

Snap! Reference Manual

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Introduction

 This a work in progress!

Welcome to the “new” Snap! manual. However, there are still many images and pages that need proper formatting and updates for version 11.

You may wish to read a very nicely typeset version of the manual.

Version 11.0

Snap! (formerly BYOB) is an extended reimplementation of Scratch (<https://scratch.mit.edu>) that allows you to Build Your Own Blocks. It also features first class lists, first class procedures, first class sprites, first class costumes, first class sounds, and first class continuations. These added capabilities make it suitable for a serious introduction to computer science for high school or college students.

In this manual we sometimes make reference to Scratch, e.g., to explain how some Snap! feature extends something familiar in Scratch. It’s very helpful to have some experience with Scratch before reading this manual, but not essential.

To run Snap!, open a browser window and visit <https://snap.berkeley.edu/snap>. The Snap! community web site at <https://snap.berkeley.edu> is covered briefly in [?@sec-appendix-community](#).

The manual is roughly organized into a few sections.

- Chapters 1 to 11 cover the primary features for writing programs in Snap!. They are organized from introductory to advanced topics.
- Chapters 12 and 13 cover the user interface components of both the Snap! editor and the community site.
- The appendices provide documentation for every block in Snap! block, as well as some of libraries provided.

The ‘New’ PDF Manual

this is currently a work in progress.

Acknowledgements

We have been extremely lucky in our mentors. Jens cut his teeth in the company of the Smalltalk pioneers: Alan Kay, Dan Ingalls, and the rest of the gang who invented personal computing and object oriented programming in the great days of Xerox PARC. He worked with John Maloney, of the MIT Scratch Team , who developed the Morphic graphics framework that's still at the heart of Snap!.

The brilliant design of Scratch, from the Lifelong Kindergarten Group at the MIT Media Lab , is crucial to Snap!. Our earlier version, BYOB, was a direct modification of the Scratch source code. Snap! is a complete rewrite, but its code structure and its user interface remain deeply indebted to Scratch. And the Scratch Team, who could have seen us as rivals, have been entirely supportive and welcoming to us.

Brian grew up at the MIT and Stanford Artificial Intelligence Labs , learning from Lisp inventor John McCarthy, Scheme inventors Gerald J. Sussman and Guy Steele , and the authors of the world's best computer science book, *Structure and Interpretation of Computer Programs* , Hal Abelson and Gerald J. Sussman with Julie Sussman , among many other heroes of computer science. (Brian was also lucky enough, while in high school, to meet Kenneth Iverson, the inventor of APL.)

In the glory days of the MIT Logo Lab, we used to say, “Logo is Lisp disguised as BASIC.” Now, with its first class procedures, lexical scope, and first class continuations, Snap! is Scheme disguised as Scratch.

Four people have made such massive contributions to the implementation of Snap! that we have officially declared them members of the team: Michael Ball and Bernat Romagosa, in addition to contributions throughout the project, have primary responsibility for the web site and cloud storage. Joan Guillén i Pelegay has contributed very careful and wise analysis of outstanding issues, including help in taming the management of translations to non-English languages. Jadga Hügle , has energetically contributed to online mini-courses about Snap! and leading workshops for kids and for adults. Jens, Jadga, and Bernat are paid to work on Snap! by SAP, which also supports our computing needs.

We have been fortunate to get to know an amazing group of brilliant middle school(!) and high school students through the Scratch Advanced Topics forum, several of whom (since grown up) have contributed code to Snap!: Kartik Chandra, Nathan Dinsmore , Connor Hudson, Ian Reynolds, and Deborah Servilla . Many more have contributed ideas and alpha-testing bug reports. UC Berkeley students who've contributed code include Achal Dave . Kyle Hotchkiss, Ivan Motyashov, and Yuan Yuan. Contributors of translations are too numerous to list here, but they're in the “About...” box in Snap! itself.

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1. Blocks, Scripts, and Sprites

This chapter describes the Snap! features inherited from Scratch; experienced Scratch users can skip to Section 1.2.

Snap! is a programming language—a notation in which you can tell a computer what you want it to do. Unlike most programming languages, though, Snap! is a *visual* language; instead of writing a program using the keyboard, the Snap! programmer uses the same drag-and-drop interface familiar to computer users.

Start Snap!. You should see the following arrangement of regions in the window:

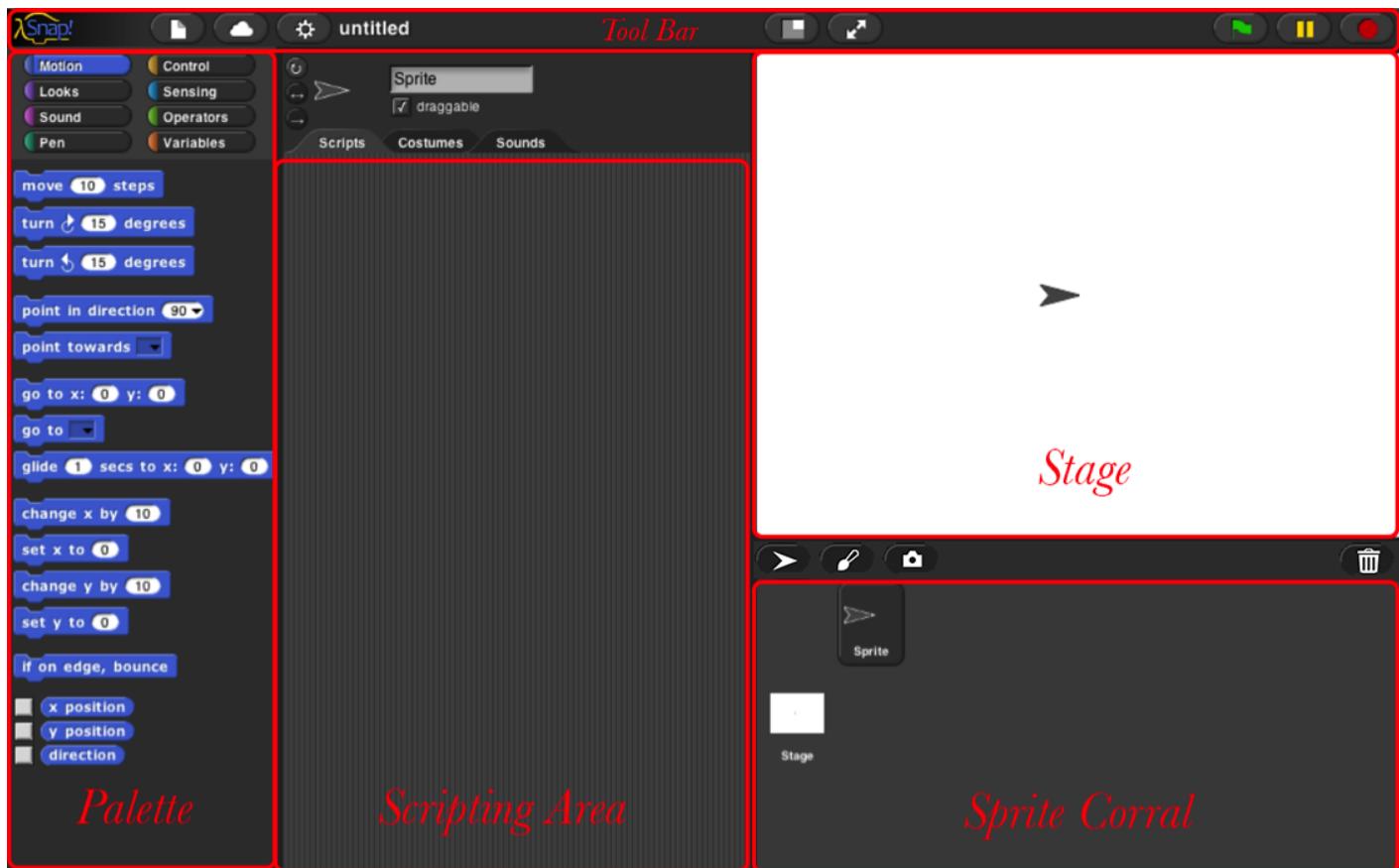
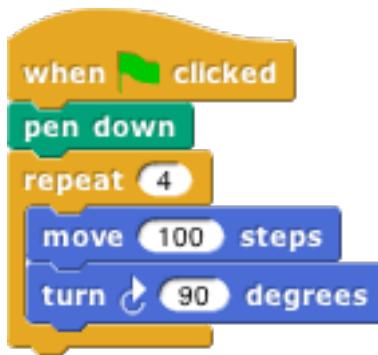


Figure 1.1.: An annotated screenshot of blank Snap! editor

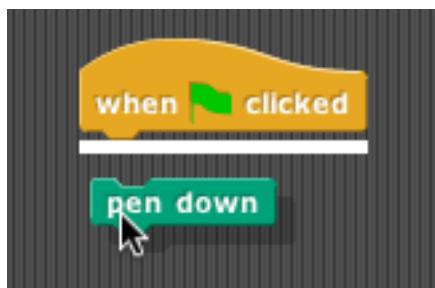
(The proportions of these areas may be different, depending on the size and shape of your browser window.)

A Snap! program consists of one or more *scripts*, each of which is made of *blocks*. Here's a typical script :

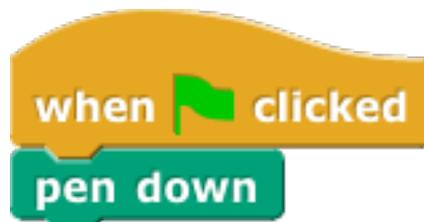
1. Blocks, Scripts, and Sprites



The five blocks that make up this script have three different colors, corresponding to three of the eight *palettes* in which blocks can be found. The palette area at the left edge of the window shows one palette at a time, chosen with the eight buttons just above the palette area. In this script, the gold blocks are from the Control palette; the green block is from the Pen palette; and the blue blocks are from the Motion palette. A script is assembled by dragging blocks from a palette into the *scripting area* in the middle part of the window. Blocks snap together (hence the name Snap! for the language) when you drag a block so that its indentation is near the tab of the one above it:



(a) image7.png



(b) image8.png

The white horizontal line is a signal that if you let go of the green block it will snap into the tab of the gold one.

1.1. Hat Blocks and Command Blocks

At the top of the script is a *hat block*, which indicates when the script should be carried out. Hat block names typically start with the word “when”; in the square-drawing example in [?@fig-draw-square](#), the script should be run when the green flag near the right end of the Snap! tool bar is clicked. (The Snap! tool bar is part of the Snap! window, not the same as the browser’s or operating system’s menu bar.) A script isn’t required to have a hat block , but if not, then the script will be run only if the user clicks on the script itself. A script can’t have more than one hat block, and the hat block can be used only at the top of the script; its distinctive shape is meant to remind you of that.¹

The other blocks in our example script are *command blocks* . Each command block corresponds to an action that



¹One of the hat blocks, the generic “when anything” block , is subtly different from the others. When the stop sign is clicked, or when a project or sprite is loaded, this block doesn’t test whether the condition in its hexagonal input slot is true, so the script beneath it will not run, until some *other* script in the project runs (because, for example, you click the green flag). When generic when blocks are disabled, the stop sign will be square instead of octagonal. {#para-generic-when}

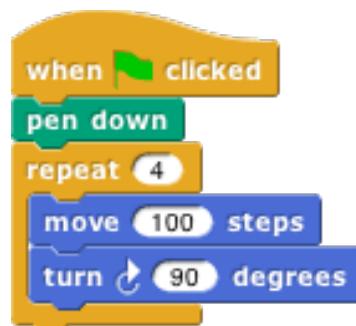


Snap! already knows how to carry out. For example, the block tells the sprite (the arrowhead shape on the *stage* at the right end of the window) to move ten steps (a step is a very small unit of distance) in the direction in which the arrowhead is pointing. We'll see shortly that there can be more than one sprite, and that each sprite has its own scripts. Also, a sprite doesn't have to look like an arrowhead, but can have any picture as a *costume*. The shape of the move block is meant to remind you of a Lego™ brick; a script is a stack of blocks. (The word "block" denotes both the graphical shape on the screen and the procedure, the action, that the block carries out.)

The number 10 in the *move* block above is called an *input* to the block. By clicking on the white oval, you can type any number in place of the 10. The sample script on the previous page uses 100 as the input value. We'll see later that inputs can have non-oval shapes that accept values other than numbers. We'll also see that you can compute input values, instead of typing a particular value into the oval. A block can have more than one input slot. For example, the *glide* block located about halfway down the Motion palette has three inputs.

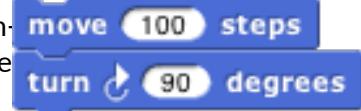
Most command blocks have that brick shape, but some, like the *repeat* block in the sample script, are C-shaped. Most C-shaped blocks are found in the Control palette. The slot inside the C shape is a special kind of input slot that accepts a *script* as the input.

In the sample script



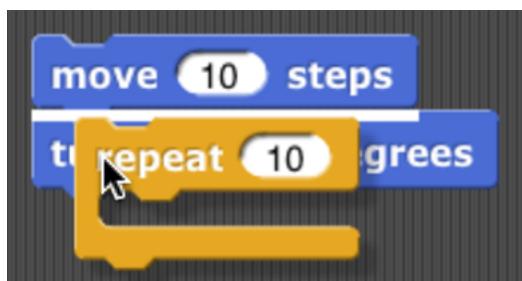
(a) image6.png

the *repeat* block has two inputs: the number 4 and the script



(a) image11.png

C-shaped blocks can be put in a script in two ways. If you see a white line and let go, the block will be inserted into the script like any command block:



(a) image12.png

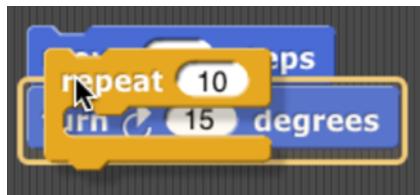


(a) image13.png

But if you see an orange halo and let go, the block will *wrap* around the haloed blocks:

The halo will always extend from the cursor position to the bottom of the script:

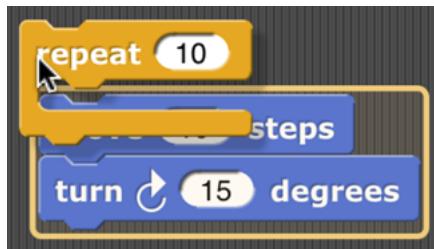
1. Blocks, Scripts, and Sprites



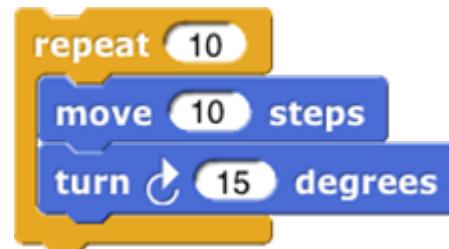
(a) image16.png



(a) image17.png



(a) image18.png



(a) image19.png

If you want only some of those blocks, after wrapping you can grab the first block you don't want wrapped, pull it down, and snap it under the C-shaped block.

For “E-shaped” blocks with more than one C-shaped slot, only the first slot will wrap around existing blocks in a script, and only if that C-shaped slot is empty before wrapping. (You can fill the other slots by dragging blocks into the desired slot.)

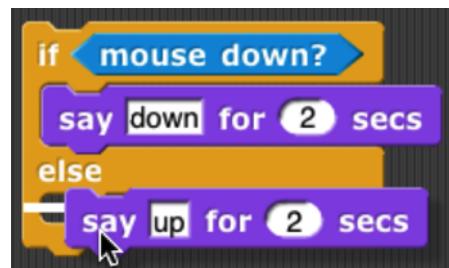


Figure 1.11.: image24.png

1.2. Sprites and Parallelism



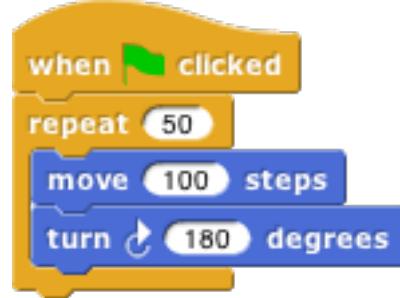
Just below the stage is the “new sprite button”. Click the button to add a new sprite to the stage. The new sprite will appear in a random position on the stage, with a random color, but always facing to the right.

Each sprite has its own scripts. To see the scripts for a particular sprite in the scripting area, click on the picture of that sprite in the *sprite corral* in the bottom right corner of the window. Try putting one of the following scripts in each sprite's scripting area:

When you click the green flag, you should see one sprite rotate while the other moves back and forth. This experiment illustrates the way different scripts can run in parallel. The turning and the moving happen together.

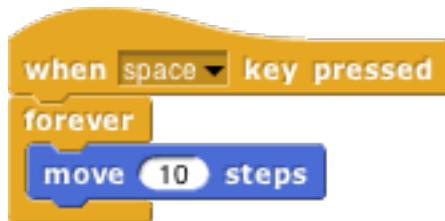


(a) image26.png

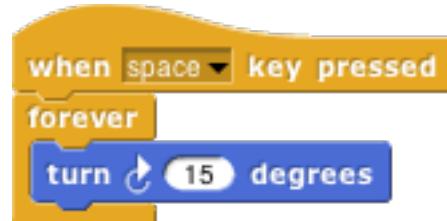


(a) image27.png

Parallelism can be seen with multiple scripts of a single sprite also. Try this example:



(a) image28.png



(a) image29.png

When you click the green flag, the sprite should move back and forth

When you press the space key, the sprite should move forever in a circle, because the move and turn blocks are run in parallel. (To stop the program, click the red stop sign at the right end of the tool bar.)

1.2.1. Costumes and Sounds

To change the appearance of a sprite, paint or import a new *costume* for it. To paint a costume, click on the Costumes tab above the scripting area, and click the paint button . The *Paint Editor* that appears is explained in Section 12.3.5. There are three ways to import a costume. First select the desired sprite in the sprite corral.

Then, one way is to click on the file icon in the tool bar, then choose the "Costumes..." menu item. You will see a list of costumes from the public media library, and can choose one. The second way, for a costume stored on your own computer, is to click on the file icon and choose the "Import..." menu item. You can then select a file in any picture format (PNG, JPEG, etc.) supported by your browser. The third way is quicker if the file you want is visible on the desktop: Just drag the file onto the Snap! window. In any of these cases, the scripting area will be replaced by something like this:



1. Blocks, Scripts, and Sprites



Figure 1.16.: image31.png

Just above this part of the window is a set of three tabs: Scripts, Costumes, and Sounds. You'll see that the Costumes tab is now selected. In this view, the sprite's *wardrobe*, you can choose whether the sprite should wear its Turtle costume or its Alonzo costume. (Alonzo, the Snap! mascot, is named after Alonzo Church, a mathematician who invented the idea of procedures as data, the most important way in which Snap! is different from Scratch.) You can give a sprite as many costumes as you like, and then choose which it will wear either by clicking in its wardrobe



or by using the

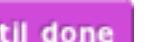
or

block in a script. (Every costume has a number as well as a name. The next costume block selects the next costume by number; after the highest-numbered costume it switches to costume 1. The Turtle, costume 0, is never chosen by next costume.) The Turtle costume is the only one that changes color to match a change in the sprite's pen color.

Tip

Protip: **switch to costume**  - 1 switches to the previous costume, wrapping like `next costume`.

In addition to its costumes, a sprite can have sounds; the equivalent for sounds of the sprite's wardrobe is called its *jukebox*. Sound files can be imported in any format (WAV, OGG, MP3, etc.) supported by your browser. Two blocks accomplish the task of playing sounds. If you would like a script to continue running while the sound is playing, use

the block **play sound**  . In contrast, you can use the block **play sound**  **until done**  to wait for the sound's completion before continuing the rest of the script.

1.2.2. Inter-Sprite Communication with Broadcast

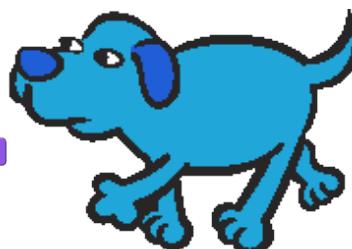
Earlier we saw an example of two sprites moving at the same time. In a more interesting program, though, the sprites on stage will *interact* to tell a story, play a game, etc. Often one sprite will have to tell another sprite to run a script. Here's a simple example:



(a) image41.png

```
when green flag clicked
say Hi! What's your name? for 2 secs
broadcast bark and wait
say Hi, Woof! What do you like to do? for 2 secs
broadcast bark and wait
say What a coincidence! for 2 secs
```

(b) image42.png



(c) image43.png

```
when I receive bark
say Woof! for 2 secs
```

(d) image44.png

broadcast bark ▾ ▶ and wait

In the block

the word “bark” is just an arbitrary name I made up. When you click on the downward arrowhead in that input slot, one of the choices (the only choice, the first time) is “new,” which then prompts you to enter a name for the new broadcast. When this block is run, the chosen message is sent to every sprite, which is why the block is called “broadcast.” (But if you click the right arrow after the message name, the block becomes

broadcast bark ▾ to all ▾ ▶ and wait

broadcast bark ▾ to dog ▾ ▶ and

and you can change it to

to send the message just to one sprite.) In this program, though, only one sprite has a script to run when that broadcast is sent, namely the dog. Because the boy’s script uses broadcast and wait rather than just broadcast, the boy doesn’t go on to his next say block until the dog’s script finishes. That’s why the two sprites take turns talking, instead of both talking at once. In Chapter 7 you’ll see a more flexible way to send a message to a specific sprite using the tell and ask blocks.

Notice, by the way, that the say block’s first input slot is rectangular rather than oval. This means the input can be any text string, not only a number. In text input slots, a space character is shown as a brown dot, so that you can count the number of spaces between words, and in particular you can tell the difference between an empty slot and one containing spaces. The brown dots are *not* shown on the stage if the text is displayed.

The stage has its own scripting area. It can be selected by clicking on the Stage icon at the left of the sprite corral. Unlike a sprite, though, the stage can’t move. Instead of costumes, it has *backgrounds*: pictures that fill the entire

1. Blocks, Scripts, and Sprites

stage area. The sprites appear in front of the current background. In a complicated project, it's often convenient to use a script in the stage's scripting area as the overall director of the action.

1.3. Nesting Sprites: Anchors and Parts

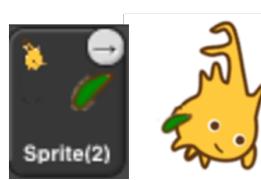
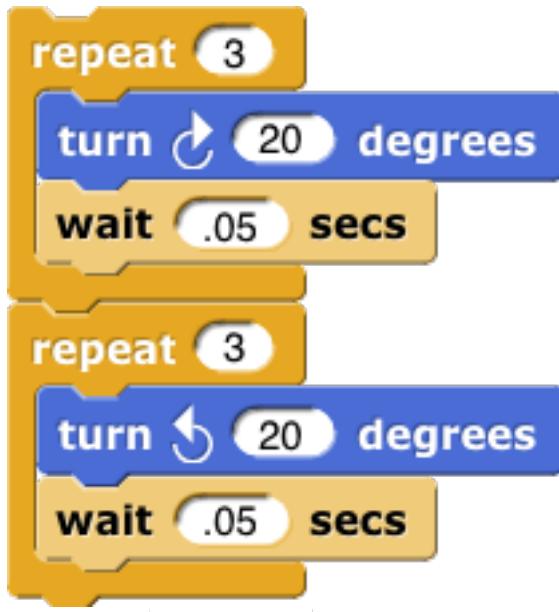
Sometimes it's desirable to make a sort of "super-sprite" composed of pieces that can move together but can also be separately articulated. The classic example is a person's body made up of a torso, limbs, and a head. Snap! allows one sprite to be designated as the *anchor* of the combined shape, with other sprites as its *parts*.

To set up sprite nesting , drag the sprite corral icon of a *part* sprite onto the stage display (not the sprite corral icon!) of the desired *anchor* sprite. The precise place where you let go of the mouse button will be the attachment point of the part on the anchor.



Sprite nesting is shown in the sprite corral icons of both anchors and parts:

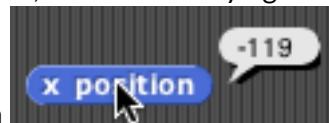
In this illustration, it is desired to animate Alonzo's arm. (The arm has been colored green in this picture to make the relationship of the two sprites clearer, but in a real project they'd be the same color, probably.) Sprite, representing Alonzo's body, is the anchor; Sprite(2) is the arm. The icon for the anchor shows small images of up to three attached parts at the bottom. The icon for each part shows a small image of the anchor in its top left corner, and a *synchronous dangling rotation flag* in the top right corner. In its initial, synchronous setting, as shown above, it means that the when the anchor sprite rotates, the part sprite also rotates as well as revolving around the anchor. When clicked, it changes from a circular arrow to a straight arrow, and indicates that when the anchor sprite rotates, the part sprite revolves around it, but does not rotate, keeping its original orientation. (The part can also be rotated separately, using its turn blocks.) Any change in the position or size of the anchor is always extended to its parts. Also, cloning the anchor (see Section VII. B) will also clone all its parts.



Top: turning the part: the green arm. Bottom: turning the anchor, with the arm synchronous (left) and dangling (right).

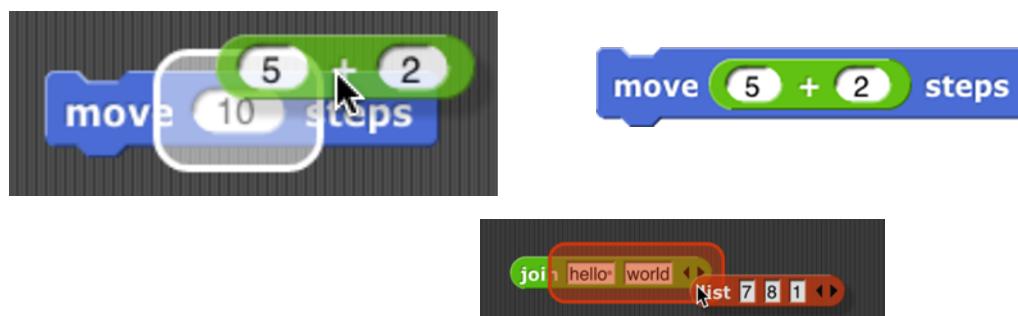
1.4. Reporter Blocks and Expressions

So far, we've used two kinds of blocks: hat blocks and command blocks. Another kind is the *reporter* block, which has an oval shape: **x position**. It's called a "reporter" because when it's run, instead of carrying out an action,



it reports a value that can be used as an input to another block. If you drag a reporter block into the scripting area by itself and click on it, the value it reports will appear in a speech balloon next to the block:

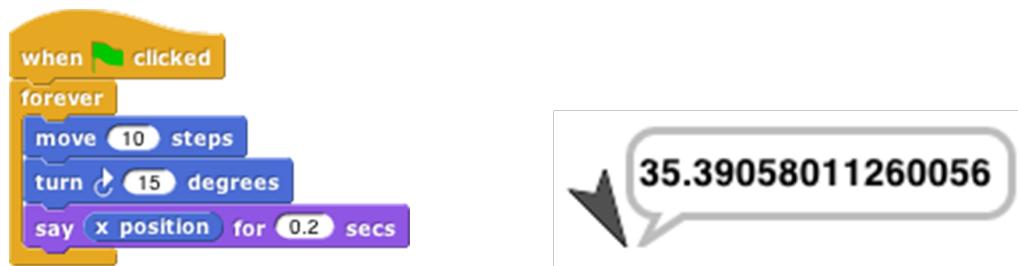
When you drag a reporter block over another block's input slot, a white "halo" appears around that input slot, analogous to the white line that appears when snapping command blocks together:



Don't drop the input over a *red* halo:

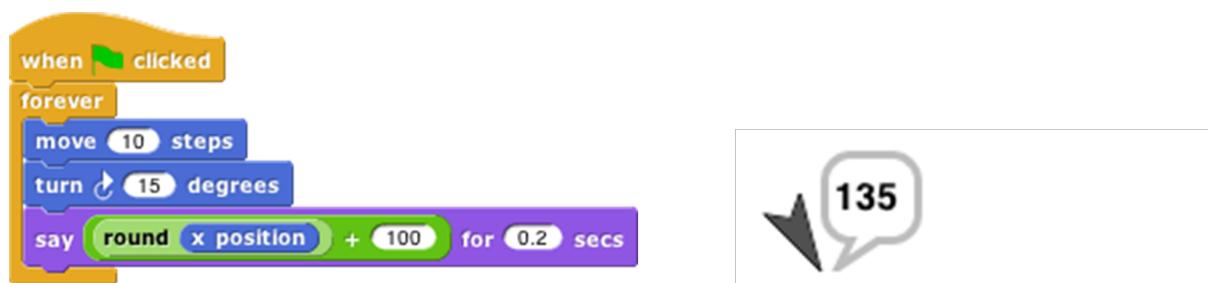
That's used for a purpose explained in Section 6.2.1.

Here's a simple script that uses a reporter block:



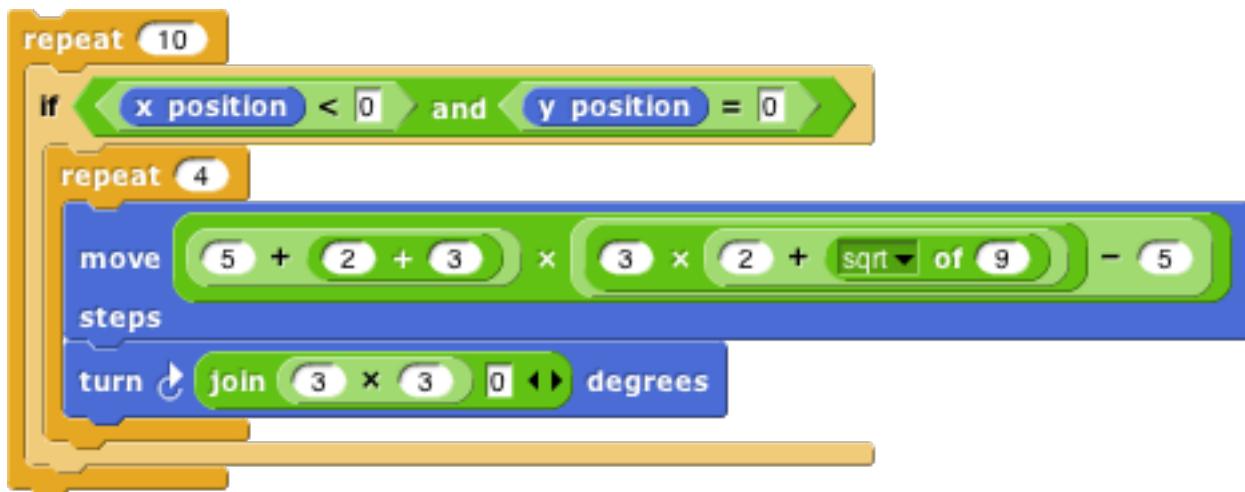
Here the *x position* reporter provides the first input to the *say* block. (The sprite's X position is its horizontal position, how far left (negative values) or right (positive values) it is compared to the center of the stage. Similarly, the Y position is measured vertically, in steps above (positive) or below (negative) the center.)

You can do arithmetic using reporters in the Operators palette:



1. Blocks, Scripts, and Sprites

The round block rounds 35.3905... to 35, and the + block adds 100 to that. (By the way, the round block is in the Operators palette, just like +, but in this script it's a lighter color with black lettering because Snap! alternates light and dark versions of the palette colors when a block is nested inside another block from the same palette:



This aid to readability is called *zebra coloring*. A reporter block with its inputs, maybe including other reporter blocks, such as `round (x position) + (100)`, is called an *expression*.

1.5. Predicates and Conditional Evaluation

Most reporters report either a number, like



, or a



text string, like . A *predicate* is a special kind of reporter that always reports true or false. Predicates have a hexagonal shape:



The special shape is a reminder that predicates don't generally make sense in an input slot of blocks that are

expecting a number or text. You wouldn't say , although (as you can see from the picture) Snap! lets you do it if you really want. Instead, you normally use predicates in special hexagonal input slots like this one:

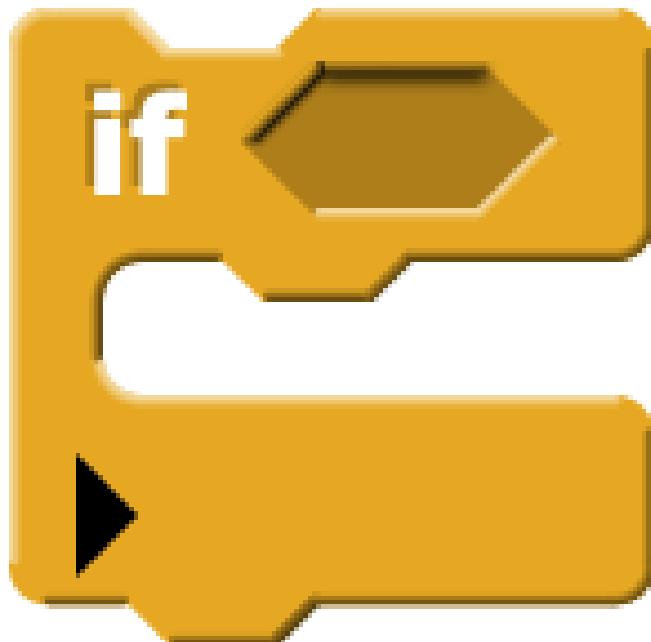


Figure 1.18.: image86.png

The C-shaped if block runs its input script if (and only if) the expression in its hexagonal input reports true.

```
if < y position < 0 >
say Help! I'm underwater!
```

```
point towards Sprite2
repeat until touching
move (3) steps
```

A really useful block in animations runs its input script *repeatedly* until a predicate is satisfied:

If, while working on a project, you want to omit temporarily some commands in a script, but you don't want to forget where they belong, you can say

```
move (10) steps
turn (15) degrees
if (false)
say I'm not going to do this. for (2) secs
glide (1) secs to x: (0) y: (0)
point in direction (90)
```

Sometimes you want to take the same action whether some condition is true or false, but with a different input value. For this purpose you can use the *reporter if* block :

```
say join I'm on the if < x position < 0 > then left else right
```

1. Blocks, Scripts, and Sprites

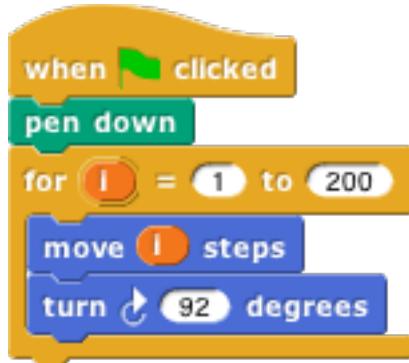
The technical term for a true or false value is a “Boolean” value; it has a capital B because it’s named after a person, George Boole, who developed the mathematical theory of Boolean values. Don’t get confused; a hexagonal block is a *predicate*, but the value it reports is a *Boolean*.

Another quibble about vocabulary: Many programming languages reserve the name “procedure” for Commands (that carry out an action) and use the name “function” for Reporters and Predicates. In this manual, a *procedure* is any computational capability, including those that report values and those that don’t. Commands, Reporters, and Predicates are all procedures. The words “a Procedure type” are shorthand for “Command type, Reporter type, or Predicate type.”

If you want to put a *constant* Boolean value in a hexagonal slot instead of a predicate-based expression, hover the mouse over the block and click on the control that appears:



1.6. Variables



Try this script:

The input to the move block is an orange oval. To get it there, drag the orange oval that’s part of the for block :



The orange oval is a *variable*: a symbol that represents a value. (I took this screenshot before changing the second number input to the for block from the default 10 to 200, and before dragging in a turn block.) For runs its script input repeatedly, just like repeat, but before each repetition it sets the variable i to a number starting with its first numeric input, adding 1 for each repetition, until it reaches the second numeric input. In this case, there will be 200 repetitions, first with i=1, then with i=2, then i=3, and so on until i=200 for the final repetition. The result is that each move draws a longer and longer line segment, and that’s why the picture you see is a kind of spiral. (If you try again with a turn of 90 degrees instead of 92, you’ll see why this picture is called a “squiral.”)

The variable i is created by the for block, and it can only be used in the script inside the block’s C-slot. (By the way, if you don’t like the name i, you can change it by clicking on the orange oval

without dragging it, which will pop up a dialog window in which you can enter a different name:



"I" isn't a very descriptive name; you might prefer "length" to indicate its purpose in the script. "I" is traditional because mathematicians tend to use letters between i and n to represent integer values, but in programming languages we don't have to restrict ourselves to single-letter variable names.)

1.6.1. Global Variables

You can create variables "by hand" that aren't limited to being used within a single block. At the top of the Variables palette, click the "Make a variable" button:



This will bring up a dialog window in which you can give your variable a name:

1. Blocks, Scripts, and Sprites



The dialog also gives you a choice to make the variable available to all sprites (which is almost always what you want) or to make it visible only in the current sprite. You'd do that if you're going to give several sprites individual variables *with the same name*, so that you can share a script between sprites (by dragging it from the current sprite's scripting area to the picture of another sprite in the sprite corral), and the different sprites will do slightly different things when running that script because each has a different value for that variable name.

If you give your variable the name "name" then the Variables palette will look like this:



There's now a "Delete a variable" button, and there's an orange oval with the variable name in it, just like the orange oval in the for block. You can drag the variable into any script in the scripting area. Next to the oval is a checkbox,

initially checked. When it's checked, you'll also see a *variable watcher* on the stage:



When you give the variable a value, the orange box in its watcher will display the value.



How do you give it a value? You use the set block :

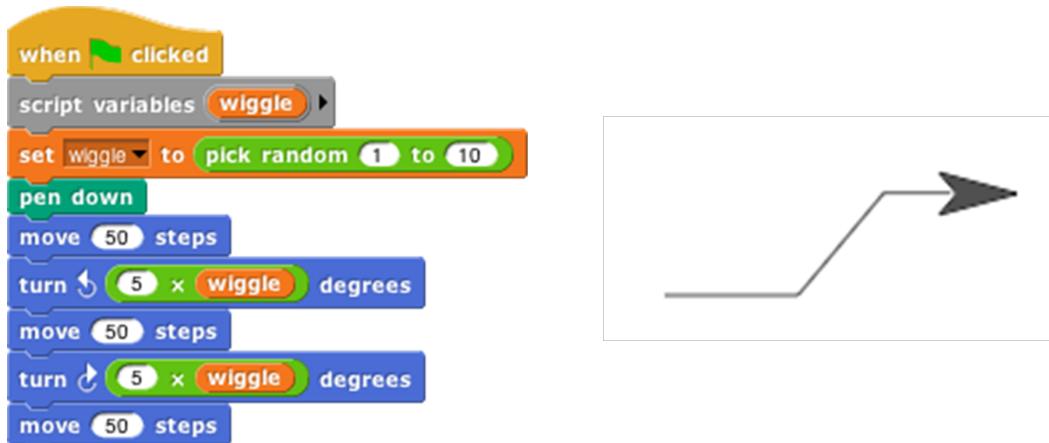
Note that you *don't* drag the variable's oval into the set block! You click on the downarrow in the first input slot, and you get a menu of all the available variable names.

If you do choose "For this sprite only" when creating a variable, its block in the palette looks like this: variable

The location-pin icon is a bit of a pun on a sprite-local variable . It's shown only in the palette.

1.6.2. Script Variables

In the name example above, our project is going to carry on an interaction with the user, and we want to remember their name throughout the project. That's a good example of a situation in which a *global* variable (the kind you make with the "Make a variable" button) is appropriate. Another common example is a variable called "score" in a game project. But sometimes you only need a variable temporarily, during the running of a particular script. In that case you can use the script variables block to make the variable:



As in the `for` block, you can click on an orange oval in the script variables block without dragging to change its name. You can also make more than one temporary variable by clicking on the right arrow at the end of the block to add another variable oval:



1.6.3. Renaming variables

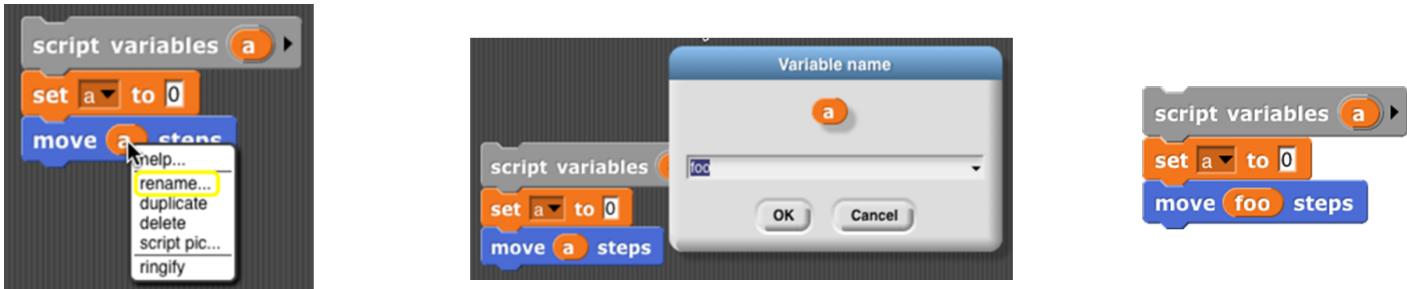
There are several reasons why you might want to change the name of a variable:

1. It has a default name, such as the `a` in `script variables` or the `i` in the `for` block.
2. It conflicts with another name, such as a global variable, that you want to use in the same script.
3. You just decide a different name would be more self-documenting.

1. Blocks, Scripts, and Sprites

In the first and third case, you probably want to change the name everywhere it appears in that script, or even in all scripts. In the second case, if you've already used both variables in the script before realizing that they have the same name, you'll want to look at each instance separately to decide which ones to rename. Both of these operations are possible by right-clicking or control-clicking on a variable oval.

If you right-click on an orange oval in a context in which the variable is *used*, then you are able to rename just that one orange oval:



If you right-click on the place where the variable is *defined* (a script variables block, the orange oval for a global variable in the Variables palette, or an orange oval that's built into a block such as the "i" in for), then you are given two renaming options, "rename" and "rename all." If you choose "rename," then the name is changed only in that one orange oval, as in the previous case:



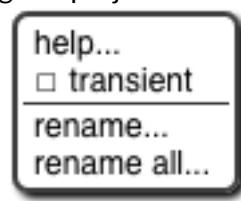
But if you choose "rename all," then the name will be changed throughout the scope of the variable (the script for a script variable, or everywhere for a global variable):

1.6.4. Transient variables

So far we've talked about variables with numeric values, or with short text strings such as someone's name. But there's no limit to the amount of information you can put in a variable; in Chapter IV you'll see how to use *lists* to collect many values in one data structure, and in Chapter VIII you'll see how to read information from web sites.



When you use these capabilities, your project may take up a lot of memory in the computer. If you get close to the amount of memory available to Snap!, then it may become impossible to save your project. (Extra space is needed temporarily to convert from Snap!'s internal representation to the form in which projects are exported or saved.) If your program reads a lot of data from the outside world that will still be available when you use it next, you might want to have values containing a lot of data removed from memory before saving the project. To do this,



right-click or control-click on the orange oval in the Variables palette, to see this menu:

You already know about the rename options, and “help...” displays a help screen about variables in general. Here we’re interested in the check box next to transient. If you check it, this variable’s value will not be saved when you save your project. Of course, you’ll have to ensure that when your project is loaded, it recreates the needed value and sets the variable to it.

1.7. Debugging

Snap! provides several tools to help you debug a program. They center around the idea of *pausing* the running of a script partway through, so that you can examine the values of variables.

1.7.1. The pause button

The simplest way to pause a program is manually, by clicking the pause button  in the top right corner of the window. While the program is paused, you can run other scripts by clicking on them, show variables on stage with the checkbox next to the variable in the Variables palette or with the `show variable` block, and do all the other things you can generally do, including modifying the paused scripts by adding or removing blocks. The  button changes shape too and clicking it again resumes the paused scripts.

1.7.2. Breakpoints : the pause all block

The pause button is great if your program seems to be in an infinite loop, but more often you’ll want to set a *breakpoint*, a particular point in a script at which you want to pause. The



block, near the bottom of the Control palette, can be inserted in a script to pause when it is run. So, for example, if your program is getting an error message in a particular block, you could use `pause all` just before that block to look at the values of variables just before the error happens.

The `pause all` block turns bright cyan while paused. Also, during the pause, you can right-click on a running script and the menu that appears will give you the option to show watchers for temporary variables of the script:



Figure 1.19.: image118.png

But what if the block with the error is run many times in a loop, and it only errors when a particular condition is true – for example, when the value of some variable is negative, which shouldn’t ever happen. In the iteration library (see Section 1.9 for more about how to use libraries) is a breakpoint block that lets you set a *conditional* breakpoint, and automatically display the relevant variables before pausing. Here’s a sample use of it:



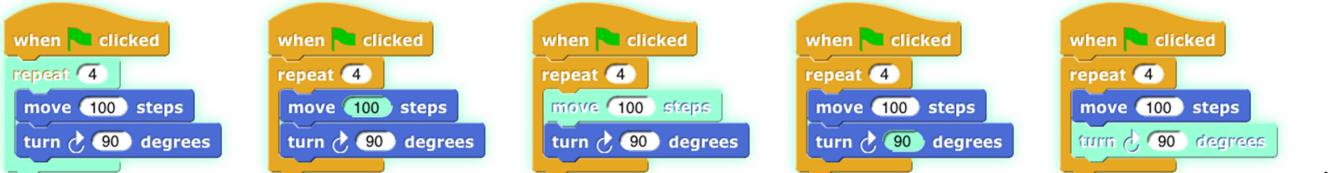
(In this contrived example, variable zot comes from outside the script but is relevant to its behavior.) When you continue (with the pause button), the temporary variable watchers are removed by this breakpoint block before resuming the script. The breakpoint block isn't magic; you could alternatively just put a pause all inside an if.²

1.7.3. Visible stepping

Sometimes you're not exactly sure where the error is, or you don't understand how the program got there. To understand better, you'd like to watch the program as it runs, at human speed rather than at computer speed. You

can do this by clicking the *visible stepping* button (), before running a script or while the script is paused.

The button will light up () and a speed control slider  will appear in the toolbar. When you start or continue the script, its blocks and input slots will light up cyan one at a time:



In this simple example, the inputs to the blocks are constant values, but if an input were a more complicated expression involving several reporter blocks, each of those would light up as they are called. Note that the input to a block is evaluated before the block itself is called, so, for example, the 100 lights up before the move.

²The hide variable and show variable blocks can also be used to hide and show primitives in the palette. The pulldown menu doesn't include primitive blocks, but there's a generally useful technique to give a block input values it wasn't expecting using run or



In order to use a block as an input this way, you must explicitly put a ring around it, by right-clicking on it and choosing ringify. More about rings in Chapter VI.

The speed of stepping is controlled by the slider. If you move the slider all the way to the left, the speed is zero, the pause button turns into a step button  , and the script takes a single step each time you push it. The name for this is *single stepping*.

If several scripts that are visible in the scripting area are running at the same time, all of them are stepped in parallel. However, consider the case of two repeat loops with different numbers of blocks. While not stepping, each script goes through a complete cycle of its loop in each display cycle, despite the difference in the length of a cycle. In order to ensure that the visible result of a program on the stage is the same when stepped as when not stepped, the shorter script will wait at the bottom of its loop for the longer script to catch up.

When we talk about custom blocks in Chapter 3, we'll have more to say about visible stepping as it affects those blocks.

1.8. Etcetera

This manual doesn't (yet) explain every block in detail. There are many more motion blocks, sound blocks, costume and graphics effects blocks, and so on. If you would like to find information on specific blocks, go to [?@sec-all-blocks](#). You can also learn what they all do by experimentation, and by reading the "help screens" that you can get by right-clicking or control-clicking a block and selecting "help..." from the menu that appears. If you forget what palette (color) a block is, but you remember at least part of its name, type control-F and enter the name in the text block that appears in the palette area.

Here are some of the primitive blocks that don't exist in Scratch:

pen trails

reports, a new costume consisting of everything that's drawn on the stage by any sprite.

Right-clicking the block in the scripting area gives the option to change it to  if vector logging is enabled. See [?@para-log-pen-vectors](#).

write Hello! size 12

Print characters in the given point size on the stage, at the sprite's position and in its direction. The sprite moves to the end of the text. (That's not always what you want, but you can save the sprite's position before using it, and sometimes you need to know how big the text turned out to be, in turtle steps.) If the pen is down, the text will be underlined.



Takes a sprite as input. Like stamp except that the costume is stamped onto the selected sprite instead of onto the stage. (Does nothing if the current sprite doesn't overlap the chosen sprite.)



Takes a sprite as input. Erases from that sprite's costume the area that overlaps with the current sprite's costume. (Does not affect the costume in the chosen sprite's

1. Blocks, Scripts, and Sprites

wardrobe, only the copy currently visible.)



See ?@fig-generic-when.



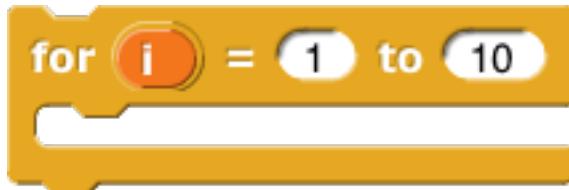
See Section 1.7.2.



Runs only this script until finished. In the Control palette even though it's gray.



Reporter version of the if/else primitive command block . Only one of the two branches is evaluated, depending on the value of the first input.



Looping block like repeat but with an index variable .



Declare local variables in a script.



See Chapter 9.



reports the value of a graphics effect.



Constant true or false value. See ?@sec-predicates-and-conditional-evaluation.



Figure 1.20.: image149.png

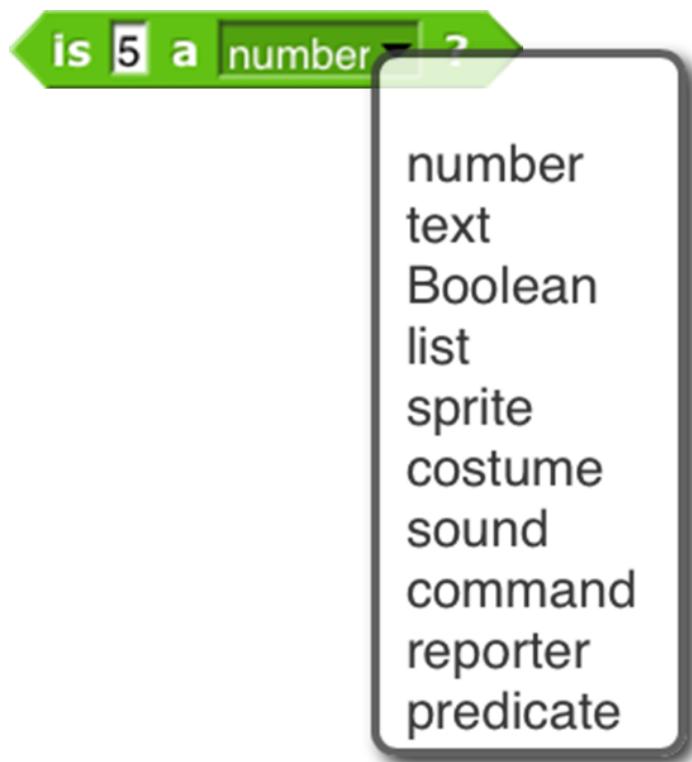


Create a primitive using JavaScript. (This block is disabled by default; the user must check "Javascript extensions" in the setting menu each time a project is loaded.)



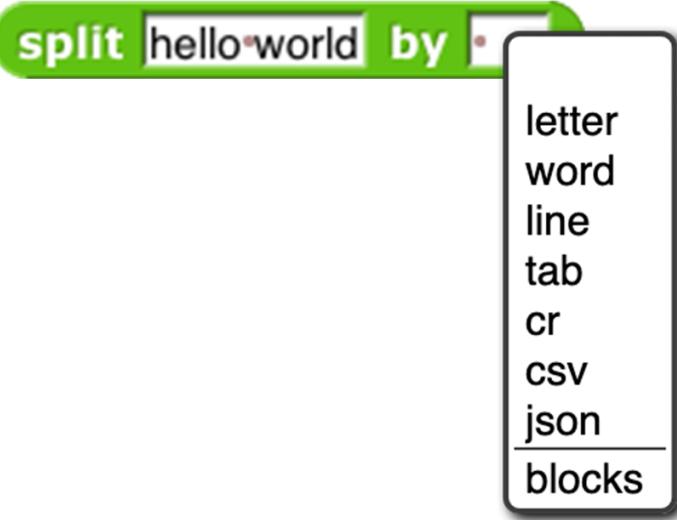
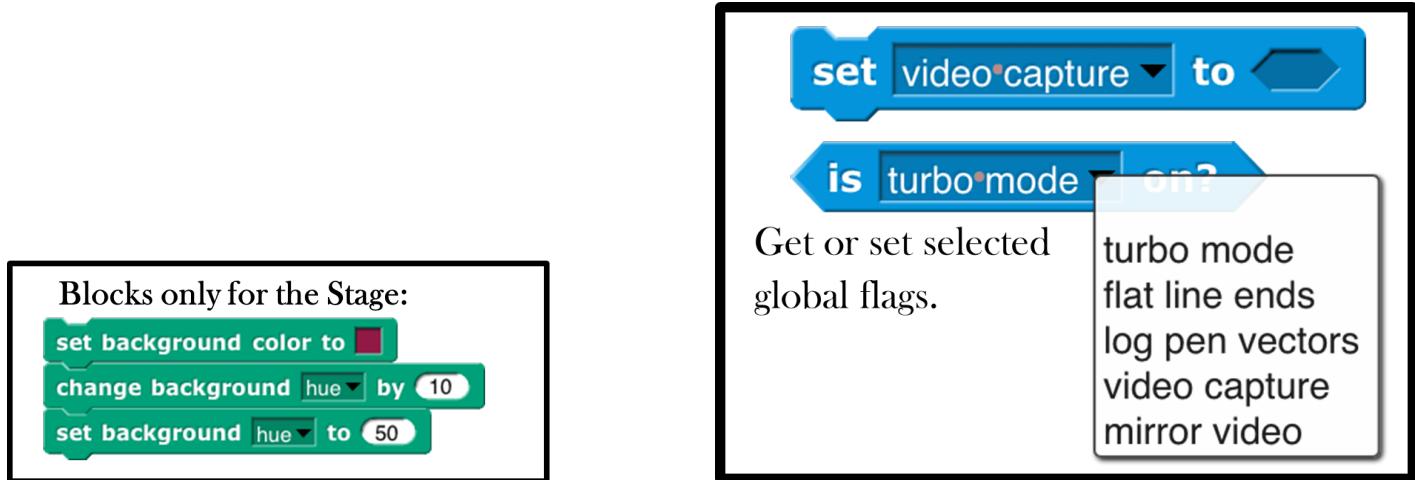
Figure 1.21.: image150.png

The at block lets you examine the screen pixel directly behind the rotation center of a sprite, the mouse, or an arbitrary (x,y) coordinate pair dropped onto the second menu slot. The first five items of the left menu let you examine the color visible at the position. (The “RGBA” option reports a list.) The “sprites” option reports a list of all sprites, including this one, any point of which overlaps this sprite’s rotation center (behind or in front). This is a hyperblock with respect to its second input.



Checks the data type of a value.

1. Blocks, Scripts, and Sprites



Turn the text into a list, using the second input as the delimiter between items. The default delimiter, indicated by the brown dot in the input slot, is a single space character. “Letter” puts each character of the text in its own list item. “Word” puts each word in an item. (Words are separated by any number of consecutive space, tab, carriage return, or newline characters.) “Line” is a newline character (0xa); “tab” is a tab character (0x9); “cr” is a carriage return (0xd). “Csv” and “json” split formatted text into lists of lists; see Section 4.5.1. “Blocks” takes a script as the first input, reporting a list structure representing the structure of the script. See Chapter XI.



{.image-2x} For lists, reports true only if its two input values are the very same list, so changing an item in one of them is visible in the other. (For =, lists that look the same are the same.) For text strings, uses case-sensitive comparison, unlike =, which is case-independent.

atan2 **÷** **max** **min** These *hidden* blocks can be found with the relabel option of any dyadic arithmetic block. They're hidden partly because writing them in Snap! is a good, pretty easy programming exercise. Note: the two inputs to atan2 are Δx and Δy in that order, because we measure angles clockwise from north. max /index{max block} and min /index{min block} are variadic; by clicking the arrowhead, you can provide additional inputs.



Similarly, these hidden predicates can be found by relabeling the relational predicates.

1.8.1. Metaprogramming (see Chapter 11)



Figure 1.22.: image172.png

These blocks support *metaprogramming*, which means manipulating blocks and scripts as data. This is not the same as manipulating procedures (see Chapter VI.), which are what the blocks *mean*; in metaprogramming the actual blocks, what you see on the screen, are the data. This capability is new in version 8.0.

1.8.2. First class list blocks (see Chapter IV, page46):

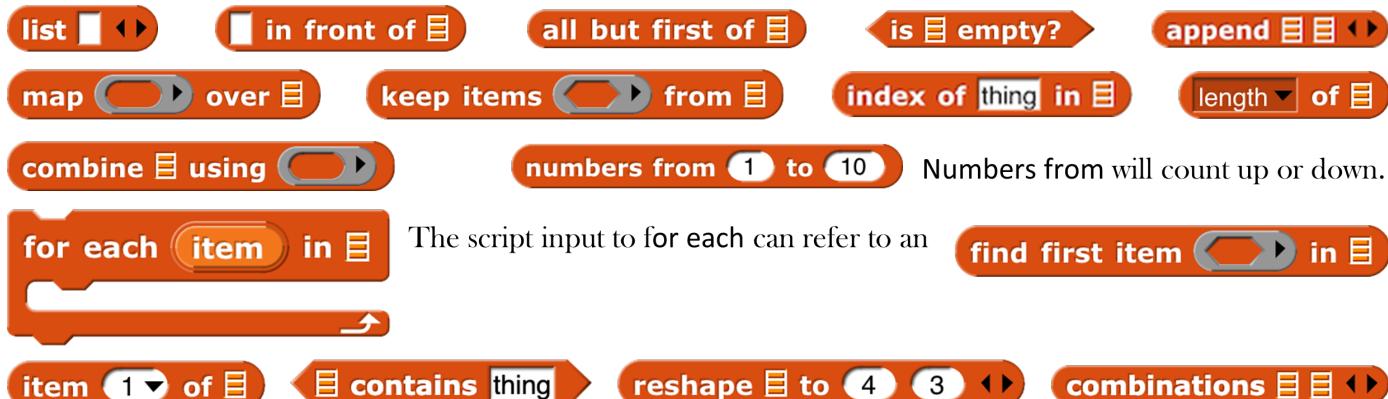


Figure 1.23.: image173.png

Numbers from will count up or down.



First class procedure blocks (see Chapter VI, page65):

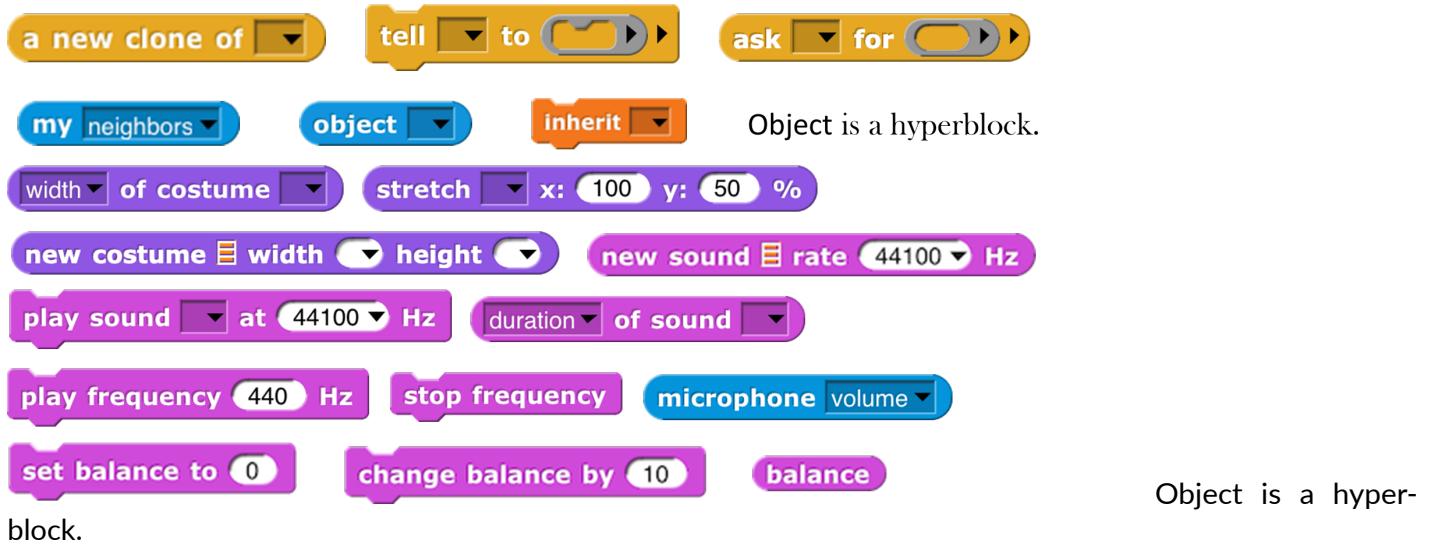


First class continuation blocks (see Chapter X, page93):

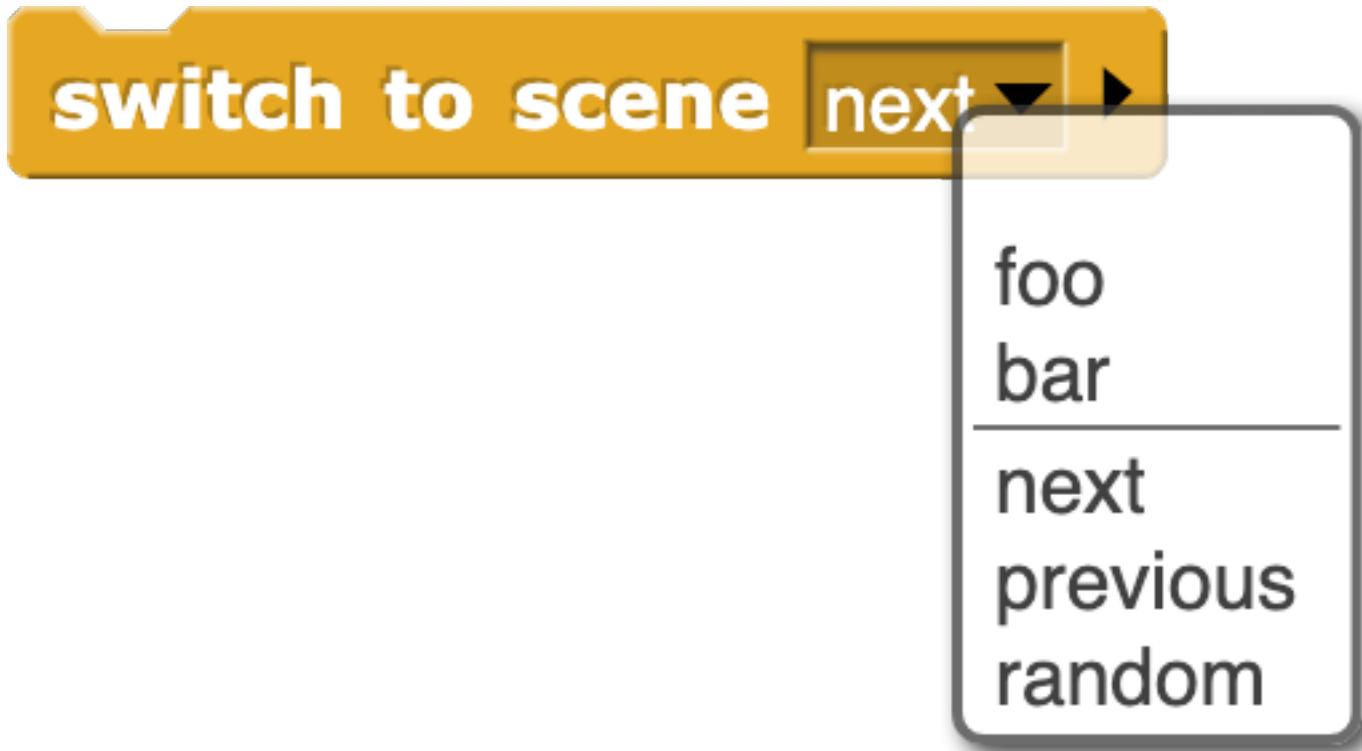


First class sprite, costume, and sound blocks (see Chapter VII, page73):

1. Blocks, Scripts, and Sprites



Scenes:



The major new feature of version 7.0 is *scenes*: A project can include within it sub-projects, called scenes, each with its own stage, sprites, scripts, and so on. This block makes another scene active, replacing the current one.

Nothing is automatically shared between scenes: no sprites, no blocks, no variables. But the old scene can send a message to the new one, to start it running, with optional payload as in broadcast (See [?@sec-broadcast](#)).



Figure 1.24.: image282.png

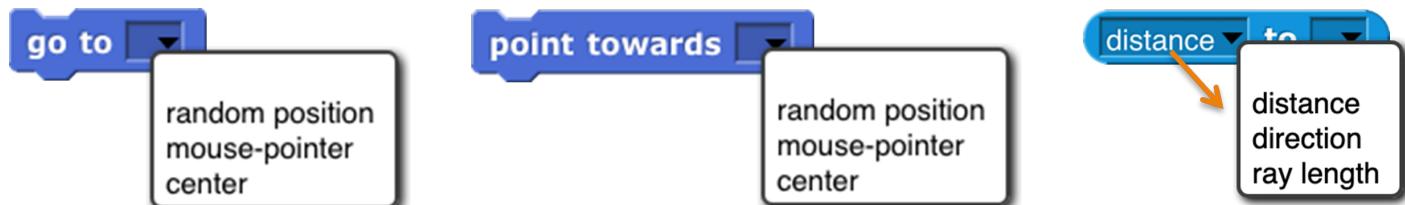
In particular, you can say



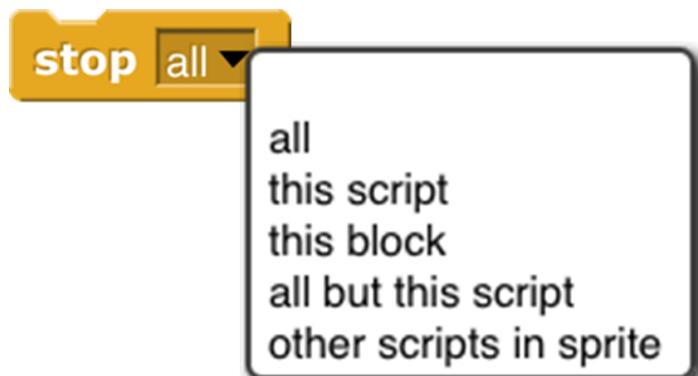
Figure 1.25.: image281.png

if the new scene expects to be started with a green flag signal.

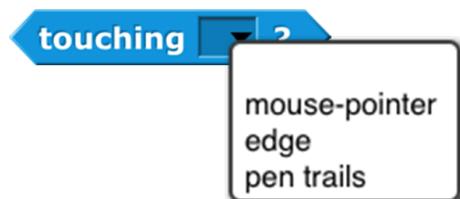
These aren't new blocks but they have a new feature: These accept two-item (x,y) lists as input, and have extended menus (also including other sprites):



"Center" means the center of the stage, the point at (0,0). "Direction" is in the point in direction sense, the direction that would leave this sprite pointing toward another sprite, the mouse, or the center. "Ray length" is the distance from the center of this sprite to the nearest point on the other sprite, in the current direction.



{image-inline} The stop block has two extra menu choices. Stop this block is used inside the definition of a custom block to stop just this invocation of this custom block and continue the script that called it. Stop all but this script is good at the end of a game to stop all the game pieces from moving around, but keep running this script to provide the user's final score. The last two menu choices add a tab at the bottom of the block because the current script can continue after it.

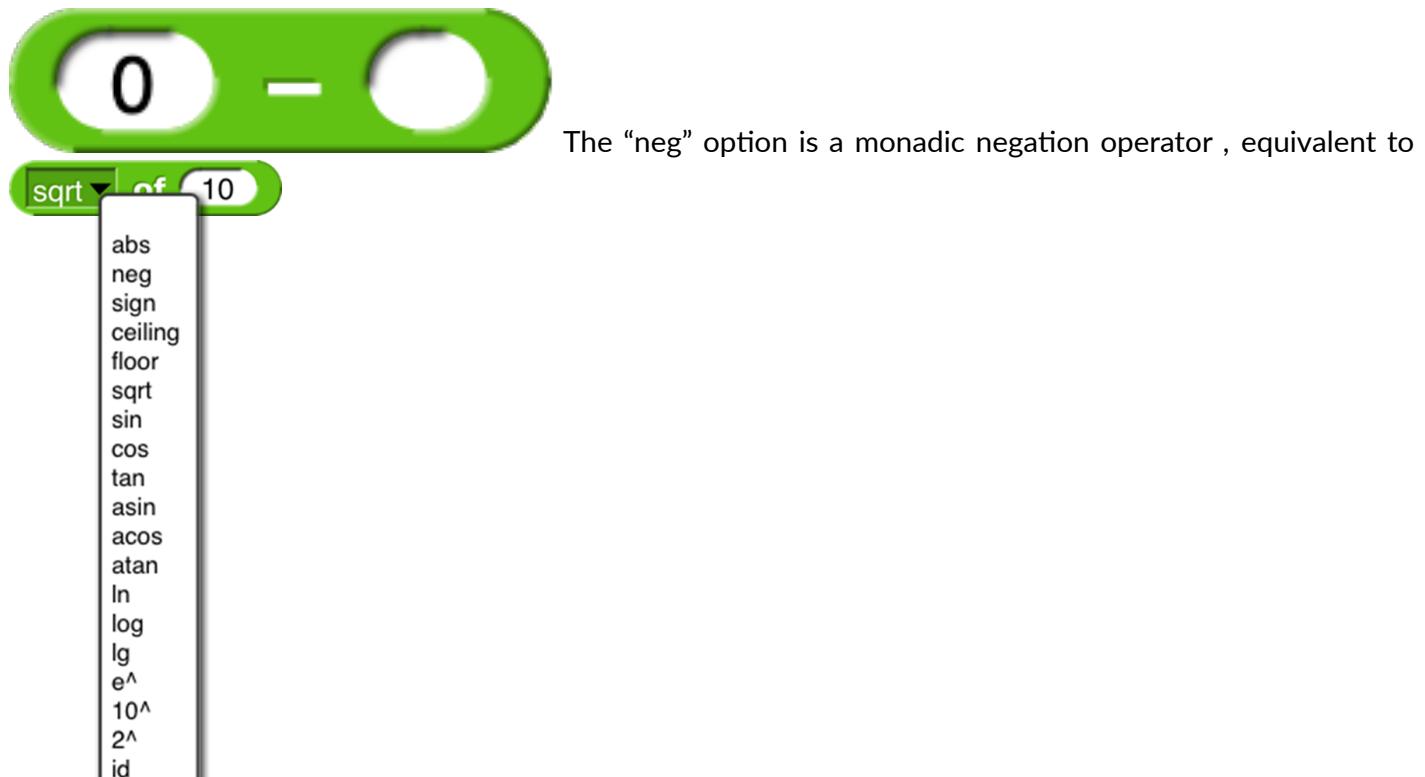


The new "pen trails" option is true if the sprite is touching any drawn or stamped ink on the stage. Also, touching will not detect hidden sprites, but a hidden sprite can use it to detect visible sprites.



The video on block has a snap option that takes a snapshot and reports it as a costume. It is hyperized with respect to its second input.

1. Blocks, Scripts, and Sprites

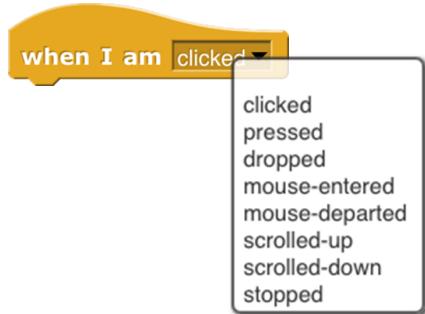


. “lg” is log2. “id” is the identity function, which reports its input. “sign” reports 1 for positive input, 0 for zero input, or -1 for negative input.

💡 Two Different Length Of Blocks

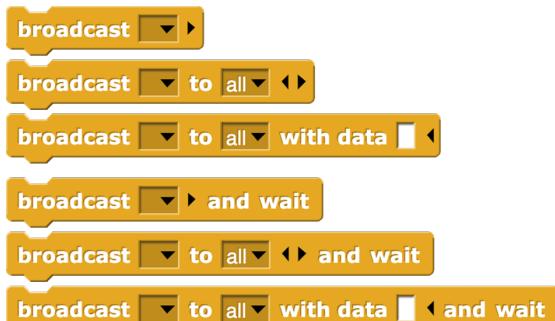
The green text block "length of text world" and the orange list block "length of [list]" are shown side-by-side. Below them, the text "changed to clarify it is different from" is displayed.

Two rows of Scratch blocks demonstrating variadic operators. The top row shows "sum list [7 8 1]" and "product list [7 8 1]". The bottom row shows "++" and "***". A note states: "+ and × are *variadic*: they take two or more inputs. If you drop a list on the arrowheads, the block name



(a) image309.png

Extended mouse interaction events, sensing clicking, dragging, hovering, etc. The “stopped” option triggers when all scripts are stopped, as with the stop button; it is useful for robots whose hardware interface must be told to turn off motors. A `when I am stopped` script can run only for a limited time.



(a) image310.png

Extended broadcast : Click the right arrowhead to direct the message to a single sprite or the stage. Click again to add any value as a payload to the message. {#parabroadcast}



(a) image311.png

Extended `when I receive`: Click the right arrowhead to expose a script variable (click on it to change its name, like any script variable) that will be set to the data of a matching broadcast. If the first input is set to “any message,” then the data variable will be set to the message, if no payload is included with the broadcast, or to a two-item list containing the message and the payload.

1. Blocks, Scripts, and Sprites

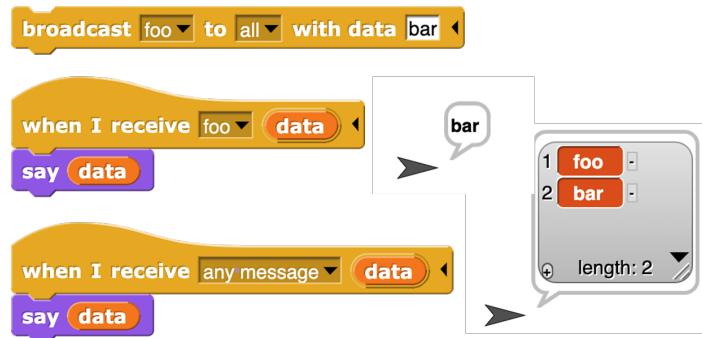


Figure 1.29.: image312.png



Figure 1.30.: image355.png



If the input is set to “any key,” then a right arrowhead appears: and if you click it, a script variable key is created whose value is the key that was pressed. (If the key is one that’s represented in the input menu by a word or phrase, e.g., “enter” or “up arrow,” then the value of key will be that word or phrase, except for the space character, which is represented as itself in key.)



The RGB(A) option accepts a single number, which is a grayscale value 0-255; a two-number list, grayscale plus opacity 0-255; a three-item RGB list, or a four-item RGBA list.

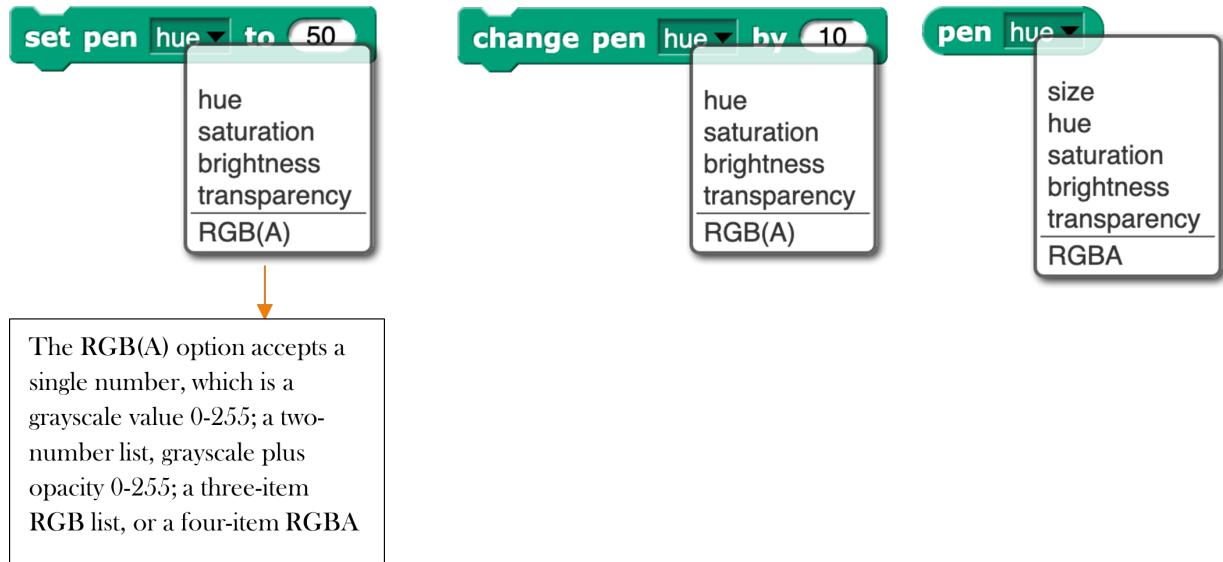


Figure 1.31.: image358.png

1.8.3. Using Lists with the Ask Block

These ask features and more in the Menus library.



Figure 1.32.: image359.png

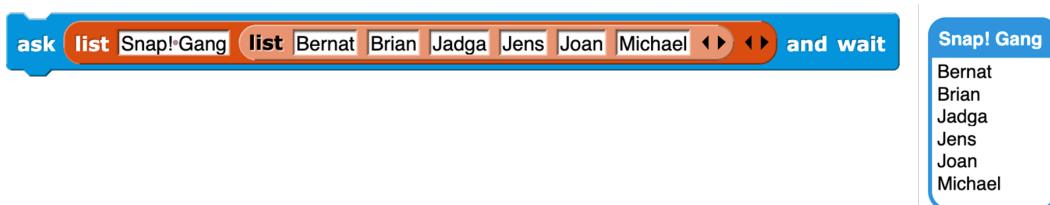


Figure 1.33.: image360.png

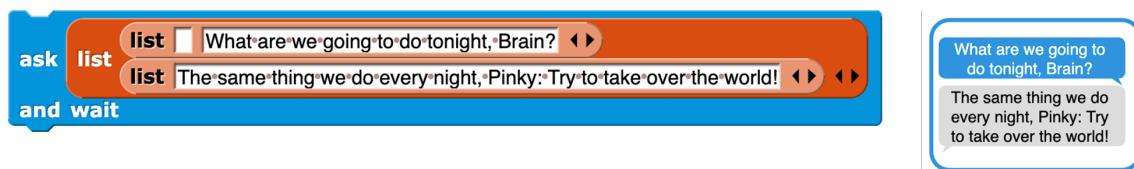


Figure 1.34.: image361.png

1. Blocks, Scripts, and Sprites



Figure 1.35.: image362.png



(a) image363.png

The **of** block has an extended menu of attributes of a sprite. Position reports an (x,y) vector. Size reports the percentage of normal size, as controlled by the set size block in the Looks category. Left, right, etc. report the stage coordinates of the corresponding edge of the sprite's bounding box. Variables reports a list of the names of all variables in scope (global, sprite-local, and script variables if the right input is a script.)

1.9. Libraries

There are several collections of useful procedures that aren't Snap! primitives, but are provided as libraries. To include a library in your project, choose the Libraries... option in the file () menu.



Figure 1.37.: The import libraries dialog

The library menu is divided into five broad categories. The first is, broadly, utilities: blocks that might well be primitives. They might be useful in all kinds of projects.

The second category is blocks related to media computation: ones that help in dealing with costumes and sounds (a/k/a Jens libraries). There is some overlap with “big data” libraries, for dealing with large lists of lists.

The third category is, roughly, specific to non-media applications (a/k/a Brian libraries). Three of them are imports from other programming languages: words and sentences from Logo, array functions from APL, and streams from Scheme. Most of the others are to meet the needs of the BJC curriculum.

