'setup' procedure. We can rewrite it as follows:

```
patches-own [elevation]

to setup
  ca
  setup-patches
  setup-turtles
end
```

The line at the top, **patches-own [elevation]** declares that we have a variable for the patches, called **elevation**. Our 'setup-patches' procedure that we haven't defined yet will then use this variable. We also still need to define 'setup-turtles' as well, but, for now, here's how to define **setup-patches**:

```
to setup-patches
  ask patches
    [ set elevation (random 10000) ]
  diffuse elevation 1
  ask patches
    [ set pcolor scale-color green elevation 1000 9000 ]
end
```

The **setup-patches** procedure sets the elevation and color of every patch. First, each patch picks a random integer between 0 and 9999 and sets its *elevation* variable to that number.

We then use an observer primitive, **diffuse**, that smooths out the distribution of this variable over the neighboring patches. Remember that primitives are built in procedures in NetLogo, as opposed to procedures that you define.

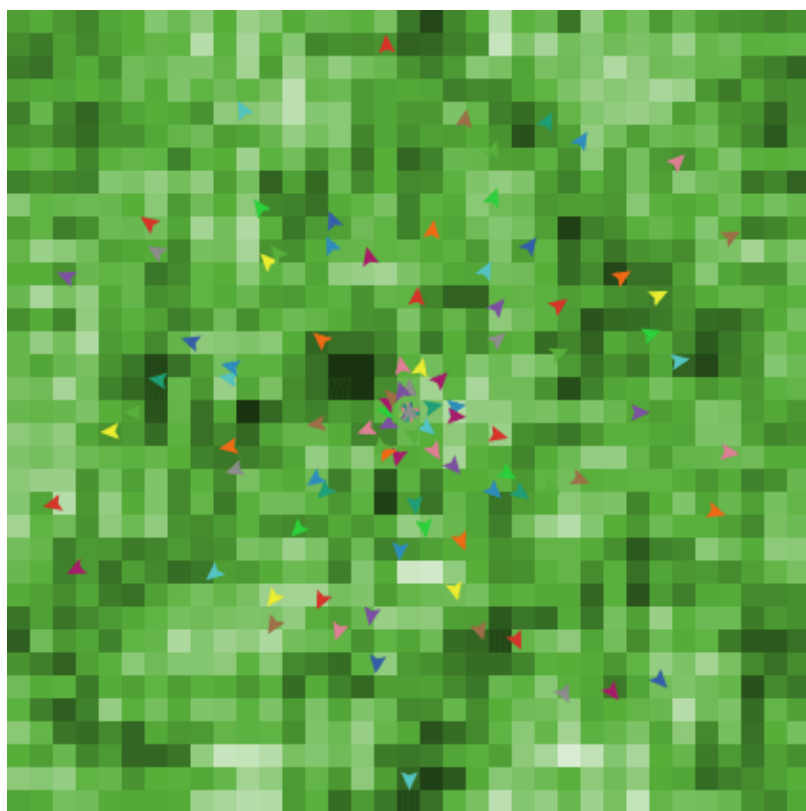
Scale-color is a reporter that uses the different values of *elevation* to assign colors to the patches. In this case, we're assigning different shades of green to all the patches. (Don't worry about the numbers given to **diffuse** and **scale-color** just yet...) The larger *elevation* is, the lighter the shade of green. Low values of *elevation* will result in darker shades.

The only part remaining in our new 'setup' that is still undefined is **setup-turtles**:

```
to setup-turtles
  crt 100
  ask turtles
    [ fd (random screen-edge-x) ]
end
```

Setup-turtles is exactly what we were doing in the old **setup** procedure.

After typing all of this in, press the 'setup' button back in the Interface tab. Voila! A lush NetLogo landscape complete with turtles and green patches appears. After seeing the new 'setup' work a few times, you may find it helpful to read through the procedure definitions again.



Here's a way for you to see what **diffuse** does. Return to the Procedures tab, and use a semicolon to 'deactivate' the diffuse command like this:

```
;diffuse elevation 1
```

Semicolons are very useful in writing procedures. They can be used as above to save you from having to delete code to try something else out and then having to rewrite them. Also, they can be used to add some explanatory text to your procedures. A lot of people like to do this to make their procedures more readable to others. Notice that all the text to the right of a semicolon becomes gray.

Press 'setup' again — looks different, doesn't it? This is because, as mentioned above, **diffuse** has each patch share its value of *elevation* with all its neighbors, by having every patch reset its value of *elevation* to a new value that depends on the value of *elevation* all around it. For further explanation of how diffuse works, go to the [Primitives Dictionary](#) if you'd like. Also, it may help to toy with the values being passed to it and see what happens.

We're now prepared to create some kind of dialog between the turtles and the patches. In fact, we even have an idea for a project here. Notice that we called the patch variable 'elevation', and that our landscape sort of looks topographical? We're going to have our turtles do what is called 'hill-climbing', where every turtle seeks to find the highest elevation it can.

In order to do this, we will learn how to write more complex instructions. Go to the Command Center, and type **O> show max values—from patches [elevation] and show min values—from patches [elevation]**. These two reporters will, respectively, search over all the patches to return to you the highest elevation and the lowest. These commands work like this (you can read about them in the NetLogo [Primitives Dictionary](#)):

Look up 'values—from' in the dictionary. It shows "values—from AGENTSET [expression]" and says it returns a list. In this case, it looks at the expression (elevation) for each agent in the agentset (patches) and returns all of these as a list of elevations.

Look up 'min' in the dictionary. It shows "min *list*" and says it's a reporter. So it takes the list of elevations and reports the smallest value.

'Show' displays this value in the command center.

We will use these reporters — **max values—from patches [elevation]** and **min values—from patches [elevation]** — in our model.

Just in case we end up needing the highest and lowest elevation in several places in our procedures, let's make a shortcut. We'll do a little extra work now so that if we need these values later, we'll have a shortcut to use. First, at the top of your code (right after the 'patches—own' declaration), declare two global variables as such:

```
globals [highest ;; the highest patch elevation
         lowest] ;; the lowest patch elevation
```

(Notice the use of semicolons here. Although the names of the global variables are descriptive, the semicolons allow us to describe the variables even more.)

Global variables can be used by all the agents in the model. In particular, patches can use *highest* and *lowest* in the **setup—patches** procedure. We need to store the highest and lowest elevations in these global variables once, and then everyone will have quick access to them after

that. Write:

```
to setup-patches
  ask patches
    [ set elevation (random 10000) ]
  diffuse elevation 1
  ask patches
    [ set pcolor scale-color green elevation 1000 9000 ]
  set highest max values-from patches [elevation]
  set lowest min values-from patches [elevation]
  ask patches [
    if (elevation > (highest - 100))
      [set pcolor white]
    if (elevation < (lowest + 100))
      [set pcolor black] ]
end
```

Now we have saved the highest and lowest points in our terrain and displayed them graphically.

Look at the last two commands, the **if** commands. Each patch, when it runs these commands, compares its own value of *elevation* to our global variables *highest* and *lowest*. If the comparison reports 'true', the patch executes the commands inside the brackets. In this case, the patch changes its color. If the comparison reports 'false', the patch skips over the commands inside the brackets.

These **ifs** cause all patches whose value of *elevation* is NEAR to the highest (within about 1% for our values) change their color to white, and all patches whose values are NEAR to the lowest become black. We want this so that they'll be easier to see. You can make a couple of quick changes here if you wish — they won't affect the rest of the model. For example, instead of saying 'set pcolor white' and 'set pcolor black', you can say 'set pcolor blue' and 'set pcolor red' (or whatever other colors you may wish). Also, you can change the range of 'highest peaks' and 'lowest peaks' by changing the number 100 to some other number.

After this, create two monitors in the Interface tab with the Toolbar. (You make them just like buttons and sliders, using the monitor icon on the Toolbar.) Name one of them *highest* and the other one *lowest*. The reporters you'll want in each of them happen to be *highest* and *lowest* as well. (If you want to learn more about reporters, you can look them up in the [NetLogo Programming Guide](#).) Now every time you click 'setup' and redistribute the values of *elevation*, you'll know exactly what the highest and lowest elevations are, and where they can be found.



An Uphill Algorithm

Okay. Finally we're ready to start hill-climbing. To rehash: we've got some turtles randomly spread out from the origin; and we've got a landscape of patches, whose primary attribute is their *elevation*. Lastly, we have two kinds of tools to help us understand the patch landscape: each patch has a color, depending on its value of *elevation*, and we have a pair of monitors telling us what the highest peak and lowest valley are. What we need now is for the turtles to wander around, each trying to get to the patch that has the highest elevation.

Let's try a simple algorithm first. We'll assume three things: 1), that the turtles cannot see ahead farther than just one patch; 2), that each turtle can move only one square each turn; and 3), that turtles are blissfully ignorant of each other. Before, we had a procedure **move-turtles** like this:

```
to move-turtles
  ask turtles [
    set heading (random 360)
    fd 1
  ]
end
```

But now we don't want them to move randomly about. We want each turtle to look at the *elevation* of each patch directly around it, and move to the patch with the highest elevation. If none of the patches around it have a higher elevation than the patch it is on, it'll stay put. This new procedure should replace 'move-turtles' inside of 'go'. Type in the following code and run it once or twice:

```
;; each turtle goes to the highest elevation in a radius of one
to move-to-local-max
  ask turtles [
    set heading uphill elevation
    if ( elevation-of patch-ahead 1 > elevation )
    [ fd 1 ]
  ]
end
```

Now that you've seen the uphill algorithm work in the model, let's go through the new primitives involved. (If you haven't run the model yet since writing 'move-to-local-max', give it a try.) There are three new primitives here: '**uphill**', '**-of**', and '**patch-ahead**'. 'uphill elevation' finds the heading to the patch with the highest value of *elevation* in the patches in a one-patch radius of the turtle. Then through the use of the command 'set heading', the turtle sets its heading to that direction. 'elevation-of patch-ahead 1' has each turtle look at the variable *elevation* in the patch on which the turtle would be if it went forward 1. If the test reports true, the turtle moves itself forward 1. (The test is necessary because if the turtle is already on the peak, we don't want it to move off it!)

Go ahead and type that in, but before you test it out by pressing the 'go' button, ask yourself this question: what do you think will happen? Try and predict how a turtle will move, where it will go, and how long it'll take to get there. When you're all set, press the button and see for yourself.

Surprised? Try to understand why the turtles converge to their peaks so quickly. Maybe you don't believe the algorithm we've chosen works 'correctly'. There's a simple procedure you can make to test it. write a procedure **recolor-patches** so that it says:

```
to recolor-patches
  ask patches
  [
    set elevation pycor
    set pcolor scale-color green elevation
                      (0 - screen-edge-y) screen-edge-y
  ]
end
```

Press 'setup'. The model looks the same as it did before because **recolor-patches** hasn't been run yet. Instead of making a button that calls your testing procedure, let's do something different. Type `observer>recolor-patches` into the command center, the procedure gets called. Now, when you press 'go', see that the turtles all head for the highest elevation — the top of the screen.

Another common tool to see what's going on is to write **turtles> pd** in the Command Center. Then each turtle traces its path with its color. This will show you where the turtle has been.

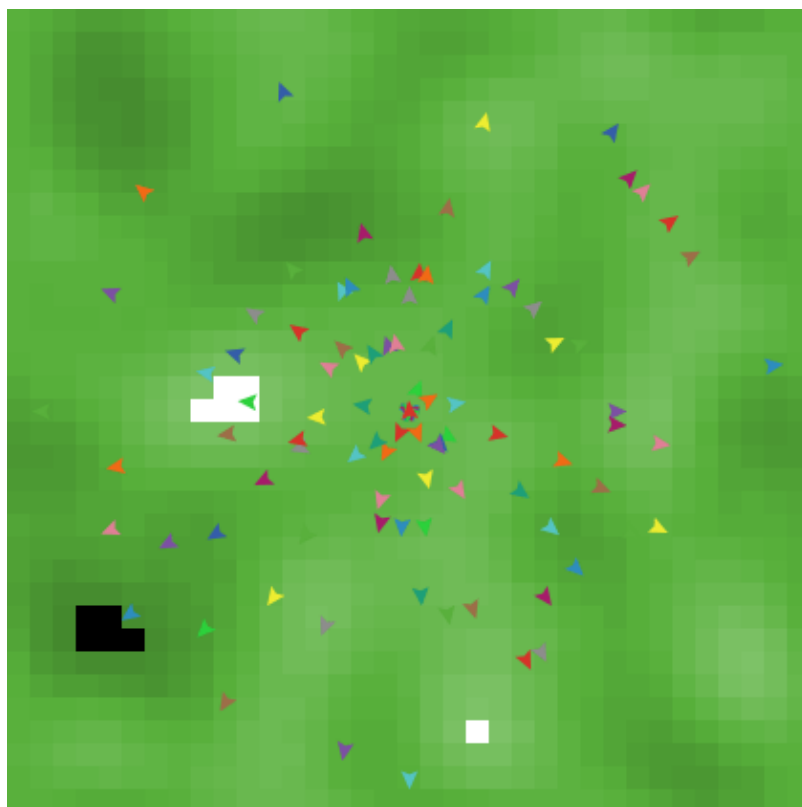
Our turtles rapidly arrive at local maxima in our landscape. Local maxima and minima abound in a randomly generated landscape like this one. Our goal is to still get the turtles to find an 'optimal maximum', which is one of the white patches.

Part of the problem is that our terrain is terribly lumpy. Every patch picked a random elevation, and then we diffused these values one time. This really doesn't give us a continuous spread of elevation across the view, as you might have noticed. We can correct this problem to an arbitrary degree by diffusing more times. Replace the line:

```
diffuse elevation 1
```

with:

```
repeat 5 [ diffuse elevation 1 ]
```



The **repeat** command is another way for NetLogo to loop (besides making a forever button, which you already know how to do). **Repeat** takes a number (here, 5) and some commands (here, the **diffuse** command), and executes the commands that number of times (here, five times). Try it out, and look at the landscape (i.e. press 'setup' and see what you think). Then, press 'go' and watch the turtles' behavior. (Remember that the lighter the patch, the greater the elevation.)

Obviously, fewer peaks make for an improvement in the turtles' performance. On the other hand, maybe you feel like this is cheating — the turtles really aren't doing any better, it's just that their problem was made easier. True enough. If you call **repeat** with an even higher number (20 or so),

you'll end up with only a handful of peaks, as the values become more evenly distributed with every successive call. (Watch the values in the monitors.)

In order to specify how 'smooth' you want your world to be, let's make it easier to try different values. Maybe one time you'll want the turtles to try and 'solve a hard world', and maybe another time you'll just want to look at an easy landscape. So we'll make a global variable named "smoothness". Create a slider in the Interface tab and call it "smoothness" in the editing box. The minimum can be 0, and the maximum can be 25 or so. Then change your code to:

```
repeat smoothness [ diffuse elevation 1 ]
```

Experiment with the turtles' performance in different terrains.

We still haven't even begun to solve the problem of getting all the turtles to the highest elevation, though. So far we've just been getting the turtles to the highest point that's near them. If a turtle starts off in one corner of the world on a hill and there's a mountain in a different corner, the turtle will never find the mountain. To find the mountain, the turtle would have to go down off the hill first, but in our model, turtles only move up. Notice that the individual turtles don't use 'highest' anywhere. The turtles just look at elevations close to them and go the highest point they can see.

Before trying something else, it'd be nice if we could have some other, more precise method for evaluating the turtles' performance. Fortunately, NetLogo allows us to plot data as we go along.

To make plotting work, we'll need to create a plot in the Interface tab, and set some settings in it. Then we'll add one more procedure to the Procedures tab, which will update the plot for us.

Let's do the Procedures tab part first. Change **go** to call the new procedure we're about to add:

```
to go
  move-to-local-max
  do-plots
end
```

Now add the new procedure. What we're plotting is the number of turtles who've reached our 'peak-zone' (within 1% of the highest elevation) at some given time.

```
to do-plots
  set-current-plot "Turtles at Peaks"
  plot count turtles with
    [ elevation >= (highest - 100) ]
end
```

Note that we use the **plot** primitive to add the next point to a plot, but before doing that, we need to tell NetLogo which plot we want, since later our model might have more than one plot.

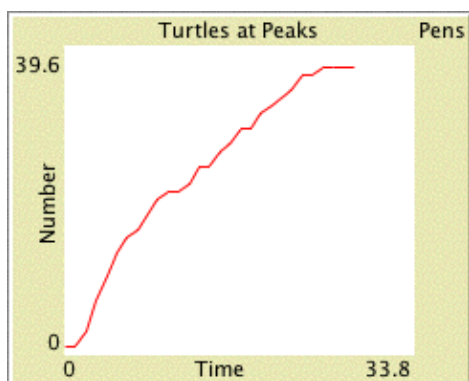
Thus we're plotting the number of turtles within 100 units of our maximum elevation at some given point in time. The **plot** command moves the current plot pen to the point that has x- coordinate equal to 1 greater than the old x- coordinate and y-coordinate equal to the value given in the plot command (in this case, the number of turtles whose elevation is within 100 of highest). Then the *plot* command draws a line from the current position of the plot pen to the last point it was on.

In order for `set-current-plot "Turtles at Peaks"` to work, you'll have to add a plot to your model in the Interface tab, then edit it so its name is "Turtles at Peaks", the exact same name used

in the code. Even one extra space will throw it off — it must be exactly the same in both places.

Note that when you create the plot you can set the minimum and maximum values on the x and y axes, and the color of the default plot pen (pick any color you like). You'll want to leave the "Autoplot?" checkbox checked, so that if anything you plot exceeds the minimum and maximum values for the axes, the axes will automatically grow so you can see all the data.

Now reset the project and run it again. You can now watch the plot be created as the model is running. If you notice that your plot doesn't look exactly like the picture below, try to think about why it doesn't look the same. If you think it's because 'go' remains pressed until you manually unpress it, we'll fix that problem by the end of the tutorial. Remember that we kept "Autoplot?" on. This allows the plot to readjust itself when it runs out of room.



You might try running the model several times under different settings (i.e. different values of *smoothness*) and watch how fast the plot converges to some value, and what fraction of the turtles make it to the top. You may want to even try the same settings several times.

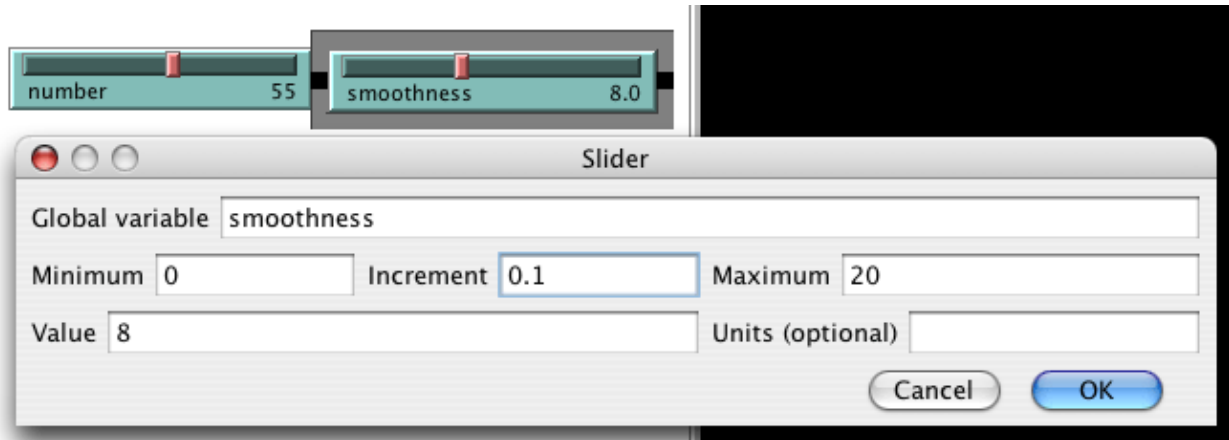
Some More Details

There are a few quirks you may already have noticed. Here are some quick changes you can make.

First, we have a green landscape — a naturally green turtle is going to be hard to see. In the ask turtles block in 'setup-turtles', you can say:

```
if (shade-of? green color)
  [ set color red ]
```

Second, instead of always using 100 turtles, you can have a variable number of turtles. Make a slider variable (say, 'number'):



Then, inside of **setup-turtles**, instead of 'crt 100', you can type:

```
crt number
```

How does using more or fewer turtles affect the success value displayed by the plot?

Third, when all the turtles have found their local maxima, wouldn't it be nice for the model to stop? This requires a few lines of code.

- Add a global variable *turtles-moved?* to the "globals" list:

```
globals [
  highest           ;; maximum patch elevation
  lowest            ;; minimum patch elevation
  turtles-moved?    ;; so we know when to stop the model
]
```

- At the end of the **go** procedure, add a test to see if any turtles have moved.

```
to go
  set turtles-moved? false
  move-to-local-max
  do-plots
  if (not turtles-moved?)
  [ stop ]
end
```

- In **move-to-local-max** if a turtle moves, set *turtles-moved?* to true.

```
to move-to-local-max
  ask turtles [
    set heading uphill elevation
    if ( elevation-of patch-ahead 1 > elevation )
    [
      fd 1
      set turtles-moved? true
    ]
  ]
end
```

Finally, what rules can you think of that would help turtles escape from lower peaks and all get to the highest ones? Try writing them.

What's Next?

So now you have a nice framework for exploring this problem of hill-climbing, using all sorts of NetLogo modeling features: buttons, sliders, monitors, plots, and the view. You've even written a quick procedure to give the turtles something to do. And that's where this tutorial leaves off.

If you'd like to look at some more documentation about NetLogo, the [Interface Guide](#) section of the manual walks you through every element of the NetLogo interface in order and explains its function. For a detailed description and specifics about writing procedures, refer to the [NetLogo Programming Guide](#).

Also, You can continue with this model if you'd like, experimenting with different variables and algorithms to see what works the best (what makes the most turtles reach the peaks).

Alternatively, you can look at other models (including the many models in the Code Examples section of the Models Library) or even go ahead and build your own model. You don't even have to model anything. It can be pleasant just to watch patches and turtles forming patterns, or whatever. Hopefully you will have learned a few things, both in terms of syntax and general methodology for model-building. The entire code that was created above is shown below.

Appendix: Complete Code

The complete model is also available in NetLogo's Models Library, in the Code Examples section. It's called "Tutorial 3".

```
patches-own [ elevation ]      ;; elevation of the patch

globals [
  highest          ;; maximum patch elevation
  lowest           ;; minimum patch elevation
  turtles-moved?   ;; so we know when to stop the model
]

;; We also have two slider variables, 'number' and
;; 'smoothness'. 'number' determines the number of
;; turtles, and 'smoothness' determines how erratic
;; terrain becomes during diffusion of 'elevation'.

;; resets everything
to setup
  ca
  setup-patches
  setup-turtles
end

;; creates a random landscape of patch elevations
to setup-patches
  ask patches [set elevation (random 10000) ]
  repeat smoothness [diffuse elevation 1 ]
  ask patches
    [ set pcolor scale-color green elevation 1000 9000 ]

  set highest max values-from patches [elevation]
  set lowest min values-from patches [elevation]
  ask patches [
```

```

    if (elevation > (highest - 100))
      [set pcolor white]
    if (elevation < (lowest + 100))
      [set pcolor black]
  ]
end

;; initializes the turtles
to setup-turtles
  crt number
  ask turtles [
    if (shade-of? green color) [ set color red ]
    fd (random screen-edge-x)
  ]
end

;; RUN-TIME PROCEDURES
;; main program control
to go
  set turtles-moved? false
  move-to-local-max
  do-plots
  if (not turtles-moved?)
    [ stop ]
end

;; each turtle goes to the highest elevation in a radius of one
to move-to-local-max
  ask turtles [
    set heading uphill elevation
    if ( elevation-of patch-ahead 1 > elevation )
    [
      fd 1
      set turtles-moved? true
    ]
  ]
end

to do-plots
  set-current-plot "Turtles at Peaks"
  plot count turtles with
    [ elevation >= (highest - 100) ]
end

```


Interface Guide

This section of the manual walks you through every element of the NetLogo interface in order and explains its function.

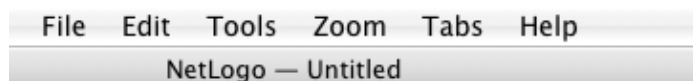
In NetLogo, you have the choice of viewing models found in the Models Library, adding to existing models, or creating your own models. The NetLogo interface was designed to meet all these needs.

The interface can be divided into two main parts: NetLogo menus, and the main NetLogo window. The main window is divided into tabs.

- [Menus](#)
- [Main Window](#)
 - ◆ [Interface Tab](#)
 - ◇ Interface Toolbar
 - ◇ Working With Interface Elements
 - ◇ View
 - ◇ Command Center
 - ◆ [Procedures Tab](#)
 - ◆ [Information Tab](#)

Menus

On Macs, if you are running the NetLogo application, the menubar is located at the top of the screen. On other platforms, the menubar is found at the top of the NetLogo window.



The functions available from the menus in the menubar are listed in the following chart.

Chart: NetLogo Menus

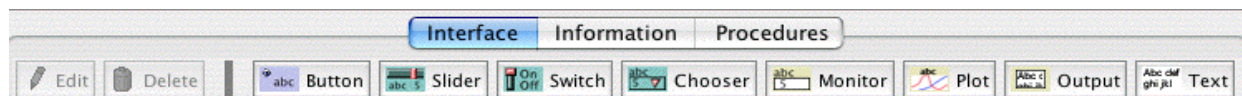
File		
	New	Starts a new model.
	Open	Opens any NetLogo model on your computer.
	Models Library	A collection of demonstration models.
	Save	Save the current model.
	Save As	Save the current model using a different name.
	Save As Applet	Used to save a web page in HTML format that has your model embedded in it as a Java "applet".
	Print	Sends the contents of the currently showing tab to your printer.
	Export World	Saves all variables, the current state of all turtles and patches, the drawing and the output area to a file.
	Export Plot	Saves the data in a plot to a file.
	Export All Plots	Saves the data in all the plots to a file.
	Export View	Save a picture of the current view (2D or 3D) to a file (in PNG format).

	Export Interface	Save a picture of the current Interface tab. (in PNG format)
	Export Output	Save the contents of the output area or the output section of the command center to a file.
	Import World	Load a file that was saved by Export World.
	Import Patch Colors	Load an image into the patches, see the <u>import-pcolors</u> command.
	Import Drawing	Load an image into the drawing, see the <u>import-drawing</u> command.
	Quit	Exits NetLogo. (On Macs, this item is on the NetLogo menu instead.)
Edit		
	Cut	Cuts out or removes the selected text and temporarily saves it to the clipboard.
	Copy	Copies the selected text.
	Paste	Places the clipboard text where cursor is currently located.
	Delete	Deletes selected text.
	Undo	Undo last text editing action you performed.
	Redo	Redo last undo action you performed.
	Select All	Select all the text in the active window.
	Find	Finds a word or sequence of characters within the Information or Procedures tabs.
	Find Next	Find the next occurrence of the word or sequence you last used Find with.
	Shift Left / Shift Right	Used in the Procedures tab to change the indentation level of code.
	Comment / Uncomment	Used in the Procedures tab to add or remove semicolons from code (semicolons are used in NetLogo code to indicate comments).
Tools		
	Halt	Stops all running code, including buttons and the command center. (Warning: since the code is interrupted in the middle of whatever it was doing, you may get unexpected results if you try to continue running the model without first pressing "setup" to start the model run over.)
	Globals Monitor	Displays the values of all global variables.
	Turtle Monitor	Displays the values of all of the variables in a particular turtle. You can can also edit the values of the turtle's variables and issue commands to the turtle. (You can also open a turtle monitor via the View; see the View section below.)
	Patch Monitor	Displays the values of all of the variables in a particular patch. You can can also edit the values of the patch's variables and issue commands to the patch. (You can also open a patch monitor via the View; see the View section below.)
	Hide/Show Command Center	Makes the command center visible or invisible. (Note that the command center can also be shown or hidden, or resized, with the mouse.)
	3D View	Opens the 3D view. See the <u>View</u> section for more information.
	Color Swatches	

		Opens the Color Swatches. See the Color Section of the Programming Guide for details.
	Shapes Editor	Draw turtle shapes. See the Shapes Editor Guide for more information.
	BehaviorSpace	Runs the model over and over with different settings. See the BehaviorSpace Guide for more information.
	System Dynamics Modeler	Opens the System Dynamics Modeler. See the System Dynamics Modeler Guide for more details.
	HubNet Control Center	Disabled if no HubNet activity is open. See the HubNet Guide for more information.
Zoom		
	Larger	Increase the overall screen size of the model. Useful on large monitors or when using a projector in front of a group.
	Normal Size	Reset the screen size of the model to the normal size.
	Smaller	Decrease the overall screen size of the model.
Tabs		This menu offers keyboard shortcuts for each of the tabs. (On Macs, it's Command 1 through Command 4. On Window, it's Control 1 through Control 4.)
Help		
	About NetLogo	Information on the current NetLogo version the user is running. (On Macs, this menu item is on the NetLogo menu instead.)
	User Manual	Opens this manual in a web browser.

Main Window

At the top of NetLogo's main window are three tabs labeled "Interface", "Information" and "Procedures". Only one tab at a time can be visible, but you can switch between them by clicking on the tabs at the top of the window.



Right below the row of tabs is a toolbar containing a row of buttons. The buttons available vary from tab to tab.

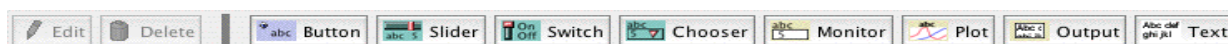
Interface Tab

The Interface tab is where you watch your model run. It also has tools you can use to inspect and alter what's going on inside the model.

When you first open NetLogo, the Interface tab is empty except for the View, where the turtles and patches appear, and the Command Center, which allows you to issue NetLogo commands.

Interface Toolbar

The toolbar contains buttons that let you edit, delete, and create items in the Interface tab (such as buttons and sliders).



The buttons in the toolbar are described below.

Working With Interface Elements

Selecting: To select an interface element, drag a rectangle around it with your mouse. A gray border will appear around the element to indicate that it is selected.

Selecting Multiple Items: You can select multiple interface elements at the same time by including them in the rectangle you drag. If multiple elements are selected, one of them is the "key" item, which means that if you use the "Edit" or "Delete" buttons on the Interface Toolbar, only the key item is affected. The key item is indicated by a darker gray border than the other items.

Unselecting: To unselect all interface elements, click the mouse on the white background of the Interface tab. To unselect an individual element, control-click (Macintosh) or right-click (other systems) the element and choose "Unselect" from the popup menu.

Editing: To change the characteristics of an interface element, select the element, then press the "Edit" button on the Interface Toolbar. You may also double click the element once it is selected. A third way to edit an element is to control-click (Macintosh) or right-click (other systems) it and choose "Edit" from the popup menu. If you use this last method, it is not necessary to select the element first.


Moving: Select the interface element, then drag it with your mouse to its new location. If you hold down the shift key while dragging, the element will move only straight up and down or straight left and right.

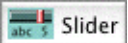
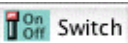

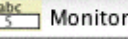
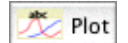
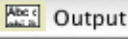
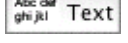
Resizing: Select the interface element, then drag the black "handles" in the selection border.

Deleting: Select the element or elements you want to delete, then press the "Delete" button on the Interface Toolbar. You may also delete an element by control-clicking (Macintosh) or right-clicking (other systems) it and choosing "Delete" from the popup menu. If you use this latter method, it is not necessary to select the element first.

To learn more about the different kinds of interface elements, refer to the chart below.

Chart: Interface Toolbar

Icon & Name	Description
	Buttons can be either <i>once-only</i> buttons or <i>forever</i> buttons. When you click on a once button, it executes its instructions once. The forever button executes the instructions over and over, until you click on the button again to stop the action. If you have assigned an action key to the button, pressing the corresponding keyboard key will act just like a button press when the button is in focus. Buttons with action keys have a letter in the upper right corner of the button to show what the action key is. If the input cursor is in another interface element such as the Command Center, pressing the action key won't trigger the button. The letter in the upper right hand corner of the button will be dimmed in this situation. To enable action keys, click in

	the white background of the Interface tab.
	Sliders are global variables, which are accessible by all agents. They are used in models as a quick way to change a variable without having to recode the procedure every time. Instead, the user moves the slider to a value and observes what happens in the model.
	Switches are a visual representation for a true/false variable. The user is asked to set the variable to either on (true) or off (false) by flipping the switch.
	Choosers let the user choose a value for a global variable from a list of choices, presented in a drop down menu.
	Monitors display the value of any expression. The expression could be a variable, a complex expression, or a call to a reporter. Monitors automatically update several times per second.
	Plots are real-time graphs of data the model is generating.
	The output area is a scrolling area of text which can be used to create a log of activity in the model. A model may only have one output area.
	Text boxes lets you add informative text labels to the Interface tab. The contents of text boxes do not change as the model runs.

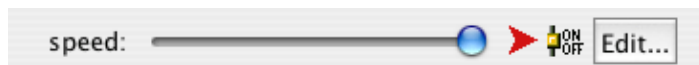
The Views

The large black square in the Interface tab is the 2D view. It's a visual representation of the NetLogo world of turtles and patches. Initially it's all black because the patches are black and there are no turtles yet. You can open the 3D View, another visual representation of the world, by clicking on the "3D" button in the View Control Strip.



There are a number of settings associated with the Views. There are a few ways of changing the settings: by using the control strip along the top edge of the View, or by editing the 2D View, as described in the "Working With Interface Elements" section above, or pressing the "Edit..." button in the control strip.

The 3D View has a similar control strip but it looks slightly different and as you may notice a few of the controls are missing. However, the controls that are present work exactly the same as the 2D View Control Strip.

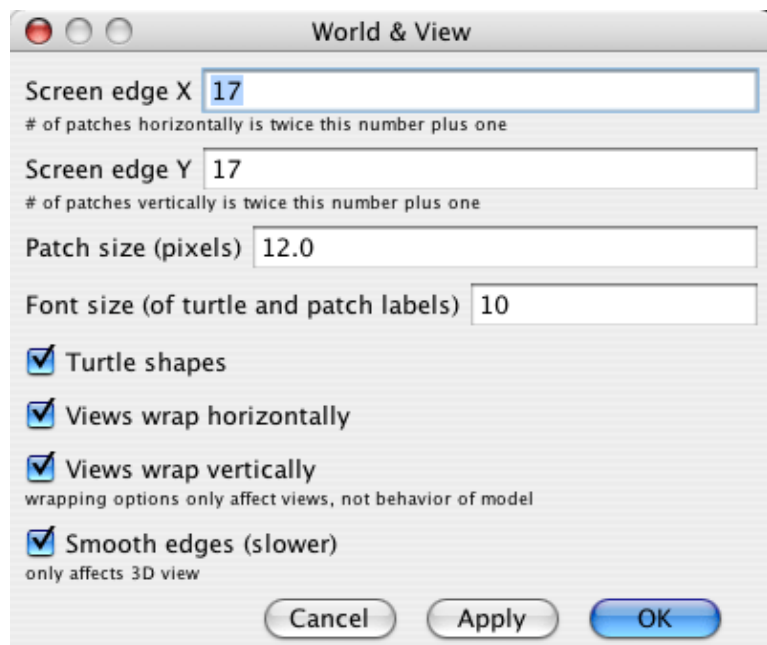


The controls in the control strip work as follows:

- The three sets of black arrows let you change the size of the world.
- The slider lets you control how fast the model runs — this is valuable since some models run so fast that it's hard to see what's going on.
- The button with the arrowhead lets you turn turtle "shapes" on and off. If shapes are off, turtles appear as colored squares, instead of having special shapes. The squares are less work for the computer to draw, so turning shapes off makes models run faster.

- The on–off switch lets you temporarily "freeze" the display. The model keeps running, but the contents of the view don't change until you unfreeze it by flipping the switch again. Most models run much faster when the view is frozen.
- The 3D button switches to the 3D View (see below).

Here are the settings for the View (accessible by editing the View, or by pressing the "Edit..." button in the control strip):



To change the size of the 2D View adjust the "Patch Size" setting, which is measured in pixels. This does not change the number of patches, only how large the patches appear in the 2D View (Note that the patch size does not affect the 3D View, as you can simply make the 3D View larger by making the window larger) .

To change the number of patches, alter the "Screen Edge X" and "Screen Edge Y" settings. (Note that changing the numbers of patches requires rebuilding the NetLogo world; you will lose all turtles and the values of all variables.)

The "Turtle Shapes" checkbox performs the same function as the shapes button in the control strip, discussed above.

The "Views wrap horizontally/vertically" checkboxes indicate whether you would like the world to appear as a torus or not. This includes wrapping shapes around the world and wrapping turtles and patches in follow and ride modes. Note that this only affects the the visual appearance, not the behavior of the model.

The "Smooth edges" checkbox controls the use of anti–aliasing in the 3D view only. It will make the lines appear less jagged but it will slow down the model.

Turtle and patch monitors are easily available through the View, just control–click (Macintosh) or right–click (other systems) on the turtle or patch you want to inspect, and choose "inspect turtle ..." or "inspect patch ..." from the popup menu. You can also watch, follow or ride a turtle by selecting

the appropriate item in the turtle submenu. (Turtle and patch monitors can also be opened from the Tools menu or by using the `inspect` command.)

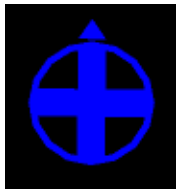
Some NetLogo models let you interact with the turtles and patches with your mouse by clicking and dragging in the View.

Manipulating the 3D View

At the bottom of the window there are buttons to move the observer, or change the perspective from which you are looking at the world.



A blue cross appears at the current focus point as you are adjusting these settings. The little blue triangle will always point up the positive y-axis, so you can orient yourself in case you get lost. It's easy to do!



To look at the world from a different angle, press the "rotate" button click and drag the mouse up, down, left, or right. The observer will continue to face the same point as before (where the blue cross is) but its position in the relation to the xy-plane will change.

To move closer or farther away from the world or the agent you are watching, following or riding, press the "zoom" button and drag up and down along the 3D View. (Note when you are in follow or ride mode zooming will switch you between ride and follow, since ride is just a special case of follow where the distance at which you are following is 0)

To change the position of the observer without changing the direction it is facing select the "move" button and drag the mouse up, down, left, and right inside the 3D View while holding down the mouse button.

To allow the mouse position and state to be passed to the model select the "interact" button and it will function just as the mouse does in the 2D view.

To return the observer and focus point to their default positions press the "Reset Perspective" button (or use the `reset-perspective` command) .

Fullscreen Mode

To enter fullscreen mode, press the "Full Screen" button, to exit fullscreen mode, press the Esc key.

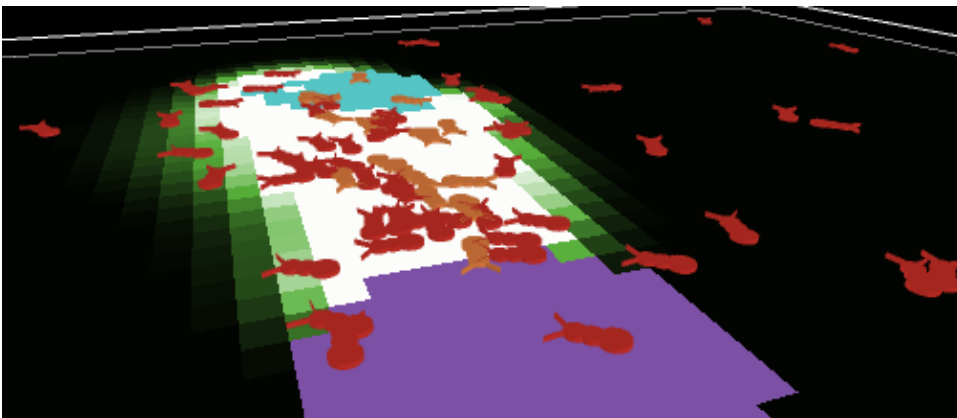
Note: Fullscreen mode doesn't work on some computers. It depends on what kind of graphics card you have. See the [System Requirements](#) for details.

3D Shapes

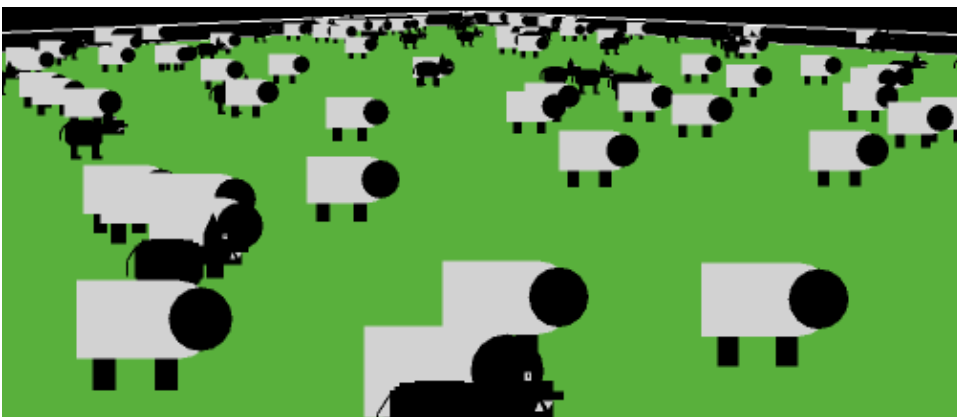
Some shapes have true 3D counterparts (a 3D circle is actually a sphere) in the 3D view so they are automatically mapped to that shape.

Shape name	3D shape
default	3D turtle shape
circle	sphere
dot	small sphere
square	cube
triangle	cone
line	3D line
cylinder	3D cylinder
line-half	3D line-half
car	3D car

All other shapes are interpreted from their 2D shapes. If a shape is a rotatable shape it is assumed to be a top view and it is extruded as if through a cookie cutter and oriented parallel to the xy-plane, as in Ants.



If a shape is non-rotatable it is assumed to be a side view so it is drawn always facing the observer (and with no thickness), as in Wolf Sheep Predation.

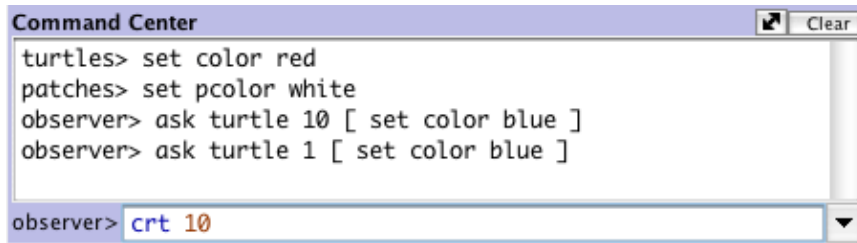


Command Center

The Command Center allows you to issue commands directly, without adding them to the model's procedures. (Commands are instructions you give to turtles, patches, and the observer.) This is useful for inspecting and manipulating agents on the fly.

([Tutorial #2: Commands](#) is an introduction to using commands in the Command Center.)

Let's take a closer look at the design of the Command Center.



You will notice there is a large display box, an agent popup menu (observer>), a "clear" button, a button (with the double-headed arrow) to relocate the command center to the right side of the window, and the history popup menu (in the lower right, with the little black triangle). The top large display box temporarily stores all of the commands that are entered into the Command Center. This area is strictly for reference; commands cannot be accessed or changed from this box. To clear this box, click "clear" in the top right corner. To toggle between a vertical and horizontal split between the Command Center and the model interface click the button with the double-headed arrow.

The smaller text box, below the large box, is where commands are entered. On the left of this box is the agent popup menu, and on the right is the history popup menu.

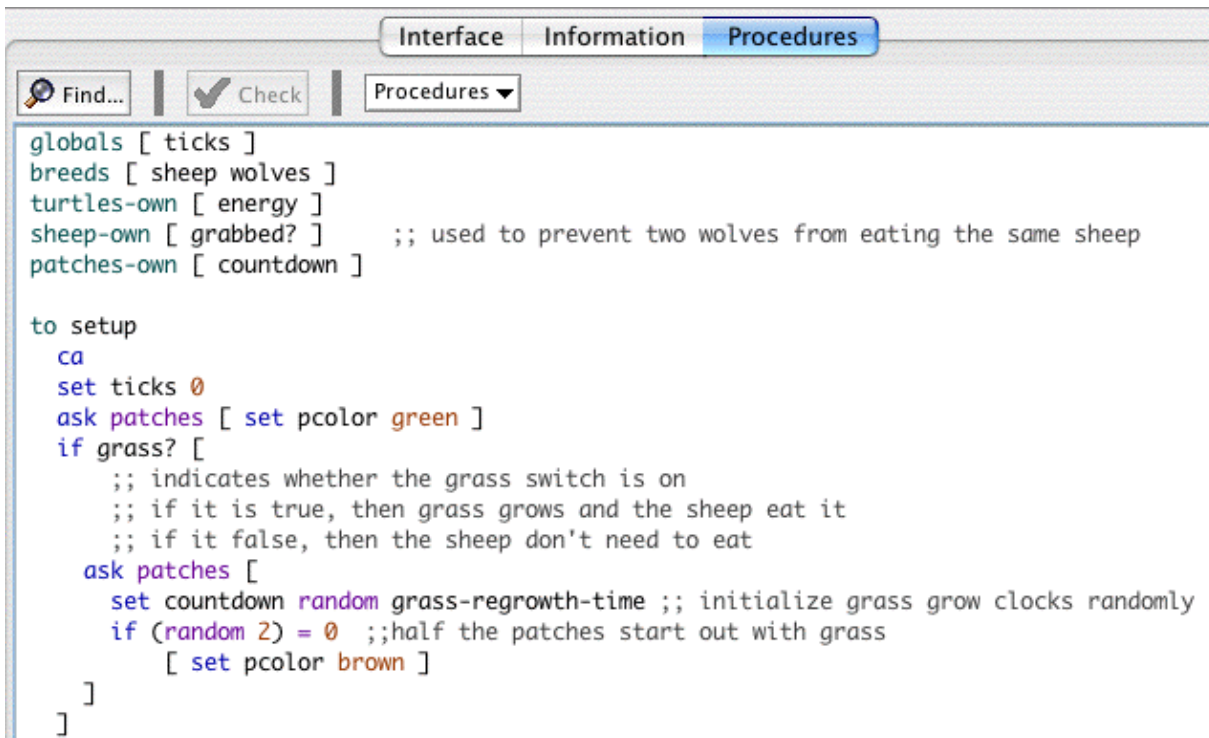
The agent popup menu allows you to select either observer, turtles, or patches. This is an easy way to assign an agent to a command and it is the same as writing `ask turtles [...]`. Note: a quicker way to change between observer, turtles, and patches is to use the tab key on your keyboard.

The history popup menu lists all of the commands entered that can be accessed and used again. The up and down arrow keys on your keyboard will retrieve that last command that was written.

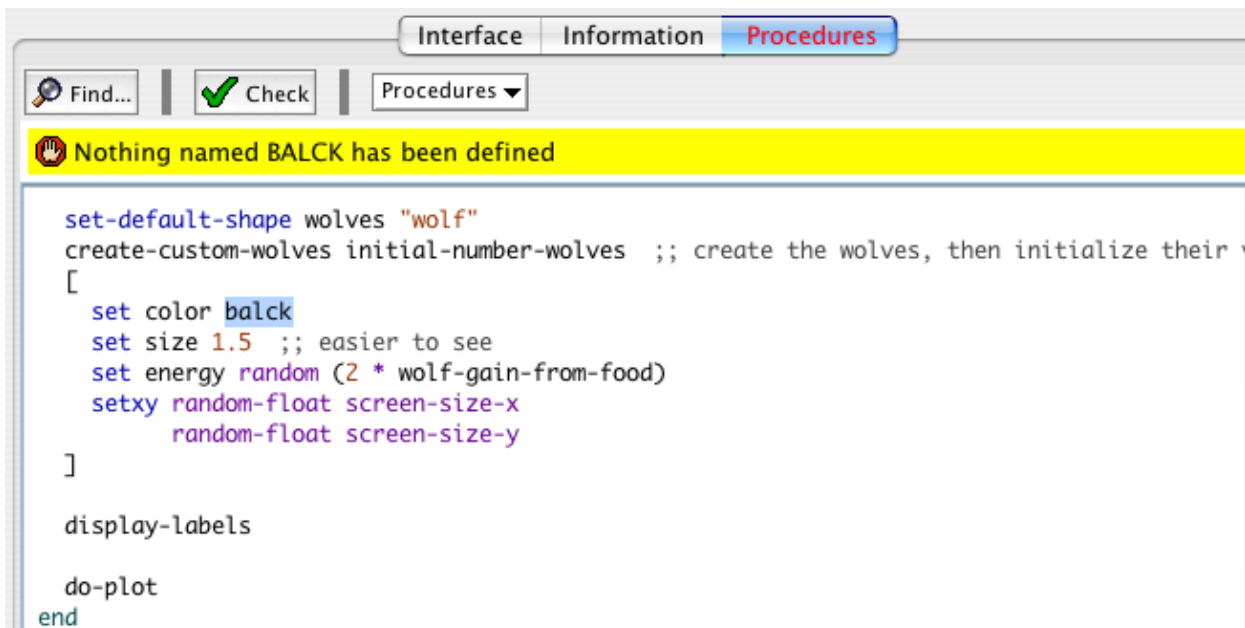
Note that pressing the "clear" function clears only the large display box and not the history. To clear the history section, choose "clear history", found at the top of its popup menu.

Procedures Tab

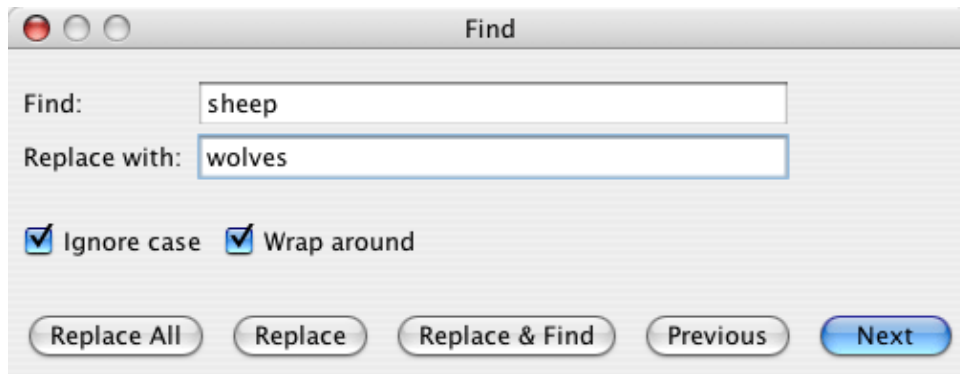
This tab is the workspace where the code for the model is stored. Commands you only want to use immediately go in the Command Center; commands you want to save and use later, over and over again, are found in the Procedures tab.



To determine if the code has any errors, you may press the "Check" button. If there are any syntax errors, the Procedures tab will turn red and the code that contains the error will be highlighted and a comment will appear in the top box. Switching tabs also causes the code to be checked and any errors will be shown, so if you switch tabs, pressing the Check button first isn't necessary.



To find a fragment of code in the procedures, click on the "Find" button in the Procedures Toolbar and the Find dialog will appear.



You may enter either a word or phrase to find or a word or phrase to find and one to replace it with. The "Ignore case" checkbox controls whether the capitalization must be the same to indicate a match. If the "Wrap around" checkbox is checked the entire Procedures tab will be checked for the phrase, starting at the cursor position, when it reaches the end it will return to the top, otherwise only the area from the cursor position to the end of the Procedures tab will be searched. The "Next" and "Previous" buttons will move down and up to find another occurrence of the search phrase. "Replace" changes the currently selected phrase with the replace phrase and "Replace & Find" changes the selected phrase and moves to the next occurrence. "Replace all" will change all instances of the the find phrase in the search area with the replace phrase.

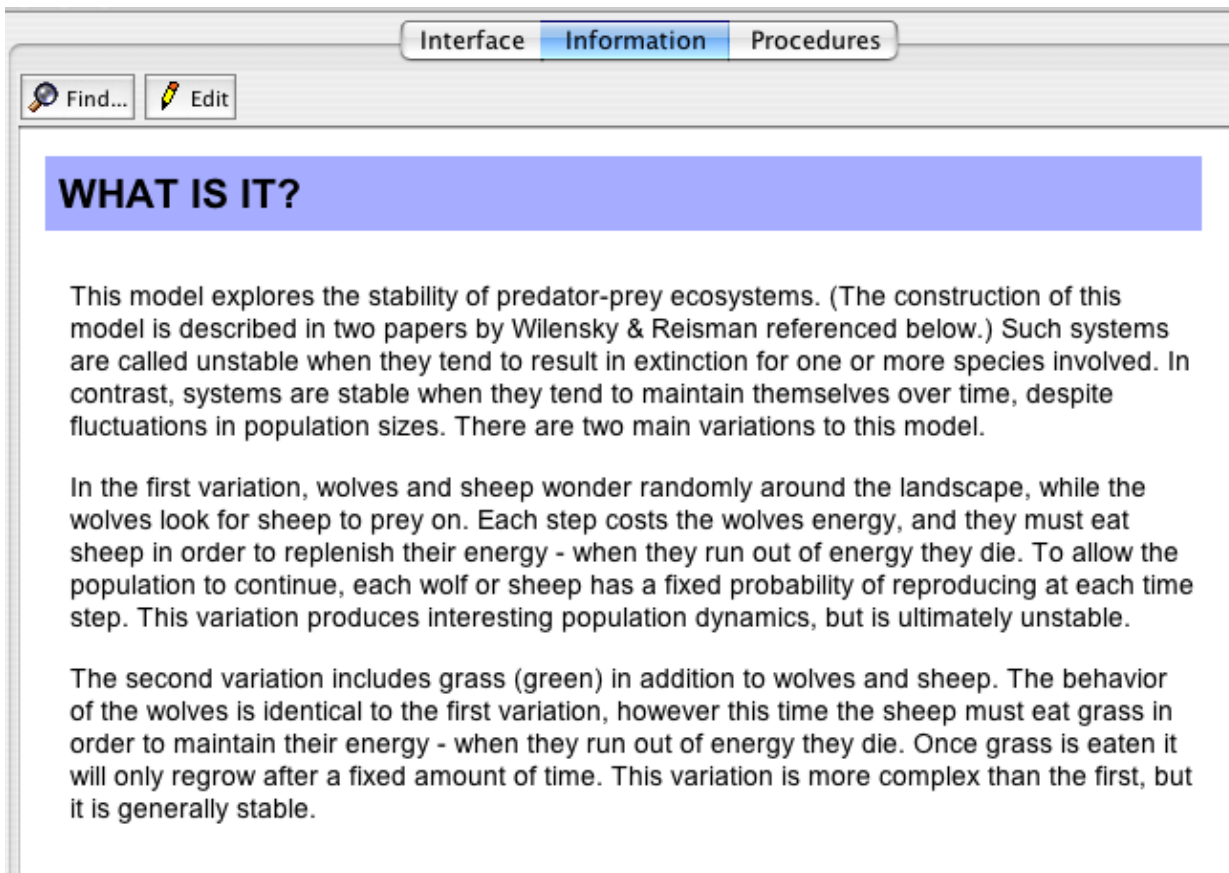
To find a particular procedure definition in your code, use the "Procedures" popup menu in the Procedures Toolbar. The menu lists all procedures in alphabetical order.

The "Shift Left", "Shift Right", "Comment", and "Uncomment" items on the Edit menu are used in the procedures tab to change the indentation level of your code or add and remove semicolons, which mark comments, from sections of code.

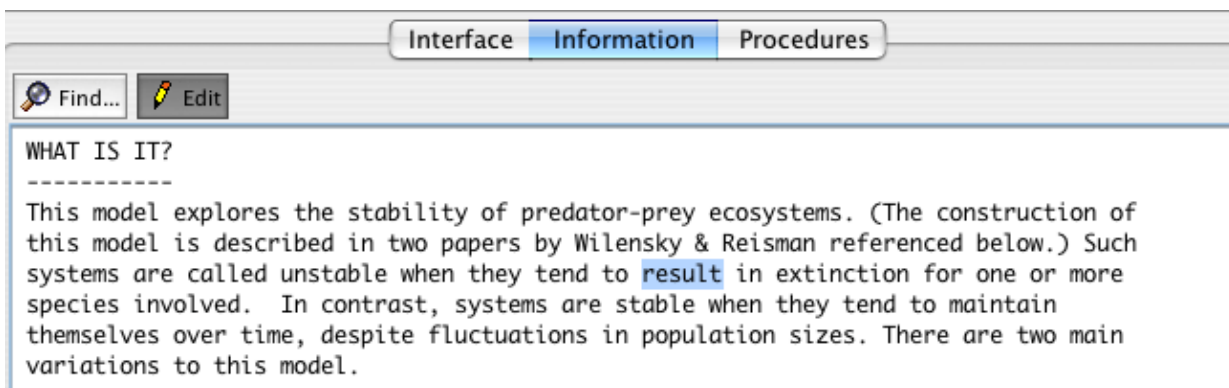
For more information about writing procedures, read [Tutorial #3: Procedures](#) and the [Programming Guide](#).

Information Tab

The Information tab provides an introduction to the model and an explanation of how to use it, things to explore, possible extensions, and NetLogo features. It is very helpful when you're first exploring a model.



We recommend reading the Information tab before starting the model. The Information tab explains what principle is being modeled and how the model was created. This display of the Information tab is not editable. To edit the content of the Info tab click the "Edit" button or double click on a word which will also scroll you to the location you clicked on and highlight the word.



You can edit the text in this view as in any text editor. However, a few different forms will be displayed specially when you switch out of the edit view.

Information Tab Markup

Description	Edit Mode	View Mode
	WHAT IS IT	

Lines that come after blank lines and contain capital letters and no lower case letters become section headers.		WHAT IS IT
Any line that has only dashes is omitted.	-----	
Anything beginning with "http://" becomes a clickable hyperlink.	http://ccl.northwestern.edu	http://ccl.northwestern.edu
E-mail addresses become clickable "mailto:" links.	bugs@ccl.northwestern.edu	bugs@ccl.northwestern.edu
Lines that begin with the pipe ' ' (shift + backslash '\') become monospaced text. This is useful for diagrams and complicated formulas, among other things.	this is preformatted text you can put spaces in it	this is preformatted text you can put spaces in it

To return to the normal view, click the edit button.

Programming Guide

The following material explains some important features of programming in NetLogo.

(Note: If you are already familiar with StarLogo or StarLogoT, then the material in the first four sections may already be familiar to you.)

The Code Example models mentioned throughout can be found in the Code Examples section of the Models Library.

- [Agents](#)
- [Procedures](#)
- [Variables](#)
- [Colors](#)
- [Ask](#)
- [Agentsets](#)
- [Breeds](#)
- [Synchronization](#)
- [Buttons](#)
- [Lists](#)
- [Math](#)
- [Random Numbers](#)
- [Turtle Shapes](#)
- [Plotting](#)
- [Strings](#)
- [Output](#)
- [File I/O](#)
- [Movies](#)
- [Perspective](#)
- [Turtle Pens](#)

Agents

The NetLogo world is made up of agents. Agents are beings that can follow instructions. Each agent can carry out its own activity, all simultaneously.

In NetLogo, there are three types of agents: turtles, patches, and the observer. Turtles are agents that move around in the world. The world is two dimensional and is divided up into a grid of patches. Each patch is a square piece of "ground" over which turtles can move. The observer doesn't have a location — you can imagine it as looking out over the world of turtles and patches.

When NetLogo starts up, there are no turtles yet. The observer can make new turtles. Patches can make new turtles too. (Patches can't move, but otherwise they're just as "alive" as turtles and the observer are.)

Patches have coordinates. The patch in the center of the world has coordinates (0, 0). We call the patch's coordinates `pxcor` and `pycor`. Just like in the standard mathematical coordinate plane, `pxcor` increases as you move to the right and `pycor` increases as you move up.

The total number of patches is determined by the settings `screen-edge-x` and `screen-edge-y`. When NetLogo starts up, both `screen-edge-x` and `screen-edge-y` are 17. This means that `pxcor` and `pycor` both range from -17 to 17, so there are 35 times 35, or 1225 patches total. (You can change the number of patches by editing NetLogo's view.)

Turtles have coordinates too: `xcor` and `ycor`. A patch's coordinates are always integers, but a turtle's coordinates can have decimals. This means that a turtle can be positioned at any point within its patch; it doesn't have to be in the center of the patch.

The world of patches isn't bounded, but "wraps" -- so when a turtle moves past the edge of the world, it disappears and reappears on the opposite edge. Every patch has the same number of "neighbor" patches -- if you're a patch on the edge of the world, some of your "neighbors" are on the opposite edge.

Procedures

In NetLogo, commands and reporters tell agents what to do. **Commands** are actions for the agents to carry out. **Reporters** carry out some operation and report a result either to a command or another reporter.

Commands and reporters built into NetLogo are called **primitives**. [The Primitives Dictionary](#) has a complete list of built-in commands and reporters.

Commands and reporters you define yourself are called **procedures**. Each procedure has a name, preceded by the keyword `to`. The keyword `end` marks the end of the commands in the procedure. Once you define a procedure, you can use it elsewhere in your program.

Many commands and reporters take **inputs** -- values that the command or reporter uses in carrying out its actions.

Examples: Here are two command procedures:

```
to setup
  ca          ;; clear the screen
  crt 10      ;; make 10 new turtles
end

to go
  ask turtles
  [ fd 1      ;; all turtles move forward one step
    rt random 10  ;; ...and turn a random amount
    lt random 10 ]
end
```

Note the use of semicolons to add "comments" to the program. Comments make your program easier to read and understand.

In this program,

- `setup` and `go` are user-defined commands.
- `ca` ("clear all"), `crt` ("create turtles"), `ask`, `lt` ("left turn"), and `rt` ("right turn") are all primitive commands.

- random and turtles are primitive reporters. random takes a single number as an input and reports a random integer that is less than the input (in this case, between 0 and 9). turtles reports the agentset consisting of all the turtles. (We'll explain about agentsets later.)

`setup` and `go` can be called by other procedures or by buttons. Many NetLogo models have a once button that calls a procedure called `setup`, and a forever button that calls a procedure called `go`.

In NetLogo, you must specify which agents — turtles, patches, or the observer — are to run each command. (If you don't specify, the code is run by the observer.) In the code above, the observer uses `ask` to make the set of all turtles run the commands between the square brackets.

`ca` and `crt` can only be run by the observer. `fd`, on the other hand, can only be run by turtles. Some other commands and reporters, such as `set`, can be run by different agent types.

Here are some more advanced features you can take advantage of when defining your own procedures.

Procedures with inputs

Your own procedures can take inputs, just like primitives do. To create a procedure that accepts inputs, include a list of input names in square brackets after the procedure name. For example:

```
to draw-polygon [num-sides size]
  pd
  repeat num-sides
    [ fd size
      rt (360 / num-sides) ]
end
```

Elsewhere in the program, you could ask turtles to each draw an octagon with a side length equal to its ID-number:

```
ask turtles [ draw-polygon 8 who ]
```

Reporter procedures

Just like you can define your own commands, you can define your own reporters. You must do two special things. First, use to-report instead of `to` to begin your procedure. Then, in the body of the procedure, use report to report the value you want to report.

```
to-report absolute-value [number]
  ifelse number >= 0
    [ report number ]
    [ report 0 - number ]
end
```

Variables

Variables are places to store values (such as numbers). A variable can be a global variable, a turtle variable, or a patch variable.

If a variable is a global variable, there is only one value for the variable, and every agent can access it. But each turtle has its own value for every turtle variable, and each patch has its own value for every patch variable.

Some variables are built into NetLogo. For example, all turtles have a `color` variable, and all patches have a `pcolor` variable. (The patch variable begins with "p" so it doesn't get confused with the turtle variable.) If you set the variable, the turtle or patch changes color. (See next section for details.)

Other built-in turtle variables including `xcor`, `ycor`, and `heading`. Other built-in patch variables include `pxcor` and `pycor`. (There is a complete list [here](#).)

You can also define your own variables. You can make a global variable by adding a switch or a slider to your model, or by using the `globals` keyword at the beginning of your code, like this:

```
globals [ clock ]
```

You can also define new turtle and patch variables using the `turtles-own` and `patches-own` keywords, like this:

```
turtles-own [ energy speed ]
patches-own [ friction ]
```

These variables can then be used freely in your model. Use the `set` command to set them. (If you don't set them, they'll start out storing a value of zero.)

Global variables can be read and set at any time by any agent. As well, a turtle can read and set patch variables of the patch it is standing on. For example, this code:

```
ask turtles [ set pcolor red ]
```

causes every turtle to make the patch it is standing on red. (Because patch variables are shared by turtles in this way, you can't have a turtle variable and a patch variable with the same name.)

In other situations where you want an agent to read or set a different agent's variable, you put `-of` after the variable name and then specify which agent you mean. Examples:

```
set color-of turtle 5 red
;; turtle with ID number 5 turns red
set pcolor-of patch 2 3 green
;; patch with pxcor of 2 and pycor of 3 turns green
ask turtles [ set pcolor-of patch-at 1 0 blue ]
;; every turtle turns the patch to its east blue
ask patches with [any? turtles-here]
[ set color-of random-one-of turtles-here yellow ]
;; on every patch, a random turtle turns yellow
```

Local variables

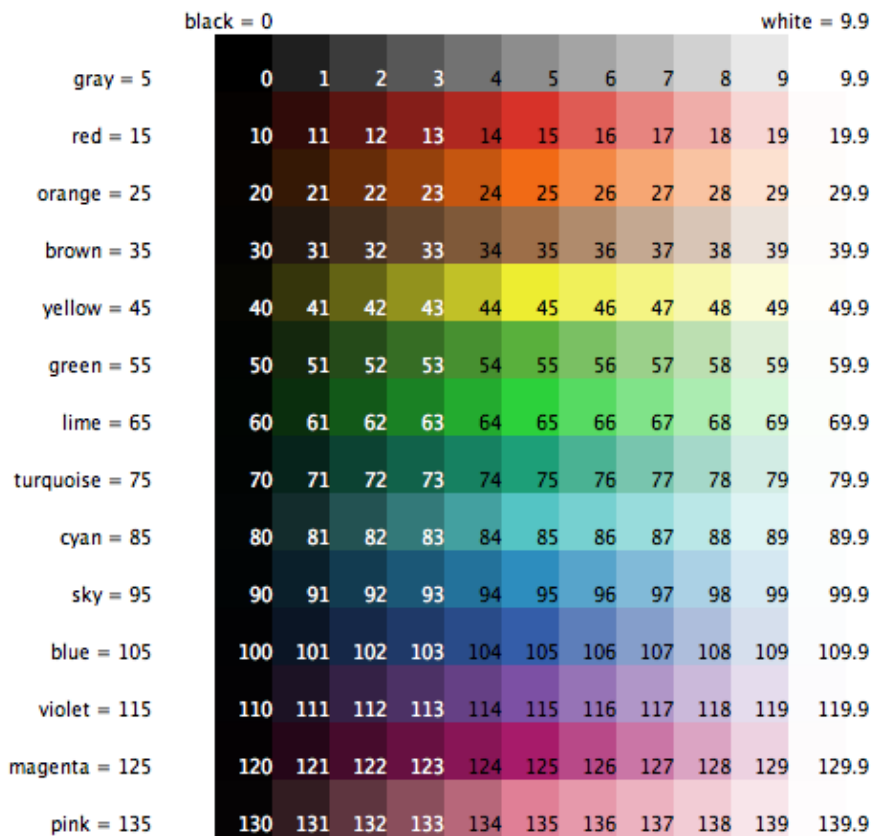
A local variable is defined and used only in the context of a particular procedure or part of a procedure. To create a local variable, use the `let` command. You can use this command anywhere. If you use it at the top of a procedure, the variable will exist throughout the procedure. If you use it inside a set of square brackets, for example inside an "ask", then it will exist only inside

those brackets.

```
to swap-colors [turtle1 turtle2]
  let temp color-of turtle1
  set (color-of turtle1) (color-of turtle2)
  set (color-of turtle2) temp
end
```

Colors

NetLogo represents colors as numbers in the range 0 to 140, with the exception of 140 itself. Below is a chart showing the range of colors you can use in NetLogo.

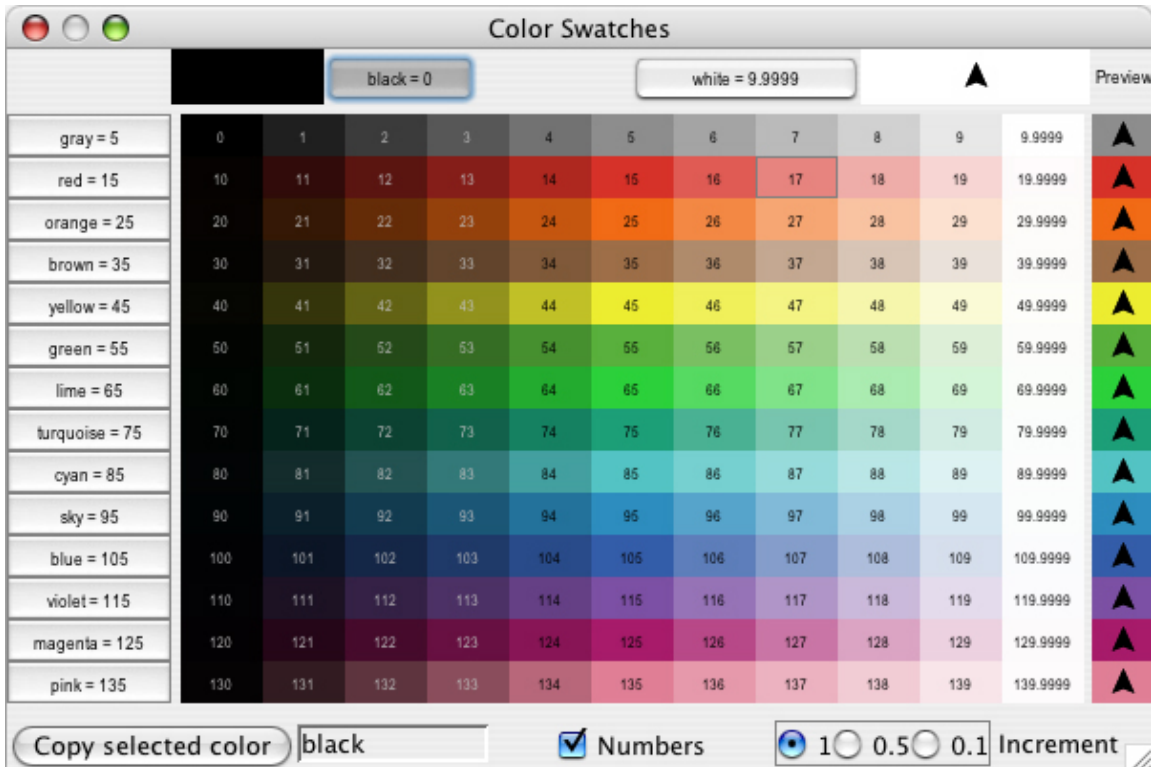


The chart shows that:

- Some of the colors have names. (You can use these names in your code.)
- Every named color except black and white has a number ending in 5.
- On either side of each named color are darker and lighter shades of the color.
- 0 is pure black. 9.9 is pure white.
- 10, 20, and so on are all so dark they appear black. 19.9, 29.9 and so on are all so light they appear white.

Code Example: The color chart was made in NetLogo with the Color Chart Example model.

You can also view a similar chart, and experiment with the colors, by opening the Color Swatches from the Tools Menu.



When you click on any one of the color swatches (or the color buttons) that color will be displayed against all of the other standard colors along the right edge of the dialog and black and white along the top. In the bottom left corner the value of the currently selected color is displayed so you can copy the color and easily insert it into your code. In the bottom right corner there are three increment options, 1 , 0.5 , and 0.1. These numbers indicate the difference between two adjacent swatches. When the increment is 1 there are 10 different shades in each row so when the increment is 0.1 there are 100 different shades in each row.

Note: If you use a number outside the 0 to 140 range, NetLogo will repeatedly add or subtract 140 from the number until it is in the 0 to 140 range. For example, 25 is orange, so 165, 305, 445, and so on are orange too, and so are -115, -255, -395, etc. This calculation is done automatically whenever you set the turtle variable `color` or the patch variable `pcolor`. Should you need to perform this calculation in some other context, use the [wrap-color](#) primitive.

If you want a color that's not on the chart, more can be found between the integers. For example, 26.5 is a shade of orange halfway between 26 and 27. This doesn't mean you can make any color in NetLogo; the NetLogo color space is only a subset of all possible colors. A fixed set of discrete hues. Starting from one of those hues, you can either decrease its brightness (darken it) or decrease its saturation (lighten it), but you cannot decrease both brightness and saturation. Also, for display color values are rounded to the nearest 0.1, so for example there's no visible difference between 26.5 and 26.52.

There are a few primitives that are helpful for working with color shades. The [scale-color](#) primitive is useful for converting numeric data into colors. And [shade-of?](#) will tell you if two colors are "shades" of the same basic hue. For example, `shade-of? orange 27` is true, because 27 is

a lighter shade of orange.

Code Example: Scale-color Example shows you how to use the scale-color reporter.

For many models, the NetLogo color system is a convenient way of expressing colors. But sometimes you'd like to be able to specify colors the conventional way, by specifying HSB (hue/saturation/brightness) or RGB (red/green/blue) values. The `hsb` and `rgb` primitives let you do this. `extract-hsb` and `extract-rgb` let you convert colors in the other direction.

Since the NetLogo color space doesn't include all hues, `hsb` and `rgb` can't always give you the exact color you ask for, but they try to come as close as possible.

Code Example: You can use the HSB and RGB Example model to experiment with the HSB and RGB color systems.

Ask

NetLogo uses the `ask` command to specify commands that are to be run by turtles or patches. All code to be run by turtles **must** be located in a turtle "context". You can establish a turtle context in any of three ways:

- In a button, by choosing "Turtles" from the popup menu. Any code you put in the button will be run by all turtles.
- In the Command Center, by choosing "Turtles" from the popup menu. Any commands you enter will be run by all the turtles.
- By using `ask turtles`.

The same goes for patches and the observer, except that code to be run by the observer must not be inside any `ask`.

Here's an example of the use of `ask` syntax in a NetLogo procedure:

```
to setup
  ca
  crt 100          ;; create 100 turtles
  ask turtles
  [ set color red    ;; turn them red
    rt random-float 360  ;; give them random headings
    fd 50 ]          ;; spread them around
  ask patches
  [ if (pxcor > 0)      ;; patches on the right side
    [ set pcolor green ] ] ;; of the screen turn green
end
```

The models in the Models Library are full of other examples. A good place to start looking is in the Code Examples section.

Usually, the observer uses `ask` to ask all turtles or all patches to run commands. You can also use `ask` to have an individual turtle or patch run commands. The reporters `turtle`, `patch`, and `patch-at` are useful for this technique. For example:

```
to setup
  ca
  crt 3                ;; make 3 turtles
  ask turtle 0         ;; tell the first one...
    [ fd 1 ]           ;; ...to go forward
  ask turtle 1         ;; tell the second one...
    [ set color green ] ;; ...to become green
  ask turtle 2         ;; tell the third one...
    [ rt 90 ]          ;; ...to turn right
  ask patch 2 -2       ;; ask the patch at (2,-2)
    [ set pcolor blue ] ;; ...to become blue
  ask turtle 0         ;; ask the first turtle
    [ ask patch-at 1 0  ;; ...to ask patch to the east
      [ set pcolor red ] ;; ...to become red
    ]
end
```

Every turtle created has an ID number. The first turtle created has ID 0, the second turtle ID 1, and so forth. The `turtle` primitive reporter takes an ID number as an input, and reports the turtle with that ID number. The `patch` primitive reporter takes values for `pxcor` and `pycor` and reports the patch with those coordinates. And the `patch-at` primitive reporter takes *offsets*: distances, in the x and y directions, *from* the first agent. In the example above, the turtle with ID number 0 is asked to get the patch east (and no patches north) of itself.

You can also select a subset of turtles, or a subset of patches, and ask them to do something. This involves a concept called "agentsets". The next section explains this concept in detail.

Agentsets

An agentset is exactly what its name implies, a set of agents. An agentset can contain either turtles or patches, but not both at once.

You've seen the `turtles` primitive, which reports the agentset of all turtles, and the `patches` primitive, which reports the agentset of all patches.

But what's powerful about the agentset concept is that you can construct agentsets that contain only *some* turtles or *some* patches. For example, all the red turtles, or the patches with `pxcor` evenly divisible by five, or the turtles in the first quadrant that are on a green patch. These agentsets can then be used by `ask` or by various reporters that take agentsets as inputs.

One way is to use `turtles-here` or `turtles-at`, to make an agentset containing only the turtles on my patch, or only the turtles on some other particular patch. There's also `turtles-on` so you can get the set of turtles standing on a given patch or set of patches, or the set of turtles standing on the same patch as a given turtle or set of turtles.

Here are some more examples of how to make agentsets:

```
;; all red turtles:
turtles with [color = red]
;; all red turtles on my patch
turtles-here with [color = red]
```

```
;; patches on right side of screen
patches with [pxcor > 0]
;; all turtles less than 3 patches away
turtles in-radius 3
;; the four patches to the east, north, west, and south
patches at-points [[1 0] [0 1] [-1 0] [0 -1]]
;; shorthand for those four patches
neighbors4
;; turtles in the first quadrant that are on a green patch
turtles with [(xcor > 0) and (ycor > 0)
              and (pcolor = green)]
;; turtles standing on my neighboring four patches
turtles-on neighbors4
```

Once you have created an agentset, here are some simple things you can do:

- Use ask to make the agents in the agentset do something
- Use any? to see if the agentset is empty
- Use count to find out exactly how many agents are in the set

And here are some more complex things you can do:

- Pick a random agent from the set using random-one-of. For example, we can make a randomly chosen turtle turn green:

```
set color-of random-one-of turtles green
```

Or tell a randomly chosen patch to sprout a new turtle:

```
ask random-one-of patches [ sprout 1 [ ] ]
```

- Use the max-one-of or min-one-of reporters to find out which agent is the most or least along some scale. For example, to remove the richest turtle, you could say

```
ask max-one-of turtles [sum assets] [ die ]
```

- Make a histogram of the agentset using the histogram-from command.
- Use values-from to make a list of values, one for each agent in the agentset. Then use one of NetLogo's list primitives to do something with the list. (See the "Lists" section below.) For example, to find out how rich the richest turtle is, you could say

```
show max values-from turtles [sum assets]
```

- Use turtles-from and patches-from reporters to make new agentsets by gathering together the results reported by other agents.

This only scratches the surface -- see the Models Library for many more examples, and consult the Primitives Guide and Primitives Dictionary for more information about all of the agentset primitives.

More examples of using agentsets are provided in the individual entries for these primitives in the NetLogo Dictionary. In developing familiarity with programming in NetLogo, it is important to begin to think of compound commands in terms of how each element passes information to the next one. Agentsets are an important part of this conceptual scheme and provide the NetLogo developer with a lot of power and flexibility, as well as being more similar to natural language.

Code Example: Ask Agentset Example

Breeds

NetLogo allows you to define different "breeds" of turtles. Once you have defined breeds, you can go on and make the different breeds behave differently. For example, you could have breeds called `sheep` and `wolves`, and have the wolves try to eat the sheep.

You define breeds using the `breeds` keyword, at the top of your model, before any procedures:

```
breeds [wolves sheep]
```

The order in which breeds are declared is also the order in which they are layered in the view. So breeds defined later will appear on top of breeds defined earlier; in this example, sheep will be drawn over wolves.

When you define a breed such as `sheep`, an agentset for that breed is automatically created, so that all of the agentset capabilities described above are immediately available with the `sheep` agentset.

The following new primitives are also automatically available once you define a breed:

`create-sheep`, `create-custom-sheep` (`cct-sheep` for short), `hatch-sheep`, `sprout-sheep`, `sheep-here`, and `sheep-at`.

Also, you can use `sheep-own` to define new turtle variables that only turtles of the given breed have.

A turtle's breed agentset is stored in the `breed` turtle variable. So you can test a turtle's breed, like this:

```
if breed = wolves [ ... ]
```

Note also that turtles can change breeds. A wolf doesn't have to remain a wolf its whole life. Let's change a random wolf into a sheep:

```
ask random-one-of wolves [ set breed sheep ]
```

The `set-default-shape` primitive is useful for associating certain turtle shapes with certain breeds. See the section on shapes below.

Here is a quick example of using breeds:

```
breeds [mice frogs]
mice-own [cheese]
to setup
  ca
  create-custom-mice 50
    [ set color white
      set cheese random 10 ]
  create-custom-frogs 50
    [ set color green ]
```

end

Code Example: Breeds and Shapes Example

Buttons

Buttons in the interface tab provide an easy way to control the model. Typically a model will have at least a "setup" button, to set up the initial state of the world, and a "go" button to make the model run continuously. Some models will have additional buttons that perform other actions.

A button contains some NetLogo code. That code is run when you press the button.

A button may be either a "once button", or a "forever button". You can control this by editing the button and checking or unchecking the "Forever" checkbox. Once buttons run their code once, then stop and pop back up. Forever buttons keep running their code over and over again, until either the code hits the `stop` command, or you press the button again to stop it. If you stop the button, the code doesn't get interrupted. The button waits until the code has finished, then pops up.

Normally, a button is labeled with the code that it runs. For example, a button that says "go" on it usually contains the code "go", which means "run the go procedure". (Procedures are defined in the Procedures tab; see below.) But you can also edit a button and enter a "display name" for the button, which is a text that appears on the button instead of the code. You might use this feature if you think the actual code would be confusing to your users.

When you put code in a button, you must also specify which agents you want to run that code. You can choose to have the observer run the code, or all turtles, or all patches. (If you want the code to be run by only some turtles or some patches, you could make an observer button, and then have the observer use the `ask` command to ask only some of the turtles or patches to do something.)

When you edit a button, you have the option to assign an "action key". This makes that key on the keyboard behave just like a button press. If the button is a forever button, it will stay down until the key is pressed again (or the button is clicked). Action keys are particularly useful for games or any model where rapid triggering of buttons is needed.

Buttons take turns

More than one button can be pressed at a time. If this happens, the buttons "take turns", which means that only one button runs at a time. Each button runs its code all the way through while the other buttons wait, then the next button gets its turn.

In the following examples, "setup" is a once button and "go" is a forever button.

Example #1: The user presses "setup", then presses "go" immediately, before the "setup" has popped back up. Result: "setup" finishes before "go" starts.

Example #2: While the "go" button is down, the user presses "setup". Result: the "go" button finishes its current iteration. Then the "setup" button runs. Then "go" starts running again.

Example #3: The user has two forever buttons down at the same time. Result: first one button runs its code all the way through, then the other runs its code all the way through, and so on, alternating.