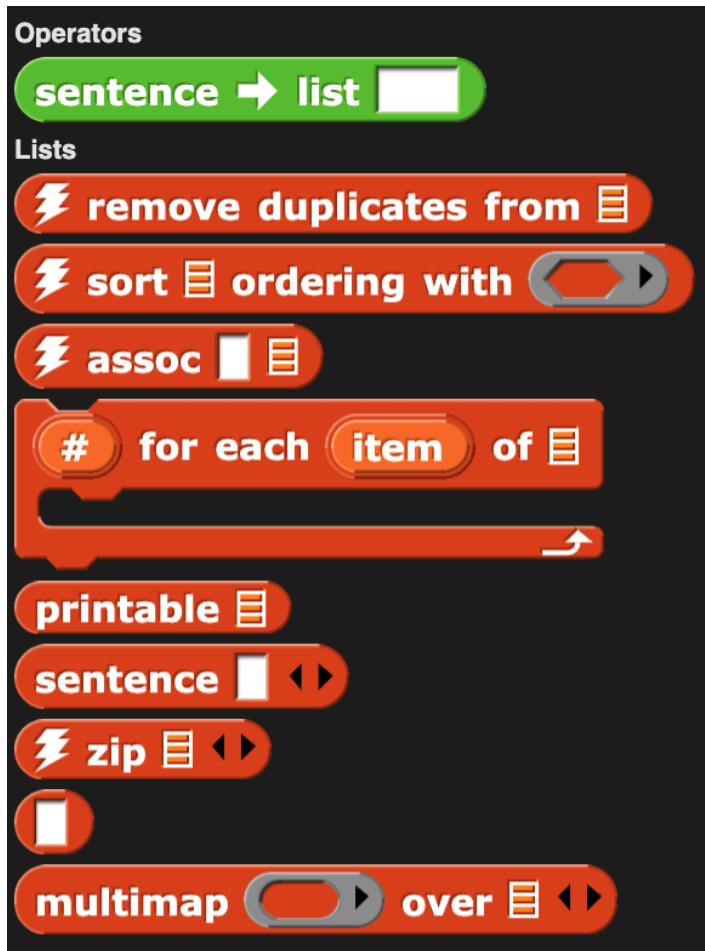
The fourth category is major packages (extensions) provided by users.

The fifth category provides support for hardware devices such as robots, through general interfaces, replacing specific hardware libraries in versions before 7.0.

When you click on the one-line description of a library, you are shown the actual blocks in the library and a longer explanation of its purpose. You can browse the libraries to find one that will satisfy your needs.

The libraries and their contents may change, but as of this writing the list library has these blocks:

1. Blocks, Scripts, and Sprites

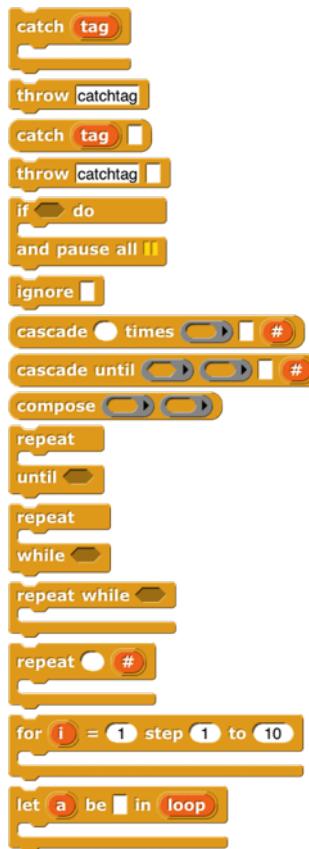


(The lightning bolt (⚡) before the name in several of these blocks means that they use compiled HOFs or JavaScript primitives to achieve optimal speed. They are officially considered experimental.) Remove duplicates from reports a list in which no two items are equal. The sort block takes a list and a two-input comparison predicate, such as `<`, and reports a list with the items sorted according to that comparison. The assoc block is for looking up a key in an *association list*: a list of two-item lists. In each two-item list, the first is a key and the second is a value. The inputs are a key and an association list; the block reports the first key-value pair whose key is equal to the input key.

`For each item` is a variant of the primitive version that provides a `#` variable containing the position in the input list of the currently considered item. Multimap is a version of map that allows multiple list inputs, in which case the mapping function must take as many inputs as there are lists; it will be called with all the first items, all the second items, and so on. Zip takes any number of lists as inputs; it reports a list of lists: all the first items, all the second items, and so on. The `no-name` identity function reports its input.

Sentence and sentence list are borrowed from the word and sentence library to serve as a variant of append that accepts non-lists as inputs. Printable takes a list structure of any depth as input and reports a compact representation of the list as a text string.

The iteration, composition library has these blocks:



`Catch` and `throw` provide a nonlocal exit facility. You can drag the tag from a `catch` block to a `throw` inside its C-slot, and the `throw` will then jump directly out to the matching `catch` without doing anything in between.

`If do` and `pause all` is for setting a breakpoint while debugging code. The idea is to put `show variable` blocks for local variables in the C-slot; the watchers will be deleted when the user continues from the pause.

`Ignore` is used when you need to call a reporter but you don't care about the value it reports. (For example, you are writing a script to time how long the reporter takes.)

The `cascade` blocks take an initial value and call a function repeatedly on that value, $f(f(f(f\dots(x))))$.

The `compose` block takes two functions and reports the function $f(g(x))$.

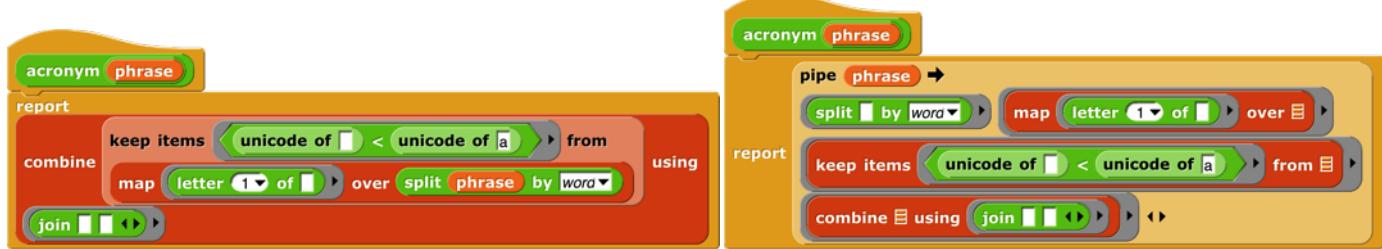
The first three `repeat` blocks are variants of the primitive `repeat until` block, giving all four combinations of whether the first test happens before or after the first repetition, and whether the condition must be true or false to continue repeating. The last `repeat` block is like the `repeat` primitive, but makes the number of repetitions so far available to the repeated script. The next two blocks are variations on `for`: the first allows an explicit step instead of using ± 1 , and the second allows any values, not just numbers; inside the script



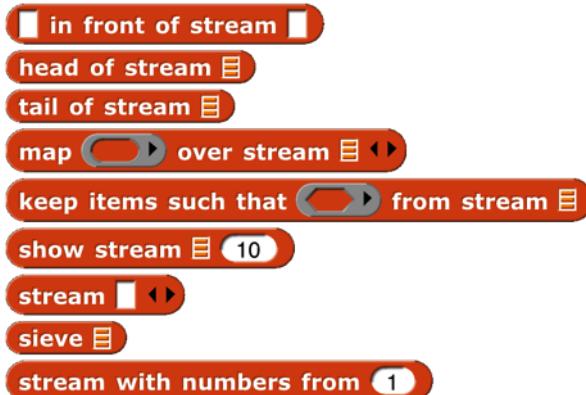
you say
replacing the grey block in the picture with an expression to give the next desired value for the loop index.

Pipe allows reordering a nested composition with a left-to-right one:

1. Blocks, Scripts, and Sprites



The stream library has these blocks:



Streams are a special kind of list whose items are not computed until they are needed. This makes certain computations more efficient, and also allows the creation of lists with infinitely many items, such as a list of all the positive integers. The first five blocks are stream versions of the list blocks.

in front of, item 1 of, all but first of, map, and keep. Show stream takes a stream and a number as inputs, and reports an ordinary list of the first n items of the stream. Stream is like the primitive list; it makes a finite stream from explicit items. Sieve is an example block that takes as input the stream of integers starting with 2 and reports the stream of all the prime numbers. Stream with numbers from is like the numbers from block for lists, except that there is no endpoint; it reports an infinite stream of numbers.

The **word and sentence library** has these blocks:



This library has the goal of recreating the Logo approach to handling text: A text isn't best viewed as a string of characters, but rather as a *sentence*, made of *words*, each of which is a string of *letters*. With a few specialized exceptions, this is why people put text into computers: The text is sentences of natural (i.e., human) language, and the emphasis is on words as constitutive of sentences. You barely notice the letters of the words, and you don't notice the spaces between them at all, unless you're proof-reading. (Even then: Proofreading is *difficult*, because you see what you expect to see, what will make the sentence make sense, rather than the misspelling in front of your eyes.) Internally, Logo stores a sentence as a list of words, and a word as a string of letters.

Inexplicably, the designers of Scratch chose to abandon that tradition, and to focus on the representation of text as a string of characters. The one vestige of the Logo tradition from which Scratch developed is the block named *letter (1) of (world)* , rather than *character (1) of (world)*. Snap! inherits its text handling from Scratch.

In Logo, the visual representation of a sentence (a list of words) looks like a natural language sentence: a string of words with spaces between them. In Snap!, the visual representation of a list looks nothing at all like natural language. On the other hand, representing a sentence as a string means that the program must continually re-parse the text on every operation, looking for spaces, treating multiple consecutive spaces as one, and so on. Also, it's more convenient to treat a sentence as a list of words rather than a string of words because in the former case you can use the higher order functions *map*, *keep*, and *combine* on them. This library attempts to be agnostic as to the internal representation of sentences. The sentence selectors accept any combination of lists and strings; there are two sentence constructors, one to make a string (*join words*) and one to make a list (*sentence*).

The selector names come from Logo, and should be self-explanatory. However, because in a block language you don't have to type the block name, instead of the terse *butfirst* or the cryptic *bf* we spell out "all but first of" and include "word" or "sentence" to indicate the intended domain. There's no first letter of block because letter 1 of serves that need. *Join words* (the sentence-as-string constructor) is like the primitive *join* except that it puts a space in the reported value between each of the inputs. *Sentence* (the List-colored sentence-as-list constructor) accepts any number of inputs, which can be words, sentences-as-lists, or sentences-as-strings. (If inputs are lists of lists, only one level of flattening is done.) *Sentence* reports a list of words; there will be no empty words or words containing spaces. The four blocks with right-arrows in their names convert back and forth between text strings (words or sentences) and lists. (Splitting a word into a list of letters is unusual unless you're a linguist investigating orthography.) *Printable* takes a list (including a deep list) of words as input and reports a text string in which parentheses are used to show the structure, as in Lisp/Scheme.

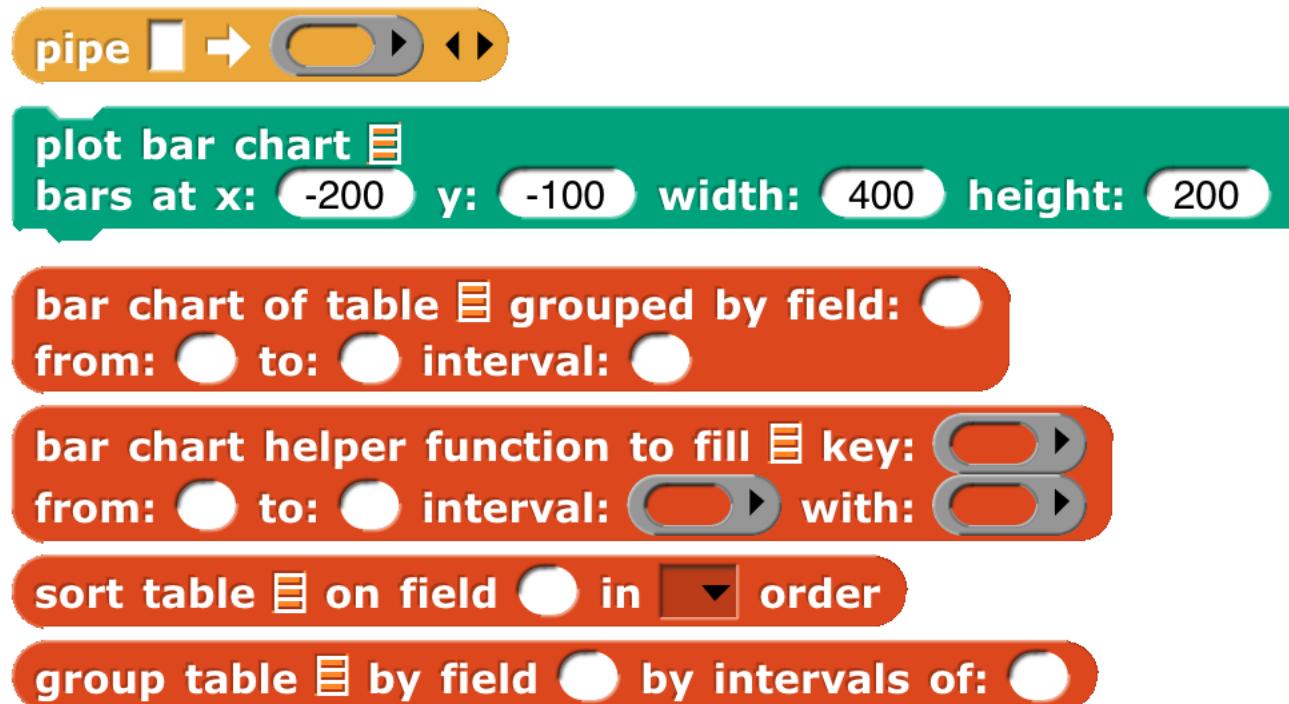
1. Blocks, Scripts, and Sprites

The pixels library has one block:

![image395.png](assets/image395.png){.image-2x}

Costumes are first class data in Snap!. Most of the processing of costume data is done by primitive blocks in the Looks category. (See page 79.) This library provides snap , which takes a picture using your computer's camera and reports it as a costume.

The bar charts library has these blocks:



Bar chart of table takes a table (typically from a CSV data set) as input and reports a summary of the table grouped by the field in the specified column number. The remaining three inputs are used only if the field values are numbers, in which case they can be grouped into buckets (e.g., decades, centuries, etc.). Those inputs specify the smallest and largest values of interest and, most importantly, the width of a bucket (10 for decades, 100 for centuries). If the field isn't numeric, leave these three inputs empty or set them to zero. Each string value of the field is its own bucket, and they appear sorted alphabetically.

Bar chart of table reports a new table with three columns. The first column contains the bucket name or smallest number. The second column contains a nonnegative integer that says how many records in the input table fall into this bucket. The third column is a subtable containing the actual records from the original table that fall into the bucket. Plot bar chart takes the table reported by bar chart and graphs it on the stage, with axes labelled appropriately. The remaining blocks are helpers for those.

If your buckets aren't of constant width, or you want to group by some function of more than one field, load the "Frequency Distribution Analysis" library instead.

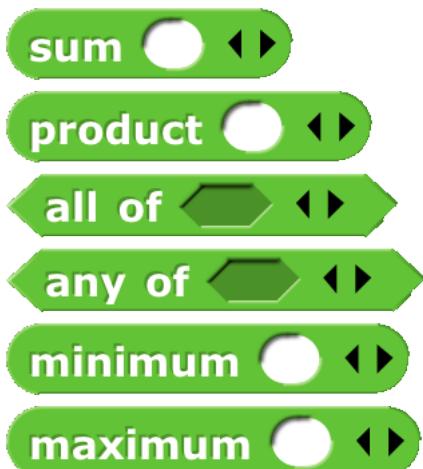
The multi-branched conditional library has these blocks:



The `catch` and `throw` blocks duplicate ones in the iteration library, and are included because they are used to implement the others. The `cases: if/then` block sets up a multi-branch conditional, similar to `cond` in Lisp or `switch` in C-family languages. The first branch is built into the `cases` block; it consists of a Boolean test in the first hexagonal slot and an action script, in the C-slot, to be run if the test reports true. The remaining branches go in the variadic hexagonal input at the end; each branch consists of an `else if` block, which includes the Boolean test and the corresponding action script, except possibly for the last branch, which can use the unconditional `else` block. As in other languages, once a branch succeeds, no other branches are tested.

1.9.1.

The variadic library has these blocks:

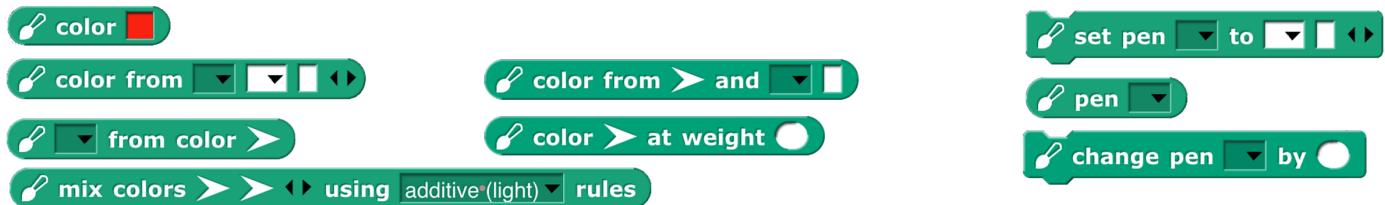


These are versions of the associative operators `and`, `or`, and `or` that take any number of inputs instead of exactly two inputs. As with any variadic input, you can also drop a list of values onto the arrowheads instead of providing the inputs one at a time. As of version 8.0, the arithmetic operators `sum`, `product`, `minimum`, and `maximum` are no longer included, because the primitive operators `+ x`, `min`, and `max` are themselves variadic.

The colors and crayons library has these blocks:

It is intended as a more powerful replacement for the primitive `set pen` block, including *first class color* support; HSL color specification as a better alternative to the HSV that Snap! inherits from JavaScript; a “fair hue” scale that compensates for the eye’s grouping a wide range of light frequencies as green while labelling mere slivers as orange or yellow; the X11/W3C standard color names; RGB in hexadecimal; a linear color scale (as in the old days, but better) based on fair hues and including shades (darker colors) and grayscale. Another linear scale is a curated set of 100 “crayons,” explained further on the next page.

1. Blocks, Scripts, and Sprites



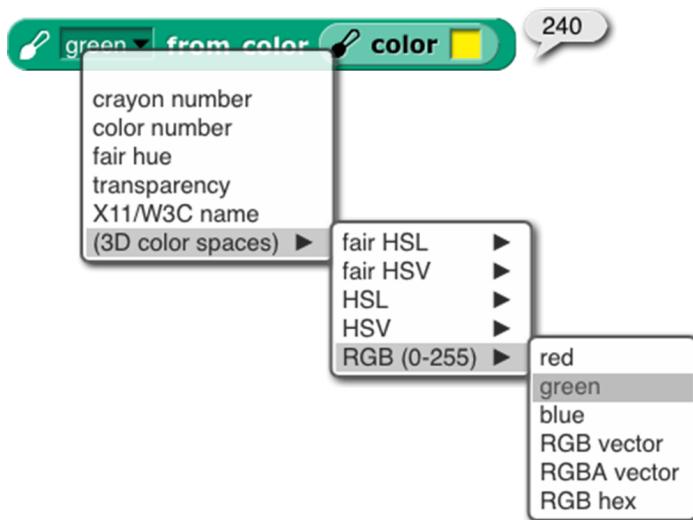
Colors are created by the



block (for direct user selection), the



color from to specify a color numerically, or by reports the color currently in use by the pen. The from color block reports names or numbers associated with a color:

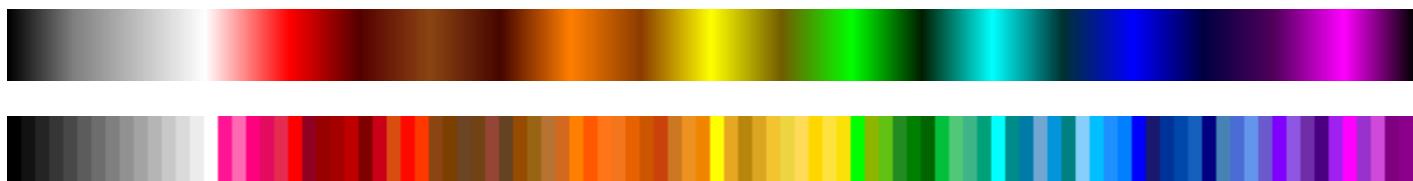


Colors can be created from other colors:



The three blocks with pen in their names are improved versions of primitive Pen blocks. In principle set pen, for example, could be implemented using a (hypothetical) set pen to color composed with the color from block, but in fact set pen benefits from knowing how the pen color was set in its previous invocation, so it's implemented separately from color from. Details in Appendix A.

The recommended way to choose a color is from one of two linear scales: the continuous *color numbers* and the discrete *crayons*:



Color numbers are based on *fair hues*, a modification of the spectrum (rainbow) hue scale that devotes less space to green and more to orange and yellow, as well as promoting brown to a real color. Here is the normal hue scale, for reference:



Here is the fair hue scale:



Here is the color number scale:

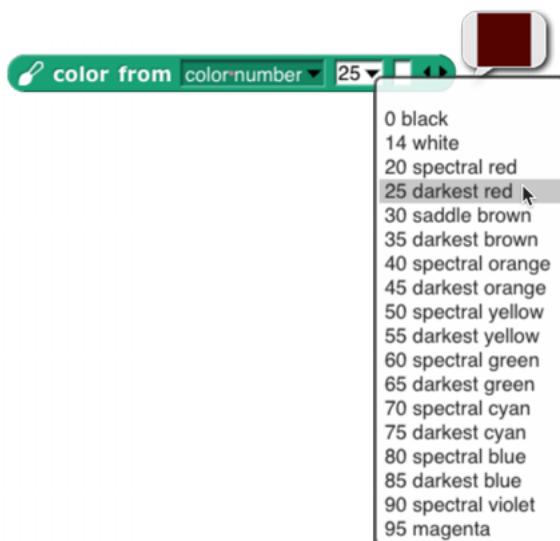


(The picture is wider so that pure spectral colors line up with the fair hue scale.)

And here are the 100 crayons :



The `color from` block, for example, provides different pulldown menus depending on which scale you choose:

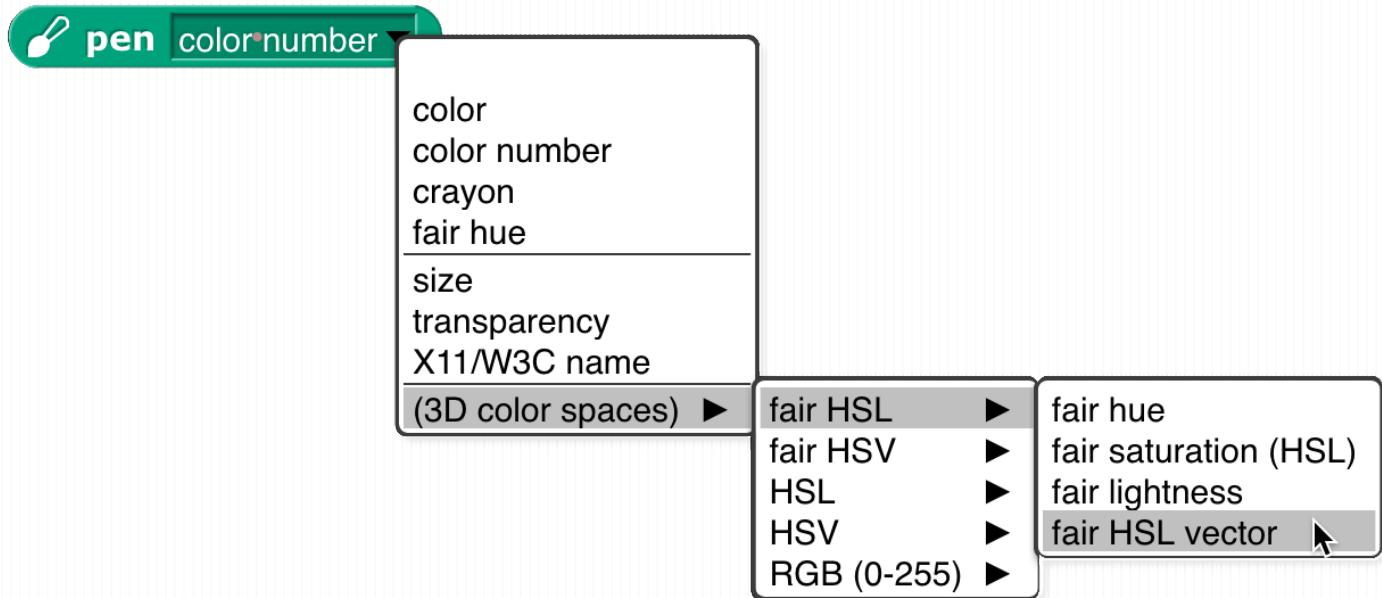


You can also type the crayon name:



There are many scales:

1. Blocks, Scripts, and Sprites



The white slot at the end of some of the blocks has two purposes. It can be used to add a transparency to a color (0=opaque, 100=transparent):



or it can be expanded to enter three or four numbers for a vector directly into the block, so these are equivalent:



But note that a transparency number in a four-number RGBA vector is on the scale 255=opaque, 0=transparent, so the following are not equivalent:



Figure 1.38.: image430.png

Set pen crayon to provides the equivalent of a box of 100 crayons. They are divided into color groups, so the menu in the set pen crayon to input slot has submenus. The colors are chosen so that starting from crayon 0, change pen crayon by 10 rotates through an interesting, basic set of ten colors:



Figure 1.39.: image440.png

Using change pen crayon by 5 instead gives ten more colors, for a total of 20:



Figure 1.40.: image441.png

(Why didn't we use the colors of the 100-crayon Crayola™ box? A few reasons, one of which is that some Crayola colors aren't representable on RGB screens. Some year when you have nothing else to do, look up "color space" on Wikipedia. Also "crayon." Oh, it's deliberate that `change pen crayon by 5` doesn't include white, since that's the usual stage background color. White is crayon 14.) Note that crayon 43 is "Variables"; all the standard block colors are included.

See Appendix A (Section B.1.1) for more information.

The **crayon library** has only the crayon features, without the rest of the colors package.

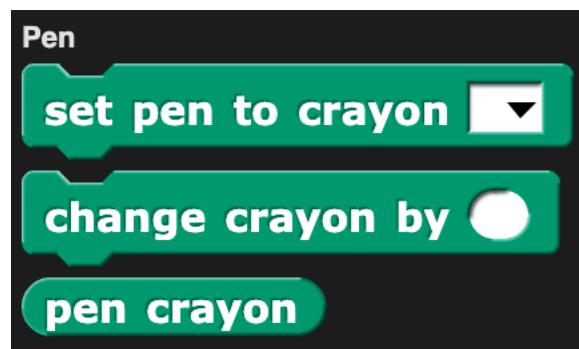


Figure 1.41.: image442.png

The catch errors library has these blocks:



Figure 1.42.: image444.png

The `safely try` block allows you to handle errors that happen when your program is run within the program, instead of stopping the script with a red halo and an obscure error message. The block runs the script in its first C-slot. If it finishes without an error, nothing else happens. But if an error happens, the code in the second C-slot is run. While that second script is running, the variable `error` contains the text of the error message that

1. Blocks, Scripts, and Sprites

would have been displayed if you weren't catching the error. The `error` block is sort of the opposite: it lets your program generate an error message, which will be displayed with a red halo unless it is caught by `safely try`. `Safely try reporting` is the reporter version of `safely try`.

The text costumes library has only two blocks:



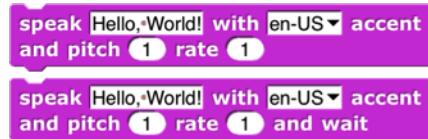
`Costume from text` reports a costume that can be used with the `switch to costume` block to make a button:

Snap!

`Costume with background` reports a costume made from another costume by coloring its background, taking a color input like the `set pen color to RGB(A)` block and a number of turtle steps of padding around the original costume. These two blocks work together to make even better buttons:



The text to speech library has these blocks:



This library interfaces with a capability in up-to-date browsers, so it might not work for you. It works best if the accent matches the text!

The parallelization library contains these blocks:



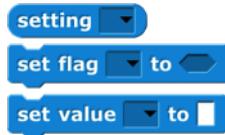
The two `do in parallel` blocks take any number of scripts as inputs. Those scripts will be run in parallel, like ordinary independent scripts in the scripting area. The `do in parallel` and `wait` version waits until all of those scripts have finished before continuing the script below the block.

The create variables library has these blocks:



These blocks allow a program to perform the same operation as the button, making global, sprite local, or script variables, but allowing the program to compute the variable name(s). It can also set and find the values of these variables, show and hide their stage watchers, delete them, and find out if they already exist.

The getters and setters library has these blocks:



The purpose of this library is to allow program access to the settings controlled by user interface elements, such as the settings menu . The setting block reports a setting; the set flag block sets yes-or-no options that have checkboxes in the user interface, while the set value block controls settings with numeric or text values, such as project name.

Certain settings are ordinarily remembered on a per-user basis, such as the “zoom blocks” value. But when these settings are changed by this library, the change is in effect only while the project using the library is loaded. No permanent changes are made. Note: this library has not been converted for version 7.0, so you’ll have to enable Javascript extensions to use it.

The bignums, rationals, complex #s library has these blocks:



Figure 1.43.: image454.png

The USE BIGNUMS block takes a Boolean input, to turn the infinite precision feature on or off. When on, all of the arithmetic operators are redefined to accept and report integers of any number of digits (limited only by the memory of your computer) and, in fact, the entire Scheme numeric tower, with exact rationals and with complex numbers. The Scheme number block has a list of functions applicable to Scheme numbers, including subtype predicates such as rational? and infinite?, and selectors such as numerator and real-part.

The ! block computes the factorial function, useful to test whether bignums are turned on. Without bignums:

1. Blocks, Scripts, and Sprites

The image shows the Scratch interface with several numeric input blocks displayed. From left to right, there is a green block for "100 !", a speech bubble block for "9.33262154439441e+157", another green block for "200 !", and a light blue block for "Infinity".

With bignums:

The image shows the Scratch interface with numeric input blocks for 100! and 200!. The value for 100! is a very large number ending in many zeros. The value for 200! is even larger and also ends in many zeros.

The 375-digit value of 200! isn't readable on this page, but if you right-click on the block and choose "result pic," you can open the resulting picture in a browser window and scroll through it. (These values end with a bunch of zero digits. That's not roundoff error; the prime factors of 100! and 200! include many copies of 2 and 5.) The block with no name is a way to enter things like $3/4$ and $4+7i$ into numeric input slots by converting the slot to Any type.

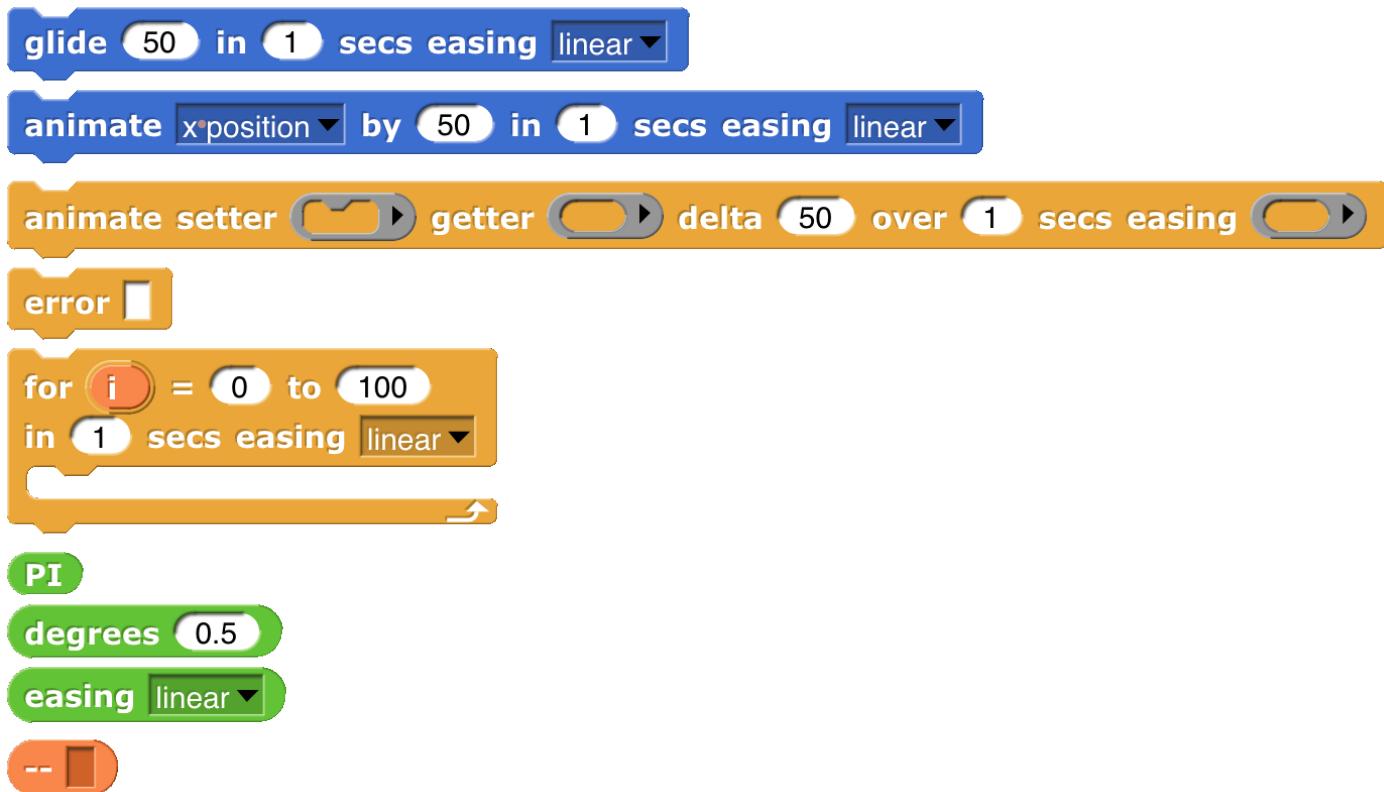
The strings, multi-line input library provides these blocks:

This section displays a series of green text processing blocks:

- use case-independent comparison**
- multiline**
- substring of [] before []**
- substring of [] after []**
- position of [] in []**
- use case-independent comparisons**
- substring of [] from position [] to position [] inclusive**
- text [] contains []**
- to lower case []**

All of these could be written in Snap! itself, but these are implemented using the corresponding JavaScript library functions directly, so they run fast. They can be used, for example, in scraping data from a web site. The command **use case-independent comparisons** applies only to this library. The **multiline** block accepts and reports a text input that can include newline characters.

The animation library has these blocks:



Despite the name, this isn't only about graphics; you can animate the values of a variable, or anything else that's expressed numerically.

The central idea of this library is an *easing function*, a reporter whose domain and range are real numbers between 0 and 1 inclusive. The function represents what fraction of the "distance" (in quotes because it might be any numeric value, such as temperature in a simulation of weather) from here to there should be covered in what fraction of the time. A linear easing function means steady progression. A quadratic easing function means starting slowly and accelerating. (Note that, since it's a requirement that $f(0)=0$ and $f(1)=1$, there is only one linear

easing function, $f(x)=x$, and similarly for other categories.) The **easing** [linear ▾] block reports some of the common easing functions.

The two Motion blocks in this library animate a sprite. Glide always animates the sprite's motion. Animate's first pulldown menu input allows you to animate horizontal or vertical motion, but will also animate the sprite's direction or size. The **animate setter** block in Control lets you animate any numeric quantity with any easing function. The getter and setter inputs are best explained by example:



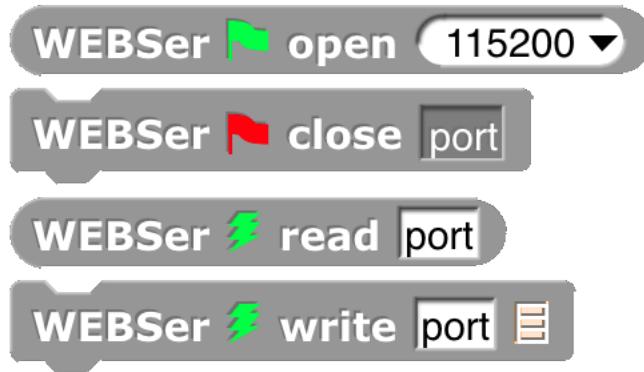
is equivalent to



The other blocks in the library are helpers for these four.

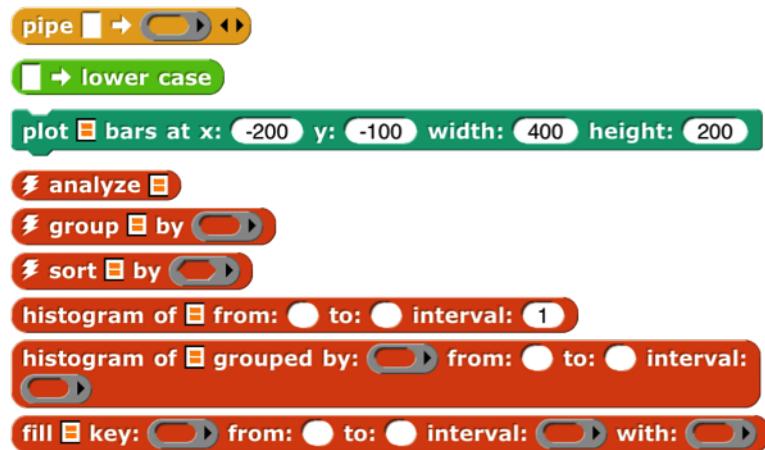
1. Blocks, Scripts, and Sprites

The serial ports library contains these blocks:



It is used to allow hardware developers to control devices such as robots that are connected to your computer via a serial port.

The frequency distribution analysis library has these blocks:

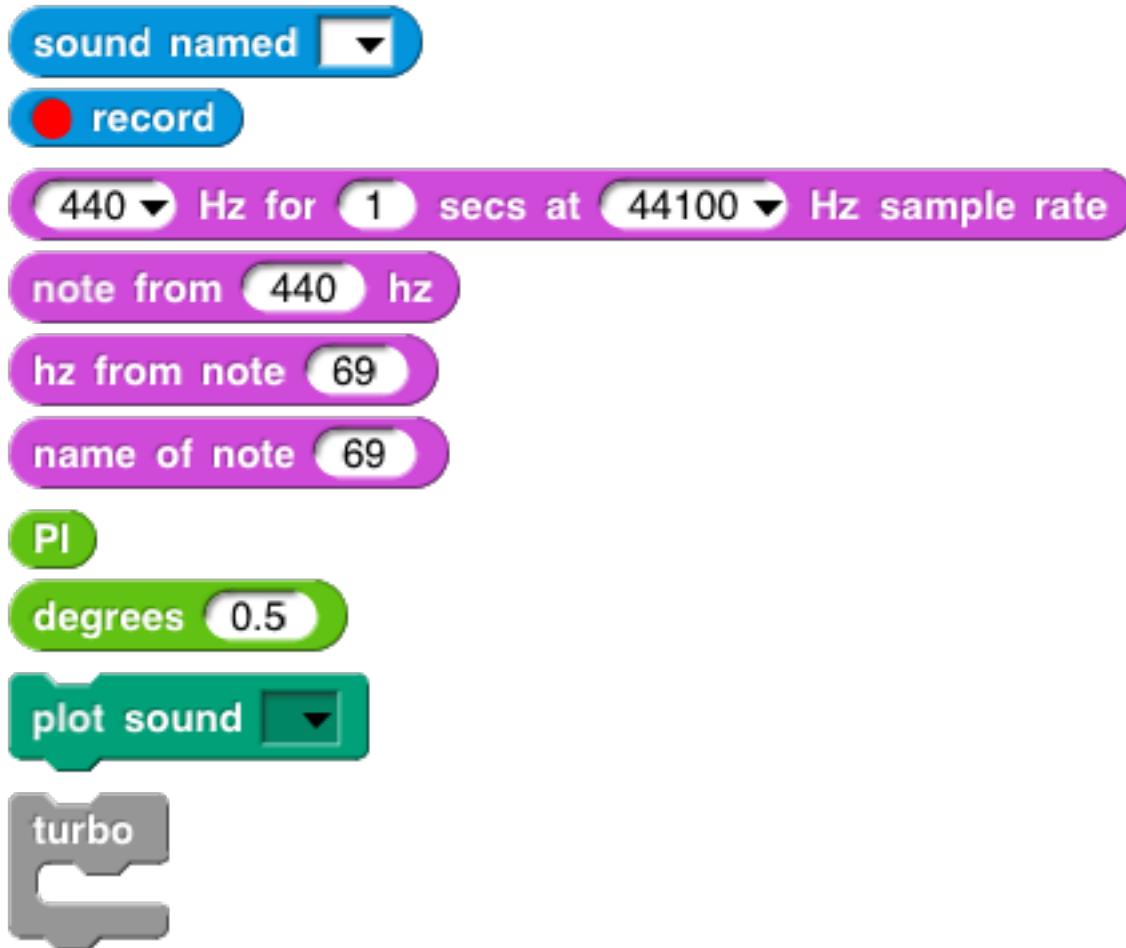


This is a collection of tools for analyzing large data sets and plotting histograms of how often some value is found in some column of the table holding the data.

For more information go here:

<https://tinyurl.com/jens-data>

The audio comp library includes these blocks:



This library takes a sound, one that you record or one from our collection of sounds, and manipulates it by systematically changing the intensity of the samples in the sound and by changing the sampling rate at which the sound is reproduced. Many of the blocks are helpers for the `plot sound` block, used to plot the waveform of a sound. The `play sound (primitive)` block plays a sound. `__ Hz for` reports a sine wave as a list of samples.

The web services library has these blocks:

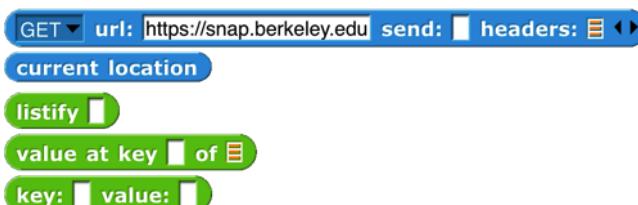


Figure 1.44.: image471.png

The first block is a generalization of the primitive `url` block , allowing more control over the various options in web requests: GET, POST, PUT, and DELETE, and fine control over the content of the message sent to the server. `Current location` reports your latitude and longitude. `Listify` takes some text in JSON format (see page 54) and converts it to a structured list. `Value at key` looks up a key-value pair in a (listified) JSON dictionary. The `key:value:` block is just a constructor for an abstract data type used with the other blocks

The database library contains these blocks:

1. Blocks, Scripts, and Sprites

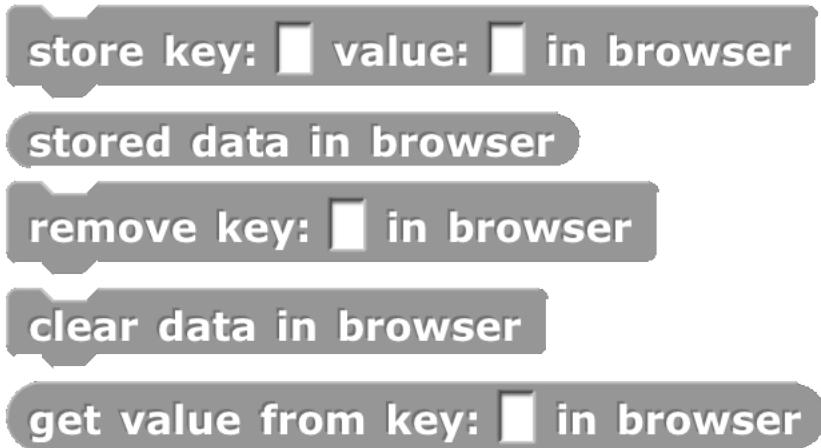
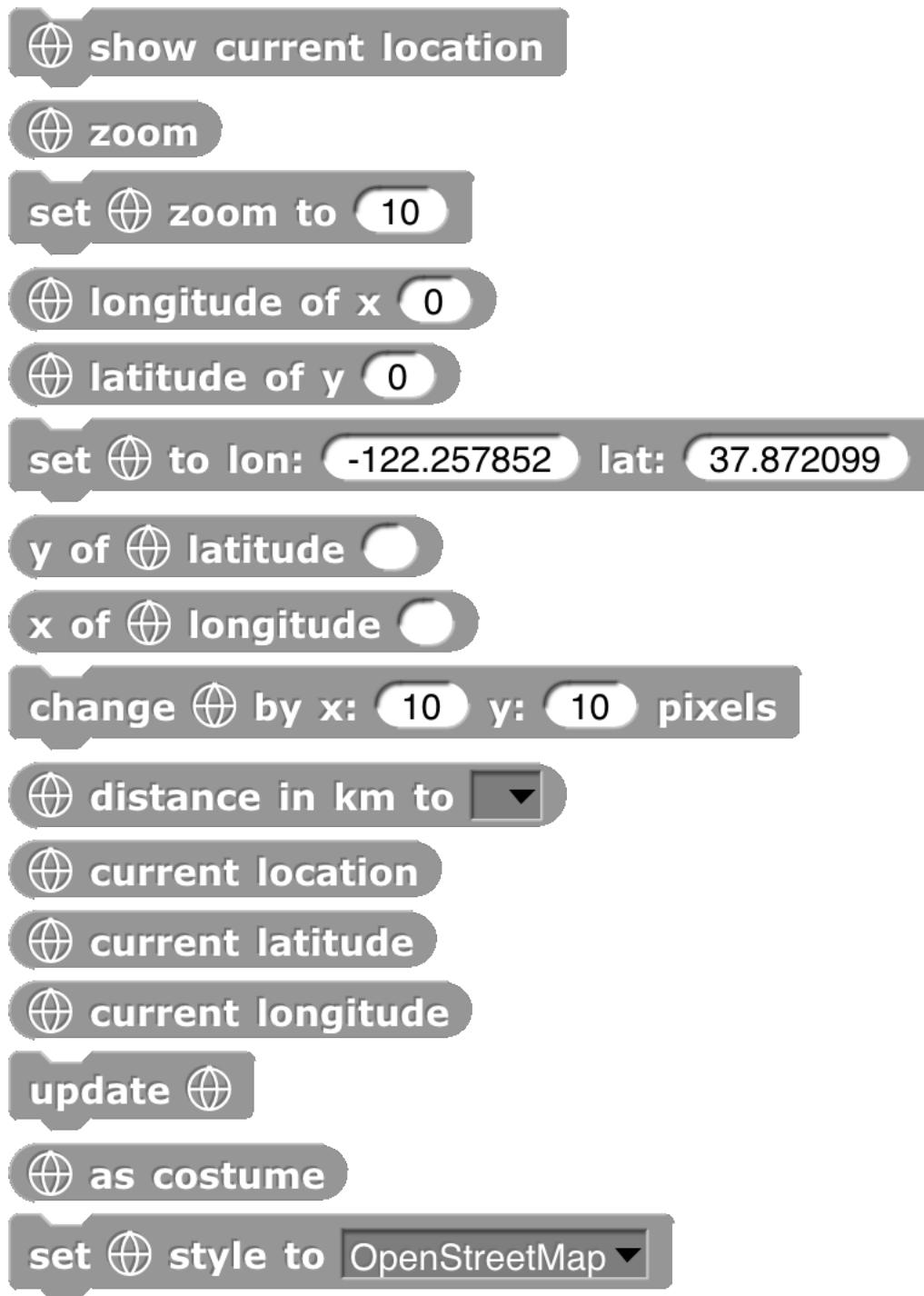


Figure 1.45.: image472.png

It is used to keep data that persist from one Snap! session to the next, if you use the same browser and the same login.

The world map library has these blocks:



Using any of the command blocks puts a map on the screen, in a layer in front of the stage's background but behind the pen trails layer (which is in turn behind all the sprites). The first block asks your browser for your current physical location, for which you may be asked to give permission. The next two blocks get and set the map's zoom amount; the default zoom of 10 fits from San Francisco not quite down to Palo Alto on the screen. A zoom of 1 fits almost the entire world. A zoom of 3 fits the United States; a zoom of 5 fits Germany. The zoom can be changed in half steps, i.e., 5.5 is different from 5, but 5.25 isn't.

The next five blocks convert between stage coordinates (pixels) and Earth coordinates (latitude and longitude). The change by x: y: block shifts the map relative to the stage. The distance to block measures the map distance (in meters) between two sprites. The three reporters with current in their names find your actual location, again supposing that geolocation is enabled on your device. Update redraws the map; as costume reports the visible

1. Blocks, Scripts, and Sprites

section of the map as a costume. Set `style` allows things like satellite pictures.

The APL primitives library contains these blocks:

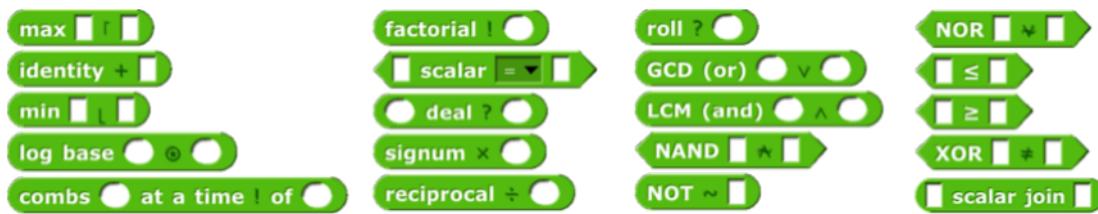


Figure 1.46.: image474.png

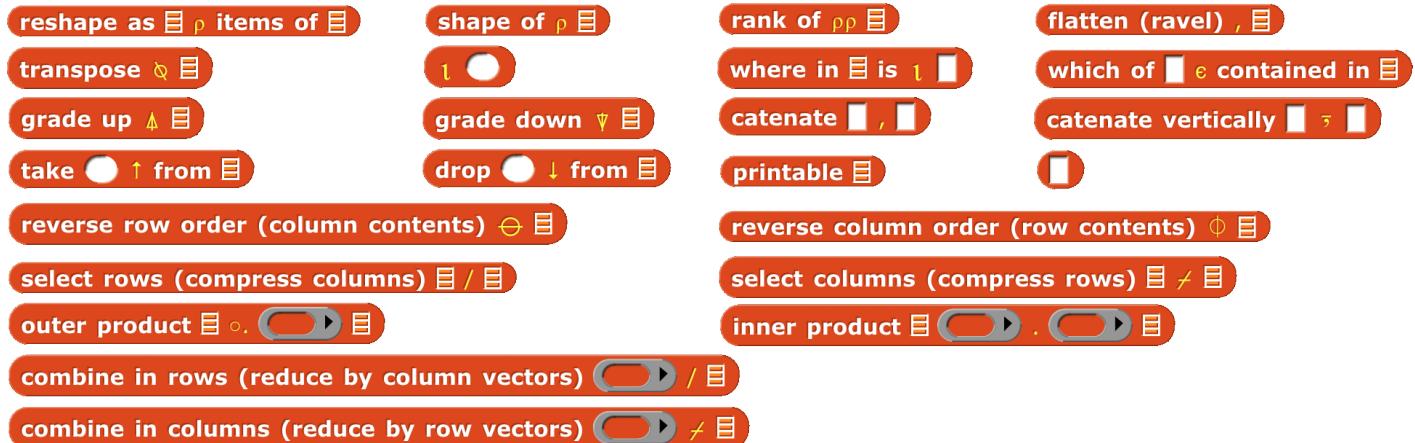


Figure 1.47.: image475.png

For more information about APL, see Appendix C).

The **list comprehension library** has one block, `zip`:



Figure 1.48.: image476.png

Its first input is a function of two inputs. The two Any-type inputs are deep lists (lists of lists of...) interpreted as trees, and the function is called with every possible combination of a leaf node of the first tree and a leaf node of the second tree. But instead of taking atoms (non-lists) as the leaves, `zip` allows the leaves of each tree to be vectors (one-dimensional lists), matrices (two-dimensional lists), etc. The Number-type inputs specify the leaf dimension for each tree, so the function input might be called with a vector from the first tree and an atom from the second tree.

The **bitwise library** provides bitwise logic functions; each bit of the reported value is the result of applying the corresponding Boolean function to the corresponding bits of the input(s). The Boolean functions are not `for`, `¬`, and `for`, `or` for `,`, and `xor` (exclusive or) for `^`. The remaining functions shift their first input left or right by the number of bits given by the second input. `\<\<` is left shift, `\>\>` is arithmetic right shift (shifting in one bits from the left), and `\>\>\>` is logical right shift (shifting in zero bits from the left). If you don't already know what these mean, find a tutorial online.

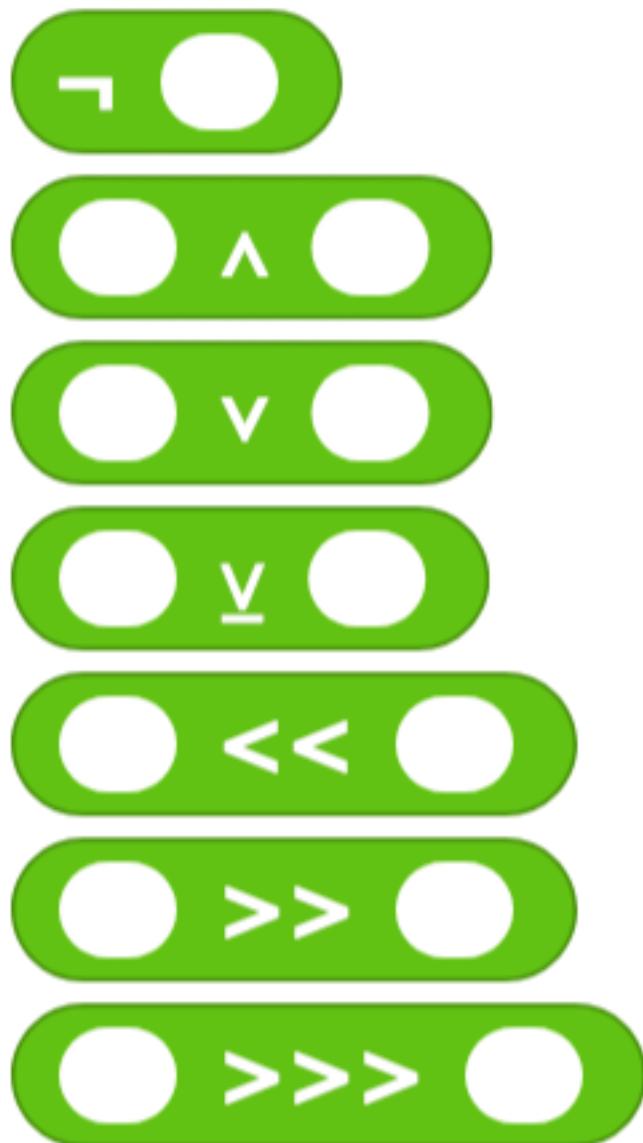


Figure 1.49.: image477.png

The **MQTT library** supports the Message Queuing Telemetry Transport protocol, for connecting with IOT devices. See <https://mqtt.org/> for more information.

1. Blocks, Scripts, and Sprites

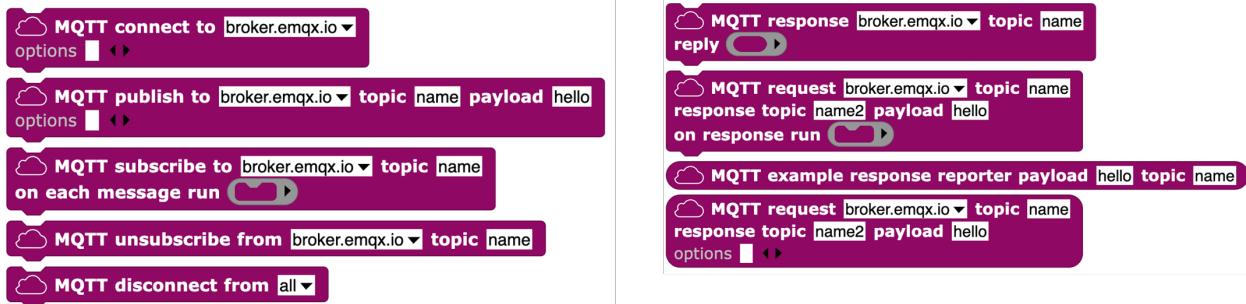


Figure 1.50.: image487.png

The **Signada library** allows you to control a microBit or similar device that works with the Signada MicroBlocks project.

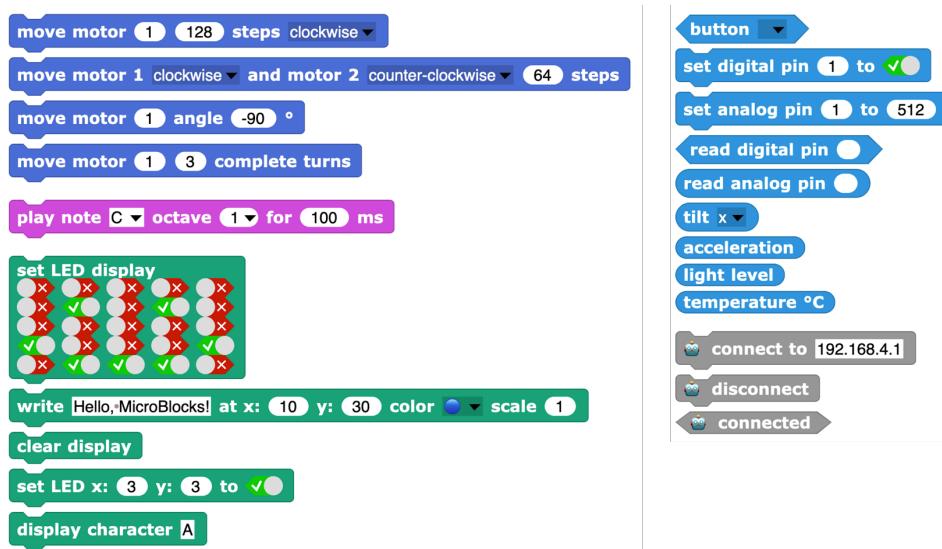


Figure 1.51.: image488.png

The **menus library** provides the ability to display hierarchical menus on the stage, using the ask block's ability to take lists as inputs. See Section 1.8.3.

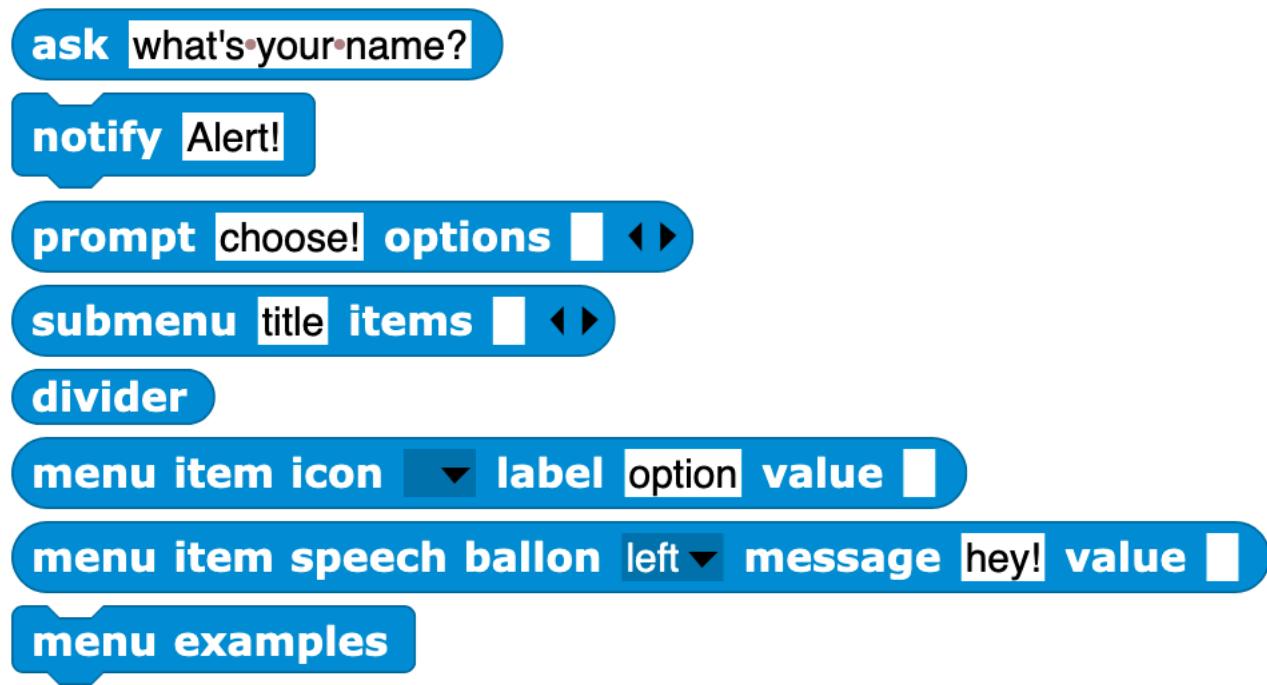


Figure 1.52.: image486.png

The **SciSnap! library** and the **TuneScope library** are too big to discuss here and are documented separately at <http://emu-online.de/ProgrammingWithSciSnap.pdf> and <https://maketolearn.org/creating-art-animations-and-music/> respectively.

2. Saving and Loading Projects and Media

After you've created a project, you'll want to save it, so that you can have access to it the next time you use Snap!. There are two ways to do that. You can save a project on your own computer, or you can save it at the Snap! web site. The advantage of saving on the net is that you have access to your project even if you are using a different computer, or a mobile device such as a tablet or smartphone. The advantage of saving on your computer is that you have access to the saved project while on an airplane or otherwise not on the net. Also, cloud projects are limited in size, but you can have all the costumes and sounds you like if you save locally. This is why we have multiple ways to save.

In either case, if you choose "Save as..." from the File menu. You'll see something like this:



(If you are not logged in to your Snap! cloud account, Computer will be the only usable option.) The text box at the bottom right of the Save dialog allows you to enter project notes that are saved with the project.

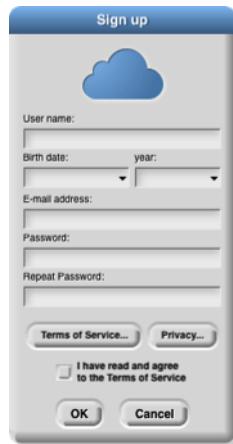
2.1. Local Storage

Click on Computer and Snap!'s Save Project dialog window will be replaced by your operating system's standard save window. If your project has a name, that name will be the default filename if you don't give a different name. Another, equivalent way to save to disk is to choose "Export project" from the File menu.

2.2. Creating a Cloud Account

The other possibility is to save your project "in the cloud", at the Snap! web site. In order to do this, you need an account with us. Click on the Cloud button () in the Tool Bar. Choose the "Signup..." option. This will show you a window that looks like the picture below:

2. Saving and Loading Projects and Media



You must choose a user name that will identify you on the web site, such as Jens. If you're a Scratch user, you can use your Scratch name for Snap! too. If you're a kid, don't pick a user name that includes your family name, but first names or initials are okay. Don't pick something you'd be embarrassed to have other users (or your parents) see! If the name you want is already taken, you'll have to choose another one. You must also supply a password.

We ask for your month and year of birth; we use this information only to decide whether to ask for your own email address or your parent's email address. (If you're a kid, you shouldn't sign up for anything on the net, not even Snap!, without your parent's knowledge.) We do not store your birthdate information on our server; it is used on your own computer only during this initial signup. We do not ask for your exact birthdate, even for this one-time purpose, because that's an important piece of personally identifiable information.

When you click "OK", an email will be sent to the email address you gave, asking you to verify (by clicking a link) that it's really your email address. We keep your email address on file so that, if you forget your password, we can send you a password-reset link. We will also email you if your account is suspended for violation of the Terms of Service. We do not use your address for any other purpose. You will never receive marketing emails of any kind through this site, neither from us nor from third parties. If, nevertheless, you are worried about providing this information, do a web search for "temporary email."

Finally, you must read and agree to the Terms of Service. A quick summary: Don't interfere with anyone else's use of the web site, and don't put copyrighted media or personally identifiable information in projects that you share with other users. And we're not responsible if something goes wrong. (Not that we expect anything to go wrong; since Snap! runs in JavaScript in your browser, it is strongly isolated from the rest of your computer. But the lawyers make us say this.)

2.3. Saving to the Cloud

Once you've created your account, you can log into it using the "Login..." option from the Cloud menu:



Use the user name and password that you set up earlier. If you check the “Stay signed in” box, then you will be logged in automatically the next time you run Snap! from the same browser on the same computer. Check the box if you’re using your own computer and you don’t share it with siblings. Don’t check the box if you’re using a public computer at the library, at school, etc.

Once logged in, you can choose the “Cloud” option in the “Save Project” dialog shown on [?@fig-saveas](#). You enter a project name, and optionally project notes; your project will be saved online and can be loaded from anywhere with net access. The project notes will be visible to other users if you publish your project.

2.4. Loading Saved Projects

Once you’ve saved a project, you want to be able to load it back into Snap!. There are two ways to do this:

1. If you saved the project in your online Snap! account, choose the “Open...” option from the File menu. Choose the “Cloud” button, then select your project from the list in the big text box and click “OK”, or choose the “Computer” button to open an operating system open dialog. (A third button, “Examples” lets you choose from example projects that we provide. You can see what each of these projects is about by clicking on it and reading its project notes.)
2. If you saved the project as an XML file on your computer, choose “Import...” from the File menu. This will give you an ordinary browser file-open window, in which you can navigate to the file as you would in other software. Alternatively, find the XML file on your desktop, and just drag it onto the Snap! window.

The second technique above also allows you to import media (costumes and sounds) into a project. Just choose “Import...” and then select a picture or sound file instead of an XML file.

Snap! can also import projects created in BYOB 3.0 or 3.1, or (with some effort; see our web site) in Scratch 1.4, 2.0 or 3.0. Almost all such projects work correctly in Snap!, apart from a small number of incompatible blocks.

2. Saving and Loading Projects and Media

If you saved projects in an earlier version of Snap! using the “Browser” option, then a Browser button will be shown in the Open dialog to allow you to retrieve those projects. But you can save them only with the Computer and Cloud options.

2.5. If you lose your project, do this first!

If you are still in **Snap!** and realize that you've loaded another project without saving the one you were working



on: **Don't edit the new project.** From the File menu choose the “Restore unsaved project” option.

Restore unsaved project will also work if you log out of Snap! and later log back in, as long as you don't edit another project meanwhile. Snap! remembers only the most recent project that you've edited (not just opened, but actually changed in the project editor).

If your project on the cloud is missing, empty, or otherwise broken and isn't the one you edited most recently, or if Restore unsaved project fails: **Don't edit the broken project.** In the “Open...” box, enter your project name, then push the Recover button. *Do this right away*, because we save only the version before the most recent, and the latest before today. So don't keep saving bad versions; Recover right away. The Recover feature works only on a project version that you actually saved, so Restore unsaved project is your first choice if you switch away from a project without saving it.

To help you remember to save your projects, when you've edited the project and haven't yet saved it, Snap! displays a pencil icon to the left of the project name on the toolbar at the top of the window:

2.6. Private and Public Projects

By default, a project you save in the cloud is private; only you can see it. There are two ways to make a project available to others. If you share a project, you can give your friends a project URL (in your browser's URL bar after you open the project) they can use to read it. If you publish a project, it will appear on the Snap! web site, and the whole world can see it. In any case, nobody other than you can ever overwrite your project; if others ask to save it, they get their own copy in their own account.

3. Building a Block

The first version of Snap! was called BYOB, for “Build Your Own Blocks.” This was the first and is still the most important capability we added to Scratch. (The name was changed because a few teachers have no sense of humor. ☺ You pick your battles.) Scratch 2.0 and later also has a partial custom block capability.

3.1. Simple Blocks

In every palette, at or near the bottom, is a button labeled “Make a block”. Also, floating near the top of the palette is a plus sign (+). Also, the menu you get by right-clicking on the background of the scripting area has a “make a block” option.



Clicking any of these will display a dialog window in which you choose the block’s name, shape, and palette/color. You also decide whether the block will be available to all sprites, or only to the current sprite and its children.

3. Building a Block

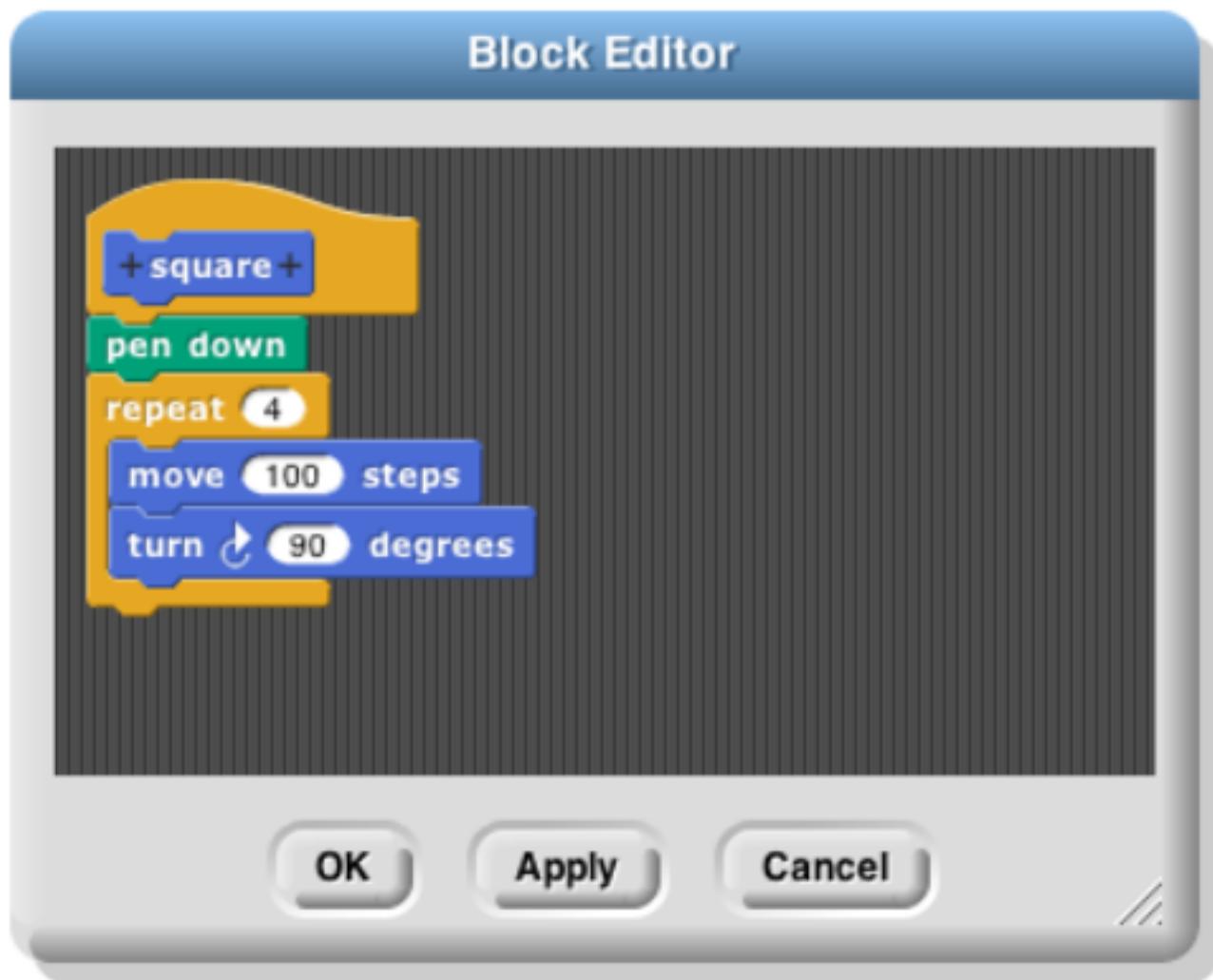
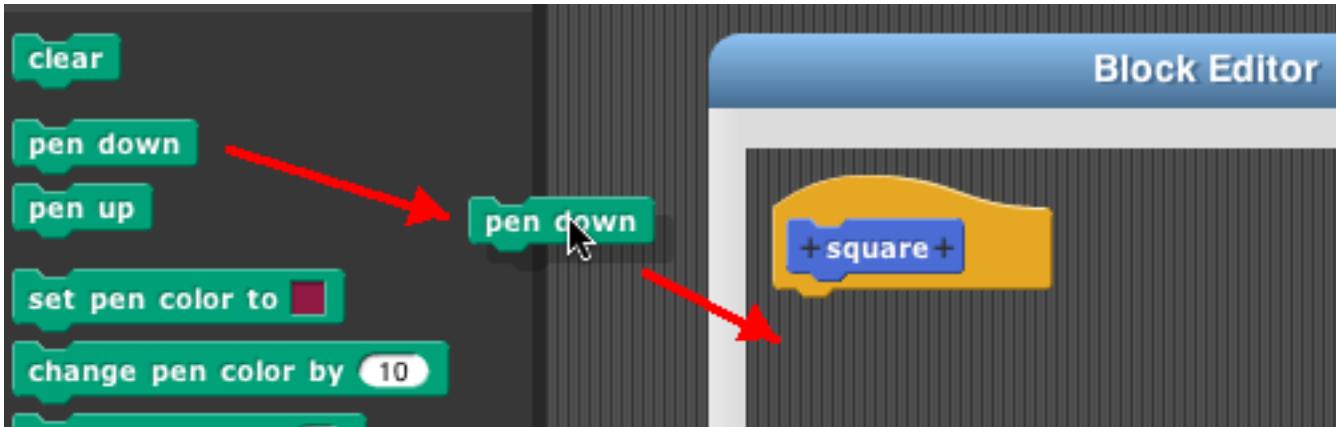


In this dialog box, you can choose the block's palette, shape, and name. With one exception, there is one color per palette, e.g., all Motion blocks are blue. But the Variables palette includes the orange variable-related blocks and the red list-related blocks. Both colors are available, along with an “Other” option that makes grey blocks in the Variables palette for blocks that don't fit any category.

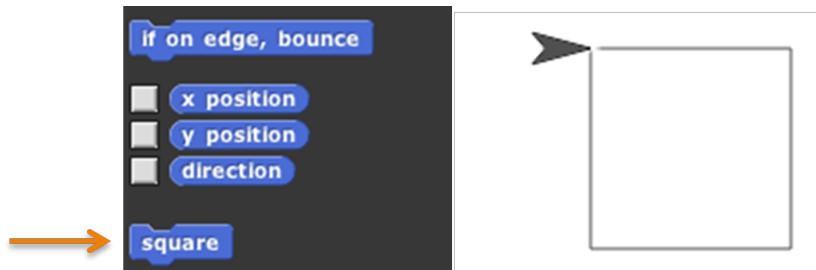
There are three block shapes, following a convention that should be familiar to Scratch users: The jigsaw-puzzle-piece shaped blocks are Commands, and don't report a value. The oval blocks are Reporters, and the hexagonal blocks are Predicates, which is the technical term for reporters that report Boolean (true or false) values.

Suppose you want to make a block named “square” that draws a square. You would choose Motion, Command, and type “square” into the name field. When you click “OK”, you enter the Block Editor. This works just like making a script in the sprite's scripting area, except that the “hat” block at the top, instead of saying something like when I am clicked, has a picture of the block you're building. This hat block is called the *prototype* of your custom block.¹ You drag blocks under the hat to program your custom block, then click OK:

¹This use of the word “prototype” is unrelated to the prototyping object oriented programming discussed later.



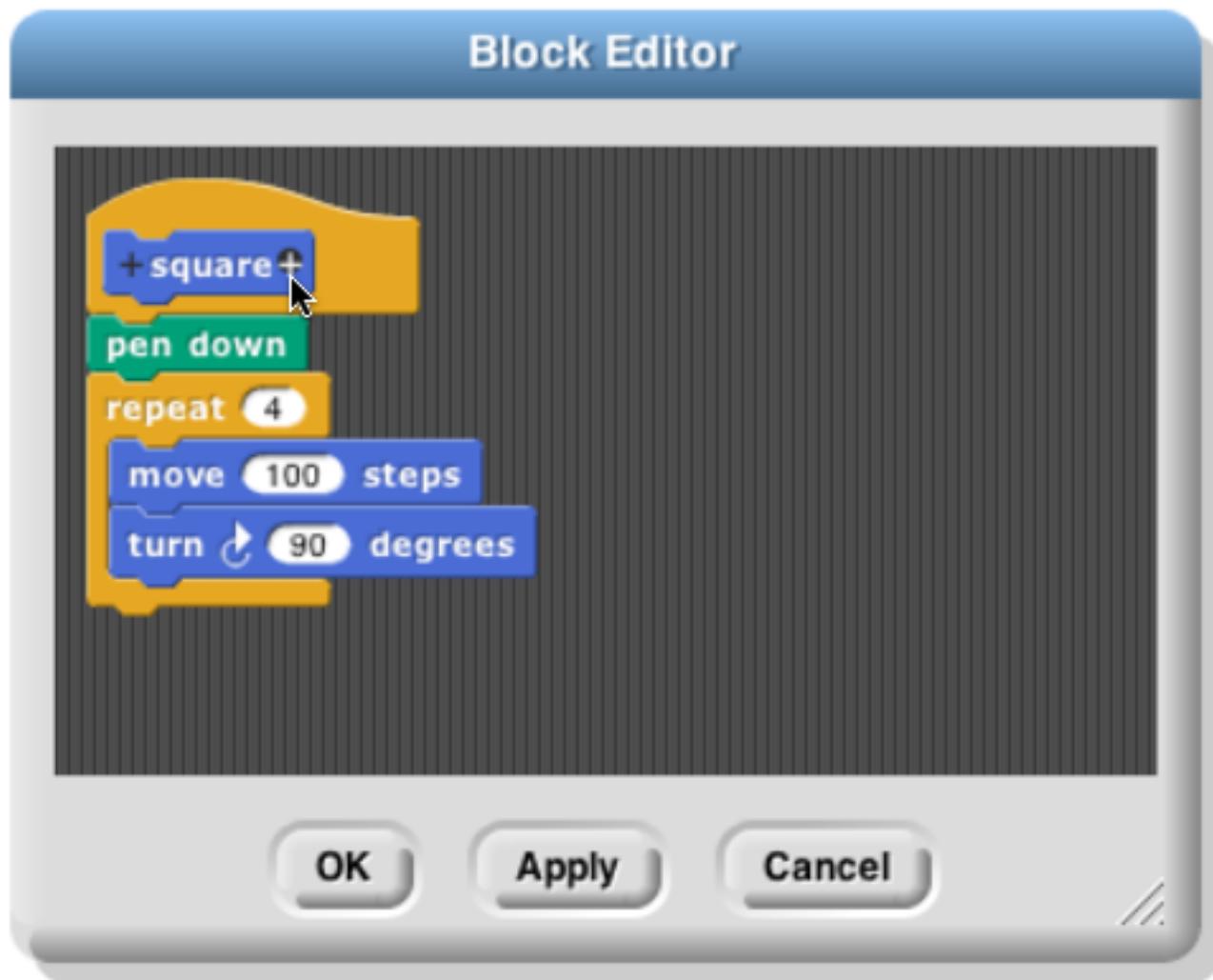
Your block appears at the bottom of the Motion palette. Here's the block and the result of using it:



3. Building a Block

3.1.1. Custom Blocks with Inputs

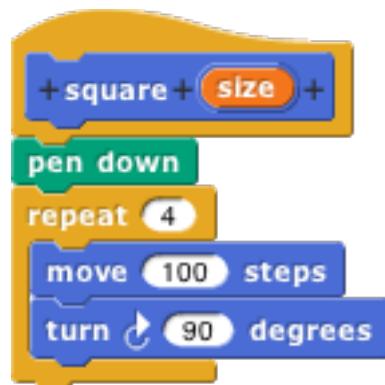
But suppose you want to be able to draw squares of different sizes. “Control-click” or “right click” on the block, choose “edit”, and the Block Editor will open. Notice the plus signs before and after the word square in the prototype block. If you hover the mouse over one, it lights up:



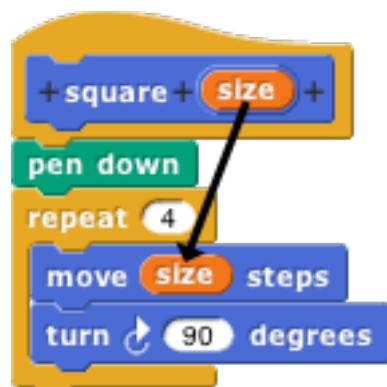
Click on the plus on the right. You will then see the “input name” dialog:



Type in the name “size” and click “OK”. There are other options in this dialog; you can choose “title text” if you want to add words to the block name, so it can have text after an input slot, like the move () steps block. Or you can select a more extensive dialog with a lot of options about your input name. But we’ll leave that for later. When you click OK, the new input appears in the block prototype:



You can now drag the orange variable down into the script, then click okay:



Your block now appears in the Motion palette with an input box: You can draw any size square by entering the length of its side in the box and running the block as usual, by clicking it or by putting it in a script.