Buttons and view updates

When you edit a button, there is a checkbox called "Force view update after each run". Below the checkbox is a note that reads "Checking this box produces smoother animation, but may make the button run more slowly."

Most of the time, it's enough to know that if you prefer smooth animation check the box and if you prefer speed uncheck it. In some models, the difference is dramatic; in others, it's hardly noticeable. It depends on the model.

What follows is a more detailed explanation of what's really going on with this checkbox.

To understand why this option is offered, you need to understand a little about how NetLogo updates the view. When something changes in the world, for example if a turtle moves or a patch changes color, the change does not always immediately become visible. NetLogo would run too slowly if changes always immediately became visible. So NetLogo waits until a certain amount of time has passed, usually about 1/5 of a second, and then redraws the view, so that all the changes that have happened so far become visible. This is sometimes called "skipping frames", by analogy with movies.

Skipping frames is good because each frame takes NetLogo time to draw, so your model runs faster if NetLogo can skip some of them. But skipping frames may be bad if the frames skipped contained information that you wanted to see. Sometimes the way a model looks when frames are being skipped can be misleading.

Even when the checkbox is on for a button, NetLogo will still skip frames while the code in the button is running. Checking the box only ensures that NetLogo will draw a frame when the code is done.

In some contexts, you may want to force NetLogo to draw a frame even in the middle of button code. To do that, use the `display` command; that forces NetLogo to refresh the view immediately.

In other contexts, you may want to force NetLogo *never* to draw a frame in the middle of button code, only at the end. To ensure that, put `no-display` at the beginning of the code and `display` at the end. Note also that NetLogo will never draw on-screen when inside a `without-interruption` block.

Turtle and patch forever buttons

There is a subtle difference between putting commands in a turtle or patch forever button, and putting the same commands in an observer button that does `ask turtles` or `ask patches`. An "ask" doesn't complete until all of the agents have finished running all of the commands in the "ask". So the agents, as they all run the commands concurrently, can be out of sync with each other, but they all sync up again at the end of the ask. The same isn't true of turtle and patch forever buttons. Since `ask` was not used, each turtle or patch runs the given code over and over again, so they can become (and remain) out of sync with each other.

At present, this capability is very rarely used in the models in our Models Library. A model that does use the capability is the Termites model, in the Biology section of Sample Models. The "go" button is a turtle forever button, so each termite proceeds independently of every other termite, and the observer is not involved at all. This means that if, for example, you wanted to add a plot to the model, you would need to add a second forever button (an observer forever button), and run both forever buttons at the same time.

At present, NetLogo has no way for one forever button to start another. Buttons are only started when you press them.

Synchronization

In both StarLogoT and NetLogo, commands are executed asynchronously; each turtle or patch does its list of commands as fast as it can. In StarLogoT, one could make the turtles "line up" by putting in a comma (,). At that point, the turtles would wait until all were finished before any went on.

The equivalent in NetLogo is to come to the end of an ask block. If you write it this way, the two steps are not synced:

```
ask turtles
  [ fd random 10
    do-calculation ]
```

Since the turtles will take varying amounts of time to move, they'll begin "do-calculation" at different times.

But if you write it this way, they are:

```
ask turtles [ fd random 10 ]
ask turtles [ do-calculation ]
```

Here, some of the turtles will have to wait after moving until all the other turtles are done moving. Then the turtles all begin "do-calculation" at the same time.

This latter form is equivalent to this use of the comma in StarLogoT:

```
fd random 10 ,
do-calculation ,
```

Lists

In the simplest models, each variable holds only one piece of information, usually a number or a string. The list feature lets you store multiple pieces of information in a single variable by collecting those pieces of information in a list. Each value in the list can be any type of value: a number, or a string, an agent or agentset, or even another list.

Lists allow for the convenient packaging of information in NetLogo. If your agents carry out a repetitive calculation on multiple variables, it might be easier to have a list variable, instead of multiple number variables. Several primitives simplify the process of performing the same computation on each value in a list.

The [Primitives Dictionary](#) has a section that lists all of the list-related primitives.

Constant Lists

You can make a list by simply putting the values you want in the list between brackets, like this: `set mylist [2 4 6 8]`. Note that the individual values are separated by spaces. You can make lists that contains numbers and strings this way, as well as lists within lists, for example `[[2 4] [3 5]]`.

The empty list is written by putting nothing between the brackets, like this: `[]`.

Building Lists on the Fly

If you want to make a list in which the values are determined by reporters, as opposed to being a series of constants, use the [list](#) reporter. The `list` reporter accepts two other reporters, runs them, and reports the results as a list.

If I wanted a list to contain two random values, I might use the following code:

```
set random-list list (random 10) (random 20)
```

This will set `random-list` to a new list of two random integers each time it runs.

To make longer lists, you can use the `list` reporter with more than two inputs, but in order to do so, you must enclose the entire call in parentheses, like this:

```
(list 1 2 3 4 5)
```

For more information, see [Varying Numbers of Inputs](#).

Some kinds of lists are most easily built using the [n-values](#) reporter, which allows you to construct a list of a specific length by repeatedly running a given reporter. You can make a list of the same value repeated, or all the numbers in a range, or a lot of random numbers, or many other possibilities. See dictionary entry for details and examples.

The [values-from](#) primitive lets you construct a list from an agentset. It reports a list containing each agent's value for the given reporter. (The reporter could be a simple variable name, or a more complex expression — even a call to a procedure defined using `to-report`.) A common idiom is

```
max values-from turtles [...]
sum values-from turtles [...]
```

and so on.

You can combine two or more lists using the [sentence](#) reporter, which concatenates lists by combining their contents into a single, larger list. Like `list`, `sentence` normally takes two inputs, but can accept any number of inputs if the call is surrounded by parentheses.

Changing List Items

Technically, only one command changes a list — `set`. This is used in conjunction with reporters.

For example, to change the third item of a list to 10, you could use the following code:

```
set mylist [2 7 5 Bob [3 0 -2]]
; mylist is now [2 7 5 Bob [3 0 -2]]
set mylist replace-item 2 mylist 10
; mylist is now [2 7 10 Bob [3 0 -2]]
```

The replace-item reporter takes three inputs. The first input specifies which item in the list is to be changed. 0 means the first item, 1 means the second item, and so forth.

To add an item, say 42, to the end of a list, use the lput reporter. (fput adds an item to the beginning of a list.)

```
set mylist lput 42 mylist
; mylist is now [2 7 10 Bob [3 0 -2] 42]
```

But what if you changed your mind? The but-last (bl for short) reporter reports all the list items but the last.

```
set mylist but-last mylist
; mylist is now [2 7 10 Bob [3 0 -2]]
```

Suppose you want to get rid of item 0, the 2 at the beginning of the list.

```
set mylist but-first mylist
; mylist is now [7 10 Bob [3 0 -2]]
```

Suppose you wanted to change the third item that's nested inside item 3 from -2 to 9? The key is to realize that the name that can be used to call the nested list [3 0 -2] is item 3 mylist. Then the replace-item reporter can be nested to change the list-within-a-list. The parentheses are added for clarity.

```
set mylist (replace-item 3 mylist
              (replace-item 2 (item 3 mylist) 9))
; mylist is now [7 10 Bob [3 0 9]]
```

Iterating Over Lists

If you want to do some operation on each item in a list in turn, the foreach command and the map reporter may be helpful.

foreach is used to run a command or commands on each item in a list. It takes an input list and a block of commands, like this:

```
foreach [2 4 6]
  [ crt ?
    show "created " + ? + " turtles" ]
=> created 2 turtles
=> created 4 turtles
=> created 6 turtles
```

In the block, the variable ? holds the current value from the input list.

Here are some more examples of foreach:

```
foreach [1 2 3] [ ask turtles [ fd ? ] ]  
;; turtles move forward 6 patches  
foreach [true false true true] [ ask turtles [ if ? [ fd 1 ] ] ]  
;; turtles move forward 3 patches
```

`map` is similar to `foreach`, but it is a reporter. It takes an input list and another reporter. Note that unlike `foreach`, the reporter comes first, like this:

```
show map [round ?] [1.2 2.2 2.7]  
;; prints [1 2 3]
```

`map` reports a list containing the results of applying the reporter to each item in the input list. Again, use `?` to refer to the current item in the list.

Here is another example of `map`:

```
show map [? < 0] [1 -1 3 4 -2 -10]  
;; prints [false true false false true true]
```

`foreach` and `map` won't necessarily be useful in every situation in which you want to operate on an entire list. In some situations, you may need to use some other technique such as a loop using `repeat` or `while`, or a recursive procedure.

The `sort-by` primitive uses a similar syntax to `map` and `foreach`, except that since the reporter needs to compare two objects, the two special variables `?1` and `?2` are used in place of `?`.

Here is an example of `sort-by`:

```
show sort-by [?1 < ?2] [4 1 3 2]  
;; prints [1 2 3 4]
```

Varying Numbers of Inputs

Some commands and reporters involving lists and strings may take a varying number of inputs. In these cases, in order to pass them a number of inputs other than their default, the primitive and its inputs must be surrounded by parentheses. Here are some examples:

```
show list 1 2  
=> [1 2]  
show (list 1 2 3 4)  
=> [1 2 3 4]  
show (list)  
=> []
```

Note that each of these special commands has a default number of inputs for which no parentheses are required. The primitives which have this capability are `list`, `word`, `sentence`, `map`, and `foreach`.

Math

NetLogo supports two different kinds of math, integer and floating point.

Integers have no fractional part and may range from -2^{31} to $2^{31}-1$. Integer operations that exceed this range will not cause runtime errors, but will produce

incorrect answers.

Floating point numbers are numbers containing a decimal point. In NetLogo, they operate according to the IEEE 754 standard for double precision floating point numbers. These are 64 bit numbers consisting of one sign bit, an 11-bit exponent, and a 52-bit mantissa. See the IEEE 754 standard for details. Any operation which produces the special quantities "infinity" or "not a number" will cause a runtime error.

In NetLogo, integers and floating point numbers are interchangeable, in the sense that as long as you stay within legal ranges, it is never an error to supply 3 when 3.0 is expected, or 3.0 when 3 is expected. In fact, 3 and 3.0 are considered equal, according to the = (equals) operator. If a floating point number is supplied in a context where an integer is expected, the fractional part is simply discarded. So for example, `crt 3.5` creates three turtles; the extra 0.5 is ignored.

Scientific notation

Very large or very small floating point numbers are displayed by NetLogo using "scientific notation". Examples:

```
O> show 0.000000000001
observer: 1.0E-12
O> show 5000000000000000000.0
observer: 5.0E19
```

Numbers in scientific notation are distinguished by the presence of the letter E (for "exponent"). It means "times ten to the power of", so for example, 1.0E-12 means 1.0 times 10 to the -12 power:

```
O> show 1.0 * 10 ^ -12
observer: 1.0E-12
```

You can also use scientific notation yourself in NetLogo code:

```
O> show 3.0E6
observer: 3000000.0
O> show 3.0E7
observer: 3.0E7
O> show 8.0E-3
observer: 0.0080
O> show 8.0E-4
observer: 8.0E-4
```

These examples show that numbers are displayed using scientific notation if the exponent is less than -3 or greater than 6.

When entering a number using scientific notation, you must include the decimal point. For example, 1E8 will not be accepted. Instead you must write 1.0E8 or 1.E8:

```
O> show 1.0E8
observer: 1.0E8
O> show 1.E8
observer: 1.0E8
O> show 1E8
ERROR: Illegal number format
```

When entering a number, the letter E may be either upper or lowercase. When printing a number, NetLogo always uses an uppercase E:

```
O> show 4.5e10
observer: 4.5E10
```

Floating point accuracy

When using floating point numbers, you should be aware that due to the limitations of the binary representation for floating point numbers, you may get answers that are slightly inaccurate. For example:

```
O> show 0.1 + 0.1 + 0.1
observer: 0.30000000000000004
O> show cos 90
observer: 6.123233995736766E-17
```

This is an inherent issue with floating point arithmetic; it occurs in all programming languages that support floating point.

If you are dealing with fixed precision quantities, for example dollars and cents, a common technique is to use only integers (cents) internally, then divide by 100 to get a result in dollars for display.

If you must use floating point numbers, then in some situations you may need to replace a straightforward equality test such as `if x = 1 [...]` with a test that tolerates slight imprecision, for example `if abs (x - 1) < 0.0001 [...]`.

Also, the [precision](#) primitive is handy for rounding off numbers for display purposes. NetLogo monitors round the numbers they display to a configurable number of decimal places, too.

Random Numbers

The random numbers used by NetLogo are what is called "pseudo-random". (This is typical in computer programming.) That means they appear random, but are in fact generated by a deterministic process. "Deterministic" means that you get the same results every time, if you start with the same random "seed". We'll explain in a minute what we mean by "seed".

In the context of scientific modeling, pseudo-random numbers are actually desirable. That's because it's important that a scientific experiment be reproducible -- so anyone can try it themselves and get the same result that you got. Since NetLogo uses pseudo-random numbers, the "experiments" that you do with it can be reproduced by others.

Here's how it works. NetLogo's random number generator can be started with a certain seed value, which can be any integer. Once the generator has been "seeded" with the [random-seed](#) command, it always generates the same sequence of random numbers from then on. For example, if you run these commands:

```
random-seed 137
show random 100
show random 100
show random 100
```

You will always get the numbers 95, 7, and 54.

Note however that you're only guaranteed to get those same numbers if you're using the same version of NetLogo. Sometimes when we make a new version of NetLogo we change the random number generator. For example, NetLogo 2.0 has a different generator than NetLogo 1.3 did. 2.0's generator (which is known as the "Mersenne Twister") is faster and generates numbers that are statistically more "random" than 1.3's (Java's built-in "linear congruential" generator).

To create a number suitable for seeding the random number generator, use the `new-seed` reporter. `new-seed` creates a seed, evenly distributed over the space of possible seeds, based on the current date and time. And it never reports the same number twice in a row.

Code Example: Random Seed Example

If you don't set the random seed yourself, NetLogo sets it to a value based on the current date and time. There is no way to find out what random seed it chose, so if you want your model run to be reproducible, you must set the random seed yourself ahead of time.

The NetLogo primitives with "random" in their names (`random`, `random-float`, `random-one-of`, and so on) aren't the only ones that use pseudo-random numbers. Some other primitives also make random choices. For example, the `sprout` command creates turtles with random colors and headings, and the `downhill` reporter chooses a random patch when there's a tie. These random choices are governed by the random seed as well, so model runs can be reproducible.

Turtle shapes

In NetLogo, turtle shapes are vector shapes. They are built up from basic geometric shapes; squares, circles, and lines, rather than a grid of pixels. Vector shapes are fully scalable and rotatable. NetLogo caches bitmap images of vector shapes size 1, 1.5, and 2 in order to speed up execution.

A turtle's shape is stored in its `shape` variable and can be set using the `set` command.

New turtles have a shape of "default". The `set-default-shape` primitive is useful for changing the default turtle shape to a different shape, or having a different default turtle shape for each breed of turtle.

The `shapes` primitive reports a list of currently available turtle shapes in the model. This is useful if, for example, you want to assign a random shape to a turtle:

```
ask turtles [ set shape random-one-of shapes ]
```

Use the Shapes Editor to create your own turtle shapes, or to add shapes to your model from our shapes library, or to transfer shapes between models. For more information, see the [Shapes Editor section](#) of this manual.

Code Examples: Breeds and Shapes Example, Shape Animation Example

Plotting

NetLogo's plotting features let you create plots to help you understand what's going on in your model.

Before you can plot, you need to create one or more plots in the Interface tab. Each plot should have a unique name. You'll be using its name to refer to it in your code in the Procedures tab.

Specifying a plot

If you only have one plot in your model, then you can start plotting to it right away. But if you have more than one plot, you have to specify which one you want to plot to. To do this, use the set-current-plot command with the name of the plot enclosed in double quotes, like this:

```
set-current-plot "Distance vs. Time"
```

You must supply the name of the plot exactly as you typed it when you created the plot. Note that later if you change the name of the plot, you'll also have to update the set-current-plot calls in your model to use the new name. (Copy and paste can be helpful here.)

Specifying a pen

When you make a new plot, it just has one pen in it. If the current plot only has one plot pen, then you can start plotting to it right away.

But you can also have multiple pens in a plot. You can create additional pens by editing the plot and using the controls in the "Plot Pens" section at the bottom of the edit dialog. Each pen should have a unique name. You'll be using its name to refer to it in your code in the Procedures tab.

For a plot with multiple pens, you have to specify which pen you want to plot with. If you don't specify a pen, plotting will take place with the first pen in the plot. To plot with a different pen, use the set-current-plot-pen command with the name of the pen enclosed in double quotes, like this:

```
set-current-plot-pen "distance"
```

Plotting points

The two basic commands for actually plotting things are plot and plotxy.

With plot you need only specify the y value you want plotted. The x value will automatically be 0 for the first point you plot, 1 for the second, and so on. (That's if the plot pen's "interval" is the default value of 1.0; you can change the interval.)

The plot command is especially handy when you want your model to plot a new point at every time step. Example:

```
to setup
  ...
  plot count turtles
end
```

```
to go
  ...
  plot count turtles
end
```

Note that in this example we plot from both the "setup" and "go" procedures. That's because we want our plot to include the initial state of the system. We plot at the end of the "go" procedure, not the beginning, because we want the plot always to be up to date after the go button stops.

If you need to specify both the x and y values of the point you want plotted, then use `plotxy` instead.

Code Example: Plotting Example

Other kinds of plots

By default, NetLogo plot pens plot in line mode, so that the points you plot are connected by a line.

If you want to move the pen without plotting, you can use the `plot-pen-up` command (`ppu` for short). After this command is issued, the `plot` and `plotxy` commands move the pen but do not actually draw anything. Once the pen is where you want it, use `plot-pen-down` to put the pen back down (`ppd` for short).

If you want to plot individual points instead of lines, or you want to draw bars instead of lines or points, you need to change the plot pen's "mode". Three modes are available: line, bar, and point. Line is the default mode.

Normally, you change a pen's mode by editing the plot. This changes the pen's default mode. It's also possible to change the pen's mode temporarily using the `set-plot-pen-mode` command. That command takes a number as input: 0 for line, 1 for bar, 2 for point.

Histograms

A histogram is a special kind of plot that measures how frequently certain values, or values in certain ranges, occur in a collection of numbers that arise in your model.

For example, suppose the turtles in your model have an `age` variable. You could create a histogram of the distribution of ages among your turtles with the `histogram-from` command, like this:

```
histogram-from turtles [age]
```

If the data you want to histogram don't come from an agentset but from a list of numbers, use the `histogram-list` command instead.

Note that using the histogram commands doesn't automatically switch the current plot pen to bar mode. If you want bars, you have to set the plot pen to bar mode yourself. (As we said before, you can change a pen's default mode by editing the plot in the Interface tab.)

The width of the bars in a histogram is controlled by the plot pen's interval. You can set a plot pen's default interval by editing the plot in the Interface tab. You can also change the interval temporarily

with the set-plot-pen-interval command or the set-histogram-num-bars. If you use the latter command, NetLogo will set the interval appropriately so as to fit the specified number of bars within the plot's current x range.

Code Example: Histogram Example

Clearing and resetting

You can clear the current plot with the clear-plot command, or clear every plot in your model with clear-all-plots. The clear-all command also clears all plots, in addition to clearing everything else in your model.

If you only want to remove only the points that the current plot pen has drawn, use plot-pen-reset.

When a whole plot is cleared, or when a pen is reset, that doesn't just remove the data that has been plotted. It also restores the plot or pen to its default settings, as they were specified in the Interface tab when the plot was created or last edited. Therefore, the effects of such commands as set-plot-x-range and set-plot-pen-color are only temporary.

Autoplotting

By default, all NetLogo plots have the "autoplotting" feature enabled. This means that if the model tries to plot a point which is outside the current displayed range, the range of the plot will grow along one or both axes so that the new point is visible.

In the hope that the ranges won't have to change every time a new point is added, when the ranges grow they leave some extra room: 25% if growing horizontally, 10% if growing vertically.

If you want to turn off this feature, edit the plot and uncheck the Autoplot checkbox. At present, it is not possible to enable or disable this feature only on one axis; it always applies to both axes.

Temporary plot pens

Most plots can get along with a fixed number of pens. But some plots have more complex needs; they may need to have the number of pens vary depending on conditions. In such cases, you can make "temporary" plot pens from code and then plot with them. These pens are called "temporary" because they vanish when the plot is cleared (by the clear-plot, clear-all-plots, or clear-all commands).

To create a temporary plot pen, use the create-temporary-plot-pen command. Once the pen has been created, you can use it like any ordinary pen. By default, the new pen is down, is black in color, has an interval of 1.0, and plots in line mode. Commands are available to change all of these settings; see the Plotting section of the Primitives Dictionary.

Conclusion

Not every aspect of NetLogo's plotting system has been explained here. See the Plotting section of the Primitives Dictionary for information on additional commands and reporters related to plotting.

Many of the Sample Models in the Models Library illustrate various advanced plotting techniques. Also check out the following code examples:

Code Examples: Plot Axis Example, Plot Smoothing Example

Strings

To input a constant string in NetLogo, surround it with double quotes.

The empty string is written by putting nothing between the quotes, like this: `" "`.

Most of the list primitives work on strings as well:

```
butfirst "string" => "tring"
butlast "string" => "strin"
empty? "" => true
empty? "string" => false
first "string" => "s"
item 2 "string" => "r"
last "string" => "g"
length "string" => 6
member? "s" "string" => true
member? "rin" "string" => true
member? "ron" "string" => false
position "s" "string" => 0
position "rin" "string" => 2
position "ron" "string" => false
remove "r" "string" => "sting"
remove "s" "strings" => "tring"
replace-item 3 "string" "o" => "strong"
reverse "string" => "gnirts"
```

A few primitives are specific to strings, such as `is-string?`, `substring`, and `word`:

```
is-string? "string" => true
is-string? 37 => false
substring "string" 2 5 => "rin"
word "tur" "tle" => "turtle"
```

Strings can be compared using the `=`, `!=`, `<`, `>`, `<=`, and `>=` operators.

To concatenate strings, that is, combine them into a single string, you can also use the `+` (plus) operator, like this:

```
"tur" + "tle" => "turtle"
```

If you need to embed a special character in a string, use the following escape sequences:

- `\n` = newline
- `\t` = tab
- `\"` = double quote
- `\\` = backslash

Output

This section is about output to the screen. Output to the screen can also be later saved to a file using the export-output command. If you need a more flexible method of writing data to external files, see the next section, File I/O.

The basic commands for generating output to the screen in NetLogo are print, show, type, and write. These commands send their output to the Command Center.

For full details on these four commands, see their entries in the Primitives Dictionary. Here is how they are typically used:

- print is useful in most situations.
- show lets you see which agent is printing what.
- type lets you print several things on the same line.
- write lets you print values in a format which can be read back in using file-read.

A NetLogo model may optionally have an "output area" in its Interface tab, separate from the Command Center. To send output there instead of the Command Center, use the output-print, output-show, output-type, and output-write commands.

The output area can be cleared with the clear-output command and saved to a file with export-output. The contents of the output area will be saved by the export-world command. The import-world command will clear the output area and set its contents to the value in imported world file. It should be noted that large amounts of data being sent to the output area can increase the size of your exported worlds.

If you use output-print, output-show, output-type, output-write, clear-output, or export-output in a model which does not have a separate output area, then the commands apply to the output portion of the Command Center.

File I/O

In NetLogo, there is a set of primitives that give you the power to interact with outside files. They all begin with the prefix **file-**.

There are two main modes when dealing with files: reading and writing. The difference is the direction of the flow of data. When you are reading in information from a file, data that is stored in the file flows into your model. On the other hand, writing allows data to flow out of your model and into a file.

When a NetLogo model runs as an applet within a web browser, it will only be able to read data from files which are in the same directory on the server as the model file. Applets cannot write to any files.

When working with files, always begin by using the primitive file-open. This specifies which file you will be interacting with. None of the other primitives work unless you open a file first.

The next **file-** primitive you use dictates which mode the file will be in until the file is closed, reading or writing. To switch modes, close and then reopen the file.

The reading primitives include file-read, file-read-line, file-read-characters, and file-at-end? Note that the file must exist already before you can open it for reading.

Code Examples: File Input Example

The primitives for writing are similar to the primitives that print things in the Command Center, except that the output gets saved to a file. They include file-print, file-show, file-type, and file-write. Note that you can never "overwrite" data. In other words, if you attempt to write to a file with existing data, all new data will be appended to the end of the file. (If you want to overwrite a file, use file-delete to delete it, then open it for writing.)

Code Examples: File Output Example

When you are finished using a file, you can use the command file-close to end your session with the file. If you wish to remove the file afterwards, use the primitive file-delete to delete it. To close multiple opened files, one needs to first select the file by using file-open before closing it.

```
;; Open 3 files
file-open "myfile1.txt"
file-open "myfile2.txt"
file-open "myfile3.txt"

;; Now close the 3 files
file-close
file-open "myfile2.txt"
file-close
file-open "myfile1.txt"
file-close
```

Or, if you know you just want to close every file, you can use file-close-all.

Two primitives worth noting are file-write and file-read. These primitives are designed to easily save and retrieve NetLogo constants such as numbers, lists, booleans, and strings. file-write will always output the variable in such a manner that file-read will be able to interpret it correctly.

```
file-open "myfile.txt" ;; Opening file for writing
ask turtles
  [ file-write xcor file-write ycor ]
file-close

file-open "myfile.txt" ;; Opening file for reading
ask turtles
  [ setxy file-read file-read ]
file-close
```

Code Examples: File Input Example and File Output Example

Letting the user choose

The [user-choose-directory](#), [user-choose-file](#), and [user-choose-new-file](#) primitives are useful when you want the user to choose a file or directory for your code to operate on.

Movies

This section describes how to capture a QuickTime movie of a NetLogo model.

First, use the [movie-start](#) command to start a new movie. The filename you provide should end with `.mov`, the extension for QuickTime movies.

To add a frame to your movie, use either [movie-grab-view](#) or [movie-grab-interface](#), depending on whether you want the movie to show just the current view, or the entire Interface tab. In a single movie, you must use only one **movie-grab-** primitive or the other; you can't mix them.

When you're done adding frames, use [movie-close](#).

```
;; export a 30 frame movie of the view
setup
movie-start "out.mov"
movie-grab-view ;; show the initial state
repeat 30
[ go
  movie-grab-view ]
movie-close
```

By default, a movie will play back at 15 frames per second. To make a movie with a different frame rate, call [movie-set-frame-rate](#) after [movie-start](#) but before grabbing any frames.

To check the frame rate of your movie, or to see how many frames you've grabbed, call [movie-status](#), which reports a string that describes the state of the current movie.

To throw away a movie and delete the movie file, call [movie-cancel](#).

NetLogo movies are exported as uncompressed QuickTime files. To play a QuickTime movie, you can use [QuickTime Player](#), a free download from Apple.

Since the movies are not compressed, they can take up a lot of disk space. You will probably want to compress your movies with third-party software. The software may give you a choice of different kinds of compression. Some kinds of compression are lossless, while others are lossy. "Lossy" means that in order to make the files smaller, some of the detail in the movie is lost. Depending on the nature of your model, you may want to avoid using lossy compression, for example if the view contains fine pixel-level detail.

Code Example: Movie Example

Perspective

The 2D and the 3D view show the world from the perspective of the observer. By default the observer is looking down on the world from the positive z-axis at the origin. You can change the

perspective of the observer by using the follow, ride and watch observer commands and follow-me, ride-me and watch-me turtle commands. When in follow or ride mode the observer moves with the subject agent around the world. The difference between follow and ride is only visible in the 3D view. In the 3D view the user can change the distance behind the agent using the mouse. When the observer is following at zero distance from the agent it is actually riding the agent. When the observer is in watch mode it tracks the movements of one turtle without moving. In both views you will see a spotlight appear on the subject and in the 3D view the observer will turn to face the subject. To determine which agent is the focus you can use the subject reporter.

Code Example: Perspective Example

Turtle Pens

In past versions of NetLogo when turtles had their pen down they changed the pcolor of the patch below them. We have improved NetLogo's support for drawing as in more traditional logos. Turtles have, by default, a one pixel wide pen that draws (or erases) in a separate layer between the turtles and the patches. Turtles draw in their own color. The size of the pen is variable and can be set using the pen-size turtle variable. Turtles can stamp an image of their current shape into this layer using the stamp command. To remove lines and stamps turtles need only to switch to pen-erase mode using the pe command. You can import images directly into the drawing using the import-drawing command.

There are still some features present in many logos but not in NetLogo and some features work differently in NetLogo.

Features that are not supported:

- flood-color or fill – fill the enclosed area with the pen color
- screen-color, bgcolor or setbg – set the background color (the same effect can be achieved by `ask patches [set pcolor blue]`)
- reverse-lines
- refresh mode – Some logos allow the user to back-up the movement of the turtle. NetLogo does not track the movements of turtles
- WINDOW and FENCE – these are analogous to infinite plane and bounded world topologies, which we hope to add in a future version.

Features that work differently:

- When turtles are created in NetLogo the default mode is pen-up instead of pen-down.
- Clearing – See clear-all, clear-drawing

Shapes Editor Guide

The Shapes Editor allows you to create and save turtle designs. NetLogo uses fully scalable and rotatable vector shapes, which means it lets you create designs by combining basic geometric elements, which can appear on-screen in any size or orientation.

Getting Started

To begin making shapes, choose **Shapes Editor** in the Tools menu. A new window will open listing all the shapes currently in the model, beginning with *default*, the default shape. The Shapes Editor allows you to edit shapes, create new shapes, and borrow shapes from a library or from another model.

Importing Shapes

Every new model in NetLogo starts off containing a small core set of frequently used shapes. Many more shapes are available by using the **Import from library...** button. This brings up a dialog where you can select one or more shapes and bring them into your model. Select the shapes, then press the **Import** button.

Similarly, you can use the **Import from model...** button to borrow shapes from another model.

Default shapes

Here are the shapes that are included by default in every new NetLogo model:



First row: default, airplane, arrow, box, bug, butterfly, car
Second row: circle, circle 2, cow, face happy, face neutral, face sad, fish
Third row: flag, flower, house, leaf, line, pentagon, person
Fourth row: plant, square, square 2, star, target, tree, triangle
Fifth row: triangle 2, truck, turtle, wheel, x

Shapes library

And here are the shapes in the shapes library (including all of the default shapes, too):



Creating and Editing Shapes

Pressing the **New** button will make a new shape. Or, you may select an existing shape and press **Edit**.

Tools

In the upper left corner of the editing window is a group of drawing tools. The arrow is the selection tool, which selects an already drawn element.

To draw a new element, use one of the other seven tools:

- The **line** tool draws line segments.
- The **circle**, **square**, and **polygon** tools come in two versions, solid and outline.

When using the polygon tool, click the mouse to add a new segment to the polygon. When you're done adding segments, double click.

After you draw a new element, it is selected, so you can move, delete, or reshape it if you want:

- To move it, drag it with the mouse
- To delete it, press the Delete button.
- To reshape it, drag the small "handles" that appear on the element only when it is selected.
- To change its color, click on the new color.

Previews

As you draw your shape, you will also see it in five smaller sizes in the five preview areas found near the bottom of the editing window. The previews show your shape as it might appear in your model, including how it looks as it rotates. The number below each preview is the size of the preview in pixels. When you edit the view, patch size is also measured in pixels. So for example, the preview with "20" below it shows you how your shape would look on a turtle (of size 1) on patches of size 20 pixels.

The rotatable feature can be turned off if you want a shape that always faces the same way, regardless of the turtle's heading.

Overlapping Shapes

New elements go on top of previous elements. You can change the layering order by selecting an element and then using the **Bring to front** and **Send to back** buttons.

Undo

At any point you can use the **Undo** button to undo the edit you just performed.

Colors

Elements whose color matches the *Color that changes* (selected from a drop-down menu — the default is gray) will change color according to the value of each turtle's *color* variable in your model. Elements of other colors don't change. For example, you could create cars that always have yellow headlights and black wheels, but different body colors.

Other buttons

The "Rotate Left" and "Rotate Right" buttons rotate elements by 90 degrees. The "Flip Horizontal" and "Flip Vertical" buttons reflect elements across the axes.

These four buttons will rotate or flip the entire shape, unless an element is selected, in which case only that element is affected.

These buttons are especially handy in conjunction with the "Duplicate" button if you want to make shapes that are symmetrical. For example, if you were making a butterfly, you could draw the butterfly's left wing with the polygon tool, then duplicate the wing with the "Duplicate" button, then turn the copy into a right wing with the "Flip Horizontal" button.

Shape Design

It's tempting to draw complicated, interesting shapes, but remember that in most models, the patch size is so small that you won't be able to see very much detail. Simple, bold, iconic shapes are usually best.

Keeping a Shape

When the shape is done, give it a name and press the **Done** button at the bottom of the editing window. The shape and its name will now be included in the list of shapes along with the "default" shape.

Using Shapes in a Model

In the model's code or in the command center, you can use any of the shapes that are in the model. For example, suppose you want to create 50 turtles with the shape "rabbit". Provided there is some shape called *rabbit* in this model, give this command to the observer in the command center:

```
O> crt 50
```

And then give these commands to the turtles to spread them out, then change their shape:

```
T> fd random 15
T> set shape "rabbit"
```

Voila! Rabbits! Note the use of double quotes around the shape name. Shape names are strings.

The `set-default-shape` command is also useful for assigning shapes to turtles.

BehaviorSpace Guide

This guide has three parts:

- **What is BehaviorSpace?**: A general description of the tool, including the ideas and principles behind it.
- **How It Works**: Walks you through how to use the tool and highlights its most commonly used features.
- **Advanced Usage**: How to use BehaviorSpace from the command line, or from your own Java code.

What is BehaviorSpace?

BehaviorSpace is a software tool integrated with NetLogo that allows you to perform experiments with models. It runs a model many times, systematically varying the model's settings and recording the results of each model run. This process is sometimes called "parameter sweeping". It lets you explore the model's "space" of possible behaviors and determine which combinations of settings cause the behaviors of interest.

Why BehaviorSpace?

The need for this type of experiment is revealed by the following observations. Models often have many settings, each of which can take a range of values. Together they form what in mathematics is called a parameter space for the model, whose dimensions are the number of settings, and in which every point is a particular combination of values. Running a model with different settings (and sometimes even the same ones) can lead to drastically different behavior in the system being modeled. So, how are you to know which particular configuration of values, or types of configurations, will yield the kind of behavior you are interested in? This amounts to the question of where in its huge, multi-dimension parameter space does your model perform best?

For example, suppose you want speedy synchronization from the agents in the Fireflies model. The model has four sliders — number, cycle-length, flash-length and number-flashes — that have approximately 2000, 100, 10 and 3 possible values, respectively. That means there are $2000 * 100 * 10 * 3 = 600,000$ possible combinations of slider values! Trying combinations one at a time is hardly an efficient way to learn which one will evoke the speediest synchronization.

BehaviorSpace offers you a much better way to solve this problem. If you specify a subset of values from the ranges of each slider, it will run the model with each possible combination of those values and, during each model run, record the results. In doing so, it samples the model's parameter space — not exhaustively, but enough so that you will be able to see relationships form between different sliders and the behavior of the system. After all the runs are over, a dataset is generated which you can open in a different tool, such as a spreadsheet, database, or scientific visualization application, and explore.

By enabling you to explore the entire "space" of behaviors a model can exhibit, BehaviorSpace can be a powerful assistant to the modeler.

Historical Note

Old versions of NetLogo (prior to 2.0) included an earlier version of the BehaviorSpace tool. That version was much different. It wasn't nearly as flexible in the kinds of experiments it let you set up. But, it had facilities for display and analyzing experiment results that are missing from the current version. With the current version, it is assumed that you will use other software to analyze your results. We hope to re-add data display and analysis facilities to a future version of BehaviorSpace.

How It Works

To begin using BehaviorSpace, open your model, then choose the BehaviorSpace item on NetLogo's Tools menu.

Managing experiment setups

The dialog that opens lets you create, edit, duplicate, delete, and run experiment setups. Experiments are listed by name and how by model runs the experiment will consist of.

Experiment setups are considered part of a NetLogo model and are saved as part of the model.

To create a new experiment setup, press the "New" button.

Creating an experiment setup

In the new dialog that appears, you can specify the following information. Note that you don't always need to specify everything; some parts can be left blank, or left with their default values, depending on your needs.

Experiment name: If you have multiple experiments, giving them different names will help you keep them straight.

Vary variables as follows: This is where you specify which settings you want varied, and what values you want them to take. Variables can include sliders, switches, choosers, and any global variables in your model.

Variables can also include `screen-edge-x` and `screen-edge-y`, and `random-seed`. These are not, strictly speaking, variables, but BehaviorSpace lets you vary them as if they were. Varying `screen-edge-x/y` lets you explore the effect of world size upon your model. Varying `random-seed` lets you repeat runs by using a known seed for the NetLogo random number generator. Note that you're also free to use the `random-seed` command in your experiment's setup commands. For more information on random seeds, see the [Random Numbers](#) section of the Programmer's Guide.

You may specify values either by listing the values you want used, or by specifying that you want to try every value within a given range. For example, to give a slider named `number` every value from 100 to 1000 in increments of 50, you would enter:

```
[ "number" [100 50 1000]]
```

Or, to give it only the values of 100, 200, 400, and 800, you would enter:

```
[ "number" 100 200 400 800 ]
```

Be careful with the brackets here. Note that there are fewer square brackets in the second example. Including or not including this extra set of brackets is how you tell BehaviorSpace whether you are listing individual values, or specifying a range.

Also note that the double quotes around the variable names are required.

You can vary as many settings as you want, including just one, or none at all. Any settings that you do not vary will retain their current values. Not varying any settings is useful if you just want to do many runs with the current settings.

What order you list the variables in determines what order the runs will be done in. All values for a later variable will be tried before moving to the next value for an earlier variable. So for example if you vary both x and y from 1 to 3, and x is listed first, then the order of model runs will be: x=1 y=1, x=1 y=2, x=1 y=3, x=2 y=1, and so on.

Repetitions: Sometimes the behavior of a model can vary a lot from run to run even if the settings don't change, if the model uses run numbers. If you want to run the model more than once at each combination of settings, enter a higher number here than one.

Measure runs using these reporters: This is where you specify what data you want to collect from each run. For example, if you wanted to record how the population of turtles rose and fell during each run, you would enter:

```
count turtles
```

You can enter one reporter, or several, or none at all. If you enter several, each reporter must be on a line by itself, for example:

```
count frogs
count mice
count birds
```

If you don't enter any reporters, the runs will still take place. This is useful if you want to record the results yourself your own way, such as with the `export-world` command.

Measure runs at every tick: Normally NetLogo will measure model runs at every tick, using the reporters you entered in the previous box. If you're doing very long model runs, you might not want all that data. Uncheck this box if you only want to measure each run after it ends.

Setup commands: These commands will be used to begin each model run. Typically, you will enter the name of a procedure that sets up the model, typically `setup`. But it is also possible to include other commands as well.

Go commands: These commands will be run over and over again to advance to the model to the next "tick". Typically, this will be the name of a procedure, such as `go`, but you may include any commands you like.

Stop condition: This lets you do model runs of varying length, ending each run when a certain condition becomes true. For example, suppose you wanted each run to last until there were no more turtles. Then you would enter:

```
not any? turtles
```

If you want the length of runs to all be of a fixed length, just leave this blank.

Final commands: These are any extra commands that you want run once, when the run ends. Usually this is left blank, but you might use it to call the `export-world` command or record the results of the run in some other way.

Time limit: This lets you set a fixed maximum length for each run. If you don't want to set any maximum, but want the length of the runs to be controlled by the stop condition instead, enter 0.

Running an experiment

When you're done setting up your experiment, press the "OK" button, followed by the "Run" button.

You will be prompted to select the formats you would like the data from your experiment saved in. Data is collected for each interval, run or tick, according to the setting of **Measure runs at every tick** option.

Table format lists each interval in a row, with each metric in a separate column. Table data is written to the output file as each run completes. Table format is suitable for automated processing of the data, such as importing into a database or a statistics package.

Spreadsheet format calculates the min, mean, max, and final values for each metric, and then lists each interval in a row, with each metric in a separate column. Spreadsheet data is more human-readable than Table data, especially if imported into a spreadsheet application.

(Note however that spreadsheet data is not written to the results file until the experiment finishes. Since spreadsheet data is stored in memory until the experiment is done, very large experiments could run out of memory. And if anything interrupts the experiment, such as a runtime error, running out of memory, or a crash or power outage, no results will be written. For long experiments, you may want to use both spreadsheet and table formats so that if something happens you'll at least get a table of partial results.)

After selecting your output formats, BehaviorSpace will prompt you for the name of a file to save the results to. The default name ends in ".csv". You can change it to any name you want, but don't leave off the ".csv" part; that indicates the file is a Comma Separated Values (CSV) file. This is a plain-text data format that is readable by any text editor as well as by most popular spreadsheet and database programs.

A dialog will appear, titled "Running Experiment". In this dialog, you'll see a progress report of how many runs have been completed so far and how much time has passed. If you entered any reporters for measuring the runs, and if you left the "Measure runs at every tick" box checked, then you'll see a plot of how they vary over the course of each run.

You can also watch the runs in the main NetLogo window. (If the "Running Experiment" dialog is in the way, just move it to a different place on the screen.) The view and plots will update as the model runs. If you don't need to see them update, then use the checkboxes in the "Running Experiment" dialog to turn the updating off. This will make the experiment go faster.

If you want to stop your experiment before it's finished, press the "Abort" button. But note that you'll lose any results that were generated up to that point.

When all the runs have finished, the experiment is complete.

Advanced usage

Running from the command line

It is possible to run BehaviorSpace experiments "headless", that is, from the command line, without any graphical user interface (GUI). This is useful for automating runs on a single machine or a cluster of machines.

No Java programming is required. Experiment setups can be created in the GUI and then run later from the command line, or, if you prefer, you can create or edit experiment setups directly using XML.

It is easiest if you create your experiment setup ahead of time in the GUI, so it is saved as part of the model. To run an experiment setup saved in a model, here is an example command line:

```
java -Xmx512M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --experiment experiment1
```

After the named experiment has run, the results are sent to standard output in spreadsheet format, as CSV. (To change this, see below.)

When running the HeadlessWorkspace class as an application, it forces the system property `java.awt.headless` to be true. This tells Java to run in headless mode, allowing NetLogo to run on machines when a graphical display is not available.

Note the use of `-Xmx` to specify a maximum heap size of 512 megabytes. If you don't specify a maximum heap size, you will get your VM's default size, which may be unusably small. (512 megabytes is an arbitrary size which should be more than large enough for most models; you can specify a different limit if you want.)

The `--model` argument is used to specify the model file you want to open.

The `--experiment` argument is used to specify the name of the experiment you want to run. (At the time you create an experiment setup in the GUI, you assign it a name.)

Here's another example that shows some additional, optional arguments:

```
java -Xmx512M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --experiment experiment2 \
  --screen-edge-x 100 \
  --screen-edge-y 100 \
  --no-results
```

Note the use of the optional `--screen-edge-x` and `screen-edge-y` arguments to specify a different world size than that saved in the model. (It's also possible for the experiment setup to specify values for `screen-edge-x` and `screen-edge-y`; if they are specified by the experiment setup, then there is no need to specify them on the command line.)

Note also the use of the optional `--no-results` argument to specify that no output is to be generated. This is useful if the experiment setup generates all the output you need by some other means, such as exporting world files or writing to a text file.

Yet another example:

```
java -Xmx512M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --experiment experiment2 \
  --table table-output.csv \
  --spreadsheet spreadsheet-output.csv
```

The optional `--table <filename>` argument specifies that output should be generated in a table format and written to the given file as CSV data. If `-` is specified as the filename, then the output is sent to the standard system output stream. Table data is written as it is generated, with each complete run.

The optional `--spreadsheet <filename>` argument specified that spreadsheet output should be generated and written to the given file as CSV data. If `-` is specified as the filename, then the output is sent to the standard system output stream. Spreadsheet data is not written out until all runs in the experiment are finished.

Note that it is legal to specify both `--table` and `--spreadsheet`, and if you do, both kinds of output file will be generated.

The default output behavior, when no output formats are specified, is to send table output to the system standard output stream.

Here is one final example that shows how to run an experiment setup which is stored in a separate XML file, instead of in the model file:

```
java -Xmx512M -cp NetLogo.jar \
  org.nlogo.headless.HeadlessWorkspace \
  --model Fire.nlogo \
  --setup-file fire-setups.xml \
  --experiment experiment3
```


If the XML file contains more than one experiment setup, it is necessary to use the `--experiment` argument to specify the name of the setup to use.

The next section has information on how to create standalone experiment setup files using XML.

Setting up experiments in XML

We don't yet have detailed documentation on authoring experiment setups in XML, but if you already have some familiarity with XML, then the following pointers may be enough to get you started.

The structure of BehaviorSpace experiment setups in XML is determined by a Document Type Definition (DTD) file. The DTD is stored in NetLogo.jar, as `system/behaviorspace.dtd`. (JAR files are also zip files, so you can extract the DTD from the JAR using Java's "jar" utility or with any program that understands zip format.)

The easiest way to learn what setups look like in XML, though, is to author a few of them in BehaviorSpace's GUI, save the model, and then examine the resulting .nlogo file in a text editor. The experiment setups are stored towards the end of the .nlogo file, in a section that begins and ends with a `experiments` tag. Example:

```
<experiments>
  <experiment name="experiment" repetitions="10" runMetricsEveryTick="true">
    <setup>setup</setup>
    <go>go</go>
    <exitCondition>not any? fires</exitCondition>
    <metric>burned-trees</metric>
    <enumeratedValueSet variable="density">
      <value value="40"/>
      <value value="0.1"/>
      <value value="70"/>
    </enumeratedValueSet>
  </experiment>
</experiments>
```

In this example, only one experiment setup is given, but you can put as many as you want between the beginning and ending `experiments` tags.

Between looking at the DTD, and looking at examples you create in the GUI, it will hopefully be apparent how to use the tags to specify different kind of experiments. The DTD specifies which tags are required and which are optional, which may be repeated and which may not, and so forth.

When XML for experiment setups is included in a model file, it does not begin with any XML headers, because not the whole file is XML, only part of it. If you keep experiment setups in their own file, separate from the model file, then the extension on the file should be .xml not .nlogo, and you'll need to begin the file with proper XML headers, as follows:

```
<?xml version="1.0" encoding="us-ascii"?>
<!DOCTYPE experiments SYSTEM "behaviorspace.dtd">
```

The second line must be included exactly as shown. In the first line, you may specify a different encoding than `us-ascii`, such as `UTF-8`, but NetLogo doesn't support non-ASCII characters in most situations, so specifying a different encoding may be pointless.

Controlling API

If BehaviorSpace is not sufficient for your needs, a possible alternative is to use our Controlling API, which lets you write Java code that controls NetLogo. The API lets you run BehaviorSpace experiments from Java code, or, you can write custom code that controls NetLogo more directly to do BehaviorSpace-like things. See the Controlling section of the User Manual for further details on both possibilities.

Conclusion

BehaviorSpace is still under development. We'd like to hear from you about what what additional features would be useful to you in your work. Please write us at feedback@ccl.northwestern.edu.

HubNet Guide

This section of the User Manual introduces the HubNet system and includes instructions to set up and run a HubNet activity.

HubNet is a technology that lets you use NetLogo to run *participatory simulations* in the classroom. In a participatory simulation, a whole class takes part in enacting the behavior of a system as each student controls a part of the system by using an individual device, such as a networked computer or TI-83+ calculator.

For example, in the Gridlock simulation, each student controls a traffic light in a simulated city. The class as a whole tries to make traffic flow efficiently through the city. As the simulation runs, data is collected which can afterwards be analyzed on a computer or calculator.

For more information on participatory simulations and their learning potential, please visit the [Participatory Simulations Project web site](#).

Understanding HubNet

NetLogo

NetLogo is a programmable modeling environment. It comes with a large library of existing simulations, both participatory and traditional, that you can use and modify. Content areas include social science and economics, biology and medicine, physics and chemistry, and mathematics and computer science. You and your students can also use it to build your own simulations. For more about NetLogo, see the [NetLogo Users Manual](#).

In traditional NetLogo simulations, the simulation runs according to rules that the simulation author specifies. HubNet adds a new dimension to NetLogo by letting simulations run not just according to rules, but by direct human participation.

Since HubNet builds upon NetLogo, we recommend that before trying HubNet for the first time, you become familiar with the basics of NetLogo. To get started using NetLogo models, see [Tutorial #1: Running Models](#) in the NetLogo Users Manual.

HubNet Architecture

HubNet simulations are based on a client-server architecture. The activity leader uses the NetLogo application to run a HubNet activity. When NetLogo is running a HubNet activity, we refer to it as a HubNet server. Participants use a client application to log in and interact with the HubNet server.

There are two types of HubNet available. With [Computer HubNet](#), participants run the HubNet Client application on computers connected by a regular computer network. In [Calculator HubNet](#), created in conjunction with Texas Instruments, participants use TI-83+ graphing calculators as clients which communicate via the TI-Navigator system.

We hope to add support for other types of clients such as cell phones and PDA's (Personal Digital Assistants).

Computer HubNet

Activities

The following activities are available in the Models Library, in the Computer HubNet Activities folder. For many models, you will find a discussion of its educational goals and suggested ways to incorporate it into your classroom in the Participatory Simulations Guide on the [Participatory Simulations Project web site](#). More information can also be found in the Information Tab in each model.

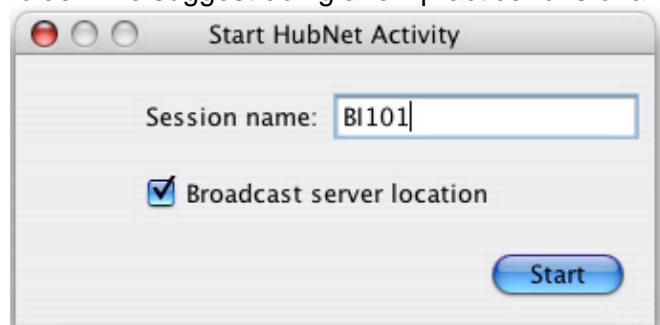
- Disease -- A disease spreads through the simulated population of students.
- Gridlock -- Students use traffic lights to control the flow of traffic through a city.
- Polling -- Ask students questions and plot their answers.
- Tragedy of the Commons -- Students work as farmers sharing a common resource.

Requirements

To use Computer HubNet, you need a networked computer with NetLogo installed for the activity leader, and a networked computer with NetLogo installed for each participant. We also suggest an attached projector for the leader to project the entire simulation to the participants.

Starting an activity

You'll find the HubNet activities in NetLogo's Models Library, in the HubNet Computer Activities folder. We suggest doing a few practice runs of an activity before trying it in front of a class.



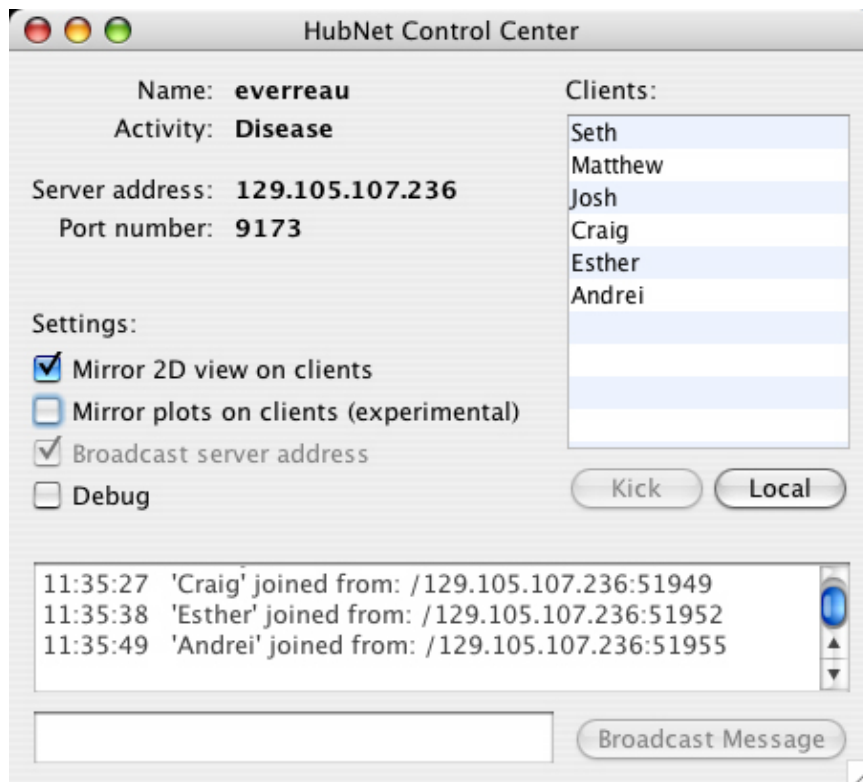
Open a Computer HubNet model. NetLogo will prompt you to enter the name of your new HubNet session. This is the name that participants will use to identify this activity. Enter a name and press Start.

NetLogo will open the HubNet Control Center, which lets you interact with the HubNet server.

In each activity, you'll see a box on the screen labeled "QuickStart Instructions". This contains step by step instructions to run the activity. Click the "Next>>>" button to advance to the next instruction.

You, as the leader, should then notify everyone that they may join. To join the activity, participants launch the HubNet Client application and enter their name. They should see your activity listed and can join your activity by selecting it and pressing Enter. If the activity you started is not listed the student can enter the server address manually which can be found in the HubNet Control Center.

HubNet Control Center



The HubNet Control Center lets you interact with the HubNet server. It displays the name, activity, address and port number of your server. The "Mirror 2D View" checkbox controls whether the HubNet participants can see the view on their clients, assuming there is a view in the client setup. The "Mirror plots" checkbox controls whether participants will receive plot information.

The client list on the right displays the names of clients that are currently connected to you activity. To remove a participant from the activity, select their name in the list and press the Kick button. To launch your own HubNet client press the Local button, this is particularly useful when you are debugging an activity.

The lower part of the Control Center displays messages when a participant joins or leaves the activity. To broadcast a message to all the participants, click on the field at the bottom, type your message and press Broadcast Message.

Troubleshooting

I started a HubNet activity, but when participants open a HubNet Client, my activity isn't listed.

On some networks, the HubNet Client cannot automatically detect a HubNet server. Tell your participants to manually enter the server name and port of your HubNet server, which appear in the HubNet Control Center.

Note: The technical details on this are as follows. In order for the client to detect the server, multicast routing must be available between them. Not all networks support multicast routing. In

particular, networks that use the IPsec protocol typically do not support multicast. The IPsec protocol is used on many virtual private networks (VPN's).

When a participant tries to connect to my activity, nothing happens after they click Enter.

If your computer or network has a firewall, it may be impeding the HubNet server from communicating. Make sure that your computer and network are not blocking ports used by the HubNet server (ports 9173 – 9180).

The view on the HubNet client is grey.

- Verify that the "Mirror 2D view" checkbox in the HubNet Control Center is selected.
- Make sure that the display switch in the model is on.
- The view on the server must be exactly the same size as on the client. If you changed the size of the view on the HubNet server, you need to restore it to its original dimensions.

There is no view on the HubNet client.

Some activities don't have a view on the client.

I can't quit a HubNet client.

You will have to force the client to quit. On OS X, force quit the application by selecting Force Quit... in the Apple menu. On Windows, press Ctrl–Alt–Delete to open the Task Manager, select HubNet Client and press End Task.

My computer went to sleep while running a HubNet activity. When I woke the computer up, I got an error and HubNet wouldn't work anymore.

The HubNet server may stop working if the computer goes to sleep. If this happens, quit the NetLogo application and start over. Change the settings on your computer so it won't sleep again.

My problem is not addressed on this page.

Please send us an email at feedback@ccl.northwestern.edu.

Known Limitations

If HubNet malfunctions, please send us an email at bugs@ccl.northwestern.edu.

Please note that:

- HubNet has not yet been extensively tested with large numbers of clients (i.e. more than about 25). Unexpected results may occur with more clients.
- Out-of-memory conditions are not handled gracefully
- Sending large amounts of plotting messages to the clients can take a long time.
- NetLogo does not handle malicious clients in a robust manner (in other words, it is likely vulnerable to denial-of-service type attacks).
- Performance does not degrade gracefully over slow or unreliable network connections.
- If you are on a wireless network or sub-LAN, the IP address in the HubNet Control Center is

not always the entire IP address of the server.

- Authoring new HubNet activities is more arcane and difficult than it should be.
- Computer HubNet has only been tested on LANs, and not on dial-up connections or WANs.

Calculator HubNet

Requirements

To use Calculator HubNet, you need:

- **A computer with an attached projector.** This computer will run NetLogo and project the simulation for class viewing.
- **A classroom set of Texas Instruments TI-83+ graphing calculators.**
- **The TI-Navigator calculator network from Texas Instruments.**

NOTE: Calculator HubNet works with a prototype version of the TI-Navigator system, and is not yet compatible with the commercially available version. To learn more about the TI-Navigator system, please visit the [Texas Instruments](#) website.

We are actively working in partnership with Texas Instruments on integrating the new TI-Navigator with Calculator HubNet. We expect to release a new version in the near future.

For more information about Calculator HubNet, please refer to the Participatory Simulations Guide which can be found on the [Participatory Simulations Project web site](#).

Teacher workshops

For information on upcoming workshops and NetLogo and HubNet use in the classroom, please contact us at feedback@ccl.northwestern.edu.

HubNet Authoring Guide

To learn about authoring or modifying HubNet activities, see the [HubNet Authoring Guide](#).

Getting help

If you have any questions about Computer HubNet or Calculator HubNet, or need help getting started, please email us at feedback@ccl.northwestern.edu.

HubNet Authoring Guide

This explains how to use NetLogo to modify the existing HubNet activities or build your own, new HubNet activities.

- [General HubNet Information](#)
- [NetLogo Primitives](#)
 - ♦ [Setup](#)
 - ♦ [Data Extraction](#)
 - ♦ [Sending Data](#)
- [Calculator HubNet Information](#)
- [Computer HubNet Information](#)
 - ♦ [How To Make an Interface for a Client](#)
 - ♦ [View Updates on the Clients](#)
 - ♦ [Plot Updates on the Clients](#)
 - ♦ [Clicking in the View on Clients](#)
 - ♦ [Text Area for Input and Display](#)

General HubNet Information

If you are interested in more general information on what HubNet is or how to run HubNet activities, you should refer to the [HubNet Guide](#).

NetLogo Primitives

This section will introduce the set of primitives used to turn a NetLogo Model into a HubNet Activity. These commands allow you to send data to and receive data from the clients.

Setup

In order to make a NetLogo model into a HubNet Activity, it is necessary to first indicate whether the clients are computers or calculators and then establish a connection between the server (your computer) and the clients (the students' calculators or computers) using the following primitives:

hubnet-set-client-interface client-type client-info

If *client-type* is "COMPUTER", *client-info* is a list containing a string with the file name and path (relative to the model) to the file which will serve as the client's interface. This interface will be sent to any clients that log in.

```
hubnet-set-client-interface "COMPUTER" [ "clients/Disease client.nlogo" ]  
;; when clients log in, they will get the interface described in t  
;; Disease client.nlogo in the clients subdirectory of the model d
```

This primitive must be called before you use any other HubNet primitives including `hubnet-reset` so NetLogo knows which type of HubNet you are going to be using.

hubnet-reset

Starts up the HubNet system. HubNet must be started to use any of the other HubNet primitives with the exception of `hubnet-set-client-interface`. HubNet remains running as long as this model is open; it stops running when the model is closed or you quit NetLogo.

If you are using Computer HubNet, you will be prompted for a session name. This is an identifier to make servers discovered by the client uniquely identifiable.

These primitives are usually called from the `startup` procedure rather than `setup` of the NetLogo model since they should only be called **once** in a model.

Data extraction

During the activity you will be transferring data between the HubNet clients and the server. The following primitives allow you to extract data from the clients:

hubnet-message-waiting?

This looks for new information sent by the clients. It reports TRUE if there is new data, and FALSE if there is not.

hubnet-fetch-message

If there is any new data sent by the clients, this retrieves the next piece of data, so that it can be accessed by `hubnet-message`. This will cause an error if there is no new data from the clients. So be sure to check for data with `hubnet-message-waiting?` before calling this.

hubnet-message-source

This reports the user name of the client that sent the data. This will cause an error if no data has been fetched. So be sure to fetch the data with `hubnet-fetch-message` before calling this.

hubnet-message-tag

This reports the tag that is associated with the data that was sent. For Calculator HubNet, this will report one of the variable names set with the `hubnet-set-client-interface` primitive. For Computer HubNet, this will report one of the Display Names of the interface elements in the client interface. (See [below](#) for more information about the Computer HubNet tags.) For both types of HubNet, this primitive will cause an error if no data has been fetched. So be sure to fetch the data with `hubnet-fetch-message` before calling this.

hubnet-message

This reports the data collected by `hubnet-fetch-message`. This will cause an error if no data has been fetched. So be sure to fetch the data with `hubnet-fetch-message` before calling this.

There are two additional data extraction primitives that are only used in Computer HubNet models.

hubnet-enter-message?

Reports true if a new computer client just entered the simulation. Reports false otherwise.

hubnet-exit-message?

Reports true if a new computer client just exited the simulation. Reports false otherwise.

For both `hubnet-enter-message?` and `hubnet-exit-message?`, `hubnet-message-source` will contain the user name of the client that just logged on or off. Also, if `hubnet-message` and `hubnet-message-tag` are used while `hubnet-enter-message?` or `hubnet-exit-message?` are true, a Runtime Error will be given.

Generally part of your go procedure will include checking for waiting messages and handling them.

```
to listen-clients
  while [ hubnet-message-waiting? ]
  [
```

```

hubnet-fetch-message
ifelse hubnet-enter-message?
[ create-new-student ]
[
  ifelse hubnet-exit-message?
  [ remove-student ]
  [ execute-command hubnet-message-tag ]
]
]
end

```

Sending data

It is also possible to send data from NetLogo to the clients. For Calculator HubNet, NetLogo sends the data to the Navigator server, and then the calculators can then access it. For Computer HubNet, NetLogo is able to send the data directly to the clients.

The primitives for sending data to the server are:

hubnet-broadcast tag-name value

This broadcasts *value* from NetLogo to the variable, in the case of Calculator HubNet, or interface element, in the case of Computer HubNet, with the name *tag-name* to all the clients.

hubnet-broadcast-view

This broadcasts the current state of the 2D View in the NetLogo model to all the Computer HubNet Clients. It does nothing for Calculator HubNet.

hubnet-send list-of-strings tag-name value

hubnet-send string tag-name value

When using Calculator HubNet this primitive acts in exactly the same manner as *hubnet-broadcast*. For Computer HubNet, it has the following effects:

- ◊ When *string* is the first input, this sends *value* from NetLogo to the tag *tag-name* on the client that has *string* for a user name.
- ◊ When *list-of-strings* is the first input, this sends *value* from NetLogo to the tag *tag-name* on all the clients that have a user name that is in the *list-of-strings*.
- ◊ All the information for the current state of the View is sent at this time, regardless of whether the clients' Views were already up to date.

Note: Sending a message to a non-existent client, using *hubnet-send*, generates a *hubnet-exit-message*.

hubnet-send-view string

hubnet-send-view list-of-strings

For Calculator HubNet, does nothing.

For Computer HubNet, it acts as follows:

- ◊ For a *string*, this sends the current state of the 2D View in the NetLogo model to the Computer HubNet Client with *string* for its user name.
- ◊ For a *list-of-strings*, this sends the current state of the 2D View in the NetLogo model to all the Computer HubNet clients that have a user name that is in the *list-of-strings*.
- ◊ All the information for the current state of the view is sent at this time, regardless of whether the clients' views were already up to date.

Note: Sending the View to a non-existent client, using *hubnet-send-view*, generates a *hubnet-exit-message*.

When using Calculator HubNet the `hubnet-send` and the `hubnet-broadcast` primitives, take a number, a string, a list of numbers, or a matrix (a list of lists) of numbers as the `value` input. When using Computer HubNet, you may send any kind of information with the exceptions of patches, turtles, and agentsets.

Here are some examples of using the two primitives to send various types of data that you can send:

data type	hubnet-broadcast example	hubnet-send example
number	<code>hubnet-broadcast "A" 3.14</code>	<code>hubnet-send "jimmy" "A" 3.14</code>
string	<code>hubnet-broadcast "STR1"</code> <code>"HI THERE"</code>	<code>hubnet-send ["12" "15"] "STR1"</code> <code>"HI THERE"</code>
list of numbers	<code>hubnet-broadcast "L2" [1 2 3]</code>	<code>hubnet-send</code> <code>hubnet-message-source "L2" [1 2 3]</code>
matrix of numbers	<code>hubnet-broadcast "[A]" [[1 2] [3 4]]</code>	<code>hubnet-send "suzy" "[A]" [[1 2] [3 4]]</code>
list of strings (only for Computer HubNet)	<code>hubnet-broadcast</code> <code>"user-names" [{"jimmy"</code> <code>"suzy"} [{"bob" "george"}]</code>	<code>hubnet-send "teacher"</code> <code>"user-names" [{"jimmy" "suzy"}]</code> <code>["bob" "george"]]</code>

Examples

Study the models in the "HubNet Computer Activities" and the "HubNet Calculator Activities" sections of the Models Library to see how these primitives are used in practice in the Procedures window. Disease is a good one with which to start.

Calculator HubNet Information

The calculators are able to send and receive the following data types from NetLogo:

- Valid calculator lists, such as `L1` or `PLOTS`
- Valid calculator matrices, such as `[A]` or `[B]`
- Valid calculator strings, such as `Str1` or `Str5`
- Numbers, such as `A` or `B`

The length of the list of numbers that a calculator sends depends on what information you want to send to the NetLogo model. Further, how those numbers are interpreted by the model is also up to you.

For more information on writing the calculator program portion of a HubNet Activity, please [contact us](#).

Saving

The data sent by calculators or NetLogo is saved in the order that the server receives the data.

Computer HubNet Information

The following information is specific to Computer HubNet.

How To Make an Interface for a Client

Open a new model in NetLogo. Add any interface buttons, sliders, switches, monitors, plots, choosers, or text boxes that you want in the Interface Tab. For buttons and monitors, you only need to type a Display Name. Any code you write in the Code or Reporter sections will be ignored. The Display Name you give to the interface element is the tag that is returned by the `hubnet-message-tag` reporter in the NetLogo code.

For example, if in the Interface Tab of the client interface you had a button called "Move Left", a slider called "step-size", a switch called "all-in-one-step?", and a monitor called "Location:", the tags for these interface elements will be as follows:

interface element	tag
Move Left	Move Left
step-size	step-size
all-in-one-step?	all-in-one-step?
Location:	Location:

Be aware that this causes the restriction that you can only have **one** interface element with a specific name. Having more than one interface element with the same Display Name in the client interface will cause unpredictable behavior. For instance, if we had a monitor called Milk Supply and a plot named Milk Supply, when we send data to the client using the tag Milk Supply, the client will just pick either the plot or the monitor to give the data to.

If you wish to have a View in the client for a model, the view in the client and the one in the NetLogo model must have the same number of patches and the same patch size. If they do not, the view on the client will not display information sent by the server.

If you wish to make a client without a view in the client, you will have to hand edit the file after you have finished adding all the other interface elements in NetLogo. To do this, open the client file in a text editor such as Notepad on Windows, or TextEdit on Macs. You should see a file that starts with something similar to this:

```
; add model procedures here
```

```
@#$#@#$#@
GRAPHICS-WINDOW
321
10
636
325
17
17
9.0
1
10
0
0
```

```
CC-WINDOW
323
339
638
459
Command Center
```

You should remove all the text that is in the GRAPHICS-WINDOW section and then save the file. So that after you are done the beginning of the file should look similar to this:

```
; add model procedures here
```

```
@#$@#$#@
CC-WINDOW
323
339
638
459
Command Center
```

For more examples, study the models and interface files in the "HubNet Computer Activities" section of the Models Library. Disease.nlogo and Disease client.nlogo are good ones to start with.

View Updates on the Clients

Currently, there are two ways of sending the clients the View. The first way is done automatically by NetLogo and HubNet when 2D View mirroring is enabled and the client has a View in the interface. Whenever a patch or turtle is redrawn in the NetLogo View, it will be redrawn on **all** the clients. Actually, updates are accumulated and sent out periodically (about five times a second). This means that a lot of messages can be sent to the clients if a lot of turtles or patches are being redrawn. It is possible to reduce the number of messages sent to the clients, and thus possibly speed up the model, by making the View in the model not update. This can be done using the `no-display` and `display` primitives or by toggling the display on/off switch in the View Control Strip.

A second way of sending the clients the View is to use the `hubnet-broadcast-view` and `hubnet-send-view` primitives. `hubnet-broadcast-view` and `hubnet-send-view` both send the entire View to the clients instead of just the patches that need to be redrawn. This makes them less efficient, but for some models this feature is necessary. To send the View to the clients using this scheme, you must use the following NetLogo code:

```
hubnet-broadcast-view
```

to send to all the logged in clients.

To just send the View to a subset of all the clients use:

```
hubnet-send-view user-name-list
```

where *user-name-list* is either a single string or a list of strings of the user names of clients that you want to send it to.

If there is no View in the clients or if the Mirror View on Clients checkbox in the HubNet Control Center is not checked, then no view messages are sent to the clients.

NOTE: Since `hubnet-broadcast-view` and `hubnet-send-view` are experimental primitives, their behaviors may change in a future release.

Note: Some of the View features in NetLogo are not yet implemented on the HubNet clients such as View Wrapping and Observer Perspectives.

Plot Updates on the Clients

When a plot in the NetLogo model changes and a plot with the exact same name exists on the clients, a message with that change is sent to the clients causing the client's plot to make the same change. For example, let's pretend there is a HubNet model that has a plot called Milk Supply in NetLogo and the clients. Milk Supply is the current plot in NetLogo and in the Command Center you type:

```
plot 5
```

This will cause a message to be sent to all the clients telling them that they need to plot a point with a y value of 5 in the next position of the plot. Notice, if you are doing a lot of plotting all at once, this can generate a lot of plotting messages to be sent to the clients.

If there is no plot with the exact same name in the clients or if the Mirror Plots on Clients checkbox in the HubNet Control Center is not checked, then no plot updates are sent to the clients.

Clicking in the View on Clients

If the View is included in the client, it is possible for the client to send locations in the View to NetLogo by clicking in the client's View. The tag reported by `hubnet-message-tag` for client clicks is the same as what is needed to send the View to a client, the string "View".

`hubnet-message` reports a two item list with the x coordinate being the first item and the y coordinate being the second item. So for example, to turn any patch that was clicked on by the client red, you would use the following NetLogo code:

```
if hubnet-message-tag = "View"
[
  ask patches with [ pxcor = (round item 0 hubnet-message) and
                    pycor = (round item 1 hubnet-message) ]
  [ set pcolor red ]
]
```

Text Area for Input and Display

A few models use an experimental interface element in the HubNet client that allows the modeler to display text on the client that can change throughout the run of the activity. Further, it can allow users to send text back to the server. If you are interested in using it in an activity, please [contact us](#) for further information.

Extensions Guide

NetLogo allows users to write new commands and reporters in Java and use them in their models. This section of the User Manual introduces this facility.

The first part discusses how to use an extension in your model once you have written one, or once someone has given you one.

The second part is intended for Java programmers interested in writing their own extensions.

Caution! The extensions facility is new in NetLogo 2.0.1 and is still in an early stage of development. Therefore it is considered "experimental". It is likely to continue to change and grow. If you write an extension now, it may need changes in order to continue to work in future NetLogo versions.

- [Using Extensions](#)
- [Writing Extensions](#)

The [NetLogo API Specification](#) contains further details.

Using Extensions

NetLogo extensions have names that end in ".jar" (short for "Java Archive").

To use an extension in a model, add the `__extensions` keyword at the beginning of the Procedures tab, before declaring any breeds or variables. (The keyword begins with two underscores to indicate that it is experimental. In a future NetLogo version, it may have a different name and syntax.)

`__extensions` takes one input, a list of strings. Each string contains the name of a NetLogo extension. For example:

```
__extensions [ "sound.jar" ]
```

NetLogo will look for extensions in two places: the directory that holds the model, and the NetLogo extensions folder.

So to install a NetLogo extension for use by any model, put the extension file (for example, "sound.jar") in the "extensions" directory inside the NetLogo directory. Or, you can just keep the extension in the same folder as the model that uses it.

You can also use extensions that are not installed in your NetLogo extensions folder by providing a path relative to the directory that contains the model, or an absolute path:

```
__extensions [ "lib/sound.jar" ]      ;; relative path
__extensions [ "../jars/sound.jar" ]  ;; relative path
__extensions [ "c:\\myfiles\\sound.jar" ] ;; absolute Windows path
__extensions [ "/Users/me/sound.jar" ]  ;; absolute Mac/Unix path
```

You may also use an extension which is stored on an Internet server instead of your local computer.

Just use the URL where you have stored the extension. For example:

```
__extensions [ "http://yourdomain.net/jars/sound.jar" ]
```

Using `__extensions` tells NetLogo to find and open the specified extension and makes the custom commands and reporters found in the extension available to the current model. You can use these commands and reporters just as if they were built-in NetLogo primitives.

To use more than one extension, list each extension separately. For example,

```
__extensions [ "sound.jar" "speech.jar" ]
```

Some extensions depend on additional files. Check the instructions that come with the extension to see if you need to keep any other files with the extension.

Applets

Models saved as applets (using "Save as Applet" on NetLogo's File menu) cannot make use of extensions. (We plan to fix this in a future release.)

Writing Extensions

We assume you have experience programming in Java.

Summary

A NetLogo extension is a JAR that contains:

- one or more classes that implement `org.nlogo.api.Primitive`,
- a main class that implements `org.nlogo.api.ClassManager`, and
- a NetLogo extension manifest file.

The manifest file must contain three tags:

- `Extension-Name`, the name of the extension.
- `Class-Manager`, the fully-qualified name of a class implementing `org.nlogo.api.ClassManager`.
- `NetLogo-Version`, the version of NetLogo for which this JAR is intended. If a user opens the extension with a different version of NetLogo, a warning message is issued.

Tutorial

Let's write an extension that provides a single reporter called `first-n-integers`.

`first-n-integers` will take a single numeric input n and report a list of the integers 1 through n . (Of course, you could easily do this just in NetLogo; it's only an example.)

1. Write primitives

A command performs an action; a reporter reports a value. To create a new command or reporter, create a class that implements the interface [org.nlogo.api.Command](#) or [org.nlogo.api.Reporter](#), which extend [org.nlogo.api.Primitive](#). In most cases, you can extend the abstract class [org.nlogo.api.DefaultReporter](#) or [org.nlogo.api.DefaultCommand](#).

`DefaultReporter` requires that we implement:

```
Object report (Argument args[], Context context)
    throws ExtensionException;
```

Since our reporter takes an argument, we also implement:

```
Syntax getSyntax();
```

Here's the implementation of our reporter, in a file called `IntegerList.java`:

```
import org.nlogo.api.*;

public class IntegerList extends DefaultReporter
{
    // take one number as input, report a list
    public Syntax getSyntax() {
        return Syntax.reporterSyntax(
            new int[] {Syntax.TYPE_NUMBER}, Syntax.TYPE_LIST
        );
    }

    public Object report(Argument args[], Context context)
        throws ExtensionException
    {
        // create a NetLogo list for the result
        LogoList list = new LogoList();

        // use typesafe helper method from
        // org.nlogo.api.Argument to access argument
        int n = args[0].getIntegerValue();

        if (n < 0) {
            // signals a NetLogo runtime error to the modeler
            throw new ExtensionException
                ("input must be positive");
        }

        // populate the list
        for (int i = 1; i <= n; i++) {
            list.add(new Integer(i));
        }
        return list;
    }
}
```

Notice:

- To access arguments, use [org.nlogo.api.Argument](#)'s typesafe helper methods, such

```
as getIntegerValue().
```

- Throw `org.nlogo.api.ExtensionException` to signal a NetLogo runtime error to the modeler.

A Command is just like a Reporter, except that reporters implement `Object report(...)` while commands implement `void perform(...)`.

2. Write a ClassManager

Each extension must include, in addition to any number of command and reporter classes, a class that implements the interface `org.nlogo.api.ClassManager`. The ClassManager tells NetLogo which primitives are part of this extension. In simple cases, extend the abstract class `org.nlogo.api.DefaultClassManager`, which provides empty implementations of the methods from ClassManager that you aren't likely to need.

Here's the class manager for our example extension, `SampleExtension.java`:

```
import org.nlogo.api.*;

public class SampleExtension extends DefaultClassManager {
    public void load(PrimitiveManager primitiveManager) {
        primitiveManager.addPrimitive
            ("first-n-integers", new IntegerList());
    }
}
```

`addPrimitive()` tells NetLogo that our reporter exists and what its name is.

3. Write a Manifest

The extension must also include a manifest. The manifest is a text file which tells NetLogo the name of the extension and the location of the ClassManager.

The manifest must contain three tags:

- `Extension-Name`, the name of the extension.
- `Class-Manager`, the fully-qualified name of a class implementing `org.nlogo.api.ClassManager`.
- `NetLogo-Version`, the version of NetLogo for which this JAR is intended. If a version mismatch is detected when a JAR is imported, a warning message will be issued, and the user will have the opportunity to cancel. If the user chooses to continue, NetLogo will attempt to import the JAR anyway, which of course may fail.

Here's a manifest for our example extension, `manifest.txt`:

```
Extension-Name: example
Class-Manager: SampleExtension
NetLogo-Version: 2.0.2
```

4. Create a JAR

To create an extension JAR, first compile your classes as usual. Make sure `NetLogo.jar` (from the NetLogo distribution) is in your classpath. For example:

```
$ javac -classpath NetLogo.jar IntegerList.java SampleExtension.java
```

Then create a JAR containing the resulting class files and the manifest. For example:

```
$ jar cvfm example.jar manifest.txt IntegerList.class SampleExtension.class
```

For information about manifest files, JAR files and Java tools, see java.sun.com.

5. Use your extension in a model

To use our example extension, put the extension JAR in the NetLogo extensions folder, or in the same directory as the model that will use the extension. At the top of the Procedures tab write:

```
__extensions [ "example.jar" ]
```

Now you can use `first-n-integers` just like it was a built-in NetLogo reporter. For example, select the Interface tab and type in the Command Center:

```
O> show first-n-integers 5  
observer: [1 2 3 4 5]
```

Extension development tips

Debugging extensions

There are special NetLogo primitives to help you as you develop and debug your extension. Like the extensions facility itself, these are considered experimental and will be changed at a later date. (That's why they have underscores in their name.)

- `print __dump-extensions` prints information about loaded extensions
- `print __dump-extension-prims` prints information about loaded extension primitives
- `__reload-extensions` forces NetLogo to reload all extensions the next time you compile your model. Without this command, changes in your extension JAR will not take effect until you open a model or restart NetLogo.

Third party JARs

If your extension depends on code stored in a separate JAR, copy the extra JARs into the "extensions" directory of the NetLogo installation. Whenever an extension is imported, NetLogo makes all the JARs in this folder available to the extension.

If you plan to distribute your extension to other NetLogo users, make sure to provide installation instructions that describe which files should be copied to their extensions directory.

Conclusion

Don't forget to consult the [NetLogo API Specification](#) for full details on these classes, interfaces, and methods.

Note that there is no way for the modeler to get a list of commands and reporters provided by an extension, so it's important that you provide adequate documentation.

The extensions facility is considered experimental. This initial API doesn't include everything you might expect. Some facilities exist but are not yet documented. If you don't see a capability you want, please let us know. Do not hesitate to contact us at feedback@ccl.northwestern.edu with questions, as we may be able to find a workaround or provide additional guidance where our documentation is thin.

Hearing from users of this API will also allow us to appropriately focus our efforts for future releases. We are committed to making NetLogo flexible and extensible, and we very much welcome your feedback.

Controlling Guide

NetLogo can be invoked from another Java program and controlled by that program. For example, you might want to call NetLogo from a small program that does something simple like automate a series of model runs.

This section of the User Manual introduces this facility for Java programmers. We'll assume that you know the Java language and related tools and practices.

Note: The controlling facility is considered "experimental". It is likely to continue to change and grow. Code you write now that uses it may need changes in order to continue to work in future NetLogo versions.

- [Example \(with GUI\)](#)
- [Example \(headless\)](#)
- [BehaviorSpace](#)
- [Other Options](#)
- [Conclusion](#)

The [NetLogo API Specification](#) contains further details.

Example (with GUI)

Here is a small but complete program that starts the full NetLogo application, opens a model, moves a slider, sets the random seed, runs the model for 50 ticks, and then prints a result:

```
import org.nlogo.app.App;
import org.nlogo.compiler.CompilerException;
import java.awt.EventQueue;

public class Example1 {
    public static void main(String[] argv) {
        App.main(argv);
        try {
            EventQueue.invokeAndWait
                ( new Runnable()
                  { public void run() {
                      try {
                          App.app.open
                            ("models/Sample Models/Earth Science/"
                             + "Fire.nlogo");
                      }
                      catch( java.io.IOException ex ) {
                          ex.printStackTrace();
                      }
                  } } );
            App.app.command("set density 62");
            App.app.command("random-seed 0");
            App.app.command("setup");
            App.app.command("repeat 50 [ go ]");
            System.out.println
                (App.app.report("burned-trees"));
        }
        catch(Exception ex) {
            ex.printStackTrace();
        }
    }
}
```

```

    }
  }
}

```

In order to compile and run this, `NetLogo.jar` (from the NetLogo distribution) must be in the classpath.

Note the use of `EventQueue.invokeLaterAndWait` to ensure that a method is called from the right thread. This is because most of the methods on the `App` class may only be called some certain threads. Most of the methods may *only* be called from the AWT event queue thread; but a few methods, such as `command()`, may only be called from threads *other* than the AWT event queue thread (such as, in this example, the main thread).

Rather than continuing to discuss this example in full detail, we refer you to the [NetLogo API Specification](#), which documents all of the ins and outs of the classes and methods used above. Additional methods are available as well.