3. Building a Block

3.1.2. Editing Block Properties

What if you change your mind about a block's color (palette) or shape (command, reporter, predicate)? If you click in the hat block at the top that holds the prototype, but not in the prototype itself, you'll see a window in which you can change the color, and *sometimes* the shape, namely, if the block is not used in any script, whether in a scripting area or in another custom block. (This includes a one-block script consisting of a copy of the new block pulled out of the palette into the scripting area, seeing which made you realize it's the wrong category. Just delete that copy (drag it back to the palette) and then change the category.)

If you "right-click/control-click" the hat block, you get this menu:



"Script pic" exports a picture of the script. (Many of the illustrations in this manual were made that way.) "Translations" opens a window in which you can specify how your block should be translated if the user chooses a language other than the one in which you are programming. "Block variables" lets you create a variant of script variables for this block: A script variable is created when a block is called, and it disappears when that call finishes. What if you want a variable that's local to this block, as a script variable is, but doesn't disappear between invocations? That's a block variable. If the definition of a block includes a block variable, then every time that (custom) block is dragged from the palette into a script, the block variable is created. Every time that copy of the block is called, it uses the same block variable, which preserves its value between calls. Other copies of the block have their own block variables. The "in palette" checkbox determines whether or not this block will be visible in the palette. It's normally checked, but you may want to hide custom blocks if you're a curriculum writer creating a Parsons problem. To unhide blocks, choose "Hide Blocks" from the File menu and uncheck the checkboxes. "Edit" does the same thing as regular clicking, as described earlier.

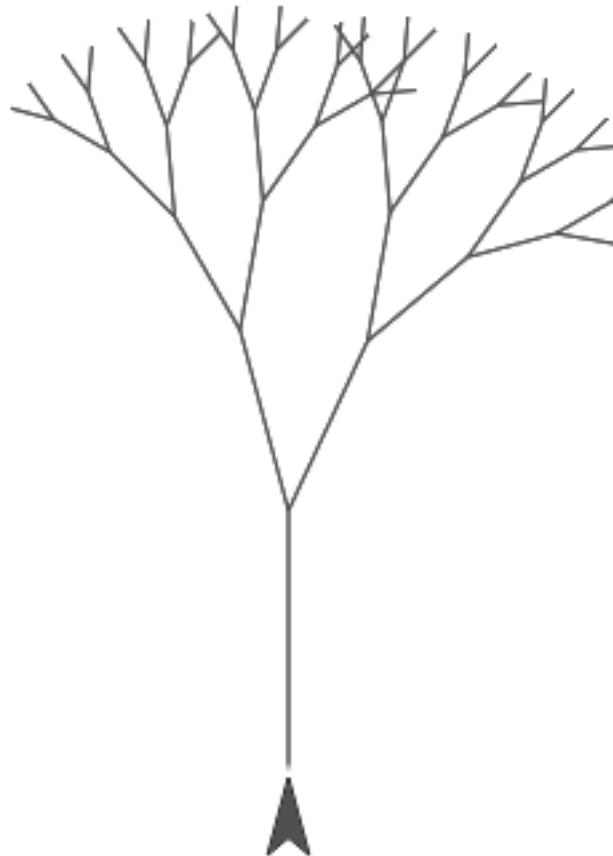
3.2. Recursion

Since the new custom block appears in its palette as soon as you start editing it, you can write recursive blocks (blocks that call themselves) by dragging the block into its own definition:

```

tree size [size], depth [depth]
if [depth > 0]
  move [size] steps
  turn [15] degrees
  tree size [0.7 × size], depth [depth - 1]
  turn [40] degrees
  tree size [0.7 × size], depth [depth - 1]
  turn [25] degrees
  move [-size] steps
when [green flag] clicked
pen down
point in direction [0°]
tree size [100], depth [6]

```



(If you added inputs to the block since opening the editor, click “Apply” before finding the block in the palette, or drag the block from the top of the block editor rather than from the palette.)

If recursion is new to you, here are a few brief hints: It's crucial that the recursion have a *base case*, that is, some small(est) case that the block can handle without using recursion. In this example, it's the case depth=0, for which the block does nothing at all, because of the enclosing if. Without a base case, the recursion would run forever, calling itself over and over.

Don't try to trace the exact sequence of steps that the computer follows in a recursive program. Instead, imagine that inside the computer there are many small people, and if Theresa is drawing a tree of size 100, depth 6, she hires Tom to make a tree of size 70, depth 5, and later hires Theo to make another tree of size 70, depth 5. Tom in turn hires Tammy and Tallulah, and so on. Each little person has his or her own local variables “size” and “depth”, each with different values.

You can also write recursive reporters, like this block to compute the factorial function:

3. Building a Block



Note the use of the report block. When a reporter block uses this block, the reporter finishes its work and reports the value given; any further blocks in the script are not evaluated. Thus, the if else block in the script above could have been just an if, with the second report block below it instead of inside it, and the result would be the same, because when the first report is seen in the base case, that finishes the block invocation, and the second report is ignored. There is also a stop this block block that has a similar purpose, ending the block invocation early, for command blocks. (By contrast, the stop this script block stops not only the current block invocation, but also the entire toplevel script that called it.)

Here's a slightly more compact way to write the factorial function:

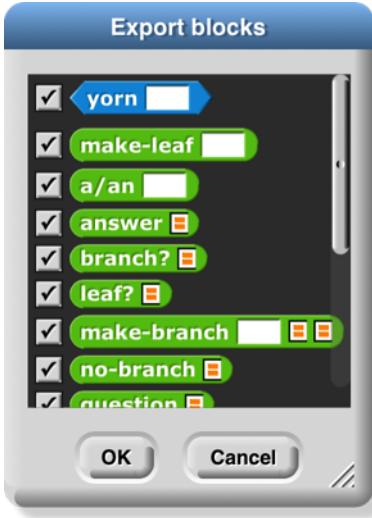


For more on recursion, see *Thinking Recursively* by Eric Roberts. (The original edition is ISBN 978-0471816522; a more recent *Thinking Recursively in Java* is ISBN 978-0471701460.)

3.3. Block Libraries

When you save a project (see Chapter II above), any custom blocks you've made are saved with it. But sometimes you'd like to save a collection of blocks that you expect to be useful in more than one project. Perhaps your blocks implement a particular data structure (a stack, or a dictionary, etc.), or they're the framework for building a multilevel game. Such a collection of blocks is called a *block library*.

To create a block library, choose “Export blocks...” from the “File” menu. You then see a window like this:



The window shows all of your global custom blocks. You can uncheck some of the checkboxes to select exactly which blocks you want to include in your library. (You can “right-click” or “control-click” on the export window for a menu that lets you check or uncheck all the boxes at once.) Then press “OK”. An XML file containing the blocks will appear in your Downloads location.

To import a block library, use the “Import...” command in the “File” menu, or just drag the XML file into the Snap! window.

Several block libraries are included with Snap!; for details about them, see Section 1.9.

3.4. Custom blocks and Visible Stepping

Visible stepping normally treats a call to a custom block as a single step. If you want to see stepping inside a custom block you must take these steps *in order*:

1. Turn on “Visible Stepping” by pressing the footprints button:
2. Select “Edit” in the context menu(s) of the block(s) you want to examine.
3. Then start the program.

The Block Editor windows you open in step 2 do not have full editing capability. You can tell because there is only one “OK” button at the bottom, not the usual three buttons. Use the button to close these windows when done stepping.

4. First class lists

A data type is *first class* in a programming language if data of that type can be

- the value of a variable
- an input to a procedure
- the value returned by a procedure
- a member of a data aggregate
- anonymous (not named)

In Scratch, numbers and text strings are first class. You can put a number in a variable, use one as the input to a block, call a reporter that reports a number, or put a number into a list.

But Scratch's lists are not first class. You create one using the "Make a list" button, which requires that you give the list a name. You can't put the list into a variable, into an input slot of a block, or into a list item—you can't have lists of lists. None of the Scratch reporters reports a list value. (You can use a reduction of the list into a text string as input to other blocks, but this loses the list structure; the input is just a text string, not a data aggregate.)

A fundamental design principle in Snap! is that ***all data should be first class***. If it's in the language, then we should be able to use it fully and freely. We believe that this principle avoids the need for many special-case tools, which can instead be written by Snap! users themselves.

Note that it's a data type that's first class, not an individual value. Don't think, for example, that some lists are first class, while others aren't. In Snap!, lists are first class, period.



Everything first-class

4.1. The list Block

At the heart of providing first class lists is the ability to make an "anonymous" list—to make a list without simultaneously giving it a name. The list reporter block does that.

list ▶ as it appears in the Variables palette

list She Loves You ▶

▶ The items of a list don't all have to be the same type:

list list For No One ▶ 41 ▶

list ▶ Clicking the left arrowhead lets you make an empty list.

4. First class lists

At the right end of the block are two left-and-right arrowheads . Clicking on these changes the number of inputs to list, i.e., the number of elements in the list you are building. Shift-clicking changes by three at a time.

You can use this block as input to many other blocks:



Snap! does not have a “Make a list” button like the one in Scratch . If you want a global “named list,” make a global variable and use the set block to put a list into the variable.

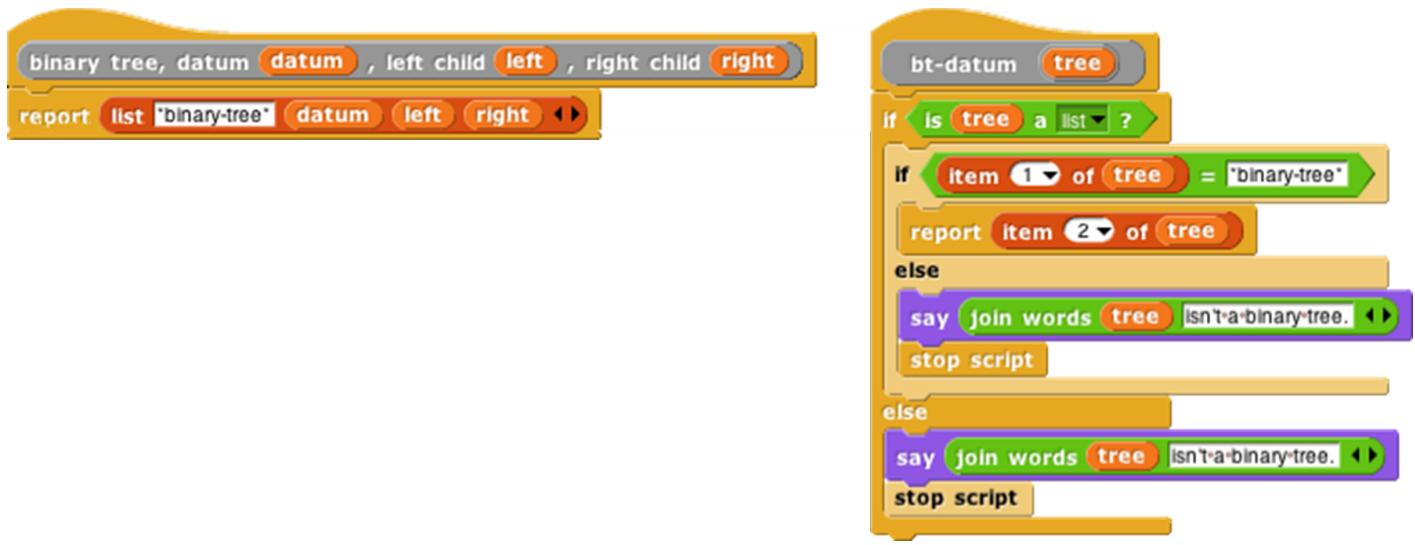
4.2. Lists of Lists

Lists can be inserted as elements in larger lists. We can easily create ad hoc structures as needed:



Notice that this list is presented in a different format from the “She Loves You” list above. A two-dimensional list is called a *table* and is by default shown in *table view*. We’ll have more to say about this later.

We can also build any classic computer science data structure out of lists of lists, by defining *constructors* (blocks to make an instance of the structure), *selectors* (blocks to pull out a piece of the structure), and *mutators* (blocks to change the contents of the structure) as needed. Here we create binary trees with selectors that check for input of the correct data type; only one selector is shown but the ones for left and right children are analogous.



4.3. Functional and Imperative List Programming

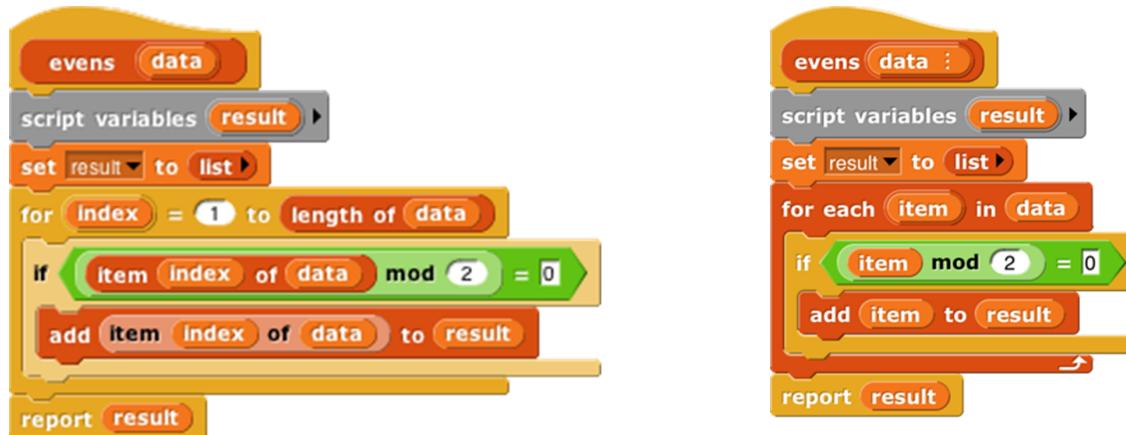
There are two ways to create a list inside a program. Scratch users will be familiar with the *imperative* programming style, which is based on a set of command blocks that modify a list:



As an example, here are two blocks that take a list of numbers as input, and report a new list containing only the even numbers from the original list:¹

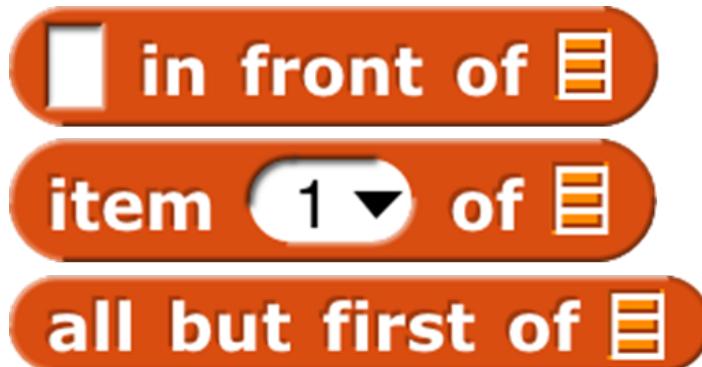
¹Note to users of earlier versions: From the beginning, there has been a tension in our work between the desire to provide tools such as `for` (used in this example) and the higher order functions introduced on the next page as primitives, to be used as easily as other primitives, and the desire to show how readily such tools can be implemented in Snap! itself. This is one instance of our general pedagogic understanding that learners should both use abstractions and be permitted to see beneath the abstraction barrier. Until version 5.0, we used the uneasy compromise of a library of tools written in Snap! and easily, but not easily enough, loaded into a project. By not loading the tools, users or teachers could explore how to program them. In 5.0 we made them true primitives, partly because that's what some of us wanted all along and partly because of the increasing importance of fast performance as we explore "big data" and media computation. In version 10.0 we introduced "hybrid" primitives, implemented in high speed Javascript but with an "Edit" option that will open, not the primitive implementation, but the version written in Snap!. This gives us editable primitives without dramatically slowing users' projects.

4. First class lists

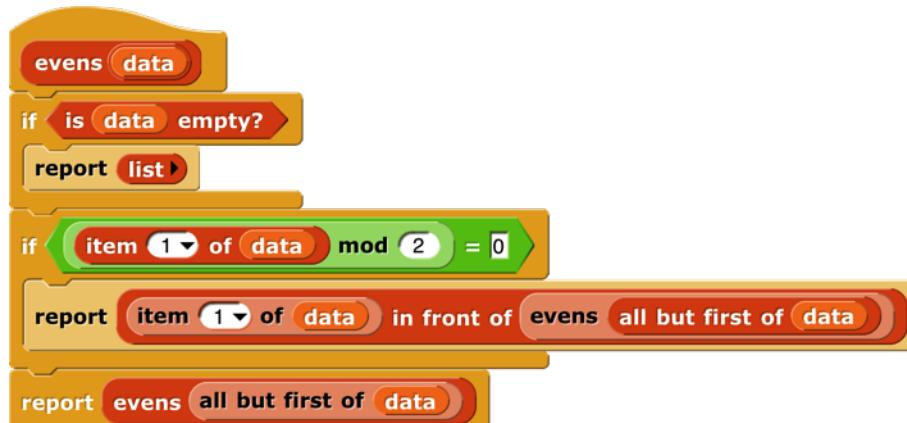


In these scripts, we first create a temporary variable, then put an empty list in it, then go through the items of the input list using the add ... to (result) block to modify the result list, adding one item at a time, and finally report the result.

Functional programming is a different approach that is becoming important in “real world” programming because of parallelism , i.e., the fact that different processors can be manipulating the same data at the same time. This makes the use of mutation (changing the value associated with a variable, or the items of a list) problematic because with parallelism it’s impossible to know the exact sequence of events, so the result of mutation may not be what the programmer expected. Even without parallelism, though, functional programming is sometimes a simpler and more effective technique, especially when dealing with recursively defined data structures. It uses reporter blocks, not command blocks, to build up a list value:



In a functional program, we often use recursion to construct a list, one item at a time. The `in front of` block makes a list that has one item added to the front of an existing list, *without changing the value of the original list*. A nonempty list is processed by dividing it into its first item (`item 1 of`) and all the rest of the items (`all but first of`), which are handled through a recursive call:



Snap! uses two different internal representations of lists, one (dynamic array) for imperative programming and the other (linked list) for functional programming. Each representation makes the corresponding built-in list blocks (commands or reporters, respectively) most efficient. It's possible to mix styles in the same program, but if the same list is used both ways, the program will run more slowly because it converts from one representation to the other repeatedly. (The `item () of []` block doesn't change the representation.) You don't have to know the details of the internal representations, but it's worthwhile to use each list in a consistent way.

4.4. Higher Order List Operations and Rings

There's an even easier way to select the even numbers from a list:



Figure 4.1.: image556.png

The `keep` block takes a Predicate expression as its first input, and a list as its second input. It reports a list containing those elements of the input list for which the predicate returns `true`. Notice two things about the predicate input: First, it has a grey ring around it. Second, the `mod` block has an empty input. `Keep` puts each item of its input list, one at a time, into that empty input before evaluating the predicate. (The empty input is supposed to remind you of the “box” notation for variables in elementary school: $\boxed{2}+3=7$.) The grey ring is part of the `keep` block as it appears in the palette:



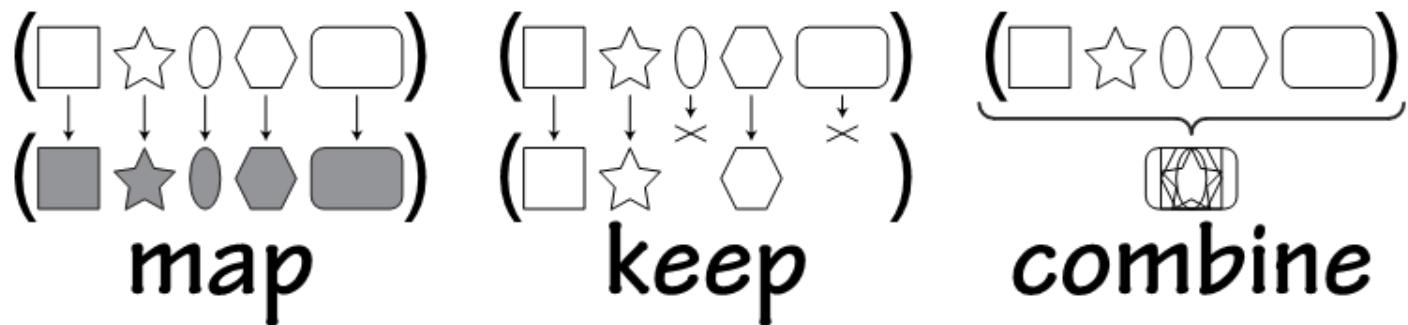
What the ring means is that this input is a block (a predicate block, in this case, because the interior of the ring is a hexagon), rather than the value reported by that block. Here's the difference:



Figure 4.2.: image634.png

Evaluating the `=` block without a ring reports `true` or `false`; evaluating the block with a ring reports the block itself. This allows `keep` to evaluate the `=` predicate repeatedly, once for each list item. A block that takes another block as input is called a *higher order* block (or higher order procedure, or higher order function).

4. First class lists



Snap! provides four higher order function blocks for operating on lists:

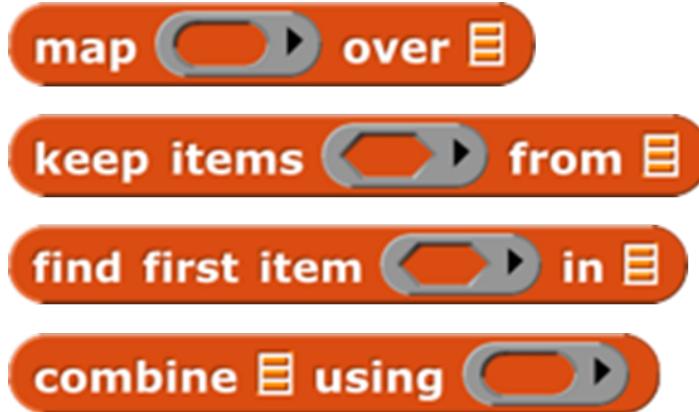


Figure 4.3.: image636.png

4.4.1. The `map` block

You've already seen `keep`. `Find first` is similar, but it reports just the first item that satisfies the predicate, not a list of all the matching items. It's equivalent to `item 1 of keep items from` but faster because it stops looking as soon as it finds a match. If there are no matching items, it returns an empty string.

`Map` takes a Reporter block and a list as inputs. It reports a new list in which each item is the value reported by the Reporter block as applied to one item from the input list. That's a mouthful, but an example will make its meaning clear:



Figure 4.4.: image637.png

By the way, we've been using arithmetic examples, but the list items can be of any type, and any reporter can be used. We'll make the plurals of some words:



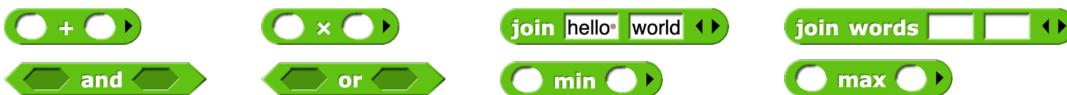
These examples use small lists, to fit the page, but the higher order blocks work for any size list.

An empty gray ring represents the *identity function*, which just reports its input. Leaving the ring in `map` empty is the most concise way to make a shallow copy of a list (that is, in the case of a list of lists, the result is a new toplevel list whose items are the same (uncopied) lists that are items of the toplevel input list). To make a deep copy of a list (that is, one in which all the sublists, sublists of sublists, etc. are copied), use the list as input to the



block (one of the variants of the `sqrt` of block). This works because `id of` is a hyperblock.

The third higher order block, `combine`, computes a single result from *all* the items of a list, using a two-input reporter as its second input. In practice, there are only a few blocks you'll ever use with `combine`:



These blocks take the sum of the list items, take their product, string them into one word, combine them into a sentence (with spaces between items), see if all items of a list of Booleans are true, see if any of the items is true, find the smallest, or find the largest.



Why + but not -? It only makes sense to combine list items using an *associative* function: one that doesn't care in what order the items are combined (left to right or right to left). $(2+3)+4 = 2+(3+4)$, but $(2-3)-4 \neq 2-(3-4)$.

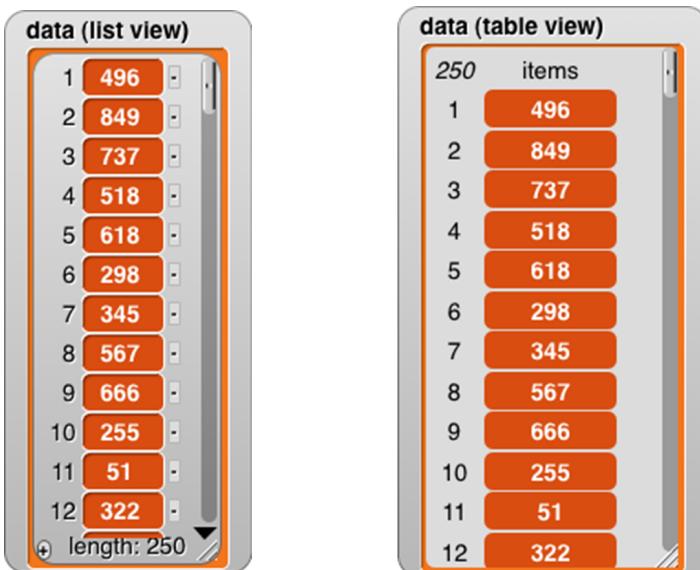
The functions `map`, `keep`, and `find first` first have an advanced mode with rarely-used features: If their function input is given explicit input names (by clicking the arrowhead at the right end of the gray ring), then it will be called for each list item with *three* inputs: the item's value (as usual), the item's position in the input list (its index), and the entire input list. No more than three input names can be used in this context.



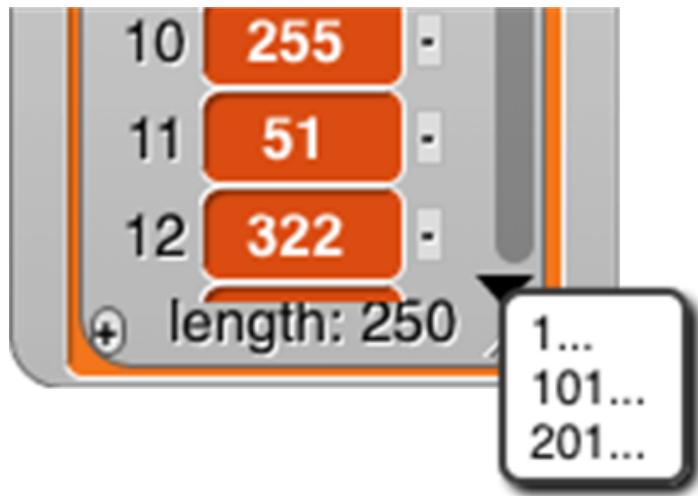
4.5. Table View vs. List View

We mentioned earlier that there are two ways of representing lists visually. For one-dimensional lists (lists whose items are not themselves lists) the visual differences are small:

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For one-dimensional lists, it's not really the appearance that's important. What matters is that the *list* view allows very versatile direct manipulation of the list through the picture: you can edit the individual items, you can delete items by clicking the tiny buttons next to each item, and you can add new items at the end by clicking the tiny plus sign in the lower left corner. (You can just barely see that the item deletion buttons have minus signs in them.) Even if you have several watchers for the same list, all of them will be updated when you change anything. On the other hand, this versatility comes at an efficiency cost; a list view watcher for a long list would be way too slow. As a partial workaround, the list view can only contain 100 items at a time; the downward-pointing arrowhead opens a menu in which you can choose which 100 to display.



By contrast, because it doesn't allow direct editing, the *table* view watcher can hold hundreds of thousands of items and still scroll through them efficiently. The table view has flatter graphics for the items to remind you that they're not clickable to edit the values.

Right-clicking on a list watcher (in either form) gives you the option to switch to the other form. The right-click menu also offers an `open in dialog...` option that opens an *offstage* table view watcher, because the watchers can take up a lot of stage space that may make it hard to see what your program is actually doing. Once the *offstage* dialog box is open, you can close the stage watcher. There's an OK button on the *offstage* dialog to close it if you want. Or you can right-click it to make *another* *offstage* watcher, which is useful if you want to watch two parts of the list at once by having each watcher scrolled to a different place.

Table view is the default if the list has more than 100 items, or if any of the first ten items of the list are lists, in which case it makes a very different-looking two-dimensional picture:

	A	B
1	John	Lennon
2	Paul	McCartney
3	George	Harrison
4	Ringo	Starr

```

list [list John Lennon v] 
list [list Paul McCartney v] 
list [list George Harrison v] 
list [list Ringo Starr v]

```

In this format, the column of red items has been replaced by a spreadsheet-looking display. For short, wide lists, this display makes the content of the list very clear. A vertical display, with much of the space taken up by the “machinery” at the bottom of each sublist, would make it hard to show all the text at once. (The pedagogic cost is that the structure is no longer explicit; we can’t tell just by looking that this is a list of row-lists, rather than a list of column-lists or a primitive two-dimensional array type. But you can choose list view to see the structure.)

Beyond such simple cases, in which every item of the main list is a list of the same length, it’s important to keep in mind that the design of table view has to satisfy two goals, not always in agreement: (1) a visually compelling display of two-dimensional arrays, and (2) highly efficient display generation, so that Snap! can handle very large lists, since “big data” is an important topic of study. To meet the first goal perfectly in the case of “ragged right” arrays in which sublists can have different lengths, Snap! would scan the entire list to find the maximum width before displaying anything, but that would violate the second goal.

Snap! uses the simplest possible compromise between the two goals: It examines only the first ten items of the list to decide on the format. If none of those are lists, or they’re all lists of one item, and the overall length is no more than 100, list view is used. If the any of first ten items is a list, then table view is used, and the number of columns in the table is equal to the largest number of items among the first ten items (sublists) of the main list.

Table views open with standard values for the width and height of a cell, regardless of the actual data. You can change these values by dragging the column letters or row numbers. Each column has its own width, but changing the height of a row changes the height for all rows. (This distinction is based not on the semantics of rows vs. columns, but on the fact that a constant row height makes scrolling through a large list more efficient.) Shift-dragging a column label will change the width of that column.

If you tried out the adjustments in the previous paragraph, you may have noticed that a column letter turns into a number when you hover over it. Labeling rows and columns differently makes cell references such as “cell 4B” unambiguous; you don’t have to have a convention about whether to say the row first or the column first. (“Cell B4” is the same as “cell 4B.”) On the other hand, to extract a value from column B in your program, you have to say `item 2 of`, not `item B of`. So it’s useful to be able to find out a column number by hovering over its letter.

Any value that can appear in a program can be displayed in a table cell:

	A	B
1	type	example
2	number	87
3	text	Rumplestiltskin
4	block	
5	sprite	

```

list [list type example v] 
list [list number 87 v] 
list [list text Rumplestiltskin v] 
list [list block repeat (10)] 
list [list sprite self v]

```

This display shows that the standard cell dimensions may not be enough for large value images. By expanding the entire speech balloon and then the second column and all the rows, we can make the result fit:

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The screenshot shows a table with 5 rows and 2 columns. Row 1: A, type | example. Row 2: A, number | 87. Row 3: A, text | Rumplestiltskin. Row 4: A, block | repeat [10 v]. Row 5: A, sprite | a yellow cat. Below the table is a script consisting of the following blocks:

- list type example
- list number 87
- list text Rumplestiltskin
- list block repeat [10 v]
- list sprite my self

But we make an exception for cases in which the value in a cell is a list (so that the entire table is three-dimensional). Because lists are visually very big, we don't try to fit the entire value in a cell:

The screenshot shows a table with 3 rows and 2 columns. Row 1: A, list [name Brian Harvey]. Row 2: A, list [address 784-Soda Hall Berkeley CA-94720]. Row 3: A, list [phone +1-510-642-8311]. Below the table is a script consisting of the following blocks:

- list name list Brian Harvey
- list address list 784-Soda Hall Berkeley CA-94720
- list phone list +1-510-642-8311

Even if you expand the size of the cells, Snap! will not display sublists of sublists in table view. There are two ways to see these inner sublists: You can switch to list view, or you can double-click on a list icon in the table to open a dialog box showing just that sub-sub-list in table view.

One last detail: If the first item of a list is a list (so table view is used), but a later item isn't a list, that later item will be displayed on a red background, like an item of a single-column list:

The screenshot shows a table with 3 rows and 2 columns. Row 1: A, foo. Row 2: A, bar. Row 3: A, single. Below the table is a script consisting of the following blocks:

- list list foo
- list list bar
- list single

So, in particular, if only the first item is a list, the display will look almost like a one-column display.

4.5.1. Comma-Separated Values

Spreadsheet and database programs generally offer the option to export their data as CSV (comma-separated values) lists. You can import these files into Snap! and turn them into tables (lists of lists), and you can export tables in CSV format. Snap! recognizes a CSV file by the extension .csv in its filename.

A CSV file has one line per table row, with the fields separated by commas within a row:

```
John,Lennon,rhythm guitar
Paul,McCartney,bass guitar
George,Harrison,lead guitar
Ringo,Starr,drums
```

Here's what the corresponding table looks like:

The image shows two views of the same data: the Beatles' band members and their instruments. On the left, under "table view", the data is presented as a 4x3 grid:

	A	B	C
1	John	Lennon	rhythm guitar
2	Paul	McCartney	bass guitar
3	George	Harrison	lead guitar
4	Ringo	Starr	drums

On the right, under "list view", the data is shown as three separate lists:

- list 1 (top):** John, Lennon, rhythm guitar. A note indicates length: 3.
- list 2 (middle):** Paul, McCartney, bass guitar. A note indicates length: 3.
- list 3 (bottom):** George, Harrison, lead guitar. A note indicates length: 4.

Here's how to read a spreadsheet into Snap!:

1. Make a variable with a watcher on stage:
2. Right-click on the watcher and choose the “import” option. (If the variable’s value is already a list, be sure to click on the outside border of the watcher; there is a different menu if you click on the list itself.) Select the file with your csv data.
3. There is no 3; that’s it! Snap! will notice that the name of the file you’re importing is something.csv and will turn the text into a list of lists automatically.

Or, even easier, just drag and drop the file from your desktop onto the Snap! window, and Snap! will automatically create a variable named after the file and import the data into it.

If you actually want to import the raw CSV data into a variable, either change the file extension to .txt before loading it, or choose “raw data” instead of “import” in the watcher menu.

If you want to export a list, put a variable watcher containing the list on the stage, right-click its border, and choose “Export.” (Don’t right-click an item instead of the border; that gives a different menu.)

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4.5.2. Multi-dimensional lists and JSON

CSV format is easy to read, but works only for one- or two-dimensional lists. If you have a list of lists of lists, Snap! will instead export your list as a JSON (JavaScript Object Notation) file. I modified my list:



and then exported again, getting this file:

```
[["John", "Lennon", "rhythm guitar"], [[{"James": "Paul"}, {"McCartney": "bass guitar"}, {"George": "Harrison guitar"}], [{"Ringo": "Starr", "drums": ""}]]
```

You can also import lists, including tables, from a .json file. (And you can import plain text from a .txt file.) Drag and drop works for these formats also.

4.6. Hyperblocks

A *scalar* is anything other than a list. The name comes from mathematics, where it means a magnitude without direction, as opposed to a vector, which points toward somewhere. A scalar function is one whose domain and range are scalars, so all the arithmetic operations are scalar functions, but so are the text ones such as `letter` and the Boolean ones such as `not`.

The major new feature in Snap! 6.0 is that the domain and range of most scalar function blocks is extended to multi-dimensional lists, with the underlying scalar function applied termwise:



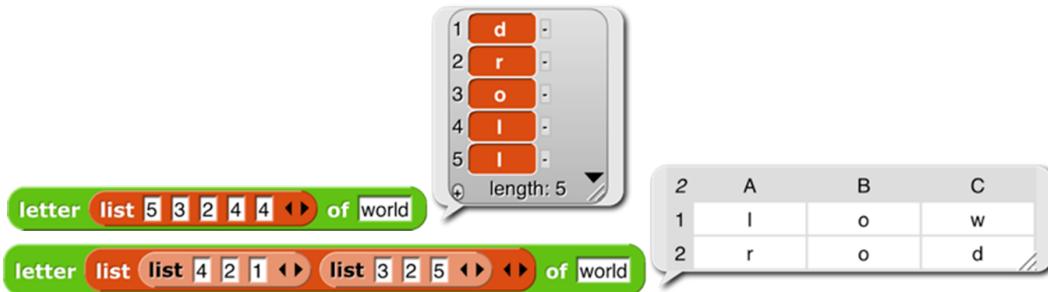
Mathematicians, note in the last example above that the result is just a termwise application of the underlying function ($7 \times 3, 8 \times 5$, etc.), *not* matrix multiplication. See Appendix C for that. For a dyadic (two-input) function, if the lengths don't agree, the length of the result (in each dimension) is the length of the shorter input:



However, if the *number of dimensions* differs in the two inputs, then the number of dimensions in the result agrees with the *higher-dimensional* input; the lower-dimensional one is used repeatedly in the missing dimension(s):



($7 \times 6, 8 \times 10, 1 \times 20, 40 \times 6, 20 \times 10$, etc.). In particular, a *scalar* input is paired with every scalar in the other input:



One important motivation for this feature is how it simplifies and speeds up media computation, as in this shifting of the Alonzo costume to be bluer:



Each pixel of the result has $\frac{3}{4}$ of its original red and green, and three times its original blue (with its transparency unchanged). By putting some sliders on the stage, you can play with colors dynamically:



There are a few naturally scalar functions that have already had specific meanings when applied to lists and therefore are not hyperblocks: = and identical to (because they compare entire structures, not just scalars, always reporting a single Boolean result), and and or (because they don't evaluate their second input at all if the first input determines the result), join (because it converts non-scalar (and other non-text) inputs to text string form), and is a (type) (because it applies to its input as a whole). Blocks whose inputs are "natively" lists, such as

length ▾ of

as and **in front of**, are never hyperblocks.

reshape **to** **4** **3** **◀▶**

The **reshape** block takes a list (of any depth) as its first input, and then takes zero or more sizes along the dimensions of an array. In the example it will report a table (a matrix) of four rows and three columns. If no sizes are given, the result is an empty list. Otherwise, the cells of the specified shape are filled with the atomic values from the input list. If more values are needed than provided, the block starts again at the head of the list, using values more than once. If more values are provided than needed, the extras are ignored; this isn't an error.

combinations **◀▶**

The **combinations** block takes any number of lists as input; it reports a list in which each item is a list whose length is the number of inputs; item i of a sublist is an item of input i . Every possible combination of items of the inputs is included, so the length of the reported list is the product of the lengths of the inputs.

4. First class lists

combinations `list [a b] [list [x y z]]`

	A	B
1	a	x
2	a	y
3	a	z
4	b	x
5	b	y
6	b	z

item 1 of []

The `item` of block has a special set of rules, designed to preserve its pre-hyperblock meaning and also provide a useful behavior when given a list as its first (index) input:

1. If the index is a number, then `item` of reports the indicated top-level item of the list input; that item may be a sublist, in which case the entire sublist is reported (the original meaning of `item` of):

2. If the index is a list of numbers (no sublists), then `item` of reports a list of the indicated top-level items (rows, in a matrix; a straightforward hyperization):

3. If the index is a list of lists of numbers, then `item` of reports an array of only those scalars whose position in the list input matches the index input in all dimensions (as of Snap! 6.6):

4. If a list of list of numbers includes an empty sublist, then all items are chosen along that dimension:

To get a column or columns of a spreadsheet, use an empty list in the row selector (as of Snap! 6.6):

The screenshot shows a block-based programming interface with a central orange block labeled "item". This block has several options: "list", "length", "rank", "dimensions", "flatten", "columns", and "reverse". Each option is followed by a smaller block that provides more detail. To the right of the main interface is a table representing a spreadsheet with four rows and three columns, labeled A, B, and C.

	A	B	C
1	Lennon	John	Lennon
2	McCartney	Paul	McCartney
3	Harrison	George	Harrison
4	Starr	Ringo	Starr

The length of block is extended to provide various ways of looking at the shape and contents of a list. The options other than `length` are mainly useful for *lists of lists*, to any depth. These new options work well with hyperblocks and the APL library.

- `length`: reports the number of (toplevel) items in the list, as always.
- `rank` : reports the number of *dimensions* of the list, i.e., the maximum depth of lists of lists of lists. (That example would be rank 4.)
- `dimensions` : reports a list of numbers, each of which is the maximum length in one dimension, so a spreadsheet of 1000 records, each with 4 fields, would report the list [1000 4].
- `flatten` : reports a flat, one-dimensional list containing the *atomic* (non-list) items anywhere in the input list.
- `columns` : reports a list in which the rows and columns of the input list are interchanged, so the shape of the transpose of a shape [1000 4] list would be [4 1000]. This option works only for lists whose rank is at most 2. The name reflects the fact that the toplevel items of the reported table are the columns of the original table.
- `reverse`: reports a list in which the (toplevel) items of the input list are in reverse order.

The remaining three options report a (generally multi-line) text string. The input list may not include any atomic (non-list) data other than text or numbers. The `lines` option is intended for use with rank-one lists of text strings; it reports a string in which each list item becomes a line of text. You can think of it as the opposite of the `split by line` block . The `csv` option (comma-separated values) is intended for rank-two lists that represent a spreadsheet or other tabular data. Each item of the input list should be a list of atoms; the block reports a text string in which each item of the big list becomes a line of text in which the items of that sublist are separated by commas. The `json` option is for lists of any rank; it reports a text string in which the list structure is explicitly represented using square brackets. These are the opposites of `split by csv` and `split by json`.

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The image shows a sequence of Squeak Hyperblocks illustrating various operations on lists:

- length of**: Returns 4.
- rank of**: Returns 2.
- dimensions of**: Returns length: 2.
- flatten of**: Returns a single list [1 2 3 ..., 10 11 12].
- columns of**: Returns a 3x4 matrix:

3	A	B	C
1	1	4	7
2	2	5	8
3	3	6	9
- reverse of**: Returns a 4x3 matrix:

4	A	B	C
1	10	11	12
2	7	8	9
3	4	5	6
4	1	2	3
- lines of**: Returns 1, 2, 3, 4. An error message "Error: unable to convert to TXT" is shown above the output.
- csv of**: Returns the CSV string "1,2,3\n4,5,6\n7,8,9\n10,11,12".
- json of**: Returns the JSON array "[["1","2","3"], ["4","5","6"], ["7","8","9"], ["10","11","12"]]".

The idea of extending the domain and range of scalar functions to include arrays comes from the language APL. (All the great programming languages are based on mathematical ideas. Our primary ancestors are Smalltalk, based on models, and Lisp, based on lambda calculus. Prolog, a great language not (so far) influencing Snap!, is based on logic. And APL, now joining our family, is based on linear algebra, which studies vectors and matrices. Those other programming languages are based on the weaknesses of computer hardware.) Hyperblocks are not the whole story about APL, which also has mixed-domain functions and higher order functions. Some of what's missing is provided in the APL library. (See Appendix B.)

5. Typed Inputs

5.1. Scratch's Type Notation

Prior to version 3, Scratch block inputs came in two types : Text-or-number type and Number type. The former is indicated by a rectangular box, the latter by a rounded box:  . A third Scratch type, Boolean (true/false), can be used in certain Control blocks with hexagonal slots.

The Snap! types are an expanded collection including Procedure, List, and Object types. Note that, with the exception of Procedure types, all of the input type shapes are just reminders to the user of what the block expects; they are not enforced by the language.

5.2. The Snap! Input Type Dialog

In the Block Editor input name dialog, there is a right-facing arrowhead after the “Input name” option:

![image692.png](assets/image692.png){.image-2x}

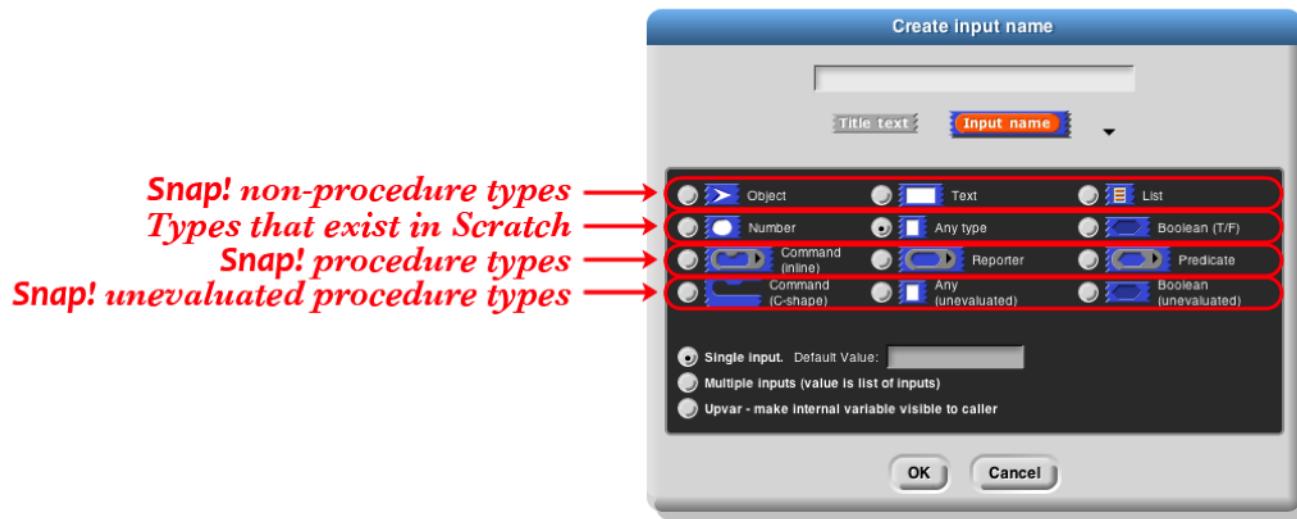
Clicking that arrowhead opens the “long” input name dialog :



There are twelve input type shapes, plus three mutually exclusive modifiers, listed in addition to the basic choice between title text and an input name. The default type, the one you get if you don't choose anything else, is “Any”, meaning that this input slot is meant to accept any value of any type. If the size input in your block should be an oval-shaped numeric slot rather than a generic rectangle, click “Number”

The arrangement of the input types is systematic. As the pictures on this and the next page show, each row of types is a category, and parts of each column form a category. Understanding the arrangement will make it a little easier to find the type you want.

5. Typed Inputs



The second row of input types contains the ones found in Scratch: Number, Any, and Boolean. (The reason these are in the second row rather than the first will become clear when we look at the column arrangement.) The first row contains the new Snap! types other than procedures: Object, Text, and List. The last two rows are the types related to procedures, discussed more fully below.

The List type is used for first class lists, discussed in Chapter IV above. The red rectangles inside the input slot are meant to resemble the appearance of lists as Snap! displays them on the stage: each element in a red rectangle.

The Object type is for sprites, costumes, sounds, and similar data types.

The Text type is really just a variant form of the Any type, using a shape that suggests a text input.¹

5.2.1. Procedure Types

Although the procedure types are discussed more fully later, they are the key to understanding the column arrangement in the input types. Like Scratch, Snap! has three block shapes : jigsaw-piece for command blocks, oval for reporters, and hexagonal for predicates. (A *predicate* is a reporter that always reports true or false.) In Snap! these blocks are first class data; an input to a block can be of Command type, Reporter type, or Predicate type. Each of these types is directly below the type of value that that kind of block reports, except for Commands, which don't report a value at all. Thus, oval Reporters are related to the Any type, while hexagonal Predicates are related to the Boolean (true or false) type.

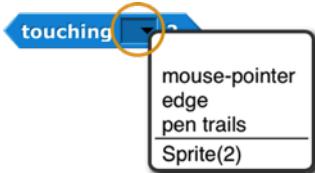
The unevaluated procedure types in the fourth row are explained in Section VI.E below. In one handwavy sentence, they combine the *meaning* of the procedure types with the *appearance* of the reported value types two rows higher. (Of course, this isn't quite right for the C-shaped command input type, since commands don't report values. But you'll see later that it's true in spirit.)

¹In Scratch, every block that takes a Text-type input has a default value that makes the rectangles for text wider than tall. The blocks that aren't specifically about text either are of Number type or have no default value, so those rectangles are taller than wide. At first some of us (bh) thought that Text was a separate type that always had a wide input slot; it turns out that this isn't true in Scratch (delete the default text and the rectangle narrows), but we thought it a good idea anyway, so we allow Text-shaped boxes even for empty input slots. (This is why Text comes just above Any in the input type selection box.)

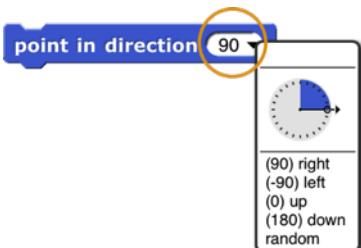


5.2.2. Pulldown inputs

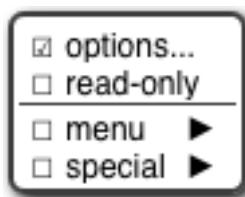
Certain primitive blocks have *pulldown* inputs, either *read-only*, like the input to the *is ()* touching block:



(indicated by the input slot being the same (cyan, in this case) color as the body of the block), or *writeable*, like the input to the *point in direction ()* block:



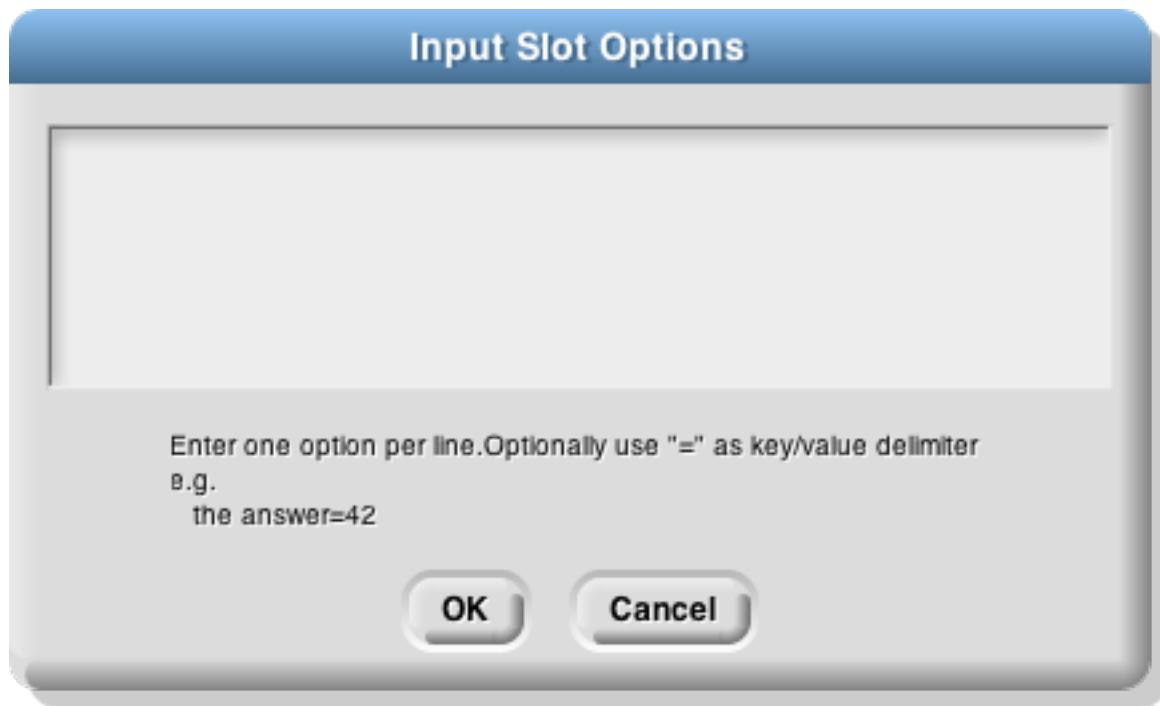
(indicated by the white input slot), which means that the user can type in an arbitrary input instead of using the pulldown menu.



Custom blocks can also have such inputs. To make a pulldown input, open the long form input dialog, choose a text type (Any, Text, or Number) and click the icon in the bottom right corner, or control/right-click in the dialog. You will see this menu:

5. Typed Inputs

Click the “read-only” checkbox if you want a read-only pulldown input. Then from the same menu, choose “options...” to get this dialog box:

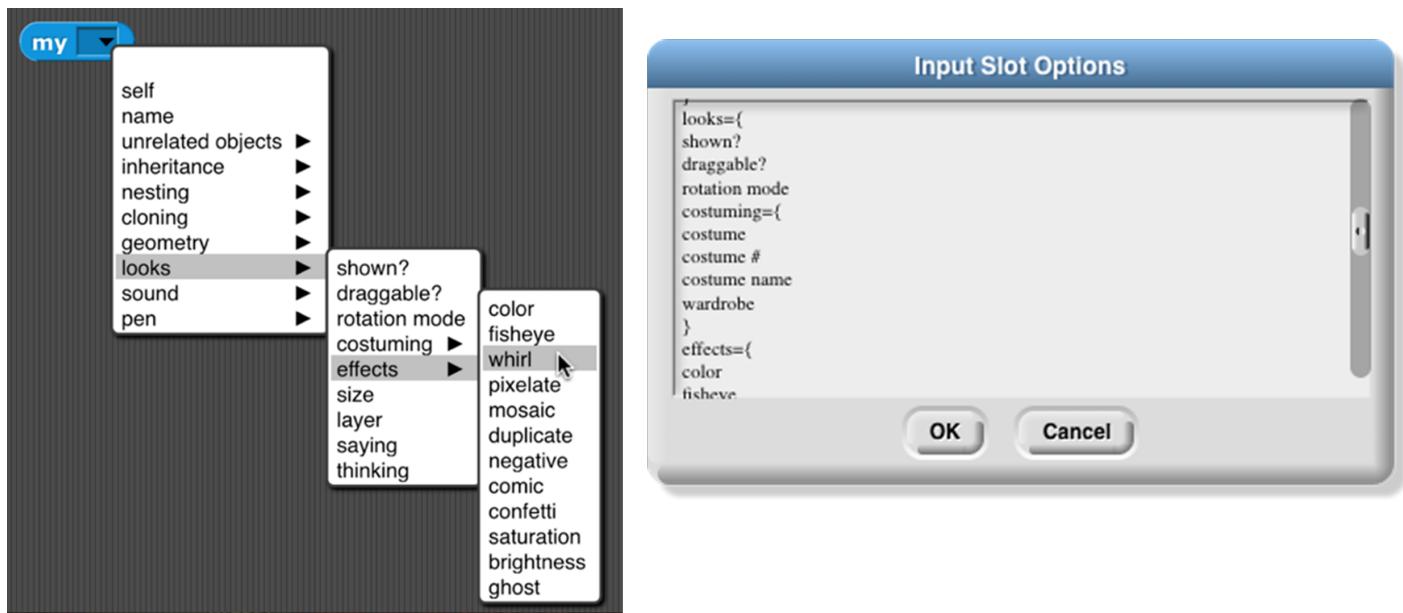


Each line in the text box represents one menu item. If the line does not contain any of the characters “=”, “~”, or “{}” then the text is both what’s shown in the menu and the value of the input if that entry is chosen.

If the line contains an equal sign “=”, then the text to the left of the equal sign is shown in the menu, and the text to the right is what appears in the input slot if that entry is chosen, and is also the value of the input as seen by the procedure.

If the line consists of a tilde “~”, then it represents a separator (a horizontal line) in the menu, used to divide long menus into visible categories. There should be nothing else on the line. This separator is not choosable, so there is no input value corresponding to it.

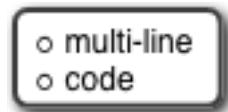
If the line ends with the two characters equal sign and open brace “={”, then it represents a *submenu*. The text before the equal sign is a name for the submenu, and will be displayed in the menu with an arrowhead ↗ at the end of the line. This line is not clickable, but hovering the mouse over it displays the submenu next to the original menu. A line containing a close brace “}” ends the submenu; nothing else should be on that line. Submenus may be nested to arbitrary depth.



Alternatively, instead of giving a menu listing as described above, you can put a JavaScript function that returns the desired menu in the textbox. This is an experimental feature and requires that JavaScript be enabled in the Settings menu.

It is also possible to get the special menus used in some primitive blocks, by choosing from the “menu” submenu: “broadcast messages, sprites and stage, costumes, sounds, variables” that can be set in this scope, the play note (piano keyboard), or the point in direction (360°) dial. Finally, you can make the input box accept more than one line of text (that is, text including a newline character) from the “special” submenu, either “multi-line” for regular text or “code” for monospace-font computer code.

If the input type is something other than text, then clicking the button will instead show this menu:



As an example, we want to make this block:

The second input must be a read-only object menu:



5.2.3. Input variants

We now turn to the three mutually exclusive options that come below the type array.

5. Typed Inputs

The “single input” option: In Scratch, all inputs are in this category. There is one input slot in the block as it appears in its palette. If a single input is of type Any, Number, Text, or Boolean, then you can specify a default value that will be shown in that slot in the palette, like the “10” in the move (10) steps block. In the prototype block at the top of the script in the Block editor, an an input with name “size” and default value 10 looks like this:



The “Multiple inputs” option: The list block introduced earlier accepts any number of inputs to specify the items of the new list. To allow this, Snap! introduces the arrowhead notation (??) that expands and contracts the block, adding and removing input slots. (Shift-clicking on an arrowhead adds or removes three input slots at once.) Custom blocks made by the Snap! user have that capability, too. If you choose the “Multiple inputs” button, then arrowheads will appear after the input slot in the block. More or fewer slots (as few as zero) may be used. When the block runs, all of the values in all of the slots for this input name are collected into a list, and the value of the input as seen inside the script is that list of values:

The ellipsis (...) in the orange input slot name box in the prototype indicates a multiple or *variadic* input .

The third category, “Upvar – make internal variable visible to caller”, isn’t really an input at all, but rather a sort of output from the block to its user. It appears as an orange variable oval in the block, rather than as an input slot. Here’s an example; the uparrow (↑) in the prototype indicates this kind of internal variable name:



The variable *i* (in the block on the right above) can be dragged from the for block into the blocks used in its C-shaped command slot. Also, by clicking on the orange *i*, the user can change the name of the variable as seen in the calling script (although the name hasn’t changed inside the block’s definition). This kind of variable is called an *upvar* for short, because it is passed *upward* from the custom block to the script that uses it.

Note about the example: for is a primitive block, but it doesn’t need to be. You’re about to see (next chapter) how it can be written in Snap!. Just give it a different name to avoid confusion, such as my for as above.

5.2.4. Prototype Hints

We have mentioned three notations that can appear in an input slot in the prototype to remind you of what kind of input this is. Here is the complete list of such notations:

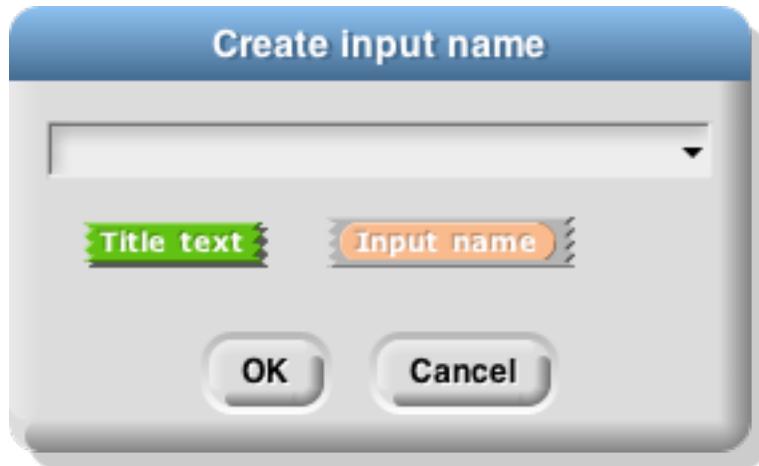
5. Typed Inputs

- square
- pointRight
- stepForward
- ⚙ gears
- ▲ gearPartial
- ⚙ gearBig
- 📄 file
- ◀ fullScreen
- ◀ grow
- ◀ normalScreen
- ◀ shrink
- █████ smallStage
- █████ normalStage
- turtle
- turtleOutline
- █████ stage
- ██ pause
- ██ flag
- octagon
- ██ cloud
- ██ cloudGradient
- ██ cloudOutline
- ↻ turnRight
- ↶ turnLeft
- ⟳ turnAround
- █████ storage
- █████ poster
- ⚡ flash
- 🖌 brush
- ✓ tick
- checkBox
- rectangle
- █████ rectangleSolid
- circle
- circleSolid
- ellipse
- ＼ line
- + cross
- ⊕ crosshairs
- paintbucket
- eraser
- pipette
- speechBubble
- speechBubbleOutline
- ↗ loop
- ⬅ turnBack
- ➡ turnForward
- ↑ arrowUp
- ↑ arrowUpOutline
- ↑ arrowUpThin
- ↑ arrowUpDownThin
- ⬅ arrowLeft
- ↖ arrowLeftOutline
- ← arrowLeftThin
- ↔ arrowLeftRightThin
- ↓ arrowDown
- ↓ arrowDownOutline
- ↓ arrowDownThin
- ➡ arrowRight
- ↗ arrowRightOutline
- arrowRightThin
- robot
- magnifyingGlass
- magnifierOutline
- selection
- polygon
- closedBrush
- notes
- camera
- location
- footprints
- keyboard
- █████ keyboardFilled
- ⊕ globe
- ██ globeBig
- ☰ list
- ◀ flipVertical
- ◀ flipHorizontal
- ↳ new line

- = default value
- ... multiple input
- ↑ upvar
- # number
- λ procedure types
- ↴ list
- ? Boolean
- ¶ multi-line text
- > object

5.2.5. Title Text and Symbols

Some primitive blocks have symbols as part of the block name:  . Custom blocks can use symbols too. In the Block Editor, click the plus sign in the prototype at the point where you want to insert the symbol. Then click the “title text” picture below the text box that’s expecting an input slot name. The dialog will then change to look like this:

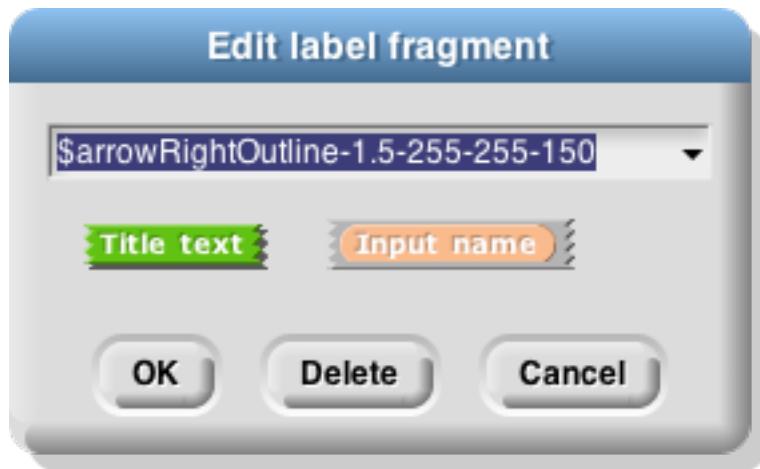


The important part to notice is the arrowhead that has appeared at the right end of the text box. Click it to see the menu shown here at the left.

Choose one of the symbols. The result will have the symbol you want:  The available symbols are, pretty much, the ones that are used in Snap! icons.

But I'd like the arrow symbol bigger, and yellow, so I edit its name:

5. Typed Inputs



This makes the symbol 1.5 times as big as the letters in the block text, using a color with red-green-blue values of 255-255-150 (each between 0 and 255). Here's the result:



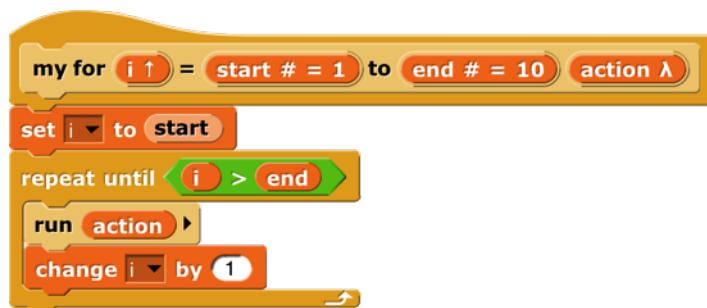
The size and color controls can also be used with text: \$foo-8-255-120-0 will make a huge orange foo.

Note the last entry in the symbol menu: "new line". This can be used in a block with many inputs to control where the text continues on another line, instead of letting Snap! choose the line break itself.

6. Procedures as Data

6.1. Call and Run

In the for block example above, the input named action has been declared as type “Command (C-shaped)”; that’s why the finished block is C-shaped. But how does the block actually tell Snap! to carry out the commands inside the C-slot? Here is a simple version of the block script:



This is simplified because it assumes, without checking, that the ending value is greater than the starting value; if not, the block should (depending on the designer’s purposes) either not run at all, or change the variable by -1 for each repetition instead of by 1.

The important part of this script is the run block near the end. This is a Snap! built-in command block that takes a Command-type value (a script) as its input, and carries out its instructions. (In this example, the value of the input **action** is the script that the user puts in the C-slot of the my for block.) There is a similar call reporter block for invoking a Reporter or Predicate block. The call and run blocks are at the heart of Snap!’s first class procedure feature; they allow scripts and blocks to be used as data—in this example, as an input to a block—and eventually carried out under control of the user’s program.

Here’s another example, this time using a Reporter-type input in a map block (see Section 4.4.1):



Figure 6.1.: image743.png

Here we are calling the Reporter multiply by (10) three times, once with each item of the given list as its input, and collecting the results as a list. (The reported list will always be the same length as the input list.) Note that the multiplication block has two inputs, but here we have specified a particular value for one of them (10), so the

6. Procedures as Data

call block knows to use the input value given to it just to fill the other (empty) input slot in the multiplication block. In the my map definition, the input function is declared to be type Reporter, and data is of type List.

6.1.1. Call/Run with inputs

The call block (like the run block) has a right arrowhead at the end; clicking on it adds the phrase “with inputs” and then a slot into which an input can be inserted:



If the left arrowhead is used to remove the last input slot, the “with inputs” disappears also. The right arrowhead can be clicked as many times as needed for the number of inputs required by the reporter block being called.

If the number of inputs given to call (not counting the Reporter-type input that comes first) is the same as the number of empty input slots, then the empty slots are filled from left to right with the given input values. If call is given exactly one input, then every empty input slot of the called block is filled with the same value:



If the number of inputs provided is neither one nor the number of empty slots, then there is no automatic filling of empty slots. (Instead you must use explicit parameters in the ring, as discussed in Section C below.)

An even more important thing to notice about these examples is the *ring* around the Reporter-type input slots in call and map above. This notation indicates that *the block itself*, not the number or other value that the block would report when called, is the input. If you want to use a block itself in a non-Reporter-type (e.g., Any-type) input slot, you can enclose it explicitly in a ring, found at the top of the Operators palette.



As a shortcut, if you right-click or control-click on a block (such as the () + () block in this example), one of the choices in the menu that appears is “ringify” and/or “unringify”. The ring indicating a Reporter-type or Predicate-type input slot is essentially the same idea for reporters as the C-shaped input slot with which you’re already familiar; with a C-shaped slot, it’s *the script* you put in the slot that becomes the input to the C-shaped block.

There are three ring shapes. All are oval on the outside, indicating that the ring reports a value, the block or script inside it, but the inside shapes are command, reporter, or predicate, indicating what kind of block or script is expected. Sometimes you want to put something more complicated than a single reporter inside a reporter ring; if so, you can use a script, but the script must report a value, as in a custom reporter definition.

6.1.2. Variables in Ring Slots

Note that the run block in the definition of the my for block (see [{@sec-call-and-run}](#)) doesn’t have a ring around its input variable action. When you drag a variable into a ringed input slot, you generally do want to use the *value* of the variable, which will be the block or script you’re trying to run or call, rather than the orange variable reporter itself. So Snap! automatically removes the ring in this case. If you ever do want to use the variable *block itself*, rather than the value of the variable, as a Procedure-type input, you can drag the variable into the input slot, then control-click or right-click it and choose “ringify” from the menu that appears. (Similarly, if you ever want

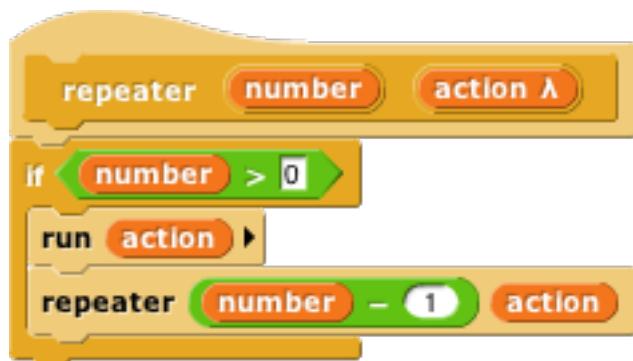
to call a function that will report a block to use as the input, such as item (1) of () applied to a list of blocks, you can choose “unringify” from the menu. Almost all the time, though, Snap! does what you mean without help.)

6.2. Writing Higher Order Procedures

A *higher order procedure* is one that takes another procedure as an input, or that reports a procedure. In this document, the word “procedure” encompasses scripts, individual blocks, and nested reporters. (Unless specified otherwise, “reporter” includes predicates. When the word is capitalized inside a sentence, it means specifically oval-shaped blocks. So, “nested reporters” includes predicates, but “a Reporter-type input” doesn’t.)

Although an Any-type input slot (what you get if you use the small input-name dialog box) will accept a procedure input, it doesn’t automatically ring the input as described above. So the declaration of Procedure-type inputs makes the use of your custom higher order block much more convenient.

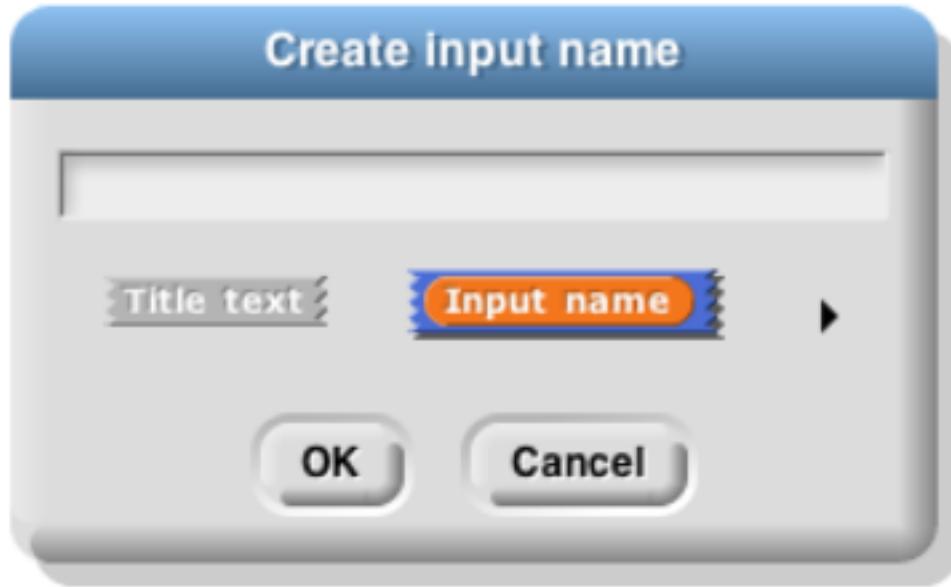
Why would you want a block to take a procedure as input? This is actually not an obscure thing to do; the primitive conditional and looping blocks (the C-shaped ones in the Control palette) take a script as input. Users just don’t usually think about it in those terms! We could write the repeat block as a custom block this way, if Snap! didn’t already have one:



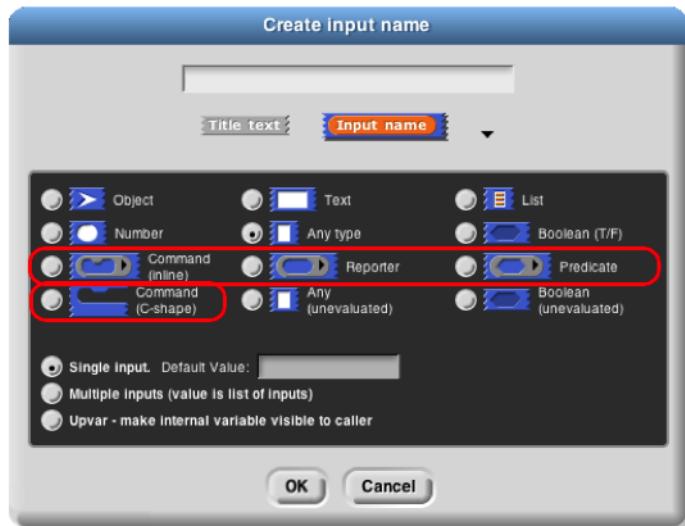
The lambda (“ ”) next to action in the prototype indicates that this is a C-shaped block, and that the script enclosed by the C when the block is used is the input named action in the body of the script. The only way to make sense of the variable action is to understand that its value is a script.

To declare an input to be Procedure-type, open the input name dialog as usual, and click on the arrowhead:

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Then, in the long dialog, choose the appropriate Procedure type. The third row of input types has a ring in the shape of each block type (jigsaw for Commands, oval for Reporters, and hexagonal for Predicates). In practice, though, in the case of Commands it's more common to choose the C-shaped slot on the fourth row, because this "container" for command scripts is familiar to Scratch users. Technically the C-shaped slot is an *unevaluated* procedure type, something discussed in Section E below. The two Command-related input types (inline and C-shaped) are connected by the fact that if a variable, an item () of () block, or a custom Reporter block is dropped onto a C-shaped slot of a custom block, it turns into an inline slot, as in the repeater block's recursive call above. (Other built-in Reporters can't report scripts, so they aren't accepted in a C-shaped slot.)



Why would you ever choose an inline Command slot rather than a C shape? Other than the run block discussed below, the only case I can think of is something like the C/C++/Java for loop, which actually has *three* command script inputs (and one predicate input), only one of which is the "featured" loop body:



Okay, now that we have procedures as inputs to our blocks, how do we use them? We use the blocks run (for commands) and call (for reporters). The run block's script input is an inline ring, not C-shaped, because we

anticipate that it will be rare to use a specific, literal script as the input. Instead, the input will generally be a variable whose value is a script.

The run and call blocks have arrowheads at the end that can be used to open slots for inputs to the called procedures. How does Snap! know where to use those inputs? If the called procedure (block or script) has empty input slots, Snap! “does the right thing.” This has several possible meanings:

1. If the number of empty slots is exactly equal to the number of inputs provided, then Snap! fills the empty slots from left to right:



2. If exactly one input is provided, Snap! will fill any number of empty slots with it:

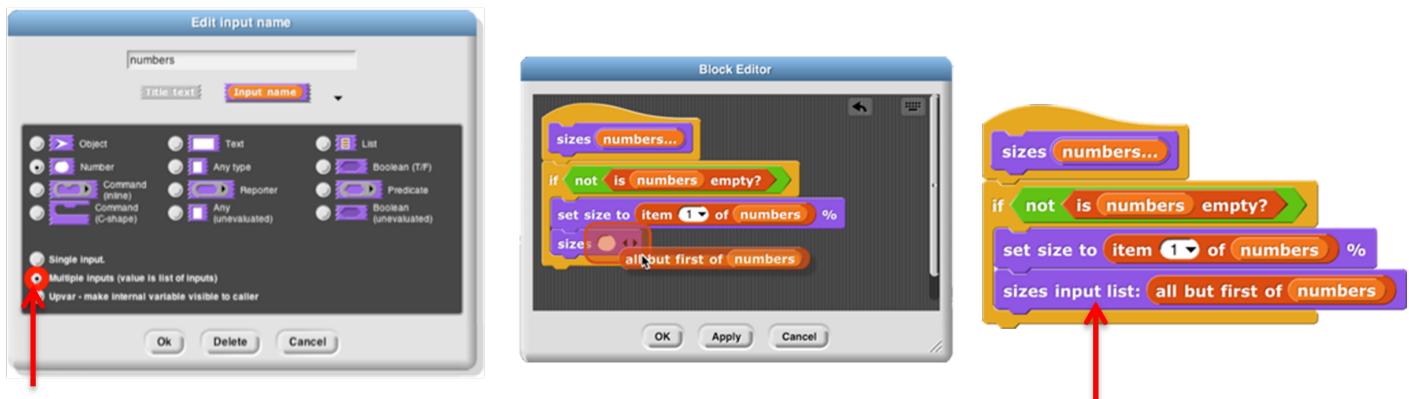


3. Otherwise, Snap! won’t fill any slots, because the user’s intention is unclear.

If the user wants to override these rules, the solution is to use a ring with explicit input names that can be put into the given block or script to indicate how inputs are to be used. This will be discussed more fully below.

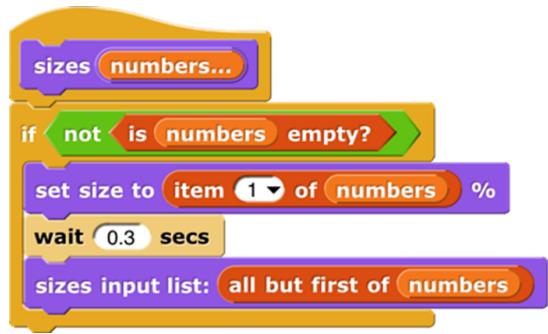
6.2.1. Recursive Calls to Multiple-Input Blocks

A relatively rare situation not yet considered here is the case of a recursive block that has a variable number of inputs. Let’s say the user of your project calls your block with five inputs one time, and 87 inputs another time. How do you write the recursive call to your block when you don’t know how many inputs to give it? The answer is that you collect the inputs in a list (recall that, when you declare an input name to represent a variable number of inputs, your block sees those inputs as a list of values in the first place), and then, in the recursive call, you drop that input list onto the arrowheads that indicate a variable-input slot, rather than onto the input slot:



Note that the halo you see while dragging onto the arrowheads is red instead of white, and covers the input slot as well as the arrowheads. And when you drop the expression onto the arrowheads, the words “input list:” are added to the block text and the arrowheads disappear (in this invocation only) to remind you that the list represents all of the multiple inputs, not just a single input. The items in the list are taken *individually* as inputs to the script. Since numbers is a list of numbers, each individual item is a number, just what sizes wants. This block will take any number of numbers as inputs, and will make the sprite grow and shrink accordingly:

6. Procedures as Data



sizes 50 100 50 ↵



The user of this block calls it with any number of *individual numbers* as inputs. But inside the definition of the block, all of those numbers form a *list* that has a single input name, *numbers*. This recursive definition first checks to make sure there are any inputs at all. If so, it processes the first input (item (1) of ()the list), then it wants to make a recursive call with all but the first number (all but first of ()). But sizes doesn't take a list as input; it takes numbers as inputs! So this would be wrong:

sizes all but first of numbers

6.3. Formal Parameters

The rings around Procedure-type inputs have an arrowhead at the right. Clicking the arrowhead allows you to give the inputs to a block or script explicit names, instead of using empty input slots as we've done until now.



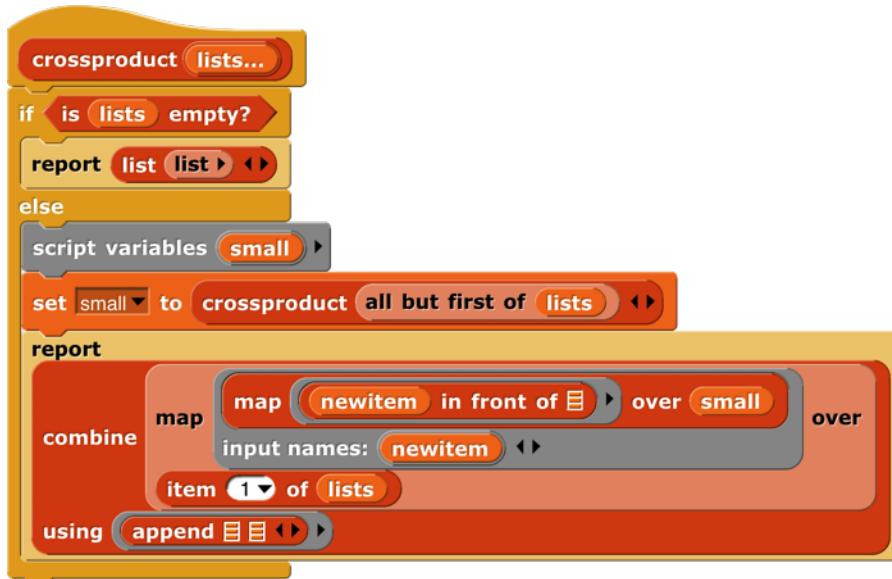
The names **#1**, **#2**, etc. are provided by default, but you can change a name by clicking on its orange oval in the "input names" list. Be careful not to *drag* the oval when clicking; that's how you use the input inside the ring. The names of the input variables are called the *formal parameters* of the encapsulated procedure.

Here's a simple but contrived example using explicit names to control which input goes where inside the ring:



Here we just want to put one of the inputs into two different slots. If we left all three slots empty, Snap! would not fill any of them, because the number of inputs provided (2) would not match the number of empty slots (3).

Here is a more realistic, much more advanced example:



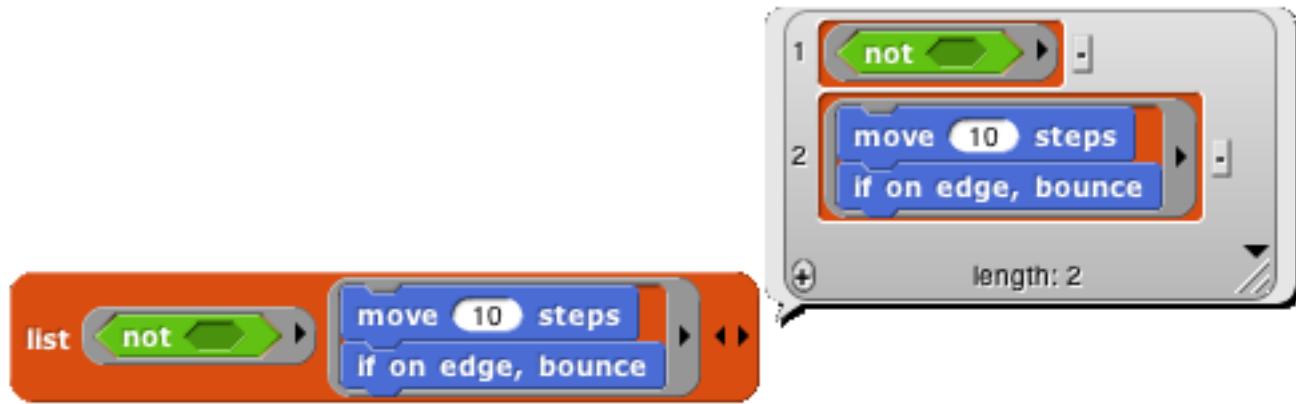
This is the definition of a block that takes any number of lists, and reports the list of all possible combinations of one item from each list. The important part for this discussion is that near the bottom there are two *nested* calls to map, the higher order function that applies an input function to each item of an input list. In the inner block, the function being mapped is `() in front of`, and that block takes two inputs. The second, the empty List-type slot, will get its value in each call from an item of the inner map's list input. But there is no way for the outer map to communicate values to empty slots of the `() in front of` block. We must give an explicit name, `newitem`, to the value that the outer map is giving to the inner one, then drag that variable into the `() in front of` block.

By the way, once the called block provides names for its inputs, Snap! will not automatically fill empty slots, on the theory that the user has taken control. In fact, that's another reason you might want to name the inputs explicitly: to stop Snap! from filling a slot that should really remain empty.

6.4. Procedures as Data

Here's an example of a situation in which a procedure must be explicitly marked as data by pulling a ring from the Operators palette and putting the procedure (block or script) inside it:

6. Procedures as Data



Here, we are making a list of procedures. But the list block accepts inputs of any type, so its input slots are not ringed. We must say explicitly that we want the block *itself* as the input, rather than whatever value would result from evaluating the block.

Besides the list block in the example above, other blocks into which you may want to put procedures are set () to () (to set the value of a variable to a procedure), say () and think () (to display a procedure to the user), and report () (for a reporter that reports a procedure):



6.5. Special Forms

The primitive if else block has two C-shaped command slots and chooses one or the other depending on a Boolean test. Because Scratch doesn't emphasize functional programming, it lacks a corresponding reporter block to choose between two expressions. Snap! has one, but we could write our own:



Our block works for these simple examples, but if we try to use it in writing a recursive operator , it'll fail:



The problem is that when any block is called, all of its inputs are computed (evaluated) before the block itself runs. The block itself knows only the values of its inputs, not what expressions were used to compute them. In

particular, all of the inputs to my if then else block are evaluated first thing. That means that even in the base case, factorial will try to call itself recursively, causing an infinite loop. We need my if then else block to be able to select only one of the two alternatives to be evaluated.

We have a mechanism to allow that: declare the then variable yes and else variable no inputs to be of type Reporter rather than type Any. Then, when calling the block, those inputs will be enclosed in a ring so that the expressions themselves, rather than their values, become the inputs:



In this version, the program works, with no infinite loop. But we've paid a heavy price: this reporter-if is no longer as intuitively obvious as the Scratch command-if. You have to know about procedures as data, about rings, and about a trick to get a constant value in a ringed slot. (The id () block implements the identity function, which reports its input.¹ We need it because rings take only reporters as input, not numbers.) What we'd like is a reporter-if that behaves like this one, delaying the evaluation of its inputs, but looks like our first version, which was easy to use except that it didn't work.

Such blocks are indeed possible. A block that seems to take a simple expression as input, but delays the evaluation of that input by wrapping an “invisible ring” around it (and, if necessary, an id ()-like transformation of constant data into constant functions) is called a *special form*. To turn our if block into a special form, we edit the block's prototype, declaring the inputs yes and no to be of type “Any (unevaluated)” instead of type Reporter. The script for the block is still that of the second version, including the use of call to evaluate either yes or no but not both. But the slots appear as white Any-type rectangles, not Reporter-type rings, and the factorial block will look like our first attempt.

In a special form's prototype, the unevaluated input slot(s) are indicated by a lambda (“λ”) next to the input name, just as if they were declared as Procedure type. They are Procedure type, really; they're just disguised to the user of the block.

Special forms trade off implementor sophistication for user sophistication. That is, you have to understand all about procedures as data to make sense of the special form implementation of my if then else. But any experienced Scratch programmer can use my if then else without thinking at all about how it works internally.

6.5.1. Special Forms in Scratch

Special forms are actually not a new invention in Snap!. Many of Scratch's conditional and looping blocks are really special forms. The hexagonal input slot in the if block is a straightforward Boolean value, because the value can be computed once, before the if block makes its decision about whether or not to run its action input. But the forever if, repeat until (), and wait until () blocks' inputs can't be Booleans; they have to be of type “Boolean (unevaluated),” so that Scratch can evaluate them over and over again. Since Scratch doesn't have custom C-shaped blocks, it can afford to handwave away the distinction between evaluated and unevaluated Booleans, but Snap! can't. The pedagogic value of special forms is proven by the fact that no Scratcher ever

¹There is a primitive id function in the menu of the sqrt of block, but we think seeing its (very simple) implementation will make this example easier to understand.

6. Procedures as Data

notices that there's anything strange about the way in which the hexagonal inputs in the Control blocks are evaluated.

Also, the C-shaped slot familiar to Scratch users is an unevaluated procedure type; you don't have to use a ring to keep the commands in the C-slot from being run before the C-shaped block is run. Those commands themselves, not the result of running them, are the input to the C-shaped Control block. (This is taken for granted by Scratch users, especially because Scratchers don't think of the contents of a C-slot as an input at all.) This is why it makes sense that "C-shaped" is on the fourth row of types in the long form input dialog, with other unevaluated types.

7. Object Oriented Programming with Sprites

Object oriented programming is a style based around the abstraction *object*: a collection of *data* and *methods* (procedures, which from our point of view are just more data) that you interact with by sending it a *message* (just a name, maybe in the form of a text string, and perhaps additional inputs). The object responds to the message by carrying out a method, which may or may not report a value back to the asker. Some people emphasize the *data hiding* aspect of OOP (because each object has local variables that other objects can access only by sending request messages to the owning object) while others emphasize the *simulation* aspect (in which each object abstractly represents something in the world, and the interactions of objects in the program model real interactions of real people or things). Data hiding is important for large multi-programmer industrial projects, but for Snap! users it's the simulation aspect that's important. Our approach is therefore less restrictive than that of some other OOP languages; we give objects easy access to each others' data and methods.

Technically, object oriented programming rests on three legs:

1. *Message passing*: There is a notation by which any object can send a message to another object.
- 2.

Local state: Each object can remember the important past history of the computation it has performed. ("Important" means that it need not remember every message it has handled, but only the lasting effects of those messages that will affect later computation.)

3. *Inheritance*: It would be impractical if each individual object had to contain methods, many of them identical to those of other objects, for all of the messages it can accept. Instead, we need a way to say that this new object is just like that old object except for a few differences, so that only those differences need be programmed explicitly.

7.1. First Class Sprites

Like Scratch, Snap! comes with things that are natural objects: its sprites. Each sprite can own local variables; each sprite has its own scripts (methods). A Scratch animation is plainly a simulation of the interaction of characters in a play. There are two ways in which Scratch sprites are less versatile than the objects of an OOPlanguage. First, Scratch message passing is weak in three respects: Messages can only be broadcast, not addressed to an individual sprite; messages can't take inputs; and methods can't return values to their caller. Second, and more basic, in the OOP paradigm objects are *data*; they can be the value of a variable, an element of a list, and so on, but that's not the case for Scratch sprites.

Snap! sprites are first class data. They can be created and deleted by a script, stored in a variable or list, and sent messages individually. The children of a sprite can inherit sprite-local variables, methods (sprite-local procedures), and other attributes (e.g., x position).

The fundamental means by which programs get access to sprites is the my () reporter block. It has a dropdown-menu input slot that, when clicked, gives access to all the sprites, plus the stage.



reports

a single sprite, the one asking the question.

my other sprites ▾

reports a list of all sprites other

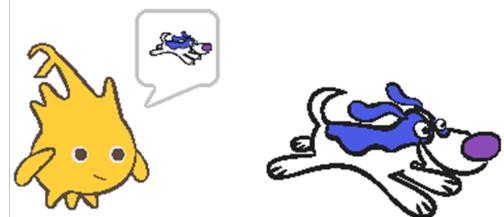
than the one asking the question.

my neighbors ▾

reports a list of all sprites that are *near* the one asking—the ones that are candidates for having collided with this one, for example. The **my ()** block has many other options, discussed below. If you know the name of a particular sprite, the object reporter will report the sprite itself.

An object or list of objects reported by **my ()** or **object ()** can be used as input to any block that accepts any input type, such as **set's (set () to ())** second input. If you say () an object, the resulting speech balloon will contain a smaller image of the object's costume or (for the stage) background.

say item 1 of my other sprites



7.2. Permanent and Temporary Clones

a new clone of myself ▾

The **a new clone of myself** block is used to create and report an instance (a clone) of any sprite. (There is also a command version, for historical reasons.) There are two different kinds of situations in which clones are used. One is that you've made an example sprite and, when you start the project, you want a fairly large number of essentially identical sprites that behave like the example. (Hereafter we'll call the example sprite the "parent" and the others the "children.") Once the game or animation is over, you don't need the copies any more. (As we'll see, "copies" is the wrong word because the parent and the children *share* a lot of properties. That's why we use the word "clones" to describe the children rather than "copies.") These are *temporary* clones. They are automatically deleted when the user presses either the "green flag" or the "red stop sign". In Scratch 2.0 and later, all clones are temporary.

The other kind of situation is what happens when you want specializations of sprites. For example, let's say you have a sprite named Dog. It has certain behaviors, such as running up to a person who comes near it. Now you decide that the family in your story really likes dogs, so they adopt a lot of them. Some are cocker spaniels, who wag their tails when they see you. Others are rottweilers, who growl at you when they see you. So you make a clone of Dog, perhaps rename it Cocker Spaniel, and give it a new costume and a script for what to do when someone gets near. You make another clone of Dog, perhaps rename it Rottweiler, and give it a new costume, etc. Then you make three clones of Cocker Spaniel (so there are four altogether) and two clones of Rottweiler. Maybe you hide the Dog sprite after all this, since it's no breed in particular. Each dog has its own position, special behaviors, and so on. You want to save all of these dogs in the project. These are *permanent* clones. In BYOB 3.1, the predecessor to Snap!, all clones are permanent.

One advantage of temporary clones is that they don't slow down Snap! even when you have a lot of them. (If you're curious, one reason is that permanent clones appear in the sprite corral, where their pictures have to be updated to reflect the clone's current costume, direction, and so on.) We have tried to anticipate your needs, as

a new clone of myself ▾

follows: When you make a clone in a script, using the **a new clone of myself** block, it is "born" temporary. But when you make a clone from the user interface, for example by right-clicking on a sprite

and choosing “cline”, it is born permanent. The reason this makes sense is that you don’t create 100 kinds of dogs automatically. Each kind has many different characteristics, programmed by hand. But when your project is running, it might create 100 rottweilers, and those will be identical unless you change them in the program.

You can change a temporary sprite to permanent by right-clicking it and choosing “edit.” (It’s called “edit” rather than, say, “permanent” because it also shifts the scripting area to reflect that sprite, as if you’d pressed its button in the sprite corral.) You can change a permanent sprite to temporary by right-clicking it and choosing “release.”



You can also change the status of a clone in your program with with true or false as the second input.

7.3. Sending Messages to Sprites

The messages that a sprite accepts are the blocks in its palettes, including both “all sprites” and “this sprite only” blocks. (For custom blocks, the corresponding methods are the scripts as seen in the Block Editor.)

The way to send a message to a sprite (or the stage) is with the tell () to () block (for command messages) or the say () block (for reporter messages).



A small point to note in the examples above: all dropdown menus include an empty entry at the top, which can be selected for use in higher order procedures like the for each and map examples. Each of the sprites in my (neighbors) or my (other sprites) is used to fill the blank space in turn.

By the way, if you want a list of *all* the sprites, including this sprite, you can use either of these:



Tell () and ask () and wait wait until the other sprite has carried out its method before this sprite’s script continues. (That has to be the case for ask () and wait, since we want to do something with the value it reports.) So tell () is analogous to broadcast () and wait. Sometimes the other sprite’s method may take a long time, or may even be a forever loop, so you want the originating script to continue without waiting. For this purpose we have the launch () block:



Launch () is analogous to broadcast without the “wait.”

Snap! 4.1, following BYOB 3.1, used an extension of the of block to provide access to other sprites’ methods. That interface was designed back when we were trying hard to avoid adding new primitive blocks; it allowed us

7. Object Oriented Programming with Sprites

to write ask () and wait and tell () as tool procedures in Snap! itself. That technique still works, but is deprecated, because nobody understood it, and now we have the more straightforward primitives.

7.3.1. Polymorphism

Suppose you have a Dog sprite with two clones CockerSpaniel and PitBull. In the Dog sprite you define this method ("For this sprite only block"):



Note the *location* (map-pin) symbol before the block's name. The symbol is not part of the block title; it's a visual reminder that this is a *sprite-local* block. Sprite-local variables are similarly marked.

But you don't define greet () as friend or greet () as enemy in Dog. Each kind of dog has a different behavior. Here's what a CockerSpaniel does:



And here's what a PitBull does:



Greet () is defined in the Dog sprite. If Fido is a particular cocker spaniel, and you ask Fido to greet someone, Fido inherits the greet () method from Dog, but Dog itself couldn't actually run that method, because Dog doesn't have greet () as friend or greet () as enemy. And perhaps only individual dogs such as Fido have friend? () methods. Even though the greet () method is defined in the Dog sprite, when it's running it remembers what specific dog sprite called it, so it knows which greet () as friend to use. Dog's greet () block is called a *polymorphic* method, because it means different things to different dogs, even though they all share the same script.

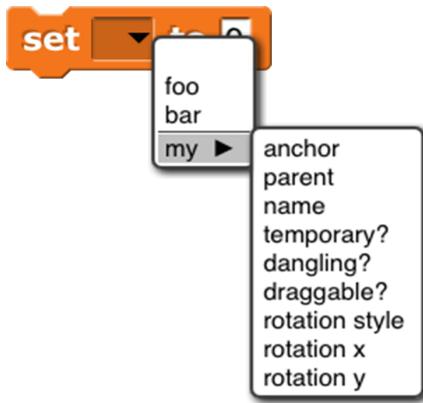
7.4. Local State in Sprites: Variables and Attributes

A sprite's memory of its own past history takes two main forms. It has *variables*, created explicitly by the user with the "Make a variable" button; it also has *attributes*, the qualities every sprite has automatically, such as position, direction, and pen color. Each variable can be examined using its own orange oval block; there is one set () to () block to modify all variables. Attributes, however, have a less uniform programming interface in Scratch:

- A sprite's *direction* can be examined with the direction block, and modified with the point in direction () block. It can also be modified less directly using the blocks turn (), point towards (), and if on edge, bounce.
- There is no way for a script to examine a sprite's *pen color*, but there are blocks set pen color to (<color>), set pen color to (<number>), and change pen color to () to modify it.
- A sprite's *name* can be neither examined nor modified by scripts; it can be modified by typing a new name directly into the box that displays the name, above the scripting area.

The block, if any, that examines a variable or attribute is called its *getter*; a block (there may be more than one, as in the direction example above) that modifies a variable or attribute is called a *setter*.

In Snap! we allow virtually all attributes to be examined. But instead of adding dozens of reporters, we use a more uniform interface for attributes: The my block's menu (in Sensing; see page 78) includes many of the attributes of a sprite. It serves as a general getter for those attributes, e.g., my (anchor) to find the sprite, if any, to which this sprite is attached in a nesting arrangement (see page 10). Similarly, the same set () to () block used to set variable values allows setting some sprite attributes.



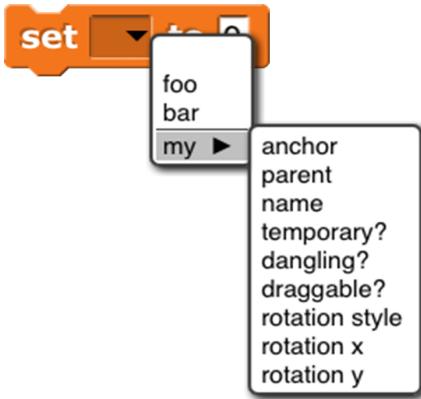
7.5. Prototyping: Parents and Children

Most current OOP languages use a *class/instance* approach to creating objects. A class is a particular *kind of object*, and an instance is an *actual object* of that type. For example, there might be a Dog class, and several instances Fido, Spot, and Runt. The class typically specifies the methods shared by all dogs (RollOver, SitUpAndBeg, Fetch, and so on), and the instances contain data such as species, color, and friendliness. Snap! uses a different approach called *prototyping*, in which there is no distinction between classes and instances. Prototyping is better suited to an experimental, tinkering style of work: You make a single dog sprite, with both methods (blocks) and data (variables); you can actually watch it and interact with it on the stage; and when you like it, you use it as the prototype from which to clone other dogs. If you later discover a bug in the behavior of dogs, you can edit a method in the parent, and all of the children will automatically share the new version of the method block. Experienced class/instance programmers may find prototyping strange at first, but it is actually a more expressive system, because you can easily simulate a class/instance hierarchy by hiding the prototype sprite! Prototyping is also a better fit with the Scratch design principle that everything in a project should be concrete and visible on

7. Object Oriented Programming with Sprites

the stage; in class-instance OOP the programming process begins with an abstract, invisible entity, the class, that must be designed before any concrete objects can be made.¹

There are three ways to make a child sprite. If you control-click or right-click on a sprite in the “sprite corral” at the bottom right corner of the window, you get a menu that includes “clone” as one of the choices. There is a new clone of () block in the Control palette that creates and reports a child sprite. And sprites have a “parent” attribute that can be set, like any attribute, thereby changing the parent of an existing sprite.



7.6. Inheritance by Delegation

A clone *inherits* properties of its parent. “Properties” include scripts, custom blocks, variables, named lists, system attributes, costumes, and sounds. Each individual property can be shared between parent and child, or not shared (with a separate one in the child). The getter block for a shared property, in the child’s palette, is displayed in a lighter color; separate properties of the child are displayed in the traditional colors.

When a new clone is created, by default it shares only its methods, wardrobe, and jukebox with its parent. All other properties are copied to the clone, but not shared. (One exception is that a new *permanent* clone is given a random position. Another is that *temporary* clones share the scripts in their parent’s scripting area. A third is that sprite-local variables that the parent creates *after* cloning are shared with its children.) If the value of a shared property is changed in the parent, then the children see the new value. If the value of a shared property is changed in the *child*, then the sharing link is broken, and a new private version is created in that child. (This is the mechanism by which a child chooses not to share a property with its parent.) “Changed” in this context means using the set () to () or change () by () block for a variable, editing a block in the Block Editor, editing a costume or sound, or inserting, deleting, or reordering costumes or sounds. To change a property from unshared to shared, the child uses the inherit command block. The pulldown menu in the block lists all the things this sprite can inherit from its parent (which might be nothing, if this sprite has no parent) and is not already inheriting. But that would prevent telling a child to inherit, so if the inherit block is inside a ring, its pulldown menu includes all the things a child could inherit from this sprite. Right-clicking on the scripting area of a permanent clone gives a menu option to share the entire collection of scripts from its parent, as a temporary clone does.

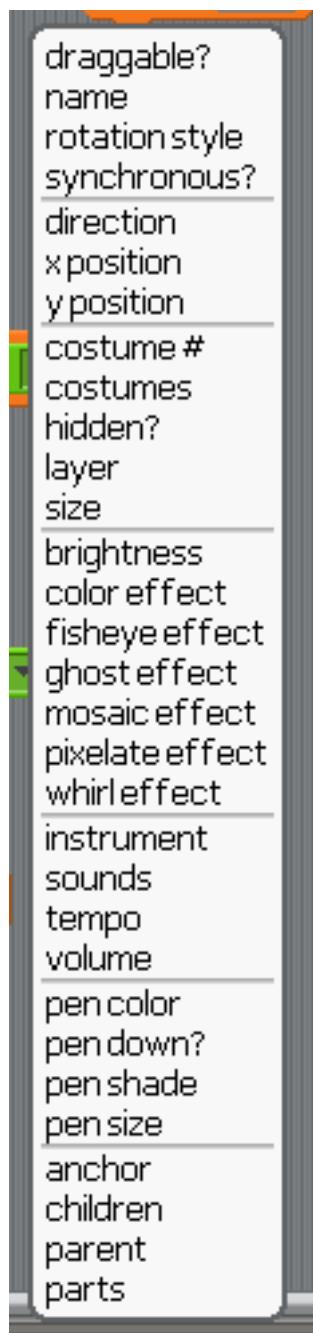
The rules are full of details, but the basic idea is simple: Parents can change their children, but children can’t directly change their parents. That’s what you’d expect from the word “inherit”: the influence just goes in one direction. When a child changes some property, it’s declaring independence from its parent (with respect to that

¹Some languages popular in the “real world” today, such as JavaScript, claim to use prototyping, but their object system is much more complicated than what we are describing (we’re guessing it’s because they were designed by people too familiar with class-instance programming); that has, in some circles, given prototyping a bad name. Our prototyping design comes from Object Logo, and before that, from Henry Lieberman. [Lieberman, H., Using Prototypical Objects to Implement Shared Behavior in Object-Oriented Systems, First Conference on Object-Oriented Programming Languages, Systems, and Applications [OOPSLA-86], ACM SigCHI, Portland, OR, September, 1986. Also in *Object-Oriented Computing*, Gerald Peterson, Ed., IEEE Computer Society Press, 1987.]

one property). What if you really want the child to be able to make a change in the parent (and therefore in itself and all its siblings)? Remember that in this system any object can tell any other object to do something:

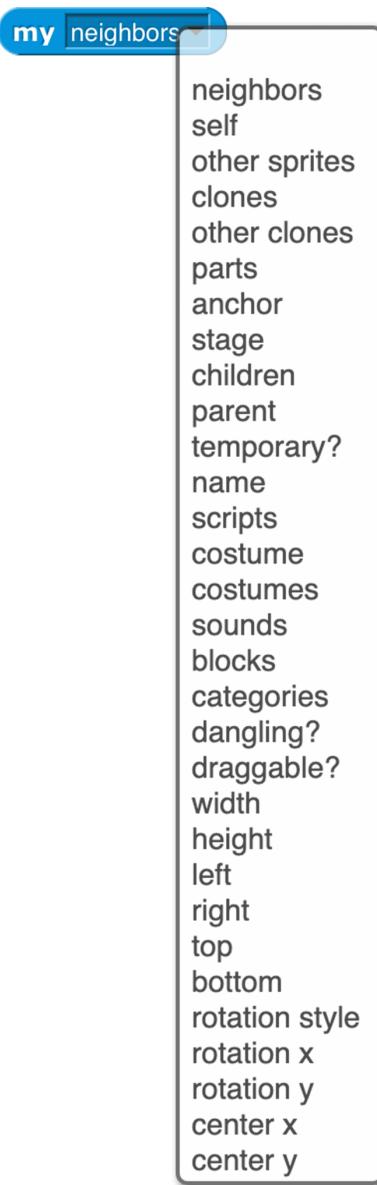


When a sprite gets a message for which it doesn't have a corresponding block, the message is *delegated* to that sprite's parent. When a sprite does have the corresponding block, then the message is not delegated. If the script that implements a delegated message refers to `my` (self), it means the child to which the message was originally sent, not the parent to which the message was delegated.



7.7. List of attributes

At the right is a picture of the dropdown menu of attributes in the my () block.



Several of these are not real attributes, but things related to attributes:

- self : this sprite
- neighbors : a list of *nearby* sprites²
- other sprites : a list of all sprites except myself
- stage : the stage, which is first-class, like a sprite
- clones : a list of my *temporary* clones
- other clones : a list of my *temporary* siblings
- parts : a list of sprites whose anchor attribute is this sprite

²Neighbors are all other sprites whose bounding boxes intersect the doubled dimensions of the requesting sprite's bounds.

- children : a list of all my clones, temporary and permanent

The others are individual attributes:

- anchor : the sprite of which I am a (nested) part
- parent : the sprite of which I am a clone
- temporary?: am I a temporary clone?
- name : my name (same as parent's name if I'm temporary)
- costumes : a list of the sprite's costumes
- sounds : a list of the sprite's sounds
- blocks: a list of the blocks visible in this sprite
- categories: a list of all the block category names
- dangling? : True if I am a part and not in synchronous orbit
- draggable?: True if the user can move me with the mouse
- width, height, left, right, top, bottom: The width or height of my costume *as seen right now*, or the left, etc., edge of my bounding box, taking rotation into account.
- rotation x, rotation y : when reading with my (), the same as x position, y position. When set () to (), changes the sprite's rotation center *without moving the sprite*, like dragging the rotation center in the paint editor.
- center x, center y: the x and y position of the center of my bounding box, rounded off—the geometric center of the costume.

7.8. First Class Costumes and Sounds

Costumes and sounds don't have methods, as sprites do; you can't ask them to do things. But they *are* first class: you can make a list of them, put them in variables, use them as input to a procedure, and so on. My (costumes) and my (sounds) report lists of them.

7.8.1. Media Computation with Costumes

The components of a costume are its name, width, height, and pixels. The  block gives access to these components using its left menu. From its right menu you can choose the current costume, the Turtle costume, or any costume in the sprite's wardrobe. Since costumes are first class, you can also drop an expression whose value is a costume, or a list of costumes, on that second input slot. (Due to a misfeature, even though you can select Turtle in the right menu, the block reports 0 for its width and height, and an empty string for the other components.) The costume's width and height are in its standard orientation, regardless of the sprite's current direction. (This is different from the sprite's width and height, reported by the my () block.)

But the really interesting part of a costume is its bitmap , a list of *pixels*. (A pixel, short for “picture element,” represents one dot on your display.) Each pixel is itself a list of four items, the red, green, and blue components of its color (in the range 0-255) and what is standardly called its “transparency” but should be called its opacity, also in the range 0-255, in which 0 means that the pixel is invisible and 255 means that it's fully opaque: you can't see anything from a rearward layer at that point on the stage. (Costume pixels typically have an opacity of 0 only for

7. Object Oriented Programming with Sprites

points inside the bounding box of the costume but not actually part of the costume; points in the interior of a costume typically have an opacity of 255.) Intermediate values appear mainly at the edge of a costume, or at sharp boundaries between colors inside the costume, where they are used to reduce “jaggies”: the staircase-like shape of a diagonal line displayed on an array of discrete rectangular screen coordinates. Note that the opacity of a sprite pixel is determined by combining the costume’s opacity with the sprite’s ghost effect. (The latter really is a measure of transparency: 0 means opaque and 100 means invisible.)

The bitmap is a one-dimensional list of pixels, not an array of *height* rows of *width* pixels each. That’s why the pixel list has to be combined with the dimensions to produce a costume. This choice partly reflects the way bitmaps are stored in the computer’s hardware and operating system, but also makes it easy to produce transformations of a costume with map:



In this simplest possible transformation, the red value of all the pixels have been changed to a constant 150. Colors that were red in the original (such as the logo printed on the t-shirt) become closer to black (the other color components being near zero); the blue jeans become purple (blue plus red); perhaps counterintuitively, the white t-shirt, which has the maximum value for all three color components, loses some of its red and becomes cyan, the color opposite red on the color wheel. In reading the code, note that the function that is the first input to map is applied to a single pixel, whose first item is its red component. Also note that this process works only on bitmap costumes; if you call (pixels) of a costume () on a vector costume (one with “svg” in the corner of its picture), it will be converted to pixels first.

One important point to see here is that a bitmap (list of pixels) is not, by itself, a costume. The new costume () width () height () block creates a costume by combining a bitmap, a width, and a height. But, as in the example above, switch to costume () will accept a bitmap as input and will automatically use the width and height of the current costume. Note that there’s no name input; costumes computed in this way are all named costume. Note also that the use of switch to costume does *not* add the computed costume to the sprite’s wardrobe; to do that, say



Here’s a more interesting example of color manipulation:



Each color value is constrained to be 0, 80, 160, or 240. This gives the picture a more cartoonish look. Alternatively, you can do the computation taking advantage of hyperblocks:



Here’s one way to exchange red and green values:



It's the `list [2 1 3 4]` list that determines the rearrangement of colors: green~~red~~red, red~~green~~green, and the other two unchanged. That list is inside another list because otherwise it would be selecting rows of the pixel array, and we want to select columns. We use (pixels) of costume (current) rather than costume apple because the latter is always a red apple, so this little program would get stuck turning it green, instead of alternating colors.

The stretch block takes a costume as its first input, either by selecting a costume from the menu or by dropping a costume-valued expression such as `item 3 of my costumes` onto it. The other two inputs are percents of the original width and height, as advertised, so you can make fun house mirror versions of costumes:



The resulting costumes can be used with `switch to costume ()` and so on.

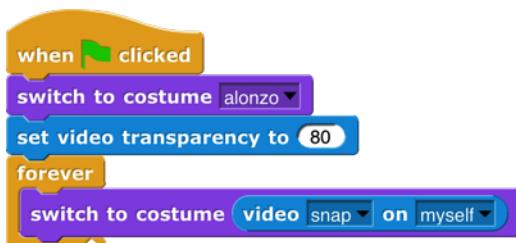
Finally, you can use pictures from your computer's camera in your projects using these blocks:

Using the video (motion) on (myself) block turns on the camera and displays what it sees on the stage, regardless of the inputs given. The camera remains on until you click the red stop button, your program runs the stop all block, or you turn it off explicitly with the `set [mirror video] to [✓]` block. The video image on the stage is partly ghosted, to an extent determined by the `set [video capture] to [x]` set video transparency to () block, whose input really is transparency and not opacity. (Small numbers make the video more visible.) By default, the video image is mirrored, like the selfie camera on your cell phone: When you raise your left hand, your image raises its right hand. You can control this mirroring with the block.

The video snap on block then takes a still picture from the camera, and trims it to fit on the selected sprite. (Video snap on stage means to use the entire stage-sized rectangle.) For example, here's a camera snapshot trimmed to fit Alonzo:



The "Video Capture" project in the Examples collection repeatedly takes such trimmed snapshots and has the Alonzo sprite use the current snapshot as its costume, so it looks like this:



7. Object Oriented Programming with Sprites

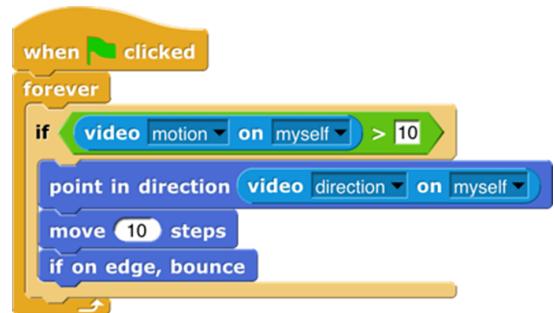


(The picture above was actually taken with transparency set to 50, to make the background more visible for printing.) Because the sprite is always still in the place where the snapshot was taken, its costume exactly fits in with the rest of the full-stage video. If you were to add a move (100) steps block after the switch to costume (), you'd see something like this:



This time, the sprite's costume was captured at one position, and then the sprite is shown at a different position. (You probably wouldn't want to do this, but perhaps it's helpful for explanatory purposes.)

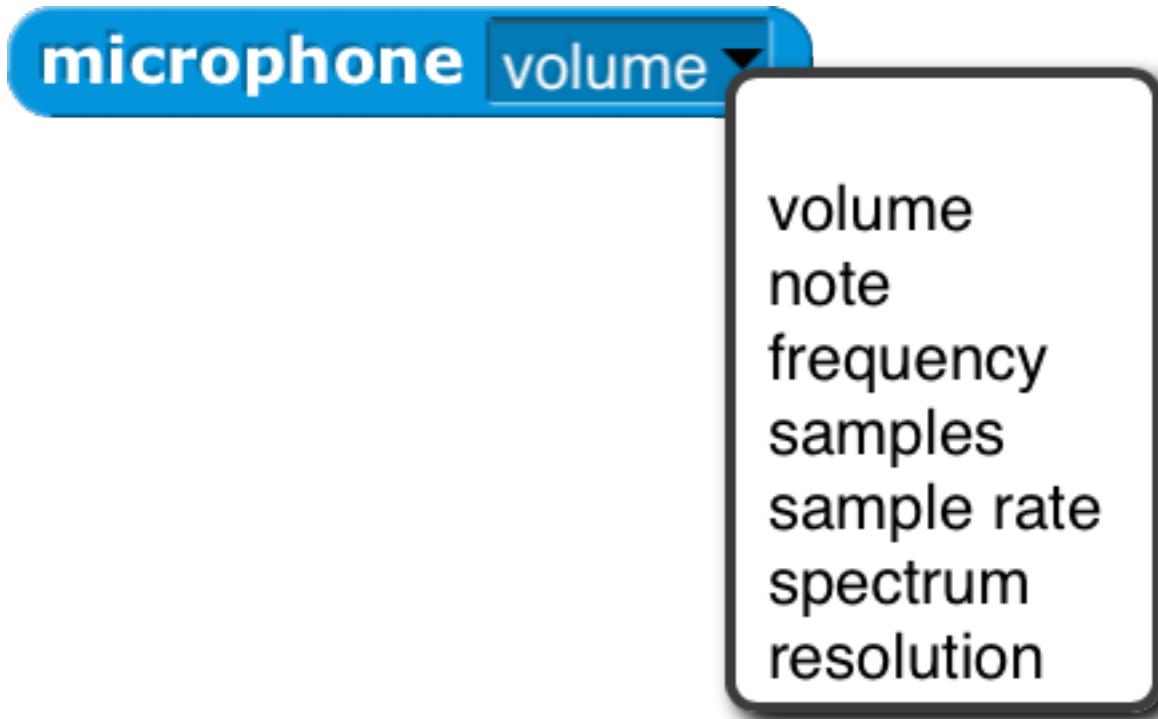
What you *would* want to do is push the sprite around the stage:



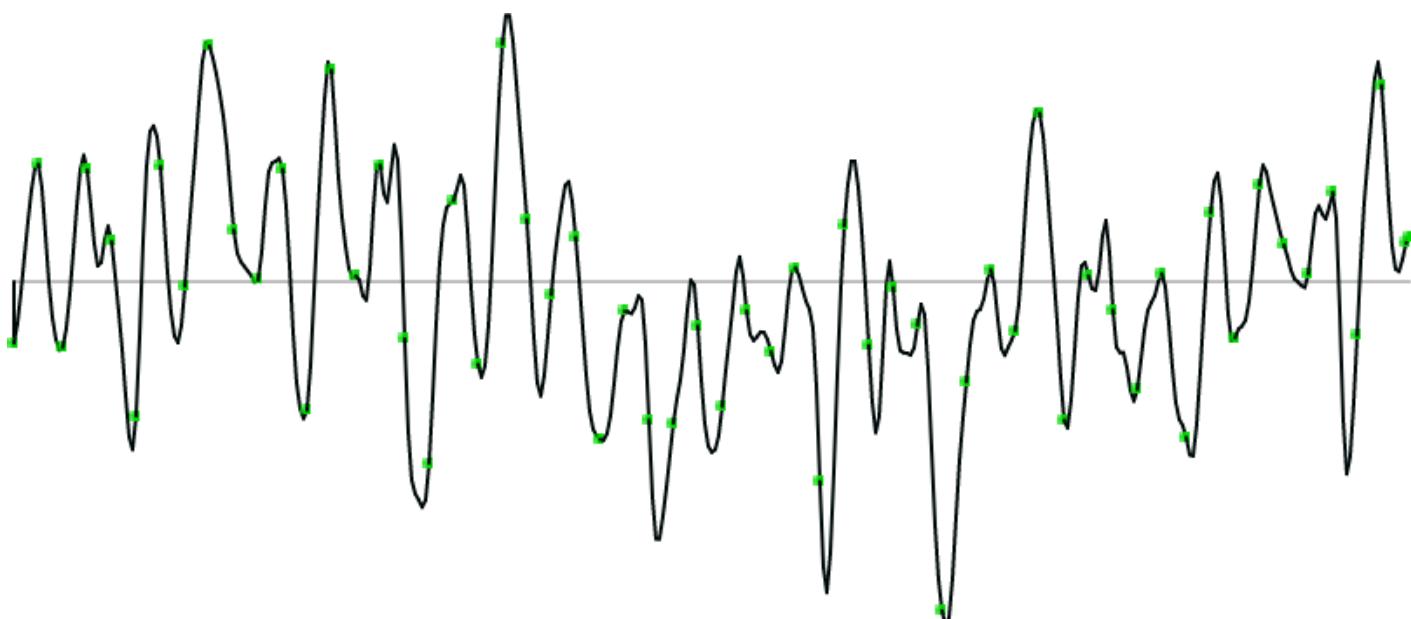
(Really these should be Jens's picture; it's his project. But he's vacationing. ☺) Video (motion) on () compares two snapshots a moment apart, looking only at the part within the given trim (here myself, meaning the current sprite, not the person looking into the camera), to detect a difference between them. It reports a number, measuring the number of pixels through which some part of the picture has moved. Video (direction) on () also compares two snapshots to detect motion, but what it reports is the direction (in the point in direction () sense) of the motion. So the script above moves the sprite in the direction in which it's being pushed, but only if a significant amount of motion is found; otherwise the sprite would jiggle around too much. And yes, you can run the second script without the first to push a balloon around the stage.

7.8.2. Media Computation with Sounds

The starting point for computation with sound is the microphone () block. It starts by recording a brief burst of sound from your microphone. (How brief? On my computer, 0.010667 seconds, but you'll see shortly how to find out or control the sample size on your computer.)



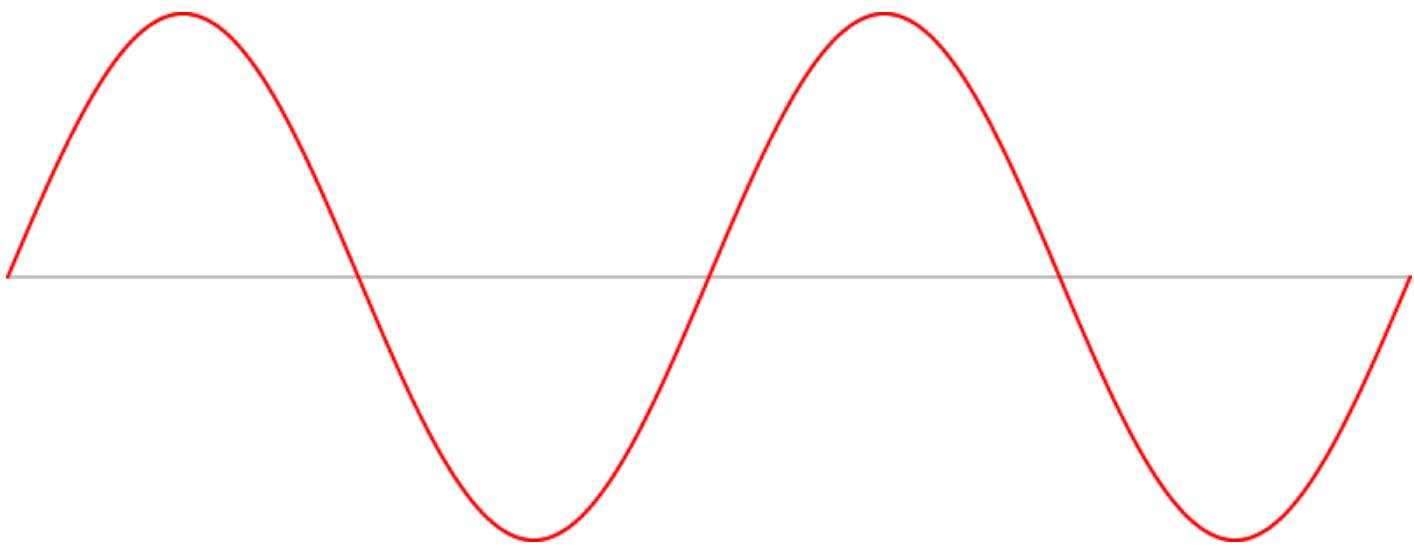
Just as the *pixel* is the smallest piece of a picture, the *sample* is the smallest piece of a sound.  It says here: that on my computer, 48,000 samples are recorded per second, so each sample is 1/48,000 of a second. The value of a sample is between -1 and 1, and represents the sound pressure on the microphone—how hard the air is pushing—at that instant. (You can skip the next page or so if you know about Fourier analysis.) Here's a picture of 400 samples:



7. Object Oriented Programming with Sprites

In this graph, the x axis represents the time at which each sample was measured; the y axis measures the value of the sample at that time. The first obvious thing about this graph is that it has a lot of ups and downs. The most basic up-and-down function is the *sine wave*:

Every periodic function (more or less, any sample that sounds like music rather than sounding like static) is composed of a sum of sine waves of different frequencies.

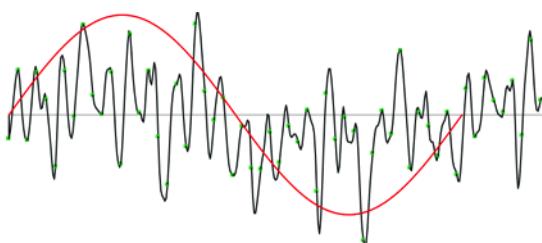


Look back at the graph of our sampled sound. There is a green dot every seven samples. There's nothing magic about the number seven; I tried different values until I found one that looked right. What "right" means is that, for the first few dots at least, they coincide almost perfectly with the high points and low points of the graph. Near the middle (horizontally) of the graph, the green dots don't seem anywhere near the high and low points, but if you find the very lowest point of the graph, about 2/3 of the way along, the dots start lining up almost perfectly again.

The red graph above shows two cycles of a sine wave. One cycle goes up, then down, then up again. The amount of time taken for one cycle is the *period* of the sine function. If the green dots match both ups and downs in the captured sound, then two dots—14 samples, or $14/48000$ of a second—represent the period. The first cycle and a half of the graph looks like it could be a pure sine wave, but after that, the tops and bottoms don't line up, and there are peculiar little jiggles, such as the one before the fifth green dot. This happens because sine waves of different periods are added together.

It turns out to be more useful to measure the reciprocal of the period, in our case, $48000/14$ or about 3429 *cycles per second*. Another name for "cycles per second" is "Hertz," abbreviated Hz, so our sound has a component at 3249 Hz. As a musical note, that's about an A (a little flat), four octaves above middle C. (Don't worry too much about the note being a little off; remember that the 14-sample period was just eyeballed and is unlikely to be exactly right.)

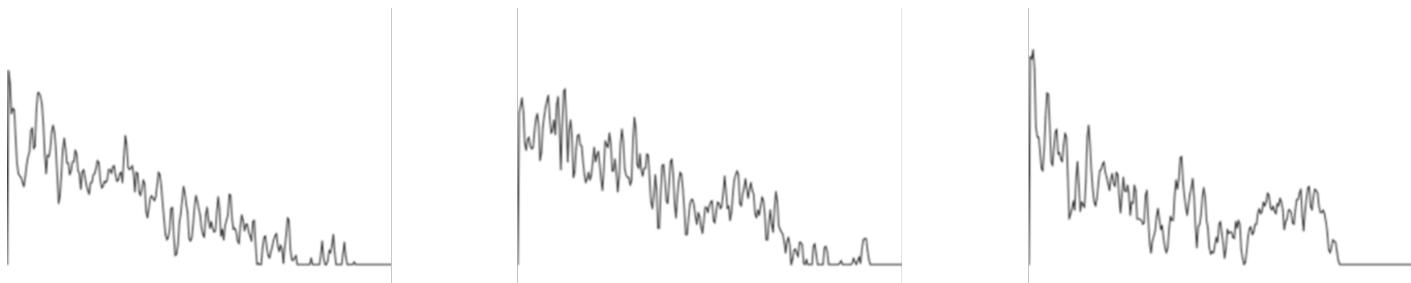
Four octaves above middle C is really high! That would be a shrill-sounding note. But remember that a complex waveform is the sum of multiple sine waves at different frequency. Here's a different up-and-down regularity:



It's not obvious, but in the left part of the graph, the signal is more above the x axis than below it. Toward the right, it seems to be more below than above the axis. At the very right it looks like it might be climbing again.

The period of the red sine wave is 340 samples, or $340/48000$ second. That's a frequency of about 141 Hz, about D below middle C. Again, this is measuring by eyeball, but likely to be close to the right frequency.

All this eyeballing doesn't seem very scientific. Can't we just get the computer to find all the relevant frequencies? Yes, we can, using a mathematical technique called *Fourier analysis*. (Jean-Baptiste Joseph Fourier, 1768–1830, made many contributions to mathematics and physics, but is best known for working out the nature of periodic functions as a sum of sine waves.) Luckily we don't have to do the math; the microphone () block will do it for us, if we ask for microphone (spectrum):



These are frequency spectra from (samples of) three different songs. The most obvious thing about these graphs is that their overall slope is downward; the loudest frequency is the lowest frequency. That's typical of music.

The next thing to notice is that there's a regularity in the spacing of spikes in the graph. This is partly just an artifact; the frequency (horizontal) axis isn't continuous. There are a finite number of "buckets" (default: 512), and all the frequencies within a bucket contribute to the amplitude (vertical axis) of that bucket. The spectrum is a list of that many amplitudes. But the patterns of alternating rising and falling values are real; the frequencies that are multiples of the main note being sampled will have higher amplitude than other frequencies.

Samples and spectrum are the two most detailed representations of a sound. But the microphone () block has other, simpler options also:

- volume: the instantaneous volume when the block is called
- note: the MIDI note number (as in play note) of the main note heard
- frequency: the frequency in Hz of the main note heard
- sample rate: the number of samples being collected per second
- resolution: the size of the array in which data are collected (typically 512, must be a power of 2).

The block for sounds that corresponds to new picture for pictures is . Its first input is a list of samples, and its second input specifies how many samples occupy one second.

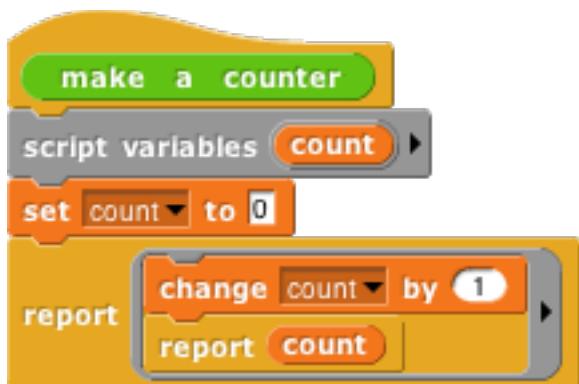
new sound **rate** **44100** ▾ **H**

8. OOP with Procedures

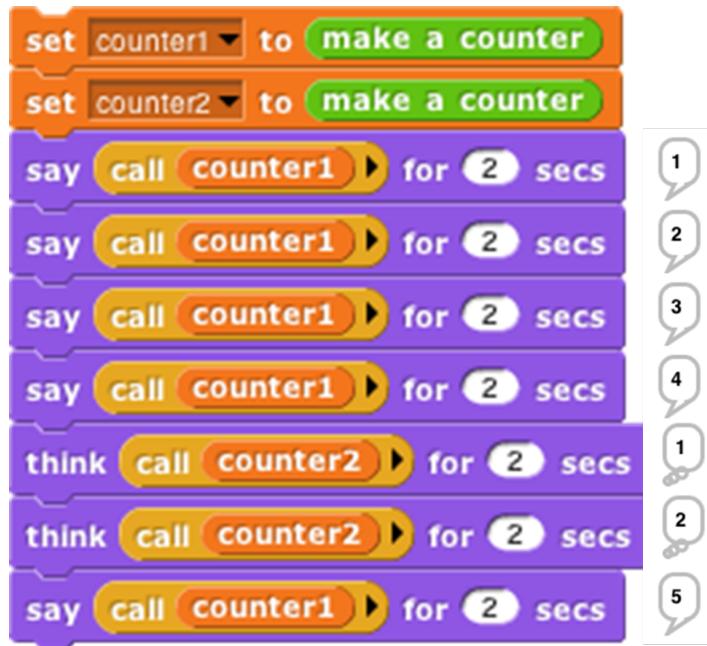
The idea of object oriented programming is often taught in a way that makes it seem as if a special object oriented programming language is necessary. In fact, any language with first class procedures and lexical scope allows objects to be implemented explicitly; this is a useful exercise to help demystify objects.

The central idea of this implementation is that an object is represented as a *dispatch procedure* that takes a message as input and reports the corresponding method. In this section we start with a stripped-down example to show how local state works, and build up to full implementations of class-instance and prototyping OOP.

8.1. Local State with Script Variables



This script implements an object *class*, a type of object, namely the counter class . In this first simplified version there is only one method, so no explicit message passing is necessary. When the make a counter block is called, it reports a procedure, the ringed script inside its body. That procedure implements a specific counter object, an instance of the counter class. When invoked, a counter instance increases and reports its count variable. Each counter has its own local count:

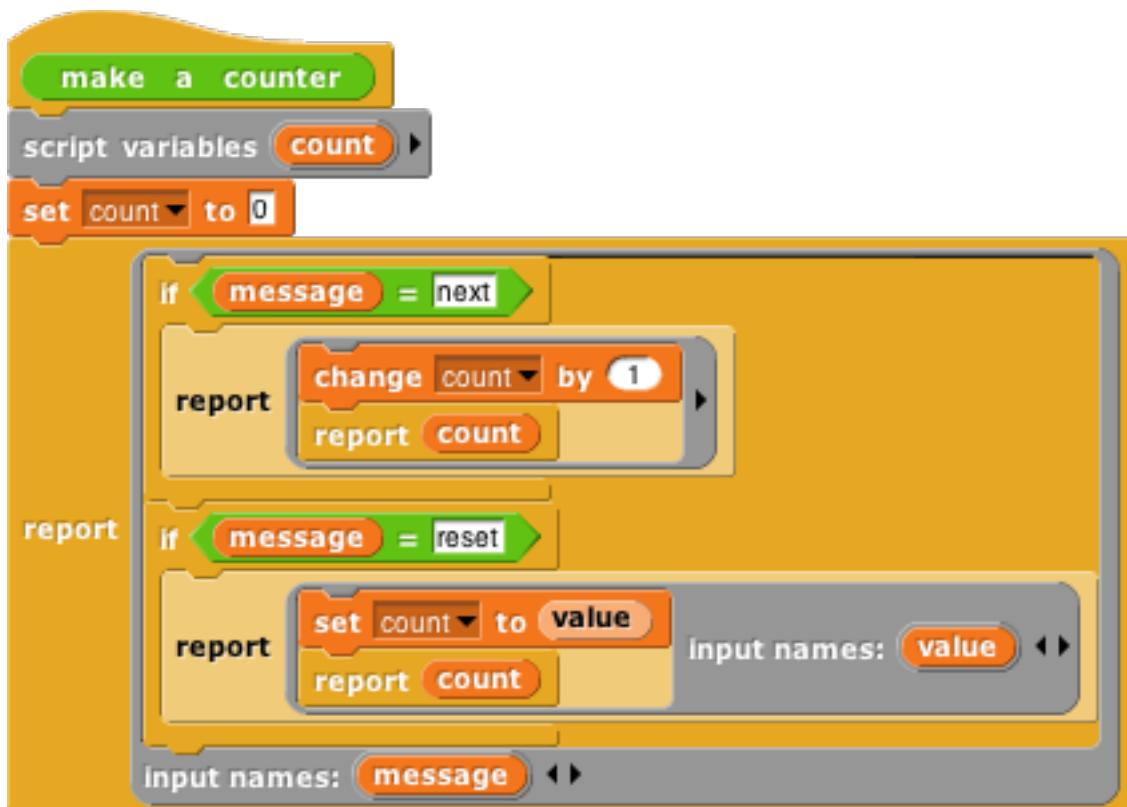


This example will repay careful study, because it isn't obvious why each instance has a separate count. From the point of view of the make a counter procedure, each invocation causes a new count variable to be created. Usually such *script variables* are temporary, going out of existence when the script ends. But this one is special, because make a counter returns *another script* that makes reference to the count variable, so it remains active. (The script variables block makes variables local to a script. It can be used in a sprite's script area or in the Block Editor. Script variables can be “exported” by being used in a reported procedure, as here.)

In this approach to OOP, we are representing both classes and instances as procedures. The make a counter block represents the class, while each instance is represented by a nameless script created each time make a counter is called. The script variables created inside the make a counter block but outside the ring are *instance variables*, belonging to a particular counter.

8.2. Messages and Dispatch Procedures

In the simplified class above, there is only one method, and so there are no messages; you just call the instance to carry out its one method. Here is a more refined version that uses message passing :

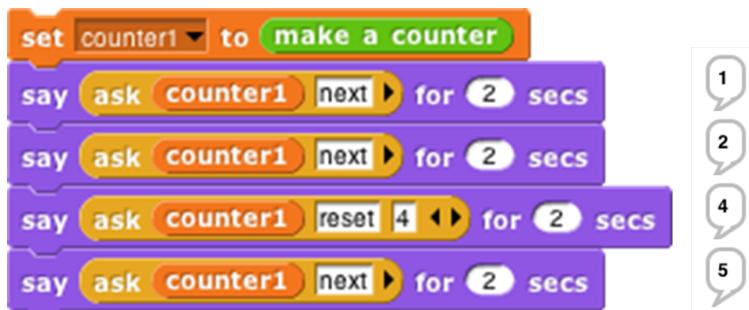


Again, the make a counter block represents the counter class, and again the script creates a local variable count each time it is invoked. The large outer ring represents an instance. It is a *dispatch procedure* : it takes a message (just a text word) as input, and it reports a method. The two smaller rings are the methods. The top one is the next method; the bottom one is the reset method. The latter requires an input, named value.

In the earlier version, calling the instance did the entire job. In this version, calling the instance gives access to a method, which must then be called to finish the job. We can provide a block to do both procedure calls in one:

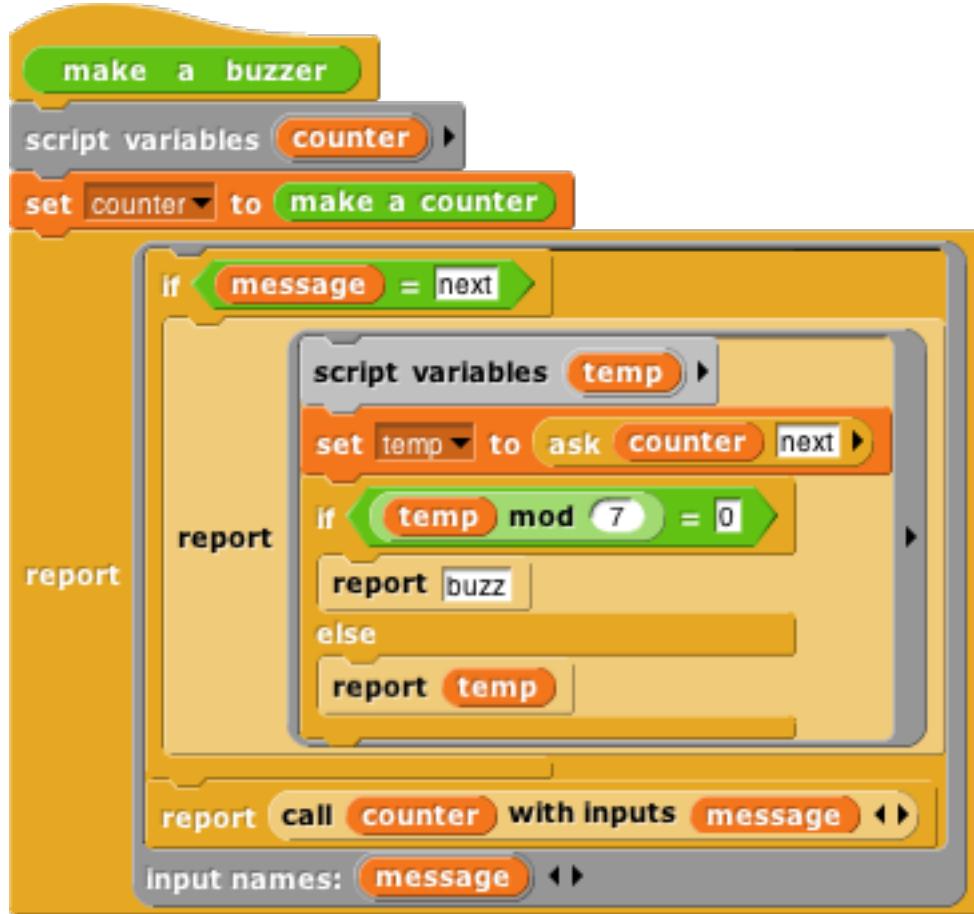


The ask block has two required inputs: an object and a message. It also accepts optional additional inputs, which Snap! puts in a list; that list is named args inside the block. Ask has two nested call blocks. The inner one calls the object, i.e., the dispatch procedure. The dispatch procedure always takes exactly one input, namely the message. It reports a method, which may take any number of inputs; note that this is the situation in which we drop a list of values onto the arrowheads of a multiple input (in the outer call block). Note also that this is one of the rare cases in which we must unringify the inner call block, whose value when called gives the method.



8.3. Inheritance via Delegation

So, our objects now have local state variables and message passing. What about inheritance? We can provide that capability using the technique of *delegation*. Each instance of the child class contains an instance of the parent class, and simply passes on the messages it doesn't want to specialize:



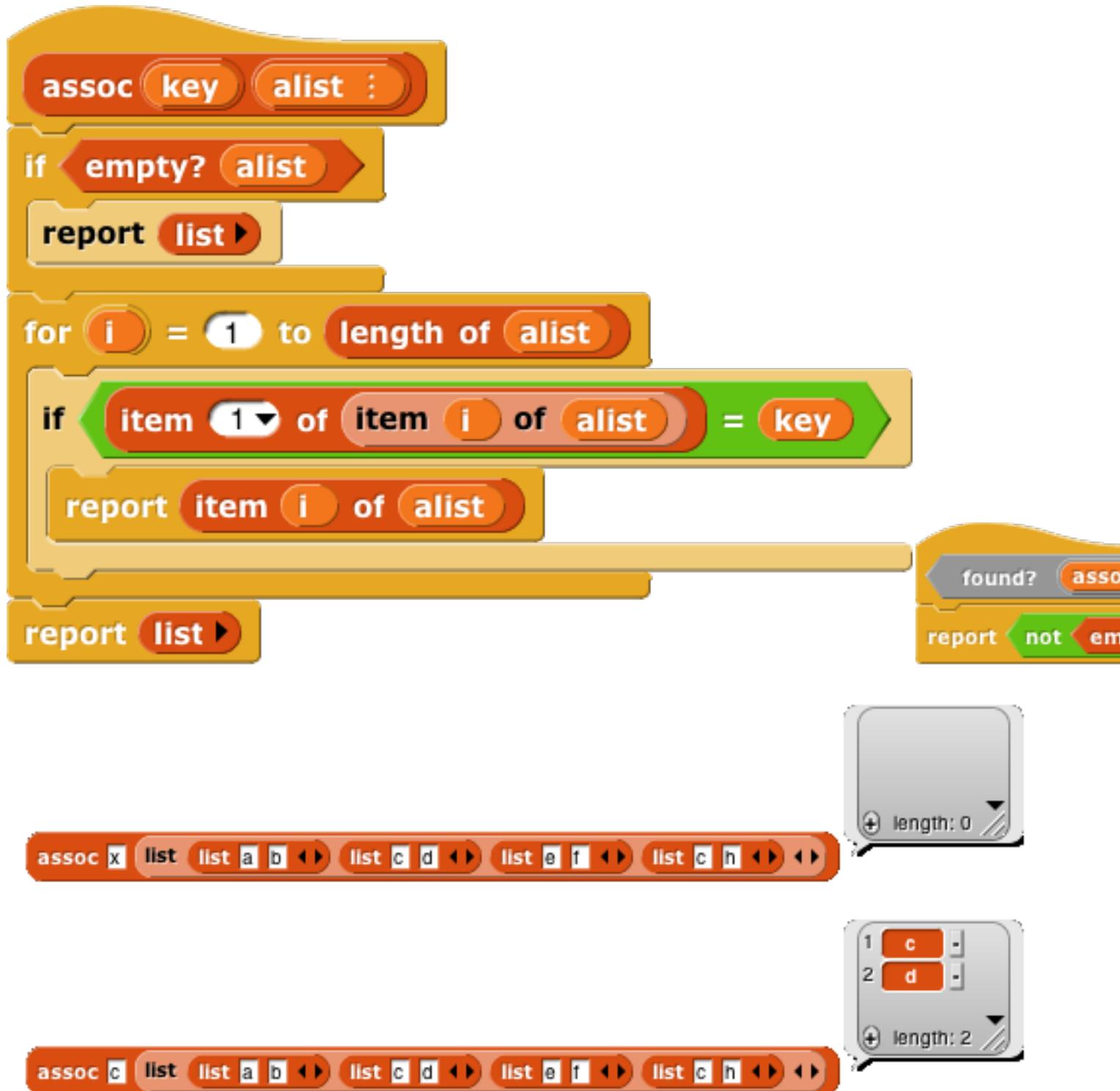
This script implements the `buzzer` class, which is a child of `counter`. Instead of having a count (a number) as a local state variable, each `buzzer` has a `counter` (an object) as a local state variable. The class specializes the `next` method, reporting what the `counter` reports unless that result is divisible by 7, in which case it reports "buzz." (Yeah, it should also check for a digit 7 in the number, but this code is complicated enough already.) If the message is anything other than `next`, though, such as `reset`, then the `buzzer` simply invokes its `counter`'s dispatch procedure. So the `counter` handles any message that the `buzzer` doesn't handle explicitly. (Note that in the non-`next` case we call the `counter`, not ask it something, because we want to report a method, not the value that the message reports.) So, if we ask a `buzzer` to reset to a value divisible by 7, it will end up reporting that number, not "buzz."

8.4. An Implementation of Prototyping OOP

In the class-instance system above, it is necessary to design the complete behavior of a class before you can make any instances of the class. This is okay for top-down design, but not great for experimentation. Here we sketch the implementation of a *prototyping OOP* system: You make an object, tinker with it, make clones of it, and keep tinkering. Any changes you make in the parent are inherited by its children. In effect, that first object is both the class and an instance of the class. In the implementation below, children share properties (methods and

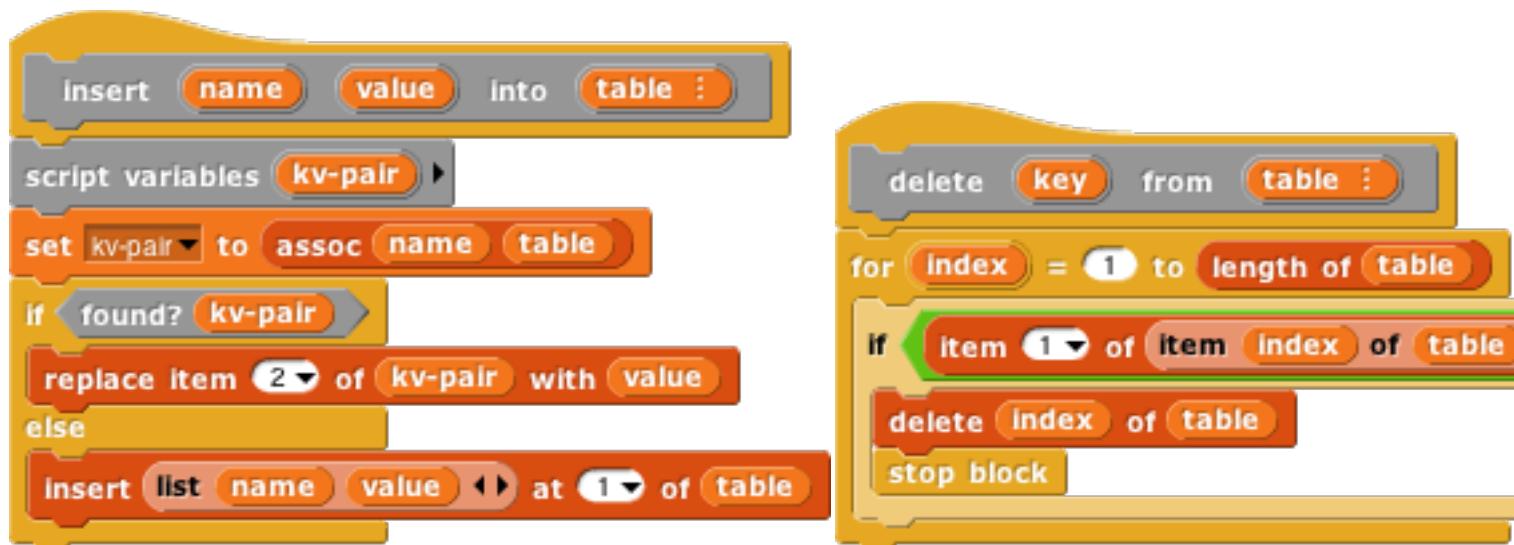
local variables) of their parent unless and until a child changes a property, at which point that child gets a private copy. (If a child wants to change something for its entire family, it must ask the parent to do it.)

Because we want to be able to create and delete properties dynamically, we won't use Snap! variables to hold an object's variables or methods. Instead, each object has two *tables*, called **methods** and **data**, each of which is an *association list*: a list of two-item lists, in which each of the latter contains a *key* and a corresponding *value*. We provide a lookup procedure to locate the key-value pair corresponding to a given key in a given table.



There are also commands to insert and delete entries:

8. OOP with Procedures

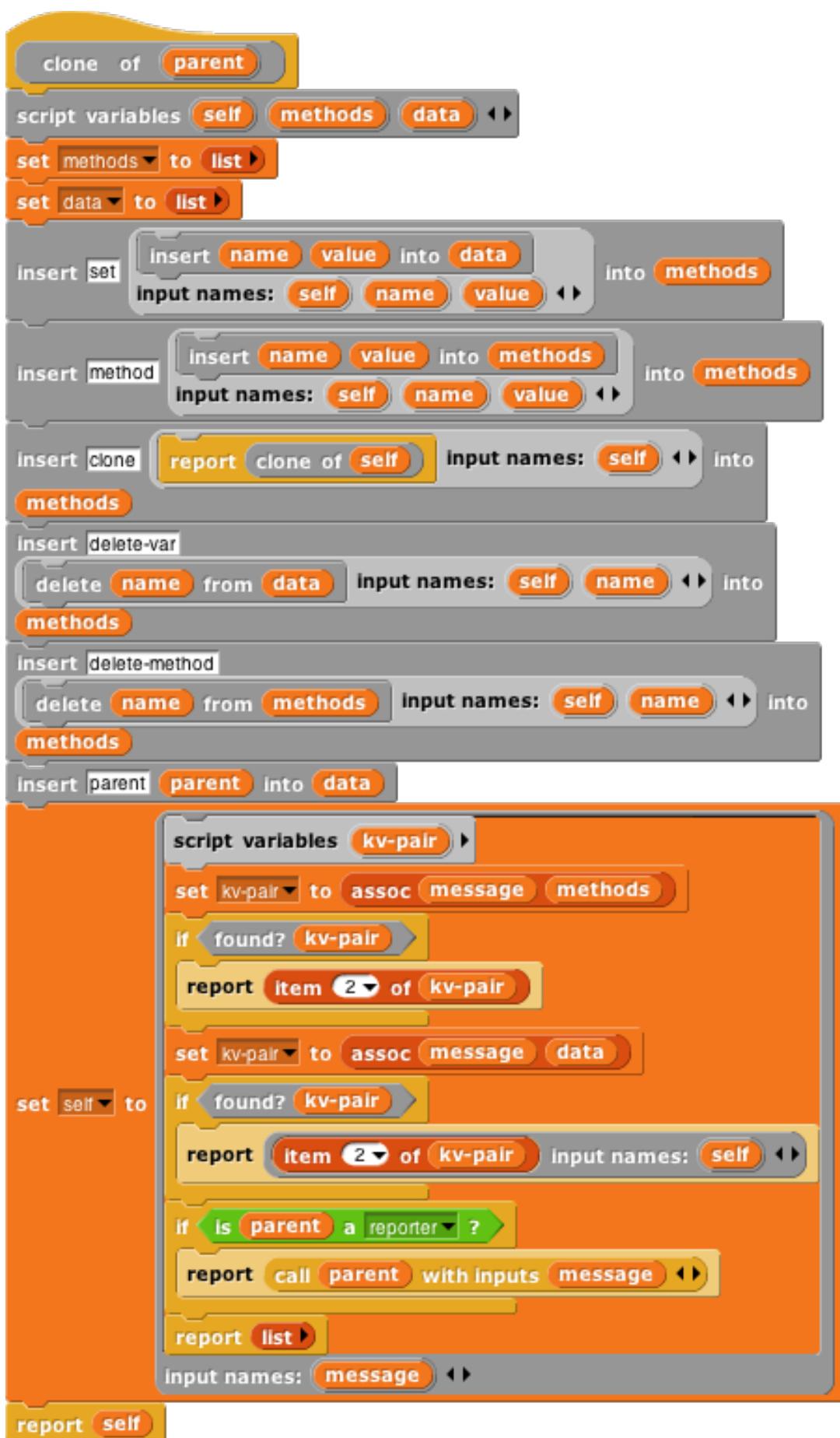


As in the class-instance version, an object is represented as a dispatch procedure that takes a message as its input and reports the corresponding method. When an object gets a message, it will first look for that keyword in its methods table . If it's found, the corresponding value is the method we want. If not, the object looks in its data table. If a value is found there, what the object returns is *not* that value, but rather a reporter method that, when called, will report the value. This means that what an object returns is *always* a method.

If the object has neither a method nor a datum with the desired name, but it does have a parent, then the parent (that is, the parent's dispatch procedure) is invoked with the message as its input. Eventually, either a match is found, or an object with no parent is found; the latter case is an error, meaning that the user has sent the object a message not in its repertoire.

Messages can take any number of inputs, as in the class-instance system, but in the prototyping version, every method automatically gets the object to which the message was originally sent as an extra first input. We must do this so that if a method is found in the parent (or grandparent, etc.) of the original recipient, and that method refers to a variable or method, it will use the child's variable or method if the child has its own version.

The clone of () block below takes an object as its input and makes a child object. It should be considered as an internal part of the implementation; the preferred way to make a child of an object is to send that object a clone message.



8. OOP with Procedures

Every object is created with predefined methods for set, method, delete-var, delete-method, and clone. It has one predefined variable, parent. Objects without a parent are created by calling new object:



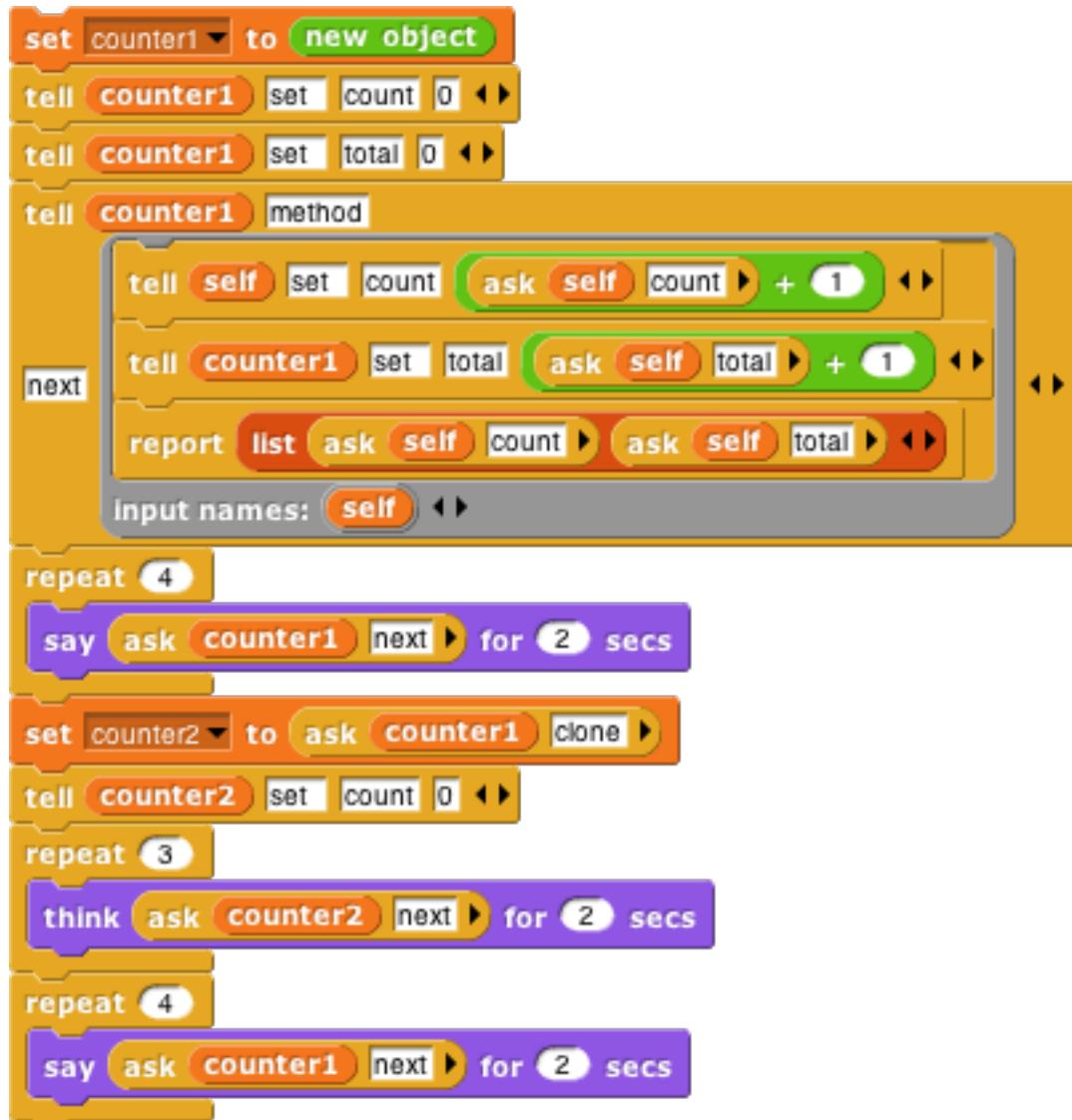
As before, we provide procedures to call an object's dispatch procedure and then call the method. But in this version, we provide the desired object as the first method input. We provide one procedure for Command methods and one for Reporter methods:



(Remember that the “Input list:” variant of the run and call blocks is made by dragging the input expression over the arrowheads rather than over the input slot.)

The script below demonstrates how this prototyping system can be used to make counters. We start with one prototype counter, called counter1. We count this counter up a few times, then create a child counter2 and give it its own count variable, but *not* its own total variable. The next method always sets counter1's total variable, which therefore keeps count of the total number of times that *any* counter is incremented. Running this script should say and think the following lists:

[1 1] [2 2] [3 3] [4 4] (1 5) (2 6) (3 7) [5 8] [6 9] [7 10] [8 11]



9. The Outside World

The facilities discussed so far are fine for projects that take place entirely on your computer's screen. But you may want to write programs that interact with physical devices (sensors or robots) or with the World Wide Web. For these purposes Snap! provides a single primitive block:



Figure 9.1.: image148.png

This might not seem like enough, but in fact it can be used to build the desired capabilities.

9.1. The World Wide Web

The input to the url block is the URL (Uniform Resource Locator) of a web page. The block reports the body of the Web server's response (minus HTTP header), *without interpretation*. This means that in most cases the response is a description of the page in HTML (HyperText Markup Language) notation. Often, especially for commercial web sites, the actual information you're trying to find on the page is actually at another URL included in the reported HTML. The Web page is typically a very long text string, and so the primitive split block is useful to get the text in a manageable form, namely, as a list of lines:

```

1 <!DOCTYPE html>
2 <!-- Woot, not HTML2! -->
3 <html><head>
4 <meta http-equiv="content-type" content="text/html; charset=utf-8">
5 <title>Snap! (Build Your Own Blocks) 4.0</title>
6 <meta coding="utf-8">
7 <link rel="shortcut icon" href="snapsource/favicon.ico">
8 <link href="liam4/bootstrap.css" rel="stylesheet">
9 <link rel="stylesheet" href="liam4/index.css">
10
11 <script type="text/javascript">
12
13 var _gaq = _gaq || [];
14 _gaq.push(['_setAccount', 'UA-30925559-2']);
15 _gaq.push(['_trackPageview']);
16
17 (function() {
18   var ga = document.createElement('script'); ga.type = 'text/javascript'; ga.asy
19   ga.src = ('https:' == document.location.protocol ? 'https://ssl' : 'http://www')
20   '.google-analytics.com/ga.js';
21   var s = document.getElementsByTagName('script')[0]; s.parentNode.insertE
22 })();
23

```

split url snap.berkeley.edu by line ▾ length: 384

Figure 9.2.: image871.png

The second input to split is the character to be used to separate the text string into a list of lines, or one of a set of common cases (such as line, which separates on carriage return and/or newline characters).

This might be a good place for a reminder that list-view watchers scroll through only 100 items at a time. The downarrow near the bottom right corner of the speech balloon in the picture presents a menu of hundred-item ranges. (This may seem unnecessary, since the scroll bar should allow for any number of items, but doing it this way makes Snap! much faster.) In table view, the entire list is included.

If you include a protocol name in the input to the url block (such as `http://` or `https://`), that protocol will be used. If not, the block first tries HTTPS and then, if that fails, HTTP.

A security restriction in JavaScript limits the ability of one web site to initiate communication with another site. There is an official workaround for this limitation called the CORS protocol (Cross-Origin Resource Sharing), but the target site has to allow `snap.berkeley.edu` explicitly, and of course most don't. To get around this problem, you can use third-party sites ("cors proxies") that are not limited by JavaScript and that forward your requests.

9.2. Hardware Devices

Another JavaScript security restriction prevents Snap! from having direct access to devices connected to your computer, such as sensors and robots. (Mobile devices such as smartphones may also have useful devices built in, such as accelerometers and GPS receivers.) The url block is also used to interface Snap! with these external capabilities.