Example (headless)

The example code in this case is very similar to the previous example, but with methods on an instance of the `HeadlessWorkspace` class substituted for static methods on `App`.

```

import org.nlogo.headless.HeadlessWorkspace;
import org.nlogo.compiler.CompilerException;

public class Example2 {
    public static void main(String[] argv) {
        HeadlessWorkspace workspace =
            new HeadlessWorkspace() ;
        try {
            workspace.open
                ("models/Sample Models/Earth Science/"
                 + "Fire.nlogo");
            workspace.command("set density 62");
            workspace.command("random-seed 0");
            workspace.command("setup");
            workspace.command("repeat 50 [ go ]") ;
            System.out.println
                (workspace.report("burned-trees"));
            workspace.dispose();
        }
        catch(Exception ex) {
            ex.printStackTrace();
        }
    }
}

```

In order to compile and run this, either `NetLogo.jar` or `NetLogoLite.jar` (from the NetLogo distribution) must be in your classpath. (The latter jar is smaller, but is only capable of headless operation, not full GUI operation.) When running in a context that does not support a graphical display, the system property `java.awt.headless` must be true, to force Java to run in headless mode; `HeadlessWorkspace` automatically sets this property for you.

Since there is no GUI, NetLogo primitives which send output to the command center or output area now go to standard output instead. `export-world` can still be used to save the model's state.

`export-view` works for writing an image file with a snapshot of the (otherwise invisible) 2D view. The `report()` method is useful for getting results out of the model and into your Java code.

You can make multiple instances of `HeadlessWorkspace` and they will operate independently on separate threads without interfering with each other.

When running headless, there are some restrictions:

- Plotting primitives are non-functional. (However, calling them will not produce any ill effects.)
- The `movie-*` primitives are not available; trying to use them will cause a Java exception.
- `user-*` primitives which query the user for input, such as `user-yes-or-no` will cause a Java exception.
- Sliders, switches, and choosers do not enforce constraints on the values they accept. For example, in the full NetLogo application, if you try to set a switch to a value other than true or false, the switch will not accept the new value. Similarly, a chooser enforces that its value is a valid choice, and a slider enforces that its value is permitted by its minimum, maximum, and increment. When running headless, none of these checks occur.

We plan to lift these restrictions in a future version of NetLogo.

The [NetLogo API Specification](#) contains further details.

BehaviorSpace

The Controlling API supports running BehaviorSpace experiments headless. (It does not support running them in BehaviorSpace's GUI, although you can write your own BehaviorSpace-like Java code to run your own BehaviorSpace-like experiments if you want.)

Note that it is definitely not necessary to use the API to do headless BehaviorSpace runs. Headless BehaviorSpace is supported directly from the command line with no Java programming at all required. See the [BehaviorSpace Guide](#) for instructions.

In most cases, the command line support will be enough, without needing to use the API. In some situations, though, you may want additional flexibility afforded by the API.

The `HeadlessWorkspace` has four methods for running experiments: three variants of `runExperiment`, plus `runExperimentFromModel`.

`runExperimentFromModel` is used when the experiment setup is already stored in the model file.

The two forms of `runExperiment` that take `File` arguments are used when the experiment setup is stored in a standalone XML file, separate from the model file. If the file contains only one setup, you only need to pass in the `File` object. If the file contains multiple setups, you must also pass in a `String` object holding the experiment name.

The form of `runExperiment` that takes only a `String` argument (and an argument to specify the output format) is used to pass the XML for the experiment setup directly.

All of these methods take a `PrintWriter` as a destination for the results. If you just want to send them to standard output, you can pass `new java.io.PrintWriter(System.out)`.

The [BehaviorSpace Guide](#) explains how to specify experiment setups in XML.

The [NetLogo API Specification](#) contains further details on the `HeadlessWorkspace` class and its methods.

Other Options

When your program controls NetLogo using the `App` class, the entire NetLogo application is present, including tabs, menubar, and so forth. This arrangement is suitable for controlling or "scripting" a NetLogo model, but not ideal for embedding a NetLogo model in a larger application.

We also have a separate, similar API which allows embedding only parts of NetLogo, such as only the tabs (not the whole window), or only the contents of the Interface tab. At present, this additional API is not documented. If you are interested in using it, please contact us at feedback@ccl.northwestern.edu.

Conclusion

Don't forget to consult the [NetLogo API Specification](#) for full details on these classes and methods.

As mentioned before, the controlling facility is considered experimental. This initial API doesn't necessarily include everything you might expect. Some facilities exist, but are not yet documented. So if you don't see the capability you want, contact us; we may be able to help you do what you want. Please do not hesitate to contact us at feedback@ccl.northwestern.edu with questions, as we may be able to find a workaround or provide additional guidance where our documentation is thin.

NetLogo GoGo Extension

What is the Gogo Board?

The GoGo Board extension lets you connect NetLogo to the physical world, using sensors, motors, light bulbs, LEDs, relays and other devices. The NetLogo GoGo Extension provides primitives to communicate with a GoGo board via a serial interface.

A GoGo Board is an open source, easy-to-build, low cost, general purpose board especially designed to be used in educational projects. It was created by Arnan Sipitakiat at the MIT Media Lab. A GoGo Board has 8 sensor ports and 4 output ports, and also a connector for add-on boards (such as a display or a wireless communication module). Using the Gogo Board extension, NetLogo models can interact with the physical world in two ways. First, it can gather data from the environment, such as temperature, ambient light, or user input. This information can be used by the model to change or calibrate its behavior. Secondly, it can control output devices – NetLogo could control motors, toys, remote controlled cars, electrical appliances, light bulbs, and automated laboratory equipment.

How to get a Gogo Board?

The GoGo Board is not a commercial product, and thus cannot be bought at stores. To get a GoGo Board, you have to build one yourself or ask someone to do it for you. The board was especially designed to be easy and cheap to build, even if you don't have electronics skills. The main resource about the GoGo Board is the website www.gogoboard.org, where you will find step-by-step instructions on how to buy components, design the printed circuit board, and assemble it. The GoGo Board mailing list is gogoboard@yahoogroups.com.

Installing the GoGo Extension

The GoGo Board needs to communicate with the computer in some way, and to do so it uses the serial port. The choice of this port instead of a USB port was motivated by the board's low cost principle: the components needed to build a USB compatible board would be more expensive. If your computer does not have a serial port, you need to purchase a USB-to-Serial adapter, which can be easily found in computer stores with prices ranging from US\$ 15 to US\$ 30 (if you have a Mac or Linux machine, make sure the adapter is compatible with your platform). To communicate with the GoGo Board through the serial port, the GoGo Extension uses Sun Microsystem's [Java Communications API](#). In each platform (PC, Mac, Linux), the procedures for installing the software needed to enable serial communication are slightly different.

Mac OS X

There is no official implementation of the Java Communications API for OS X, but the [RXTX](#) project provides an open-source implementation. You can [download](#) the RXTX installer for OS X from SourceForge. Be sure to follow all the directions in the installer to create lock file directories and make sure your user is in the appropriate groups to use the lock files.

There are several commercial implementations of the Java Communications API for OS X which have not been tested with the GoGo extension, but, in theory, should work. Please contact us if you

successfully use them, or run into problems trying.

Windows

Sun provides an implementation of the Java Communications API for Windows, which you can [download](#).

Once downloaded, extract the files into a temporary directory. Several files need to be copied into your Java Runtime Environment, or JRE, installation. If you are using the version of NetLogo which comes with its own Java VM, then your JRE installation is in the `jre` subdirectory of the NetLogo folder. Otherwise, it is in a directory like `c:\j2sdk1.4`. The files `comm.jar` and `javax.comm.properties` must be copied into the `lib` folder of the JRE installation. The files `win32comm.dll` must be copied to the `bin` folder of the JRE installation. The file `PlatformSpecific` has more detailed instructions.

Linux and others

There is no official implementation of the Java Communications API for Linux. You can use the [RXTX](#) implementation. Kevin Hester has written some [installation instructions](#).

Using the GoGo Extension

The GoGo Extensions comes pre-installed. To use the extension in your model, add a line to the top of your procedures tab:

```
__extensions [ "gogo.jar" ]
```

After loading the extension, see what ports are available by typing the following into the command center:

```
show gogo-ports
```

You can open the serial port the GoGo Board is connected to with the `gogo-open` command, and see if the board is responding with the `ping` reporter.

On Windows:

```
gogo-open "COM1"
show ping
```

On Linux:

```
gogo-open "/dev/ttyS01"
show ping
```

For more information on NetLogo extensions, see the [Extensions Guide](#).

Please note that the NetLogo extensions facility is under development and is still considered experimental, so the syntax is likely to change in a future version of NetLogo. Models saved as applets (using "Save as Applet" on NetLogo's File menu) cannot make use of extensions. (We plan to fix this in a future release.)

For examples that use the GoGo extension, see the GoGo section under Code Examples in NetLogo's Models Library.

Primitives

[gogo-open](#) [gogo-open](#) [gogo-open?](#) [gogo-ports](#) [output-port-coast](#) [output-port-off](#)
[output-port-reverse](#) [output-port-\[that|this\]way](#) [ping](#) [sensor](#) [set-output-port-power](#)
[talk-to-output-ports](#)

gogo-close

gogo-close

Close the connection to the GoGo Board.

See also [gogo-open](#) and [gogo-open?](#).

gogo-open

gogo-open *port-name*

Open a connection to the GoGo Board connected to serial port named *port-name*. See [gogo-ports](#) for more information about port names.

If the GoGo Board is not responding, or you attempt to open a port without a GoGo Board connected to it, an error will be generated.

Example:

```
gogo-open "COM1"
```

See also [gogo-open](#) and [gogo-close](#).

gogo-open?

gogo-open?

Reports true if there is a connection to a GoGo board open. Reports false otherwise.

gogo-ports

gogo-ports

Reports a list of serial port names which a GoGo Board **may** be connected to. On certain computers, you might get a list of two or three different serial ports. In that case, try to open each of them until the connection is successful.

output-port-coast

output-port-coast

Turns off the power of the active ports. When attached to motors, does not apply a braking force as output-port-off does. Therefore, the motor will gradually slow down before stopping completely. This will have the same effect as output-port-off on most output devices other than motors. The output-ports effected by this command are determined by the talk-to-output-ports command.

The following code will will turn on output port a for 1 second, and then stop the motor gradually:

```
talk-to-output-ports ["a"]
output-port-on
wait 1
output-port-coast
```

output-port-off

output-port-off

Turns off power to the output ports. If using motors, a braking force is applied. The output ports effected by this command are determined by the talk-to-output-ports command.

output-port-reverse

output-port-reverse

Reverses the direction of the output ports. The output ports effected by this command are determined by the talk-to-output-ports command.

output-port-[that/this]way

output-port-thatway

output-port-thisway

Apply power to the output port in a given direction. Output ports can be powered in two directions, arbitrarily called *thisway* and *thatway*. The output-ports effected by the command are determined by the talk-to-output-ports command. Note that this is different from output-port-reverse because *thisway* and *thatway* will always be the same direction provided the connector's polarity is the same.

talk-to-output-ports

talk-to-output-ports *output-portlist*

This command will set the corresponding output ports as active. They will be the ones affected by the commands such as output-port-on and output-port-off. The user can talk to one or multiple ports at the same time. Output ports are typically connected to motors, but you could also use bulbs, LEDs and relays. Output ports are identified by one letter names: "a", "b", "c", and "d".

Examples:

```
;; talk to all output-ports
talk-to-output-ports [ "a" "b" "c" "d" ]
;; will give power to all output-ports
output-port-on

;; talk to output-ports A and D
talk-to-output-ports [ "a" "d" ]
;; will turn off output-ports A and D.
;; The other output-ports will keep
;; their current state
output-port-off

talk-to-output-ports [ "c" "b" ]
;; turn off remaining output-ports
output-port-off
```

ping

ping

Checks the status of GoGo board. This is mostly used to make sure the board is connected to the correct serial port. It reports true if the GoGo Board responds to a diagnostic message, and false otherwise.

Example:

```
show ping
```

sensor

sensor *sensor*

Reports the value of the sensor named *sensor* as a number. Sensors are named by numbers 1 to 8. Value ranges between 0–1023. 1023 is returned when there is no sensor attached to the port (highest resistance), or when the sensor is an open state. Zero is returned when the sensor is short circuited (no resistance).

Examples:

```
show sensor 1
;; will show the value of sensor 1

foreach [ 1 2 3 4 5 6 7 8 ]
  [show (word "Sensor " ? " = " sensor ?)]
;; will show the value of all sensors in the Command Center

if sensor 1 < 500 [ ask turtles [ fd 10 ]]
;; will move all turtles 10 steps forward if sensor 1's value is less than 500.

forever [if sensor 1 < 500 [ ask turtles [ fd 10 ] ] ]
;; will continuously check sensor 1's value and
;; move all turtles 10 steps forward every time
;; that the sensor value is less than 500.
```

set-output-port-power

set-output-port-power *power-level*

Sets the power level of the active output ports. *power-level* is a number between 0 (off) and 7 (full-power). The output-ports effected by those command are determined by the talk-to-output-ports command. Note that for many practical applications it is more efficient to use mechanical devices, such as gears and pulleys, to control the torque of motors.

Example:

```
talk-to-motors ["a" "b" "c" "d"]
set-motor-power 4
;; will lower the power of all output ports by half of the full power .
```


NetLogo Sound Extension

The NetLogo Sound Extension provides primitives to add sound to NetLogo models.

The extension simulates a 128-key electronic keyboard with 47 drums and 128 melodic instruments, as provided by General MIDI Level 1 specification.

It supports 15 polyphonic instrument channels and a single percussion channel. Using more than 15 different melodic instruments simultaneously in a model will cause some sounds to be lost or cut off.

The pitch of a melodic instrument is specified by a key number. The keys on the keyboard are numbered consecutively from 0 to 127, where 0 is the left-most key. Middle C is key number 60.

The loudness of an instrument is specified by a velocity, which represents the force with which the keyboard key is depressed. Velocity ranges from 0 to 127, where 64 is the standard velocity. A higher velocity results in a louder sound.

Using the Sound Extension

The sound extension comes pre-installed. To use the extension in your model, add a line to the top of your procedures tab:

```
__extensions [ "sound.jar" ]
```

For more information on NetLogo extensions, see the Extensions Guide. Please note that the NetLogo extensions facility is under development and is still considered experimental, so the syntax is likely to change in a future version of NetLogo. Models saved as applets (using "Save as Applet" on NetLogo's File menu) cannot make use of extensions. (We plan to fix this in a future release.)

For examples that use the sound extension, see the Sound section under Code Examples in the NetLogo Models Library.

Primitives

drums instruments play-drum play-note start-note stop-note stop-instrument stop-music

drums

drums

Reports a list of the names of the 47 drums for use with "play-drum".

instruments

instruments

Reports a list of the names of the 128 instruments for use with "play-note", "start-note" and "stop-note".

play-drum

play-drum *drum velocity*

Plays a drum.

```
play-drum "ACOUSTIC SNARE" 64
```

play-note

play-note *instrument keynumber velocity duration*

Plays a note for a specified duration, in seconds.

```
;; play a trumpet at middle C for two seconds
play-note "TRUMPET" 60 64 2
```

start-note

start-note *instrument keynumber velocity*

Starts a note.

The note will continue until "stop-note", "stop-instrument" or "stop-music" is called.

```
;; play a violin at middle C
start-note "VIOLIN" 60 64

;; play a C-major scale on a xylophone
foreach [60 62 64 65 67 69 71 72] [
  start-note "XYLOPHONE" ? 65
  wait 0.2
  stop-note "XYLOPHONE" ?
]
```

stop-note

stop-note *instrument keynumber*

Stops a note.

```
;; stop a violin note at middle C
stop-note "VIOLIN" 60
```

stop-instrument

stop-instrument *instrument*

Stops all notes of an instrument.

```
;; stop all cello notes
stop-instrument "CELLO"
```

stop-music

stop-music

Stops all notes.

Sound names

Drums

- | | |
|------------------------|--------------------|
| 35. Acoustic Bass Drum | 59. Ride Cymbal 2 |
| 36. Bass Drum 1 | 60. Hi Bongo |
| 37. Side Stick | 61. Low Bongo |
| 38. Acoustic Snare | 62. Mute Hi Conga |
| 39. Hand Clap | 63. Open Hi Conga |
| 40. Electric Snare | 64. Low Conga |
| 41. Low Floor Tom | 65. Hi Timbale |
| 42. Closed Hi Hat | 66. Low Timbale |
| 43. Hi Floor Tom | 67. Hi Agogo |
| 44. Pedal Hi Hat | 68. Low Agogo |
| 45. Low Tom | 69. Cabasa |
| 47. Open Hi Hat | 70. Maracas |
| 47. Low Mid Tom | 71. Short Whistle |
| 48. Hi Mid Tom | 72. Long Whistle |
| 49. Crash Cymbal 1 | 73. Short Guiro |
| 50. Hi Tom | 74. Long Guiro |
| 51. Ride Cymbal 1 | 75. Claves |
| 52. Chinese Cymbal | 76. Hi Wood Block |
| 53. Ride Bell | 77. Low Wood Block |
| 54. Tambourine | 78. Mute Cuica |
| 55. Splash Cymbal | 79. Open Cuica |
| 56. Cowbell | 80. Mute Triangle |
| 57. Crash Cymbal 2 | 81. Open Triangle |
| 58. Vibraslap | |

Instruments

Piano

1. Acoustic Grand Piano
2. Bright Acoustic Piano
3. Electric Grand Piano
4. Honky-tonk Piano
5. Electric Piano 1
6. Electric Piano 2
7. Harpsichord
8. Clavi

Chromatic Percussion

9. Celesta
10. Glockenspiel
11. Music Box
12. Vibraphone
13. Marimba
14. Xylophone
15. Tubular Bells
16. Dulcimer

Organ

Reed

65. Soprano Sax
66. Alto Sax
67. Tenor Sax
68. Baritone Sax
69. Oboe
70. English Horn
71. Bassoon
72. Clarinet

Pipe

73. Piccolo
74. Flute
75. Recorder
76. Pan Flute
77. Blown Bottle
78. Shakuhachi
79. Whistle
80. Ocarina

Synth Lead

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- 17. Drawbar Organ
- 18. Percussive Organ
- 19. Rock Organ
- 20. Church Organ
- 21. Reed Organ
- 22. Accordion
- 23. Harmonica
- 24. Tango Accordion

Guitar

- 25. Nylon String Guitar
- 26. Steel Acoustic Guitar
- 27. Jazz Electric Guitar
- 28. Clean Electric Guitar
- 29. Muted Electric Guitar
- 30. Overdriven Guitar
- 31. Distortion Guitar
- 32. Guitar harmonics

Bass

- 33. Acoustic Bass
- 34. Fingered Electric Bass
- 35. Picked Electric Bass
- 36. Fretless Bass
- 37. Slap Bass 1
- 38. Slap Bass 2
- 39. Synth Bass 1
- 40. Synth Bass 2

Strings

- 41. Violin
- 42. Viola
- 43. Cello
- 44. Contrabass
- 45. Tremolo Strings
- 47. Pizzicato Strings
- 47. Orchestral Harp
- 48. Timpani

Ensemble

- 49. String Ensemble 1
- 50. String Ensemble 2
- 51. Synth Strings 1
- 52. Synth Strings 2
- 53. Choir Aahs
- 54. Voice Oohs
- 55. Synth Voice
- 56. Orchestra Hit

Brass

- 57. Trumpet
- 58. Trombone
- 59. Tuba
- 60. Muted Trumpet
- 61. French Horn
- 62. Brass Section
- 63. Synth Brass 1
- 64. Synth Brass 2

- 81. Square Wave
- 82. Sawtooth Wave
- 83. Calliope
- 84. Chiff
- 85. Charang
- 86. Voice
- 87. Fifths
- 88. Bass and Lead

Synth Pad

- 89. New Age
- 90. Warm
- 91. Polysynth
- 92. Choir
- 93. Bowed
- 94. Metal
- 95. Halo
- 96. Sweep

Synth Effects

- 97. Rain
- 98. Soundtrack
- 99. Crystal
- 100. Atmosphere
- 101. Brightness
- 102. Goblins
- 103. Echoes
- 104. Sci-fi

Ethnic

- 105. Sitar
- 106. Banjo
- 107. Shamisen
- 108. Koto
- 109. Kalimba
- 110. Bag pipe
- 111. Fiddle
- 112. Shanai

Percussive

- 113. Tinkle Bell
- 114. Agogo
- 115. Steel Drums
- 116. Woodblock
- 117. Taiko Drum
- 118. Melodic Tom
- 119. Synth Drum
- 120. Reverse Cymbal

Sound Effects

- 121. Guitar Fret Noise
- 122. Breath Noise
- 123. Seashore
- 124. Bird Tweet
- 125. Telephone Ring
- 126. Helicopter
- 127. Applause
- 128. Gunshot

FAQ (Frequently Asked Questions)

Feedback from users is very valuable to us in designing and improving NetLogo. We'd like to hear from you. Please send comments, suggestions, and questions to feedback@ccl.northwestern.edu, and bug reports to bugs@ccl.northwestern.edu.

General

- Why is it called NetLogo?
- What programming language was NetLogo written in?
- How do I cite NetLogo in an academic publication?
- How do I cite a model from the Models Library in an academic publication?
- What license is NetLogo released under? Are there any legal restrictions on use, redistribution, etc.?
- Is the source code to NetLogo available?
- Do you offer any workshops or other training opportunities for NetLogo?
- What's the difference between StarLogo, MacStarLogo, StarLogoT, and NetLogo?
- Has anyone built a model of <x>?
- Are NetLogo models runs scientifically reproducible?
- Are there any NetLogo textbooks?
- Is NetLogo available in a Spanish version, German version, (your language here) version, etc.?
- Is NetLogo compiled or interpreted?
- Will NetLogo and NetLogo 3D remain separate?

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- The download form doesn't work for me. Can I have a direct link to the software?
- Downloading NetLogo takes too long. Is it available any other way, such as on a CD?
- I downloaded and installed NetLogo but the Models Library has few or no models in it. How can I fix this?
- Can I have multiple versions of NetLogo installed at the same time?
- I'm on a UNIX system and I can't untar the download. Why?
- How do I install NetLogo on Windows 2003?

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- I tried to run one of the applets on your site, but it didn't work. What should I do?
- Can I make my model available as an applet while keeping the code secret?
- Can a model saved as an applet use `import-world`, `file-open`, and other commands that read files?

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- Can I run NetLogo from a CD?
- How do I change the number of patches?
- Can I use the mouse to "paint" in the view?
- How big can my model be? How many turtles, patches, procedures, buttons, and so on can my model contain?

- Can I import an image into NetLogo?
- Can I import GIS data into NetLogo?
- My model runs slowly. How can I speed it up?
- I want to try HubNet. Can I?
- Can I run a NetLogo model from the command line? Can I run it without a GUI?
- Can I have more than one model open at a time?
- Can I copy or save a picture of the view?
- Can I make a movie of my model?
- Does NetLogo support multiple processors?
- Can I distribute NetLogo model runs across a cluster of computers?
- Can I use screen-edge-x or screen-edge-y, etc., as the minimum or maximum of a slider?
- Can I change the choices in a chooser on the fly?
- Can I divide the code for my model up into several files?

Programming

- How is the NetLogo language different from the StarLogoT language? How do I convert my StarLogoT model to NetLogo?
- How does the NetLogo language differ from other Logos?
- The NetLogo world is a torus, that is, the edges of the screen are connected to each other, so turtles and patches "wrap around". Can I use a different world topology: bounded, infinite plane, sphere, etc.?
- How do I take the negative of a number?
- My turtle moved forward 1, but it's still on the same patch. Why?
- patch-ahead 1 is reporting the same patch my turtle is already standing on. Why?
- How do I give my turtles "vision"?
- Can agents sense what's in the drawing layer?
- Does NetLogo have a command like StarLogo's "grab" command?
- I tried to put -at after the name of a variable, for example variable-at -1 0, but NetLogo won't let me. Why not?
- I'm getting numbers like 0.10000000004 and 0.799999999999 instead of 0.1 and 0.8. Why?
- How can I use different patch "neighborhoods" (circular, Von Neumann, Moore, etc.)?
- Can I connect turtles with lines, to indicate connections between them?
- How can I keep two turtles from occupying the same patch?
- How can I find out if a turtle is dead?
- How do I find out how much time has passed in my model?
- Does NetLogo have arrays?
- Does NetLogo have associative arrays or lookup tables?
- How can I convert an agentset to a list, or vice versa?
- What if I want to "ask" an agentset in random order?
- How does NetLogo decide when to switch from agent to agent when running code?

General

Why is it called NetLogo?

The "Logo" part is because NetLogo is a dialect of the Logo language.

"Net" is meant to evoke the decentralized, interconnected nature of the phenomena you can model with NetLogo. It also refers to HubNet, the networked participatory simulation environment included in NetLogo.

What programming language was NetLogo written in?

NetLogo is written entirely in Java (version 1.4.1).

How do I cite NetLogo in an academic publication?

NetLogo itself: Wilensky, U. 1999. NetLogo. <http://ccl.northwestern.edu/netlogo/>. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

HubNet: Wilensky, U. & Stroup, W., 1999. HubNet. <http://ccl.northwestern.edu/netlogo/hubnet.html>. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

How do I cite a model from the Models Library in an academic publication?

Wilensky, U. (year). Name of Model. URL of model. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

To determine the URL for a model, visit [our web-based version of the Models Library](#) and click on the name of the model. An example model URL is:
<http://ccl.northwestern.edu/netlogo/models/PepperedMoths>.

To determine the year, open the model from the NetLogo application and look in the copyright information at the bottom of the Procedures tab.

What license is NetLogo released under? Are there are any legal restrictions on use, redistribution, etc.?

The license is given in the "Copyright" section of the NetLogo User Manual, as well as in the application's about box and the README file accompanying the download.

A quick summary of the license is that use is unrestricted, including commercial use, but there are some restrictions on redistribution and/or modification (unless you contact Uri Wilensky to arrange different terms).

We are in the process of reevaluating the language of the license in response to user feedback. In the future, we intend to send out a revised license.

Is the source code to NetLogo available?

At present, no. We are evaluating how best to distribute NetLogo when it is in a more mature state. Making the source available is one possibility.

We do understand, however, that it is important that NetLogo not be a closed and non-extensible platform. That is not our intention for the product. So, for example, NetLogo includes APIs so that NetLogo can be controlled from external Java code and users can write new commands and reporters in Java. (See "Controlling" and "Extensions" in the User Manual.)

Do you offer any workshops or other training opportunities for NetLogo?

We offer workshops from time to time. If a workshop has been scheduled, we will announce it on the NetLogo home page and on the [netlogo-users](#) group. If interested in this type of opportunity, please contact us at feedback@ccl.northwestern.edu.

What's the difference between StarLogo, MacStarLogo, StarLogoT, and NetLogo?

The original StarLogo was developed at the MIT Media Lab in 1989–1990 and ran on a massively parallel supercomputer called the Connection Machine. A few years later (1994), a simulated parallel version was developed for the Macintosh computer. That version eventually became MacStarLogo. [StarLogoT](#) (1997), developed at the Center for Connected Learning and Computer-Based Modeling (CCL), is essentially an extended version of MacStarLogo with many additional features and capabilities.

Since then two multi-platform Java-based multi-agent Logos have been developed: NetLogo (from the CCL) and a Java-based version of StarLogo (from MIT).

The NetLogo language and environment differ in many respects from MIT StarLogo's. Both languages were inspired by the original StarLogo, but were redesigned in different ways. NetLogo's design was driven by the need to revise and expand the language so it is easier to use and more powerful, and by the need to support the HubNet architecture. NetLogo incorporates almost all of the extended functionality of our earlier StarLogoT, as well as a great many newer features.

Has anyone built a model of <x>?

The best place to ask this question is on the [NetLogo Users Group](#).

You should also check the Community Models section of our [Models Library](#) web page.

Are NetLogo models runs scientifically reproducible?

Yes. NetLogo's agent scheduling algorithms are deterministic, and NetLogo always uses Java's "strict math" library, which gives bit-for-bit identical results regardless of platform. But keep the following cautions in mind:

- If your model uses random numbers, then in order to get reproducible behavior, you must use the `random-seed` command to set the random seed in advance, so that your model will receive the exact same sequence of random numbers every time.
- If your model uses the `every` or `wait` commands in such a way that affects the outcome of the model, then you may get different results on different computers, or even on the same computer, since the model may run at a different speed. (Such models are rare. These two commands are common, but using them in a way that affects the outcome is not.)

- In order to reproduce model runs exactly, you must be using the exact same version of NetLogo. The details of the agent scheduling mechanism and the random number generator may change between NetLogo versions, and other changes (bugfixes in the engine, language changes, and so forth) may also affect the behavior of your model. (Then again, they may not.)
- We have expended every effort to make NetLogo model runs fully reproducible, but of course this can never truly be an iron-clad guarantee, due to the possibility of random hardware failure, and also due to the possibility of human error in the design of: your model, NetLogo, your Java VM, your hardware, and so on.

Are there any NetLogo textbooks?

We at the CCL have hoped to write several NetLogo textbooks for quite some time. These could be aimed at different audiences, such as: middle school, high school, undergraduate course in modeling or complexity, practical guide for interested adults.

Unfortunately, we have not yet been able to find the time to make these happen. If people from the user community would like to collaborate on such a venture, please let us know. We would welcome it.

Is NetLogo available in a Spanish version, German version, (your language here) version, etc.?

At present, NetLogo is available only in English.

We plan to eventually make it possible for users to produce their own foreign-language "packs" for NetLogo and share them with each other. In order to do this, we need to separate all of the English text from the rest of the source code, so that is separately editable. We're not sure when this will happen.

Is NetLogo compiled or interpreted?

Short answer: interpreted, but we are working on a compiler.

Long answer: NetLogo does include a compiler, but the compiler does not produce native code, or even Java byte code. It produces a custom intermediate representation that can be interpreted more efficiently than the original code. However, we are working on a new compiler that will generate Java byte code. Once that is done, NetLogo will qualify as compiled, not interpreted. Since Java virtual machines have "just-in-time" compilers that in turn compile Java byte code all the way to native code, the new compiler should substantially improve the speed of NetLogo. We are not sure when the new compiler will be done.

Will NetLogo and NetLogo 3D remain separate?

No. The split is temporary. Eventually a single unified version of NetLogo will support both 2D and 3D modeling. We will be sure to design the 3D world support in such a way that it doesn't get in the way when you are building 2D models.

Models built in NetLogo 3D Preview 1 may require some small changes in order to run in the

eventual unified version.

Downloading

The download form doesn't work for me. Can I have a direct link to the software?

Please write us at bugs@ccl.northwestern.edu and we'll either fix the problem with the form, or provide you with an alternate method of downloading the software.

Downloading NetLogo takes too long. Is it available any other way, such as on a CD?

At present, no. If this is a problem for you, contact us at feedback@ccl.northwestern.edu.

I downloaded and installed NetLogo but the Models Library has few or no models in it. How can I fix this?

So far, users reporting this problem all used the "without VM" download option for Windows. Uninstall NetLogo and try the "with VM" download instead.

Even if the "with VM" download fixes it for you, please contact us at bugs@ccl.northwestern.edu so we can find out more details about your setup. We'd like to fix this in a future version, but to troubleshoot it we need help from users.

Can I have multiple versions of NetLogo installed at the same time?

Yes. When you install NetLogo, the folder that is created contains has the version number in its name, so multiple versions can coexist.

On Windows systems, whichever version you installed last will be the version that opens when you double click a model file in Windows Explorer. On Macs, you can control what version opens via "Get Info" in the Finder.

I'm on a UNIX system and I can't untar the download. Why?

Some of the files in the tarball have very long pathnames, too long for the standard tar format. You must use the GNU version of tar instead (or another program which understands the GNU tar extensions). On some systems, the GNU version of tar is available under the name "gnutar". You can find out if you are already using the GNU version by typing `tar --version` and seeing if the output says "tar (GNU tar)".

How do I install NetLogo on Windows 2003 or Windows Server 2003?

On these operating systems, the NetLogo installer might not work unless you change some settings in the installer, as follows:

1. Locate the installer and right-click on it.

2. Select Properties
3. Select Compatibility tab
4. Check "Run this program in compatibility mode for:"
5. Select Windows XP
6. Click OK
7. Run the installer.

Applets

I tried to run one of the applets on your site, but it didn't work. What should I do?

Current versions of NetLogo require that your web browser support Java 1.4.1 or higher. Here's how to get the right Java:

- If you're on Windows 98 or newer, you need to download the Java browser plugin from http://www.java.com/en/download/windows_manual.jsp.
- If you're on Mac OS X, you need OS X 10.2.6 or higher. If you're on OS X 10.2, you also need Java 1.4.1 Update 1, which is available through Software Update. OS X 10.3 already has the right Java. You must also use a web browser that supports Java 1.4. Internet Explorer does not work; Safari does.
- If you're on Windows 95, MacOS 8, or MacOS 9, running models over the web is no longer supported; you must download the NetLogo 1.3.1 application and run the models that way instead.
- If you're on Linux or another Unix, you will need version 1.4.1 or higher of the Sun Java Runtime Environment. It is available for download at <http://www.java.com/>. Check your browser's home page for information about installing the Java plugin.

If you think you have the right browser and plugin, but it still doesn't work, check your browser's preferences to make sure that Java is enabled.

Can I make my model available as an applet while keeping the code secret?

No. In order for the applet to operate, the model file must be accessible also.

When you use "Save as applet" on the File menu, the HTML page generated contains a link where the user can download the model file. If you want, you can remove that link. Doing so will make it harder for the user to access the model file, but not impossible.

Can a model saved as an applet use `import-world`, `file-open`, and other commands that read files?

Yes, but only to read files that are stored in the same directory on your web server as the HTML and model files. Applets cannot read files on the user's computer, only the web server.

Usage

Can I run NetLogo from a CD?

Yes. NetLogo runs fine on a read-only file system.

How do I change how many patches there are?

A quick method is to use the three sets of black arrows in the upper left corner of the 2D view.

Another method is as follows. Select the 2D view by dragging a rectangle around it with the mouse. Click the "Edit" button in the Toolbar. A dialog will appear in which you may enter new values for "Screen Edge X" and "Screen Edge Y". (You can also right-click [Windows] or control-click [Mac] on the 2D view to edit it, or select it then double-click.)

Can I use the mouse to "paint" in the view?

NetLogo does not have a built-in set of painting tools for painting in the view. But with only a few lines of code, you can add painting capability to your model. To see how it's done, look at Mouse Example, in the Code Examples section of the Models Library. The same techniques can be used to let the user interact with your model using the mouse in other ways, too.

Another possibility is to use a special drawing model such as the Drawing Tool model by James Steiner which is available from <http://ccl.northwestern.edu/netlogo/models/community/>.

A third possibility is to create an image in another program and import it. See the answer to [Can I import a graphic into NetLogo?](#).

How big can my model be? How many turtles, patches, procedures, buttons, and so on can my model contain?

We have tested NetLogo with models that use hundreds of megabytes of RAM and they work fine. We haven't tested models that use gigabytes of RAM, though. Theoretically it should work, but you might hit some limits that are inherent in the underlying Java VM and/or operating system (either designed-in limits, or bugs).

The NetLogo engine has no fixed limits on size. On Macintosh and Windows operating systems, though, by default NetLogo ships with a 512 megabyte ceiling on how much total RAM it can use. (On other operating systems the ceiling is determined by your Java VM.)

Here's how to raise the limit if you need to:

- **Windows:** Edit this section of the "NetLogo.lax" file in the NetLogo folder:

```
# LAX.NL.JAVA.OPTION.JAVA.HEAP.SIZE.MAX
# -----
# allow the heap to get huge
lax.nl.java.option.java.heap.size.max=536870912
```

Note: this might not help on some Windows 98 or Windows ME systems.

- **Macintosh:** Edit the Contents/Info.plist file in the NetLogo application package. (You can reach this file by control-clicking the application in the Finder and choosing "Show Package Contents" from the popup menu.) The relevant section is this; the second number is the ceiling:

```
<key>VMOptions</key>
<string>-XX:+PrintJavaStackAtFatalState -Xms16M -Xmx512M</string>
```

Note that (at least as of Mac OS X 10.3), the maximum possible heap size for any Java program is two gigabytes.

- **Other:** Java VMs from Sun let you set the ceiling on the command line as follows. If you are using a VM from a different vendor, the method may be different.

```
java -Xmx512M -jar NetLogo.jar
```

Can I import an image into NetLogo?

Yes, using the `import-pcolors` and `import-drawing` commands. See Image Import Example (in the Code Examples section of the Models Library).

Can I import GIS data into NetLogo?

One simple way is to use `import-pcolors`, but that only works for importing maps that are images, not maps in other formats.

We do not have built-in support for reading common GIS formats. However, a number of our users are working with GIS data successfully using NetLogo code that reads GIS data using our file I/O primitives such as `file-open`.

It is also possible to use external software to convert GIS data into a format that is easier to read from NetLogo than the original format. This has been discussed on the [NetLogo Users Group](#) several times. We encourage users interested in using NetLogo for GIS applications to share their questions and experiences with the group.

My model runs slowly. How can I speed it up?

Here's some ways to make it run faster without changing the code:

- Edit the forever buttons in your model and turn off the "Force view update after each run" checkbox. This allows the view to skip frames, which may speed up models which are graphics-intensive. (See the Buttons section of the Programming Guide for a discussion of this.)
- Use the freeze switch in the view control strip, or the `no-display` command, to freeze the view temporarily. For example:

```
to go
  no-display
  ...
  ...
  display
end
```

If you use this technique, you should turn off the "Force view update" checkbox, since the `display` command already forces a view update.

- If your model is using all available RAM on your computer, then installing more RAM should help. If your hard drive makes a lot of noise while your model is running, you probably need more RAM.
- Use turtle size 1, 1.5, or 2 as these sizes are cached by NetLogo.

In many cases, though, if you want your model to run faster, you may need to make some changes to the code. Usually the most obvious opportunity for speedup is that you're doing too many computations that involve all the turtles or all the patches. Often this can be reduced by reworking the model so that it does less computation per time step. If you need help with this, if you contact us at feedback@ccl.northwestern.edu we may be able to help if you can send us your model or give us some idea of how it works. The members of the [NetLogo Users Group](#) may be able to help as well.

I want to try HubNet. Can I?

Yes. There are two types of HubNet available. With Computer HubNet, participants run the HubNet Client application on computers connected by a regular computer network. In Calculator HubNet, created in conjunction with [Texas Instruments](#), participants use TI-83+ graphing calculators and the [TI-Navigator](#) Classroom Learning System.

Note that Calculator HubNet works with a prototype version of the TI-Navigator system, and is not yet compatible with the commercially available TI-Navigator. We are actively working in partnership with Texas Instruments on integrating the new TI-Navigator with Calculator HubNet, which we expect to release in the near future.

For more information on HubNet, see the [HubNet Guide](#).

Can I run a NetLogo model from the command line? Can I run it without a GUI?

Yes.

If you set up your model run or runs as a BehaviorSpace experiment, then you can run the experiment from the command line. No additional programming is required. See the BehaviorSpace section of the User Manual for details.

If you don't use the BehaviorSpace method, then you can still run NetLogo from the command line and/or with no GUI, using our Controlling API. Some light Java programming is required. See the "Controlling" section of the User Manual for details and sample code.

Can I have more than one model open at a time?

One instance of NetLogo can only have one model open at a time. (We plan to change this in a future version.)

You can have multiple models open by opening multiple instances of NetLogo, though. On Windows and Linux, simply start the application again. On Macs, you'll need to duplicate the application in the Finder, then open the copy. (This will use only a very small amount of additional disk space, since most of NetLogo is actually in the NetLogo.jar file, which is stored outside the application "bundle.")

Can I save the contents of the view? Of the interface tab?

Yes, using "Export View" on the File menu, or by right-clicking (on Mac, control-clicking) the view, or using the `export-view` command. Both methods work for either the 2D and 3D view, whichever is currently active.

You can also use "Export Interface" or the `export-interface` command to save an image of the entire interface tab.

Can I make a movie of my model?

Yes. See the [Movie](#) section of the Programming Guide. Also see Movie Example, in the Code Examples section of the Models Library.

Does NetLogo take advantage of multiple processors?

Not for a single model run, no. The NetLogo engine is single threaded and we expect it to remain so.

You can take advantage of multiple processors to do multiple model runs concurrently, though, in either of two ways:

- By having multiple copies of NetLogo open, in separate Java virtual machines; see [this answer](#) for instructions.
- By writing Java code that uses the Controlling API to do "headless" model runs from the command line. This is currently the only possible way to do multiple concurrent model runs within a single Java virtual machine. See the "Controlling" section of the User Manual.

In a future version of NetLogo, we hope to improve the support for multiple processors as follows:

- Allow multiple models to be open simultaneously, each running in a different thread and hence on a different processor.
- Modify the BehaviorSpace tool to optionally do multiple model runs in parallel in a configurable number of separate threads, so the runs would be spread across available processors

Can I distribute NetLogo model runs across a cluster of computers?

Many of the same comments in the previous answer apply. It is not possible to split a single model run across multiple computers, but you can have each machine in a cluster doing one or more separate, independent model runs. To do this you'll need to write some Java code, using our Controlling API. See the "Controlling" section of the User Manual. We know of a number of users who are already using NetLogo on clusters; you might be able to share techniques with others on the [NetLogo Users Group](#).

We don't have any plans to make it possible to split a single model run across multiple computers.

Can I use screen-edge-x or screen-edge-y, etc., as the minimum or maximum of a slider?

At present, no. In a future version of NetLogo, we plan to support this.

Can I change the choices in a chooser on the fly?

At present, no. In a future version of NetLogo, we plan to support this.

Can I divide the code for my model up into several files?

At present, no. In a future version of NetLogo, we plan to support this.

Programming

How is the NetLogo language different from the StarLogoT language? How do I convert my StarLogoT model to NetLogo?

We don't have a document that specifically summarizes the differences between these two programs. If you have built models in StarLogoT before, then we suggest reading the [Programming Guide](#) section of this manual to learn about NetLogo, particularly the sections on "Ask" and "Agentsets". Looking at some of the sample models and code examples in the Models Library may help as well.

NetLogo 1.3.1 includes a StarLogoT model converter; you just open the model from the File menu and NetLogo will attempt to convert it. The converter doesn't do all that great a job though, so the result will very likely require additional changes before it will work. Note also that the model converter is no longer included in current versions of NetLogo, so if you have models you want to use it on, you will have to use NetLogo 1.3.1 to do the converting, then open the model in a current version.

If you need any help converting your StarLogo or StarLogoT model to NetLogo, please feel free to seek help on the [NetLogo Users Group](#). You may also ask us for help at feedback@ccl.northwestern.edu.

How does the NetLogo language differ from other Logos?

There is no standard definition of Logo; it is a loose family of languages. We believe that NetLogo shares enough syntax, vocabulary, and features with other Logos to earn the Logo name.

Still, NetLogo differs in some respects from most other Logos. The most important differences are as follows.

Surface differences:

- The precedence of mathematical operators is different. Infix math operators (like +, *, etc.) have lower precedence than reporters with names. For example, in many Logos, if you write `sin x + 1`, it will be interpreted as `sin (x + 1)`. NetLogo, on the other hand, interprets

it the way most other programming languages would, and the way the same expression would be interpreted in standard mathematical notation, namely as $(\sin x) + 1$.

- The `and` and `or` reporters are special forms, not ordinary functions, and they "short circuit", that is, they only evaluate their second input if necessary.
- Procedures can only be defined in the Procedures tab, not interactively in the Command Center.
- Reporter procedures, that is, procedures that "report" (return) a value, must be defined with `to-report` instead of `to`. The command to report a value from a reporter procedure is `report`, not `output`.
- When defining a procedure, the inputs to the procedure must be enclosed in square brackets, e.g. `to square [x]`.
- Variable names are always used without any punctuation: always `foo`, never `:foo` or `"foo`. To make this work, instead of a `make` command taking a quoted argument we supply a `set` special form which does not evaluate its first input.

The last three differences are illustrated in the following procedure definitions:

most Logos	NetLogo
<code>to square :x</code>	<code>to-report square [x]</code>
<code>output :x * :x</code>	<code>report x * x</code>
<code>end</code>	<code>end</code>

Deeper differences:

- NetLogo is lexically scoped, not dynamically scoped.
- NetLogo has no "word" data type (what Lisp calls "symbols"). Eventually, we may add one, but since it is seldom requested, it may be that the need doesn't arise much in agent-based modeling. We do have strings. In most situations where traditional Logo would use words, we simply use strings instead.
- Control structures such as `if` and `while` are special forms, not ordinary functions. You can't define your own special forms, so you can't define your own control structures.
- As in most Logos, functions as values are not supported. Most Logos provide similar if less general functionality, though, by allowing passing and manipulation of fragments of source code in list form. NetLogo's capabilities in this area are presently limited. A few of our built-in special forms use UCBLogo-style "templates" to accomplish a similar purpose, for example, `sort-by [length ?1 < length ?2] string-list`. In some circumstances, using `run` and `runresult` instead is workable, but unlike most Logos they operate on strings, not lists.

Of course, the NetLogo language also contains many additional features not found in most other Logos, most importantly agents and agentsets.

The NetLogo world is a torus, that is, the edges of the screen are connected to each other, so turtles and patches "wrap around". Can I use a different world topology: bounded, infinite plane, sphere, etc.?

Torus is the only topology directly supported by NetLogo, but you can often simulate a different topology without too much extra effort.

If you want the world to be a bounded rectangle, you may need to add some code to your model to enforce this. Often a helpful technique is to turn the edge patches a different color, so turtles can easily detect when they "hit" the edge. Also, there are "no-wrap" versions of primitives such as "distance" and "towards"; these should help.

If you want your turtles to move over an infinite plane, you can simulate this by having the turtles keep track of their position on the infinite plane, then hide the turtle when it goes "out of bounds". The Random Walk 360 model in the Models Library shows you how to code this.

Simulating a spherical or other topology might be difficult; we haven't seen a model that does this. (If you have one, please send it in!)

How do I take the negative of a number?

Any of these ways:

```
(- x)
-1 * x
0 - x
```

With the first way, the parentheses are required.

My turtle moved forward 1, but it's still on the same patch. Why?

Moving forward 1 is only guaranteed to take a turtle to a new patch if the turtle's heading is a multiple of 90 (that is, exactly north, south, east, or west).

It's because the turtle might not be standing in the center of a patch. It might be near a corner. For example, suppose your turtle is close to the southwest corner of a patch and is facing northeast. The length of the patch diagonal is 1.414... (the square root of two), so "fd 1" will leave the turtle near the northeast corner of the same patch.

If you don't want to have to think about these issues, one possibility is to write your model in such a way that your turtles always come to rest on patch centers.

A turtle is on a patch center when its `xcor` and `ycor` are multiples of 1.0.

`patch-ahead 1` is reporting the same patch my turtle is already standing on. Why?

See previous answer. It's the same issue.

This might not be the meaning of "ahead" you were expecting. With `patch-ahead`, you must specify the distance ahead that you want to look. If you want to know the next patch a turtle would cross into if it moved forward continuously, it is possible to find that out. See Next Patch Example, in the Code Examples section of the Models Library.

How do I give my turtles "vision"?

You can use `in-radius` to let a turtle see a circular area around it.

Several primitives let the turtle "look" at specific points. The `patch-ahead` primitive is useful for letting a turtle see what is directly in front of it. If you want the turtle to look in another direction besides straight ahead, try `patch-left-and-ahead` and `patch-right-and-ahead`.

If you want the turtle to have a full "cone" of vision, use the `in-cone` primitive.

You can also find out the next patch a turtle would cross into if it moved forward continuously. See Next Patch Example, in the Code Examples section of the Models Library.

Can agents sense what's in the drawing layer?

No. If you want to make marks that agents can sense, use patch colors.

Does NetLogo have a command like StarLogo's "grab" command?

We don't have such a command. You can use the `without-interruption` primitive to arrange exclusive interaction between agents. For example:

```
turtles-own [mate]
to setup
  ask turtles [ set mate nobody ]
end
to find-mate ;; turtle procedure
  without-interruption
  [ if mate = nobody
    [ let candidate random-one-of other-turtles-here
      with [mate = nobody]
      if candidate != nobody
      [ set mate candidate
        set mate-of candidate self ] ] ]
end
```

Using `without-interruption` ensures that while a turtle is choosing a mate, all other agents are "frozen". This makes it impossible for two turtles to choose the same mate.

I tried to put `-at` after the name of a variable, for example `variable-at -1 0`, but NetLogo won't let me. Why not?

This syntax was supported by StarLogoT and some beta versions of NetLogo, but was removed from NetLogo 1.0. Instead, for a patch variable write e.g. `pcolor-of patch-at -1 0`, and for a turtle variable write e.g. `color-of one-of turtles-at -1 0`.

I'm getting numbers like 0.10000000004 and 0.79999999999 instead of 0.1 and 0.8. Why?

See the "Math" section of the Programming Guide in the User Manual for a discussion of this issue.

How can I keep two turtles from occupying the same patch?

See One Turtle Per Patch Example, in the Code Examples section of the Models Library.

How can I find out if a turtle is dead?

When a turtle dies, it turns into `nobody`. `nobody` is a special value used in NetLogo used to indicate the absence of a turtle or patch. So for example:

```
if turtle 0 != nobody [ ... ]
```

You could also use `is-turtle?`:

```
if is-turtle? turtle 0 [ ... ]
```

How do I find out how much time has passed in my model?

NetLogo does not automatically keep track of this. If you want to keep track of the passage of time, add a global variable to your model with a name like "clock" or "steps". In your setup procedure, set the variable to 0. In your go procedure, increment the variable. Many of the models in the Models Library use this technique.

The reason NetLogo doesn't automatically keep track of this is that NetLogo is very flexible about letting you make buttons that do anything that you want them to. NetLogo has no one way of knowing which of your buttons should advance the clock and which shouldn't.

Does NetLogo have arrays?

What NetLogo calls "lists" are actually implemented internally as arrays, so they have some of the performance characteristics of arrays. For example, random access (using the `item` reporter) takes constant time. However, they're immutable arrays (they cannot be altered except by making a copy and altering the copy), so `replace-item` is linear time, not constant-time (because the whole array is copied).

For most purposes, the performance differences between lists and arrays doesn't matter; it only matters if you're dealing with very long lists.

In a future version of NetLogo we plan to change our lists to be ordinary singly linked lists as in other Logo (and Lisp) implementations. At the same time, we will also provide real, mutable arrays as a separate data type.

Does NetLogo have associative arrays or lookup tables?

No, but you can use lists to accomplish the same thing, though less efficiently. See:

- <http://groups.yahoo.com/group/netlogo-users/message/2344>
- <http://groups.yahoo.com/group/netlogo-users/message/2346>
- <http://groups.yahoo.com/group/netlogo-users/message/2354>

How can I use different patch "neighborhoods" (circular, Von Neumann, Moore, etc.)?

The `in-radius` primitives lets you access circular neighborhoods of any radius.

The `neighbors` primitive gives you a Moore neighborhood of radius 1, and the `neighbors4` primitive gives you a Von Neumann neighborhood of radius 1.

If you want a Moore or Von Neumann neighborhood of a different radius, or a different kind of neighborhood altogether, you can define it yourself, using the `at-points` primitive and/or other techniques. If the neighborhoods do not change over time, then the most efficient way to use them is to compute the neighborhoods only once, ahead of time, and store them in agentsets. See this URL for a discussion and example code:

<http://groups.yahoo.com/group/netlogo-users/message/377>.

Can I connect turtles with lines, to indicate connections between them?

Yes. See Network Example, in the Code Examples section of the Models Library.

We plan to support this more directly in a future version of NetLogo.

How can I convert an agentset to a list, or vice versa?

Here's how to convert an agentset to a list of agents:

```
values-from <agentset> [self]
```

And here's how to convert a list of agents to an agentset:

```
turtles/patches with [member? self <list>]
```

For a discussion of the whole issue of agentsets versus lists of agents, see:

- <http://groups.yahoo.com/group/netlogo-users/message/652>
- <http://groups.yahoo.com/group/netlogo-users/message/655>
- <http://groups.yahoo.com/group/netlogo-users/message/656>

What if I want to "ask" an agentset in random order?

This is possible, but the code for it is a bit awkward:

```
foreach shuffle values-from <agentset> [self]
  [ ask ?
    [ ... ] ]
```

First, `values-from` converts the agentset into a list of agents. Then, `shuffle` randomizes the order of that list. Finally, `foreach` is used to walk through the list, asking each agent in turn. The question mark is used with `foreach` to refer to the current item in the list.

We plan to support this more directly in a future version of NetLogo.

How does NetLogo decide when to switch from agent to agent when running code?

If you `ask turtles`, or `ask` a whole breed, the turtles are scheduled for execution in ascending order by ID number. If you `ask patches`, the patches are scheduled for execution by row: left to right within each row, and starting with the top row.

If you `ask` a different agentset besides the set of all turtles or patches or a breed, then the execution order will vary according to how the agentset was constructed. The execution order is chosen deterministically and reproducibly, though, and will remain the same if you `ask` the same agentset multiple times.

In a future version of NetLogo, we plan to add an option for randomized scheduling.

Once scheduled, an agent's "turn" ends only once it performs an action that affects the state of the world, such as moving, or creating a turtle, or changing the value of a global, turtle, or patch variable. (Setting a local variable doesn't count.)

To prolong an agent's "turn", use the `without-interruption` command. (The command blocks inside some commands, such as `cct` and `hatch`, have an implied `without-interruption` around them.)

NetLogo's scheduling mechanism is completely deterministic. Given the same code and the same initial conditions, the same thing will always happen, if you are using the same version of NetLogo.

In general, we suggest you write your NetLogo code so that it does not depend on a particular scheduling mechanism. We make no guarantees that the scheduling algorithm will remain the same in future versions.

Primitives Dictionary

Alphabetical: [A](#) [B](#) [C](#) [D](#) [E](#) [F](#) [G](#) [H](#) [I](#) [J](#) [L](#) [M](#) [N](#) [O](#) [P](#) [R](#) [S](#) [T](#) [U](#) [V](#) [W](#) [X](#) [Y](#) [?](#)

Categories: [Turtle](#) – [Patch](#) – [Agentset](#) – [Color](#) – [Control/Logic](#) – [World](#) – [Perspective](#)
[Input/Output](#) – [Files](#) – [List](#) – [String](#) – [Math](#) – [Plotting](#) – [Movie](#) – [System](#) – [HubNet](#)

Special: [Variables](#) – [Keywords](#) – [Constants](#)

Categories of Primitives

This is an approximate grouping. Remember that a turtle-related primitive might still be called by patches or observers, and vice versa. To see which agent (turtles, patches, observer) can actually run each command, consult each individual entry in the dictionary.

Turtle-related

[back](#) (bk) [BREED-at](#) [BREED-here](#) [BREED-on](#) [clear-turtles](#) (ct) [create-BREED](#)
[create-custom-BREED](#) [create-custom-turtles](#) (cct) [create-turtles](#) (crt) [die](#) [distance](#)
[distance-nowrap](#) [distancexy](#) [distancexy-nowrap](#) [downhill](#) [downhill4](#) [dx](#) [dy](#) [face](#) [face-nowrap](#) [facexy](#)
[facexy-nowrap](#) [forward](#) (fd) [hatch](#) [hatch-BREED](#) [hideturtle](#) (ht) [home](#) [inspect](#) [is-turtle?](#) [jump](#) [left](#) (lt)
[myself](#) [no-label](#) [nobody](#) [-of](#) [other-turtles-here](#) [other-BREED-here](#) [patch-ahead](#)
[patch-at-heading-and-distance](#) [patch-here](#) [patch-left-and-ahead](#) [patch-right-and-ahead](#)
[pen-down](#) (pd) [pen-erase](#) (pe) [pen-up](#) (pu) [right](#) (rt) [self](#) [set-default-shape](#) [setxy](#) [shapes](#)
[showturtle](#) (st) [sprout](#) [sprout-BREED](#) [stamp](#) [subject](#) [subtract-headings](#) [towards](#) [towards-nowrap](#)
[towardsxy](#) [towardsxy-nowrap](#) [turtle](#) [turtles](#) [turtles-at](#) [turtles-from](#) [turtles-here](#) [turtles-on](#)
[turtles-own](#) [uphill](#) [value-from](#)

Patch-related primitives

[clear-patches](#) (cp) [diffuse](#) [diffuse4](#) [distance](#) [distance-nowrap](#) [distancexy](#) [distancexy-nowrap](#)
[import-pcolors](#) [inspect](#) [is-patch?](#) [myself](#) [neighbors](#) [neighbors4](#) [no-label](#) [nobody](#) [nsum](#) [nsum4](#) [-of](#)
[patch](#) [patch-at](#) [patch-ahead](#) [patch-at-heading-and-distance](#) [patch-here](#) [patch-left-and-ahead](#)
[patch-right-and-ahead](#) [patches](#) [patches-from](#) [patches-own](#) [self](#) [sprout](#) [sprout-BREED](#) [subject](#)
[value-from](#)

Agentset primitives

[any?](#) [ask](#) [at-points](#) [BREED-at](#) [BREED-here](#) [BREED-on](#) [count](#) [histogram-from](#) [in-cone](#)
[in-cone-nowrap](#) [in-radius](#) [in-radius-nowrap](#) [is-agent?](#) [is-agentset?](#) [is-patch-agentset?](#)
[is-turtle-agentset?](#) [max-one-of](#) [min-one-of](#) [neighbors](#) [neighbors4](#) [one-of](#) [other-turtles-here](#)
[other-BREED-here](#) [patches](#) [patches-from](#) [random-n-of](#) [random-one-of](#) [turtles](#) [with](#) [with-max](#)
[with-min](#) [turtles-at](#) [turtles-from](#) [turtles-here](#) [turtles-on](#) [values-from](#)

Color primitives

color extract-hsb extract-rgb hsb import-pcolors pcolor rgb scale-color shade-of? wrap-color

Control flow and logic primitives

and carefully end error-message foreach if ifelse ifelse-value let loop map not or repeat report run
runresult : (semicolon) set stop startup to to-report wait while without-interruption xor

World primitives

clear-all (ca) clear-drawing (cd) clear-patches (cp) clear-turtles (ct) display import-drawing
import-pcolors no-display no-label screen-edge-x screen-edge-y screen-size-x screen-size-y

Perspective primitives

follow follow-me reset-perspective (rp) ride ride-me subject watch watch-me

HubNet primitives

hubnet-broadcast hubnet-broadcast-view hubnet-enter-message? hubnet-exit-message?
hubnet-fetch-message hubnet-message hubnet-message-source hubnet-message-tag
hubnet-message-waiting? hubnet-reset hubnet-send hubnet-send-view
hubnet-set-client-interface

Input/output primitives

beep clear-output date-and-time export-view export-interface export-output export-plot
export-all-plots export-world import-drawing import-pcolors import-world mouse-down?
mouse-inside? mouse-xcor mouse-ycor output-print output-show output-type output-write print
read-from-string reset-timer set-current-directory show timer type user-choice
user-choose-directory user-choose-file user-choose-new-file user-input user-message
user-yes-or-no? write

File primitives

file-at-end? file-close file-close-all file-delete file-exists? file-open file-print file-read
file-read-characters file-read-line file-show file-type file-write user-choose-directory
user-choose-file user-choose-new-file

List primitives

but-first but-last empty? filter first foreach fput is-list? item last length list lput map member?
modes n-values position random-n-of random-one-of reduce remove remove-duplicates
remove-item replace-item reverse sentence shuffle sort sort-by sublist values-from

String primitives

Operators (+, <, >, =, !=, <=, >=) but-first but-last empty? first is-string? item last length member? position remove remove-item read-from-string replace-item reverse substring word

Mathematical primitives

Arithmetic Operators (+, *, -, /, ^, <, >, =, !=, <=, >=) abs acos asin atan ceiling cos e exp floor int ln log max mean median min mod modes new-seed pi precision random random-exponential random-float random-gamma random-int-or-float random-normal random-poisson random-seed remainder round sin sqrt standard-deviation subtract-headings sum tan variance

Plotting primitives

autoplot? auto-plot-off auto-plot-on clear-all-plots clear-plot create-temporary-plot-pen export-plot export-all-plots histogram-from histogram-list plot plot-name plot-pen-down (ppd) plot-pen-reset plot-pen-up (ppu) plot-x-max plot-x-min plot-y-max plot-y-min plotxy ppd ppu set-current-plot set-current-plot-pen set-histogram-num-bars set-plot-pen-color set-plot-pen-interval set-plot-pen-mode set-plot-x-range set-plot-y-range

Movie primitives

movie-cancel movie-close movie-grab-view movie-grab-interface movie-set-frame-rate movie-start movie-status

System primitives

netlogo-version

Built-In Variables

Turtles

breed color heading hidden? label label-color pen-down? shape size who xcor ycor

Patches

pcolor plabel plabel-color pxcor pycor

Other

?

Keywords

breeds end globals patches-own to to-report turtles-own

Constants

Mathematical Constants

e = 2.718281828459045

pi = 3.141592653589793

Boolean Constants

false

true

Color Constants

black = 0.0

gray = 5.0

white = 9.9

red = 15.0

orange = 25.0

brown = 35.0

yellow = 45.0

green = 55.0

lime = 65.0

turquoise = 75.0

cyan = 85.0

sky = 95.0

blue = 105.0

violet = 115.0

magenta = 125.0

pink = 135.0

See the [Colors](#) section of the Programming Guide for more details.

A

abs

abs *number*

Reports the absolute value of *number*.

```
show abs -7
```

```
=> 7
```

```
show abs 5
```

```
=> 5
```

acos**acos *number***

Reports the arc cosine (inverse cosine) of the given number. The input must be in the range –1.0 to 1.0. The result is in degrees, and lies in the range 0.0 to 180.0.

and***condition1* and *condition2***

Reports true if both *condition1* and *condition2* are true.

Note that if *condition1* is false, then *condition2* will not be run (since it can't affect the result).

```
if (pxcor > 0) and (pycor > 0)
  [ set pcolor blue ] ;; the upper-right quadrant of
                      ;; patches turn blue
```

any?**any? *agentset***

Reports true if the given agentset is non-empty, false otherwise.

Equivalent to "count *agentset* > 0", but arguably more readable.

```
if any? turtles with [color = red]
  [ show "at least one turtle is red!" ]
```

Note: "nobody" is not an agentset. You only get nobody back in situations where you were expecting a single agent, not a whole agentset. If any? gets nobody as input, an error results.

See also nobody.

Arithmetic Operators (+, *, –, /, ^, <, >, =, !=, <=, >=)

All of these operators take two inputs, and all act as "infix operators" (going between the two inputs, as in standard mathematical use). NetLogo correctly supports order of operations for infix operators.

The operators work as follows: + is addition, * is multiplication, – is subtraction, / is division, ^ is exponentiation, < is less than, > is greater than, = is equal to, != is not equal to, <= is less than or equal, >= is greater than or equal.

Note that the subtraction operator (–) always takes two inputs unless you put parentheses around it, in which case it can take one input. For example, to take the negative of x, write (– x), with the parentheses.

All of the comparison operators also work on strings, and the addition operator (+) also functions as a string concatenation operator (see example below).

If you are not sure how NetLogo will interpret your code, you should insert parentheses.

```
show 5 * 6 + 6 / 3
=> 32
show 5 * (6 + 6) / 3
=> 20
show "tur" + "tle"
=> "turtle"
```

asin

asin *number*

Reports the arc sine (inverse sine) of the given number. The input must be in the range -1.0 to 1.0 . The result is in degrees, and lies in the range -90.0 to 90.0 .

ask

ask *agentset* [*commands*]

ask *agent* [*commands*]

Takes a list of commands that will be run by the specified agent or agentset.

```
ask turtles [ fd 1 ]
  ;; all turtles move forward one step
ask patches [ set pcolor red ]
  ;; all patches turn red
ask turtle 4 [ rt 90 ]
  ;; only the turtle with id 4 turns right
```

at-points

agentset *at-points* [[*x1 y1*] [*x2 y2*] ...]

Reports a subset of the given agentset that includes only the agents on the patches the given distances away from the calling agent. The distances are specified as a list of two-item lists, where the two items are the x and y offsets.

If the caller is the observer, then the points are measured relative to the origin, in other words, the points are taken as absolute patch coordinates.

If the caller is a turtle, the points are measured relative to the turtle's exact location, and not from the center of the patch under the turtle.

```
ask turtles at-points [[2 4] [1 2] [10 15]]
[ fd 1 ]  ;; only the turtles on the patches at the
          ;; distances (2,4), (1,2) and (10,15),
          ;; relative to the caller, move
```

atan**atan x y**

Reports the arc tangent, in degrees (from 0 to 360), of x divided by y.

When y is 0: if x is positive, it reports 90; if x is negative, it reports 270; if x is zero, you get an error.

Note that this version of atan is designed to conform to the geometry of the NetLogo world, where a heading of 0 is straight up, 90 is to the right, and so on clockwise around the circle. (Normally in geometry an angle of 0 is right, 90 is up, and so on, counterclockwise around the circle, and atan would be defined accordingly.)

```
show atan 1 -1
=> 135.0
show atan -1 1
=> 315.0
```

autoplot?**autoplot?**

Reports true if auto-plotting is on for the current plot, false otherwise.

auto-plot-off**auto-plot-on****auto-plot-off****auto-plot-on**

This pair of commands is used to control the NetLogo feature of auto-plotting in the current plot. Auto-plotting will automatically update the x and y axes of the plot whenever the current pen exceeds these boundaries. It is useful when wanting to display all plotted values in the current plot, regardless of the current plot ranges.

B**back****bk****back *number***

The turtle moves backward by *number* steps. (If *number* is negative, the turtle moves forward.)

Turtles using this primitive can move a maximum of one unit per time increment. So `bk 0.5` and `bk 1` both take one unit of time, but `bk 3` takes three.

See also [forward](#), [jump](#).

beep

beep

Emits a beep. Note that the beep is emitted immediately, so several beep commands in succession will only produce a single audible sound.

Example:

```
beep                                ;; emits one beep

repeat 3 [ beep ]                  ;; emits 3 beeps at the exact same time,
                                   ;; so you only hear one sound

repeat 3 [ beep wait 0.1 ]          ;; produces 3 beeps in succession,
                                   ;; seperated by 1/10th of a second
```

breed

breed



This is a built-in turtle variable. It holds the agentset of all turtles of the same breed as this turtle. (For turtles that do not have any particular breed, this is the turtles agentset of all turtles.) You can set this variable to change a turtle's breed.

See also breeds.

Example:

```
breeds [cats dogs]
;; turtle code:
if breed = cats [ show "meow!" ]
set breed dogs
show "woof!"
```

breeds

breeds [*breed1 breed2 ...*]

This keyword, like the globals, turtles-own, and patches-own keywords, can only be used at the beginning of a program, before any function definitions. It defines breeds and their associated agentsets.

Any turtle of the given breed:

- is part of the agentset named by the breed name
- has its breed built-in variable set to that agentset

Most often, the agentset is used in conjunction with ask to give commands to only the turtles of a particular breed.

The order in which breeds are declared is also the order in which they are drawn in the 2D view. So breeds defined later will appear on top of breeds defined earlier.

```
breeds [ mice frogs ]
to setup
  ca
  create-mice 50
  ask mice [ set color white ]
  create-frogs 50
  ask frogs [ set color green ]
  show breed-of one-of mice    ;; prints mice
  show breed-of one-of frogs   ;; prints frogs
end
```

See also [globals](#), [patches-own](#), [turtles-own](#), [<BREED>-own](#), [create-<BREED>](#), [create-custom-<BREED>](#), [<BREED>-at](#), [<BREED>-here](#).

but-first

bf

but-last

bl

but-first *list*

but-first *string*

but-last *list*

but-last *string*

When used on a list, but-first reports all of the list items of *list* except the first, and but-last reports all of the list items of *list* except the last.

On strings, but-first and but-last report a shorter string omitting the first or last character of the original string.

```
;; mylist is [2 4 6 5 8 12]
set mylist but-first mylist
;; mylist is now [4 6 5 8 12]
set mylist but-last mylist
;; mylist is now [4 6 8]
show but-first "string"
;; prints "tring"
show but-last "string"
;; prints "strin"
```

C

carefully

carefully [*commands1*] [*commands2*]

Runs *commands1*. If a runtime error occurs inside *commands1*, NetLogo won't stop and alert the user that an error occurred. It will suppress the error and run *commands2* instead.

The error-message reporter can be used in *commands2* to find out what error was suppressed in *commands1*. See [error-message](#).

Note: both sets of commands run without interruption (as with the without-interruption command).

```
carefully [ show 1 / 1 ] [ print error-message ]
=> 1
carefully [ show 1 / 0 ] [ print error-message ]
=> division by zero
```

ceiling

ceiling *number*

Reports the smallest integer greater than or equal to *number*.

```
show ceiling 4.5
=> 5
show ceiling -4.5
=> -4
```

clear-all

ca

clear-all



Resets all global variables to zero, and calls clear-turtles, clear-patches, clear-drawing, clear-all-plots, and clear-output.

clear-all-plots

clear-all-plots



Clears every plot in the model. See [clear-plot](#) for more information.

clear-drawing

cd

clear-drawing



Clears all lines and stamps drawn by turtles.

clear-output

clear-output

Clears all text from the model's output area, if it has one. Otherwise does nothing.

clear-patches**cp****clear-patches**

Clears the patches by resetting all patch variables to their default initial values, including setting their color to black.

clear-plot**clear-plot**

In the current plot only, resets all plot pens, deletes all temporary plot pens, resets the plot to its default values (for x range, y range, etc.), and resets all permanent plot pens to their default values. The default values for the plot and for the permanent plot pens are set in the plot Edit dialog, which is displayed when you edit the plot. If there are no plot pens after deleting all temporary pens, that is to say if there are no permanent plot pens, a default plot pen will be created with the following initial settings:

- Pen: down
- Color: black
- Mode: 0 (line mode)
- Name: "default"
- Interval: 1.0

See also [clear-all-plots](#).

clear-turtles**ct****clear-turtles**

Kills all turtles.

See also [die](#).

color

color

This is a built-in turtle variable. It holds the color of the turtle. You can set this variable to make the turtle change color.

See also [pcolor](#).

cos**cos *number***

Reports the cosine of the given angle. Assumes the angle is given in degrees.

```
show cos 180
=> -1.0
```

count**count *agentset***

Reports the number of agents in the given agentset.

```
show count turtles
;; prints the total number of turtles
show count patches with [pcolor = red]
;; prints the total number of red patches
```

create-turtles**crt****create-*<BREED>*****create-turtles *number*****create-*<BREED>* *number***

Creates *number* new turtles . New turtles start at position (0, 0), are created with the 14 primary colors, and have headings from 0 to 360, evenly spaced.

```
crt 100
ask turtles [ fd 10 ] ;; makes an evenly spaced circle
```

If the create-*<BREED>* form is used, the new turtles are created as members of the given breed.

create-custom-turtles**cct****create-custom-*<BREED>*****cct-*<BREED>***

create-custom-turtles *number* [*commands*]
create-custom-<BREED> *number* [*commands*]



Creates *number* new turtles (of the given breed, if specified). New turtles start at position (0, 0). New turtles are created with the 14 primary colors and have headings from 0 to 360, evenly spaced.

The new turtles immediately run *commands*. This is useful for giving the new turtles a different color, heading, or whatever.

```
breeds [canaries snakes]
to setup
  ca
  create-custom-canaries 50
    [ set color yellow ]
  create-custom-snakes 50
    [ set color green ]
end
```

Note: While the commands are running, no other agents are allowed to run any code (as with the `without-interruption` command). This ensures that the new turtles cannot interact with any other agents until they are fully initialized. In addition, no screen updates take place until the commands are done. This ensures that the new turtles are never drawn on-screen until they are fully initialized.

create-temporary-plot-pen

create-temporary-plot-pen *string*

A new temporary plot pen with the given name is created in the current plot and set to be the current pen.

Few models will want to use this primitive, because all temporary pens disappear when `clear-plot` or `clear-all-plots` are called. The normal way to make a pen is to make a permanent pen in the plot's Edit dialog.

If a temporary pen with that name already exists in the current plot, no new pen is created, and the existing pen is set to be the current pen. If a permanent pen with that name already exists in the current plot, you get a runtime error.

The new temporary plot pen has the following initial settings:

- Pen: down
- Color: black
- Mode: 0 (line mode)
- Interval: 1.0

See: [clear-plot](#), [clear-all-plots](#), and [set-current-plot-pen](#).

D

date-and-time

date-and-time

Reports a string containing the current date and time. The format is shown below. All fields are fixed width, so they are always at the same locations in the string. The potential resolution of the clock is milliseconds. (Whether you get resolution that high in practice may vary from system to system, depending on the capabilities of the underlying Java Virtual Machine.)

```
show date-and-time
=> "01:19:36.685 PM 19-Sep-2002"
```

die

die



The turtle dies.

```
if xcor > 20 [ die ]

;; all turtles with xcor greater than 20 die
```

See also: [ct](#)

diffuse

diffuse *patch-variable number*



Tells each patch to share (*number* * 100) percent of the value of *patch-variable* with its eight neighboring patches. *number* should be between 0 and 1.

Note that this is an observer command only, even though you might expect it to be a patch command. (The reason is that it acts on all the patches at once — patch commands act on individual patches.)

```
diffuse chemical 0.5
;; each patch diffuses 50% of its variable
;; chemical to its neighboring 8 patches. Thus,
;; each patch gets 1/8 of 50% of the chemical
;; from each neighboring patch.)
```

diffuse4

diffuse4 *patch-variable number*



Like `diffuse`, but only diffuses to the four neighboring patches (to the north, south, east, and west), not to the diagonal neighbors.

```
diffuse4 chemical 0.5
;; each patch diffuses 50% of its variable
;; chemical to its neighboring 4 patches. Thus,
;; each patch gets 1/4 of 50% of the chemical
;; from each neighboring patch.)
```

display

display

Causes the current view to be updated immediately.

Also undoes the effect of the `no-display` command, so that if display updates were suspended by that command, they will resume.

```
no-display
ask turtles [ jump 10 set color blue set size 5 ]
display
;; turtles move, change color, and grow, with none of
;; their intermediate states visible to the user, only
;; their final state
```

Even if `no-display` was not used, "display" can still be useful, because ordinarily NetLogo is free to skip some screen updates, so that fewer total updates take place, so that models run faster. This command lets you force a view update, so whatever changes have taken place in the world are visible to the user.

```
ask turtles [ set color red ]
display
ask turtles [ set color blue]
;; turtles turn red, then blue; use of "display" forces
;; red turtles to appear briefly
```

There is exception to the "immediately" rule: if the command is used by an agent that is running "without interruption" (such as via the `without-interruption` command, inside a procedure defined using `to-report`, or inside a command such as `hatch`, `sprout`, or `cct`), then the view update takes place once the agent is done running without interruption.

Note that `display` and `no-display` operate independently of the switch in the view control strip that freezes the view.

See also [no-display](#).

distance

distance *agent*



Reports the distance from this agent to the given turtle or patch.

The distance to or a from a patch is measured from the center of the patch.

Unlike "distance-nowrap", turtles and patches use the wrapped distance (around the edges of the screen) if that distance is shorter than the on-screen distance.

distance-nowrap

distance-nowrap *agent*



Reports the distance from this agent to the given turtle or patch.

The distance to or a from a patch is measured from the center of the patch.

Unlike "distance", this always reports the on-screen distance, never a distance that would require wrapping around the edges of the screen.

distancexy

distancexy *xcor ycor*



Reports the distance from this agent to the point (*xcor*, *ycor*).

The distance from a patch is measured from the center of the patch.

Unlike "distancexy-nowrap", the wrapped distance (around the edges of the screen) is used if that distance is shorter than the on-screen distance.

```
if (distancexy 0 0) > 10
  [ set color green ]
;; all turtles more than 10 units from
;; the center of the screen turn green.
```

distancexy-nowrap

distancexy-nowrap *xcor ycor*



Reports the distance from this agent to the point (*xcor*, *ycor*).

The distance from a patch is measured from the center of the patch.

Unlike "distancexy", this always reports the on-screen distance, never a distance that would require wrapping around the edges of the screen.

downhill

downhill *patch-variable*



Reports the turtle heading (between 0 and 359 degrees) in the direction of the minimum value of the variable *patch-variable*, of the patches in a one-patch radius of the turtle. (This could be as many as eight or as few as five patches, depending on the position of the turtle within its patch.)

If there are multiple patches that have the same smallest value, a random one of those patches will be selected.

If the patch is located directly to the north, south, east, or west of the patch that the turtle is currently on, a multiple of 90 degrees is reported. However, if the patch is located to the northeast, northwest, southeast, or southwest of the patch that the turtle is currently on, the direction the turtle would need to reach the nearest corner of that patch is reported.

See also [downhill4](#), [uphill](#), [uphill4](#).

downhill4

downhill4 *patch-variable*



Reports the turtle heading (between 0 and 359 degrees) as a multiple of 90 degrees in the direction of the minimum value of the variable *patch-variable*, of the four patches to the north, south, east, and west of the turtle. If there are multiple patches that have the same least value, a random patch from those patches will be selected.

See also [downhill](#), [uphill](#), [uphill4](#).

dx

dy

dx

dy



Reports the x-increment or y-increment (the amount by which the turtle's xcor or ycor would change) if the turtle were to take one step forward in its current heading.

Note: dx is simply the sine of the turtle's heading, and dy is simply the cosine. (If this is the reverse of what you expected, it's because in NetLogo a heading of 0 is north and 90 is east, which is the reverse of how angles are usually defined in geometry.)

Note: In earlier versions of NetLogo, these primitives were used in many situations where the new *patch-ahead* primitive is now more appropriate.

E

empty?

empty? *list*
empty? *string*

Reports true if the given list or string is empty, false otherwise.

Note: the empty list is written `[]`. The empty string is written `" "`.

end

end

Used to conclude a procedure. See [to](#) and [to-report](#).

error-message

error-message

Reports a string describing the error that was suppressed by carefully.

This reporter can only be used in the second block of a carefully command.

See also [carefully](#).

every

every *number* [*commands*]

Runs the given commands at most every *number* seconds.

By itself, every doesn't make commands run over and over again. You need to use every inside a loop, or inside a forever button, if you want the commands run over and over again. every only limits how often the commands run.

More technically, its exact behavior is as follows. When an agent reaches an "every", it checks a timer to see if the given amount of time has passed since the last time the same agent ran the commands in the "every" in the same context. If so, it runs the commands; otherwise they are skipped and execution continues.

Here, "in the same context" means during the same ask (or button press or command typed in the Command Center). So it doesn't make sense to write `ask turtles [every 0.5 [...]]`, because when the ask finishes the turtles will all discard their timers for the "every". The correct usage is shown below.

```
every 0.5 [ ask turtles [ fd 1 ] ]  
;; twice a second the turtles will move forward 1  
every 2 [ set index index + 1 ]  
;; every 2 seconds index is incremented
```


See also [wait](#).

exp

exp *number*

Reports the value of e raised to the *number* power.

Note: This is the same as $e ^ \textit{number}$.

export-view

export-interface

export-output

export-plot

export-all-plots

export-world

export-view *filename*

export-interface *filename*

export-output *filename*

export-plot *plotname filename*

export-all-plots *filename*

export-world *filename*

export-view writes the current contents of the current view to an external file given by the string *filename*. The file is saved in PNG (Portable Network Graphics) format, so it is recommended to supply a filename ending in ".png".

export-interface is similar, but for the whole interface tab.

export-output writes the contents of the model's output area to an external file given by the string *filename*. (If the model does not have a separate output area, the output portion of the Command Center is used.)

export-plot writes the x and y values of all points plotted by all the plot pens in the plot given by the string *plotname* to an external file given by the string *filename*. If a pen is in bar mode (mode 0) and the y value of the point plotted is greater than 0, the upper-left corner point of the bar will be exported. If the y value is less than 0, then the lower-left corner point of the bar will be exported.

export-all-plots writes every plot in the current model to an external file given by the string *filename*. Each plot is identical in format to the output of **export-plot**.

export-world writes the values of all variables, both built-in and user-defined, including all observer, turtle, and patch variables, the drawing, and the contents of the output area if one exists, to an external file given by the string *filename*. (The result file can be read back into NetLogo with the [import-world](#) primitive.)

export-plot, **export-all-plots** and **export-world** save files in in plain-text, "comma-separated

values" (.csv) format. CSV files can be read by most popular spreadsheet and database programs as well as any text editor.

If the file already exists, it is overwritten.

If you wish to export to a file in a location other than the model's location, you should include the full path to the file you wish to export. (Use the forward-slash "/" as the folder separator.)

Note that the functionality of these primitives is also available directly from NetLogo's File menu.

```
export-world "fire.csv"
;; exports the state of the model to the file fire.csv
;; located in the NetLogo folder
export-plot "Temperature" "c:/My Documents/plot.csv"
;; exports the plot named
;; "Temperature" to the file plot.csv located in
;; the C:\My Documents folder
export-all-plots "c:/My Documents/plots.csv"
;; exports all plots to the file plots.csv
;; located in the C:\My Documents folder
```

extract-hsb

extract-hsb *color*

Reports a list of three values in the range 0.0 to 1.0 representing the hue, saturation and brightness, respectively, of the given NetLogo *color* in the range 0 to 140.

See also [hsb](#), [rgb](#), [extract-rgb](#).

extract-rgb

extract-rgb *color*

Reports a list of three values in the range 0.0 to 1.0 representing the levels of red, green, and blue, respectively, of the given NetLogo *color* in the range 0 to 140.

See also [rgb](#), [hsb](#), [extract-hsb](#).

F

face

face-nowrap

face *agent*

face-nowrap *agent*



Set the caller's heading towards *agent*.

If the wrapped distance (around the edges of the screen) is shorter than the on-screen distance, face will use the heading of the wrapped path. face-nowrap never uses the wrapped path.

If the caller and the agent are at the exact same position, the caller's heading won't change.

facexy

facexy-nowrap

facexy *number number*

facexy-nowrap *number number*



Set the caller's heading towards the point (x,y).

If the wrapped distance (around the edges of the screen) is shorter than the on-screen distance, facexy will use the heading of the wrapped path. facexy-nowrap never uses the wrapped path.

If the caller is on the point (x,y), the caller's heading won't change.

file-at-end?

file-at-end?

Reports true when there are no more characters left to read in from the current file (that was opened previously with [file-open](#)). Otherwise, reports false.

```
file-open "myfile.txt"
print file-at-end?
=> false ;; Can still read in more characters
print file-read-line
=> This is the last line in file
print file-at-end
=> true ;; We reached the end of the file
```

See also [file-open](#), [file-close-all](#).

file-close

file-close

Closes a file that has been opened previously with [file-open](#).

Note that this and file-close-all are the only ways to restart to the beginning of an opened file or to switch between file modes.

If no file is open, does nothing.

See also [file-close-all](#), [file-open](#).

file-close-all

file-close-all

Closes all files (if any) that have been opened previously with file-open.

See also file-close, file-open.

file-delete

file-delete *string*

Deletes the file specified as *string*

string must be an existing file with writable permission by the user. Also, the file cannot be open. Use the command file-close to close an opened file before deletion.

Note that the string can either be a file name or an absolute file path. If it is a file name, it looks in whatever the current directory is. This can be changed using the command set-current-directory. It is defaulted to the model's directory.

file-exists?

file-exists? *string*

Reports true if *string* is the name of an existing file on the system. Otherwise it reports false.