The idea is that you run a separate program that both interfaces with the device and provides a local HTTP server that Snap! can use to make requests to the device. *Unlike Snap! itself, these programs have access to anything on your computer, so you have to trust the author of the software!* Our web site, snap.berkeley.edu, provides links to drivers for several devices, including, at this writing, the Lego NXT , Finch, Hummingbird, and Parallax S2 robots; the Nintendo Wiimote and Leap Motion sensors, the Arduino microcomputer, and Super-Awesome Sylvia 's Water Color Bot . The same server technique can be used for access to third party software libraries, such as the speech synthesis package linked on our web site.

Most of these packages require some expertise to install; the links are to source code repositories. This situation will improve with time.

9.3. Date and Time

The current block in the Sensing palette can be used to find out the current date or time. Each call to this block reports one component of the date or time , so you will probably combine several calls, like this:



for Americans, or like this:

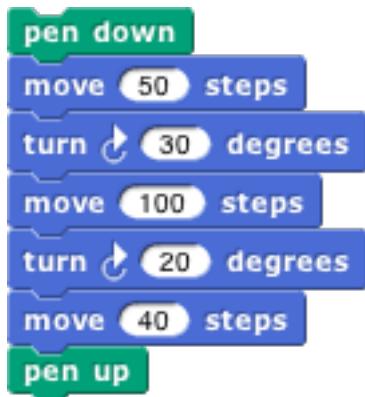


for Europeans.

10. Continuations

Blocks are usually used within a script. The *continuation* of a block within a particular script is the part of the computation that remains to be completed after the block does its job. A continuation can be represented as a ringed script. Continuations are always part of the interpretation of any program in any language, but usually these continuations are implicit in the data structures of the language interpreter or compiler. Making continuations explicit is an advanced but versatile programming technique that allows users to create control structures such as nonlocal exit and multithreading.

In the simplest case, the continuation of a command block may just be the part of the script after the block. For example, in the script



the continuation of the move 100 steps block is



But some situations are more complicated. For example, what is the continuation of move 100 steps in the following script?



That's a trick question; the move block is run four times, and it has a different continuation each time. The first time, its continuation is

10. Continuations



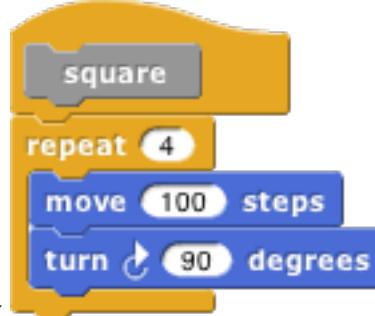
Note that there is no repeat 3 block in the actual script, but the continuation has to represent the fact that there are three more times through the loop to go. The fourth time, the continuation is just



What counts is not what's physically below the block in the script, but what computational work remains to be done.

(This is a situation in which visible code may be a little misleading. We have to put a repeat 3 block in the *picture* of the continuation, but the actual continuation is made from the evaluator's internal bookkeeping of where it's up to in a script. So it's really the original script plus some extra information. But the pictures here do correctly represent what work the process still has left to do.)

When a block is used inside a custom block, its continuation may include parts of more than one script. For



example, if we make a custom square block

and then use that block in a script:



then the continuation of the first use of move 100 steps is



in which part comes from inside the square block and part comes from the call to square. Nevertheless, ordinarily when we *display* a continuation we show only the part within the current script.

The continuation of a command block, as we've seen, is a simple script with no input slots. But the continuation of a *reporter* block has to do something with the value reported by the block, so it takes that value as input. For example, in the script



the continuation of the $3+4$ block is



Of course the name *result* in that picture is arbitrary; any name could be used, or no name at all by using the empty-slot notation for input substitution.

10.1. Continuation Passing Style

Like all programming languages, Snap! evaluates compositions of nested reporters from the inside out. For

example, in the expression Snap! first adds 4 and 5, then multiplies 3 by that sum. This often means that the order in which the operations are done is backwards from the order in which they appear in the expression: When reading the above expression you say "times" before you say "plus." In English, instead of saying "three times four plus five," which actually makes the order of operations ambiguous, you could say, "take the sum of four and five, and then take the product of three and that sum." This sounds more awkward, but it has the virtue of putting the operations in the order in which they're actually performed.

That may seem like overkill in a simple expression, but suppose you're trying to convey the expression

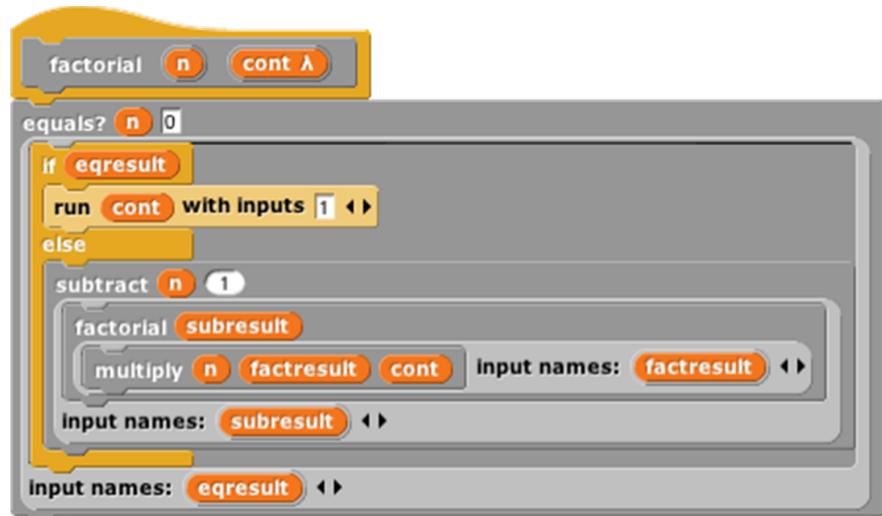
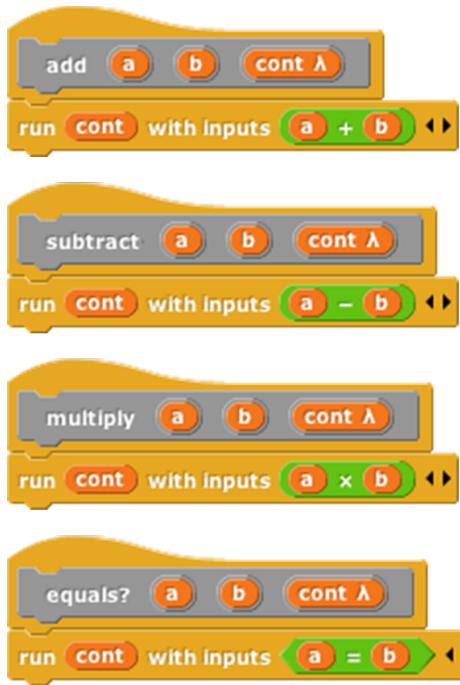


to a friend over the phone. If you say "factorial of three times factorial of two plus two plus five" you might mean any of these:



Wouldn't it be better to say, "Add two and two, take the factorial of that, add five to that, multiply three by that, and take the factorial of the result"? We can do a similar reordering of an expression if we first define versions of all the reporters that take their continuation as an explicit input. In the following picture, notice that the new blocks are *commands*, not reporters.

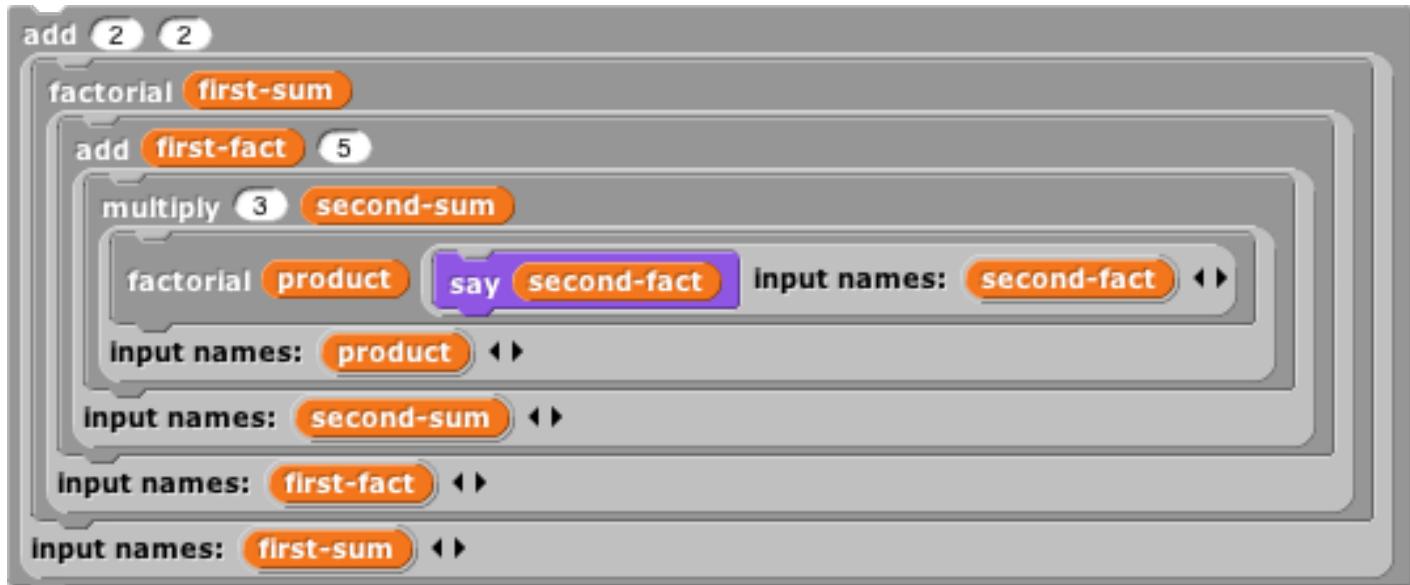
10. Continuations



We can check that these blocks give the results we want:



The original expression can now be represented as



If you read this top to bottom, don't you get "Add two and two, take the factorial of that, add five to that, multiply three by that, and take the factorial of the result"? Just what we wanted! This way of working, in which every

block is a command that takes a continuation as one of its inputs, is called *continuation-passing style (CPS)*. Okay, it looks horrible, but it has subtle virtues. One of them is that each script is just one block long (with the rest of the work buried in the continuation given to that one block), so each block doesn't have to remember what else to do—in the vocabulary of this section, the (implicit) continuation of each block is empty. Instead of the usual picture of recursion, with a bunch of little people all waiting for each other, with CPS what happens is that each little person hands off the problem to the next one and goes to the beach, so there's only one active little person at a time. In this example, we start with Alfred, an add specialist, who computes the value 4 and then hands off the rest of the problem to Francine, a factorial specialist. She computes the value 24, then hands the problem off to Anne, another add specialist, who computes 29. And so on, until finally Sam, a say specialist, says the value $2.107757298379527 \times 10^{132}$, which is a very large number!



Go back to the definitions of these blocks. The ones, such as add, that correspond to primitive reporters are simple; they just call the reporter and then call their continuation with its result. But the definition of factorial is more interesting. It doesn't just call our original factorial reporter and send the result to its continuation. CPS is used inside factorial too! It says, "See if my input is zero. Send the (true or false) result to if. If the result is true, then call my continuation with the value 1. Otherwise, subtract 1 from my input. Send the result of that to factorial, with a continuation that multiplies the smaller number's factorial by my original input. Finally, call my continuation with the product." You can use CPS to unwind even the most complicated branched recursions.

By the way, I cheated a bit above. The if/else block should also use CPS; it should take one true/false input and two *continuations*. It will go to one or the other continuation depending on the value of its input. But in fact the C-shaped blocks (or E-shaped, like if/else) are really using CPS in the first place, because they implicitly wrap rings around the sub-scripts within their branches. See if you can make an explicitly CPS if/else block.

10.2. Call/Run w/Continuation

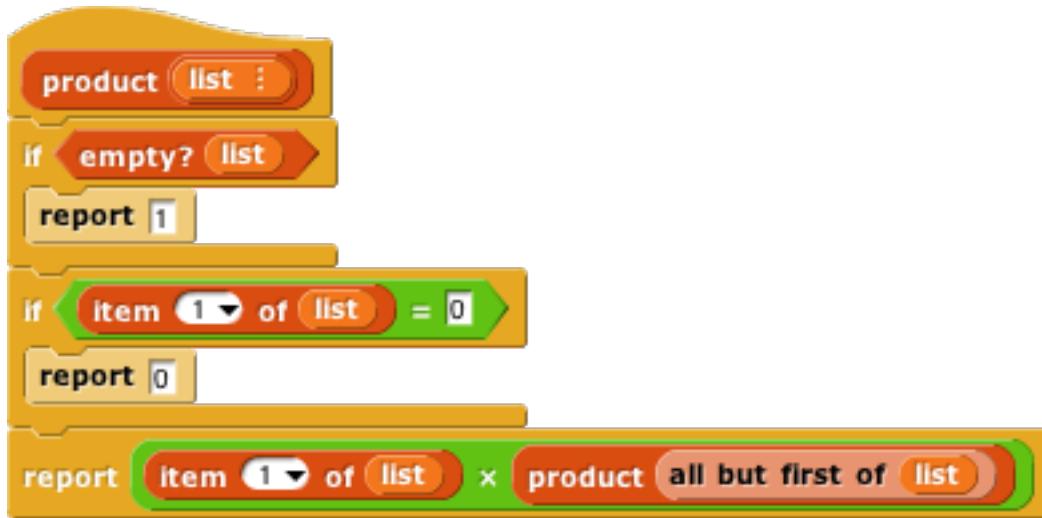
To use explicit continuation passing style, we had to define special versions of all the reporters, add and so on. Snap! provides a primitive mechanism for capturing continuations when we need to, without using continuation passing throughout a project.

Here's the classic example. We want to write a recursive block that takes a list of numbers as input, and reports the product of all the numbers:



10. Continuations

But we can improve the efficiency of this block, in the case of a list that includes a zero; as soon as we see the zero, we know that the entire product is zero.



But this is not as efficient as it might seem. Consider, as an example, the list 1,2,3,0,4,5. We find the zero on the third recursive call (the fourth call altogether), as the first item of the sublist 0,4,5. What is the continuation of the report 0 block? It's



Even though we already know that result is zero, we're going to do three unnecessary multiplications while unwinding the recursive calls.

We can improve upon this by capturing the continuation of the top-level call to product:



The **call w/continuation** block takes as its input a one-input script, as shown in the product example. It calls that script with the *continuation of the call-with-continuation block itself* as its input. In this case, that continuation is



reporting to whichever script called product. If the input list doesn't include a zero, then nothing is ever done with that continuation, and this version works just like the original product. But if the input list is 1,2,3,0,4,5, then three recursive calls are made, the zero is seen, and product-helper runs the continuation, with an input of 0. The continuation immediately reports that 0 to the caller of product, without unwinding all the recursive calls and without the unnecessary multiplications.



I could have written product a little more simply using a Reporter ring instead of a Command ring:



but it's customary to use a script to represent the input to call w/continuation because very often that input takes the form

so that the continuation is saved permanently and can be called from anywhere in the project. That's why the input slot in call w/continuation has a Command ring rather than a Reporter ring.

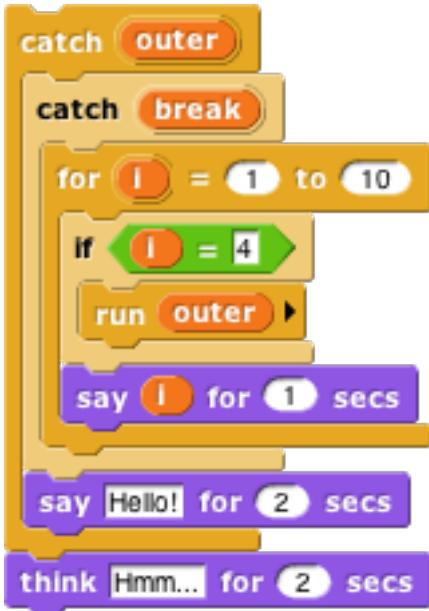
First class continuations are an experimental feature in Snap! and there are many known limitations in it. One is that the display of reporter continuations shows only the single block in which the call w/continuation is an input.

10.2.1. Nonlocal exit

Many programming languages have a break command that can be used inside a looping construct such as repeat to end the repetition early. Using first class continuations, we can generalize this mechanism to allow nonlocal exit even within a block called from inside a loop, or through several levels of nested loops:



The upvar break has as its value a continuation that can be called from anywhere in the program to jump immediately to whatever comes after the catch block in its script. Here's an example with two nested invocations of catch, with the upvar renamed in the outer one:



As shown, this will say 1, then 2, then 3, then exit both nested catches and think “Hmm.” If in the run block the variable `break` is used instead of `outer`, then the script will say 1, 2, 3, and “Hello!” before thinking “Hmm.”

There are corresponding catch and throw blocks for reporters. The catch block is a reporter that takes an expression as input instead of a C-shaped slot. But the throw block is a command; it doesn’t report a value to its own continuation, but instead reports a value (which it takes as an additional input, in addition to the catch tag) to the corresponding catch block’s continuation:



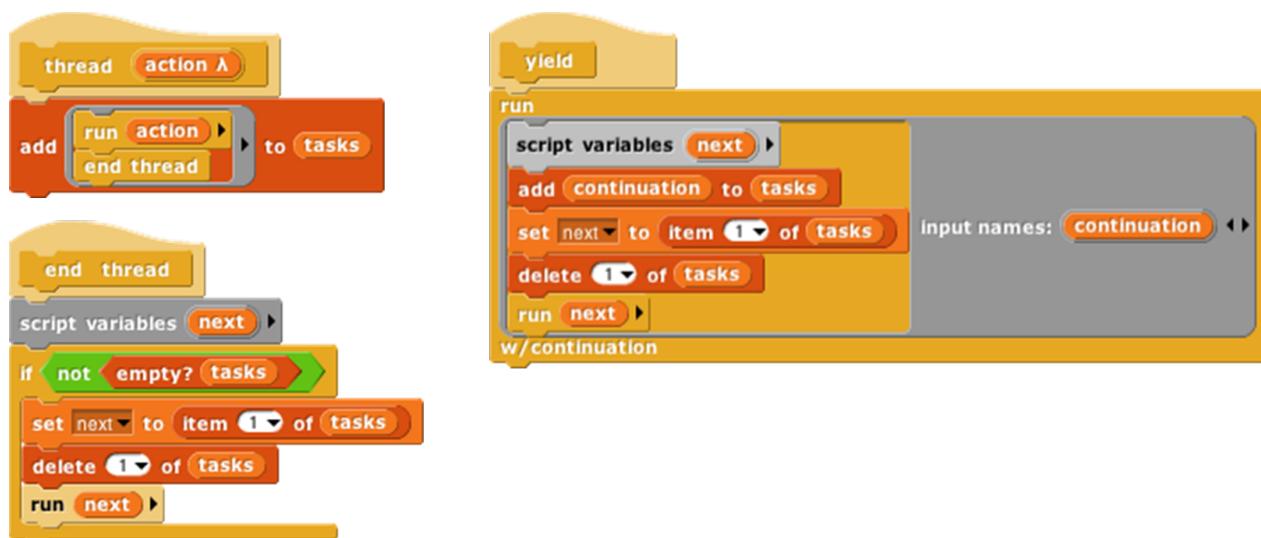
Without the throw, the inner call reports 5, the + block reports 8, so the catch block reports 8, and the `x` block reports 80. With the throw, the inner call doesn’t report at all, and neither does the + block. The throw block’s input of 20 becomes the value reported by the catch block, and the `x` block multiplies 10 and 20.

Creating a Thread System

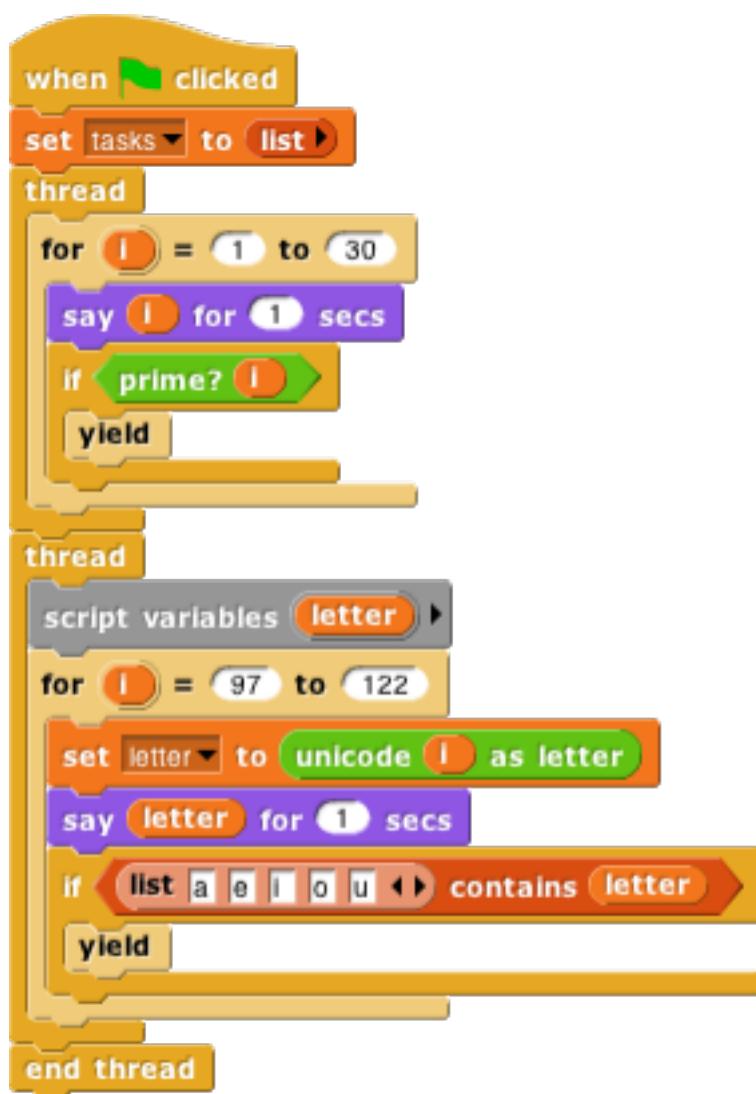
Snap! can be running several scripts at once, within a single sprite and across many sprites. If you only have one computer, how can it do many things at once? The answer is that only one is actually running at any moment, but Snap! switches its attention from one script to another frequently. At the bottom of every looping block (repeat, repeat until, forever), there is an implicit “yield” command, which remembers where the current script is up to, and switches to some other script, each in turn. At the end of every script is an implicit “end thread” command (a *thread* is the technical term for the process of running a script), which switches to another script without remembering the old one.

Since this all happens automatically, there is generally no need for the user to think about threads. But, just to show that this, too, is not magic, here is an implementation of a simple thread system. It uses a global variable named `tasks` that initially contains an empty list. Each use of the C-shaped thread block adds a continuation (the ringed script) to the list. The yield block uses `run w/continuation` to create a continuation for a partly done thread,

adds it to the task list, and then runs the first waiting task. The end thread block (which is automatically added at the end of every thread's script by the thread block) just runs the next waiting task.



Here is a sample script using the thread system. One thread says numbers; the other says letters. The number thread yields after every prime number, while the letter thread yields after every vowel. So the sequence of speech balloons is 1,2,a,3,b,c,d,e,4,5,f,g,h,i,6,7,j,k,l,m,n,o,8,9,10,11, p,q,r,s,t,u,12,13,v,w,x,y,z,14,15,16,17,18,...30.

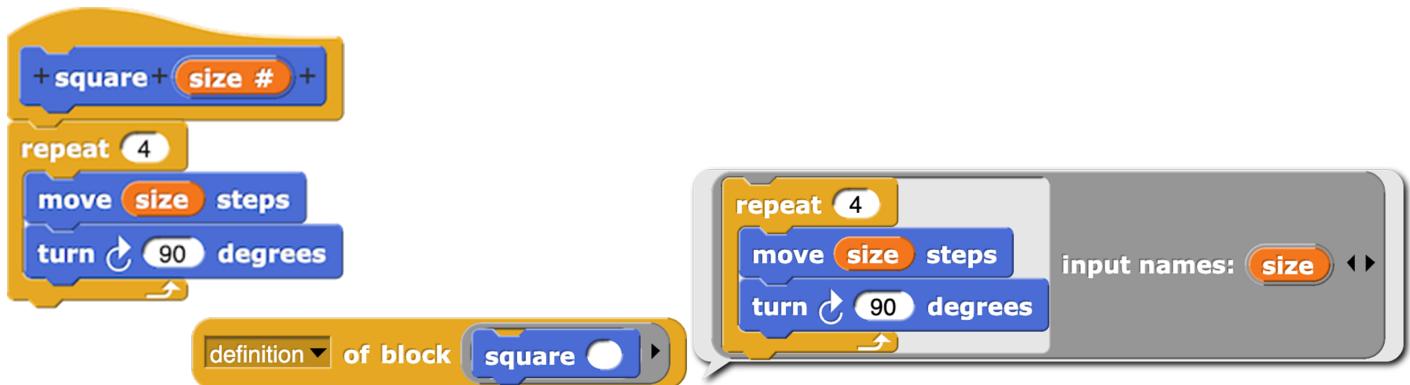


If we wanted this to behave exactly like Snap!'s own threads, we'd define new versions of repeat and so on that run yield after each repetition.

11. Metaprogramming

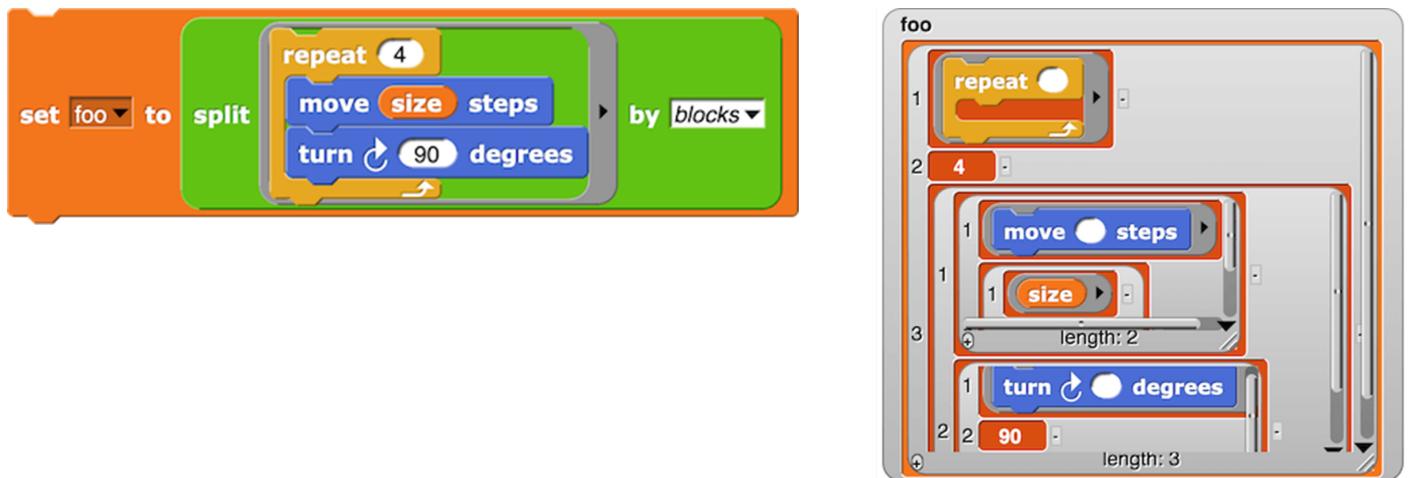
The scripts and custom blocks that make up a program can be examined or created by the program itself.

11.1. Reading a block



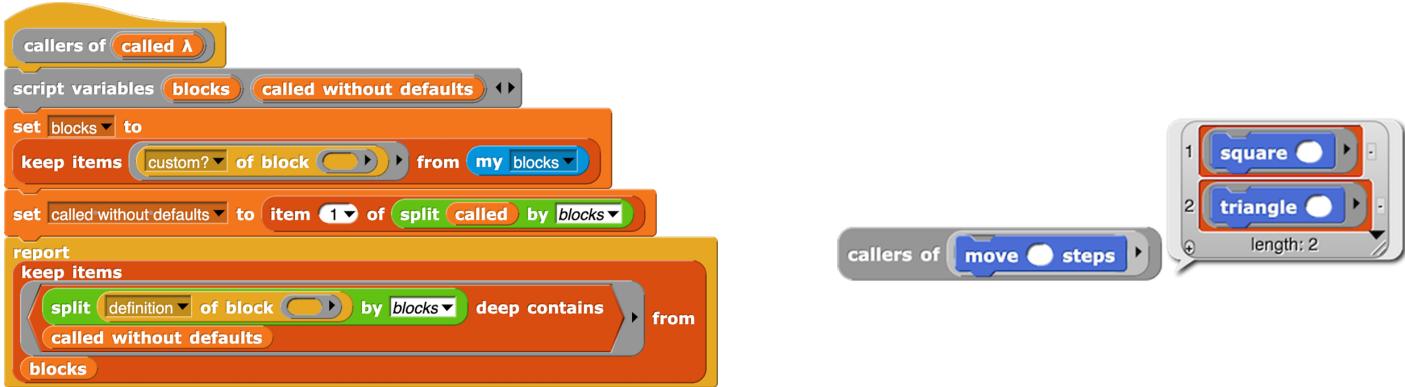
The definition of block takes a custom block (in a ring, since it's the block itself that's the input, not the result of calling the block) as input and reports the block's definition, i.e., its inputs and body, in the form of a ring with named inputs corresponding to the block's input names, so that those input names are bound in the body.

The split by blocks block takes any expression or script as input (ringed) and reports a list representing a syntax tree for the script or expression, in which the first item is a block with no inputs and the remaining items are the input values, which may themselves be syntax trees.



Using split by blocks to select custom blocks whose definitions contain another block gives us this debugging aid:

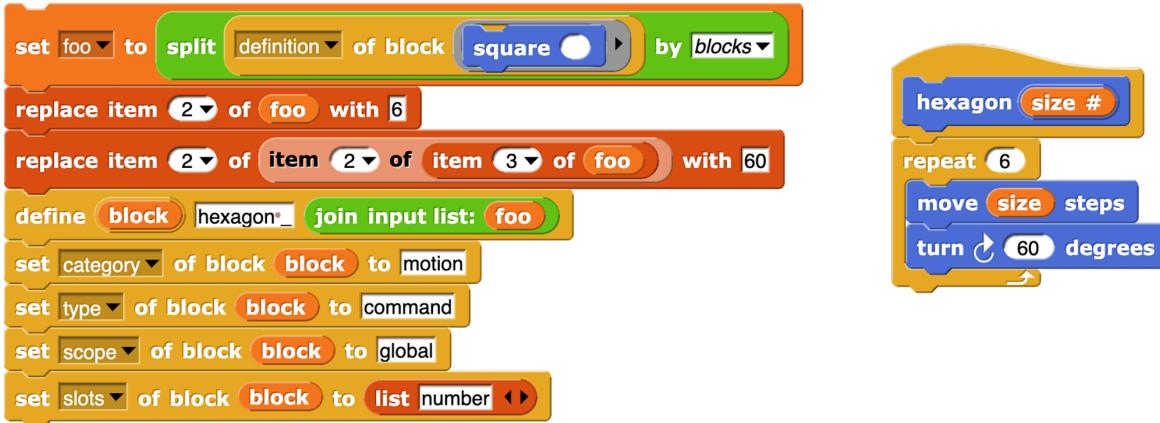
11. Metaprogramming



Note in passing the `my blocks` block, which reports a list of all visible blocks, primitive and custom. (There's also a `my categories` block, which reports a list of the names of the palette categories.) Also note `custom? of block`, which reports True if its input is a custom block.

11.2. Writing a block

The inverse function to `split by blocks` is provided by the `join` block , which when given a syntax tree as input reports the corresponding expression or script.



Here we are taking the definition of `square`, modifying the repetition count (to 6), modifying the turning angle (to 60), using `join` to turn the result back into a ringed definition, and using the `define` block to create a new hexagon block.

The `define` block has three “input” slots. The quotation marks are there because the first slot is an upvar, i.e., a way for `define` to provide information to its caller, rather than the other way around. In this case, the value of `block` is the new block itself (the hexagon block, in this example). The second slot is where you give the *label* for the new block. In this example, the label is “`hexagon_`” in which the underscore represents an input slot. So, here are a few examples of block label s:

```
set pen _ to _  
for _ = _ to _ _  
ask _ and wait  
_ of _
```

Note that the underscores are separated from the block text by spaces. Note in the case of the `for` block's label that the upvar (the `i`) and the C-slot both count as inputs. Note also that the label is not

meant to be a unique symbol that represents only this block. For example,   and



both have the label

_ of _. The label does not give the input slots names (that's done in the body, coming next) or types (that's done in the set _ of block _ to _ block, coming in two paragraphs).

The third slot is for the *definition* of the new block. This is a (ringed) script whose input names (formal parameters) will become the formal parameters of the new block. And the script is its script.

So far we know the block's label, parameters, and script. There are other things to specify about the block, and one purpose of the block upvar is to allow that. In the example on the previous page, there are four set _ of block _ to _ blocks, reproduced below for your convenience:



The category of the block can be set to any primitive or custom category. The default is other. The type is command, reporter, or predicate. Command is the default, so this setting is redundant, but we want to show all the choices in the set block. The scope is either global or sprite, with global as the default. The last input to set slots is a list of length less than or equal to the number of underscores in the label. Each item of the list is a type name, like the ones in the is (5) a (number)? block. If there is only one input, you can use just the name instead of putting it in a list. An empty or missing list item means type Any.

It's very important that these set blocks appear in the same script as the define that creates the block, because the block upvar is local to that script. You can't later say, for example,



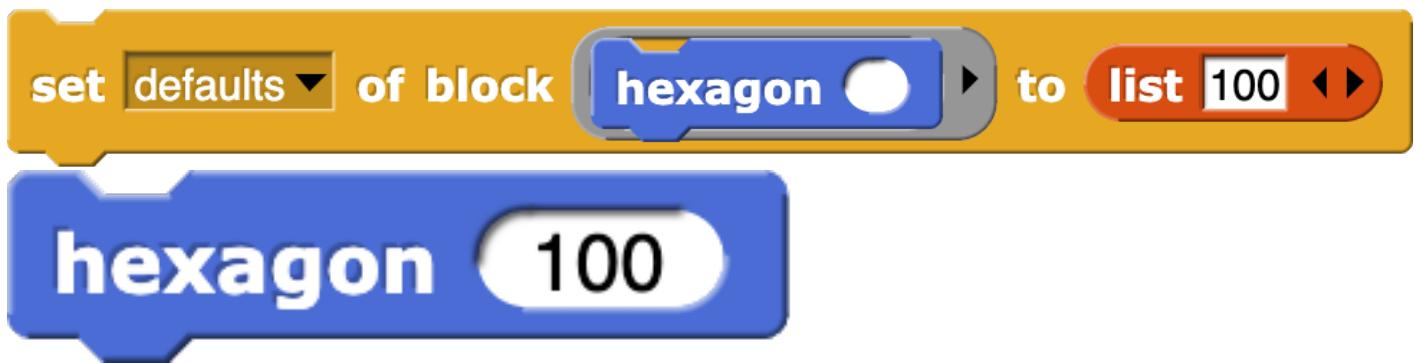
because the copy of the hexagon block in this instruction counts as "using" it.



The of block reporter is useful to copy attributes from one block to another, as we copied the definition of square, modified it, and used it to define hexagon. Some of the values this block reports are a little unfriendly:

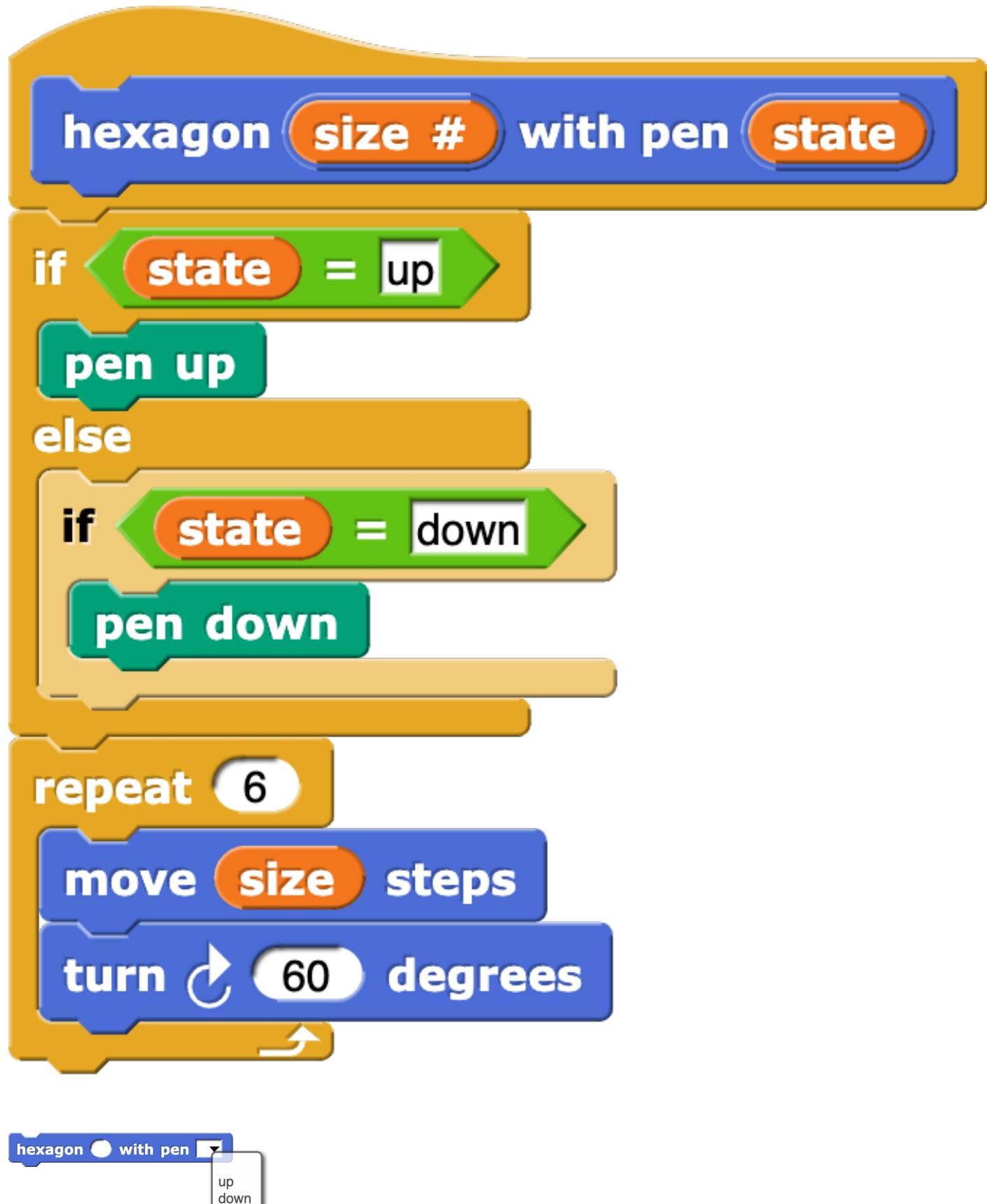
"1"? Yes, this block reports *numbers* instead of names for category, type, and scope. The reason is that maybe someday we'll have translations to other languages for custom category names, as we already do for the built-in categories, types, and scopes; if you translate a program using this block to another language, the numeric outputs won't change, simplifying comparisons in your code. The set block accepts these numbers as an alternative to the names.

There are a few more attributes of a block, less commonly used.

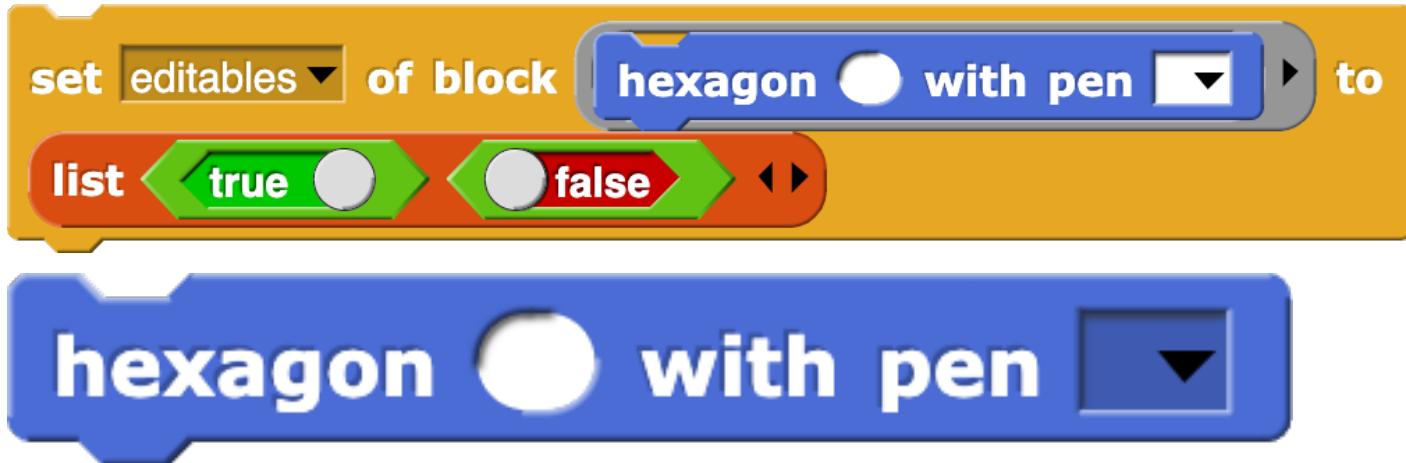


The list input is just like the one for set slots except for default values instead of types. Now for a block with a menu input:

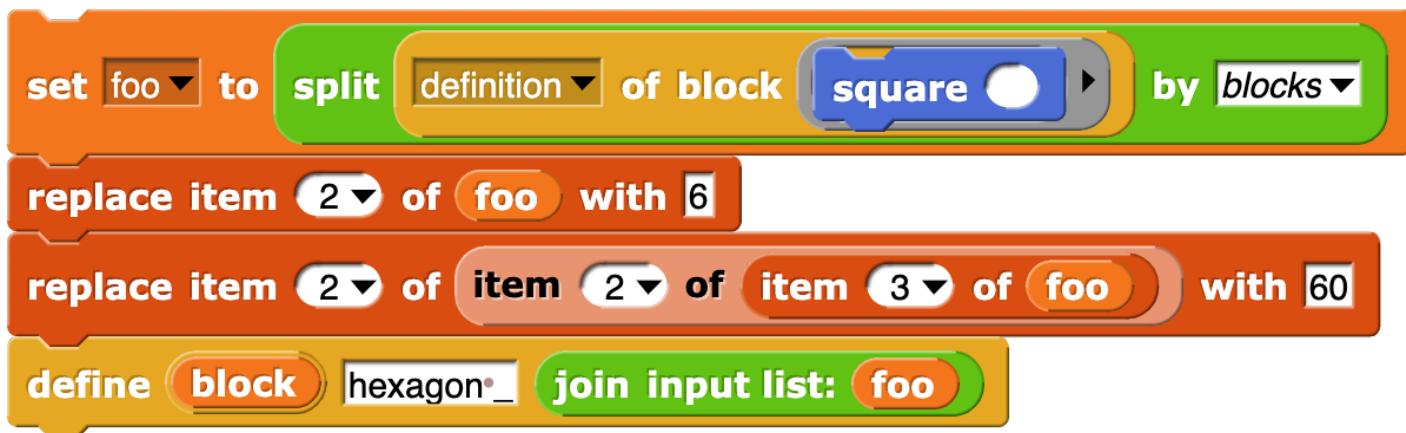




Prefer a read-only menu?



We passed too quickly over how the script turned the square block into a hexagon block:



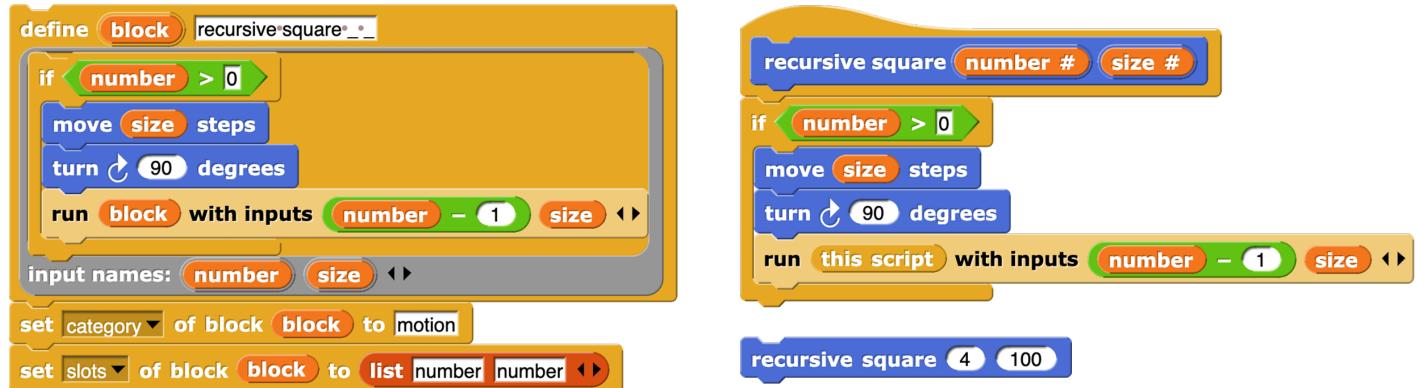
Those replace item blocks aren't very elegant. I had to look at foo by hand to figure out where the numbers I wanted to change are. This situation can be improved with a little programming:



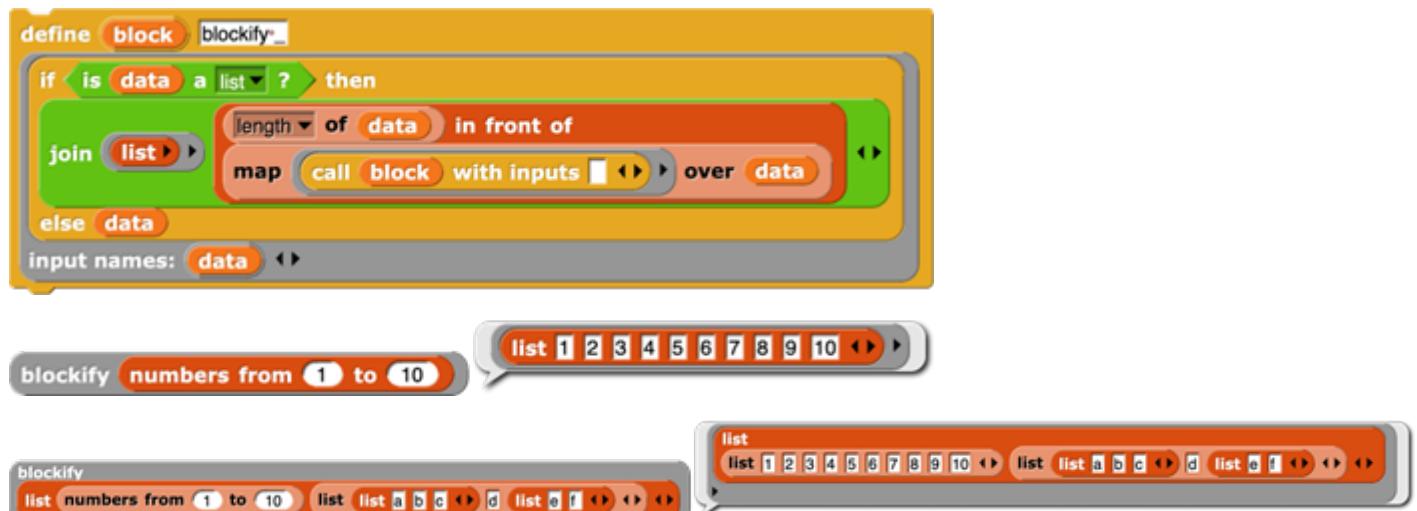
Exercise for the reader: Implement this:



Returning to the define block, there's another reason for the block upvar: It's helpful in defining a recursive procedure using `define`. For a procedure to call itself, it needs a name for itself. But in the definition input to the `define` block, `define` itself hasn't been called yet, so the new block isn't in the palette yet. So you do this:



Yes, you put `block` in the `define`, but it gets changed into this script in the resulting definition.

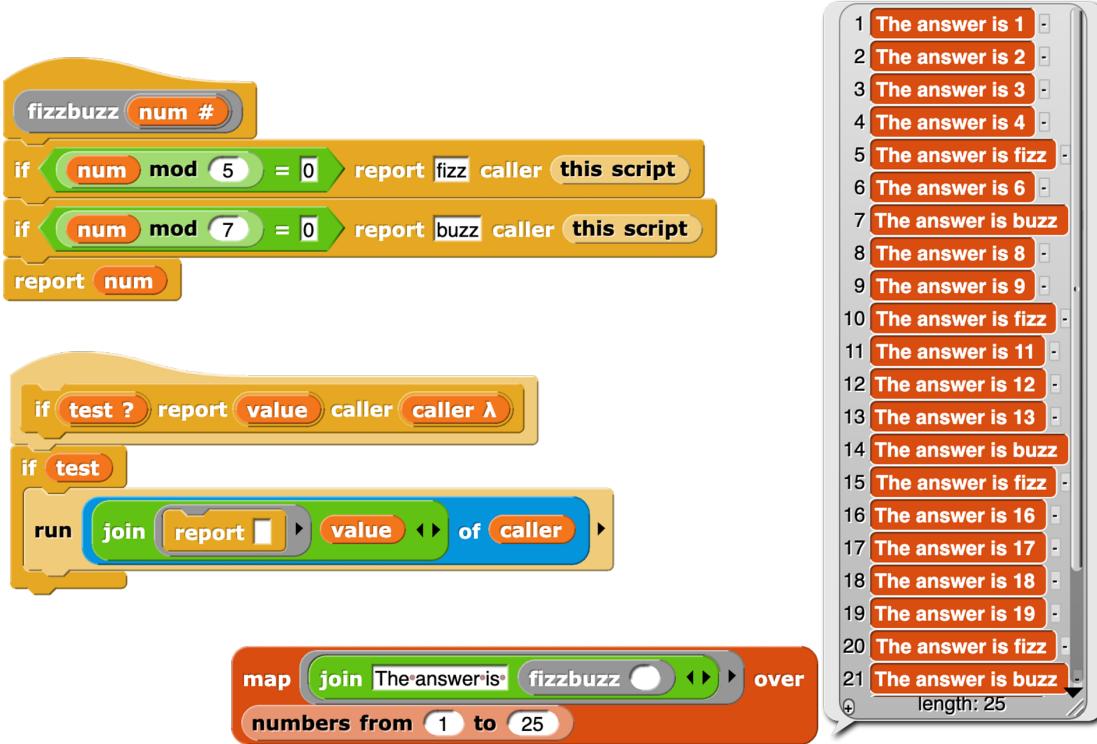


You could use this script directly in a simple case like this, but in a complicated case with a recursive call inside a ring inside the one giving the block definition, this script always means the innermost ring. But the upvar means the outer ring; note how the definition of `blockify` automatically creates a script variable to hold the outer environment.

It's analogous to using explicit formal parameters when you nest calls to higher order functions.

Note: Ordinarily, when you call a function that reports a (ringed) procedure, that procedure was created in some specific environment, and has access to that environment's variables. This is how instance variables (fields) work in object oriented programming (Chapter VIII). But the procedures made by `join` of a syntax tree have no associated environment, not even the one containing global variables. That doesn't matter if the procedure will use only its own input variables, but for access to other variables, use

11.3. Macros



Users of languages in the C family have learned to think of macros as entirely about text strings, with no relation to the syntax of the language. So you can do things like

```
#define foo baz)
```

with the result that you can only use the foo macro after an open parenthesis.

In the Lisp family of languages we have a different tradition, in which macros are syntactically just like procedure calls, except that the “procedure” is a macro, with different evaluation rules from ordinary procedures. Two things make a macro different: its input expressions are not evaluated, so a macro can establish its own syntax (but still delimited by parentheses, in Lisp, or still one block, in Snap!); and the result of a macro call is a new expression that is evaluated *as if it appeared in the caller* of the macro, with access to the caller’s variables and, implicitly, its continuation.

Snap! has long had the first part of this, the ability to make inputs unevaluated. In version 8.0 we add the ability to run code in the context of another procedure, just as we can run code in the context of another sprite, using the same mechanism: the of block. In the example on the previous page, the if _ report _ caller _ block runs a report block, but not in its own context; it causes the fizzbuzz block to report “fizz” or “buzz” as appropriate. (Yes, we know that the rules implemented here are simplified compared to the real game.) It doesn’t just report out of the entire toplevel script; you can see that map is able to prepend “The answer is” to each reported value.

join input list: (syntax tree) of this script

This macro capability isn’t fully implemented. First, we shouldn’t have to use the calling script as an explicit input to the macro. In a later release, this will be fixed; when defining a block you’ll be able to say that it’s a macro, and it will automatically get its caller’s context as an invisible input. Second, there is a possibility of confusion between the variables of the macro and the variables of its caller. (What if the macro wanted to refer to a variable

value in its caller?) The one substantial feature of Scheme that we don't yet implement is *hygienic macros*, which make it possible to keep the two namespaces separate.

12. User Interface Elements

In this chapter we describe in detail the various buttons, menus, and other clickable elements of the Snap! user interface. Here again is the map of the Snap! window:

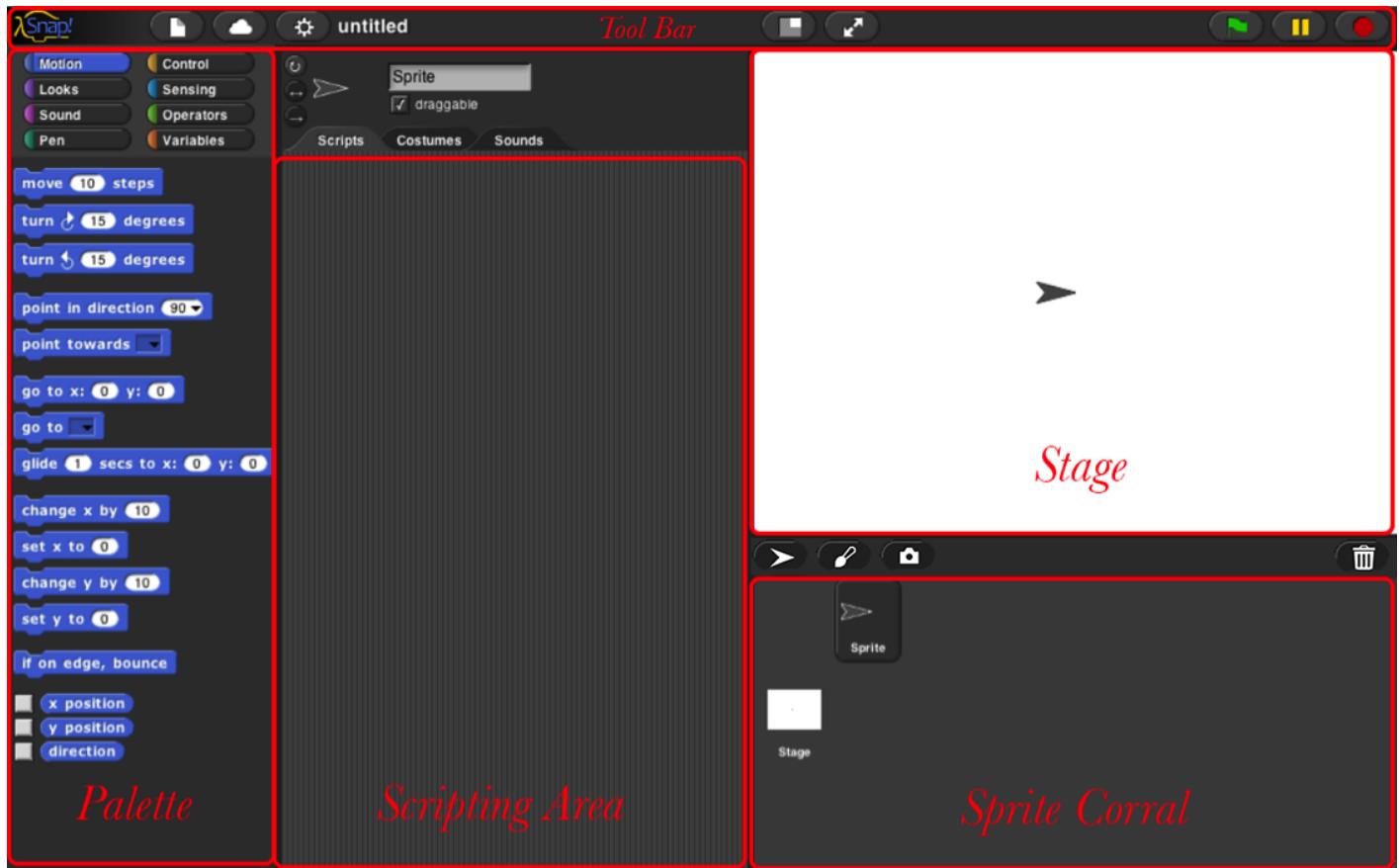


Figure 12.1.: An annotated screenshot of blank Snap! editor

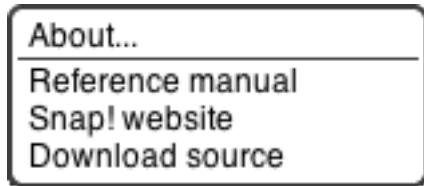
12.1. Tool Bar Features

Holding down the Shift key (Shift) while clicking on any of the menu buttons gives access to an extended menu with options, shown in red, that are experimental or for use by the developers. We're not listing those extra options here because they change frequently and you shouldn't rely on them. But they're not secrets.

12.1.1. The Snap! Logo Menu

The Snap! logo at the left end of the tool bar is clickable. It shows a menu of options about Snap! itself:

12. User Interface Elements



The “About” option displays information about Snap! itself, including version numbers for the source modules, the implementors, and the license (AGPL : you can do anything with it except create proprietary versions, basically).

The “Reference manual” option is a link to latest revision of this manual as a web page.

The “Snap! website” option opens a browser window pointing to <https://snap.berkeley.edu>, the community site for Snap!.

The “Download source” option opens a browser window displaying the GitHub repository of the source files for Snap!. At the bottom of the page are links to download the latest official release. Or you can navigate around the site to find the current development version. You can read the code to learn how Snap! is implemented, host a copy on your own computer (this is one way to keep working while on an airplane), or make a modified version with customized features. (However, access to cloud accounts is limited to the official version hosted at Berkeley.)

12.1.2. The File Menu



The file icon () shows a menu mostly about saving and loading projects. You may not see all these options, if you don't have multiple sprites, scenes, custom blocks, and custom categories.

The “Notes” option opens a window in which you can type notes about the project: How to use it, what it does, whose project you modified to create it, if any, what other sources of ideas you used, or any other information about the project. This text is saved with the project, and is useful if you share it with other users.

The “New” option starts a new, empty project. Any project you were working on before disappears, so you are asked to confirm that this is really what you want. (It disappears only from the current working Snap! window; you should save the current project, if you want to keep it, before using New.)

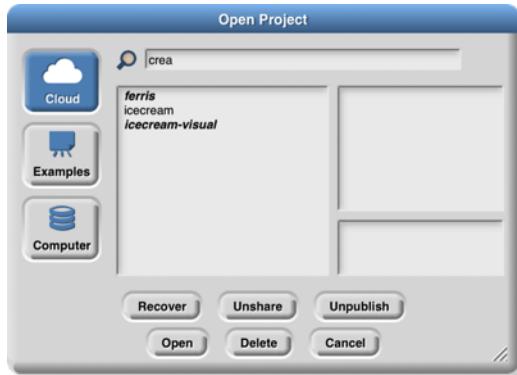
Note the ^N at the end of the line. This indicates that you can type control-N as a shortcut for this menu item. Alas, this is not the case in every browser. Some Mac browsers require command-N (⌘N) instead, while others open a new browser window instead of a new project. You'll have to experiment. In general, the keyboard shortcuts in Snap! are the standard ones you expect in other software.

The “Open...” option shows a project open dialog box in which you can choose a project to open:

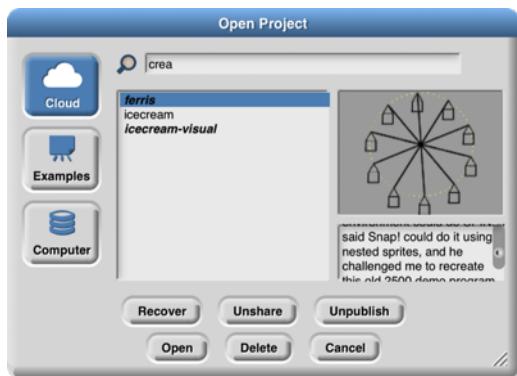


In this dialog, the three large buttons at the left select a source of projects: “Cloud” means your Snap! account’s cloud storage. “Examples” means a collection of sample projects we provide. “Computer” is for projects saved on your own computer; when you click it, this dialog is replaced with your computer’s system dialog for opening files. The text box to the right of those buttons is an alphabetical listing of projects from that source; selecting a project by clicking shows its thumbnail (a picture of the stage when it was saved) and its project notes at the right.

The search bar at the top can be used to find a project by name or text in the project notes. So in this example:



I was looking for my ice cream projects and typed “crea” in the search bar, then wondered why “ferris” matched. But then when I clicked on ferris I saw this:



My search matched the word “recreate” in the project notes.

The six buttons at the bottom select an action to perform on the selected project. In the top row, “Recover” looks in your cloud account for older versions of the chosen project. **If your project is damaged, don’t keep saving broken versions! Use “Recover” first thing.** You will see a list of saved versions; choose one to open it. Typically, you’ll see the most recent version before the last save, and the newest version saved before today. Then come buttons “Share”/“Unshare” and “Publish”/“Unpublish”. The labelling of the buttons depends on your project’s publication status. If a project is neither shared nor published (the ones in lightface type in the project list), it is

12. User Interface Elements

private and nobody can see it except you, its owner. If it is shared (**boldface** in the project list), then when you open it you'll see a URL like this one:

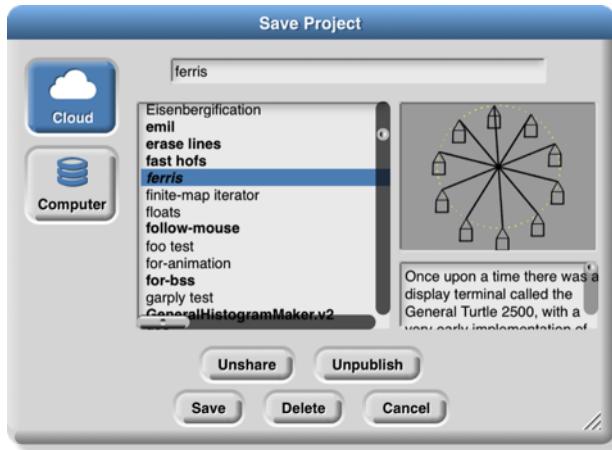
<https://snap.berkeley.edu/snapsource/snap.html#present:Username=bh&ProjectName=count%20change>

but with your username and project name. ("%20" in the project name represents a space, which can't be part of a URL.) Anyone who knows this URL can see your project. Finally, if your project is published (**bold italic** in the list), then your project is shown on the Snap! web site for all the world to see. (In all of these cases, you are the only one who can write to (save) your project.) If another user saves it, a separate copy will be saved in that user's account. Projects remember the history of who created the original version and any other "remix" versions along the way.

In the second row, the first button, "Open", loads the project into Snap! and closes the dialog box. The next button (if "Cloud" is the source) is "Delete", and if clicked it deletes the selected project. Finally, the "Cancel" button closes the dialog box without opening a project. (It does not undo any sharing, unsharing, or deletion you've done.)

Back to the File menu, the "Save" menu option saves the project to the same source and same name that was used when opening the project. (If you opened another user's shared project or an example project, the project will be saved to your own cloud account. You must be logged in to save to the cloud.)

The "Save as..." menu option opens a dialog box in which you can specify where to save the project:



This is much like the "Open" dialog, except for the horizontal text box at the top, into which you type a name for the project. You can also publish, unpublish, share, unshare, and delete projects from here. There is no "Recover" button.

The "Import..." menu option is for bringing some external resource into the current project, or it can load an entirely separate project, from your local disk. You can import costumes (any picture format that your browser supports), sounds (again, any format supported by your browser), and block libraries or sprites (XML format, previously exported from Snap! itself). Imported costumes and sounds will belong to the currently selected sprite; imported blocks are global (for all sprites). Using the "Import" option is equivalent to dragging the file from your desktop onto the Snap! window.

Depending on your browser, the "Export project..." option either directly saves to your disk or opens a new browser tab containing your complete project in XML notation (a plain text format). You can then use the browser's Save feature to save the project as an XML file, which should be named *something.xml* so that Snap! will recognize it as a project when you later drag it onto a Snap! window. This is an alternative to saving the project to your cloud account: keeping it on your own computer. It is equivalent to choosing "Computer" from the Save dialog described earlier.

The “Export summary...” option creates a web page, in HTML, with all of the information about your project: its name, its project notes, a picture of what’s on its stage, definitions of global blocks, and then per-sprite information: name, wardrobe (list of costumes), and local variables and block definitions. The page can be converted to PDF by the browser; it’s intended to meet the documentation requirements of the Advanced Placement Computer Science Principles create task.

The “Export blocks...” option is used to create a block library. It presents a list of all the global (for all sprites) blocks in your project, and lets you select which to export. It then opens a browser tab with those blocks in XML format, or stores directly to your local disk, as with the “Export project” option. Block libraries can be imported with the “Import” option or by dragging the file onto the Snap! window. This option is shown only if you have defined custom blocks.

The “Unused blocks...” option presents a listing of all the global custom blocks in your project that aren’t used anywhere, and offers to delete them. As with “Export blocks”, you can choose a subset to delete with checkboxes. This option is shown only if you have defined custom blocks.

The “Hide blocks...” option shows *all* blocks, including primitives, with checkboxes. This option does not remove any blocks from your project, but it does hide selected block in your palette. The purpose of the option is to allow teachers to present students with a simplified Snap! with some features effectively removed. The hiddenness of primitives is saved with each project, so students can load a shared project and see just the desired blocks. But users can always unhide blocks by choosing this option and unclicking all the checkboxes. (Right-click in the background of the dialog box to get a menu from which you can check all boxes or uncheck all boxes.)

The “New category...” option allows you to add your own categories to the palette. It opens a dialog box in which you specify a name *and* a color for the category. (A lighter version of the same color will be used for the zebra coloring feature.)

The “Remove a category...” option appears only if you’ve created custom categories. It opens a very small, easy-to-miss menu of category names just under the file icon in the menu bar. If you remove a category that has blocks in it, all those blocks are also removed.

The next group of options concern the scenes feature. A scene is a complete project, with its own stage, sprites, and

switch to scene **next ▾** ▶

code, but several can be merged into one project, using the block to bring another scene onscreen. The “Scenes...” option presents a menu of all the scenes in your project, where the File menu was before you clicked it. The “New scene” option creates a new, empty scene, which you can rename as you like from its context menu.

“Add scene...” is like “Import...” but for scenes. (A complete project can be imported as a scene into another project, so you have to specify that you’re importing the project *as a scene* rather than replacing the current project.)

The “Libraries...” option presents a menu of useful, optional block libraries:

12. User Interface Elements



The following sections of the libraries dialog are out of date. (8/1/2025)

- The library menu is divided into five broad categories. The first is, broadly, utilities: blocks that might well be primitives. They might be useful in all kinds of projects.
- The second category is blocks related to media computation: ones that help in dealing with costumes and sounds (a/k/a Jens libraries). There is some overlap with “big data” libraries, for dealing with large lists of lists.
- The third category is, roughly, specific to non-media applications (a/k/a Brian libraries). Three of them are imports from other programming languages: words and sentences from Logo, array functions from APL, and streams from Scheme. Most of the others are to meet the needs of the BJC curriculum.
- The fourth category is major packages provided by users.
- The fifth category provides support for hardware devices such as robots, through general interfaces, replacing specific hardware libraries in versions before 7.0.

When you click on the one-line description of a library, you are shown the actual blocks in the library and a longer explanation of its purpose. You can browse the libraries to find one that will satisfy your needs. The libraries are described in detail in Section I.H, page 25.

The “Costumes...” option opens a browser into the costume library:



You can import a single costume by clicking it and then clicking the Import button. Alternatively, you can import more than one costume by double-clicking each one, and then clicking Cancel when done. Notice that some costumes are tagged with "svg" in this picture; those are vector-format costumes that are not (yet) editable within Snap!.

If you have the stage selected in the sprite corral, rather than a sprite, the Costumes... option changes to a Backgrounds... option , with different choices in the browser:



The costume and background libraries include both bitmap (go jagged if enlarged) and vector (enlarge smoothly) images. Thanks to Scratch 2.0/3.0 for most of these images! Some older browsers refuse to import a vector

12. User Interface Elements

image, but instead convert it to bitmap.

The Sounds... option opens the third kind of media browser:

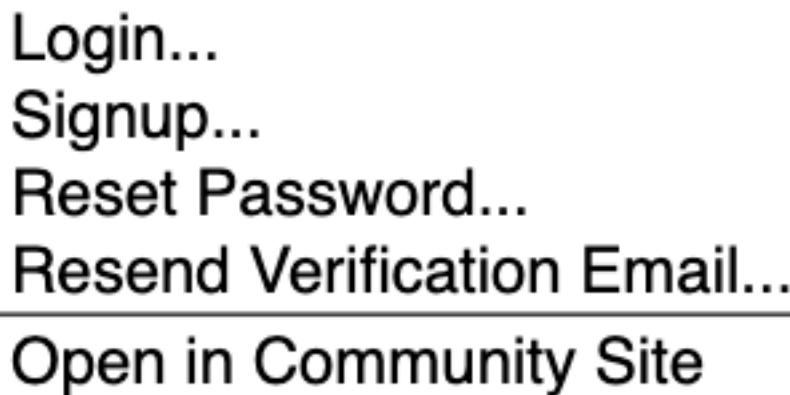


The Play buttons can be used to preview the sounds.

Finally, the Undelete sprites... option appears only if you have deleted a sprite; it allows you to recover a sprite that was deleted by accident (perhaps intending to delete only a costume).

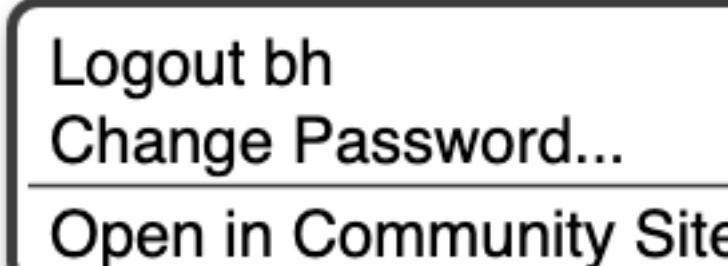
12.1.3. The Cloud Menu

The cloud icon shows a menu of options relating to your Snap! cloud account. If you are not logged in, you see the outline icon and get this menu:



Choose Login... if you have a Snap! account and remember your password. Choose Signup... if you don't have an account. Choose Reset Password... if you've forgotten your password or just want to change it. You will then get an email, at the address you gave when you created your account, with a new temporary password. Use that password to log in, then you can choose your own password, as shown below. Choose Resend Verification Email... if you have just created a Snap! account but can't find the email we sent you with the link to verify that it's really your email. (If you still can't find it, check your spam folder. If you are using a school email address, your school may block incoming email from outside the school.) The Open in Community Site option appears only if you have a project open; it takes you to the community site page about that project.

If you are already logged in, you'll see the solid icon  and get this menu:



Logout is obvious, but has the additional benefit of showing you who's logged in. Change password... will ask for your old password (the temporary one if you're resetting your password) and the new password you want, entered twice because it doesn't echo. Open in Community Site is the same as above.

12.1.4. The Settings Menu

The settings icon  shows a menu of Snap! options, either for the current project or for you permanently, depending on the option:

 Language...

Zoom blocks...

Fade blocks...

Stage size...

Microphone resolution...

JavaScript extensions

Extension blocks

Input sliders

Turbo mode

Visible stepping

Log pen vectors

Long form input dialog

Plain prototype labels

Clicking sound

Flat design

Thread safe scripts

Flat line ends

Codification support

Single palette

HSL pen color model

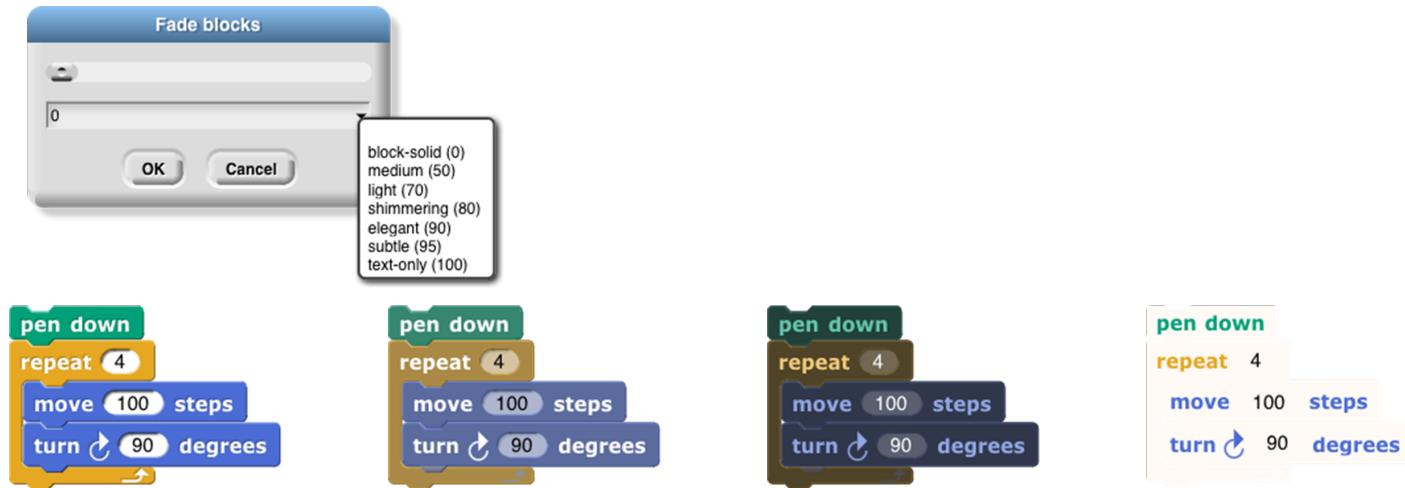
Disable click-to-run

The Language... option lets you see the Snap! user interface (blocks and messages) in a language other than English. (Note: Translations have been provided by Snap! users. If your native language is missing, send us an

email!)

The Zoom blocks... option lets you change the size of blocks, both in the palettes and in scripts. The standard size is 1.0 units. The main purpose of this option is to let you take very high-resolution pictures of scripts for use on posters. It can also be used to improve readability when projecting onto a screen while lecturing, but bear in mind that it doesn't make the palette or script areas any wider, so your computer's command-option-+ feature may be more practical. Note that a zoom of 2 is gigantic! Don't even try 10.

The Fade blocks... option opens a dialog in which you can change the appearance of blocks:



Mostly this is a propaganda aid to use on people who think that text languages are somehow better or more grown up than block languages, but some people do prefer less saturated block colors. You can use the pulldown menu for preselected fadings, use the slider to see the result as you change the fading amount, or type a number into the text box once you've determined your favorite value.

The Stage size... option lets you set the size of the *full-size* stage in pixels. If the stage is in half-size or double-size (presentation mode), the stage size values don't change; they always reflect the full-size stage.

The Microphone resolution... option sets the buffer size used by the microphone block in Settings. "Resolution" is an accurate name if you are getting frequency domain samples; the more samples, the narrower the range of frequencies in each sample. In the time domain, the buffer size determines the length of time over which samples are collected.

The remaining options let you turn various features on and off. There are three groups of checkboxes. The first is for temporary settings not saved in your project nor in your user preferences.

The JavaScript extensions option enables the use of the JavaScript function block . Because malicious projects could use JavaScript to collect private information about you, or to delete or modify your saved projects, you must enable JavaScript *each time* you load a project that uses it.

The Extension blocks option adds two blocks to the palette:



These blocks provide assorted capabilities to official libraries that were formerly implemented with the JavaScript function block. This allows these libraries to run without requiring the JavaScript extensions option. Details are subject to change.

12. User Interface Elements

Input sliders provides an alternate way to put values in numeric input slots; if you click in such a slot, a slider appears that you can control with the mouse:



The range of the slider will be from 25 less than the input's current value to 25 more than the current value. If you want to make a bigger change than that, you can slide the slider all the way to either end, then click on the input slot again, getting a new slider with a new center point. But you won't want to use this technique to change the input value from 10 to 1000, and it doesn't work at all for non-integer input ranges. This feature was implemented because software keyboard input on phones and tablets didn't work at all in the beginning, and still doesn't work perfectly on Android devices, so sliders provide a workaround. It has since found another use in providing "lively" response to input changes; if Input sliders is checked, reopening the settings menu will show an additional option called Execute on slider change. If this option is also checked, then changing a slider in the scripting area automatically runs the script in which that input appears. The project live-tree in the Examples collection shows how this can be used; it features a fractal tree custom block with several inputs, and you can see how each input affects the picture by moving a slider.

 Language...
Zoom blocks...
Fade blocks...
Stage size...
Microphone resolution...

JavaScript extensions
 Extension blocks
 Input sliders
 Execute on slider change
 Turbo mode
 Visible stepping
 Log pen vectors

Long form input dialog
 Plain prototype labels
 Clicking sound
 Flat design

Thread safe scripts
 Flat line ends
 Codification support
 Single palette
 HSL pen color model
 Disable click-to-run

12. User Interface Elements

Turbo mode makes many projects run much faster, at the cost of not keeping the stage display up to date. (Snap! ordinarily spends most of its time drawing sprites and updating variable watchers, rather than actually carrying out the instructions in your scripts.) So turbo mode isn't a good idea for a project with glide blocks or one in which the user interacts with animated characters, but it's great for drawing a complicated fractal, or computing the first million digits of π , so that you don't need to see anything until the final result. While in turbo mode, the button that normally shows a green flag instead shows a green lightning bolt. (But when π clicked hat blocks still activate when the button is clicked.)

Visible stepping enables the slowed-down script evaluation described in Chapter I. Checking this option is equivalent to clicking the footprint button above the scripting area. You don't want this on except when you're actively debugging, because even the fastest setting of the slider is still slowed a lot.

Log pen vectors tells Snap! to remember lines drawn by sprites as exact vectors, rather than remember only the pixels that the drawing leaves on the stage. This remembered vector picture can be used in two ways: First, right-clicking on a pen trails block gives an option to relabel it into a pen vectors block which, when run, reports the logged lines as a vector (svg) costume. Second, right-clicking on the stage when there are logged vectors shows an extra option, svg..., that exports a picture of the stage in vector format. Only lines are logged, not color regions made with the fill block. {#para-log-pen-vectors}

The next group of four are user preference options, preserved when you load a new project. Long form input dialog, if checked, means that whenever a custom block input name is created or edited, you immediately see the version of the input name dialog that includes the type options, default value setting, etc., instead of the short form with just the name and the choice between input name and title text. The default (unchecked) setting is definitely best for beginners, but more experienced Snap! programmers may find it more convenient always to see the long form.

Plain prototype labels eliminates the plus signs between words in the Block Editor prototype block. This makes it harder to add an input to a custom block; you have to hover the mouse where the plus sign would have been, until a single plus sign appears temporarily for you to click on. It's intended for people making pictures of scripts in the block editor for use in documentation, such as this manual. You probably won't need it otherwise.

Clicking sound causes a really annoying sound effect whenever one block snaps next to another in a script. Certain very young children, and our colleague Dan Garcia, like this, but if you are such a child you should bear in mind that driving your parents or teachers crazy will result in you not being allowed to use Snap!. It might, however, be useful for visually impaired users.

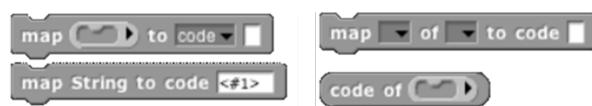
Flat design changes the "skin" of the Snap! window to a really hideous design with white and pale-grey background, rectangular rather than rounded buttons, and monochrome blocks (rather than the shaded, somewhat 3D-looking normal blocks). The monochrome blocks are the reason for the "flat" in the name of this option. The only thing to be said for this option is that, because of the white background, it may blend in better with the rest of a web page when a Snap! project is run in a frame in a larger page. (I confess I used it to make the picture of blocks faded all the way to just text two pages ago, though.)

The final group of settings change the way Snap! interprets your program; they are saved with the project, so anyone who runs your project will experience the same behavior. Thread safe scripts changes the way Snap! responds when an event (clicking the green flag, say) starts a script, and then, while the script is still running, the same event happens again. Ordinarily, the running process stops where it is, ignoring the remaining commands in the script, and the entire script starts again from the top. This behavior is inherited from Scratch, and some converted Scratch projects depend on it; that's why it's the default. It's also sometimes the right thing, especially in projects that play music in response to mouse clicks or keystrokes. If a note is still playing but you ask for another one, you want the new one to start right then, not later after the old process finishes. But if your script makes several changes to a database and is interrupted in the middle, the result may be that the database is inconsistent. When you select Thread safe scripts, the same event happening again in the middle of running a script is simply ignored. (This is arguably still not the right thing; the event should be remembered and the script

run again as soon as it finishes. We'll probably get around to adding that choice eventually.) Keyboard events (when `_` key pressed) are always thread-safe.

Flat line ends affects the drawing of thick lines (large pen width). Usually the ends are rounded, which looks best when turning corners. With this option selected, the ends are flat. It's useful for drawing a brick wall or a filled rectangle.

Codification support enables a feature that can translate a Snap! project to a text-based (rather than block-based) programming language. The feature doesn't know about any particular other language; instead, you can provide a translation for each primitive block using these special blocks :



Using these primitive blocks, you can build a block library to translate into any programming language. Watch for such libraries to be added to our library collection (or contribute one). To see some examples, open the project "Codification" in the Examples project list. Edit the blocks map to Smalltalk, map to JavaScript, etc., to see examples of how to provide translations for blocks.

The image shows the Scratch interface with the Motion palette open on the left. A context menu is displayed on the right, listing various options for customization.

Motion Palette:

- move 10 steps
- turn 15 degrees
- go to [random position]

Looks Palette:

- say [Hello!]

Pen Palette:

- clear
- pen down
- pen up
- pen down?

Control Palette:

- when green flag clicked

Context Menu Options:

- Language...
- Zoom blocks...
- Fade blocks...
- Stage size...
- Microphone resolution...
- JavaScript extensions
- Extension blocks
- Input sliders
- Turbo mode
- Visible stepping
- Log pen vectors
- Long form input dialog
- Plain prototype labels
- Clicking sound
- Flat design
- Thread safe scripts
- Flat line ends
- Codification support
- Single palette
- Show categories
- Show buttons
- HSL pen color model
- Disable click-to-run

The Single palette option puts all blocks, regardless of category, into a single palette. It's intended mainly for use by curriculum developers building *Parsons problems* : projects in which only a small set of blocks are provided, and the task is to arrange those blocks to achieve a set goal. In that application, this option is combined with the hiding of almost all primitive blocks. (See Section 12.2.2.) When Single palette is turned on, two additional options (initially on) appear in the settings menu; the Show categories option controls the appearance of the palette

category names such as **Motion** and **Looks**, while the Show buttons option controls the appearance of

Make a variable

Make a block

the **Make a variable** and **Make a block** buttons in the palette.

The HSL pen color model option changes the set pen, change pen, and pen blocks to provide menu options hue, saturation, and lightness instead of hue, saturation, and brightness (a/k/a value). Note: the name "saturation" means something different in HSL from in HSV! See Appendix A for all the information you need about colors.

The Disable click-to-run option tells Snap! to ignore user mouse clicks on blocks and scripts if it would ordinarily run the block or script. (Right-clicking and dragging still work, and so does clicking in an input slot to edit it.) This is another Parsons problem feature; the idea is that there will be buttons displayed that run code only in teacher-approved ways. But kids can uncheck the checkbox. ☐

12.1.5. Visible Stepping Controls

After the menu buttons you'll see the project name. After that comes the footprint button  used to turn on visible stepping and, when it's on, the slider to control the speed of stepping.

12.1.6. Stage Resizing Buttons

Still in the tool bar, but above the left edge of the stage, are two buttons that change the size of the stage. The

first is the shrink/grow button. Normally it looks like this:  Clicking the button displays the stage at half-normal size horizontally and vertically (so it takes up $\frac{1}{4}$ of its usual area). When the stage is half size the

button looks like this:  and clicking it returns the stage to normal size. The main reason you'd want a half size stage is during the development process, when you're assembling scripts with wide input expressions and the normal scripting area isn't wide enough to show the complete script. You'd typically then switch back to normal

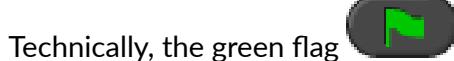
size to try out the project. The next presentation mode button normally looks like this:  Clicking the button makes the stage double size in both dimensions and eliminates most of the other user interface elements (the palette, the scripting area, the sprite corral, and most of the tool bar). When you open a shared project using a link someone has sent you, the project starts in presentation mode. While in presentation mode, the button

looks like this:  Clicking it returns to normal (project development) mode.

12.1.7. Project Control Buttons

Above the right edge of the stage are three buttons that control the running of the project.

12. User Interface Elements



Technically, the green flag is no more a project control than anything else that can trigger a hat block: typing on the keyboard or clicking on a sprite. But it's a convention that clicking the flag should start the action of the project from the beginning. It's only a convention; some projects have no flag-controlled scripts at all, but respond to keyboard controls instead. Clicking the green flag also deletes temporary clones.



Whenever any script is running (not necessarily in the current sprite), the green flag is lit: .



Shift-clicking the button enters Turbo mode, and the button then looks like a lightning bolt: . Shift-clicking again turns Turbo mode off.



Scripts can simulate clicking the green flag by broadcasting the special message .



The pause button suspends running all scripts. If clicked while scripts are running, the button changes



shape to become a play button: Clicking it while in this form resumes the suspended scripts. There is also a pause all block in the Control palette that can be inserted in a script to suspend all scripts; this provides the essence of a breakpoint debugging capability. The use of the pause button is slightly different in visible stepping mode, described in Chapter I.



The stop button stops all scripts, like the stop all block . It does not prevent a script from starting again in response to a click or keystroke; the user interface is always active. There is one exception: generic when blocks will not fire after a stop until some non-generic event starts a script. The stop button also deletes all temporary clones.

12.2. The Palette Area

At the top of the palette area are the eight buttons that select which palette (which block category) is shown: Motion, Looks, Sound, Pen, Control, Sensing, Operators, and Variables (which also includes the List and Other blocks). There are no menus behind these buttons.

12.2.1. Buttons in the Palette

Under the eight palette selector buttons, at the top of the actual palette, are two semi-transparent buttons. The



first is the *search* button , which is equivalent to typing control-F: It replaces the palette with a search bar into which you can type part of the title text of the block you're trying to find. To leave this search mode, click one of the eight palette selectors, or type the Escape key.



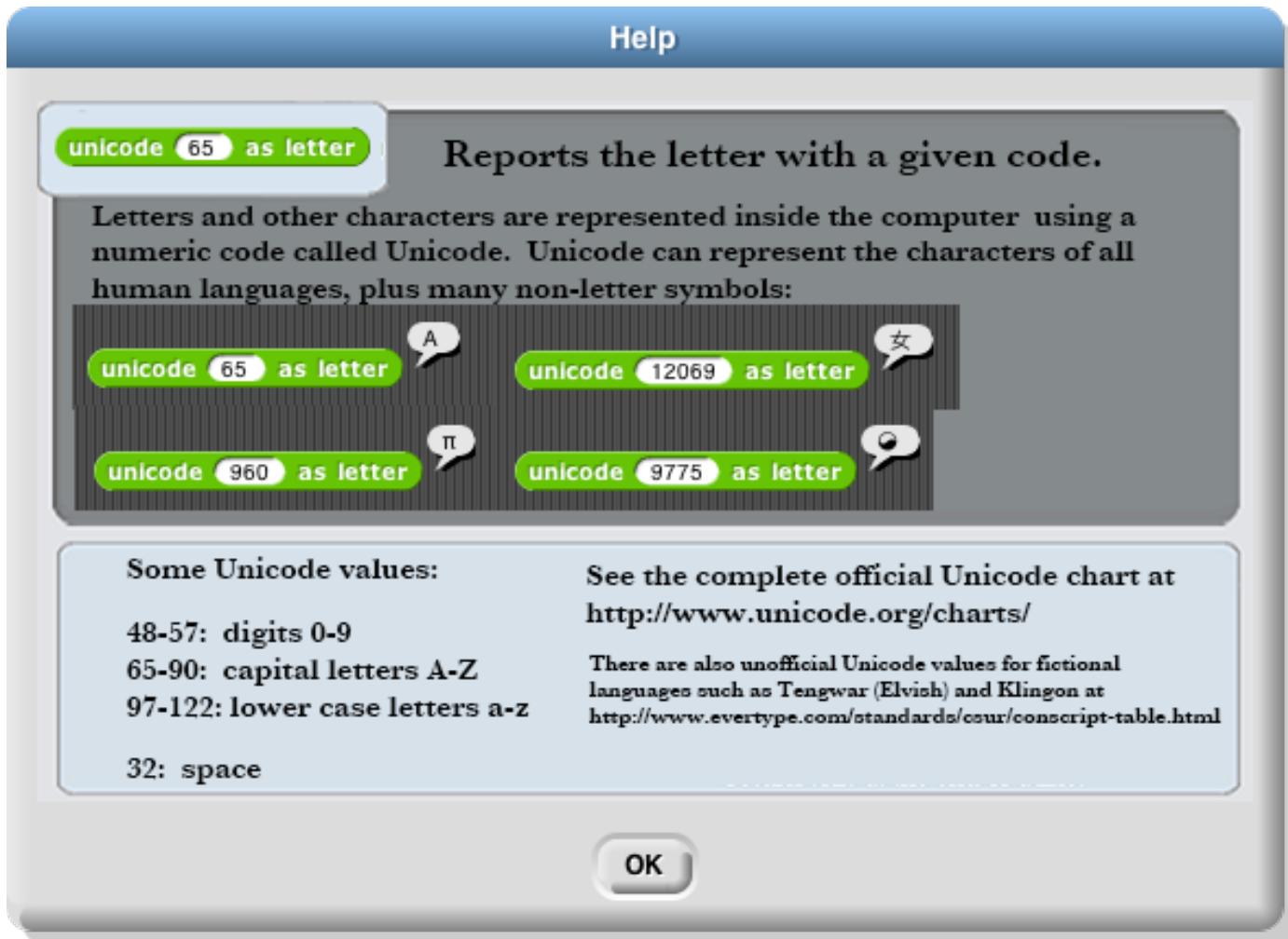
The other button is equivalent to the "Make a block" button , except that the dialog window that it opens has the current palette (color) preselected.

12.2.2. Context Menus for Palette Blocks

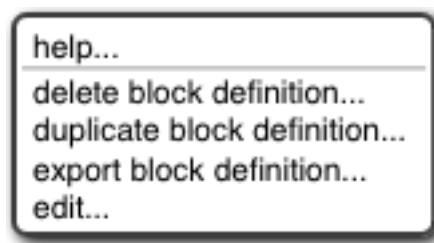
Most elements of the Snap! display can be control-clicked/right-clicked to show a *context menu*, with items relevant to that element. If you control-click/right-click a *primitive* block in the palette, you see this menu:



The help... option displays a box with documentation about the block. Here's an example:



If you control-click/right-click a *custom* (user-defined) block in the palette, you see this menu:



12. User Interface Elements

The help... option for a custom block displays the comment, if any, attached to the custom block's hat block in the Block Editor. Here is an example of a block with a comment and its help display:



If the help text includes a URL, it is clickable and will open the page in a new tab.

The delete block definition... option asks for confirmation, then deletes the custom block and removes it from any scripts in which it appears. (The result of this removal may not leave a sensible script; it's best to find and correct such scripts *before* deleting a block.) Note that there is no option to *hide* a custom block; this can be done in the Block Editor by right-clicking on the hat block.

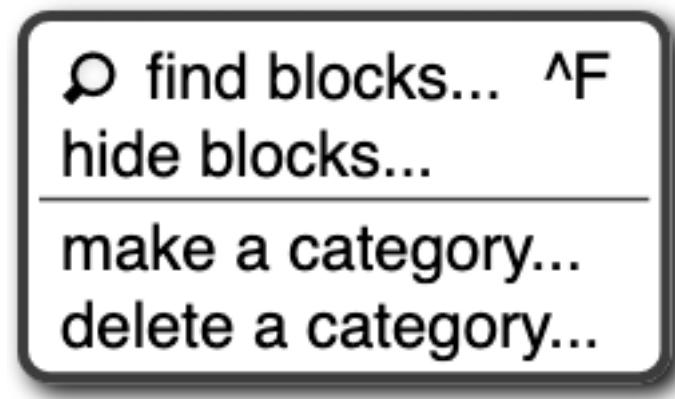
The duplicate block definition... option makes a copy of the block and opens that copy in the Block Editor. Since you can't have two custom blocks with the same title text and input types, the copy is created with "(2)" (or a higher number if necessary) at the end of the block prototype.

The export block definition... option writes a file in your browser's downloads directory containing the definition of this block and any other custom blocks that this block invokes, directly or indirectly. So the resulting file can be loaded later without the risk of red Undefined! blocks because of missing dependencies.

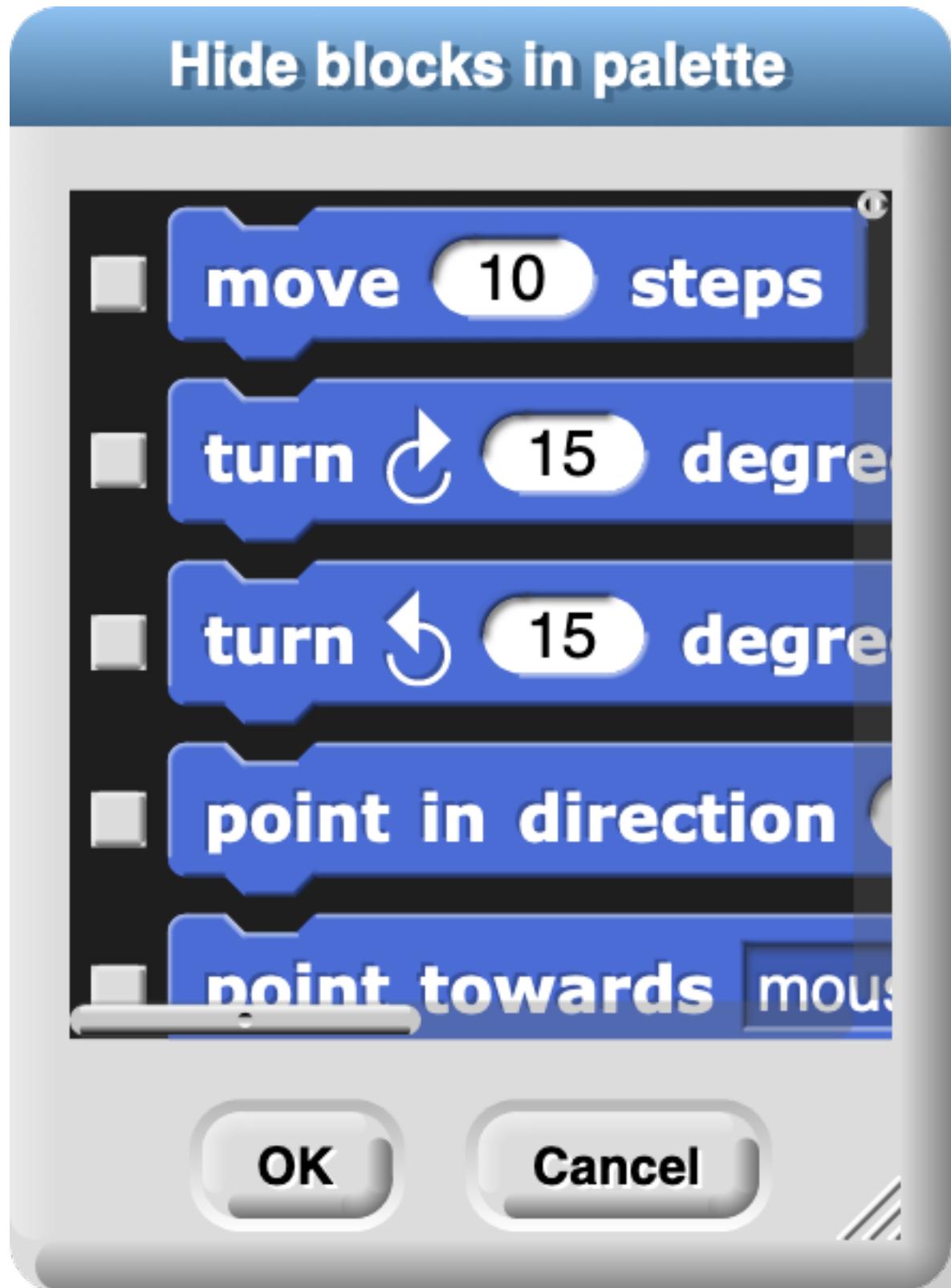
The edit... option opens a Block Editor with the definition of the custom block.

12.2.3. Context Menu for the Palette Background

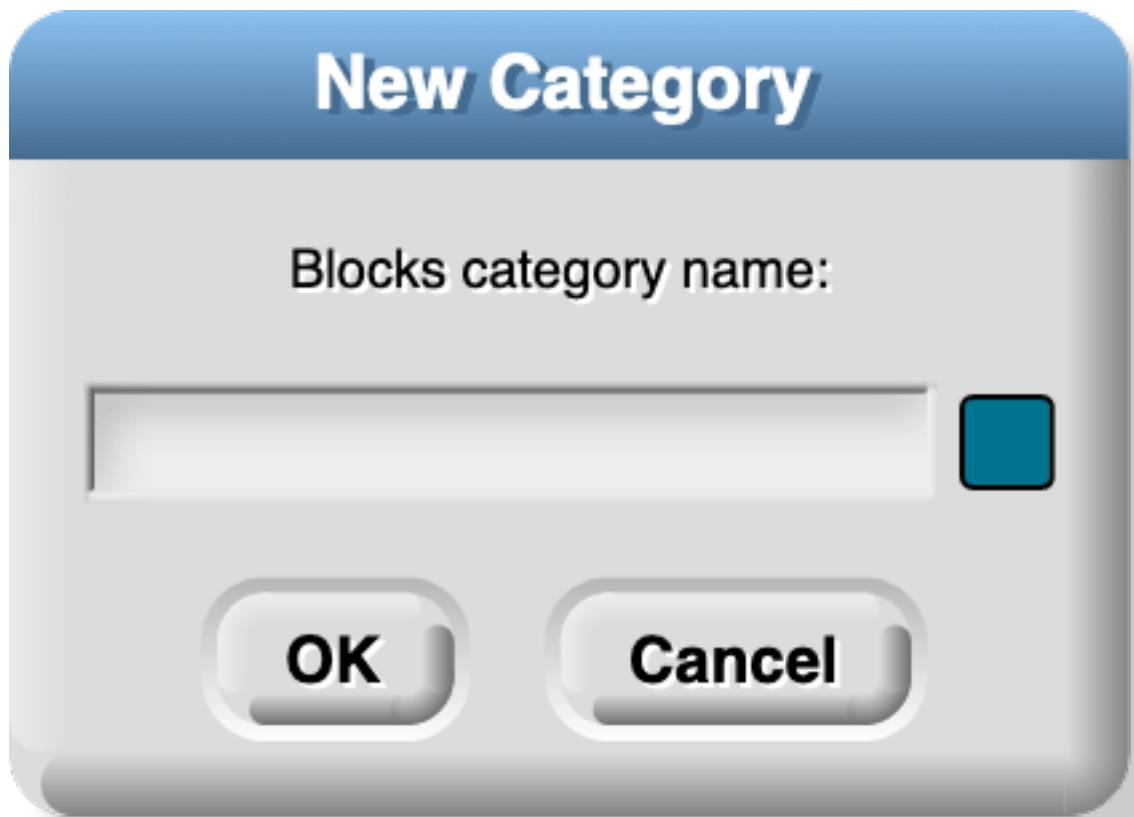
Right-click/control-click on the grey *background* of the palette area shows this menu:



The find blocks... option does the same thing as the magnifying-glass button. The hide blocks... option opens a dialog box in which you can choose which blocks (custom as well as primitive) should be hidden. (Within that dialog box, the context menu of the background allows you to check or uncheck all the boxes at once.)



The make a category... option, which is intended mainly for authors of snap extensions, lets you add custom categories to the palette. It opens a small dialog window in which you specify a name *and* a color for the new category:



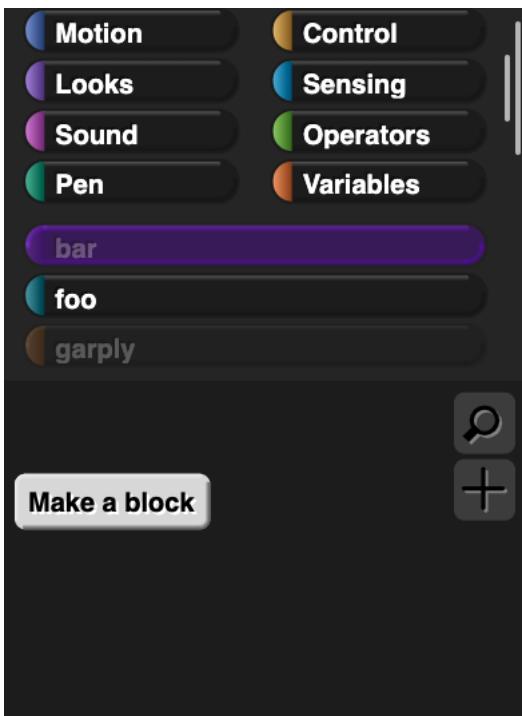
Pick a dark color, because it will be lightened for zebra coloring when users nest blocks of the same category. Custom categories are shown below the built-in categories in the category selector:



This example comes from Eckart Modrow's SciSnap! library. Note that the custom category list has its own scroll bar, which appears if you have more than six custom categories. Note also that the buttons to select a custom category occupy the full width of the palette area, unlike the built-in categories, which occupy only half of the width. Custom categories are listed in alphabetical order; this is why Prof. Modrow chose to start each category name with a number, so that he could control their order.

If there are no blocks visible in a category, the category name is dimmed in the category selector:

12. User Interface Elements



Here we see that category foo has blocks in it, but categories bar and garply are empty. The built-in categories are also subject to dimming, if all of the blocks of a category are hidden.

Palette Resizing

At the right end of the palette area, just to the left of the scripting area, is a resizing handle that can be dragged rightward to increase the width of the palette area. This is useful if you write custom blocks with very long names. You can't reduce the width of the palette below its standard value.

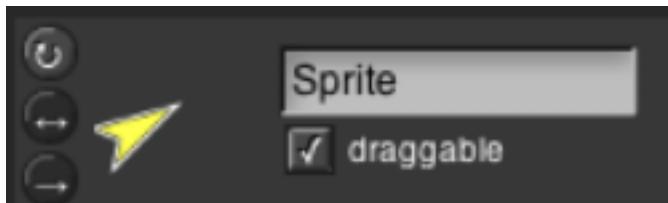


12.3. The Scripting Area

The scripting area is the middle vertical region of the Snap! window, containing scripts and also some controls for the appearance and behavior of a sprite. There is always a *current sprite*, whose scripts are shown in the scripting area. A dark grey rounded rectangle in the sprite corral shows which sprite (or the stage) is current. Note that it's only the visible *display* of the scripting area that is "current" for a sprite; all scripts of all sprites may be running at the same time. Clicking on a sprite thumbnail in the sprite corral makes it current. The stage itself can be selected as current, in which case the appearance is different, with some primitives not shown.

12.3.1. Sprite Appearance and Behavior Controls

At the top of the scripting area are a picture of the sprite and some controls for it:



Note that the sprite picture reflects its rotation, if any. There are three things that can be controlled here:

1. The three circular buttons in a column at the left control the sprite's *rotation behavior*. Sprite costumes are designed to be right-side-up when the sprite is facing toward the right (direction = 90). If the topmost button is lit, the default as shown in the picture above, then the sprite's costume rotates as the sprite changes direction. If the middle button is selected, then the costume is reversed left-right when the sprite's direction is roughly leftward (direction between 180 and 359, or equivalently, between -180 and -1). If the bottom button is selected, the costume's orientation does not change regardless of the sprite's direction.
2. The sprite's *name* can be changed in the text box that, in this picture, says "Sprite."
3. Finally, if the *draggable* checkbox is checked, then the user can move the sprite on the stage by clicking and dragging it. The common use of this feature is in game projects, in which some sprites are meant to be under the player's control but others are not.

12.3.2. Scripting Area Tabs

Just below the sprite controls are three *tabs* that determine what is shown in the scripting area:



12.3.3. Scripts and Blocks Within Scripts

Most of what's described in this section also applies to blocks and scripts in a Block Editor.

Clicking on a script (which includes a single unattached block) runs it. If the script starts with a hat block, clicking on the script runs it even if the event in the hat block doesn't happen. (This is a useful debugging technique when you have a dozen sprites and they each have five scripts with green-flag hat blocks, and you want to know what a single one of those scripts does.) The script will have a green "halo" around it while it's running. If the script is shared with clones, then while it has the green halo it will also have a count of how many instances of the script are running. Clicking a script with such a halo stops the script. (If the script includes a warp block, which might be inside a custom block used in the script, then Snap! may not respond immediately to clicks.)

If a script is shown with a *red* halo, that means that an error was caught in that script, such as using a list where a number was needed, or vice versa. Clicking the script will turn off the halo.

If any blocks have been dragged into the scripting area, then in its top right corner you'll see an *undo*



and/or *redo*



button that can be used to undo or redo block and script drops. When you undo a drop into an input slot, whatever used to be in the slot is restored. The redo button appears once you've used undo.



12. User Interface Elements

The third button  starts keyboard editing mode (See Section 12.4).

Control-click/right-clicking a primitive block within a script shows a menu like this one:



command block:

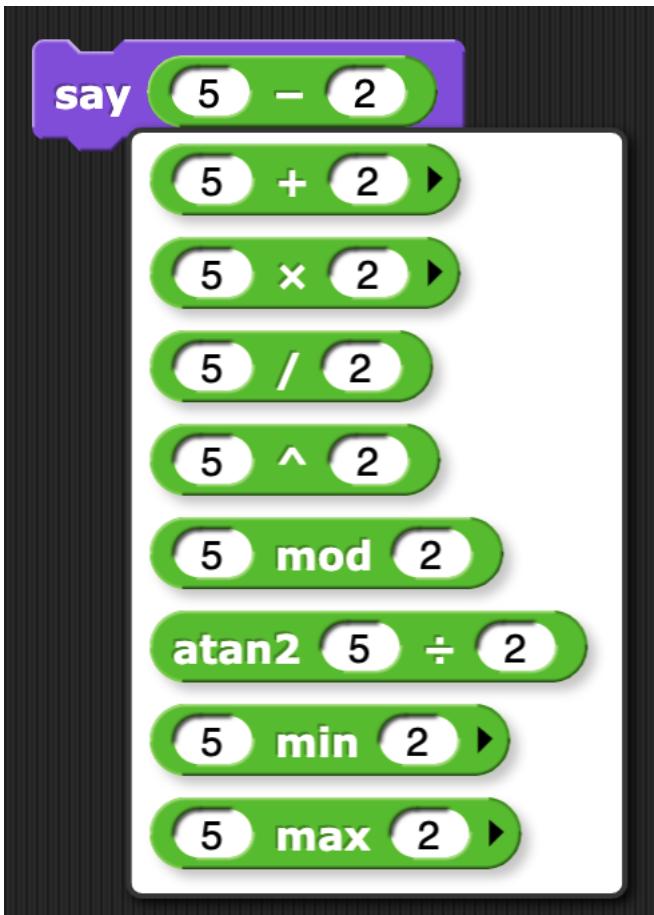


reporter block:

The help... option shows the help screen for the block, just as in the palette. The other options appear only when a block is right-clicked/control-clicked in the scripting area.

Not every primitive block has a relabel... option. When present, it allows the block to be replaced by another, similar block, keeping the input expressions in place. For example, here's what happens when you choose relabel... for an arithmetic operator:

12. User Interface Elements



Note that the inputs to the existing – block are displayed in the menu of alternatives also. Click a block in the menu to choose it, or click outside the menu to keep the original block. Note that the last three choices are not available in the palette; you must use the relabel feature to access them.

Not every reporter has a compile option; it exists only for the higher order functions. When selected, a lightning bolt



appears before the block name:

and Snap! tries to compile the function inside the ring to JavaScript, so it runs at primitive speed. This works only for simple functions (but the higher order function still works even if the compilation doesn't). The function to be compiled must be quick, because it will be uninterruptable; in particular, if it's an infinite loop, you may have to quit your browser to recover. Therefore, **save your project before** you experiment with the compilation feature. The right-click menu for a compiled higher order function will have an uncompile option. This is an experimental feature.

The duplicate option for a command block makes a copy of the *entire script* starting from the selected block. For a reporter, it copies only that reporter and its inputs. The copy is attached to the mouse, and you can drag it to another script (or even to another Block Editor window), even though you are no longer holding down the mouse button. Click the mouse to drop the script copy.

The block picture underneath the word *duplicate* for a command block is another duplication option, but it duplicates only the selected block, not everything under it in the script. Note that if the selected block is a C-shaped control block, the script inside its C-shaped slot is included. If the block is at the end of its script, this option does not appear. (Use *duplicate* instead.)

The extract option removes the selected block from the script and leaves you holding it with the mouse. In other words, it's like the block picture option, but it doesn't leave a copy of the block in the original script. If the block is at the end of its script, this option does not appear. (Just grab the block with the mouse.) A shorthand for this operation is to *shift-click* and drag out the block.

The delete option deletes the selected block from the script.

The add comment option creates a comment, like the same option in the background of the scripting area, but attaches it to the block you clicked.

The script pic... option saves a picture of the entire script, not just from the selected block to the end, into your download folder; or, in some browsers, opens a new browser tab containing the picture. In the latter case, you can use the browser's Save feature to put the picture in a file. This is a super useful feature if you happen to be writing a Snap! manual ! (If you have a Retina display, consider turning off Retina support before making script pictures; if not, they end up huge.) For reporters not inside a script, there is an additional result pic... option that calls the reporter and includes a speech balloon with the result in the picture. Note: The downloaded file is a "smart picture": It also contains the code of the script, as if you'd exported the project. If you later drag the file into the costumes tab, it will be loaded as a costume. But if you drag it into the scripts tab, it will be loaded as a script, which you can drop wherever you want it in the scripting area.

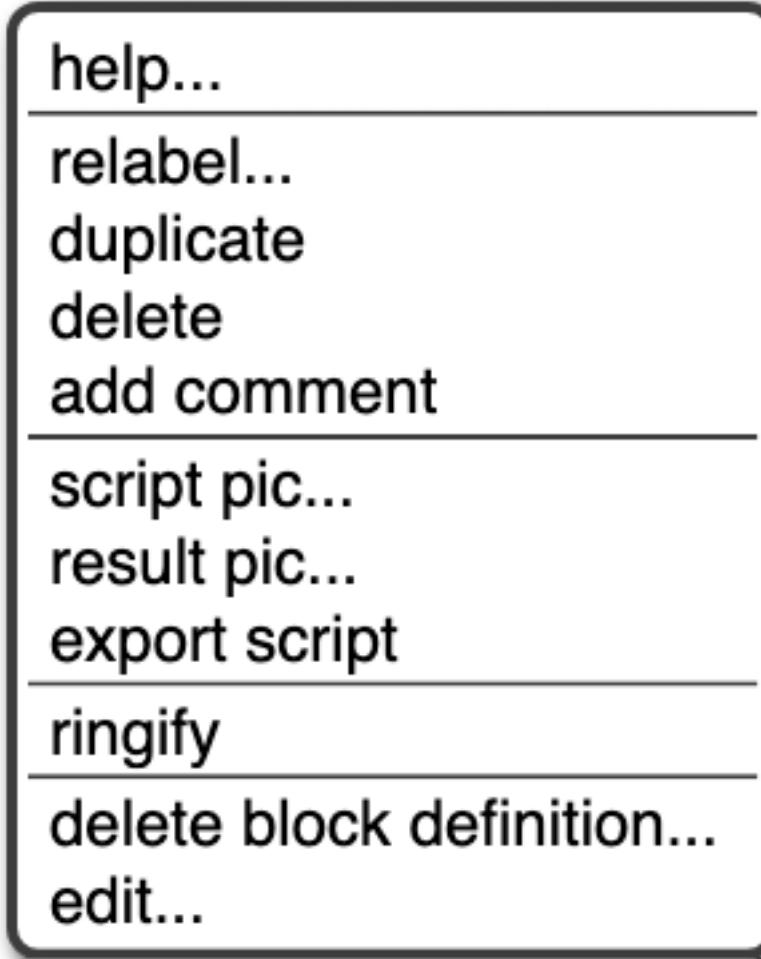
If the script does not start with a hat block, or you clicked on a reporter, then there's one more option: ringify (and, if there is already a grey ring around the block or script, unringify). Ringify surrounds the block (reporter) or the entire script (command) with a grey ring, meaning that the block(s) inside the ring are themselves data, as an input to a higher order procedure, rather than something to be evaluated within the script. See Chapter VI, Procedures as Data.

Clicking a *custom* block in a script gives a similar but different menu:



The relabel... option for custom blocks shows a menu of other same-shape custom blocks with the same inputs. At present you can't relabel a custom block to a primitive block or vice versa. The two options at the bottom, for custom blocks only, are the same as in the palette. The other options are the same as for primitive commands.

If a reporter block is in the scripting area, possibly with inputs included, but not itself serving as input to another block, then the menu is a little different again:



What's new here is the result pic... option. It's like script pic... but it includes in the picture a speech balloon with the result of calling the block.

Broadcast and broadcast and wait block s in the scripting area have an additional option: receivers... . When clicked, it causes a momentary (be looking for it when you click!) halo around the picture in the sprite corral of those sprites that have a when I receive hat block for the same message. Similarly, when I receive blocks have a senders... option that light up the sprite corral icons of sprites that broadcast the same message.

Scripting Area Background Context Menu

Control-click/right-click on the grey striped background of the scripting area gives this menu:



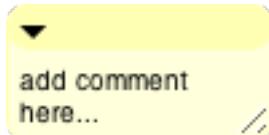
The undrop option is a sort of “undo” feature for the common case of dropping a block somewhere other than where you meant it to go. It remembers all the dragging and dropping you’ve done in this sprite’s scripting area (that is, other sprites have their own separate drop memory), and undoes the most recent, returning the block to its former position, and restoring the previous value in the relevant input slot, if any. Once you’ve undropped

12. User Interface Elements

something, the redrop option appears, and allows you to repeat the operation you just undid. These menu options are equivalent to the and buttons described earlier.

The clean up option rearranges the position of scripts so that they are in a single column, with the same left margin, and with uniform spacing between scripts. This is a good idea if you can't read your own project!

The add comment option puts a comment box, like the picture below, in the scripting area. It's attached to the mouse, as with duplicating scripts, so you position the mouse where you want the comment and click to release it. You can then edit the text in the comment as desired.



You can drag the bottom right corner of the comment box to resize it. Clicking the arrowhead at the top left changes the box to a single-line compact form, **add comment !**, so that you can have a number of collapsed comments in the scripting area and just expand one of them when you want to read it in full.

If you drag a comment over a block in a script, the comment will be attached to the block with a yellow line:



Comments have their own context menu, with obvious meanings:



Back to the options in the menu for the background of the scripting area (picture on the previous page):

The scripts pic... option saves, or opens a new browser tab with, a picture of *all* scripts in the scripting area, just as they appear, but without the grey striped background. Note that "all scripts in the scripting area" means just the top-level scripts of the current sprite, not other sprites' scripts or custom block definitions. This is also a "smart picture"; if you drag it into the scripting area, it will *create a new sprite* with those scripts in its scripting area.

Finally, the make a block... option does the same thing as the "Make a block" button in the palettes. It's a shortcut so that you don't have to keep scrolling down the palette if you make a lot of blocks.

12.3.4. Controls in the Costumes Tab

If you click on the word "Costumes" under the sprite controls, you'll see something like this:



The Turtle costume is always present in every sprite; it is costume number 0. Other costumes can be painted within Snap! or imported from files or other browser tabs if your browser supports that. Clicking on a costume selects it; that is, the sprite will look like the selected costume. Clicking on the paint brush icon  opens

the *Paint Editor*, in which you can create a new costume. Clicking on the camera icon  opens a window in which you see what your computer's camera is seeing, and you can take a picture (which will be the full size of the stage unless you shrink it in the Paint Editor). This works only if you give Snap! permission to use the camera, and maybe only if you opened Snap! in secure (HTTPS) mode, and then only if your browser loves you.

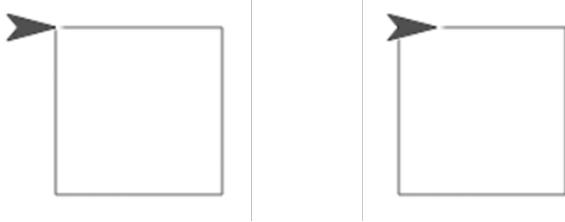


Brian's bedroom when he's staying at Paul's house.

Control-clicking/right-clicking on the turtle picture gives this menu:

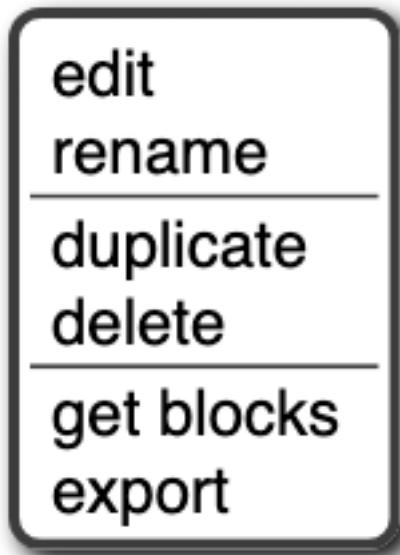


In this menu, you choose the turtle's *rotation point*, which is also the point from which the turtle draws lines. The two pictures below show what the stage looks like after drawing a square in each mode; tip (otherwise known as "Jens mode") is on the left in the pictures below, middle ("Brian mode") on the right:



As you see, “tip” means the front tip of the arrowhead; “middle” is not the middle of the shaded region, but actually the middle of the four vertices, the concave one. (If the shape were a simple isosceles triangle instead of a fancier arrowhead, it would mean the midpoint of the back edge.) The advantage of tip mode is that the sprite is less likely to obscure the drawing. The advantage of middle mode is that the rotation point of a sprite is rarely at a tip, and students are perhaps less likely to be confused about just what will happen if you ask the turtle to turn 90 degrees from the position shown. (It’s also the traditional rotation point of the Logo turtle, which originated this style of drawing.)

Costumes other than the turtle have a different context menu:



The edit option opens the Paint Editor on this costume. The rename option opens a dialog box in which you can rename the costume. (A costume’s initial name comes from the file from which it was imported, if any, or is something like costume5.) Duplicate makes a copy of the costume, in the same sprite. (Presumably you’d do that because you intend to edit one of the copies.) Delete is obvious. The get blocks option appears only for a smart costume, and brings its script to the scripting area. The export option saves the costume as a file on your computer, in your usual downloads folder.

You can drag costumes up and down in the Costumes tab in order to renumber them, so that next costume will behave as you prefer.

If you drag a *smart picture* of a script into the Costumes tab, its icon will display the text “</>” in the corner to remind you that it includes code:



Its right-click menu will have an extra get blocks option that switches to the Scripts tab with the script ready to be dropped there.

12.3.5. The Paint Editor

Here is a picture of a Paint Editor window:

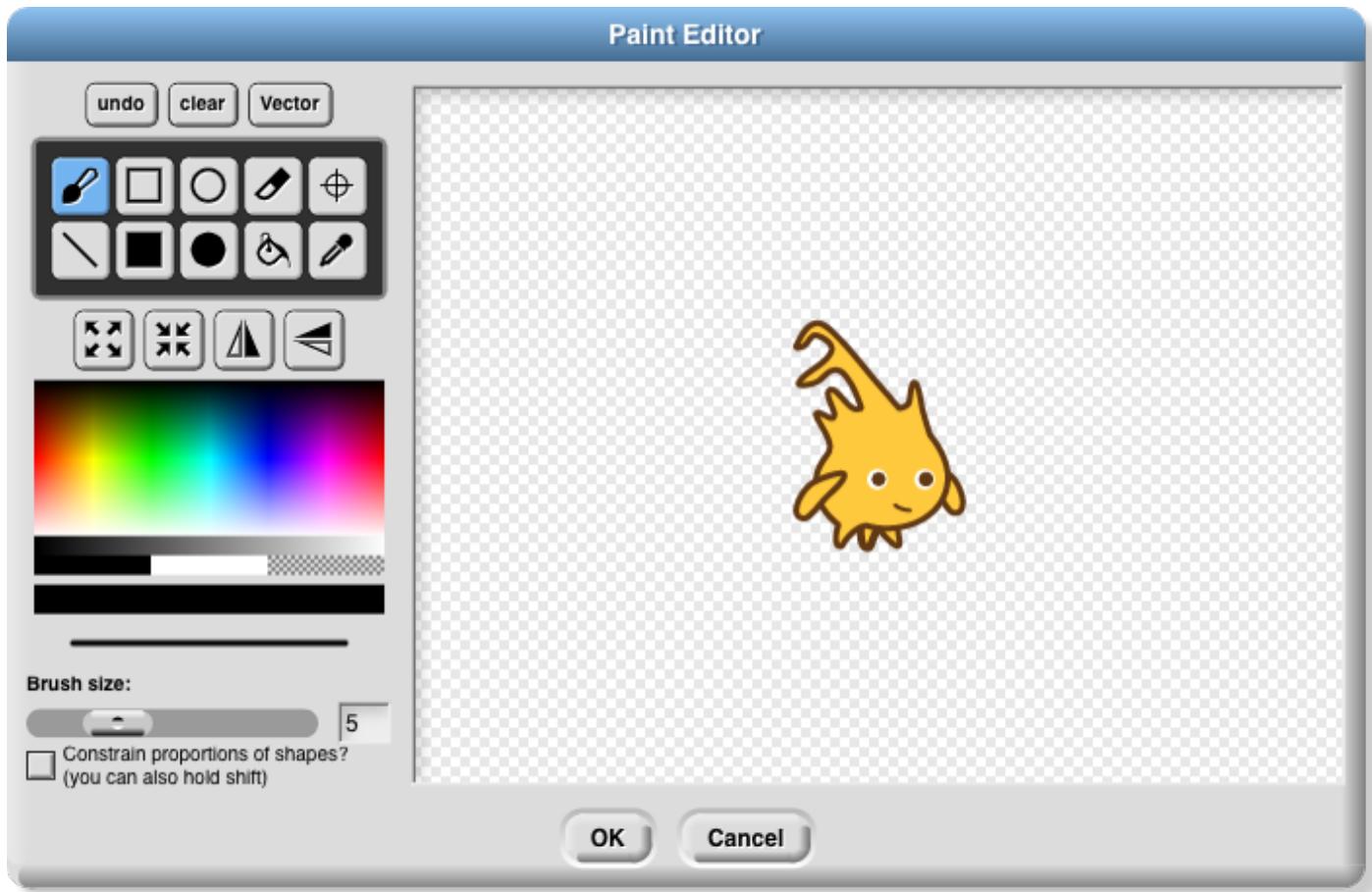


Figure 12.2.: The Paint Editor showing an Alonzo costume

If you've used any painting program, most of this will be familiar to you. Currently, costumes you import can be edited only if they are in a bitmap format (png, jpeg, gif, etc.). There is a vector editor, but it works only for creating a costume, not editing an imported vector (svg) picture. Unlike the case of the Block Editor, only one Paint Editor window can be open at a time.

The ten square buttons in two rows of five near the top left of the window are the *tools*. The top row, from left to right, are the paintbrush tool, the outlined rectangle tool , the outlined ellipse tool, the eraser tool, and the rotation point tool . The bottom row tools are the line drawing tool, the solid rectangle tool , the solid ellipse tool, the floodfill tool, and the eyedropper tool . Below the tools is a row of four buttons that immediately change the picture. The first two change its overall size; the next two flip the picture around horizontally or vertically. Below these are a color palette, a greyscale tape, and larger buttons for black, white, and transparent paint. Below these is a solid bar displaying the currently selected color. Below that is a picture of a line showing the brush width for painting and drawing, and below that, you can set the width either with a slider or by typing a number (in pixels) into the text box. Finally, the checkbox constrains the line tool to draw horizontally or vertically, the rectangle tools to draw squares, and the ellipse tools to draw circles. You can get the same effect temporarily by holding

12. User Interface Elements

down the shift key, which makes a check appear in the box as long as you hold it down. (But the Caps Lock key doesn't affect it.)

You can correct errors with the undo button, which removes the last thing you drew, or the clear button , which erases the entire picture. (Note, it does *not* revert to what the costume looked like before you started editing it! If that's what you want, click the Cancel button at the bottom of the editor.) When you're finished editing, to keep your changes, click OK.

Note that the ellipse tool s work more intuitively than ones in other software you may have used. Instead of dragging between opposite corners of the rectangle circumscribing the ellipse you want, so that the endpoints of your dragging have no obvious connection to the actual shape, in Snap! you start at the center of the ellipse you want and drag out to the edge. When you let go of the button, the mouse cursor will be on the curve. If you drag out from the center at 45 degrees to the axes, the resulting curve will be a circle; if you drag more horizontally or vertically, the ellipse will be more eccentric. (Of course if you want an exact circle you can hold down the shift key or check the checkbox.) The rectangle tools, though, work the way you expect: You start at one corner of the desired rectangle and drag to the opposite corner.

Using the eyedropper tool, you can click anywhere in the Snap! window, even outside the Paint Editor, and the tool will select the color at the mouse cursor for use in the Paint Editor. You can only do this once, because the Paint Editor automatically selects the paintbrush when you choose a color. (Of course you can click on the eyedropper tool button again.)

The only other non-obvious tool is the rotation point tool . It shows in the Paint Editor where the sprite's current rotation center is (the point around which it turns when you use a turn block); if you click or drag in the picture, the rotation point will move where you click. (You'd want to do this, for example, if you want a character to be able to wave its arm, so you use two sprites connected together. You want the rotation point of the arm sprite to be at the end where it joins the body, so it remains attached to the shoulder while waving.)

The vector editor 's controls are much like those in the bitmap editor. One point of difference is that the bitmap



editor has two buttons for solid and outline rectangles, and similarly for ellipses, but in the vector editor there is always an edge color and a fill color, even if the latter is "transparent paint," and so only one button per shape is needed. Since each shape that you draw is a separate layer (like sprites on the stage), there are controls to move the selected shape up (forward) or down (backward) relative to other shapes. There is a



selection tool to drag out a rectangular area and select all the shapes within that area.



12.3.6. Controls in the Sounds Tab

There is no Sound Editor in Snap!, and also no current sound the way there's a current costume for each sprite. (The sprite always has an appearance unless hidden, but it doesn't sing unless explicitly asked.) So the context menu for sounds has only rename, delete, and export options, and it has a clickable button labeled Play or Stop as appropriate. There is a sound *recorder*, which appears if you click the red record button (🔴):



The first, round button starts recording. The second, square button stops recording. The third, triangular button plays back a recorded sound. If you don't like the result, click the round button again to re-record. When you're satisfied, push the Save button. If you need a sound editor, consider the free (both senses) <https://audacity.sourceforge.net>.

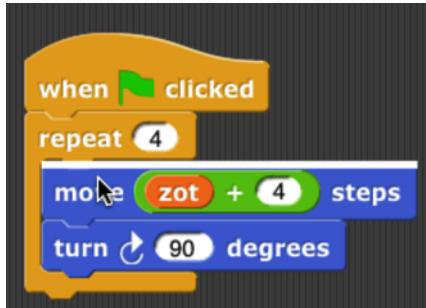
12.4. Keyboard Editing

An ongoing area of research is how to make visual programming languages usable by people with visual or motoric disabilities. As a first step in this direction, we provide a keyboard editor, so that you can create and edit scripts without tracking the mouse. So far, not every user interface element is controllable by keyboard, and we haven't even begun providing *output* support, such as interfacing with a speech synthesizer. This is an area in which we know we have a long way to go! But it's a start. The keyboard editor may also be useful to anyone who can type faster than they can drag blocks.

12.4.1. Starting and stopping the keyboard editor

There are three ways to start the keyboard editor . Shift-clicking anywhere in the scripting area will start the editor at that point: either editing an existing script or, if you shift-click on the background of the scripting area, editing a new script at the mouse position. Alternatively, typing shift-enter will start the editor on an existing script, and you can use the tab key to switch to another script. Or you can click the keyboard button at the top of the scripting area.

When the script editor is running, its position is represented by a blinking white bar:

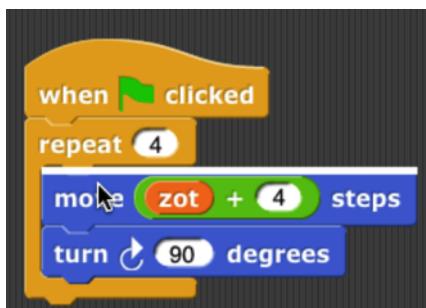


To leave the keyboard editor, type the escape key, or just click on the background of the scripting area.

12.4.2. Navigating in the keyboard editor

To move to a different script, type the tab key . Shift-tab to move through the scripts in reverse order.

A script is a vertical stack of command blocks. A command block may have input slots, and each input slot may have a reporter block in it; the reporter may itself have input slots that may have other reporters. You can navigate through a script quickly by using the up arrow and down arrow keys to move between command blocks. Once you find the command block that you want to edit, the left and right arrow keys move between editable items within that command. (Left and right arrow when there are no more editable items within the current command block will move up or down to another command block, respectively.) Here is a sequence of pictures showing the results of repeated right arrow keys starting from the position shown above:



You can rearrange scripts within the scripting area from the keyboard. Typing shift-arrow keys (left, right, up, or down) will move the current script. If you move it onto another script, the two won't snap together; the one you're moving will overlap the one already there. This means that you can move across another script to get to a free space.

12.4.3. Editing a script

Note that the keyboard editor *focus*, the point shown as a white bar or halo, is either *between* two command blocks or *on* an input slot. The editing keys do somewhat different things in each of those two cases.

The backspace key deletes a block. If the focus is between two commands, the one *before* (above) the blinking bar is deleted. If the focus is on an input slot, the reporter in that slot is deleted. (If that input slot has a default value, it will appear in the slot.) If the focus is on a *variadic* input (one that can change the number of inputs by clicking on arrowheads), then *one* input slot is deleted. (When you right-arrow into a variadic input, the focus first covers the entire thing, including the arrowheads; another right-arrow focuses on the first slot within that input group. The focus is "on the variadic input" when it covers the entire thing.)

The enter key does nothing if the focus is between commands, or on a reporter. If the focus is on a variadic input, the enter key adds one more input slot. If the focus is on a white input slot (one that doesn't have a reporter in it), then the enter key selects that input slot for *editing*; that is, you can type into it, just as if you'd clicked on the input slot. (Of course, if the focus is on an input slot containing a reporter, you can use the backspace key to delete that reporter, and then use the enter key to type a value into it.) When you finish typing the value, type the enter key again to accept it and return to navigation, or the escape key if you decide not to change the value already in the slot.

The space key is used to see a menu of possibilities for the input slot in focus. It does nothing unless the focus is on a single input slot. If the focus is on a slot with a pulldown menu of options, then the space key shows that menu. (If it's a block-colored slot, meaning that only the choices in the menu can be used, the enter key will do the same thing. But if it's a white slot with a menu, such as in the turn blocks, then enter lets you type a value, while space shows the menu.) Otherwise, the space key shows a menu of variables available at this point in the script. In either case, use the up and down arrow keys to navigate the menu, use the enter key to accept the highlighted entry, or use the escape key to leave the menu without choosing an option.

Typing any other character key (not special keys on fancy keyboards that do something other than generating a character) activates the *block search palette*. This palette, which is also accessible by typing control-F or command-F outside the keyboard editor, or by clicking the search button floating at the top of the palette, has a text entry field at the top, followed by blocks whose title text includes what you type. The character key you typed to start the block search palette is entered into the text field, so you start with a palette of blocks containing that character. Within the palette, blocks whose titles *start* with the text you type come first, then blocks in which *a word* of the title starts with the text you type, and finally blocks in which the text appears inside a word of the title. Once you have typed enough text to see the block you want, use the arrow keys to navigate to that block in the palette, then enter to insert that block, or escape to leave the block search palette without inserting the block. (When not in the keyboard editor, instead of navigating with the arrow keys, you drag the block you want into the script, as you would from any other palette.)

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If you type an arithmetic operator (+-* /) or comparison operator (<=>) into the block search text box, you can type an arbitrarily complicated expression, and a collection of arithmetic operator blocks will be constructed to match:



As the example shows, you can also use parentheses for grouping, and non-numeric operands are treated as variables or primitive functions. (A variable name entered in this way may or may not already exist in the script. Only round and the ones in the pulldown menu of the sqrt block can be used as function names.)

12.4.4. Running the selected script

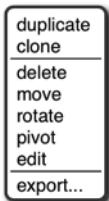
Type control-shift-enter to run the script with the editor focus, like clicking the script.

12.5. Controls on the Stage

The stage is the area in the top right of the Snap! window in which sprites move.

12.5.1. Sprites

Most sprites can be moved by clicking and dragging them. (If you have unchecked the draggable checkbox for a sprite, then dragging it has no effect.) Control-clicking/right-clicking a sprite shows this context menu:



The duplicate option makes another sprite with copies of the same scripts, same costumes, etc., as this sprite. The new sprite starts at a randomly chosen position different from the original, so you can see quickly which is which. The new sprite is *selected*: It becomes the current sprite, the one shown in the scripting area. The clone option makes a permanent clone of this sprite, with some shared attributes, and selects it.

The delete option deletes the sprite. It's not just hidden; it's gone for good. (But you can undelete it by clicking the wastebasket just below the right edge of the stage.) The edit option selects the sprite. It doesn't actually

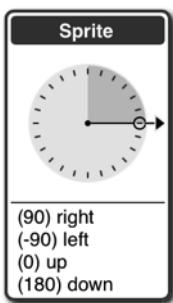
change anything about the sprite, despite the name; it's just that making changes in the scripting area will change this sprite.

The move option shows a “move handle” inside the sprite (the diagonal striped square in the middle):



You can ordinarily just grab and move the sprite without this option, but there are two reasons you might need it: First, it works even if the “draggable” checkbox above the scripting area is unchecked. Second, it works for part sprites relative to their anchor; ordinarily, dragging a part moves the entire nested sprite.

The rotate option displays a rotation menu:



You can choose one of the four compass directions in the lower part (the same as in the point in direction block) or use the mouse to rotate the handle on the dial in 15° increments.

The pivot option shows a crosshair inside the sprite:



You can click and drag the crosshair anywhere onstage to set the costume’s pivot point. (If you move it outside the sprite, then turning the sprite will revolve as well as rotate it around the pivot.) When done, click on the stage not on the crosshair. Note that, unlike moving the pivot point in the Paint Editor, this technique does not visibly move the sprite on the stage. Instead, the values of x position and y position will change.

The edit option makes this the selected sprite, highlighting it in the sprite corral and showing its scripting area. If the sprite was a temporary clone, it becomes permanent.

The export... option saves, or opens a new browser tab containing, the XML text representation of the sprite. (Not just its costume, but all of its costumes, scripts, local variables and blocks, and other properties.) You can save this tab into a file on your computer, and later import the sprite into another project. (In some browsers, the sprite is directly saved into a file.)

12.5.2. Variable watchers

Right-clicking on a variable watcher shows this menu:



The first section of the menu lets you choose one of three visualizations of the watcher:



The first (normal) visualization is for debugging. The second (large) is for displaying information to the user of a project, often the score in a game. And the third (slider) is for allowing the user to control the program behavior interactively. When the watcher is displayed as a slider, the middle section of the menu allows you to control the range of values possible in the slider. It will take the minimum value when the slider is all the way to the left, the maximum value when all the way to the right.

The third section of the menu allows data to be passed between your computer and the variable. The import... option will read a computer text file. Its name must end with .txt, in which case the text is read into the variable as is, or .csv or .json, in which case the text is converted into a list structure, which will always be a two-dimensional array for csv (comma-separated values) data, but can be any shape for json data. The raw data... option prevents that conversion to list form. The export... option does the opposite conversion, passing a text-valued variable value into a .txt file unchanged, but converting a list value into csv format if the list is one- or two-dimensional, or into json format if the list is more complicated. (The scalar values within the list must be numbers and/or text; lists of blocks, sprites, costumes, etc. cannot be exported.)

An alternative to using the import... option is simply to drag the file onto the Snap! window, in which case a variable will be created if necessary with the same name as the file (but without the extension).

If the value of the variable is a list, then the menu will include an additional blockify option; clicking it will generate an expression with nested list blocks that, if evaluated, will reconstruct the list. It's useful if you imported a list and then want to write code that will construct the same list later.

12.5.3. The stage itself

Control-clicking/right-clicking on the stage background (that is, anywhere on the stage except on a sprite or watcher) shows the stage's own context menu:



The stage's edit option selects the stage, so the stage's scripts and backgrounds are seen in the scripting area. Note that when the stage is selected, some blocks, especially the Motion ones, are not in the palette area because the stage can't move.

The show all option makes all sprites visible, both in the sense of the show block and by bringing the sprite onstage if it has moved past the edge of the stage.

The pic... option saves, or opens a browser tab with, a picture of everything on the stage: its background, lines drawn with the pen, and any visible sprites. What you see is what you get. (If you want a picture of just the background, select the stage, open its costumes tab, control-click/right-click on a background, and export it.)

The pen trails option creates a new costume for the currently selected sprite consisting of all lines drawn on the stage by the pen of any sprite. The costume's rotation center will be the current position of the sprite.

If you previously turned on the log pen vectors option, and there are logged vectors, the menu includes an extra option, svg... , that exports a picture of the stage in vector format. Only lines are logged, not color regions made with the fill block.

12.6. The Sprite Corral and Sprite Creation Buttons

Between the stage and the sprite corral at the bottom right of the Snap! window is a dark grey bar containing three buttons at the left and one at the right. The first three are used to create a new sprite. The first button



makes a sprite with just the turtle costume, with a randomly chosen position and pen color. (If you hold



down the Shift key while clicking, the new sprite's direction will also be random.) The second button makes a sprite and opens the Paint Editor so that you can make your own costume for it. (Of course you could click the first button and then click the paint button in its costumes tab; this paint button is a shortcut for all that.)



Similarly, the third button



uses your camera, if possible, to make a costume for the new sprite.

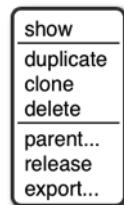
The trash can button



at the right has two uses. You can drag a sprite thumbnail onto it from the sprite corral to delete that sprite, or you can click it to undelete a sprite you deleted by accident.

In the sprite corral, you click on a sprite's "thumbnail" picture to select that sprite (to make it the one whose scripts, costumes, etc. are shown in the scripting area). You can drag sprite thumbnails (but not the stage one) to reorder them; this has no special effect on your project, but lets you put related ones next to each other, for example. Double-clicking a thumbnail flashes a halo around the actual sprite on the stage.

You can right-click/control-click a sprite's thumbnail to get this context menu:



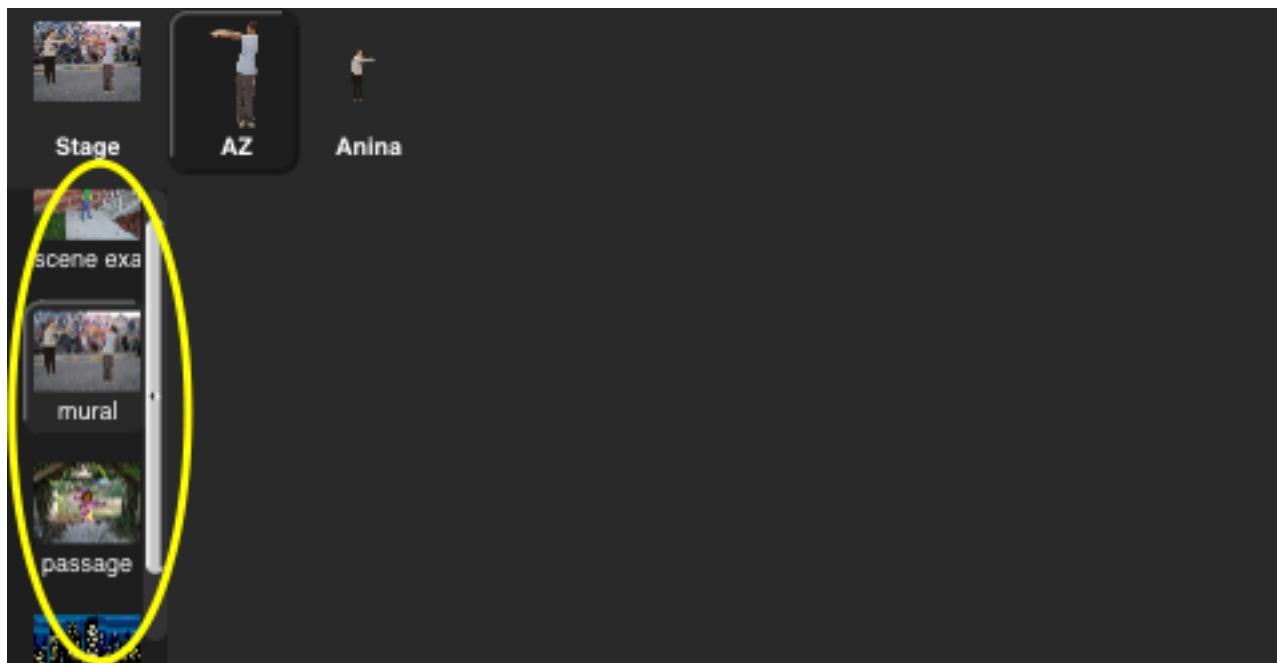
The show option makes the sprite visible, if it was hidden, and also brings it onto the stage, if it had moved past the stage boundary. The next three options are the same as in the context menu of the actual sprite on the stage, discussed above.

12. User Interface Elements

The parent... option displays a menu of all other sprites, showing which if any is this sprite's parent, and allowing you to choose another sprite (replacing any existing parent). The release option is shown only if this sprite is a (permanent, or it wouldn't be in the sprite corral) clone; it changes the sprite to a temporary clone. (The name is supposed to mean that the sprite is released from the corral.) The export... option exports the sprite, like the same option on the stage.

The context menu for the stage thumbnail has only one option, pic... , which takes a picture of everything on the stage, just like the same option in the context menu of the stage background. If pen trails are being logged, there will also be an svg... option.

If your project includes scenes, then under the stage icon in the sprite corral will be the *scene corral*:



Clicking on a scene will select it; right-clicking will present a menu in which you can rename, delete, or export the scene.

12.7. Preloading a Project when Starting Snap!

There are several ways to include a pointer to a project in the URL when starting Snap! in order to load a project automatically. You can think of such a URL as just running the project rather than as running Snap!, especially if the URL says to start in presentation mode and click the green flag. The general form is

<https://snap.berkeley.edu/run#verb:project&flag&flag...>

The “verb” above can be any of open, run , cloud, present, or dl . The last three are for shared projects in the Snap! cloud; the first two are for projects that have been exported and made available anywhere on the Internet.

Here's an example that loads a project stored at the Snap! web site (not the Snap! cloud!):

<https://snap.berkeley.edu/run#open:https://snap.berkeley.edu/snapsource/Examples/vee.xml>

The project file will be opened, and Snap! will start in edit mode (with the program visible). Using #run: instead of #open: will start in presentation mode (with only the stage visible) and will “start” the project by clicking the green flag. (“Start” is in quotation marks because there is no guarantee that the project includes any scripts triggered by the green flag. Some projects are started by typing on the keyboard or by clicking a sprite.)

If the verb is run, then you can also use any subset of the following flags:

- &editMode : Start in edit mode, not presentation mode.
- &noRun : Don't click the green flag.
- &hideControls : Don't show the row of buttons above the stage (edit mode, green flag, pause, stop).
- &lang= : fr Set language to (in this example) French.
- &noCloud : Don't allow cloud operations from this project (for running projects from unknown sources that include JavaScript code)
- &noExitWarning : When closing the window or loading a different URL, don't show the browser "are you sure you want to leave this page" message.
- &blocksZoom=n : Like the Zoom blocks option in the Settings menu.

The last of these flags is intended for use on a web page in which a Snap! window is embedded.

Here's an example that loads a shared (public) project from the Snap! cloud:

<https://snap.berkeley.edu/run#present:Username=jens&ProjectName=tree%20animation>

(Note that "Username" and "ProjectName" are TitleCased, even though the flags such as "noRun" are camelCased. Note also that a space in the project name must be represented in Unicode as %20.) The verb present behaves like run: it ordinarily starts the project in presentation mode, but its behavior can be modified with the same four flags as for run. The verb cloud (yes, we know it's not a verb in its ordinary use) behaves like open except that it loads from the Snap! cloud rather than from the Internet in general. The verb dl (short for "download") does not start Snap! but just downloads a cloud-saved project to your computer as an .xml file. This is useful for debugging; sometimes a defective project that Snap! won't run can be downloaded, edited, and then re-saved to the cloud.

12.8. Mirror Sites

If the site snap.berkeley.edu is ever unavailable, you can load Snap! at the following mirror sites :

- <https://bjc.edc.org /snapsource/snap.html>
- <https://cs10.org /snap>

A. Libraries in Snap!

B. Appendix A. Snap! color library

The Colors and Crayons library provides several tools for manipulating color. Although its main purpose is controlling a sprite's pen color, it also establishes colors as a first class data type:

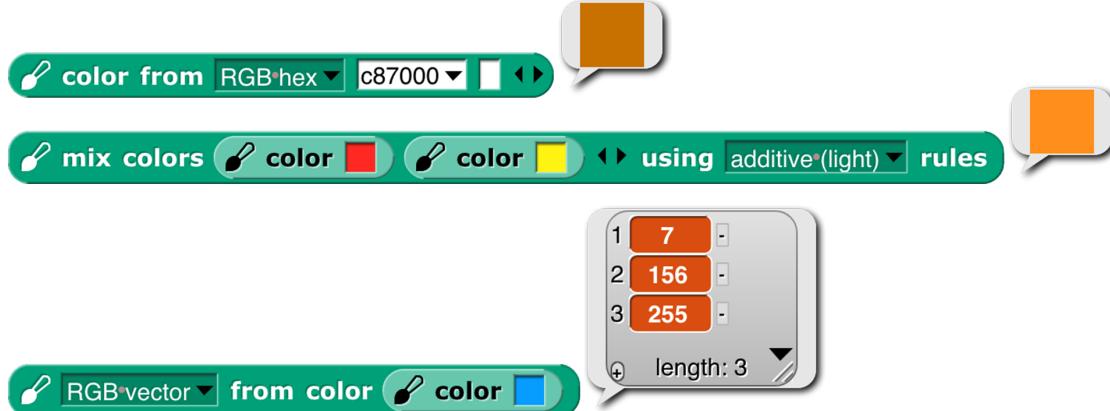


Figure B.1.: image401.png

For people who just want colors in their projects without having to be color experts, we provide two simple mechanisms: a *color number* scale with a broad range of continuous color variation and a set of 100 *crayons* organized by color family (ten reds, ten oranges, etc.) The crayons include the block colors:



Figure B.2.: image1135.png

For experts, we provide color selection by RGB, HSL, HSV, X11/W3C names, and variants on those scales.



B.1. Introduction to Color

Your computer monitor can display millions of colors, but you probably can't distinguish that many. For example, here's red 57, green 180, blue 200:  And here's red 57, green 182, blue 200:  You might be able to tell them apart if you see them side by side:   but maybe not even then.

Color space—the collection of all possible colors—is three-dimensional, but there are many ways to choose the dimensions. RGB (red-green-blue), the one most commonly used in computers, matches the way TVs and displays produce color. Behind every dot on the screen are three tiny lights: a red one, a green one, and a blue one. But if you want to print colors on paper, your printer probably uses a different set of three colors: CMY (cyan-magenta-yellow). You may have seen the abbreviation CMYK, which represents the common technique of adding black ink to the collection. (Mixing cyan, magenta, and yellow in equal amounts is supposed to result in black ink, but typically it comes out a muddy brown instead, because chemistry.) Other systems that try to mimic human perception are HSL (hue-saturation-lightness) and HSV (hue-saturation-value). There are many, many more, each designed for a particular purpose.

If you are a color professional—a printer, a web designer, a graphic designer, an artist—then you need to understand all this. It can also be interesting to learn about. For example, there are colors that you can see but your computer display can't generate. If that intrigues you, look up color theory in Wikipedia.

B.1.1. Crayons and Color Numbers

But if you just want some colors in your project, we provide a simple, one-dimensional subset of the available colors. Two subsets, actually: *crayons* and *color numbers*. Here's the difference:

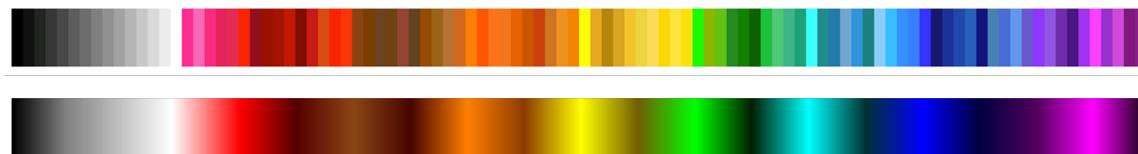
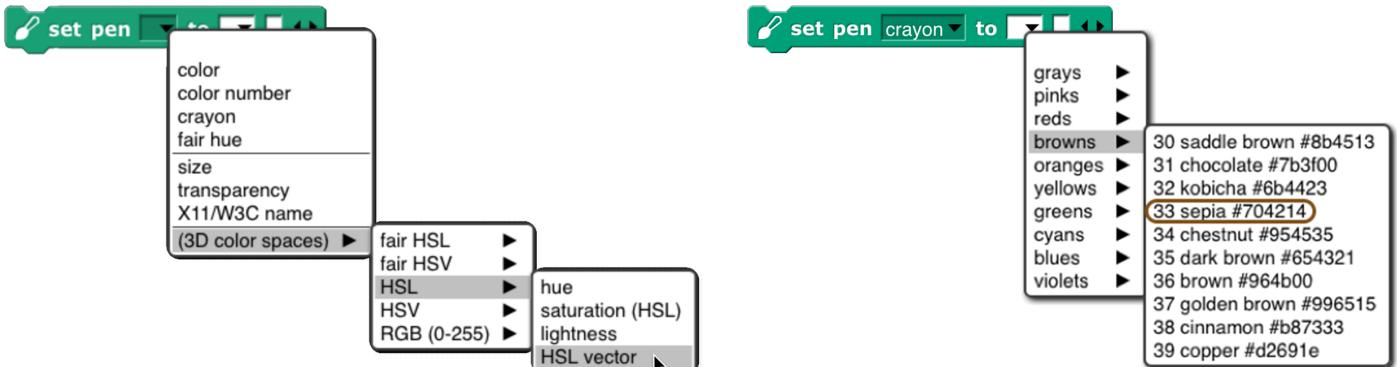


Figure B.3.: image1139.png

The first row shows 100 distinct colors. They have names; this is pumpkin , and this is denim . You're supposed to think of them as a big box of 100 crayons. They're arranged in families: grays, pinks, reds, browns, oranges, etc. But they're not consistently ordered within a family; you'd be unlikely to say "next crayon" in a project. (But look at the crayon spiral on page 145.) Instead, you'd think "I want this to look like a really old-fashioned photo" and so you'd find sepia  as crayon number 33. You don't have to memorize the numbers! You can find them in a menu with a submenu for each family.



Or, if you know the crayon name, just

The crayon numbers are chosen so that skipping by 10 gives a sensible box of ten crayons :



Alternatively, skipping by 5 gives a still-sensible set of twenty crayons :



The set of *color numbers* is arranged so that each color number is visually near each of its neighbors. Bright and dark colors alternate for each family. Color numbers range from 0 to 99, like crayon numbers, but you can use fractional numbers to get as tiny a step as you like:



(“As tiny as you like” isn’t quite true because in the end, your color has to be rounded to integer RGB values for display.)

Both of these scales include the range of shades of gray, from black to white. Since black is the initial pen color, and black isn’t a hue, Scratch and Snap! users would traditionally try to use set color to escape from black, and it wouldn’t work. By including black in the same scale as other colors, we eliminate the Black Hole problem if people use only the recommended color scales.

We are making a point of saying “color number” for what was sometimes called just “color” in earlier versions of the library, because we now reserve the name “color” for an actual color, an instance of the color data type.

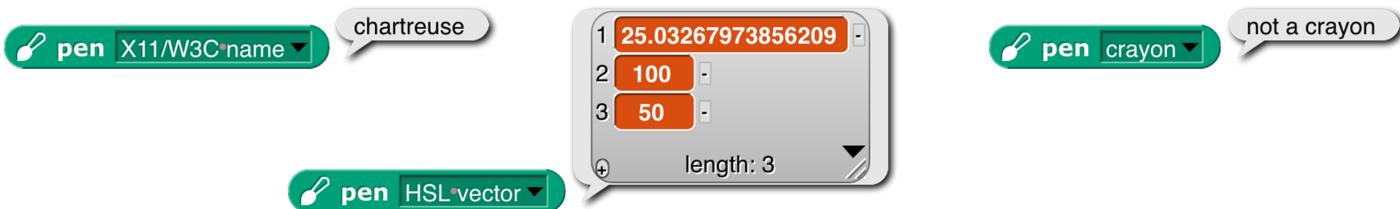
How to Use the Library

There are three library blocks specifically about controlling the pen. They have the same names as three of the primitive Pen blocks:



The first (Pen block-colored) input slot is used to select which color scale you want to use. (These blocks also allow reading or setting two block properties that are not colors: the pen size and its transparency.) The pen reporter requires no other inputs; it reports the state of the pen in whatever dimension you choose.

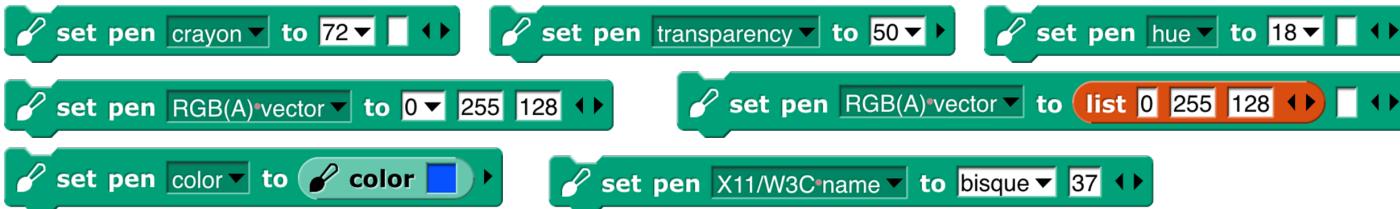
B. Appendix A. Snap! color library



As the last example shows, you can't ask for the pen color in a scale incompatible with how you set it, unless the block can deduce what you want from what it knows about the current pen color.

The change pen block applies only to numeric scales (including vectors of three or four numbers). It adds its numeric or list input to the current pen value(s), doing vector (item-by-item) addition for vector scales.

The set pen block changes the pen color to the value(s) you specify. The meaning of the white input slots depends on which attribute of the pen you're setting:



In the last example, the number 37 sets the *transparency*, on the scale 0=opaque, 100=invisible. (All color attributes are on a 0–100 scale except for RGB components, which are 0–255.) A transparency value can be combined with any of these attribute scales.

The library also includes two constructors and a selector for colors as a data type:



The latter two are inverses of each other, translating between colors and their attributes. The **color from** block's attribute menu has fewer choices than the similar **set pen** block because you can, for example, set the Red value of the existing pen color leaving the rest unchanged, but when creating a color out of nothing you have to provide its entire specification, e.g., all of Red, Green, and Blue, or the equivalent in other scales. (As you'll see on the next page, we provide two *linear* (one-dimensional) color scales that allow you to specify a color with a single number, at the cost of including only a small subset of the millions of colors your computer can generate.) If you have a color and want another color that's the same except for one number, as in the Red example, you can use this block:



Finally, the library includes the mix block and a helper:



We'll have more to say about these after a detour through color theory.

That's all you have to know about colors! Crayons for specific interesting ones, color numbers for gradual transformation from one color to the next. But there's a bit more to say, if you're interested. If not, stop here. (But look at the samples of the different scales in Section B.1.4.)

More about Colors: Fair Hues and Shades

Several of the three-dimensional arrangements of colors use the concept of “hue,” which more or less means where a color would appear in a rainbow (magenta, near the right, is a long story):

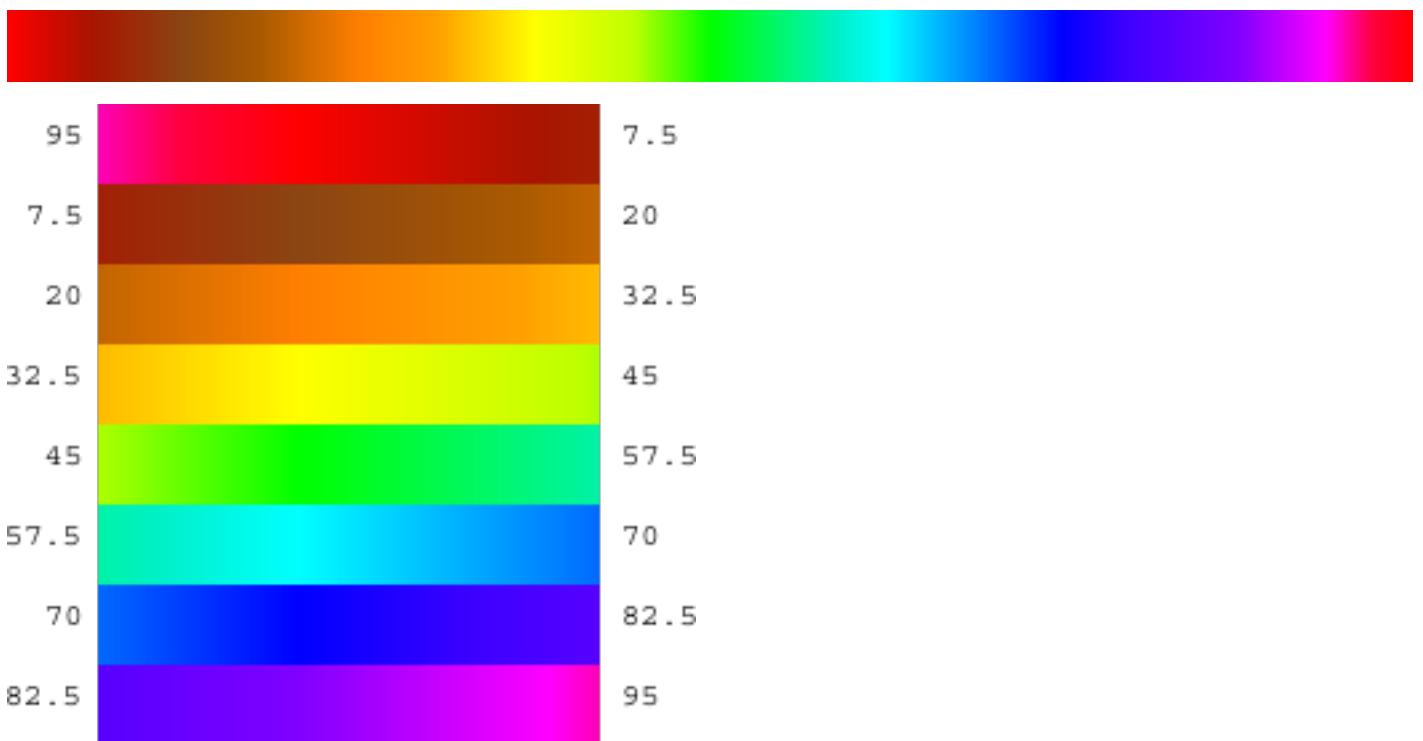


These are called “spectral” colors, after the *spectrum* of rainbow colors. But these colors aren’t equally distributed. There’s an awful lot of green, hardly any yellow, and just a sliver of orange. And no brown at all.