Note that the string can either be a file name or an absolute file path. If it is a file name, it looks in whatever the current directory is. This can be changed using the command set-current-directory. It defaults to the model's directory.

file-open

file-open *string*

This command will interpret *string* as a path name to a file and open the file. You may then use the reporters file-read, file-read-line, and file-read-characters to read in from the file, or file-write, file-print, file-type, or file-show to write out to the file.

Note that you can only open a file for reading or writing but not both. The next file i/o primitive you use after this command dictates which mode the file is opened in. To switch modes, you need to close the file using file-close.

Also, the file must exist when opening a file in reading mode. When opening a file in writing mode, all new data will be appended to the end of the original file. If there is no original file, a new blank file will be created in its place (The user needs to have writable permission in the file's directory).

Note that the string can either be a file name or an absolute file path. If it is a file name, it looks in whatever the current directory is. This can be changed using the command set-current-directory. It

is defaulted to the model's directory.

```
file-open "myfile-in.txt"
print file-read-line
=> First line in file ;; File is in reading mode
file-open "C:\\NetLogo\\myfile-out.txt"
;; assuming Windows machine
file-print "Hello World" ;; File is in writing mode
```

See also [file-close](#).

file-print

file-print *value*

Prints *value* to an opened file, followed by a carriage return.

The calling agent is *not* printed before the value, unlike [file-show](#).

Note that this command is the file i/o equivalent of [print](#), and [file-open](#) needs to be called before this command can be used.

See also [file-show](#), [file-type](#), and [file-write](#).

file-read

file-read

This reporter will read in the next constant from the opened file and interpret it as if it had been typed in the Command Center. It reports the resulting value. The result may be a number, list, string, boolean, or the special value nobody.

Whitespace separates the constants. Each call to file-read will skip past both leading and trailing whitespace.

Note that strings need to have quotes around them. Use the command [file-write](#) to have quotes included.

Also note that the [file-open](#) command must be called before this reporter can be used, and there must be data remaining in the file. Use the reporter [file-at-end?](#) to determine if you are at the end of the file.

```
file-open "myfile.data"
print file-read + 5
;; Next value is the number 1
=> 6
print length file-read
;; Next value is the list [1 2 3 4]
=> 4
```

See also [file-open](#) and [file-write](#).

file-read-characters

file-read-characters *number*

Reports the given *number* of characters from an opened file as a string. If there are fewer than that many characters left, it will report all of the remaining characters.

Note that it will return every character including newlines and spaces.

Also note that the file-open command must be called before this reporter can be used, and there must be data remaining in the file. Use the reporter file-at-end? to determine if you are at the end of the file.

```
file-open "myfile.txt"
print file-read-characters 8
;; Current line in file is "Hello World"
=> Hello Wo
```

See also file-open.

file-read-line

file-read-line

Reads the next line in the file and reports it as a string. It determines the end of the file by a carriage return, an end of file character or both in a row. It does not return the line terminator characters.

Also note that the file-open command must be called before this reporter can be used, and there must be data remaining in the file. Use the reporter file-at-end? to determine if you are at the end of the file.

```
file-open "myfile.txt"
print file-read-line
=> Hello World
```

See also file-open.

file-show

file-show *value*

Prints *value* to an opened file, preceded by the calling agent, and followed by a carriage return. (The calling agent is included to help you keep track of what agents are producing which lines of output.) Also, all strings have their quotes included similar to file-write.

Note that this command is the file i/o equivalent of show, and file-open needs to be called before this command can be used.

See also file-print, file-type, and file-write.

file-type

file-type *value*

Prints *value* to an opened file, *not* followed by a carriage return (unlike file-print and file-show). The lack of a carriage return allows you to print several values on the same line.

The calling agent is *not* printed before the value. unlike file-show.

Note that this command is the file i/o equivalent of type, and file-open needs to be called before this command can be used.

See also file-print, file-show, and file-write.

file-write

file-write *value*

This command will output *value*, which can be a number, string, list, boolean, or nobody to an opened file *not* followed by a carriage return (unlike file-print and file-show).

The calling agent is *not* printed before the value, unlike file-show. Its output will also includes quotes around strings and is prepended with a space. It will output the value in such a manner that file-read will be able to interpret it.

Note that this command is the file i/o equivalent of write, and file-open needs to be called before this command can be used.

```
file-open "locations.txt"
ask turtles
  [ file-write xcor file-write ycor ]
```

See also file-print, file-show, and file-type.

filter

filter [*reporter*] *list*

Reports a list containing only those items of *list* for which the boolean *reporter* is true -- in other words, the items satisfying the given condition.

In *reporter*, use ? to refer to the current item of *list*.

```
show filter [? < 3] [1 3 2]
=> [1 2]
show filter [first ? != "t"] ["hi" "there" "everyone"]
=> ["hi" "everyone"]
```

See also map, reduce, ?.

first

first *list*
first *string*

On a list, reports the first (0th) item in the list.

On a string, reports a one-character string containing only the first character of the original string.

floor

floor *number*

Reports the largest integer less than or equal to *number*.

```
show floor 4.5
=> 4
show floor -4.5
=> -5
```

follow

follow *turtle*



Similar to ride, but, in the 3D view, the view is behind and above *turtle*.

See also [follow-me](#), [ride](#), [reset-perspective](#), [watch](#), [subject](#).

follow-me

follow-me



Asks the observer to follow the calling turtle.

See also [follow](#).

foreach

foreach *list* [*commands*]
(foreach *list1* ... *listn* [*commands*])

With a single list, runs *commands* for each item of *list*. In *commands*, use *_?* to refer to the current item of *list*.

```
foreach [1.1 2.2 2.6] [ show ? + " -> " + round ? ]
=> 1.1 -> 1
=> 2.2 -> 2
=> 2.6 -> 3
```


With multiple lists, runs *commands* for each group of items from each list. So, they are run once for the first items, once for the second items, and so on. All the lists must be the same length. In *commands*, use ?1 through ?n to refer to the current item of each list.

Some examples make this clearer:

```
(foreach [1 2 3] [2 4 6]
  [ show "the sum is: " + (?1 + ?2) ])
=> "the sum is: 3"
=> "the sum is: 6"
=> "the sum is: 9"
(foreach list (turtle 1) (turtle 2) [3 4]
  [ ask ?1 [ fd ?2 ] ])
;; turtle 1 moves forward 3 patches
;; turtle 2 moves forward 4 patches
```

See also [map, ?](#).

forward

fd

forward *number*



The turtle moves forward by *number* steps. (If *number* is negative, the turtle moves backward.)

Turtles using this primitive can move a maximum of one unit per time increment. So `fd 0.5` and `fd 1` both take one unit of time, but `fd 3` takes three.

See also [jump](#).

fput

fput *item list*

Adds *item* to the beginning of a list and reports the new list.

```
;; suppose mylist is [5 7 10]
set mylist fput 2 mylist
;; mylist is now [2 5 7 10]
```

G

globals

globals [*var1 var2 ...*]

This keyword, like the breeds, <*BREED*>-own, patches-own, and turtles-own keywords, can only be used at the beginning of a program, before any function definitions. It defines new global variables. Global variables are "global" because they are accessible by all agents and can be used anywhere in a model.

Most often, `globals` is used to define variables or constants that need to be used in many parts of the program.

H

hatch

hatch-*<BREED>*

hatch *number* [*commands*]

hatch-*<BREED>* *number* [*commands*]



This turtle creates *number* new turtles, each identical to its parent, and asks the new turtles to run *commands*. You can use the commands to give the new turtles different colors, headings, or whatever.

If the hatch-*<BREED>* form is used, the new turtles are created as members of the given breed. Otherwise, the new turtles are the same breed as their parent.

Note: While the commands are running, no other agents are allowed to run any code (as with the `without-interruption` command). This ensures that the new turtles cannot interact with any other agents until they are fully initialized. In addition, no screen updates take place until the commands are done. This ensures that the new turtles are never drawn on-screen in an only partly initialized state.

```
hatch 1 [ lt 45 fd 1 ]
;; this turtle creates one new turtle,
;; and the child turns and moves away
hatch-sheep 1 [ set color black ]
;; this turtle creates a new turtle
;; of the sheep breed
```

heading

heading



This is a built-in turtle variable. It indicates the direction the turtle is facing. This is a number greater than or equal to 0 and less than 360. 0 is north, 90 is east, and so on. You can set this variable to make a turtle turn.

See also [right](#), [left](#), [dx](#), [dy](#).

Example:

```
set heading 45      ;; turtle is now facing northeast
set heading heading + 10 ;; same effect as "rt 10"
```

hidden?

hidden?



This is a built-in turtle variable. It holds a boolean (true or false) value indicating whether the turtle is currently hidden (i.e., invisible). You can set this variable to make a turtle disappear or reappear.

See also [hideturtle](#), [showturtle](#).

Example:

```
set hidden? not hidden?
;; if turtle was showing, it hides, and if it was hiding,
;; it reappears
```

hideturtle

ht

hideturtle



The turtle makes itself invisible.

Note: This command is equivalent to setting the turtle variable "hidden?" to true.

See also [showturtle](#).

histogram-from

histogram-from *agentset* [*reporter*]

Draws a histogram showing the frequency distribution of the values reported when all agents in the *agentset* run the given *reporter*. The heights of the bars in the histogram represent the numbers of agents with values in those ranges.

Before the histogram is drawn, first any previous points drawn by the current plot pen are removed.

The *reporter* should report a numeric value. Any non-numeric values reported are ignored.

The histogram is drawn on the current plot using the current plot pen and pen color. Use `set-plot-x-range` to control the range of values to be histogrammed, and set the pen interval (either directly with `set-plot-pen-interval`, or indirectly via `set-histogram-num-bars`) to control how many bars that range is split up into.

Be sure that if you want the histogram drawn with bars that the current pen is in bar mode (mode 1).

As of NetLogo 2.0.2, for histogramming purposes the plot's X range is not considered to include the maximum X value. Values equal to the maximum X will fall outside of the histogram's range.

```

histogram-from turtles [color]
;; draws a histogram showing how many turtles there are
;; of each color

```

Note: using this primitive amounts to the same thing as writing: `histogram-list values-from agentset [reporter],` but is more efficient.

histogram-list

histogram-list *list*

Histograms the values in the given list, after first removing any previous points drawn by the current plot pen.

See [histogram-from](#), above, for more information.

home

home



The calling turtles moves to the origin (0,0). Equivalent to `setxy 0 0`.

hsb

hsb *hue saturation brightness*

Reports a number in the range 0 to 140, not including 140 itself, that represents the given color, specified in the HSB spectrum, in NetLogo's color space.

All three values should be in the range 0.0 to 1.0.

The color reported may be only an approximation, since the NetLogo color space does not include all possible colors. (It contains only certain discrete hues, and for each hue, either saturation or brightness may vary, but not both — at least one of the two is always 1.0.)

```

show hsb 0 0 0
=> 0.0 ;; (black)
show hsb 0.5 1.0 1.0
=> 85.0 ;; (cyan)

```

See also [extract-hsb](#), [rgb](#), [extract-rgb](#).

hubnet-broadcast

hubnet-broadcast *tag-name value*

This broadcasts *value* from NetLogo to the variable, in the case of Calculator HubNet, or interface element, in the case of Computer HubNet, with the name *tag-name* to the clients.

See the [HubNet Authoring Guide](#) for details and instructions.

hubnet-broadcast-view

hubnet-broadcast-view

This broadcasts the current state of the 2D view in the NetLogo model to all the Computer HubNet Clients. It does nothing for Calculator HubNet.

Note: This is an experimental primitive and its behavior may change in a future version.

See the [HubNet Authoring Guide](#) for details and instructions.

hubnet-enter-message?

hubnet-enter-message?

Reports true if a new computer client just entered the simulation. Reports false otherwise. [hubnet-message-source](#) will contain the user name of the client that just logged on.

See the [HubNet Authoring Guide](#) for details and instructions.

hubnet-exit-message?

hubnet-exit-message?

Reports true if a computer client just exited the simulation. Reports false otherwise. [hubnet-message-source](#) will contain the user name of the client that just logged off.

See the [HubNet Authoring Guide](#) for details and instructions.

hubnet-fetch-message

hubnet-fetch-message

If there is any new data sent by the clients, this retrieves the next piece of data, so that it can be accessed by [hubnet-message](#), [hubnet-message-source](#), and [hubnet-message-tag](#). This will cause an error if there is no new data from the clients.

See the [HubNet Authoring Guide](#) for details.

hubnet-message

hubnet-message

Reports the message retrieved by [hubnet-fetch-message](#).

See the [HubNet Authoring Guide](#) for details.

hubnet-message-source

hubnet-message-source

Reports the name of the client that sent the message retrieved by [hubnet-fetch-message](#).

See the [HubNet Authoring Guide](#) for details.

hubnet-message-tag

hubnet-message-tag

Reports the tag that is associated with the data that was retrieved by [hubnet-fetch-message](#). For Calculator HubNet, this will report one of the variable names set with the [hubnet-set-client-interface](#) primitive. For Computer HubNet, this will report one of the Display Names of the interface elements in the client interface.

See the [HubNet Authoring Guide](#) for details.

hubnet-message-waiting?

hubnet-message-waiting?

This looks for a new message sent by the clients. It reports true if there is one, and false if there is not.

See the [HubNet Authoring Guide](#) for details.

hubnet-reset

hubnet-reset

Starts up the HubNet system. HubNet must be started to use any of the other hubnet primitives with the exception of [hubnet-set-client-interface](#).

See the [HubNet Authoring Guide](#) for details.

hubnet-send

hubnet-send *string tag-name value*

hubnet-send *list-of-strings tag-name value*

For Calculator HubNet, this primitive acts in exactly the same manner as [hubnet-broadcast](#). (We plan to change this in a future version of NetLogo.)

For Computer HubNet, it acts as follows:

For a *string*, this sends *value* from NetLogo to the tag *tag-name* on the client that has *string* for its user name.

For a *list-of-strings*, this sends *value* from NetLogo to the tag *tag-name* on all the clients that have a user name that is in the *list-of-strings*.

Sending a message to a non-existent client, using `hubnet-send`, generates a `hubnet-exit-message`.

See the [HubNet Authoring Guide](#) for details.

hubnet-send-view

hubnet-send-view *string*

hubnet-send-view *list-of-strings*

For Calculator HubNet, does nothing.

For Computer HubNet, it acts as follows:

For a *string*, this sends the current state of the 2D view in the NetLogo model to the Computer HubNet Client with *string* for its user name.

For a *list-of-strings*, this sends the current state of the view in the NetLogo model to all the Computer HubNet Clients that have a user name that is in the *list-of-strings*.

Sending the 2D view to a non-existent client, using `hubnet-send-view`, generates a `hubnet-exit-message`.

Note: This is an experimental primitive and its behavior may change in a future version.

See the [HubNet Authoring Guide](#) for details.

hubnet-set-client-interface

hubnet-set-client-interface *client-type client-info*

If *client-type* is "COMPUTER", *client-info* is a list containing a string with the file name and path (relative to the model) to the file which will serve as the client's interface. This interface will be sent to any clients that log in.

```
hubnet-set-client-interface
  "COMPUTER"
  ["clients/Disease client.nlogo"]
;; when clients log in, they will will get the
;; interface described in the file
;; clients/Disease client.nlogo, relative to
;; the location of the model
```

Future versions of HubNet will support other client types. Even for Computer HubNet, the meaning of the second input to this command may change.

See the [HubNet Authoring Guide](#) for details.

I

if

if *condition* [*commands*]

Reporter must report a boolean (true or false) value.

If *condition* reports true, runs *commands*.

The reporter may report a different value for different agents, so some agents may run *commands* and others don't.

```
if xcor > 0[ set color blue ]
;; turtles on the right half of the screen
;; turn blue
```

ifelse

ifelse *reporter* [*commands1*] [*commands2*]

Reporter must report a boolean (true or false) value.

If *reporter* reports true, runs *commands1*.

If *reporter* reports false, runs *commands2*.

The reporter may report a different value for different agents, so some agents may run *commands1* while others run *commands2*.

```
ask patches
[ ifelse pcolor > 0
  [ set pcolor blue ]
  [ set pcolor red ] ]
;; the left half of the screen turns red and
;; the right half turns blue
```

ifelse-value

ifelse-value *reporter* [*reporter1*] [*reporter2*]

Reporter must report a boolean (true or false) value.

If *reporter* reports true, the result is the value of *reporter1*.

If *reporter* reports false, the result is the value of *reporter2*.

This can be used when a conditional is needed in the context of a reporter, where commands (such as ifelse) are not allowed.

```
ask patches
[ set pcolor
  ifelse-value (pxcor > 0)
    [ blue ]
    [ red ] ]
;; the left half of the screen turns red and
;; the right half turns blue
show n-values 10 [ifelse-value (? < 5) [0] [1]]
=> [0 0 0 0 0 1 1 1 1 1]
show reduce [ifelse-value (?1 > ?2) [?1] [?2]]
  [1 3 2 5 3 8 3 2 1]
=> 8
```

import-drawing

import-drawing *filename*



Reads an image file into the drawing, scaling it to the size of the world, while retaining the original aspect ratio of the image. The image is centered in the drawing. The old drawing is not cleared first.

Agents cannot sense the drawing, so they cannot interact with or process images imported by import-drawing. If you need agents to sense an image, use import-pcolors.

The following image file formats are supported: BMP, JPG, GIF, and PNG. If the image format supports transparency (alpha), that information will be imported as well.

import-pcolors

import-pcolors *filename*



Reads an image file, scales it to the same dimensions as the patch grid while maintaining the original aspect ratio of the image, and transfers the resulting pixel colors to the patches. The image is centered in the patch grid. The resulting patch colors may be distorted, since the NetLogo color space does not include all possible colors. (See the Color section of the Programming Guide.) import-pcolors may be slow for some images, particularly when you have many patches and a large image with many different colors.

Since import-pcolors sets the pcolor of patches, agents can sense the image. This is useful if agents need to analyze, process, or otherwise interact with the image. If you want to simply display a static backdrop, without color distortion, see import-drawing.

The following image file formats are supported: BMP, JPG, GIF, and PNG. If the image format supports transparency (alpha), then all fully transparent pixels will be ignored. (Partially transparent pixels will be treated as opaque.)

import-world

import-world *filename*



Reads the values of all variables for a model, both built-in and user-defined, including all observer, turtle, and patch variables, from an external file named by the given string. The file should be in the format used by the [export-world](#) primitive.

Note that the functionality of this primitive is also directly available from NetLogo's File menu.

When using import-world, to avoid errors, perform these steps in the following order:

1. Open the model from which you created the export file.
2. Press the Setup button, to get the model in a state from which it can be run.
3. Import the file.
4. If you want, press Go button to continue running the model from the point where it left off.

If you wish to import a file from a location other than the model's location, you may include the full path to the file you wish to import. See [export-world](#) for an example.

in-cone

in-cone-nowrap

agentset in-cone distance angle

agentset in-cone-nowrap distance angle



This reporter lets you give a turtle a "cone of vision" in front of itself. The cone is defined by the two inputs, the vision distance (radius) and the view angle. The view angle may range from 0 to 360 and is centered around the turtle's current heading. (If the angle is 360, then in-cone is equivalent to in-radius.)

in-cone reports an agentset that includes only those agents from the original agentset that fall in the cone.

The distance to a patch is measured from the center of the patch.

in-cone allows its distance measurements to wrap around the edge of the world; in-cone-nowrap does not.

```
ask turtles
  [ ask patches in-cone 3 60
    [ set pcolor red ] ]
;; each turtle makes a red "splotch" of patches in a 60 degree
;; cone of radius 3 ahead of itself
```

in-radius

in-radius-nowrap

agentset in-radius number

agentset in-radius-nowrap number



Reports an agentset that includes only those agents from the original agentset whose distance from the caller is less than or equal to *number*.

The distance to or a from a patch is measured from the center of the patch.

in-radius allows its distance measurements to wrap around the edge of the screen;
in-radius-nowrap does not.

```
ask turtles
  [ ask patches in-radius 3
    [ set pcolor red ] ]
;; each turtle makes a red "splotch" around itself
```

inspect

inspect agent

Opens an agent monitor for the given agent (turtle or patch).

```
inspect patch 2 4
;; an agent monitor opens for that patch
inspect random-one-of sheep
;; an agent monitor opens for a random turtle from
;; the "sheep" breed
```

int

int number

Reports the integer part of number — any fractional part is discarded.

```
show int 4.7
=> 4
show int -3.5
=> -3
```

is-agent?

is-agentset?

is-boolean?

is-list?

is-number?

is-patch?

is-patch-agentset?

is-string?**is-turtle?****is-turtle-agentset?****is-agent? *value*****is-agentset? *value*****is-boolean? *value*****is-list? *value*****is-number? *value*****is-patch? *value*****is-patch-agentset? *value*****is-string? *value*****is-turtle? *value*****is-turtle-agentset? *value***

Reports true if *value* is of the given type, false otherwise.

item

item *index list***item *index string***

On lists, reports the value of the item in the given list with the given index.

On strings, reports the character in the given string at the given index.

Note that the indices begin from 0, not 1. (The first item is item 0, the second item is item 1, and so on.)

```
;; suppose mylist is [2 4 6 8 10]
show item 2 mylist
=> 6
show item 3 "my-shoe"
=> "s"
```

J

jump

jump *number*

Turtles move forward by *number* units all at once, without the amount of time passing depending on the distance.

This command is useful for synchronizing turtle movements. The command forward 15 takes 15 times longer to run than forward 1, but jump 15 runs in the same amount of time as forward 1.

Note: When turtles jump, they do not step on any of the patches along their path.

L

label

label



This is a built-in turtle variable. It may hold a value of any type. The turtle appears in the view with the given value "attached" to it as text. You can set this variable to add, change, or remove a turtle's label.

See also [no-label](#), [label-color](#), [plabel](#), [plabel-color](#).

Example:

```
ask turtles [ set label who ]
;; all the turtles now are labeled with their
;; id numbers
ask turtles [ set label no-label ]
;; all turtles now are not labeled
```

label-color

label-color



This is a built-in turtle variable. It holds a number greater than or equal to 0 and less than 140. This number determines what color the turtle's label appears in (if it has a label). You can set this variable to change the color of a turtle's label.

See also [no-label](#), [label](#), [plabel](#), [plabel-color](#).

Example:

```
ask turtles [ set label-color red ]
;; all the turtles now have red labels
```

last

last *list*

last *string*

On a list, reports the last item in the list.

On a string, reports a one-character string containing only the last character of the original string.

left

It

left *number*



The turtle turns left by *number* degrees. (If *number* is negative, it turns right.)

length

length *list*

length *string*

Reports the number of items in the given list, or the number of characters in the given string.

let

let *variable value*

Creates a new local variable and gives it the given value. A local variable is one that exists only within the enclosing block of commands.

If you want to change the value afterwards, use set.

Example:

```
let prey random-one-of sheep-here
if prey != nobody
  [ ask prey [ die ] ]
```

list

list *value1 value2*

(list *value1 ... valuen***)**

Reports a list containing the given items. The items can be of any type, produced by any kind of reporter.

```
show list (random 10) (random 10)
=> [4 9] ;; or similar list
show (list 5)
=> [5]
show (list (random 10) 1 2 3 (random 10))
=> [4 1 2 3 9] ;; or similar list
```

In

In *number*

Reports the natural logarithm of *number*, that is, the logarithm to the base e (2.71828...).

See also e, log.

locals**locals [*Vax1 var2 ...*]**

NOTE: This keyword should not be used in new models. Please use the let command instead. "locals" is included only for backwards compatibility with NetLogo version 2.0 and earlier. It will not necessarily continue to be supported in future versions of NetLogo.

Locals is a keyword used to declare "local" variables in a procedure, that is, variables that are usable only within that procedure. It must appear at the beginning of the procedure, before any commands.

See also let.

log**log *number base***

Reports the logarithm of *number* in base *base*.

```
show log 64 2
=> 6
```

See also ln.

loop**loop [*commands*]**

Runs the list of commands forever, or until the current procedure exits through use of the stop command or the report command.

Note: In most circumstances, you should use a forever button in order to repeat something forever. The advantage of using a forever button is that the user can click the button to stop the loop.

lput**lput *value list***

Adds *value* to the end of a list and reports the new list.

```
;; suppose mylist is [2 7 10 "Bob"]
set mylist lput 42 mylist
;; mylist now is [2 7 10 "Bob" 42]
```

M

map

map [*reporter*] *list*
(map [*reporter*] *list1* ... *list2*)

With a single *list*, the given reporter is run for each item in the list, and a list of the results is collected and reported.

In *reporter*, use ? to refer to the current item of *list*.

```
show map [round ?] [1.1 2.2 2.7]
=> [1 2 3]
show map [? * ?] [1 2 3]
=> [1 4 9]
```

With multiple lists, the given reporter is run for each group of items from each list. So, it is run once for the first items, once for the second items, and so on. All the lists must be the same length.

In *reporter*, use ?1 through ?n to refer to the current item of each list.

Some examples make this clearer:

```
show (map [?1 + ?2] [1 2 3] [2 4 6])
=> [3 6 9]
show (map [?1 + ?2 = ?3] [1 2 3] [2 4 6] [3 5 9])
=> [true false true]
```

See also [foreach](#), [?](#).

max

max *list*

Reports the maximum number value in the list. It ignores other types of items.

```
show max values-from turtles [xcor]
;; prints the x coordinate of the turtle which is
;; farthest right on the screen
```

max-one-of

max-one-of *agentset* [*reporter*]

Reports the agent in the agentset that has the highest value for the given reporter. If there is a tie this command returns one random agent with the highest value. If you want all such agents, use `with-max` instead.

```
show max-one-of patches [count turtles-here]

;; prints the first patch with the most turtles on it
```


See also [with-max](#)

mean

mean *list*

Reports the statistical mean of the numeric items in the given list. Ignores non-numeric items. The mean is the average, i.e., the sum of the items divided by the total number of items.

```
show mean values-from turtles [xcor]
;; prints the average of all the turtles' x coordinates
```

median

median *list*

Reports the statistical median of the numeric items of the given list. Ignores non-numeric items. The median is the item that would be in the middle if all the items were arranged in order. (If two items would be in the middle, the median is the average of the two.)

```
show median values-from turtles [xcor]
;; prints the median of all the turtles' x coordinates
```

member?

member? *value list*

member? *string1 string2*

For a list, reports true if the given value appears in the given list, otherwise reports false.

For a string, reports true or false depending on whether *string1* appears anywhere inside *string2* as a substring.

```
show member? 2 [1 2 3]
=> true
show member? 4 [1 2 3]
=> false
show member? "rin" "string"
=> true
```

See also [position](#).

min

min *list*

Reports the minimum number value in the list. It ignores other types of items.

```
show min values-from turtles [xcor]
;; prints the lowest x-coordinate of all the turtles
```

min-one-of

min-one-of *agentset* [*reporter*]

Reports a random agent in the *agentset* that reports the lowest value for the given *reporter*. If there is a tie, this command returns one random agent that meets the condition. If you want all such agents use *with-min* instead.

```
show min-one-of turtles [xcor + ycor]
;; reports the first turtle with the smallest sum of
;; coordinates
```

See also [with-min](#)

mod

number1 mod *number2*

Reports *number1* modulo *number2*: that is, the residue of *number1* (mod *number2*). *mod* is equivalent to the following NetLogo code:

```
number1 - (floor (number1 / number2)) * number2
```

Note that *mod* is "infix", that is, it comes between its two inputs.

```
show 62 mod 5
=> 2
show -8 mod 3
=> 1
```

See also [remainder](#). *mod* and *remainder* behave the same for positive numbers, but differently for negative numbers.

modes

modes list

Reports a list of the most common item or items in *list*.

The input list may contain any NetLogo values.

If the input is an empty list, reports an empty list.

```
show modes [1 2 2 3 4]
=> [2]
show modes [1 2 2 3 3 4]
=> [2 3]
show modes [ [1 2 [3]] [1 2 [3]] [2 3 4] ]
=> [[1 2 [3]]]
show modes values-from turtles [pxcor]
;; shows which columns of patches have the most
;; turtles on them
```

mouse-down?**mouse-down?**

Reports true if the mouse button is down, false otherwise.

Note: If the mouse pointer is outside of the current view , mouse-down? will always report false.

mouse-inside?**mouse-inside?**

Reports true if the mouse pointer is inside the current view, false otherwise.

mouse-xcor**mouse-ycor****mouse-xcor****mouse-ycor**

Reports the x or y coordinate of the mouse in the 2D view. The value is in terms of turtle coordinates, so it is a floating-point number. If you want patch coordinates, use `round mouse-xcor` and `round mouse-ycor`.

Note: If the mouse is outside of the 2D view, reports the value from the last time it was inside.

```
;; to make the mouse "draw" in red:
if mouse-down?
  [ set pcolor-of patch-at mouse-xcor mouse-ycor red ]
```

movie-cancel**movie-cancel**

Cancels the current movie.

movie-close**movie-cancel**

Stops the recording of the current movie.

movie-grab-view**movie-grab-interface**

movie-grab-view

movie-grab-interface

Adds an image of the current view or the interface panel to the current movie.

```
;; make a 20-step movie of the current view
setup
movie-start "out.mov"
repeat 20
[ movie-grab-view
  go ]
movie-close
```

movie-set-frame-rate

movie-set-frame-rate *frame-rate*

Sets the frame rate of the current movie. Must be called after movie-start, but before movie-grab-area,

See also movie-status, movie-set-frame-rate,

movie-start

movie-start *filename*

Creates a new movie. *filename* specifies a new QuickTime file where the movie will be saved, so it should end with ".mov".

See also movie-grab-view, movie-grab-interface, movie-cancel, movie-status, movie-set-frame-rate, movie-close.

movie-status

movie-status

Reports a string describing the current movie.

```
print movie-status
=> No movie.
movie-start
print movie-status
=> 0 frames; Framerate = 15.0.
movie-grab-view
print movie-status
1 frames; Framerate = 15.0; Size = 315x315.
```

myself

myself

"self" and "myself" are very different. "self" is simple; it means "me". "myself" means "the turtle or patch who asked me to do what I'm doing right now."

When an agent has been asked to run some code, using myself in that code reports the agent (turtle or patch) that did the asking.

myself is most often used in conjunction with `—of` to read or set variables in the asking agent.

myself can be used within blocks of code not just in the ask command, but also hatch, sprout, values-from, value-from, turtles-from, patches-from, histogram-from, with, min-one-of, and max-one-of.

```
ask turtles
  [ ask patches in-radius 3
    [ set pcolor color-of myself ] ]
;; each turtle makes a colored "splotch" around itself
```

See the "Myself Example" code example for more examples.

See also [self](#).

N

n-values

n-values *size* [*reporter*]

Reports a list of length *size* containing values computed by repeatedly running *reporter*.

In *reporter*, use ? to refer to the number of the item currently being computed, starting from zero.

```
show n-values 5 [1]
=> [1 1 1 1 1]
show n-values 5 [?]
=> [0 1 2 3 4]
show n-values 3 [turtle ?]
=> [(turtle 0) (turtle 1) (turtle 2)]
show n-values 5 [? * ?]
=> [0 1 4 9 16]
```

See also [reduce](#), [filter](#), [?](#).

neighbors

neighbors4

neighbors
neighbors4


Reports an agentset containing the 8 surrounding patches (neighbors) or 4 surrounding patches (neighbors4).

```
show sum values-from neighbors [count turtles-here]
;; prints the total number of turtles on the eight
;; patches around the calling turtle or patch
ask neighbors4 [ set pcolor red ]
;; turns the four neighboring patches red
```

netlogo-version

netlogo-version

Reports a string containing the version number of the NetLogo you are running.

```
show netlogo-version
=> "3.0.1"
```

new-seed

new-seed

Reports a number suitable for seeding the random number generator.

The numbers reported by new-seed are based on the current date and time in milliseconds and lie in the range -2147483648 to 2147483647.

new-seed never reports the same number twice in succession. (This is accomplished by waiting a millisecond if the seed for the current millisecond was already used.)

See also [random-seed](#).

no-display

no-display

Turns off all updates to the current view until the display command is issued. This has two major uses.

One, you can control when the user sees screen updates. You might want to change lots of things on the screen behind the user's back, so to speak, then make them visible to the user all at once.

Two, your model will run faster when view updating is off, so if you're in a hurry, this command will let you get results faster. (Note that normally you don't need to use no-display for this, since you can also use the on/off switch in view control strip to freeze the view.)

Note that `display` and `no-display` operate independently of the switch in the view control strip that freezes the view.

See also [display](#).

no-label

no-label

This is a special value used to remove labels from turtles and patches.

When you set a turtle's label to `no-label`, or a patch's label to `no-label`, then a label will no longer be drawn on top of the turtle or patch.

See also [label](#), [label-color](#), [plabel](#), [plabel-color](#).

nobody

nobody

This is a special value which some primitives such as `turtle`, `random-one-of`, `max-one-of`, etc. report to indicate that no agent was found. Also, when a turtle dies, it becomes equal to `nobody`.

Note: Empty agentsets are not equal to `nobody`. If you want to test for an empty agentset, use [any?](#). You only get `nobody` back in situations where you were expecting a single agent, not a whole agentset.

```
set other random-one-of other-turtles-here
if other != nobody
  [ set color-of other red ]
```

not

not *boolean*

Reports true if *boolean* is false, otherwise reports false.

```
if not (color = blue) [ fd 10 ]
;; all non-blue turtles move forward 10 steps
```

nsum

nsum4

nsum *patch-variable*

nsum4 *patch-variable*



For each patch, reports the sum of the values of *patch-variable* in the 8 surrounding patches (`nsum`) or 4 surrounding patches (`nsum4`).

Note that `nsum/nsum4` are equivalent to the combination of the `sum`, `values-from`, and `neighbors/neighbors4` primitives:

```
sum values-from neighbors [var]
  ;; does the same thing as "nsum var"
sum values-from neighbors4 [var]
  ;; does the same thing as "nsum4 var"
```

Therefore `nsum` and `nsum4` are included as separate primitives mainly for backwards compatibility with older versions of NetLogo, which did not have the `neighbors` and `neighbors4` primitives.

See also [neighbors](#), [neighbors4](#).

O

-of

VARIABLE-of agent

Reports the value of the *VARIABLE* of the given agent. Can also be used to set the value of the variable.

```
show pxcor-of random-one-of patches
;; prints the value of a random patch's pxcor variable
set color-of random-one-of turtles red
;; a randomly chosen turtle turns red
ask turtles [ set pcolor-of (patch-at -1 0) red ]
;; each turtle turns the patch on its left red
```

one-of

one-of agentset

If given a turtle agentset, reports the turtle in the set with the lowest numbered ID.

If given a patch agentset, reports the patch in the set with the highest `pycor` and, if a tie-breaker is needed, with the lowest `pxcor`.

If the agentset is empty, reports [nobody](#).

See also [random-one-of](#).

or

boolean1 or boolean2

Reports true if either *boolean1* or *boolean2*, or both, is true.

Note that if *condition1* is true, then *condition2* will not be run (since it can't affect the result).

```
if (pxcor > 0) or (pycor > 0) [ set pcolor red ]
```



```
;; patches turn red except in lower-left quadrant
```

other-turtles-here
other-*BREED*-here

other-turtles-here
other-*BREED*-here



Reports an agentset consisting of all turtles on the calling turtle's patch (*not* including the caller itself). If a breed is specified, only turtles with the given breed are included.

```
;; suppose I am one of 10 turtles on the same patch
show count other-turtles-here
=> 9
```

Example using breeds:

```
breeds [cats dogs]
show count other-dogs-here
;; prints the number of dogs (that are not me) on my patch
```

See also [turtles-here](#).

output-print
output-show
output-type
output-write

output-print *value*
output-show *value*
output-type *value*
output-write *value*

These commands are the same as the [print](#), [show](#), [type](#), and [write](#) commands except that *value* is printed in the model's output area, instead of in the Command Center. (If the model does not have a separate output area, then the Command Center is used.)

P

patch

patch *pxcor pycor*

Given two integers, reports the single patch with the given *pxcor* and *pycor*. (The coordinates are the actual coordinates; they are not computed relative to the calling agent, as with [patch-at](#).) *pxcor* and *pycor* must be integers.

```
ask (patch 3 -4) [ set pcolor green ]
;; patch with pxcor of 3 and pycor of -4 turns green
```

See also [patch-at](#).

patch-ahead

patch-ahead *distance*



Reports the single patch that is the given distance "ahead" of the calling turtle, that is, along the turtle's current heading.

```
set pcolor-of (patch-ahead 1) green
;; turns the patch 1 in front of the calling turtle
;;   green; note that this might be the same patch
;;   the turtle is standing on
```

See also [patch-at](#), [patch-left-and-ahead](#), [patch-right-and-ahead](#), [patch-at-heading-and-distance](#).

patch-at

patch-at *dx dy*

Reports the single patch at (dx, dy) from the caller, that is, dx patches east and dy patches north of the caller. (If the caller is the observer, the given offsets are computed from the origin.)

```
ask patch-at 1 -1 [ set pcolor green ]
;; if caller is the observer, turn the patch
;;   at (1, -1) green
;; if caller is a turtle or patch, turns the
;;   patch just southeast of the caller green
```

See also [patch](#), [patch-ahead](#), [patch-left-and-ahead](#), [patch-right-and-ahead](#), [patch-at-heading-and-distance](#).

patch-at-heading-and-distance

patch-at-heading-and-distance *heading distance*



patch-at-heading-and-distance reports the single patch that is the given distance from the calling turtle or patch, along the given absolute heading. (In contrast to patch-left-and-ahead and patch-right-and-ahead, the calling turtle's current heading is not taken into account.)

```
set pcolor-of (patch-at-heading-and-distance -90 1) green
;; turns the patch 1 to the west of the calling patch
;;   green
```

See also [patch](#), [patch-at](#), [patch-left-and-ahead](#), [patch-right-and-ahead](#).

patch-here

patch-here



patch-here reports the patch under the turtle.

Note that this reporter isn't available to a patch because a patch can just say "self".

patch-left-and-ahead patch-right-and-ahead

patch-left-and-ahead *angle distance*
patch-right-and-ahead *angle distance*



Reports the single patch that is the given distance from the calling turtle, in the direction turned left or right the given angle (in degrees) from the turtle's current heading.

(If you want to find a patch in a given absolute heading, rather than one relative to the current turtle's heading, use `patch-at-heading-and-distance` instead.)

```
set pcolor-of (patch-right-and-ahead 30 1) green
;; the calling turtle "looks" 30 degrees right of its
;;   current heading at the patch 1 unit away, and turns
;;   that patch green; note that this might be the same
;;   patch the turtle is standing on
```

See also [patch](#), [patch-at](#), [patch-at-heading-and-distance](#).

patches

patches

Reports the agentset consisting of all patches.

patches-from

patches-from *agentset* [*reporter*]

Reports a patch agentset made by gathering together all the patches reported by *reporter* for each agent in *agentset*.

For each agent, the reporter must report a patch agentset, a single patch, or nobody.

```
patches-from turtles [patch-here]
;; reports the set of all patches with turtles on them;
;; if there are many more patches than turtles, this will
;; run much faster than "patches with [any? turtles-here]"
```

See also [turtles-from](#).

patches-own

patches-own [*var1 var2 ...*]

This keyword, like the `globals`, `breeds`, `<BREED>-own`, and `turtles-own` keywords, can only be used at the beginning of a program, before any function definitions. It defines the variables that all patches can use.

All patches will then have the given variables and be able to use them.

All patch variables can also be directly accessed by any turtle standing on the patch.

See also [globals](#), [turtles-own](#), [breeds](#), [<BREED>-own](#).

pcolor

pcolor



This is a built-in patch variable. It holds the color of the patch. You can set this variable to make the patch change color.

All patch variables can be directly accessed by any turtle standing on the patch.

See also [color](#).

pen-down

pd

pen-erase

pe

pen-up

pu

pen-down

pen-erase

pen-up



The turtle changes modes between drawing lines, removing lines or neither. The lines will always be displayed on top of the patches and below the turtles. To change the color of the pen set the color of the turtle using `set color`.

Note: When a turtle's pen is down, all movement commands cause lines to be drawn, including `jump` and `setxy`.

Note: These commands are equivalent to setting the turtle variable "pen-mode" to "down", "up", and "erase".

pen-mode



This is a built-in turtle variable. It holds the state of the turtle's pen. You set the variable to draw lines, erase lines or stop either of these actions.

pen-size



This is a built-in turtle variable. It holds the width of the line, in pixels, that the turtle will draw (or erase) when the pen is down (or erasing).

plabel

plabel



This is a built-in patch variable. It may hold a value of any type. The patch appears in the view with the given value "attached" to it as text. You can set this variable to add, change, or remove a patch's label.

All patch variables can be directly accessed by any turtle standing on the patch.

See also [no-label](#), [plabel-color](#), [label](#), [label-color](#).

plabel-color

plabel-color



This is a built-in patch variable. It holds a number greater than or equal to 0 and less than 140. This number determines what color the patch's label appears in (if it has a label). You can set this variable to change the color of a patch's label.

All patch variables can be directly accessed by any turtle standing on the patch.