And this is already a handwave, because the range of colors that can be generated by RGB monitors doesn’t include some of the *true* spectral colors. See [Spectral color](#) in Wikipedia for all the gory details.

This isn’t a problem with the physics of rainbows. It’s in the human eye and the human brain that certain ranges of wavelength of light waves are lumped together as named colors. The eye is just “tuned” to recognize a wide range of colors as green. (See [Rods and Cones](#).) And different human cultures give names to different color ranges. Nevertheless, in old Scratch projects, you’d say change pen color by 1 and it’d take forever to reach a color that wasn’t green.

For color professionals, there are good reasons to want to work with the physical rainbow hue layout. But for amateurs using a simplified, one-dimensional color model, there’s no reason not to use a more programmer-friendly hue scale:



In this scale, each of the seven rainbow colors and brown get an equal share. (Red’s looks too small, but that’s because it’s split between the two ends: hue 0 is pure red, brownish reds are to its right, and purplish reds are wrapped around to the right end.) We call this scale “fair hue” because each color family gets a fair share of the total hue range. (By the way, you were probably taught “... green, blue, indigo , violet” in school, but it turns out that color names were different in Isaac Newton’s day, and the color he called “blue” is more like modern cyan, while his “indigo” is more like modern blue. See [Wikipedia Indigo](#).)

Our *color number* scale is based on fair hues, adding a range of grays from black (color number 0) to white (color number 14) and also adding *shades* of the spectral colors. (In color terminology, a *shade* is a darker version of a color; a lighter version is called a *tint*.) Why do we add shades but not tints ? Partly because I find shades more exciting. A shade of red can be dark candy apple red or maroon , but a tint is just some kind of pink

B. Appendix A. Snap! color library

 . This admitted prejudice is supported by an objective fact: Most projects are made on a white background , so dark colors stand out better than light ones.

So, in our color number scale, color numbers 0 to 14 are kinds of gray ; the remaining color numbers go through the fair hues, but alternating full-strength colors with shades.

crayons by 10

crayons by 5

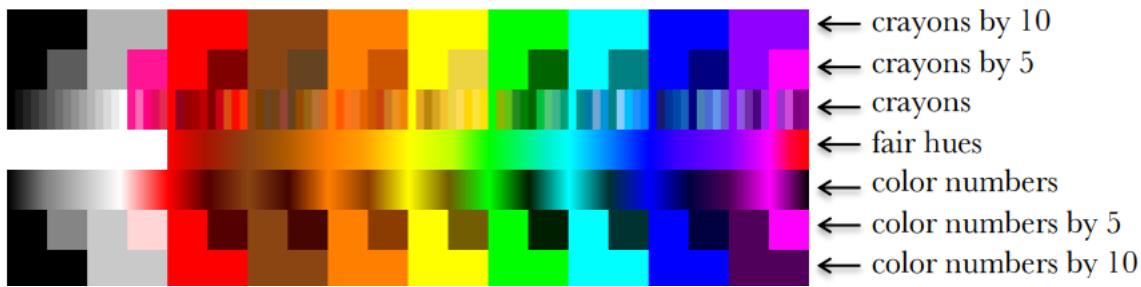
crayons

fair hues

color numbers

color numbers by 5

color numbers by 10



This chart shows how the color scales discussed so far are related. Note that all scales range from 0 to 100; the fair hues scale has been compressed in the chart so that similar colors line up vertically. (Its dimensions are different because it doesn't include the grays at the left. Since there are eight color families, the pure, named fair hues are at multiples of $100/8=12.5$, starting with red=0.)

White is crayon 14 and color number 14. This value was deliberately chosen not to be a multiple of 5 so that the every-fifth-crayon and every-tenth-crayon selections don't include it, so that all of the crayons in those smaller boxes are visible against a white stage background.

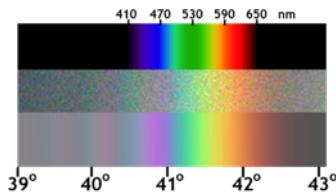


Figure B.4.: (attribution: Wikipedia user Andys. CC BY-Magenta is a mixture of red and blue.
SA.)

The light gray at color number 10 is slightly different from crayon 10 just because of roundoff in computing crayon values. Color number 90 is different from crayon 90 because the official RGB violet (equal parts red and blue) is actually lighter than spectral violet. The purple family is also unusual because magenta, crayon and color number 95, is lighter than the violet at 90. In other families, the color numbers, crayons, and (scaled) fair hues all agree at multiples of ten. These multiple-of-ten positions are the standard RGB primary and secondary colors, e.g., the yellow at color number 50 is (255, 255, 0) in RGB. (Gray, brown, and orange don't have such simple RGB settings.)

Among purples, the official spectral violet (crayon 90) is the end of the spectrum. Magenta , brighter than violet, isn't a spectral color at all. (In the picture at the left, the top part is the spectrum of white light spread out through a prism; the middle part is a photograph of a rainbow, and the bottom part is a digital simulation of a rainbow.)

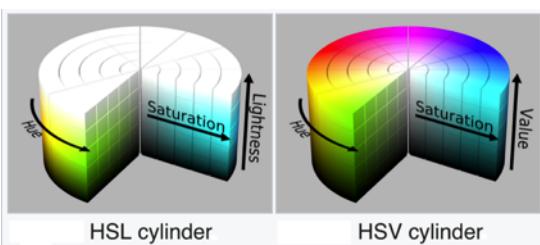
The color numbers at odd multiples of five are generally darker shades than the corresponding crayons. The latter are often official named shades, e.g., teal, crayon 65, is a half-intensity shade of cyan. The odd-five *color numbers*, though, are often darker, since they are chosen to be the darkest color in a given family that's visibly different from black. The pink at color number 15, though, is quite different from crayon 15, because the former is a pure tint of red, whereas the crayon, to get a more interesting pink, has a little magenta mixed in. Color numbers at multiples of five are looked up in a table; other color values are determined by linear interpolation in RGB space. (Crayons are of course all found by table lookup.)

The `from color` block behaves specially when you ask for the *color number* of a color. Most colors don't exactly match a color number, and for other attributes of a color (crayon number, X11 name) you don't get an answer unless the color exactly matches one of the names or numbers in that attribute. But for color number, the block tries to find the *nearest color number* to the color you specify. The result will be only approximate; you can't use the number you get to recreate the input color. But you can start choosing nearby color numbers as you animate the sprite.

B.1.2. Perceptual Spaces: HSV and HSL



RGB is the right way to think about colors if you're building or programming a display monitor; CMYK is the right way if you're building or programming a color printer. But neither of those coordinate systems is very intuitive if you're trying to understand what color you see if, for example, you mix 37% red light, 52% green, and 11% blue. The *hue* scale is one dimension of most attempts at a perceptual scale. The square at the right has pale blues along the top edge, dark blues along the right edge, various shades of gray toward the left, black at the bottom, and pure spectral blue in the top right corner. Although no other point in the square is pure blue, you can tell at a glance that no other spectral color is mixed with the blue.



Aside from hue, the other two dimensions of a color space have to represent how much white and/or black is mixed with the spectral color. (Bear in mind that "mixing black" is a metaphor when it comes to monitors. There really is black paint, but there's no such thing as black light.) One such space, HSV, has one dimension for the amount of color (vs. white), called *saturation*, and one for the amount of black, imaginatively called *value*. HSV stands for Hue-Saturation -Value . (Value is also called *brightness*.) The *value* is actually measured backward from the above description; that is, if value is 0, the color is pure black; if value is 100, then a saturation of 0 means all white, no spectral color; a saturation of 100 means no white at all. In the square in the previous paragraph, the x axis is the saturation and the y axis is the value. The entire bottom edge is black, but only the top left corner is white. HSV is the traditional color space used in Scratch and Snap!. Set pen color set the hue; set pen shade set the value. There was originally no Pen block to set the saturation, but there's a set brightness effect Looks block to control the saturation of the sprite's costume. (I speculate that the Scratch designers, like me, thought tints were less vivid than shades against a white background, so they made it harder to control tinting.)

attribution: Wikipedia user SharkD, CC BY-SA 3.0

B. Appendix A. Snap! color library

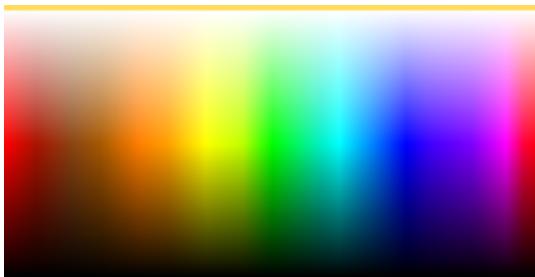
But if you're looking at colors on a computer display, HSV isn't really a good match for human perception. Intuitively, black and white should be treated symmetrically. This is the HSL (hue-saturation-lightness) color space.



Saturation, in HSL, is a measure of the *grayness* or *dullness* of a color (how close it comes to being on a black-and-white scale) and *lightness* measures *spectralness* with pure white at one end, pure black at the other end, and spectral color in the middle. The *saturation* number is actually the opposite of grayness: 0 means pure gray, and 100 means pure spectral color, provided that the *lightness* is 50, midway between black and white. Colors with lightness other than 50 have some black or white mixed in, but saturation 100 means that the color is as fully saturated as it can be, given the amount of white or black needed to achieve that lightness. Saturation less than 100 means that *both white and black* are mixed with the spectral color. (Such mixtures are called *tones* of the spectral color.) Perceptually, colors with saturation 100% don't look gray: [REDACTED] but colors with saturation 75% do: [REDACTED]

Note that HSV and HSL both have a dimension called "saturation," but *they're not the same thing!* In HSV, "saturation" means non-whiteness, whereas in HSL it means non-grayness (vividness).

More fine print: It's misleading to talk about the spectrum of light wavelengths as if it were the same as perceived hue. If your computer display is showing you a yellow area, for example, it's doing it by turning on its red and green LEDs over that area, and what hits your retina is *still two wavelengths of light, red and green, superimposed*. You could make what's perceptually the same yellow by using a single intermediate wavelength. Your eye and brain don't distinguish between those two kinds of yellow. Also, your brain automatically adjusts perceived hue to correct for differences in illumination. When you place a monochrome object so that it's half in sunlight and half in the shade, you see it as one even though what's reaching your eyes from the two regions differs a lot. And, sadly, it's HSL whose use of "saturation" disagrees with the official international color vocabulary standardization committee. I learned all this from this tutorial, which you might find more coherent than jumping around Wikipedia if you're interested.



Although traditional Scratch and Snap! use HSV in programs, they use HSL in the color picker. The horizontal axis is hue (fair hue, in this version) and the vertical axis is *lightness*, the scale with black at one end and white at the other end. It would make no sense to have only the bottom half of this selector (HSV Value) or only the top half (HSV Saturation). And, given that you can only fit two dimensions on a flat screen, it makes sense to pick HSL saturation (vividness) as the one to keep at 100%. (In this fair-hue picker, some colors appear twice: "spectral" (50% lightness) browns as shades ($\approx 33\%$ lightness) of red or orange, and shades of those browns.)

Software that isn't primarily about colors (so, *not* including Photoshop, for example) typically use HSV or HSL, with web-based software more likely to use HSV because that's what's built into the JavaScript programming language provided by browsers. But if the goal is to model human color perception, neither of these color spaces is satisfactory, because they assume that all full-intensity spectral colors are equally bright. But if you're like most

people, you see spectral yellow  as much brighter than spectral blue  . There are better perceptual color spaces with names like $L^*u^*v^*$ and $L^*a^*b^*$ that are based on research with human subjects to determine true perceived brightness. Wikipedia explains all this and more at HSL and HSV, where they recommend ditching both of these simplistic color spaces. [?](#)

B.1.3. Mixing Colors

Given first class colors, the next question is, what operations apply to them, the way arithmetic operators apply to numbers and higher order functions apply to lists? The equivalent to adding numbers is mixing colors, but unfortunately there isn't a simple answer to what that means.

The easiest kind of color mixing to understand is *additive* mixing, which is what happens when you shine two colored lights onto a (white) wall. It's also what happens in your computer screen, where each dot (pixel) of an image is created by a tiny red light, a tiny green light, and a tiny blue light that can be combined at different strengths to make different colors. Essentially, additive mixing of two colors is computed by adding the two red components, the two green components, and the two blue components. It's not quite that simple only because each component of the result must be in the range 0 to 255. So, red (255, 0, 0) mixed with green (0, 255, 0) gives (255, 255, 0), which is yellow. But red (255, 0, 0) plus yellow (255, 255, 0) can't give (510, 255, 0). Just limiting the red in the result to 255 would mean that red plus yellow is yellow, which doesn't make sense. Instead, if the red value has to be reduced by half (from 510 to 255), then *all three* values must be reduced by half, so the result is (255, 128, 0), which is orange. (Half of 255 is 127.5, but each RGB value must be an integer.)



A different kind of color mixing based on light is done when different colored transparent plastic sheets are held in front of a white light, as is done in theatrical lighting. In that situation, the light that gets through both filters is what remains after some light is filtered out by the first one and some of what's left is filtered out by the second one. In red-green-blue terms, a red filter filters out green and blue; a yellow filter allows red and green through, filtering out blue. But there isn't any green light for the yellow filter to pass; it was filtered out by the red filter. Each filter can only remove light, not add light, so this is called *subtractive* mixing:

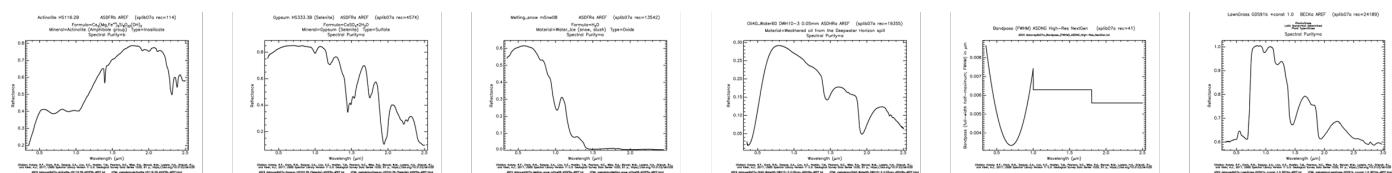


Perhaps confusingly, the numerical computation of subtractive mixing is done by *multiplying* the RGB values, taken as fractions of the maximum 255, so red (1, 0, 0) times yellow (1, 1, 0) is red again.

Those are both straightforward to compute. Much, much more complicated is trying to simulate the result of mixing *paints*. It's not just that we'd have to compute a more complicated function of the red, green, and blue values; it's that RGB values (or any other three-dimensional color space) are inadequate to describe the behavior of paints. Two paints can look identical, and have the same RGB values, but may still behave very differently when mixed with other colors. The differences are mostly due to the chemistry of the paints, but are also affected by exactly how the colors are mixed. The mixing is mostly subtractive; red paint *absorbs* most of the colors other than red, so what's reflected off the surface is whatever isn't absorbed by the colors being mixed. But there can be an additive component also.

The proper mathematical abstraction to describe a paint is a *reflectance graph*, like this:

B. Appendix A. Snap! color library



(These aren't paints, but minerals, and one software-generated spectrum, from the US Geological Survey's Spectral Library. The details don't matter, just the fact that a graph like these gives much more information than three RGB numbers.) To mix two paints properly, you multiply the y values (as fractions) at each matching x coordinate of the two graphs.

Having said all that, the mix block takes the colors it is given as inputs and converts them into what we hope are *typical* paint reflectance spectra that would look like those colors, and then mixes those spectra and converts back to RGB.



But unlike the other two kinds of mixing, in this case we can't say that these colors are "the right answer"; what would happen with real paints depends on their chemical composition and how they're mixed. There are three more mixing options, but these three are the ones that correspond to real-world color mixing.

The mix block will accept any number of colors, and will mix them in equal proportion. If (for any kind of mixing) you want more of one color than another, use the color at weight block to make a "weighted color":



This mixes four parts red paint to one part green paint. All colors in a mixture can be weighted:



(Thanks to Scott Burns for his help in understanding paint mixing, along with David Briggs's tutorial. Remaining mistakes are bh's.)

B.1.4. tl;dr

For normal people, Snap! provides three simple, one-dimensional scales: *crayons* for specific interesting colors, *color numbers* for a continuum of high-contrast colors with a range of hues and shading, and *fair hues* for a continuum without shading. For color nerds, it provides three-dimensional color spaces RGB, HSL, HSV, and fair-hue variants of the latter two. We recommend "fair HSL" for zeroing in on a desired color.

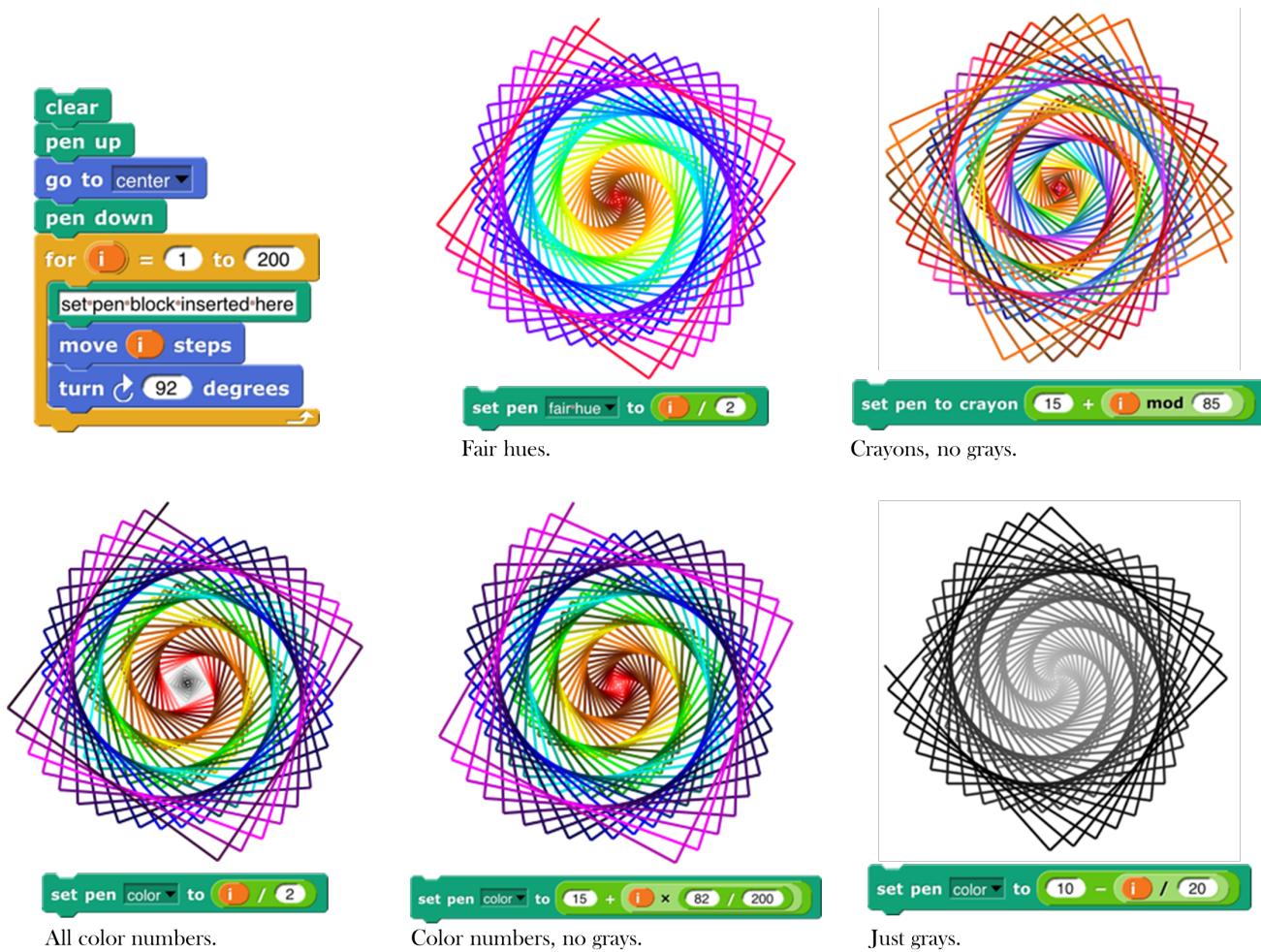


Figure B.5.: image1242.png

B.1.5. Subappendix: Geeky details on fair hue

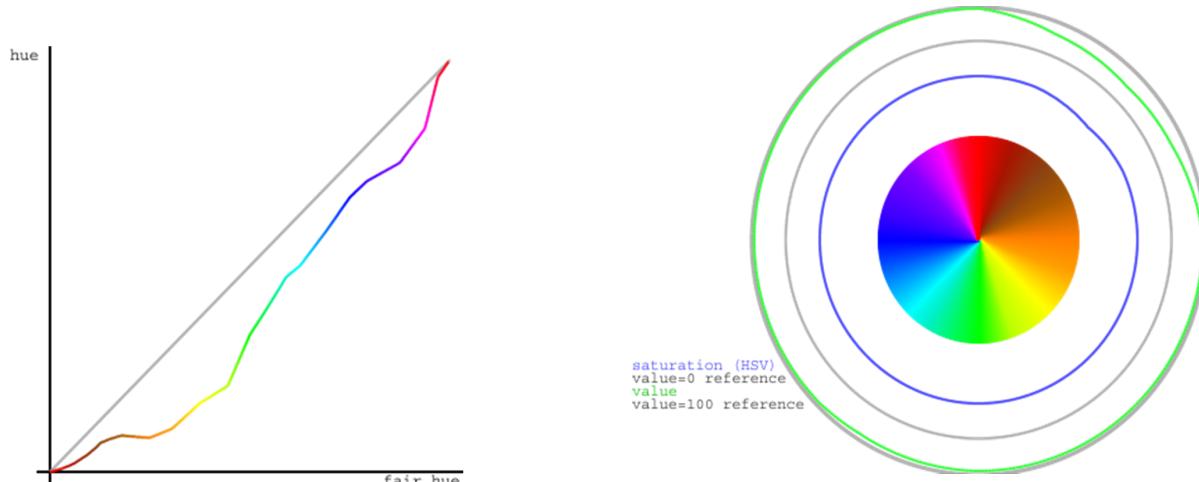


Figure B.6.: image1243.png

B. Appendix A. Snap! color library

The left graph shows that, unsurprisingly, all of the brown fair hues make essentially no progress in real hue, with the orange-brown section actually a little retrograde, since browns are really shades of orange and so the real hues overlap between fair browns and fair oranges. Green makes up some of the distance, because there are too many green real hues and part of the goal of the fair hue scale is to squeeze that part of the hue spectrum. But much of the catching up happens very quickly, between pure magenta at fair hue 93.75 and the start of the purple-red section at fair hue 97. This abrupt change is unfortunate, but the alternatives involve either stealing space from red or stealing space from purple (which already has to include both spectral violet and RGB magenta). The graph has discontinuous derivative at the table-lookup points, of which there are two in each color family, one at the pure-named-RGB colors at multiples of 12.5, and the other roughly halfway to the next color family, except for the purple family, which has lookup points at 87.5 (approximate spectral violet), 93.75 (RGB magenta), and 97 (turning point toward the red family). (In the color picker, blue captures cyan and purple space in dark shades. This, too, is an artifact of human vision.)

The right graph shows the HSV saturation and value for all the fair hues. Saturation is at 100%, as it should be in a hue scale, except for a very slight drop in part of the browns. (Browns are shades of orange, not tints, so one would expect full saturation, except that some of the browns are actually mixtures with related hues.) But value, also as expected, falls substantially in the browns, to a low of about 56% (halfway to black) for the “pure” brown at 45° (fair hue 12.5). But the curve is smooth, without inflection points other than that minimum-value pure brown.

“Fair saturation” and “fair value” are by definition 100% for the entire range of fair hues. This means that in the browns, the real saturation and value are the product (in percent) of the innate shading of the specific brown fair hue and the user’s fair saturation/value setting. When the user’s previous color setting was in a real scale and the new setting is in a fair scale, the program assumes that the previous saturation and value were entirely user-determined; when the previous color setting was in a brown fair hue and the new setting is also in a fair scale, the program remembers the user’s intention from the previous setting. (Internal calculations are based on HSV, even though we recommend HSL to users, because HSV comes to us directly from the JavaScript color management implementation.) This is why the set pen block includes options for “fair saturation” and so on.

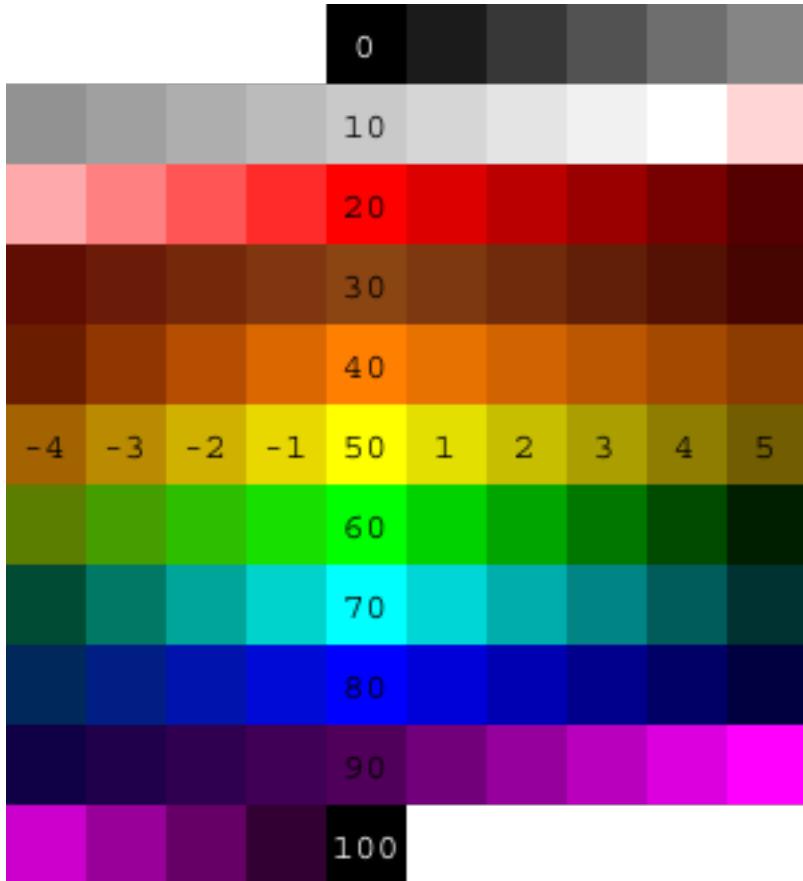
For the extra-geeky, here are the exact table lookup points (fair hue, [0,100]):

list	0	5.8	12.5	18	25	30.5	37.5	44.5	50	59	62.5	69	75	79.25	87.5	93.75	97	100	◀ ▶
------	---	-----	------	----	----	------	------	------	----	----	------	----	----	-------	------	-------	----	-----	-----

and here are the RGB settings at those points:

list																				
255	0	0	170	20	0	139	69	19	170	90	0	255	127	0	255	160	0	255	255	0
255	127	0	255	160	0	0	255	255	0	190	255	0	0	255	0	240	200	0	0	255
0	255	0	0	240	200	0	0	255	255	0	127	255	0	255	0	255	0	255	0	
0	0	255	0	0	255	0	128	0	255	0	255	0	255	0	64	0	0	0	0	
255	0	64	0	0	0	0	255	0	0	0	0	0	0	0	0	0	0	0	0	

B.1.6. Subappendix: Geeky details on color numbers



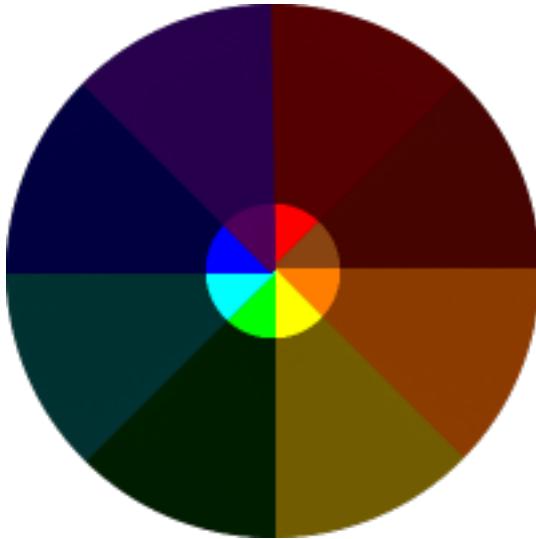
Here is a picture of integer color numbers, but remember that color numbers are continuous. (As usual, “continuous” values are ultimately converted to integer RGB values, so there’s really some granularity.) Color numbers 0-14 are continuously varying grayscale, from 0=black to 14=white. Color numbers $14+\epsilon$ to 20 are linearly varying shades of pink, with RGB Red at color number 20.

Beyond that point, in each color family, the multiple of ten color number in the middle is the RGB standard color of that family, in which each component is either 255 or 0. (Exceptions are brown, which is of course darker than any of those colors; orange, with its green component half-strength: [255, 127, 0]; and violet, discussed below.) The following multiple of five is the number of the darkest color in that family, although not necessarily the same hue as the multiple of ten color number. Color numbers between the multiple of ten and the following multiple of five are shades of colors entirely within the family. Color numbers in the four before the multiple of ten are mixtures of this family and the one before it. So, for example, in the green family, we have

- 55 Darkest yellow.
- (55, 60) shades of yellow-green mixtures. As the color number increases, both the hue and the lightness (or value, depending on your religion) increase, so we get brighter and greener colors.
- 60 Canonical green, [0, 255, 0], whose W3C color name is “lime,” not “green.”
- (60, 65) Shades of green. No cyan mixed in.
- 65 Darkest green.
- (65,70) Shades of green-cyan mixtures.

B. Appendix A. Snap! color library

In the color number chart, all the dark color numbers look a lot like black, but they're quite different. Here are the darkest colors in each color number family.

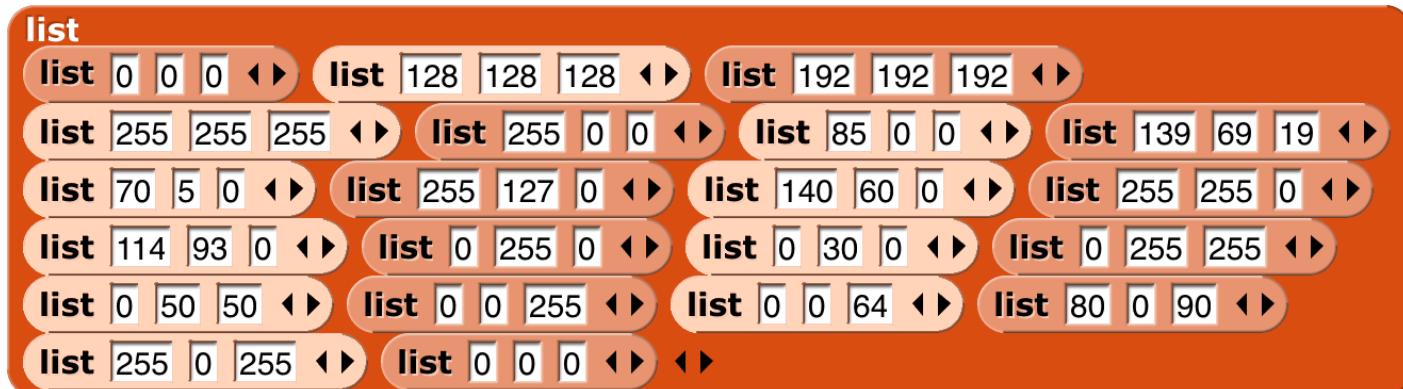


Darkest yellow doesn't look entirely yellow. You might see it as greenish or brownish. As it turns out, the darkest color that really looks yellow is hardly dark at all. This color was hand-tweaked to look neither green nor brown to me, but ymmv.

In some families, the center+5 crayon is an important named darker version of the center color: In the red family, [128, 0, 0] is "maroon." In the cyan family, [0, 128, 128] is "teal." An early version of the color number scale used these named shades as the center+5 color number also. But on this page we use the word "darkest" advisedly: You can't find a darker shade of this family anywhere in the color number scale, but you *can* find lighter shades. Teal is color number 73.1, $(70 + 5 \cdot \frac{255-128}{255-50})$, because darkest cyan, color 75, is [0, 50, 50]. The color number for maroon is left as an exercise for the reader.

The purple family is different from the others, because it has to include both spectral violet and extraspectral RGB magenta. Violet is usually given as RGB [128, 0, 255], but that's much brighter than the violet in an actual spectrum (see Figure B.4). We use [80, 0, 90], a value hand-tweaked to look as much as possible like the violet in rainbow photos, as color number 90. (Crayon 90 is [128, 0, 255].) Magenta, [255, 0, 255], is color number 95. This means that the colors get *brighter*, not darker, between 90 and 95. The darkest violet is actually color number 87.5, so it's bluer than standard violet, but still plainly a purple and not a blue. It's [39, 0, 76]. It's not hand-tweaked; it's a linear interpolation between darkest blue, [0, 0, 64], and the violet at color number 90. I determined by experiment that color number 87.5 is the darkest one that's still unambiguously purple. (According to Wikipedia, "violet" names only the spectral color, while "purple" is the name of the whole color family.)

Here are the reference points for color numbers that are multiples of five, except for item 4, which is used for color 14, not color 15:



The very pale three-input list blocks are for color numbers that are odd multiples of five, generally the “darkest” members of each color family. (The block colors were adjusted in Photoshop; don’t ask how to get blocks this color in Snap!).

C. Appendix B. APL features

The book *A Programming Language* was published by mathematician Kenneth E. Iverson in 1962. He wanted a formal language that would look like what mathematicians write on chalkboards. The then-unnamed language would later take its name from the first letters of the words in the book's title. It was little-known until 1964, when a formal description of the just-announced IBM System/360 in the *IBM Systems Journal* used APL notation. (Around the same time, Iverson's associate Adin Falkoff gave a talk on APL to a New York Association for Computing Machinery chapter, with an excited 14-year-old Brian Harvey in the audience.) But it wasn't until 1966 that the first public implementation of the language for the System/360 was published by IBM. (It was called "APL\360" because the normal slash character / represents the "reduce" operator in APL, while backslash is "expand.")

The crucial idea behind APL is that mathematicians think about collections of numbers, one-dimensional vectors and two-dimensional *matrices*, as valid objects in themselves, what computer scientists later learned to call "first class data." A mathematician who wants to add two vectors writes $v1 + v2$, not "for $i = 1$ to $\text{length}(v1)$, $\text{result}[i]=v1[i]+v2[i]$." Same for a programmer using APL.

There are three kinds of function in APL: scalar functions, mixed functions, and operators. A *scalar function* is one whose natural domain is individual numbers or text characters. A *mixed function* is one whose domain includes arrays (vectors, matrices, or higher-dimensional collections). In Snap!, scalar functions are generally found in the green Operators palette, while mixed functions are in the red Lists palette. The third category, confusingly for Snap! users, is called *operators* in APL, but corresponds to what we call higher order functions : functions whose domain includes functions.

Snap! hyperblocks are scalar functions that behave like APL scalar functions: they can be called with arrays as inputs, and the underlying function is applied to each number in the arrays. (If the function is *monadic*, meaning that it takes one input, then there's no complexity to this idea. Take the square root of an array, and you are taking the square root of each number in the array. If the function is *dyadic*, taking two inputs, then the two arrays must have the same shape. Snap! is more forgiving than APL; if the arrays don't agree in number of dimensions, called the *rank* of the array, the lower-rank array is matched repeatedly with subsets of the higher-rank one; if they don't agree in length along one dimension, the result has the shorter length and some of the numbers in the longer-length array are ignored. An exception in both languages is that if one of the two inputs is a scalar, then it is matched with every number in the other array input.)

As explained in Section IV.F, this termwise extension of scalar functions is the main APL-like feature built into Snap! itself. We also include an extension of the item block to address multiple dimensions, an extension to the length block with five list functions from APL, and a new primitive reshape block. The APL library extends the implementation of APL features to include a few missing scalar functions and several missing mixed functions and operators.

Programming in APL really is very different in style from programming in other languages, even Snap!. This appendix can't hope to be a complete reference for APL, let alone a tutorial. If you're interested, find one of those in a library or a (probably used) bookstore, read it, and do the exercises. Sorry to sound like a teacher, but the notation is sufficiently weird as to take a lot of practice before you start to think in APL.

A note on versions: There is a widely standardized APL2, several idiosyncratic extensions, and a successor language named J. The latter uses plain ASCII characters, unlike the ones with APL in their names, which use the mathematician's character set, with Greek letters, typestyles (boldface and/or italics in books; underlined, upper case, or lower case in APL) as loose type declarations, and symbols not part of anyone's alphabet, such as \otimes .

C. Appendix B. APL features

for floor and ⌊ for ceiling. To use the original APL, you needed expensive special computer terminals. (This was before you could download fonts in software. Today the more unusual APL characters are in Unicode at U+2336 to U+2395.) The character set was probably the main reason APL didn't take over the world. APL2 has a lot to recommend it for Snap! users, mainly because it moves from the original APL idea that all arrays must be uniform in dimension, and the elements of arrays must be numbers or single text characters, to our idea that a list can be an element of another list, and that such elements don't all have to have the same dimensions. Nevertheless, its mechanism for allowing both old-style APL arrays and more general "nested arrays" is complicated and hard for an APL beginner (probably all but two or three Snap! users) to understand. So we are starting with plain APL. If it turns out to be wildly popular, we may decide later to include APL2 features.

Here are some of the guiding ideas in the design of the APL library:

- Goal: Enable interested **Snap!** users to learn the feel and style of APL programming. It's really worth the effort. For example, we didn't hyperize the = block because Snap! users expect it to give a single yes-or-no answer about the equality of two complete structures , whatever their types and shapes. In APL, = is a scalar function; it compares two numbers or two characters. How could APL users live without the ability to ask if two *structures* are equal? Because in APL you can say ⌊/,a=b to get that answer. Reading from right to left, a=b reports an array of Booleans (represented in APL as 0 for False, 1 for True); the comma operator turns the shape of the array into a simple vector; and ⌊/ means "reduce with and"; "reduce" is our combine function. That six-character program is much less effort than the equivalent



in Snap!. Note in passing that if you

wanted to know *how many* corresponding elements of the two arrays are equal, you'd just use +/ instead of ⌊/. Note also that our APLish blocks are a little verbose, because they include up to three notations for the function: the usual Snap! name (e.g., flatten), the name APL programmers use when talking about it (ravel), and, in yellow type, the symbol used in actual APL code (,). We're not consistent about it; transpose ⌈目 seems self-documenting. And LCM (and) is different even though it has two names; it turns out that if you represent Boolean values as 0 and 1, then the algorithm to compute the least common multiple of two integers computes the and function if the two inputs happen to be Boolean. Including the APL symbols serves two purposes: the two or three Snap! users who've actually programmed in APL will be sure what function they're using, but more importantly, the ones who are reading an APL tutorial while building programs in Snap! will find the block that matches the APL they're reading.

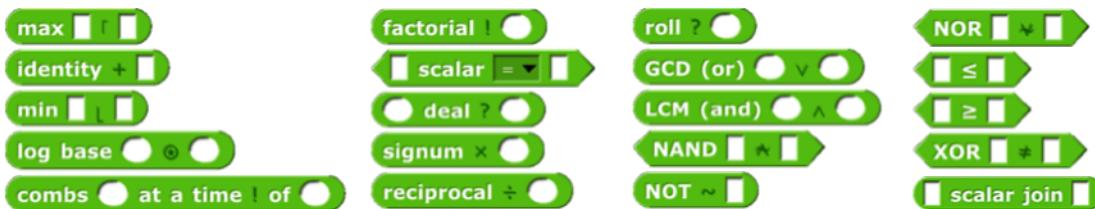
- Goal: Bring the best and most general APL ideas into "mainstream" **Snap!** programming style. Media computation , in particular, becomes much simpler when scalar functions can be applied to an entire picture or sound. Yes, map provides essentially the same capability, but the notation gets complicated if you want to map over columns rather than rows. Also, Snap! lists are fundamentally one-dimensional, but real data often have more dimensions. A Snap! programmer has to be thinking all the time about the convention that we represent a matrix as a list of rows, each of which is a list of individual cells. That is, row 23 of a spreadsheet is item 23 of spreadsheet, but column 23 is map (item 23 of _) over spreadsheet. APL treats rows and columns more symmetrically.
- Non-goal: Allow programs written originally in APL to run in **Snap!** essentially unchanged. For example, in APL the atomic text unit is a single character, and strings of characters are lists. We treat a text string as scalar, and that isn't going to change. Because APL programmers rarely use conditionals, instead computing functions involving arrays of Boolean values to achieve the same effect, the notation they do have for conditionals is primitive (in the sense of Paleolithic, not in the sense of built in). We're not changing ours.
- Non-goal: Emulate the terse APL syntax. It's too bad, in a way; as noted above, the terseness of expressing a computation affects APL programmers' sense of what's difficult and what isn't. But you can't say "terse" and "block language" in the same sentence. Our whole *raison d'être* is to make it possible to build a program without having to memorize the syntax or the names of functions, and to allow those names to be long

enough to be self-documenting. And APL's syntax has its own issues, of which the biggest is that it's hard to use functions with more than two inputs; because most mathematical dyadic functions use infix notation (the function symbol between the two inputs), the notion of "left argument" and "right argument" is universal in APL documentation. The thing people most complain about, that there is no operator precedence (like the multiplication-before-addition rule in normal arithmetic notation), really doesn't turn out to be a problem. Function grouping is strictly right to left, so $2 \times 3 + 4$ means two times seven, not six plus four. That takes some getting used to, but it really doesn't take long if you immerse yourself in APL. The reason is that there are too many infix operators for people to memorize a precedence table. But in any case, block notation eliminates the problem, especially with Snap!'s zebra coloring. You can see and control the grouping by which block is inside which other block's input slot. Another problem with APL's syntax is that it bends over backward not to have reserved words, as opposed to Fortran, its main competition back then. So the dyadic \circ "circular functions" function uses the left argument to select a trig function. $1\circ x$ is $\sin(x)$, $2\circ x$ is $\cos(x)$, and so on. $-1\circ x$ is $\arcsin(x)$. What's $0\circ x$? Glad you asked; it's $\sqrt{1 - x^2}$.

C.1. Boolean values

Snap! uses distinct Boolean values true and false that are different from other data types. APL uses 1 and 0, respectively. The APL style of programming depends heavily on doing arithmetic on Booleans, although their conditionals insist on only 0 or 1 in a Boolean input slot, not other numbers. Snap! arithmetic functions treat false as 0 and true as 1, so our APL library tries to report Snap! Boolean values from predicate functions.

C.1.1. Scalar functions



These are the scalar functions in the APL library. Most of them are straightforward to figure out. The scalar = block provides an APL-style version of = (and other exceptions) as a hyperblock that extends termwise to arrays. Join, the only non-predicate non-hyper scalar primitive, has its own scalar join block . 7 deal 52 reports a random vector of seven numbers from 1 to 52 with no repetitions, as in dealing a hand of cards. Signum of a number reports 1 if the number is positive, 0 if it's zero, or -1 if it's negative. Roll 6 reports a random roll of a six-sided die.

To roll 8 dice, use `roll ? reshape as list 8 ↵ p items of list 6 ↵`, which would look much more pleasant as `?8⍳6`. But perhaps our version is more instantly readable by someone who didn't grow up with APL. All the library functions have help messages available.

C.1.2. Mixed functions

Mixed functions include lists in their natural domain or range. That is, one or both of its inputs *must* be a list, or it always reports a list. Sometimes both inputs are naturally lists; sometimes one input of a dyadic mixed function is naturally a scalar, and the function treats a list in that input slot as an implicit map, as for scalar functions. This means you have to learn the rule for each mixed function individually.

shape of  The shape of function takes any input and reports a vector of the maximum size of the structure along each dimension. For a vector, it returns a list of length 1 containing the length of the input. For a matrix, it returns a two-item list of the number of rows and number of columns of the input. And so on for higher dimensions. If the input isn't a list at all, then it has zero dimensions, and shape of reports an empty vector. Equivalent to the dimensions of primitive, as of 6.6.



rank of

Rank of isn't an actual APL primitive, but the composition  (shape of shape of a structure), which reports the number of dimensions of the structure (the length of its shape vector), is too useful to omit. (It's very easy to type the same character twice on the APL keyboard, but less easy to drag blocks together.) Equivalent to the rank of primitive, as of 6.6.

reshape as p items of

Reshape takes a shape vector (such as shape might report) on the left and any structure on the right. It ignores the shape of the right input, stringing the atomic elements into a vector in row-major order (that is, all of the first row left to right, then all of the second row, etc.). (The primitive reshape takes the inputs in the other order.) It then reports an array with the shape specified by the first input containing the items of the second:



If the right input has more atomic elements than are required by the left-input shape vector, the excess are ignored without reporting an error. If the right input has too few atomic elements, the process of filling the reported array starts again from the first element. This is most useful in the specific case of an atomic right input, which produces an array of any desired shape all of whose atomic elements are equal. But other cases are sometimes useful too:



identity matrix, size 

$ID \leftarrow \{(\omega, \omega) \rho 1, \omega \rho 0\}$

report

reshape as list size size ⌘ p items of

1 in front of reshape as list size ⌘ p items of list 0 ⌘

flatten (ravel) , ⚡

Flatten takes an arbitrary structure as

input and reports a vector of its atomic elements in row-major order. Lispians call this flattening the structure, but APLers call it “ravel” because of the metaphor of pulling on a ball of yarn, so what they really mean is “unravel.” (But the snarky sound of that is uncalled-for, because a more advanced version that we might implement someday is more like raveling.) One APL idiom is to apply this to a scalar in order to turn it into a one-element vector, but we can’t use it that way because you can’t type a scalar value into the List-type input slot. Equivalent to the primitive flatten of block.

catenate [] , []

catenate vertically [] ⚡ []

Catenate is like our primitive append, with two differences: First, if either input is a scalar, it is treated like a one-item vector. Second, if the two inputs are of different rank, the catenate function is recursively mapped over the higher-rank input:

The screenshot shows a 'catenate' block with two inputs. The first input is 'reshape as list 2 3 ↗ items of 1 6', which creates a 2x3 matrix from a 1D list. The second input is 'list 20 30 40 ↗', which is a 1D list. An arrow points from the output of the first block to the second, indicating they are concatenated. The resulting matrix is displayed as:

2	A	B	C	D	E	F
1	1	2	3	20	30	40
2	4	5	6	20	30	40

Catenate vertically is similar, but it adds new rows instead of adding new columns.

iota

Iintegers (I think that's what it stands for, although APLers just say “iota”) takes a positive integer input and reports a vector of the integers from 1 to the input. This is an example of a function classed as “mixed” not because of its domain but because of its range. The difference between this block and the primitive numbers from block is in its treatment of lists as inputs. Numbers from is a hyperblock, applying itself to each item of its input list:

The screenshot shows a 'numbers from' block with two inputs. Both inputs are 'numbers from 1 to 3'. An arrow points from the first input to the second, indicating they are combined. The resulting matrix is displayed as:

3	A	B	C
1	1		
2	1	2	
3	1	2	3

Iota has a special meaning for list inputs: The input must be a shape vector; the result is an array with that shape in which each item is a list of the indices of the cell along each dimension. A picture is worth 103 words, but Snap! isn't so good at displaying arrays with more than two dimensions, so here we reduce each cell's index list to a string:

The screenshot shows a 'reduce' block with two inputs. The first input is 'join [] , [] ↗' followed by a 'list 2 3 ↗' block. The second input is 'list 2 3 ↗'. An arrow points from the first input to the second, indicating they are concatenated. The resulting matrix is displayed as:

2	A	B	C
1	1,1	1,2	1,3
2	2,1	2,2	2,3

where in ⚡ is 1

Dyadic iota is like the index of primitive except for its handling of multi-dimensional arrays. It looks only for atomic elements, so a vector in the second input doesn't mean to search for that vector as a row of a matrix, which is what it means to index of, but rather to look separately for each item of the vector, and report a list of the locations of each item. If the first input is a multi-dimensional array, then the location of an item is a vector with the indices along each row.

C. Appendix B. APL features

```
where in reshape as list 3 2 p items of 1 6 is 1 4
```

The output shows a 2x2 matrix with values 1, 2, 2, -.

In this example, the 4 is in the second row, second column. (This is actually an extension of APL iota, which is more like a hyperized index of.) Generalizing, if the rank of the second input is less than the rank of the first input by two or more, then iota looks for the entire second input in the first input. The reported position is a vector whose length is equal to the difference between the two ranks. If the rank of the second input is one less than the rank of the first, the reported value is a scalar, the index of the entire second input in the first.

```
where in reshape as list 3 2 p items of 1 6 is 1 list 3 4 p
```

The output shows a 2x2 matrix with values 1, 2, 2, - and a speech bubble saying 2.

However, if the two ranks are equal, then the block is hyperized; each item of the second input is located in the first input. As the next example shows, only the first instance of each item is found (e.g., the 1 in position 2, not the 1 in position 4); if an item does not occur in the left input, what is reported is one more than the length of the left input (here, 8).

```
where in list 3 1 4 1 5 9 3 p is 1 list 1 2 3 p
```

The output shows a 3x2 matrix with values 1, 2, 8, 1, - and a speech bubble saying 8.

Why the strange design decision to report $\text{length}+1$ when something isn't found, instead of a more obvious flag value such as 0 or false? Here's why:

```
encode example
script variables alpha code cleartext ciphertext
set alpha to split abcdefghijklmnopqrstuvwxyz by letter
set code to catenate item 26 deal ? 26 of alpha , *
set cleartext to split the*rain*in*spain*doesn't*freeze by letter
set ciphertext to reduce join / item where in alpha is 1 cleartext of code
report ciphertext
```

mzo*ltbc*bc*yetbc*xsoyc*m*klooro

Note that code has 27 items, not 26. The asterisk at the end is the ciphertext is the translation of all non-alphabet characters (spaces and the apostrophe in “doesn’t”). This is a silly example, because it makes up a random cipher every time it’s called, and it doesn’t report the cipher, so the recipient can’t decipher the message. And you wouldn’t want to make the spaces in the message so obvious. But despite being silly, the example shows the benefit of reporting $\text{length}+1$ as the position of items not found.

which of e contained in

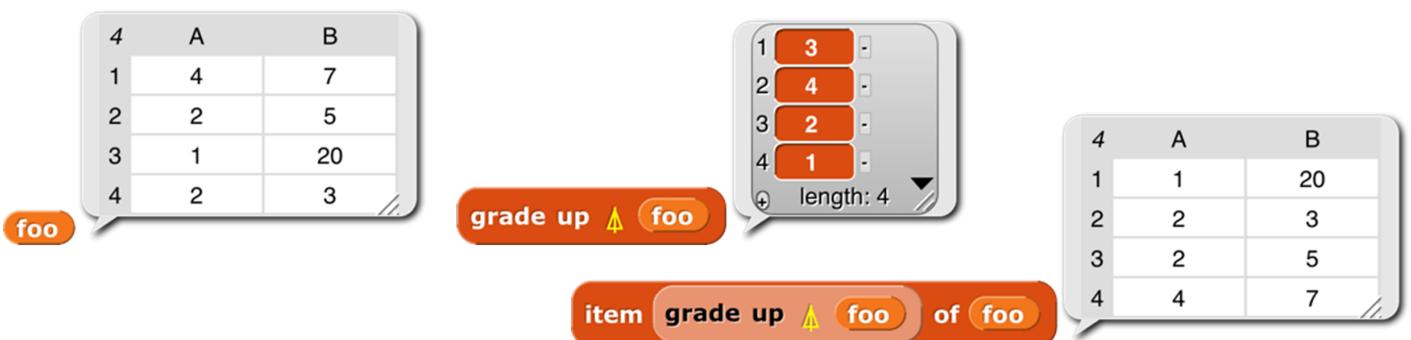
The contained in block is like a hyperized contains with the input order reversed. It reports an array of Booleans the same shape as the left input. The shape of the right input doesn't matter; the block looks only for atomic elements.



grade up

grade down

The blocks grade up and grade down are used for sorting data. Given an array as input, it reports a vector of the indices in which the items (the rows, if a matrix) should be rearranged in order to be sorted. This will be clearer with an example:



The result from grade up tells us that item 3 of **foo** comes first in sorted order, then item 4, then 2, then 1. When we actually select items of **foo** based on this ordering, we get the desired sorted version. The result reported by grade down is almost the reverse of that from grade up, but not quite, if there are equal items in the list. (The sort is stable, so if there are equal items, then whichever comes first in the input list will also be first in the sorted list.)

Why this two-step process? Why not just have a sort primitive in APL? One answer is that in a database application you might want to sort one array based on the order of another array:



This is the list of employees of a small company. (Taken from *Structure and Interpretation of Computer Programs* by Abelson and Sussman. Creative Commons licensed.) Each of the smaller lists contains a person's name, job title, and yearly salary. We would like to sort the employees' names in big-to-small order of salary. First we extract column 3 of the database, the salaries:

C. Appendix B. APL features

A screenshot of a software interface. At the top is a table titled "9 items" containing the following data:

	items
1	60000
2	40000
3	35000
4	25000
5	30000
6	650000
7	75000
8	18000
9	25000

Below the table is a navigation bar with the following buttons: item, list, list ▶, list [3] ▶▶, of, database.

Then we use grade down to get the reordering indices:

A screenshot of a software interface. On the right is a table showing the result of the grade down operation:

1	6
2	7
3	1
4	2
5	3
6	5
7	9
8	4
9	8

Below the table is a navigation bar with the following buttons: grade down ▾, item, list, list ▶, list [3] ▶▶, of, database.

At this point we could use the index vector to sort the salaries:

A screenshot of a software interface. On the right is a table showing the sorted salary data:

	items
1	650000
2	75000
3	60000
4	40000
5	35000
6	30000
7	25000
8	25000
9	18000

Below the table is a navigation bar with the following buttons: item, grade down ▾, item, list, list ▶, list [3] ▶▶, of, database, of, item, list, list ▶, list [3] ▶▶, of, database.

But what we actually want is a list of *names*, sorted by salary:

The screenshot shows two rows of APL code execution. The top row shows the result of an 'item grade down' operation, resulting in a list of 9 items: Oliver Warbucks, Eben Scrooge, Ben Bitdiddle, Alyssa P Hacker, Cy D Fect, Louis Reasoner, Aull DeWitt, Lem E Tweakit, and Robert Cratchet. The bottom row shows the result of an 'item list' operation where index 1 is selected from a list of 3, resulting in the first item of the database.

9	items
1	Oliver Warbucks
2	Eben Scrooge
3	Ben Bitdiddle
4	Alyssa P Hacker
5	Cy D Fect
6	Louis Reasoner
7	Aull DeWitt
8	Lem E Tweakit
9	Robert Cratchet

By taking the index vector from grade down of column 3 and telling item to apply it to column 1, we get what we set out to find. As usual the code is more elegant in APL: `database[;3;1]`.

In case you've forgotten, `item list 3 ⌶ ⌈ ⌊ of database` or `item list list 3 ⌶ ⌈ ⌉ ⌊ ⌋ of database` would select the third row of the database; we need the list 3 in the second input slot of the outer list to select by columns rather than by rows.

`take ⌈ ⌉ ↑ from ⌂` `drop ⌈ ⌉ ↓ from ⌂`

Select (if take) or select all but (if drop) the first (if $n > 0$) or last (if $n < 0$) $|n|$ items from a vector, or rows from a matrix. Alternatively, if the left input is a two-item vector, select rows with the first item and columns with the second.

`select rows (compress columns) ⌂ / ⌂`

`select columns (compress rows) ⌂ ⌁ ⌂`

The compress block selects a subset of its right input based on the Boolean values in its left input, which must be a vector of Booleans whose length equals the length of the array (the number of rows, for a matrix) in the right input. The block reports an array of the same rank as the right input, but containing only those rows whose corresponding Boolean value is true. The columns version `⌢` is the same but selecting columns rather than selecting rows.

A word about the possibly confusing names of these blocks: There are two ways to think about what they do. Take the standard / version, to avoid talking about both at once. One way to think about it is that it selects some of the rows. The other way is that it shortens the columns. For Lispians, which includes you since you've learned about keep, the natural way to think about / is that it keeps some of the rows. Since we represent a matrix as a list of rows, that also fits with how this function is implemented. (Read the code; you'll find a keep inside.) But APL people think about it the other way, so when you read APL documentation, / is described as operating on the last dimension (the columns), while `⌢` is described as operating on rows. We were more than a month into this project before I understood all this. You get long block names so it won't take you a month!

`reverse row order (column contents) ⌘ ⌂`

reverse column order (row ⌂)

`transpose ⌁ ⌂` Don't confuse this block with the reduce block, whose APL symbol is also a slash. In that block, what comes to the left of the slash is a dyadic combining function; it's the APL equivalent of combine. This block is more nearly equivalent to keep. But keep takes a predicate function as input, and calls the function for each item of the second input. With compress, the predicate function, if any, has already been called on all the items of the right input in parallel, resulting in a vector of Boolean values. This is a typical APL move; since hyperblocks are equivalent to an implicit map, it's easy to make the vector of Booleans, because any scalar function, including

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predicates, can be applied to a list instead of to a scalar. The reason both blocks use the / character is that both of them reduce the size of the input array, although in different ways.

The reverse row order, reverse column order , and transpose blocks form a group: the group of reflections of a matrix. The APL symbols are all a circle with a line through it; the lines are the different axes of reflection. So the reverse row order block reverses which row is where; the reverse column order block reverses which column is where; and the transpose block turns rows into columns and vice versa:

The image shows three APL blocks with accompanying matrices. The first block, 'reverse row order (column contents) ⌈', shows a 3x4 matrix with rows [9, 5, 1] and columns [A, B, C, D]. The second block, 'reverse column order (row contents) ⌋', shows a 3x4 matrix with columns [4, 8, 12] and rows [A, B, C, D]. The third block, 'transpose ⌚ reshape as list 3 4 ⌈ ⌋ items of 1 12', shows a 4x3 matrix with rows [1, 2, 3, 4] and columns [A, B, C].

	A	B	C	D
1	9	10	11	12
2	5	6	7	8
3	1	2	3	4

	A	B	C	D
1	4	3	2	1
2	8	7	6	5
3	12	11	10	9

	A	B	C
1	1	5	9
2	2	6	10
3	3	7	11
4	4	8	12

Except for reverse row order, these work only on full arrays, not ragged-right lists of lists, because the result of the other two would be an array in which some rows had “holes”: items 1 and 3 exist, but not item 2. We don’t have a representation for that. (In APL, all arrays are full, so it’s even more restrictive.)

C.1.3. Higher order functions

The final category of function is operators –APL higher order functions. APL has no explicit map function, because the hyperblock capability serves much the same need. But APL2 did add an explicit map, which we might get around to adding to the library next time around. Its symbol is “ (diaeresis or umlaut).

The APL equivalent of keep is compress, but it’s not a higher order function. You create a vector of Booleans (0s and 1s, in APL) before applying the function to the array you want to compress.

But APL does have a higher order version of combine:

The image shows two APL blocks. The first block, 'combine in rows (reduce by column vectors) / ⌊', has a symbol with a diagonal line. The second block, 'combine in columns (reduce by row vectors) ⌋ ⌈', has a symbol with a diagonal line and a dot.

The reduce block works just like combine, taking a dyadic function and a list. The / version translates each row to a single value; the ⌋ version translates each column to a single value. That’s the only way to think about it from the perspective of combining individual elements: you are adding up, or whatever the function is, the numbers in a single row (/) or in a single column (⌊). But APLers think of a matrix as made up of vectors, either row vectors or column vectors. And if you think of what these blocks do as adding vectors, rather than adding individual numbers, it’s clear that in

A screenshot of the Scratch IDE showing a script. The script starts with a **reshape as list [3 4 <--> p items of 1 12]** block. A callout bubble shows a 3x4 matrix with columns labeled A, B, C, D and rows labeled 1, 2, 3. The matrix contains the following values:

	A	B	C	D
1	1	2	3	4
2	5	6	7	8
3	9	10	11	12

The script continues with a **combine in rows (reduce by column vectors)** block followed by a **reshape as list [3 4 <--> p items of 1 12]** block. A callout bubble shows a vertical vector with three elements: 10, 26, and 42. Below it, a note says "+ length: 3".

the vector $(10, 26, 42)$ is the sum of column vectors $(1, 5, 9) + (2, 6, 10) + (3, 7, 11) + (4, 8, 12)$. In pre-6.0 Snap!, we'd get the same result this way:

The script uses a **map** block with a **combine [] using + over** block nested inside. The **map** block also includes a **reshape as list [3 4 <--> p items of 1 12]** block.

mapping over the rows of the matrix, applying **combine** to each row. Combining rows, reducing column vectors.

outer product The outer product block takes two arrays (vectors, typically) and a dyadic scalar function as inputs. It reports an array whose rank is the sum of the ranks of the inputs (so, typically a matrix), in which each item is the result of applying the function to an atomic element of each array. The third element of the second row of the result is the value reported by the function with the second element of the left input and the third element of the right input. (The APL symbol $\circ.$ is pronounced “jot dot.”) The way to think about this block is “multiplication table” from elementary school:

A screenshot of the Scratch IDE showing a script. The script starts with an **outer product** block with two "numbers from 1 to 10" inputs and a $\circ.$ operation. A callout bubble shows a 10x10 multiplication table where each cell i,j is the product of i and j .

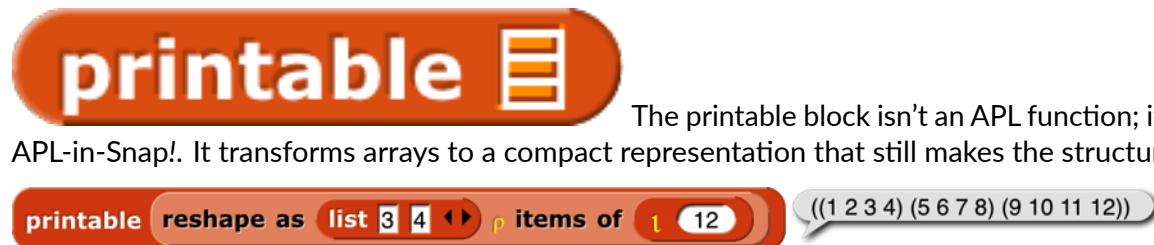
inner product The inner product block takes two matrices and two operations as input. The number of columns in the left matrix must equal the number of rows in the right matrix. When the two operations are $+$ and \times , this is the matrix multiplication familiar to mathematicians:

A screenshot of the Scratch IDE showing a script. The script uses an **inner product** block with two "reshape as list [3 4 <--> p items of 1 12]" inputs and operations \times and $+$. A callout bubble shows a 3x2 matrix A and a 2x3 matrix B, with their product calculated as follows:

	A	B
1	250	260
2	634	660
3	1018	1060

But other operations can be used. One common inner product is $\cdot \cdot$ (“or dot and”) applied to Boolean matrices, to find rows and columns that have corresponding items in common.

C. Appendix B. APL features



Experts will recognize this as the Lisp representation of list structure.

The Snap! Community Site

The Snap! community website is what you see when you visit <https://snap.berkeley.edu>. {#sec-appendix-community}

User Accounts

Saving and Loading Projects

Sharing and Publishing Projects

Creating Project Collections

Sharing and Publishing Collections

Collaborating on Collections

“Free for All” Collections

All Snap! Blocks

Table C.1.: All Snap! Blocks

Block	Text Label	Type	Category	Lisp
	move _ steps	command	motion	(move 10)
	turn \$clockwise _ degrees	command	motion	(right 15)
	turn \$counterclockwise _ degrees	command	motion	(left 15)
	point in direction _	command	motion	(head 90)
	point towards _	command	motion	(face [mouse-pointer])
	go to x: _ y: _	command	motion	(go 0 0)
	go to _	command	motion	(goto "[random position]")
	glide _ secs to x: _ y: _	command	motion	(glide 1 0 0)
	change x by _	command	motion	(+x 10)
	set x to _	command	motion	(x= 0)
	change y by _	command	motion	(+y 10)
	set y to _	command	motion	(y= 0)
	if on edge, bounce	command	motion	(bounce)
	position	reporter	motion	(pos)
	x position	reporter	motion	(x)
	y position	reporter	motion	(y)
	direction	reporter	motion	(dir)
	switch to costume _	command	looks	(wear nil)
	next costume	command	looks	(next)
	costume #	reporter	looks	(costume#)
	say _ for _ secs	command	looks	(sayFor Hello! 2)

Block	Text Label	Type	Category	Lisp
	say _	command	looks	(say Hello!)
	think _ for _ secs	command	looks	(thinkFor Hmm... 2)
	think _	command	looks	(think Hmm...)
	_ of costume _	reporter	looks	(costume [width] [current])
	stretch _ x: _ y: _ %	reporter	looks	(stretch [current] 100 50)
	skew _ to _ degrees _ %	reporter	looks	(skew [current] 0 50)
	new costume _ width _ height _	reporter	looks	(newCostume nil nil nil)
	change _ effect by _	command	looks	(+effect [ghost] 25)
	set _ effect to _	command	looks	(effect= [ghost] 0)
	clear graphic effects	command	looks	(clearEffects)
	_ effect	reporter	looks	(effect [ghost])
	change size by _	command	looks	(+size 10)
	set size to _ %	command	looks	(size= 100)
	size	reporter	looks	(size)
	show	command	looks	(show)
	hide	command	looks	(hide)
	shown?	predicate	looks	(shown)
	go to _ layer	command	looks	(layer [front])
	go back _ layers	command	looks	(back 1)
	play sound _	command	sound	(play nil)

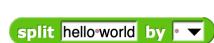
Block	Text Label	Type	Category	Lisp
play sound until done	play sound _ until done	command	sound	(playAll nil)
stop all sounds	stop all sounds	command	sound	(stopSounds)
play sound at Hz	play sound _ at _ Hz	command	sound	(playAt nil 44100)
duration of sound	_ of sound _	reporter	sound	(sound [duration] nil)
new sound rate Hz	new sound _ rate _ Hz	reporter	sound	(newSound nil 44100)
rest for beats	rest for _ beats	command	sound	(rest 0.2)
play note for beats	play note _ for _ beats	command	sound	(note 60 0.5)
set instrument to	set instrument to _	command	sound	(instrument 1)
change tempo by	change tempo by _	command	sound	(+tempo 20)
set tempo to bpm	set tempo to _ bpm	command	sound	(tempo= 60)
tempo				
change volume by	tempo	reporter	sound	(tempo)
set volume to %	change volume by _	command	sound	(+vol 10)
volume	set volume to _ %	command	sound	(vol= 100)
volume				
change balance by	volume	reporter	sound	(vol)
set balance to	change balance by _	command	sound	(+pan 10)
balance	set balance to _	command	sound	(pan= 0)
play frequency Hz	balance	reporter	sound	(pan)
stop frequency	play frequency _ Hz	command	sound	(freq 440)
stop frequency	stop frequency	command	sound	(stopFreq)
clear				
clear		command	pen	(clear)
pen down				
pen down		command	pen	(down)
pen up				
pen up		command	pen	(up)
pen down?	pen down?	predicate	pen	(down?)
set pen color to	set pen color to _	command	pen	(setColor "rgba(145,26,68,1)
change pen hue by	change pen _ by _	command	pen	(+pen [hue] 10)

Block	Text Label	Type	Category	Lisp
set pen hue to 50	set pen _ to _	command	pen	(pen= [hue] 50)
pen hue ▾	pen _	reporter	pen	(pen [hue])
change pen size by 1	change pen size by _	command	pen	(+penSize 1)
set pen size to 1	set pen size to _	command	pen	(penSize= 1)
stamp	stamp	command	pen	(stamp)
fill	fill	command	pen	(fill)
write Hello! size 12	write _ size _	command	pen	(write Hello! 12)
pen trails	pen trails	reporter	pen	(trails)
paste on ▾	paste on _	command	pen	(paste nil)
cut from ▾	cut from _	command	pen	(cut nil)
broadcast ▾ ▶	broadcast _ _	command	control	(send nil)
broadcast ▾ and wait	broadcast _ _ and wait	command	control	(sendAll nil)
wait 1 secs	wait _ secs	command	control	(wait 1)
wait until ▾	wait until _	command	control	(waitFor nil)
forever	forever _	command	control	(forever nil)
repeat 10	repeat _ _	command	control	(repeat 10 nil)
repeat until ▾	repeat until _ _	command	control	(until nil nil)
for i = 1 to 10	for _ = _ to _ _	command	control	(for i 1 10 nil)

Block	Text Label	Type	Category	Lisp
	if _ _ _	command	control	(if nil nil)
	if _ _ else _	command	control	(ifElse nil nil nil)
	if _ then _ else _	reporter	control	(ifThen nil nil nil)
	report _	command	control	(report nil)
	stop _	command	control	(stop [all])
	run _ _	command	control	(run nil)
	launch _ _	command	control	(fork nil)
	call _ _	reporter	control	(call nil)
	pipe _ \$arrowRight _	reporter	control	(pipe nil nil)
	tell _ to _ _	command	control	(tell nil nil)
	ask _ for _ _	reporter	control	(ask nil nil)
	create a clone of _	command	control	(clone [myself])
	a new clone of _	reporter	control	(newClone [myself])
	delete this clone	command	control	(removeClone)
	pause all \$pause	command	control	(pause)
	switch to scene _ _	command	control	(scene [next])

Block	Text Label	Type	Category	Lisp
	define _ _ _	command	control	(define block nil nil)
	delete block _	command	control	(deleteBlock nil)
	set _ of block _ to _	command	control	(setBlock [label] nil nil)
	_ of block _	reporter	control	(block [definition] nil)
	this _	reporter	control	(this [script])
	set slot _ to _	command	control	(doSetSlot nil nil)
	touching _ ?	predicate	sensing	(touch [mouse-pointer])
	touching _ ?	predicate	sensing	(touchColor "rgba(145,26,68,1")
	color _ is touching _ ?	predicate	sensing	(colorTouch "rgba(145,26,68,1") "rgba(145,26,68,1")
	ask _ and wait	command	sensing	(doAsk "what's your name?")
	answer	reporter	sensing	(answer)
	mouse position	reporter	sensing	(mouse)
	mouse x	reporter	sensing	(mouseX)
	mouse y	reporter	sensing	(mouseY)
	mouse down?	predicate	sensing	(mouseDown)
	key _ pressed?	predicate	sensing	(key [space])
	_ to _	reporter	sensing	(relation [distance] [mouse-pointer])
	_ at _	reporter	sensing	(aspect [hue] [mouse-pointer])
	reset timer	command	sensing	(resetTimer)

Block	Text Label	Type	Category	Lisp
	timer	reporter	sensing	(timer)
	current _	reporter	sensing	(current [date])
	_ of _	reporter	sensing	(attribute "[costume #]" nil)
	my _	reporter	sensing	(my [neighbors])
	object _	reporter	sensing	(object [myself])
	url _	reporter	sensing	(url snap.berkeley.edu)
	microphone _	reporter	sensing	(audio [volume])
	video _ on _	reporter	sensing	(video [motion] [myself])
	set video transparency to _	command	sensing	(transparency 50)
	is _ on?	predicate	sensing	(global "[turbo mode]")
	set _ to _	command	sensing	(global= "[video capture]" nil)
	-	reporter	operators	(+ nil nil)
	- - -	reporter	operators	(- nil nil)
	-	reporter	operators	(* nil nil)
	- / -	reporter	operators	(/ nil nil)
	- ^ -	reporter	operators	(^ nil nil)
	_ mod _	reporter	operators	(mod nil nil)
	-	reporter	operators	(min nil nil)

Block	Text Label	Type	Category	Lisp
 max	_	reporter	operators	(max nil nil)
 round	round _	reporter	operators	(round nil)
 sqrt ▾ of 10	_ of _	reporter	operators	(fn [sqrt] 10)
 atan2	_ ÷ _	reporter	operators	(atan2 nil nil)
 pick random 1 to 10	pick random _ to _	reporter	operators	(rand 1 10)
 <	_	predicate	operators	(< nil nil)
 =	_	predicate	operators	(= nil nil)
 >	_	predicate	operators	(> nil nil)
 and	_	predicate	operators	(and nil nil)
 or	_	predicate	operators	(or nil nil)
 not	not _	predicate	operators	(not nil)
 true	_	predicate	operators	(bool t)
 join hello world	join _	reporter	operators	(join "hello " "world")
 split hello world by	split _ by _	reporter	operators	(split "hello world" " ")
 letter 1 of world	letter _ of _	reporter	operators	(letter 1 world)
 length ▾ of text world	_ of text _	reporter	operators	(text [length] world)
 unicode of a	unicode of _	reporter	operators	(unicode a)
 unicode 65 as letter	unicode _ as letter	reporter	operators	(toLetter 65)
 is 5 a number ?	is _ a _ ?	predicate	operators	(is 5 [number])
 is _ identical to _ ?	is _ ?	predicate	operators	(same nil nil)

Block	Text Label	Type	Category	Lisp
 JavaScript function () ()	JavaScript function (_) { _ }	reporter	operators	(js nil nil)
 set [] to 0	set _ to _	command	variables	(set nil 0)
 change [] by 1	change _ by _	command	variables	(+= nil 1)
 show variable []	show variable _	command	variables	(showVar nil)
 hide variable []	hide variable _	command	variables	(hideVar nil)
 inherit []	inherit _	command	variables	(inherit nil)
 list []	list _	reporter	lists	(list nil)
 numbers from 1 to 10	numbers from _ to _	reporter	lists	(range 1 10)
 [] in front of []	_ in front of _	reporter	lists	(cons nil nil)
 item 1 of []	item _ of _	reporter	lists	(item 1 nil)
 all but first of []	all but first of _	reporter	lists	(cdr nil)
 length of []	_ of _	reporter	lists	(data [length] nil)
 index of thing in []	index of _ in _	reporter	lists	(# thing nil)
 [] contains thing	_ contains _	predicate	lists	(contains nil thing)
 is [] empty?	is _ empty?	predicate	lists	(empty nil)
 map [] over []	map _ over _	reporter	lists	(map nil nil)
 keep items [] from []	keep items _ from _	reporter	lists	(keep nil nil)
 find first item [] in []	find first item _ in _	reporter	lists	(find nil nil)
 combine [] using []	combine _ using _	reporter	lists	(combine nil nil)
 for each item [] in []	for each _ in _ _	command	lists	(forEach item nil nil)

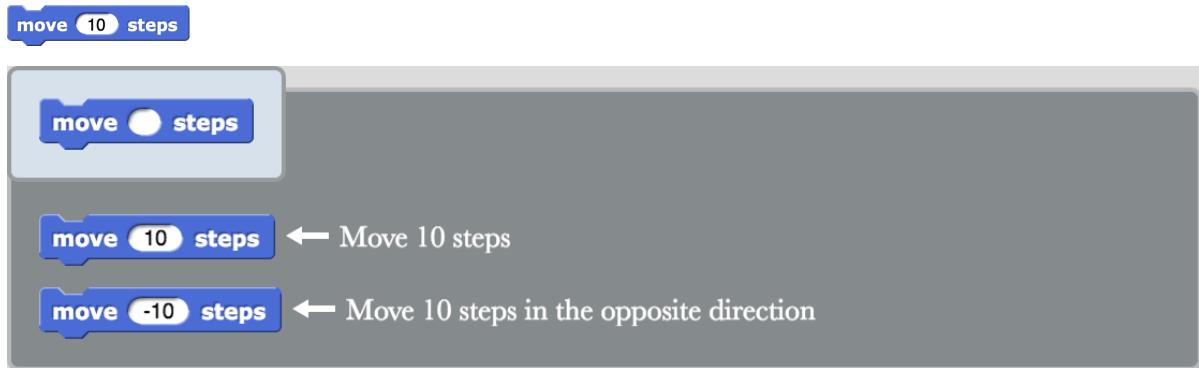
Block	Text Label	Type	Category	Lisp
add [thing] to [list]	add _ to _	command	lists	(add thing nil)
delete [1] of [list]	delete _ of _	command	lists	(del 1 nil)
insert [thing] at [1] of [list]	insert _ at _ of _	command	lists	(ins thing 1 nil)
replace item [1] of [list] with [thing]	replace item _ of _ with _	command	lists	(put 1 nil thing)
append [list1] [list2]	append _	reporter	lists	(append nil nil)
reshape [list] to [4] [3]	reshape _ to _	reporter	lists	(reshape nil 4 3)
combinations [list] [n]	combinations _	reporter	lists	(combinations nil nil)

Part I.

Motion Blocks

move steps

Moves a sprite a set number of steps (one coordinate) in whichever direction the sprite is facing.



Example Images

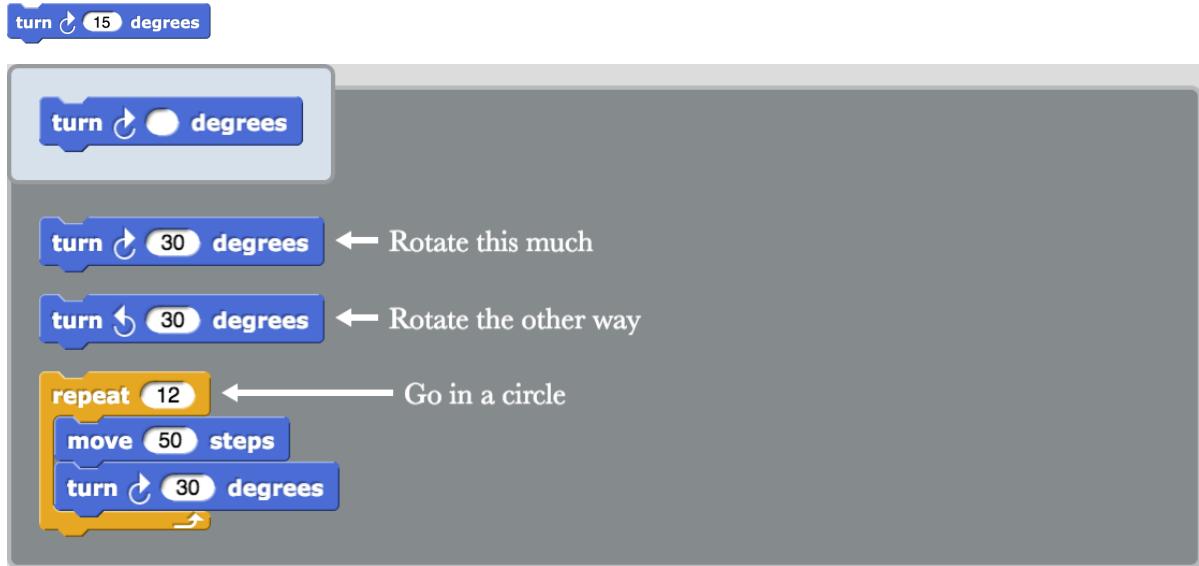
No examples yet.

Example Projects

No examples yet.

turn degrees

Turns the sprite a specified degree of angle in the clockwise direction



Example Images

No examples yet.

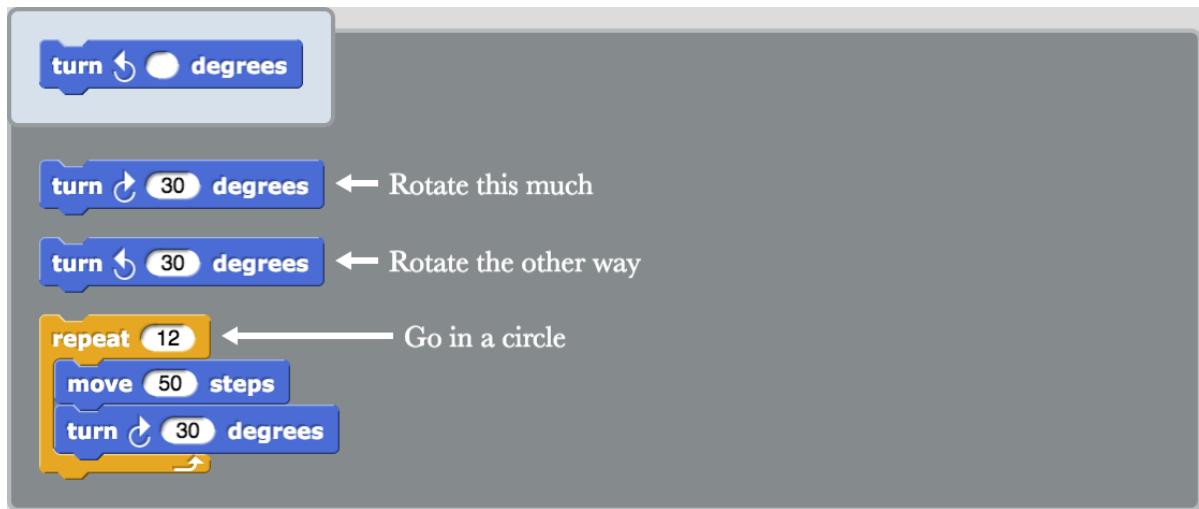
Example Projects

No examples yet.

turn degrees

Complete Me

turn  15 degrees



Example Images

No examples yet.