See also [no-label](#), [plabel](#), [label](#), [label-color](#).

plot

plot *number*

Increments the x-value of the plot pen by `plot-pen-interval`, then plots a point at the updated x-value and a y-value of *number*. (The first time the command is used on a plot, the point plotted has an x-value of 0.)

plot-name**plot-name**

Reports the name of the current plot (a string).

plot-pen-down**ppd****plot-pen-up****ppu****plot-pen-down****plot-pen-up**

Puts down (or up) the current plot-pen, so that it draws (or doesn't). (By default, all pens are down initially.)

plot-pen-reset**plot-pen-reset**

Clears everything the current plot pen has drawn, moves it to (0,0), and puts it down. If the pen is a permanent pen, the color and mode are reset to the default values from the plot Edit dialog.

plotxy**plotxy *number1 number2***

Moves the current plot pen to the point with coordinates (*number1*, *number2*). If the pen is down, a line, bar, or point will be drawn (depending on the pen's mode).

plot-x-min**plot-x-max****plot-y-min****plot-y-max****plot-x-min****plot-x-max****plot-y-min****plot-y-max**

Reports the minimum or maximum value on the x or y axis of the current plot.

These values can be set with the commands `set-plot-x-range` and `set-plot-y-range`. (Their default values are set from the plot Edit dialog.)

position

position *item list*

position *string1 string2*

On a list, reports the first position of *item* in *list*, or false if it does not appear.

On strings, reports the position of the first appearance *string1* as a substring of *string2*, or false if it does not appear.

Note: The positions are numbered beginning with 0, not with 1.

```

;; suppose mylist is [2 7 4 7 "Bob"]
show position 7 mylist
=> 1
show position 10 mylist
=> false
show position "rin" "string"
=> 2

```

See also [member?](#).

precision

precision *number places*

Reports *number* rounded to *places* decimal places.

If *places* is negative, the rounding takes place to the left of the decimal point.

```

show precision 1.23456789 3
=> 1.235
show precision 3834 -3
=> 4000

```

print

print *value*

Prints *value* in the Command Center, followed by a carriage return.

The calling agent is *not* printed before the value, unlike [show](#).

See also [show](#), [type](#), and [write](#).

See also [output-print](#).

pxcor
pycor

pxcor
pycor


These are built-in patch variables. They hold the x and y coordinate of the patch. They are always integers. You cannot set these variables, because patches don't move.

pxcor is greater than or equal to ($-\text{screen-edge-x}$) and less than or equal to screen-edge-x ; similarly for pycor and screen-edge-y .

All patch variables can be directly accessed by any turtle standing on the patch.

See also [xcor](#), [ycor](#).

R

random

random number

If *number* is positive, reports a random integer greater than or equal to 0, but strictly less than *number*.

If *number* is negative, reports a random integer less than or equal to 0, but strictly greater than *number*.

If *number* is zero, the result is always 0 as well.

Note: In versions of NetLogo prior to version 2.0, this primitive reported a floating point number if given a floating point input. This is no longer the case. If you want a floating point answer, you must now use [random-float](#) instead.

```
show random 3
;; prints 0, 1, or 2
show random -3
;; prints 0, -1, or -2
show random 3.0
;; prints 0, 1, or 2
show random 3.5
;; prints 0, 1, 2, or 3
```

See also [random-float](#).

random-float

random-float *number*

If *number* is positive, reports a random floating point number greater than or equal to 0.0 but strictly less than *number*.

If *number* is negative, reports a random floating point number less than or equal to 0.0, but strictly greater than *number*.

If *number* is zero, the result is always 0.0.

```
show random-float 3
;; prints a number at least 0.0 but less than 3.0,
;; for example 2.589444906014774
show random-float 2.5
;; prints a number at least 0.0 but less than 2.5,
;; for example 1.0897423196760796
```

random-exponential

random-gamma

random-normal

random-poisson

random-exponential *mean*

random-gamma *alpha lambda*

random-normal *mean standard-deviation*

random-poisson *mean*

Reports an accordingly distributed random number with the *mean* and, in the case of the normal distribution, the *standard-deviation*.

random-exponential reports an exponentially distributed random floating point number.

random-gamma reports a gamma-distributed random floating point number as controlled by the floating point alpha and lambda parameters. Both inputs must be greater than zero. (Note: for results with a given mean and variance, use inputs as follows: alpha = mean * mean / variance; lambda = 1 / (variance / mean).)

random-normal reports a normally distributed random floating point number.

random-poisson reports a Poisson-distributed random integer.

```
show random-exponential 2
;; prints an exponentially distributed random floating
;; point number with a mean of 2
show random-normal 10.1 5.2
;; prints a normally distributed random floating point
;; number with a mean of 10.1 and a standard deviation
;; of 5.2
show random-poisson 3.4
;; prints a Poisson-distributed random integer with a
```

```
;; mean of 3.4
```

random-int-or-float

random-int-or-float *number*

NOTE: This primitive should not be used in new models. It is included only for backwards compatibility with NetLogo 1.x. It will not necessarily continue to be supported in future versions of NetLogo.

When a NetLogo 1.x model is read into NetLogo 2.0 or higher, all uses of the "random" primitive are automatically converted to "random-int-or-float" instead, because the meaning of "random" has changed. It used to sometimes return an integer and sometimes a floating point number; now it always returns an integer. This primitive mimics the old behavior, as follows:

If *number* is positive, reports a random number greater than or equal to 0 but strictly less than *number*.

If *number* is negative, the number reported is less than or equal to 0, but strictly greater than *number*.

If *number* is zero, the result is always zero as well.

If *number* is an integer, reports a random integer.

If *number* is floating point (has a decimal point), reports a floating point number.

```
show random-int-or-float 3
;; prints 0, 1, or 2
show random-int-or-float 5.0
;; prints a number at least 0.0 but less than 5.0,
;; for example 4.686596634174661
```

random-n-of

random-n-of *size agentset*

From an agentset, reports an agentset of size *size* randomly chosen from the input set.

From an list, reports a list of size *size* randomly chosen from the input set. The items in the result appear in the same order that they appeared in the input list. (If you want them in random order, use `shuffle` on the result.)

It is an error for *size* to be greater than the size of the input.

```
ask random-n-of 50 patches [ set pcolor green ]
;; 50 randomly chosen patches turn green
```

See also [random-one-of](#).

random-one-of

random-one-of *agentset*
random-one-of *list*

From an agentset, reports a random agent. If the agentset is empty, reports nobody.

From a list, reports a random list item. It is an error for the list to be empty.

```
ask random-one-of patches [ set pcolor green ]
;; a random patch turns green
set pcolor-of random-one-of patches green
;; another way to say the same thing
ask patches with [any? turtles-here]
  [ show random-one-of turtles-here ]
;; for each patch containing turtles, prints one of
;; those turtles

;; suppose mylist is [1 2 3 4 5 6]
show random-one-of mylist
;; prints a value randomly chosen from the list
```

See also one-of and random-n-of.

random-seed

random-seed *number*

Sets the seed of the pseudo-random number generator to the integer part of *number*. The seed may be any integer in the range supported by NetLogo (−2147483648 to 2147483647).

See the Random Numbers section of the Programming Guide for more details.

```
random-seed 47823
show random 100
=> 57
show random 100
=> 91
random-seed 47823
show random 100
=> 57
show random 100
=> 91
```

read-from-string

read-from-string *string*

Interprets the given string as if it had been typed in the Command Center, and reports the resulting value. The result may be a number, list, string, or boolean value, or the special value "nobody".

Useful in conjunction with the user-input primitive for converting the user's input into usable form.

```
show read-from-string "3" + read-from-string "5"
```

```
=> 8
show length read-from-string "[1 2 3]"
=> 3
crt read-from-string user-input "Make how many turtles?"
;; the number of turtles input by the user
;; are created
```

reduce

reduce [*reporter*] *list*

Reduces a list from left to right using *reporter*, resulting in a single value. This means, for example, that `reduce [?1 + ?2] [1 2 3 4]` is equivalent to $((1 + 2) + 3) + 4$. If *list* has a single item, that item is reported. It is an error to reduce an empty list.

In *reporter*, use ?1 and ?2 to refer to the two objects being combined.

Since it can be difficult to develop an intuition about what `reduce` does, here are some simple examples which, while not useful in themselves, may give you a better understanding of this primitive:

```
show reduce [?1 + ?2] [1 2 3]
=> 6
show reduce [?1 - ?2] [1 2 3]
=> -4
show reduce [?2 - ?1] [1 2 3]
=> 2
show reduce [?1] [1 2 3]
=> 1
show reduce [?2] [1 2 3]
=> 3
show reduce [sentence ?1 ?2] [[1 2] [3 [4]] 5]
=> [1 2 3 [4] 5]
show reduce [fput ?2 ?1] (fput [] [1 2 3 4 5])
=> [5 4 3 2 1]
```

Here are some more useful examples:

```
;; find the longest string in a list
to-report longest-string [strings]
  report reduce
    [ifelse-value (length ?1 >= length ?2) [?1] [?2]]
    strings
end

show longest-string ["hi" "there" "!"]
=> "there"

;; count the number of occurrences of an item in a list
to-report occurrences [x xs]
  report reduce
    [ifelse-value (?2 = x) [?1 + 1] [?1]] (fput 0 xs)
end

show occurrences 1 [1 2 1 3 1 2 3 1 1 4 5 1]
=> 6

;; evaluate the polynomial, with given coefficients, at x
```

```
to-report eval-polynomial [coeffs x]
  report reduce [(x * ?1) + ?2] coeffs
end
```

```
;; evaluate 3x^2 + 2x + 1 at x = 4
show eval-polynomial [3 2 1] 4
=> 57
```

remainder

remainder *number1 number2*

Reports the remainder when *number1* is divided by *number2*. This is equivalent to the following NetLogo code:

```
number1 - (int (number1 / number2)) * number2

show remainder 62 5
=> 2
show remainder -8 3
=> -2
```

See also [mod](#). `mod` and `remainder` behave the same for positive numbers, but differently for negative numbers.

remove

remove *item list*

remove *string1 string2*

For a list, reports a copy of *list* with all instances of *item* removed.

For strings, reports a copy of *string2* with all the appearances of *string1* as a substring removed.

```
set mylist [2 7 4 7 "Bob"]
set mylist remove 7 mylist
;; mylist is now [2 4 "Bob"]
show remove "na" "banana"
=> "ba"
```

remove-duplicates

remove-duplicates *list*

Reports a copy of *list* with all duplicate items removed. The first of each item remains in place.

```
set mylist [2 7 4 7 "Bob" 7]
set mylist remove-duplicates mylist
;; mylist is now [2 7 4 "Bob"]
```

remove-item

remove-item *index list*
remove-item *index string*

For a list, reports a copy of *list* with the item at the given index removed.

For strings, reports a copy of *string2* with the character at the given index removed.

Note that the indices begin from 0, not 1. (The first item is item 0, the second item is item 1, and so on.)

```
set mylist [2 7 4 7 "Bob"]
set mylist remove-item 2 mylist
;; mylist is now [2 7 7 "Bob"]
show remove-item 3 "banana"
=> "banna"
```

repeat

repeat *number* [*commands*]

Runs *commands* *number* times.

```
pd repeat 36 [ fd 1 rt 10 ]
;; the turtle draws a circle
```

replace-item

replace-item *index list value*
replace-item *index string1 string2*

On a list, replaces an item in that list. *index* is the index of the item to be replaced, starting with 0. (The 6th item in a list would have an index of 5.) Note that "replace-item" is used in conjunction with "set" to change a list.

Likewise for a string, but the given character of *string1* removed and the contents of *string2* spliced in instead.

```
show replace-item 2 [2 7 4 5] 15
=> [2 7 15 5]
show replace-item 1 "sat" "lo"
=> "slot"
```

report

report *value*

Immediately exits from the current to-report procedure and reports *value* as the result of that procedure. report and to-report are always used in conjunction with each other. See [to-report](#) for a discussion of how to use them.

reset-perspective rp

reset-perspective

The observer stops watching, following, or riding any turtles (or patches). (If it wasn't watching, following, or riding anybody, nothing happens.) In the 3D view, the observer also returns to its default position (above the origin, looking straight down).

See also [follow](#), [ride](#), [watch](#).

reset-timer

reset-timer

Resets the global clock to zero. See also [timer](#).

reverse

reverse *list* reverse *string*

Reports a reversed copy of the given list or string.

```
show mylist
;; mylist is [2 7 4 "Bob"]
set mylist reverse mylist
;; mylist now is ["Bob" 4 7 2]
show reverse "string"
=> "gnirts"
```

rgb

rgb *red green blue*

Reports a number in the range 0 to 140, not including 140 itself, that represents the given color, specified in the RGB spectrum, in NetLogo's color space.

All three inputs should be in the range 0.0 to 1.0.

The color reported may be only an approximation, since the NetLogo color space does not include all possible colors. (See [hsb](#) for a description of what parts of the HSB color space NetLogo colors cover; this is difficult to characterize in RGB terms.)

```
show rgb 0 0 0
=> 0.0 ;; black
show rgb 0 1.0 1.0
=> 85.0 ;; cyan
```

See also [extract-rgb](#), [hsb](#), and [extract-hsb](#).

ride

ride *turtle*



Set the perspective to *turtle*.

Every time *turtle* moves the observer also moves. Thus, in the 2D View the turtle will stay at the center of the view. In the 3D view it is as if looking through the eyes of the turtle. If the turtle dies, the view will return to the default position.

See also [reset-perspective](#), [watch](#), [follow](#), [subject](#).

ride-me

ride-me



Asks the observer to ride the calling turtle.

See also [ride](#).

right rt

right *number*



The turtle turns right by *number* degrees. (If *number* is negative, it turns left.)

round

round *number*

Reports the integer nearest to *number*.

If the decimal portion of *number* is exactly .5, the number is rounded in the **positive** direction.

Note that rounding in the positive direction is not always how rounding is done in other software programs. (In particular, it does not match the behavior of StarLogoT, which always rounded numbers ending in 0.5 to the nearest even integer.) The rationale for this behavior is that it matches how turtle coordinates relate to patch coordinates in NetLogo. For example, if a turtle's xcor is -4.5, then it is on the boundary between a patch whose pxcor is -4 and a patch whose pxcor is -5, but the turtle must be considered to be in one patch or the other, so the turtle is considered to be in the patch whose pxcor is -4, because we round towards the positive numbers.

```
show round 4.2  
=> 4
```



```
show round 4.5
=> 5
show round -4.5
=> -4
```

run

run *string*

This agent interprets the given string as a sequence of one or more NetLogo commands and runs them.

The code runs in the agent's current context, which means it has access to the values of local variables, "myself", and so on.

See also [runresult](#).

runresult

runresult *string*

This agent interprets the given string as a NetLogo reporter and runs it, reporting the result obtained.

The code runs in the agent's current context, which means it has access to the values of local variables, "myself", and so on.

See also [run](#).

S

scale-color

scale-color *color number range1 range2*

Reports a shade of *color* proportional to *number*.

If *range1* is less than *range2*, then the larger the number, the lighter the shade of *color*. But if *range2* is less than *range1*, the color scaling is inverted.

If *number* is less than *range1*, then the darkest shade of *color* is chosen.

If *number* is greater than *range2*, then the lightest shade of *color* is chosen.

Note: for *color* shade is irrelevant, e.g. green and green + 2 are equivalent, and the same spectrum of colors will be used.

```
ask turtles [ set color scale-color red age 0 50 ]
;; colors each turtle a shade of red proportional
;; to its value for the age variable
```

screen-edge-x screen-edge-y

screen-edge-x screen-edge-y

These reporters give the maximum x-coordinate and maximum y-coordinate (respectively) of the world.

screen-edge-x and -y are the "half-width" and "half-height" of the NetLogo world -- the distances from the origin to the edges. screen-size is the same as $((2 * \text{screen-edge}) + 1)$.

Note: You can set the size of the world only by editing the current view -- these are reporters which cannot be set.

```
cct 100 [ setxy (random-float screen-edge-x)
                (random-float screen-edge-y) ]
;; distributes 100 turtles randomly in the
;; first quadrant
```

screen-size-x screen-size-y

screen-size-x screen-size-y

These reporters give the total width and height of the NetLogo world.

Screen-size is the same as $((2 * \text{screen-edge}) + 1)$.

self

self



Reports this turtle or patch.

"self" and "myself" are very different. "self" is simple; it means "me". "myself" means "the turtle or patch who asked me to do what I'm doing right now."

```
ask turtles with [self != myself]
[ die ]
;; this turtle kills all other turtles
```

See also [myself](#).

; (semicolon)

; *comments*

After a semicolon, the rest of the line is ignored. This is useful for adding "comments" to your code — text that explains the code to human readers. Extra semicolons can be added for visual effect.

NetLogo's Edit menu has items that let you comment or uncomment whole sections of code.

sentence

se

sentence *value1 value2*
(sentence *value1 ... valuen*)

Makes a list out of the values. If any value is a list, its items are included in the result directly, rather than being included as a sublist. Examples make this clearer:

```
show sentence 1 2
=> [1 2]
show sentence [1 2] 3
=> [1 2 3]
show sentence 1 [2 3]
=> [1 2 3]
show sentence [1 2] [3 4]
=> [1 2 3 4]
show sentence [[1 2]] [[3 4]]
=> [[1 2] [3 4]]
show (sentence [1 2] 3 [4 5] (3 + 3) 7)
=> [1 2 3 4 5 6 7]
```

set

set *variable value*

Sets *variable* to the given value.

Variable can be any of the following:

- An global variable declared using "globals"
 - The global variable associated with a slider, switch, or chooser
 - A variable belonging to the calling agent
 - If the calling agent is a turtle, a variable belonging to the patch under the turtle.
 - An expression of the form *VARIABLE*-of *agent*
 - A local variable created by the let command
-

set-current-directory

set-current-directory *string*

Sets the current directory that is used by the primitives file-delete, file-exists?, and file-open.

The current directory is not used if the above commands are given an absolute file path. This is defaulted to the user's home directory for new models, and is changed to the model's directory when a model is opened.

Note that in Windows file paths the backslash needs to be escaped within a string by using another backslash "C:\\"

The change is temporary and is not saved with the model.

Note: in applets, this command has no effect, since applets are only allowed to read files from the same directory on the server where the model is stored.

```
set-current-directory "C:\\NetLogo"
;; Assume it is a Windows Machine
file-open "myfile.txt"
;; Opens file "C:\\NetLogo\\myfile.txt"
```

set-current-plot**set-current-plot *plotname***

Sets the current plot to the plot with the given name (a string). Subsequent plotting commands will affect the current plot.

set-current-plot-pen**set-current-plot-pen *penname***

The current plot's current pen is set to the pen named *penname* (a string). If no such pen exists in the current plot, a runtime error occurs.

set-default-shape**set-default-shape turtles *string*****set-default-shape *breed string***

Specifies a default initial shape for all turtles, or for a particular breed. When a turtle is created, or it changes breeds, its shape is set to the given shape.

The specified breed must be either turtles or a breed defined by the breeds keyword, and the specified string must be the name of a currently defined shape.

In new models, the default shape for all turtles is "default".

Note that specifying a default shape does not prevent you from changing an individual turtle's shape later; turtles don't have to be stuck with their breed's default shape.

```
create-turtles 1 ;; new turtle's shape is "default"
create-cats 1    ;; new turtle's shape is "default"

set-default-shape turtles "circle"
create-turtles 1 ;; new turtle's shape is "circle"
create-cats 1    ;; new turtle's shape is "circle"

set-default-shape cats "cat"
set-default-shape dogs "dog"
create-cats 1    ;; new turtle's shape is "cat"
ask cats [ set breed dogs ]
    ;; all cats become dogs, and automatically
    ;; change their shape to "dog"
```

See also [shape](#).

set-histogram-num-bars

set-histogram-num-bars *integer*

Set the current plot pen's plot interval so that, given the current x range for the plot, there would be *integer* number of bars drawn if the histogram-from or histogram-list commands were called.

See also [histogram-from](#).

set-plot-pen-color

set-plot-pen-color *number*

Sets the color of the current plot pen to *number*.

set-plot-pen-interval

set-plot-pen-interval *number*

Tells the current plot pen to move a distance of *number* in the x direction during each use of the plot command. (The plot pen interval also affects the behavior of the histogram-from and histogram-list commands.)

set-plot-pen-mode

set-plot-pen-mode *number*

Sets the mode the current plot pen draws in to *number*. The allowed plot pen modes are:

- 0 (line mode) the plot pen draws a line connecting two points together.
- 1 (bar mode): the plot pen draws a bar of width plot-pen-interval with the point plotted as the upper (or lower, if you are plotting a negative number) left corner of the bar.

- 2 (point mode): the plot pen draws a point at the point plotted. Points are not connected.

The default mode for new pens is 0 (line mode).

set-plot-x-range

set-plot-y-range

set-plot-x-range *min max*

set-plot-y-range *min max*

Sets the minimum and maximum values of the x or y axis of the current plot.

The change is temporary and is not saved with the model. When the plot is cleared, the ranges will revert to their default values as set in the plot's Edit dialog.

setxy

setxy *x y*



The turtle sets its x-coordinate to *x* and its y-coordinate to *y*.

Equivalent to `set xcor x set ycor y`, except it happens in one time step instead of two.

```
setxy 0 0
;; turtle moves to the middle of the center patch
```

shade-of?

shade-of? *color1 color2*

Reports true if both colors are shades of one another, false otherwise.

```
show shade-of? blue red
=> false
show shade-of? blue (blue + 1)
=> true
show shade-of? gray white
=> true
```

shape

shape



This is a built-in turtle variable. It holds a string that is the name of the turtle's current shape. You can set this variable to change a turtle's shape. New turtles have the shape "default" unless the a different shape has been specified using set-default-shape.

Example:

```
ask turtles [ set shape "wolf" ]
;; assumes you have made a "wolf"
;; shape in NetLogo's Shapes Editor
```

See also [set-default-shape](#), [shapes](#).

shapes

shapes

Reports a list of strings containing all of the turtle shapes in the model.

New shapes can be created, or imported from the shapes library or from other models, in the [Shapes Editor](#).

```
show shapes
=> ["default" "airplane" "arrow" "box" "bug" ...
ask turtles [ set shape random-one-of shapes ]
```

show

show *value*

Prints *value* in the Command Center, preceded by the calling agent, and followed by a carriage return. (The calling agent is included to help you keep track of what agents are producing which lines of output.) Also, all strings have their quotes included similar to [write](#).

See also [print](#), [type](#), and [write](#).

See also [output-show](#).

showturtle

st

showturtle



The turtle becomes visible again.

Note: This command is equivalent to setting the turtle variable "hidden?" to false.

See also [hideturtle](#).

shuffle

shuffle *list*

Reports a new list containing the same items as the input list, but in randomized order.

```
show shuffle [1 2 3 4 5]
```

```
=> [5 2 4 1 3]
show shuffle [1 2 3 4 5]
=> [1 3 5 2 4]
```

sin

sin *number*

Reports the sine of the given angle. Assumes angle is given in degrees.

```
show sin 270
=> -1.0
```

size

size



This is a built-in turtle variable. It holds a number that is the turtle's apparent size. The default size is 1.0, which means that the turtle is the same size as a patch. You can set this variable to change a turtle's size.

sort

sort *list*

Reports a new list containing the same items as the input list, but in ascending order.

If there is at least one number in the list, the list is sorted in numerically ascending order and any non-numeric items of the input list are discarded.

If there are no numbers, but at least one string in the list, the list is sorted in alphabetically ascending order and any non-string items are discarded.

sort-by

sort-by [*reporter*] *list*

Reports a new list containing the same items as the input list, in a sorted order defined by the boolean (true or false) *reporter*.

In *reporter*, use ?1 and ?2 to refer to the two objects being compared. *reporter* should be true if ?1 comes strictly before ?2 in the desired sort order, and false otherwise.

```
show sort-by [?1 < ?2] [3 1 4 2]
=> [1 2 3 4]
show sort-by [?1 > ?2] [3 1 4 2]
=> [4 3 2 1]
show sort-by [length ?1 < length ?2] ["zzz" "z" "zz"]
=> ["z" "zz" "zzz"]
```

sprout**sprout-<BREED>****sprout** *number* [*commands*]**sprout-<BREED>** *number* [*commands*]

Creates *number* new turtles on the current patch. The new turtles have random colors and orientations, and they immediately run *commands*. This is useful for giving the new turtles different colors, headings, or whatever.

If the sprout-<BREED> form is used, the new turtles are created as members of the given breed.

```
sprout 1 [ set color red ]
sprout-sheep 1 [ set color black ]
```

Note: While the commands are running, no other agents are allowed to run any code (as with the without-interruption command). This ensures that the new turtles cannot interact with any other agents until they are fully initialized. In addition, no screen updates take place until the commands are done. This ensures that the new turtles are never drawn on-screen until they are fully initialized.

sqrt**sqrt** *number*

Reports the square root of *number*.

stamp**stamp**

The calling turtle leaves an image of its shape in the drawing at its current location.

Note: The shapes made by stamp may not be pixel-for-pixel identical from computer to computer.

standard-deviation**standard-deviation** *list*

Reports the unbiased statistical standard deviation of a *list* of numbers. Ignores other types of items.

```
show standard-deviation [1 2 3 4 5 6]
=> 1.8708286933869707
show standard-deviation values-from turtles [energy]
;; prints the standard deviation of the variable "energy"
;; from all the turtles
```

startup

startup



User-defined procedure which, if it exists, will be called when a model is first loaded.

```
to startup
  setup
end
```

stop

stop

The calling agent exits immediately from the enclosing procedure, ask, or ask-like construct (cct, hatch, sprout). Only the current procedure stops, not all execution for the agent.

Note: stop can be used to stop a forever button. If the forever button directly calls a procedure, then when that procedure stops, the button stops. (In a turtle or patch forever button, the button won't stop until every turtle or patch stops — a single turtle or patch doesn't have the power to stop the whole button.)

subject

subject

Reports the turtle (or patch) that the observer is currently watching, following, or riding. Reports nobody if there is no such turtle (or patch).

See also watch, follow, ride.

sublist

substring

sublist *list position1 position2*

substring *string position1 position2*

Reports just a section of the given list or string, ranging between the first position (inclusive) and the second position (exclusive).

Note: The positions are numbered beginning with 0, not with 1.

```
show sublist [99 88 77 66] 1 3
=> [88 77]
show substring "turtle" 1 4
=> "urt"
```

subtract-headings

subtract-headings *heading1 heading2*

Computes the difference between the given headings, that is, the number of degrees in the smallest angle by which heading2 could be rotated to produce heading1. A positive answer means a clockwise rotation, a negative answer counterclockwise. The result is always in the range -180 to 180 , but is never exactly -180 .

Note that simply subtracting the two headings using the $-$ (minus) operator wouldn't work. Just subtracting corresponds to always rotating clockwise from heading2 to heading1; but sometimes the counterclockwise rotation is shorter. For example, the difference between 5 degrees and 355 degrees is 10 degrees, not -350 degrees.

```
show subtract-headings 80 60
=> 20
show subtract-headings 60 80
=> -20
show subtract-headings 5 355
=> 10
show subtract-headings 355 5
=> -10
show subtract-headings 180 0
=> 180
show subtract-headings 0 180
=> 180
```

sum

sum *list*

Reports the sum of the items in the list.

```
show sum values-from turtles [energy]
;; prints the total of the variable "energy"
;; from all the turtles
```

T

tan

tan *number*

Reports the tangent of the given angle. Assumes the angle is given in degrees.

timer

timer

Reports how many seconds have passed since the command reset-timer was last run (or since NetLogo started). The potential resolution of the clock is milliseconds. (Whether you get resolution

that high in practice may vary from system to system, depending on the capabilities of the underlying Java Virtual Machine.)

to

to *procedure-name*

to *procedure-name* [*input1 input2 ...*]

Used to begin a command procedure.

```
to setup
  ca
  crt 500
end

to circle [radius]
  cct 100 [ fd radius ]
end
```

to-report

to-report *procedure-name*

to-report *procedure-name* [*input1 input2 ...*]

Used to begin a reporter procedure.

The body of the procedure should use `report` to report a value for the procedure. See [report](#).

```
to-report average [a b]
  report (a + b) / 2
end

to-report absolute-value [number]
  ifelse number >= 0
    [ report number ]
    [ report (- number) ]
end

to-report first-turtle?
  report who = 0 ;; reports true or false
end
```

towards

towards-nowrap

towards *agent*

towards-nowrap *agent*



Reports the heading from this agent to the given agent.

If the wrapped distance (around the edges of the screen) is shorter than the on-screen distance, `towards` will report the heading of the wrapped path. `towards-nowrap` never uses the wrapped path.

Note: asking for the heading from an agent to itself, or an agent on the same location, will cause a runtime error.

towardsxy

towardsxy-nowrap

towardsxy *x y*

towardsxy-nowrap *x y*



Reports the heading from the turtle or patch towards the point (x,y).

If the wrapped distance (around the edges of the screen) is shorter than the on-screen distance, towardsxy will report the heading of the wrapped path. towardsxy-nowrap never uses the wrapped path.

Note: asking for the heading to the point the agent is already standing on will cause a runtime error.

turtle

turtle *number*

Reports the turtle with the given ID number, or nobody if there is no such turtle. *number* must be an integer.

```
set color-of turtle 5 red
;; turtle with id number 5 turns red
ask turtle 5 [ set color red ]
;; another way to do the same thing
```

turtles

turtles

Reports the agentset consisting of all turtles.

```
show count turtles
;; prints the number of turtles
```

turtles-at

BREED-at

turtles-at *dx dy*

BREED-at *dx dy*

Reports an agentset containing the turtles on the patch (dx, dy) from the caller (including the caller itself if it's a turtle). If the caller is the observer, dx and dy are calculated from the origin (0,0).

```
;; suppose I have 40 turtles at the origin
show count turtles-at 0 0
```

```
=> 40
```

If the name of a breed is substituted for "turtles", then only turtles of that breed are included.

```
breeds [cats dogs]
create-custom-dogs 5 [ setxy 2 3 ]
show count dogs-at 2 3
=> 5
```

turtles-from

turtles-from *agentset* [*reporter*]

Reports a turtle agentset made by gathering together all the turtles reported by *reporter* for each agent in *agentset*.

For each agent, the reporter must report a turtle agentset, a single turtle, or nobody.

```
turtles-from patches [random-one-of turtles-here]
;; reports a turtle set containing one turtle from
;; each patch (that has any turtles on it)
turtles-from neighbors [turtles-here]
;; if run by a turtle or patch, reports the set of
;; all turtles on the neighboring eight patches; note that
;; this could be written more concisely using turtles-on,
;; like this:
;;   turtles-on neighbors
```

See also [patches-from](#), [turtles-on](#).

turtles-here

BREED-here

turtles-here

BREED-here

Reports an agentset containing all the turtles on the caller's patch (including the caller itself if it's a turtle).

```
ca
crt 10
ask turtle 0 [ show count turtles-here ]
=> 10
```

If the name of a breed is substituted for "turtles", then only turtles of that breed are included.

```
breeds [cats dogs]
create-cats 5
create-dogs 1
ask dogs [ show count cats-here ]
=> 5
```

See also [other-turtles-here](#).

turtles-on *BREED-on*

turtles-on *agent*
 turtles-on *agentset*
BREED-on agent
BREED-on agentset

Reports an agentset containing all the turtles that are on the given patch or patches, or standing on the same patch as the given turtle or turtles.

```
ask turtles [
  if not any? turtles-on patch-ahead 1
    [ fd 1 ]
]
ask turtles [
  if not any? turtles-on neighbors [
    die-of-loneliness
  ]
]
```

If the name of a breed is substituted for "turtles", then only turtles of that breed are included.

See also [turtles-from](#).

turtles-own *BREED-own*

turtles-own [*var1 var2 ...*]
BREED-own [var1 var2 ...]

The turtles-own keyword, like the globals, breed, *<BREED>-own*, and patches-own keywords, can only be used at the beginning of a program, before any function definitions. It defines the variables belonging to each turtle.

If you specify a breed instead of "turtles", only turtles of that breed have the listed variables. (More than one breed may list the same variable.)

```
breeds [cats dogs hamsters]
turtles-own [eyes legs]    ;; applies to all breeds
cats-own [fur kittens]
hamsters-own [fur cage]
dogs-own [hair puppies]
```

See also [globals](#), [patches-own](#), [breeds](#), *<BREED>-own*.

type

type *value*

Prints *value* in the Command Center, *not* followed by a carriage return (unlike [print](#) and [show](#)). The lack of a carriage return allows you to print several values on the same line.

The calling agent is *not* printed before the value. unlike show.

```
type 3 type " " print 4
=> 3 4
```

See also print, show, and write.

See also output-type.

U

uphill

uphill *patch-variable*



Reports the turtle heading (between 0 and 359 degrees) in the direction of the maximum value of the variable *patch-variable*, of the patches in a one-patch radius of the turtle. (This could be as many as eight or as few as five patches, depending on the position of the turtle within its patch.)

If there are multiple patches that have the same greatest value, a random one of those patches will be selected.

If the patch is located directly to the north, south, east, or west of the patch that the turtle is currently on, a multiple of 90 degrees is reported. However, if the patch is located to the northeast, northwest, southeast, or southwest of the patch that the turtle is currently on, the direction the turtle would need to reach the nearest corner of that patch is reported.

See also uphill4, downhill, downhill4.

uphill4

uphill4 *patch-variable*



Reports the turtle heading (between 0 and 359 degrees) as a multiple of 90 degrees in the direction of the maximum value of the variable *patch-variable*, of the four patches to the north, south, east, and west of the turtle. If there are multiple patches that have the same greatest value, a random patch from those patches will be selected.

See also uphill, downhill, downhill4.

user-choice

user-choice *value list-of-choices*

Opens a dialog with *value* displayed as the message and a button corresponding to each item in *list-of-choices*.

Reports the item in *list-of-choices* that is associated with the button the user presses.

value may be of any type, but is typically a string.

```
if "yes" = (user-choice
            "Set up the model?"
            ["no" "yes"])
  [ setup ]
```

user-choose-directory

user-choose-directory

Opens a dialog that allows the user to choose an existing directory on the system.

It reports a string with the absolute path or false if the user cancels.

```
set-current-directory user-choose-directory
;; Assumes the user will choose a directory
```

user-choose-file

user-choose-file

Opens a dialog that allows the user to choose an existing file on the system.

It reports a string with the absolute file path or false if the user cancels.

```
file-open user-choose-file
;; Assumes the user will choose a file
```

user-choose-new-file

user-choose-new-file

Opens a dialog that allows the user to choose a new file on the system.

It reports a string with the absolute file path or false if the user cancels.

Note that no file is ever created or overwritten with this reporter.

```
file-open user-choose-new-file
;; Assumes the user will choose a file
```

user-input

user-input *value*

Reports the string that a user types into an entry field in a dialog with title *value*.

value may be of any type, but is typically a string.

```
show user-input "What is your name?"
```

user-message

user-message *value*

Opens a dialog with *value* displayed as the message.

value may be of any type, but is typically a string.

```
user-message "There are " + count turtles + " turtles."
```

user-yes-or-no?

user-yes-or-no? *value*

Reports true or false based on the user's response to *value*.

value may be of any type, but is typically a string.

```
if user-yes-or-no? "Set up the model?"
  [ setup ]
```

V

value-from

value-from *agent* [*reporter*]

Reports the value of the reporter for the given agent (turtle or patch).

```
show value-from (turtle 5) [who * who]
=> 25
show value-from (patch 0 0) [count turtles in-radius 3]
;; prints the number of turtles located within a
;; three-patch radius of the origin
```

values-from

values-from *agentset* [*reporter*]

Reports a list that contains the value of the reporter for each agent in the agentset.

```
ca
crt 4
show values-from turtles [who]
=> [0 1 2 3]
show values-from turtles [who * who]
=> [0 1 4 9]
```

variance

variance *list*

Reports the sample variance of a *list* of numbers. Ignores other types of items.

The sample variance is the sum of the squares of the deviations of the numbers from their mean, divided by one less than the number of numbers in the list.

```
show variance [2 7 4 3 5]
=> 3.7
```

W

wait

wait *number*

Wait the given number of seconds. (You can use floating-point numbers to specify fractions of seconds.) Note that you can't expect complete precision; the agent will never wait less than the given amount, but might wait slightly more.

```
repeat 10 [ fd 1 wait 0.5 ]
```

See also [every](#).

watch

watch *agent*



Puts a spotlight on *agent*. In the 3D view the observer will also turn to face the subject.

See also [follow](#), [subject](#), [reset-perspective](#), [watch-me](#).

watch-me

watch-me



Asks the observer to watch the calling agent.

See also [watch](#).

while

while [reporter] [commands]

If *reporter* reports false, exit the loop. Otherwise run *commands* and repeat.

The reporter may have different values for different agents, so some agents may run *commands* a different number of times than other agents.

```
while [any? other-turtles-here]
  [ fd 1 ]
;; turtle moves until it finds a patch that has
;; no other turtles on it
```

who**who**

This is a built-in turtle variable. It holds the turtle's id number (an integer greater than or equal to zero). You cannot set this variable; a turtle's id number never changes.

When NetLogo starts, or after you use the clear-all or clear-turtles commands, new turtles are created with ids in order, starting at 0. If a turtle dies, though, a new turtle may eventually be assigned the same id number that was used by the dead turtle.

Example:

```
show values-from (turtles with [color = red]) [who]
;; prints a list of the id numbers of all red turtles
;; in the Command Center
ca
cct 100
  [ ifelse who <50
    [ set color red ]
    [ set color blue ] ]
;; turtles 0 through 49 are red, turtles 50
;; through 99 are blue
```

You can use the turtle reporter to retrieve a turtle with a given id number. See also turtle.

with**agentset with [reporter]**

Takes two inputs: on the left, an agentset (usually "turtles" or "patches"). On the right, a boolean reporter. Reports a new agentset containing only those agents that reported true -- in other words, the agents satisfying the given condition.

```
show count patches with [pcolor = red]
;; prints the number of red patches
```

with-max

agentset with-max [reporter]

Takes two inputs: on the left, an agentset (usually "turtles" or "patches"). On the right, a reporter. Reports a new agentset containing all agents reporting the maximum value of the given reporter.

```
show count patches with-max [pxcor]
;; prints the number of patches on the right edge
```

See also [max-one-of](#)

with-min

agentset with-min [reporter]

Takes two inputs: on the left, an agentset (usually "turtles" or "patches"). On the right, a reporter. Reports a new agentset containing only those agents that have the minimum value of the given reporter.

```
show count patches with-min [pycor]
;; prints the number of patches on the bottom edge
```

See also [min-one-of](#)

without-interruption

without-interruption [commands]

The agent runs all the commands in the block without allowing other agents to "interrupt". That is, other agents are put "on hold" and do not execute any commands until the commands in the block are finished.

```
crt 5
ask turtles
  [ without-interruption
    [ type 1 fd 1 type 2 ] ]
=> 1212121212
;; because each turtle will output 1 and move,
;; then output 2. however:
ask turtles
  [ type 1 fd 1 type 2 ]
=> 1111122222
;; because each turtle will output 1 and move,
;; then output 2
```

word

word value1 value2 ***(word value1 ... valuen)***

Concatenates the inputs together and reports the result as a string.

```

show word "tur" "tle"
=> "turtle"
word "a" 6
=> "a6"
set directory "c:\\foo\\fish\\"
show word directory "bar.txt"
=> "c:\\foo\\fish\\bar.txt"
show word [1 54 8] "fishy"
=> "[1 54 8]fishy"
show (word "a" "b" "c" 1 23)
=> "abc123"

```

wrap-color

wrap-color *number*

wrap-color checks whether *number* is in the NetLogo color range of 0 to 140 (not including 140 itself). If it is not, wrap-color "wraps" the numeric input to the 0 to 140 range.

The wrapping is done by repeatedly adding or subtracting 140 from the given number until it is in the 0 to 140 range. (This is the same wrapping that is done automatically if you assign an out-of-range number to the color turtle variable or pcolor patch variable.)

```

show wrap-color 150
=> 10
show wrap-color -10
=> 130

```

write

write *value*

This command will output *value*, which can be a number, string, list, boolean, or nobody to the Command Center *not* followed by a carriage return (unlike print and show).

The calling agent is *not* printed before the value, unlike show. Its output will also includes quotes around strings and is prepended with a space.

```

write "hello world"
=> "hello world"

```

See also print, show, and type.

See also output-write.

X

xcor

xcor

This is a built-in turtle variable. It holds the current x coordinate of the turtle. This is a floating point number, not an integer. You can set this variable to change the turtle's location.

This variable is always greater than or equal to $(- \text{screen-edge-x} - 0.5)$ and strictly less than $(\text{screen-edge-x} + 0.5)$.

See also [setxy](#), [ycor](#), [pxcor](#), [pycor](#).

xor***boolean1 xor boolean2***

Reports true if either *boolean1* or *boolean2* is true, but not when both are true.

```
if (pxcor > 0) xor (pycor > 0)
  [ set pcolor blue ]
;; upper-left and lower-right quadrants turn blue
```

Y**ycor****ycor**

This is a built-in turtle variable. It holds the current y coordinate of the turtle. This is a floating point number, not an integer. You can set this variable to change the turtle's location.

This variable is always greater than or equal to $(- \text{screen-edge-y} - 0.5)$ and strictly less than $(\text{screen-edge-y} + 0.5)$.

See also [setxy](#), [xcor](#), [pxcor](#), [pycor](#).

?**?****?, ?1, ?2, ...**

These are special local variables. They hold the current inputs to a reporter or command block for certain primitives (for example, the current item of a list being visited by [foreach](#) or [map](#)).

? is always equivalent to ?1.

You may not set these variables, and you may not use them except with certain primitives, currently [foreach](#), [map](#), [reduce](#), [filter](#), [sort-by](#), and [n-values](#). See those entries for example usage.