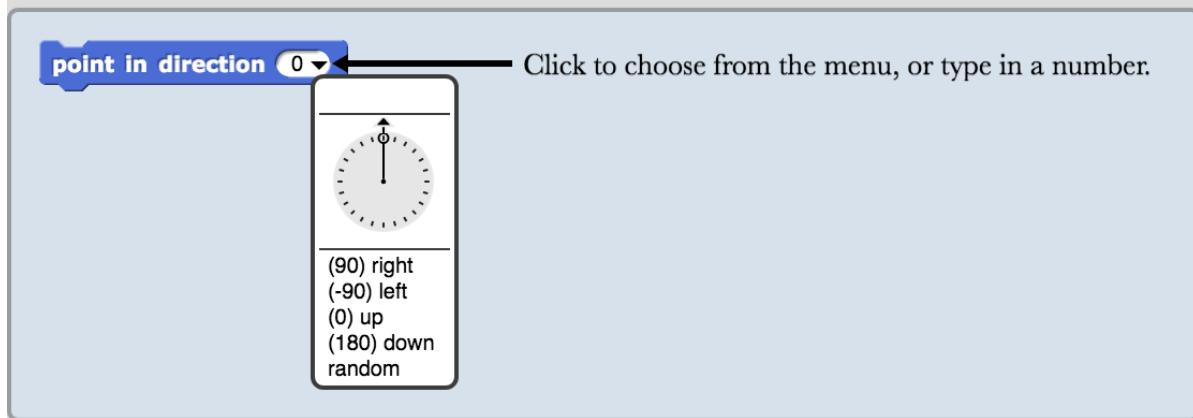
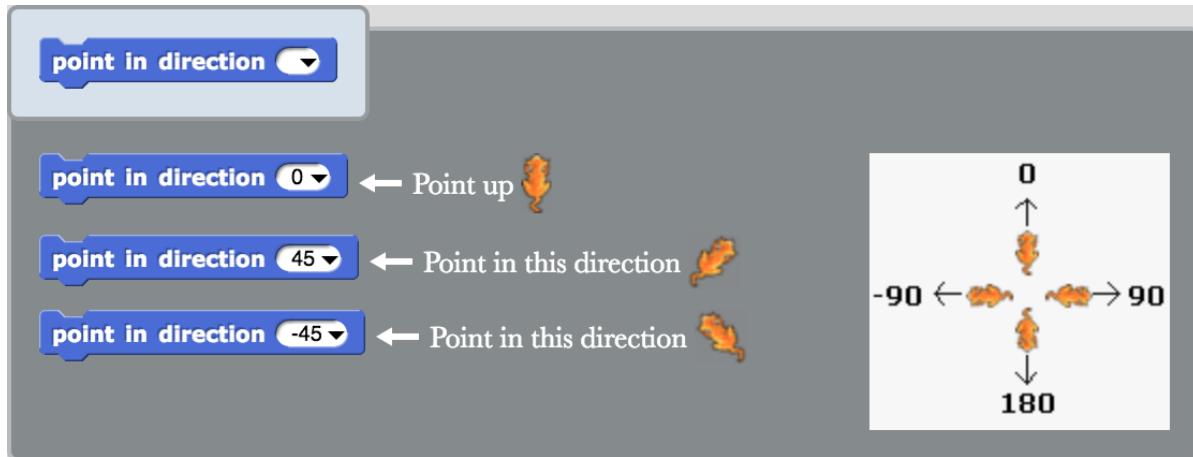
Example Projects

No examples yet.

point in direction

Complete Me

point in direction 90 ▾



Example Images

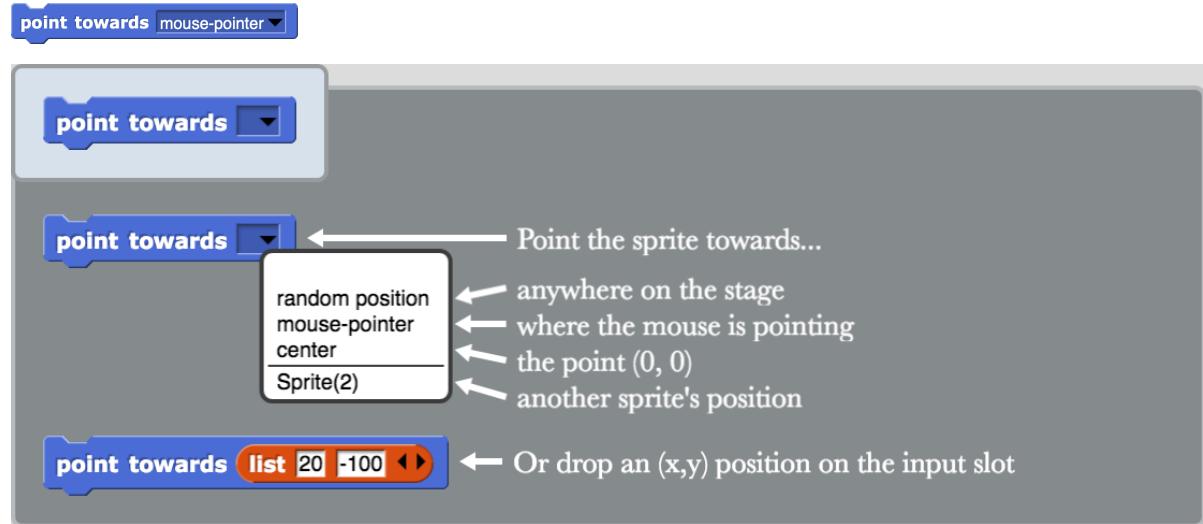
No examples yet.

Example Projects

No examples yet.

point towards

Complete Me



Example Images

No examples yet.

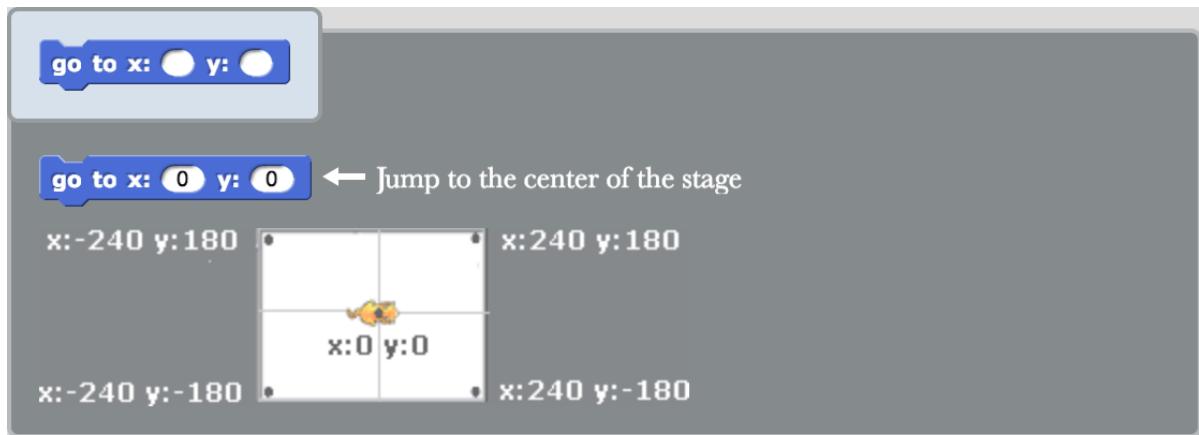
Example Projects

No examples yet.

go to x: y:

Complete Me

go to x: 0 y: 0



You can use **go to x: 0 y: 0** to tell a sprite to jump to any location on the stage.

Example Images

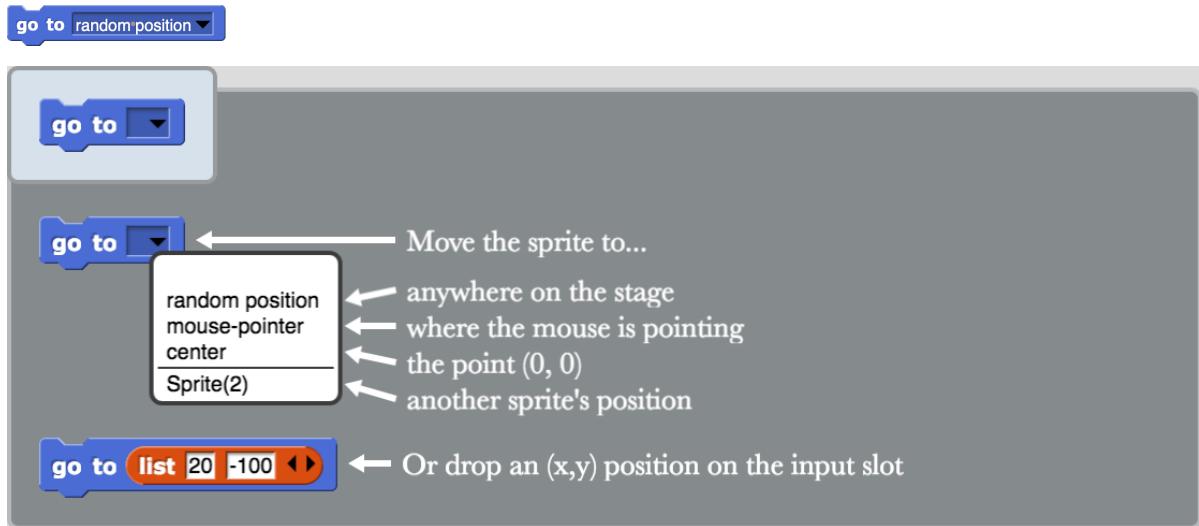
No examples yet.

Example Projects

No examples yet.

go to

Complete Me



Example Images

No examples yet.

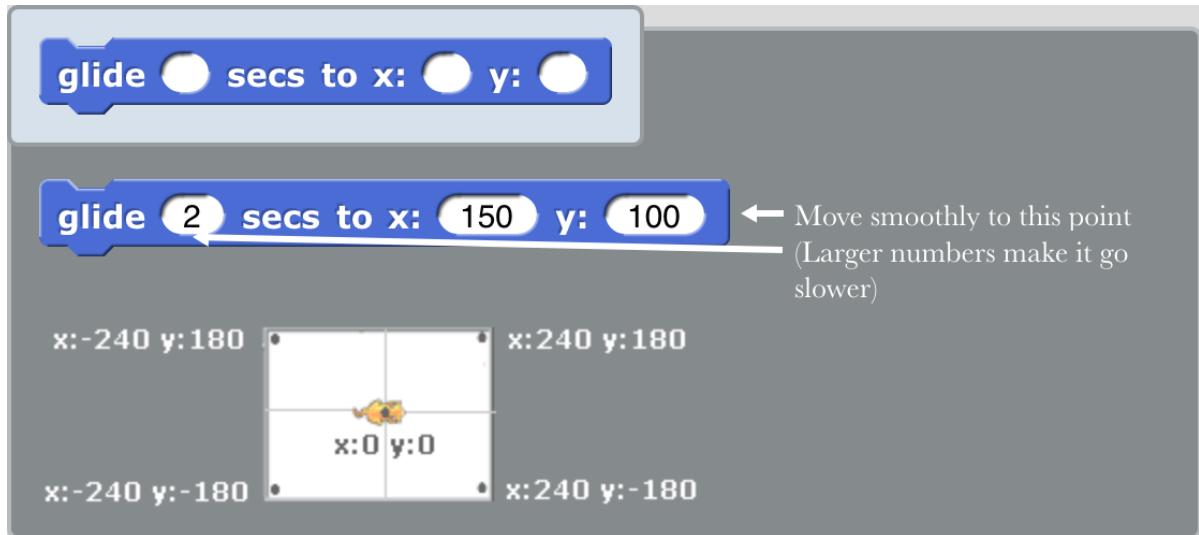
Example Projects

No examples yet.

Glide Secs to Position

Complete Me

glide 1 secs to x: 0 y: 0



Example Images

No examples yet.

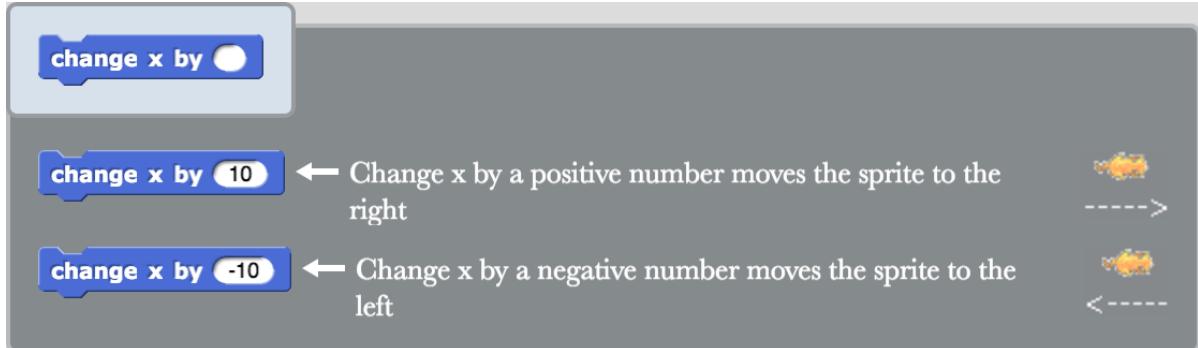
Example Projects

No examples yet.

change x by

Complete Me

change x by 10



Example Images

No examples yet.

Example Projects

No examples yet.

set x to

Complete Me

A Scratch script consisting of the following blocks:

- set x to [0]** (Top)
- set x to [0]** ← Jump to the middle of stage
- wait [1 sec]** ← Wait one second
- set x to [240]** ← Jump to the far right edge of stage
- wait [1 sec]** ← Wait one second
- set x to [-240]** ← Jump to the far left edge of stage

The stage shows a yellow fish sprite at the center (x:0). The stage width is marked as 240 units, with -240 on the left edge and 240 on the right edge.

set x to [] sets the sprite's x position (left to right). Type in a negative number to make the sprite go to the left side of the stage. Type in a positive number to go to the right side of the stage.

Example Images

No examples yet.

Example Projects

No examples yet.

change y by

Complete Me

change y by 10



change y by 10

← Change y by a positive number moves the sprite up



change y by -10

← Change y by a negative number moves the sprite down

Example Images

No examples yet.

Example Projects

No examples yet.

set y to

Complete Me

set y to 0

A Scratch script consisting of the following blocks:

- set y to [0 v]
- set y to [0 v] ← Jump to the middle of stage
- wait [1 sec] v
- set y to [180 v] ← Jump to the top of stage
- wait [1 sec] v
- set y to [-180 v] ← Jump to the bottom of stage

The stage shows a yellow cat sprite at the center, with its y-position labeled as 0. Reference lines indicate the top at 180, the middle at 0, and the bottom at -180.

set y to sets the sprite's y position (up and down). Type in a negative number to make the sprite go to the bottom half of the stage. Type in a positive number to go to the top half of the stage.

Example Images

No examples yet.

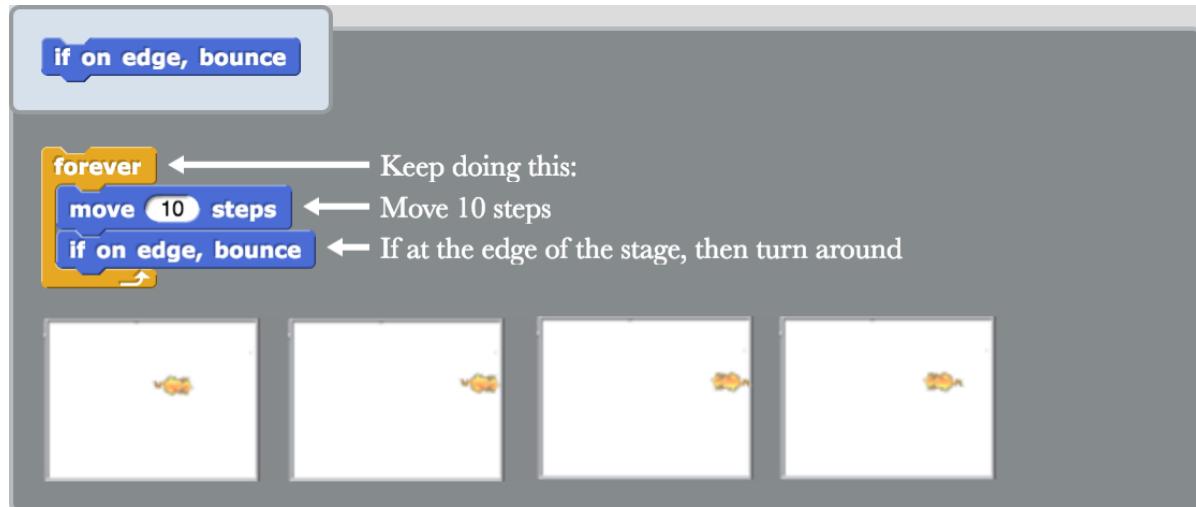
Example Projects

No examples yet.

if on edge, bounce

Complete Me

if on edge, bounce



if on edge, bounce checks to see if this sprite has reached the edge – and if it has, it turns away from the edge. (And then is ready for the next move.)

Example Images

No examples yet.

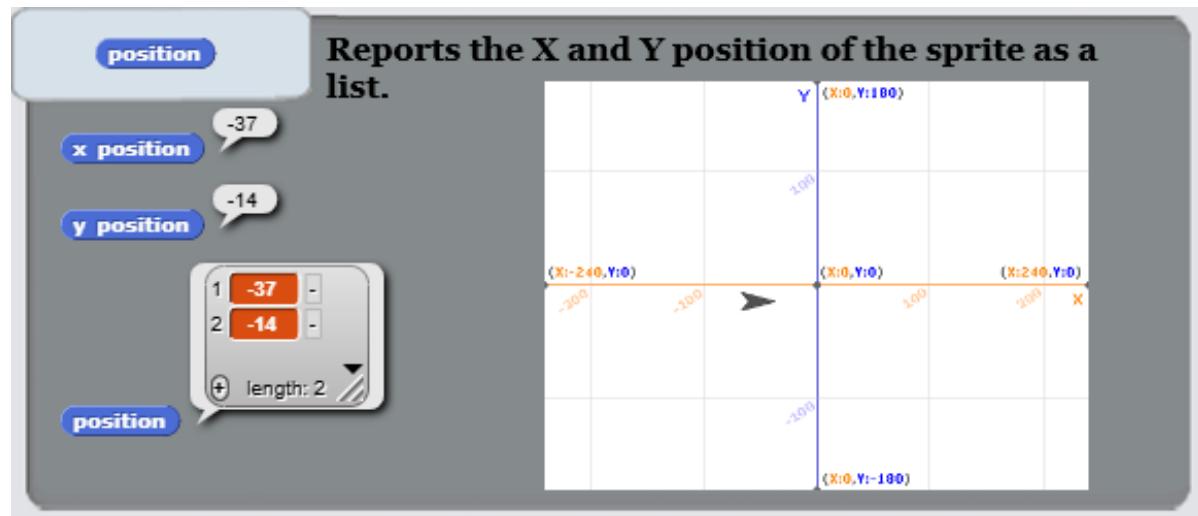
Example Projects

No examples yet.

position

Complete Me

position



Example Images

No examples yet.

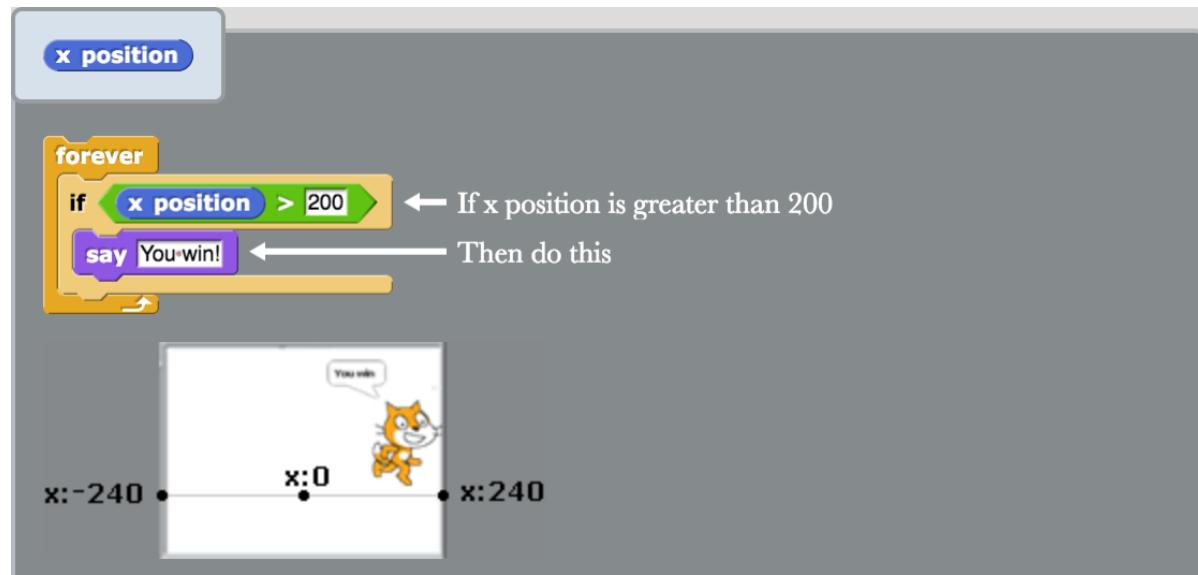
Example Projects

No examples yet.

x position

Complete Me

x position



Example Images

No examples yet.

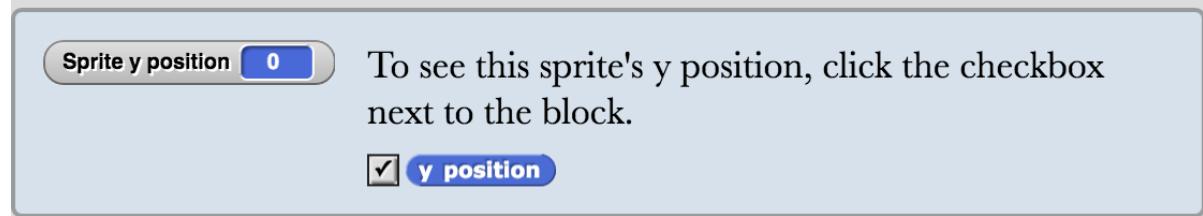
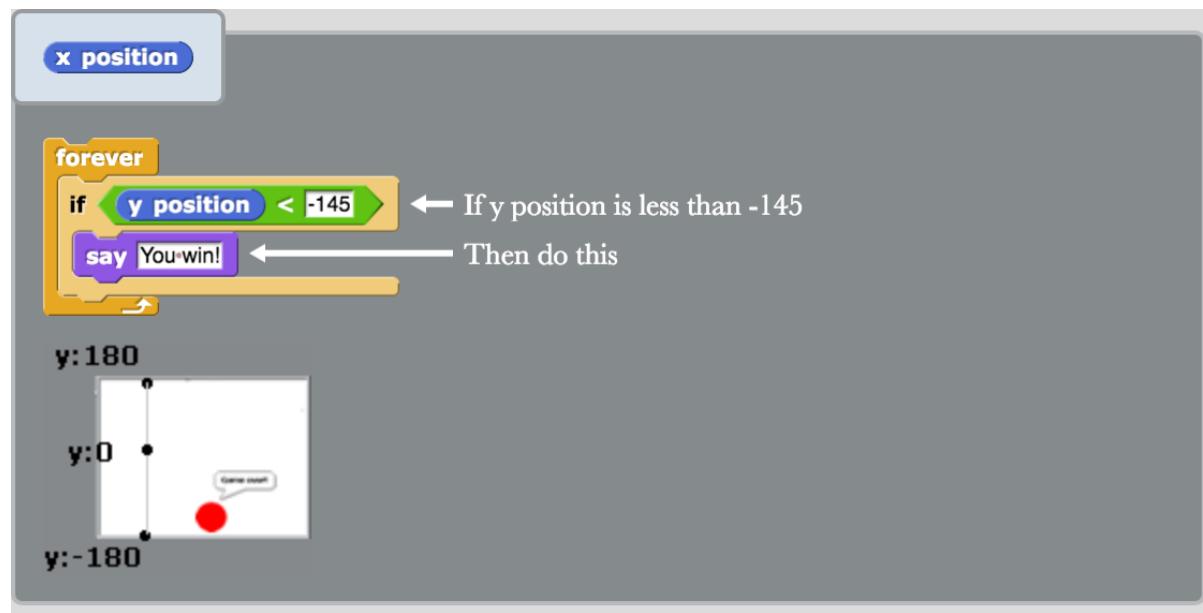
Example Projects

No examples yet.

y position

Complete Me

y position



Example Images

No examples yet.

Example Projects

No examples yet.

direction

Complete Me

direction

A Scratch script consisting of a grey hat block labeled "direction". Inside is a "forever" loop. The loop contains an "if" condition: "if [direction v] = [0 v]" followed by a "say [Looking up!]" block. A callout points to the "if" condition with the text "If pointing in direction 0 (up)" and to the "say" block with "Then do this".

Sprite direction 90 To see this sprite's current direction, click the checkbox next to the block.

direction

Example Images

No examples yet.

Example Projects

No examples yet.

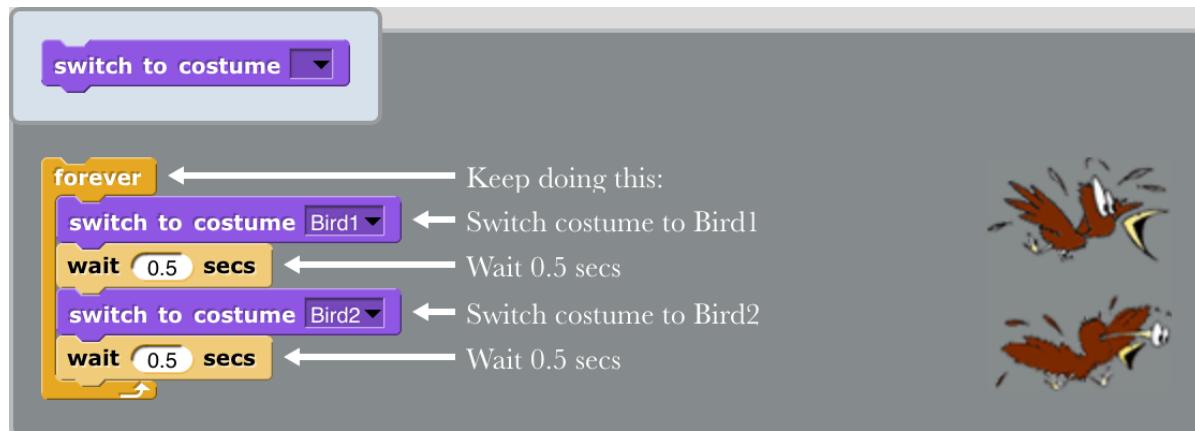
Part II.

Looks Blocks

switch to costume

Complete Me

switch to costume ▾



You can refer to a costume by name or by number. For example:

switch to costume happy face ▾

switch to costume which one

You can also use an actual computed costume:

switch to costume stretch happy face ▾ x: 200 y: 100 %

Example Images

No examples yet.

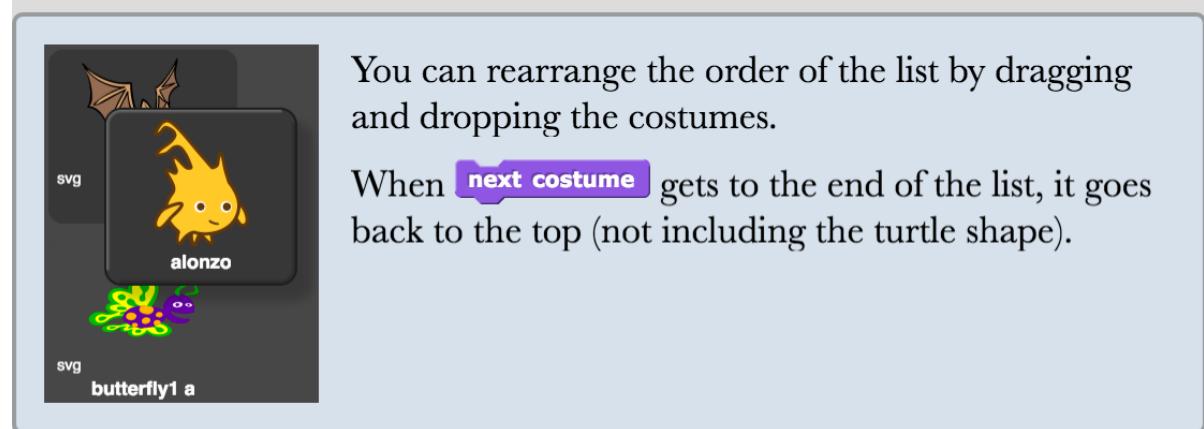
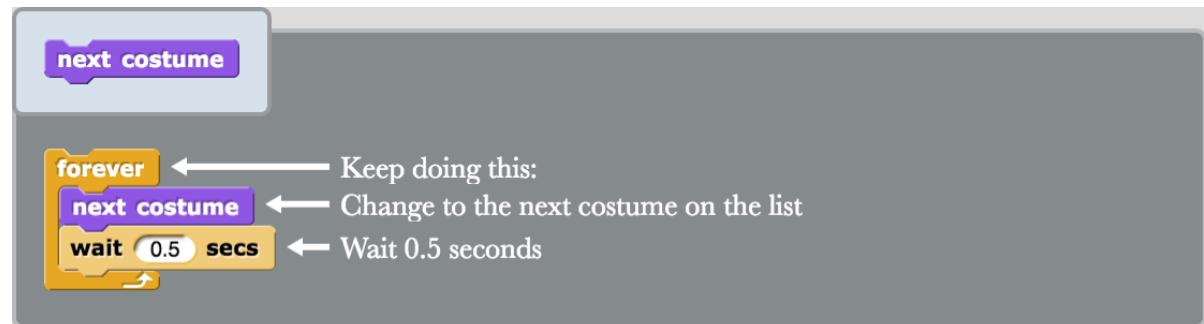
Example Projects

No examples yet.

next costume

Complete Me

next costume



Example Images

No examples yet.

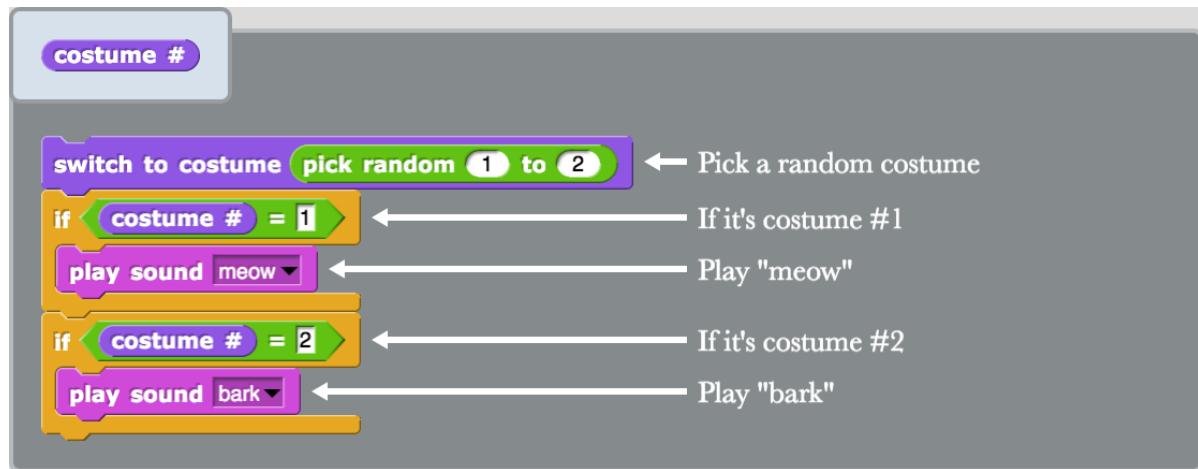
Example Projects

No examples yet.

costume number

Complete Me

costume #



Example Images

No examples yet.

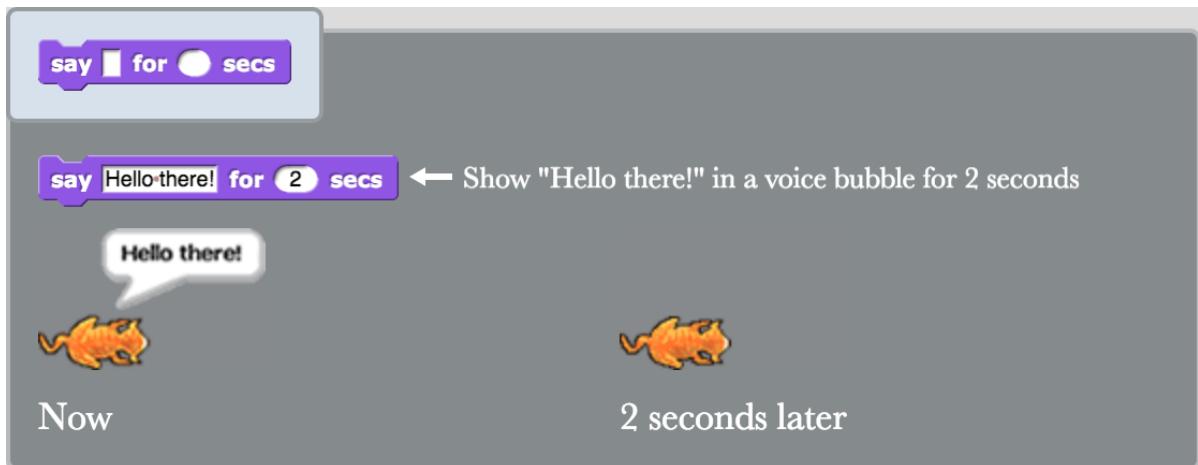
Example Projects

No examples yet.

say for secs

Complete Me

say Hello! for 2 secs



Example Images

No examples yet.

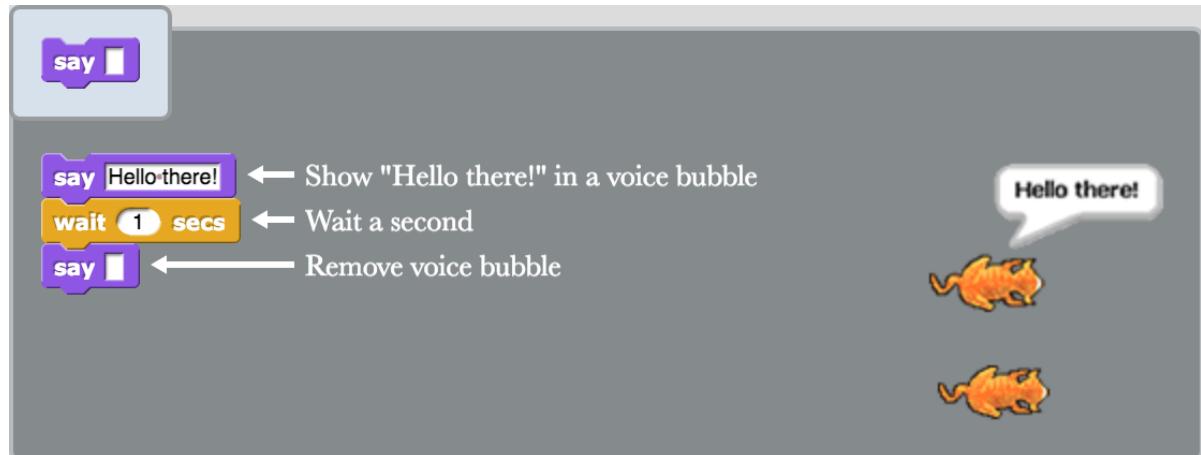
Example Projects

No examples yet.

say

Complete Me

say [Hello!]



You can type any phrase into **say**

The words will appear above the sprite, in a voice bubble.

Example Images

No examples yet.

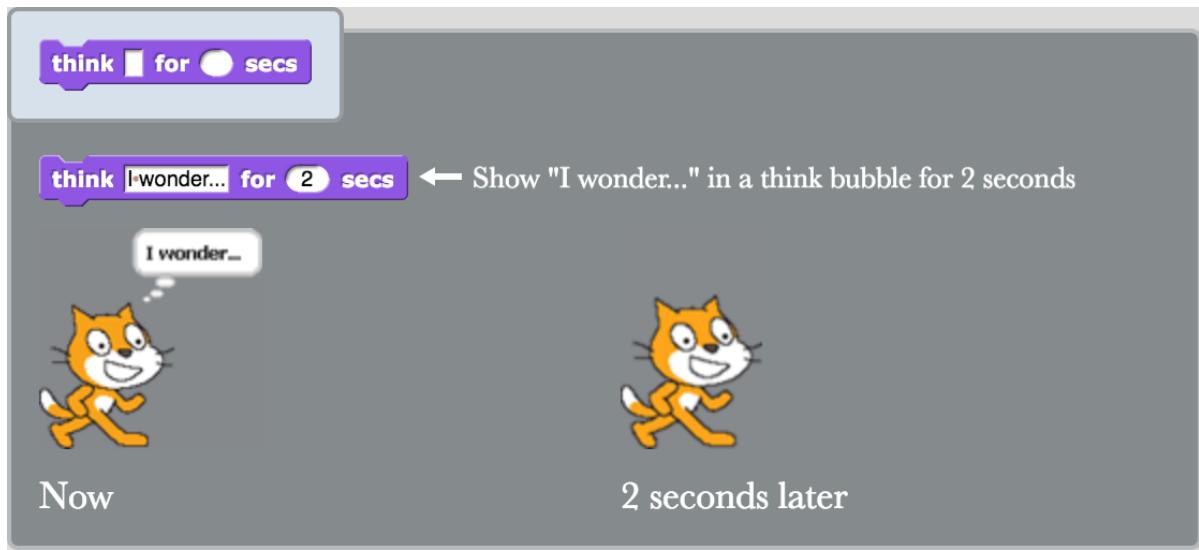
Example Projects

No examples yet.

think for secs

Complete Me

think Hmm... for 2 secs



Example Images

No examples yet.

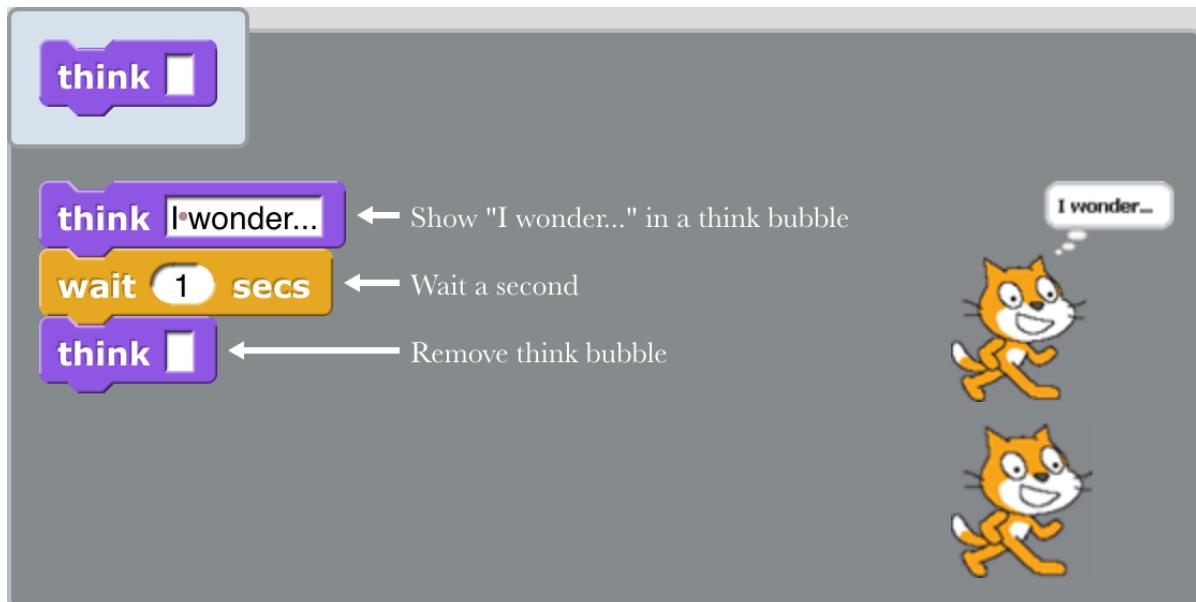
Example Projects

No examples yet.

think

Complete Me

think Hmm...



You can type any phrase into **think []**

The words will appear above the sprite, in a think bubble.

Example Images

No examples yet.

Example Projects

No examples yet.

Attribute of Costume

Complete Me

A Scratch script demonstrating costume attributes. It starts with a `width of costume current` control block. This triggers a loop that prints the width and height of the current costume in pixels. Inside the loop, there is a `show picture` control block with a list of costumes: Turtle, current, alonzo, ballerina, bear2, blue. A speech bubble shows the output of the script, which is a table of pixel values:

	A	B	C	D
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	47	6	255	92
9	47	7	255	235
10	47	6	255	255
11	47	6	255	255
12	47	6	255	255
13	47	6	255	255
14	47	6	255	255
15	47	6	255	255
16	47	6	255	255
17	47	6	255	255
18	47	6	255	255
19	47	6	255	255
20	47	6	255	255

Finally, the script ends with a `pixels of costume costume` control block.

Report attributes of a costume.

Width and height are reported in pixels, but don't change in presentation mode. Pixels are reported as a list of lists, in which each sublist is the RGBA values for one pixel (Red, Green, Blue, Alpha). "Alpha" is the opacity (inverse of ghost effect). All values are between 0 and 255.

The pixel list does not have width or height information; it needs a width to make it a viewable costume. `show picture` in the Pixels library uses the current costume's width.

Example Images

No examples yet.

Example Projects

No examples yet.

Stretch Costume

Complete Me

stretch [current ▾] x: 100 y: 50 %

Stretch a costume.



stretch [alonzo ▾] x: 100 y: 50 %



stretch [alonzo ▾] x: 50 y: 100 %

Note that this is a reporter, not a command! It reports the stretched costume. If you want the sprite to wear it, you have to say

switch to costume **stretch** [alonzo ▾] x: 50 y: 100 %

Note: If the first input is a list of pixels rather than a costume, then the x and y inputs are interpreted not as a percent (of the costume's original dimensions) but as an absolute number of pixels, so you can do this:



switch to costume
stretch
map
if item 4 of [] > 0 then 255 in front of [all but first of []]
else
over pixels of costume pen trails
x: width of costume pen trails y: height of costume pen trails %

1. Find **pixels** **of costume** **some costume**
2. Transform the pixels using MAP
3. Use STRETCH to restore the width and height

Example Images

No examples yet.

Example Projects

No examples yet.

Skew Costume by Degrees

Complete Me

skew current ▾ to 0 ▾ degrees 50 %



Example Images

No examples yet.

Example Projects

No examples yet.

New Costume

Complete Me

new costume  **width**  **height** 



Example Images

No examples yet.

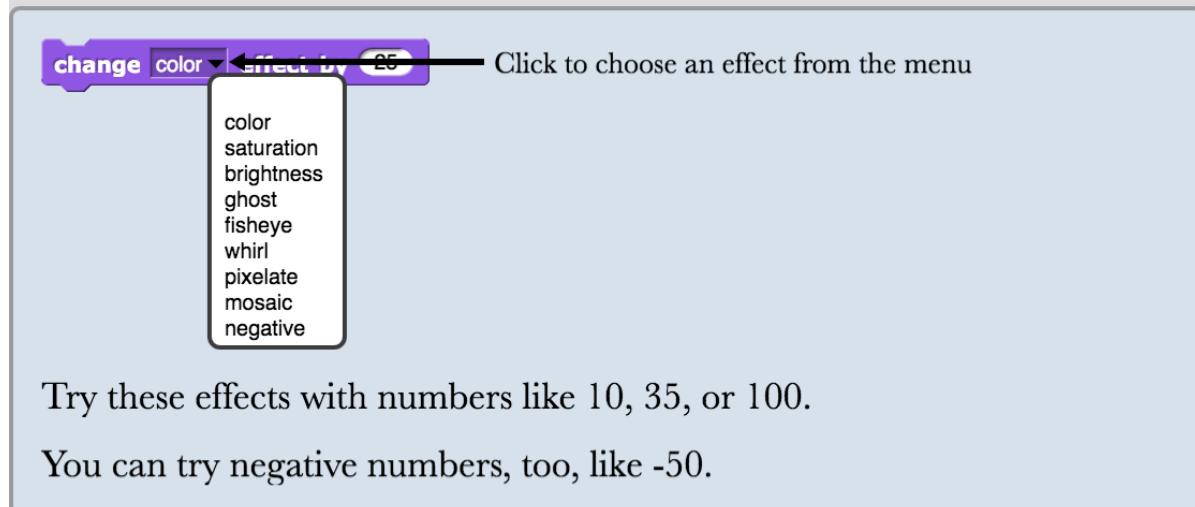
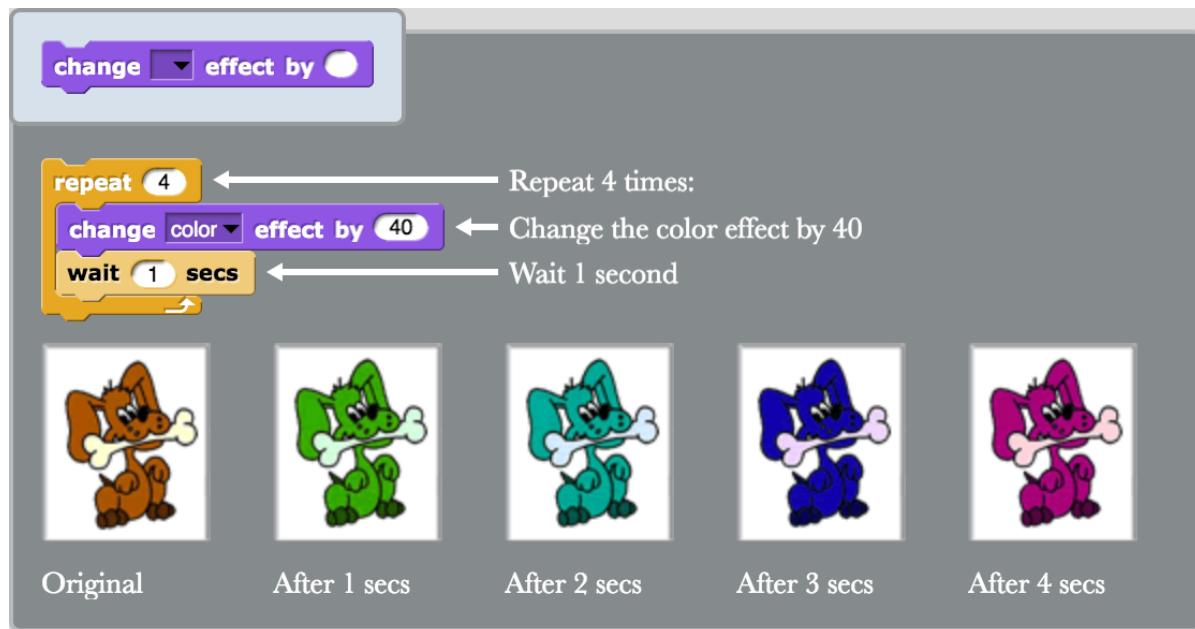
Example Projects

No examples yet.

change effect by

Complete Me

change ghost effect by 25



Example Images

No examples yet.

change effect by

Example Projects

No examples yet.

set effect to

Complete Me

set ghost effect to 0

set [color v] effect to [0]

set [color v] effect to [50]

set [fisheye v] effect to [50]

set [whirl v] effect to [50]

set [pixelate v] effect to [50]

set [mosaic v] effect to [50]

set [brightness v] effect to [50]

Click to choose an effect from the menu

← Type in a number between -100 and 100

- color
- saturation
- brightness
- ghost
- fisheye
- whirl
- pixelate
- mosaic
- negative

Example Images

No examples yet.

set effect to

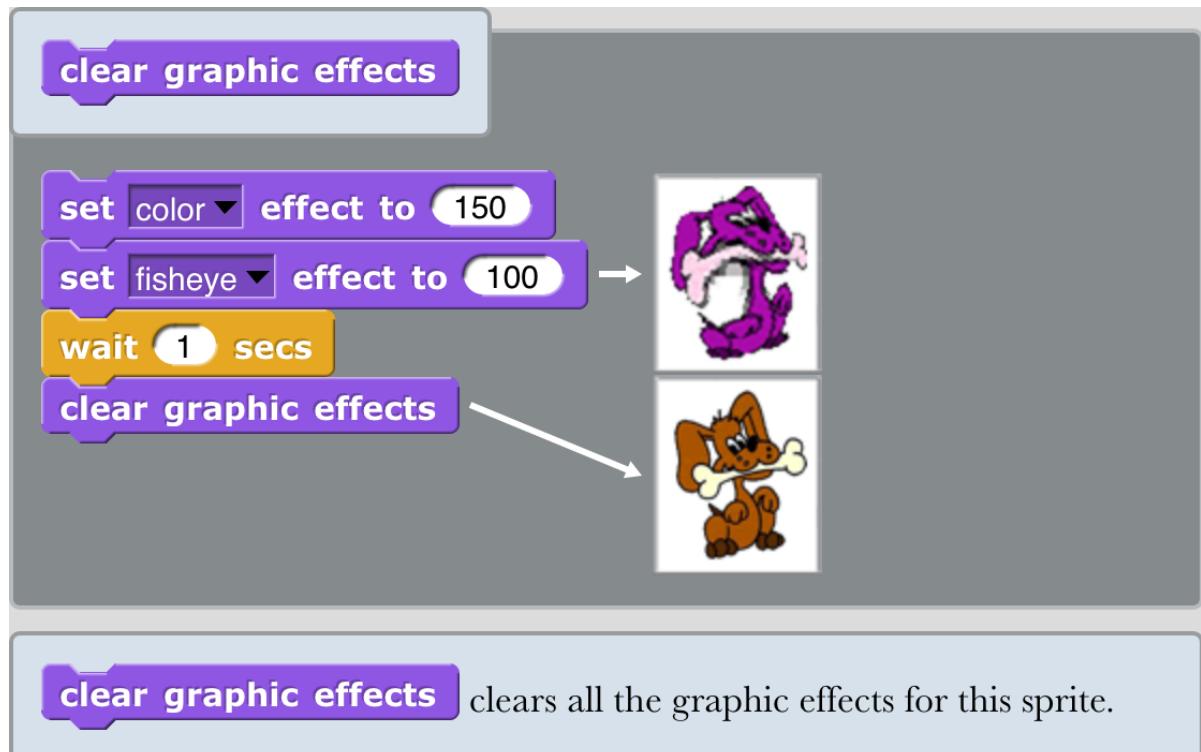
Example Projects

No examples yet.

clear graphic effects

Complete Me

clear graphic effects



Example Images

No examples yet.

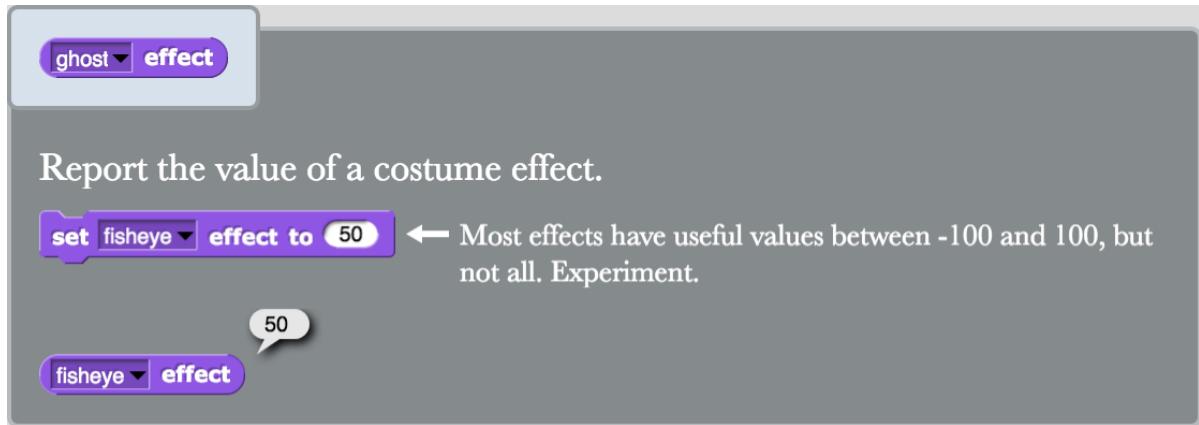
Example Projects

No examples yet.

_ effect

Complete Me

ghost ▾ effect



Example Images

No examples yet.

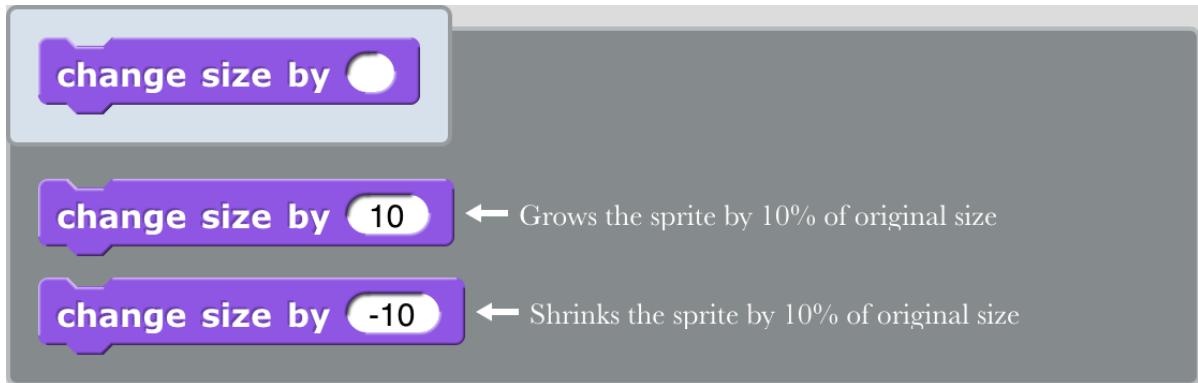
Example Projects

No examples yet.

change size by

Complete Me

change size by 10



Example Images

No examples yet.

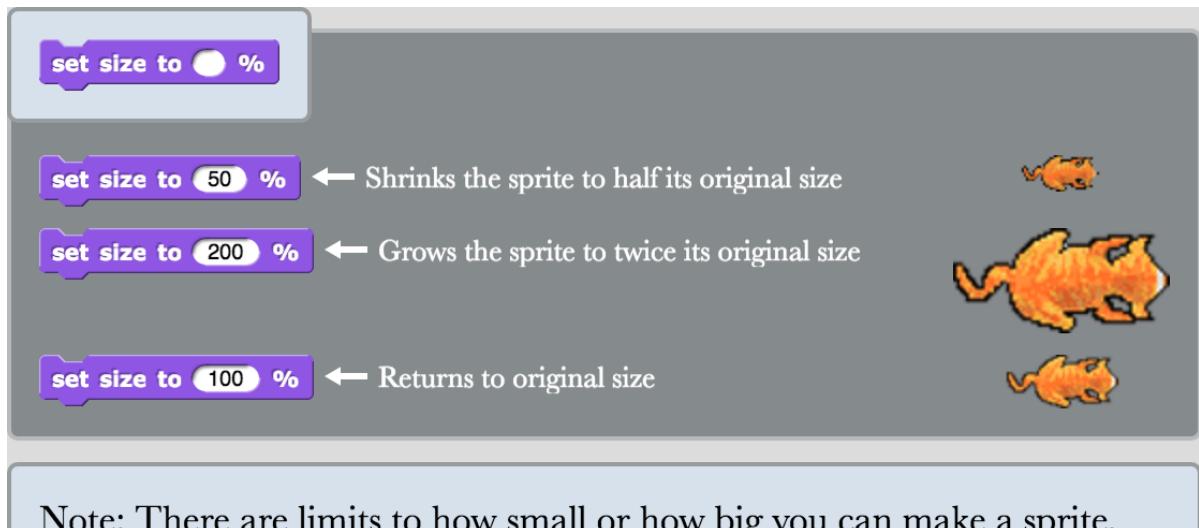
Example Projects

No examples yet.

Set Sprite Size

Complete Me

`set size to [100 %]`



A Scratch script demonstrating the effect of different size settings. It starts with a green cat sprite. The first script, "set size to [100 %]", is shown in a callout box. The second script, "set size to [50 %]", is followed by the text "← Shrinks the sprite to half its original size" and shows a smaller green cat. The third script, "set size to [200 %]", is followed by the text "← Grows the sprite to twice its original size" and shows a larger green cat. The fourth script, "set size to [100 %]", is followed by the text "← Returns to original size" and shows the original green cat again.

Note: There are limits to how small or how big you can make a sprite. Experiment with different numbers to see how small or big you can make it.

Example Images

No examples yet.

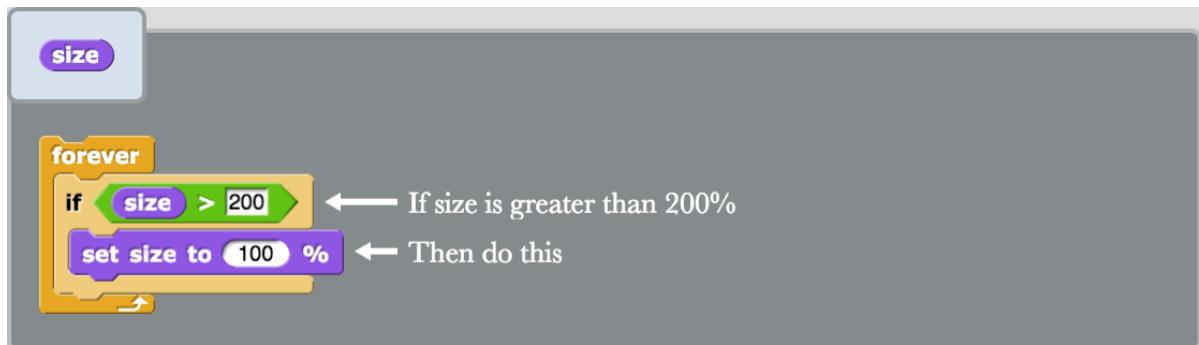
Example Projects

No examples yet.

size

Complete Me

size



size reports the % of the original size of the object.

Sprite size [100] To view the value of size, click the checkbox next to the block **size**

Note: There are limits to how small or how big you can make a sprite. Experiment with different numbers to see how small or big you can make it.

Example Images

No examples yet.

Example Projects

No examples yet.

show

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

hide

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

shown?

Complete Me

shown?

shown?

Report true if sprite is shown.

Use show to show the sprite.

Use hide to hide the sprite.

Example Images

No examples yet.

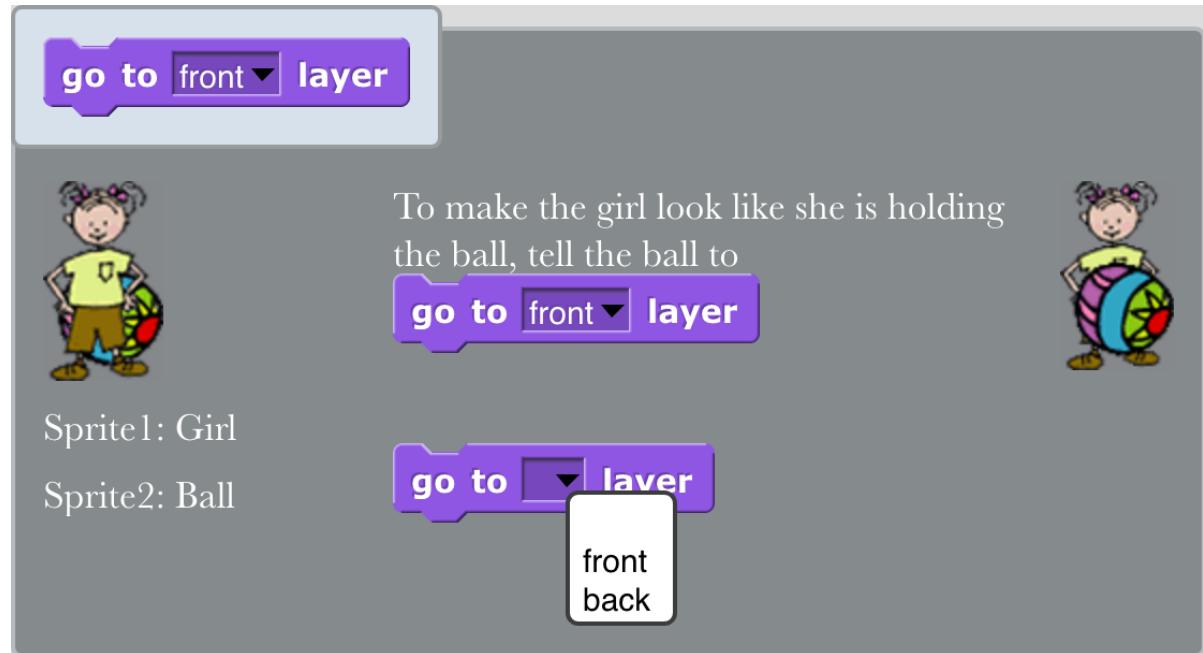
Example Projects

No examples yet.

go to layer

Complete Me

go to front layer



Example Images

No examples yet.

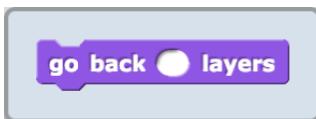
Example Projects

No examples yet.

go back layers

Complete Me

go back 1 layers



To make the candles look like they are on top of the cake, the cake has to go back 4 layers



Sprite1: Cake

Sprites 2,3,4,5:
Candles

Example Images

No examples yet.

Example Projects

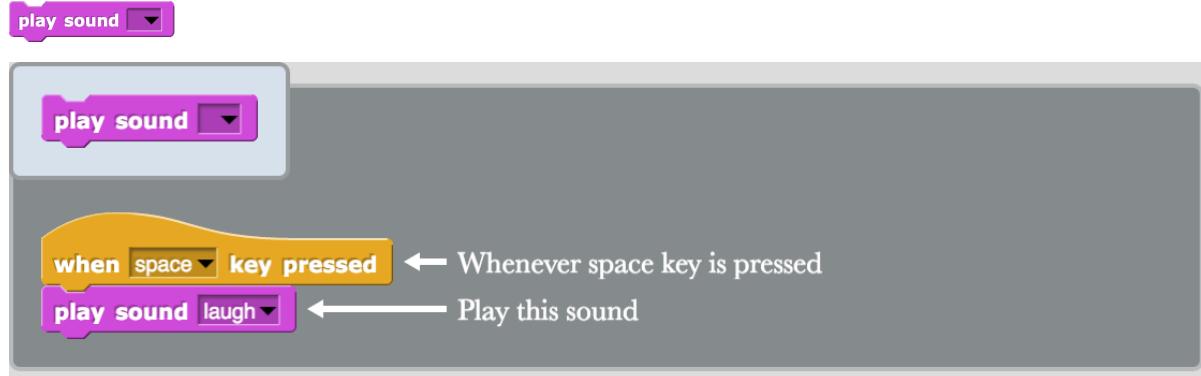
No examples yet.

Part III.

Sound Blocks

Play Sound

Complete Me



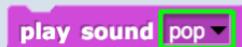
If your computer has a microphone, you can record your own sounds.



Go to Sounds and click Record.



Use this to record.
Then click 



Choose your sound from the menu.

Example Images

No examples yet.

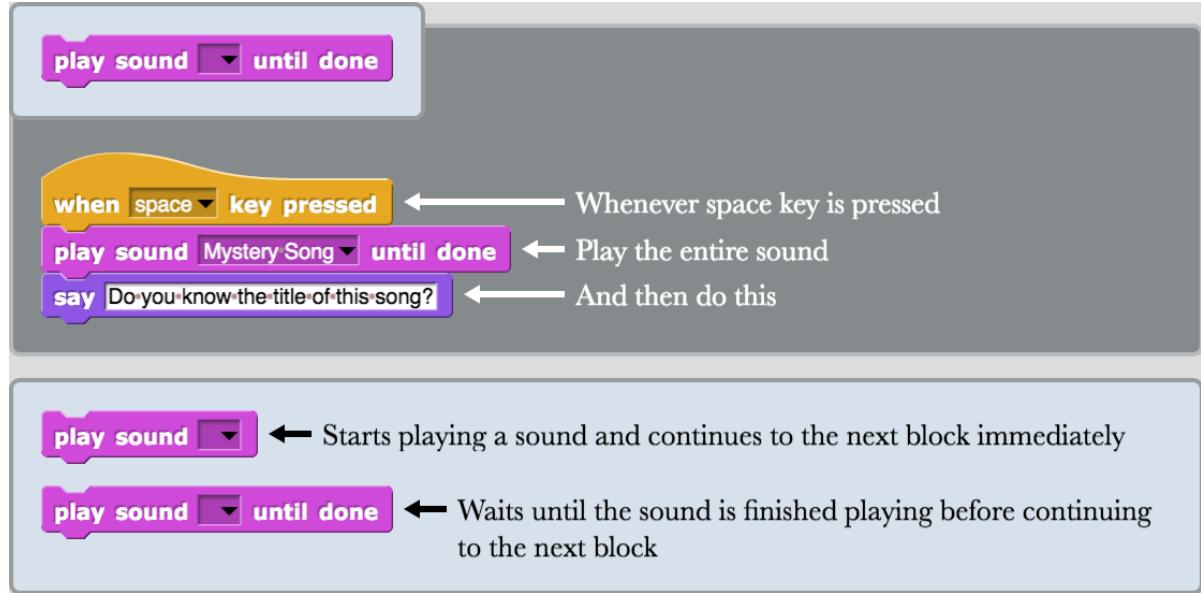
Example Projects

No examples yet.

Play Sound Until Done

Complete Me

play sound ▾ until done



Example Images

No examples yet.

Example Projects

No examples yet.

Stop All Sounds

Complete Me

stop all sounds



Example Images

No examples yet.

Example Projects

No examples yet.

Play Sound Hz

Complete Me

play sound at 44100 Hz

play sound at 44100 Hz

A higher sampling rate will take less time to finish the sound, but will make it higher pitched (squeakier). Similarly, a lower sampling rate will slow down the sound, but also make it lower pitched (deeper).

Most sounds have a natural sampling rate of 44100 Hz (44.1 kHz), because that's the rate at which CDs are made.

The highest pitch that can be included in a sound is just under half the sampling rate, so CDs can reproduce up to 20 kHz, which is about the limit of human hearing.

Example Images

No examples yet.

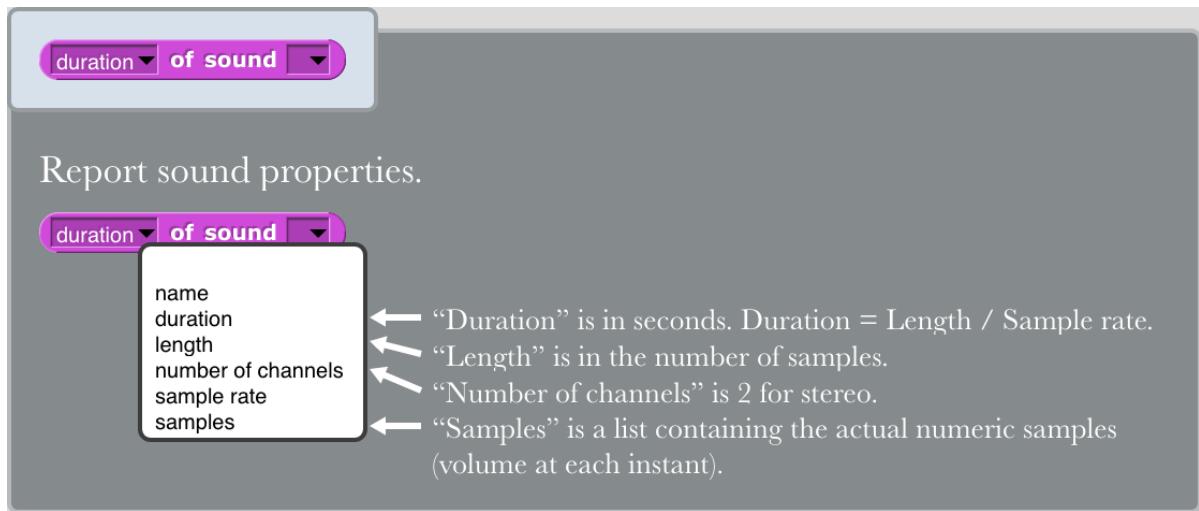
Example Projects

No examples yet.

Attribute Of Sound

Complete Me

duration ▾ of sound ▾



Example Images

No examples yet.

Example Projects

No examples yet.

New Sound Rate Hz

Complete Me

new sound  rate  Hz



Example Images

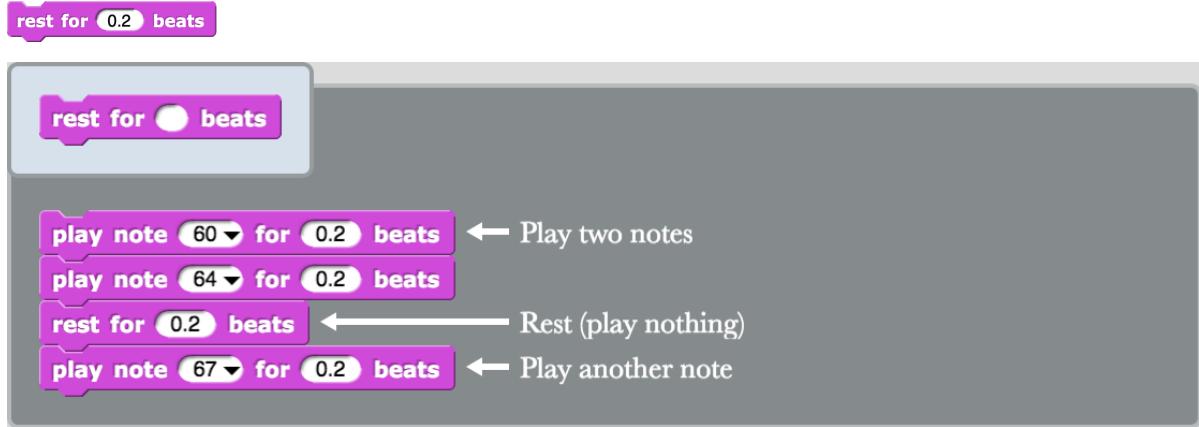
No examples yet.

Example Projects

No examples yet.

Rest For Beats

Complete Me



Example Images

No examples yet.

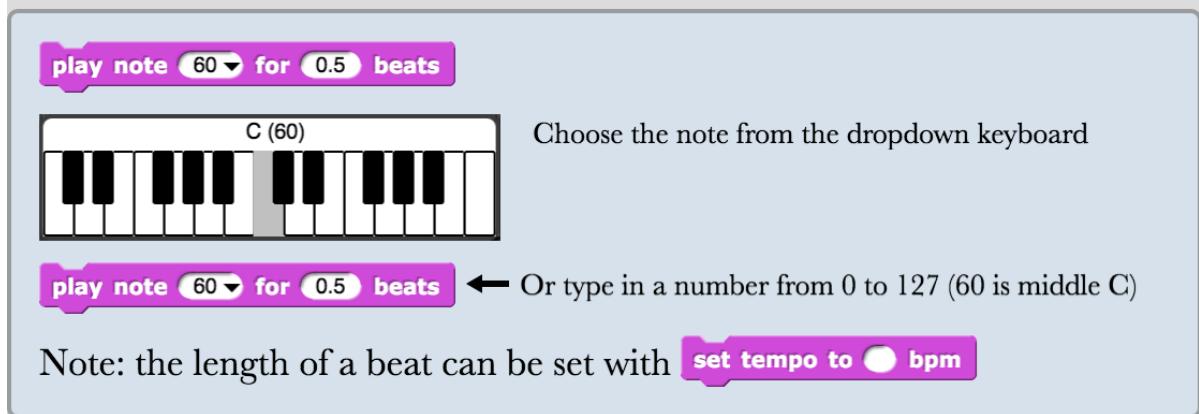
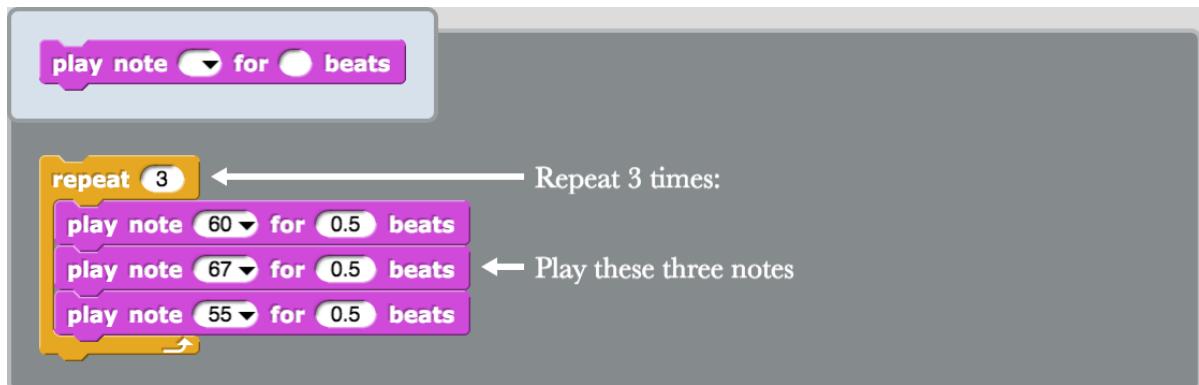
Example Projects

No examples yet.

Play Note For Beats

Complete Me

`play note 60 for 0.5 beats`



Example Images

No examples yet.

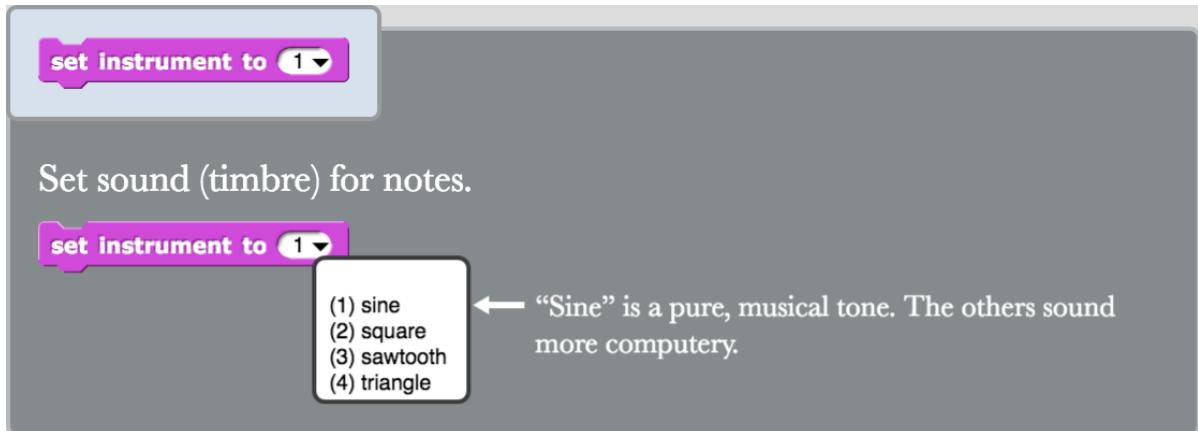
Example Projects

No examples yet.

Set Instrument

Complete Me

set instrument to 1 ▾



Example Images

No examples yet.

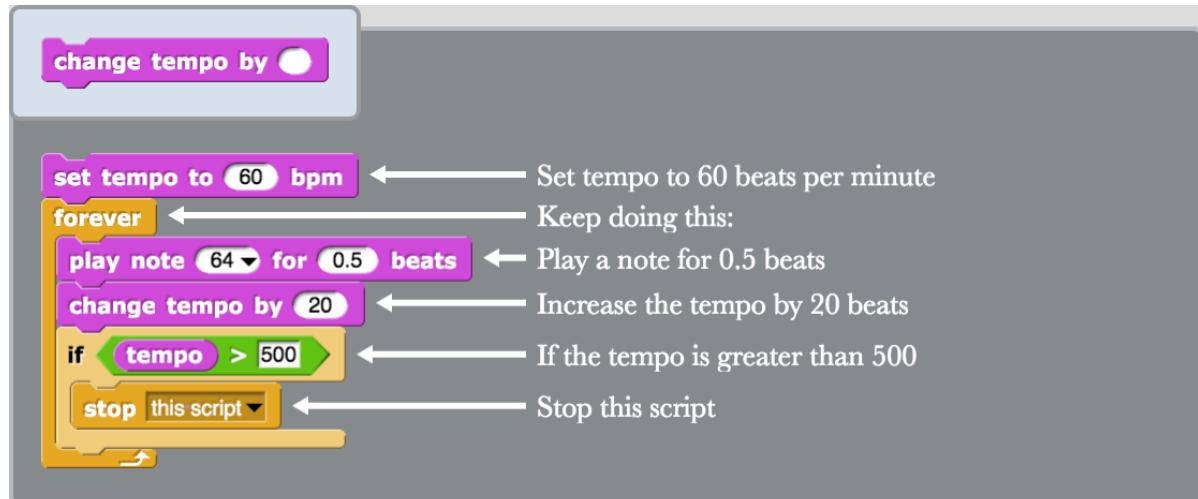
Example Projects

No examples yet.

Change Tempo

Complete Me

change tempo by 20



Tempo is the speed (bpm = beats per minute) at which Snap! notes and drums play. The larger the tempo value, the faster the notes and drums will play.

play note [60] for [0.5] beats ← 0.5 beats = 0.5 seconds at 60 bpm

play note [48] for [0.2] beats ← 0.2 beats = 0.1 seconds at 120 bpm

Example Images

No examples yet.

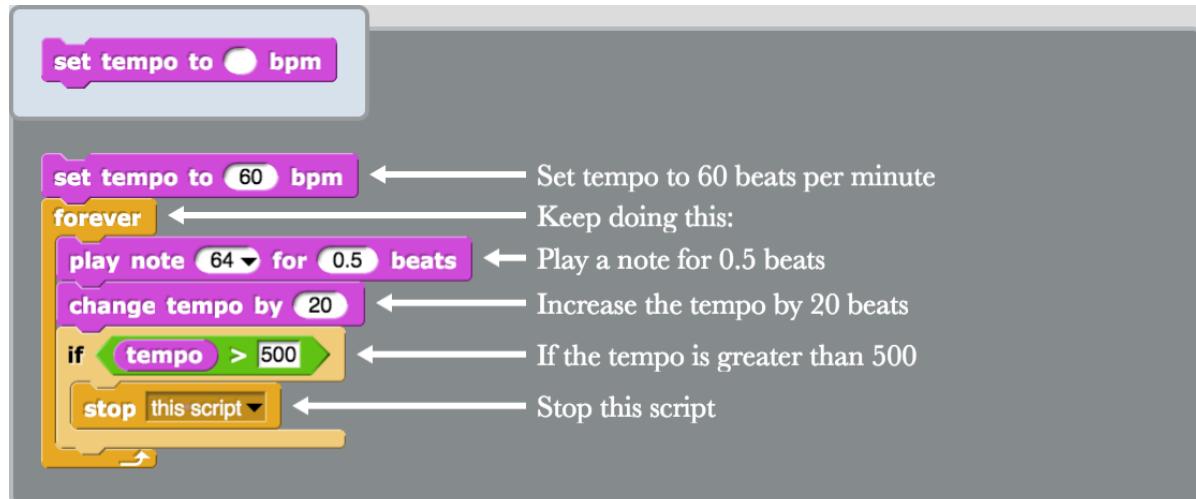
Example Projects

No examples yet.

Set Tempo

Complete Me

```
set tempo to 60 bpm
```



Tempo is the speed (bpm = beats per minute) at which Snap! notes and drums play. The larger the tempo value, the faster the notes and drums will play.

```
play note [60] for [0.5] beats
```

← 0.5 beats = 0.5 seconds at 60 bpm

```
play note [48] for [0.2] beats
```

← 0.2 beats = 0.1 seconds at 120 bpm

Example Images

No examples yet.

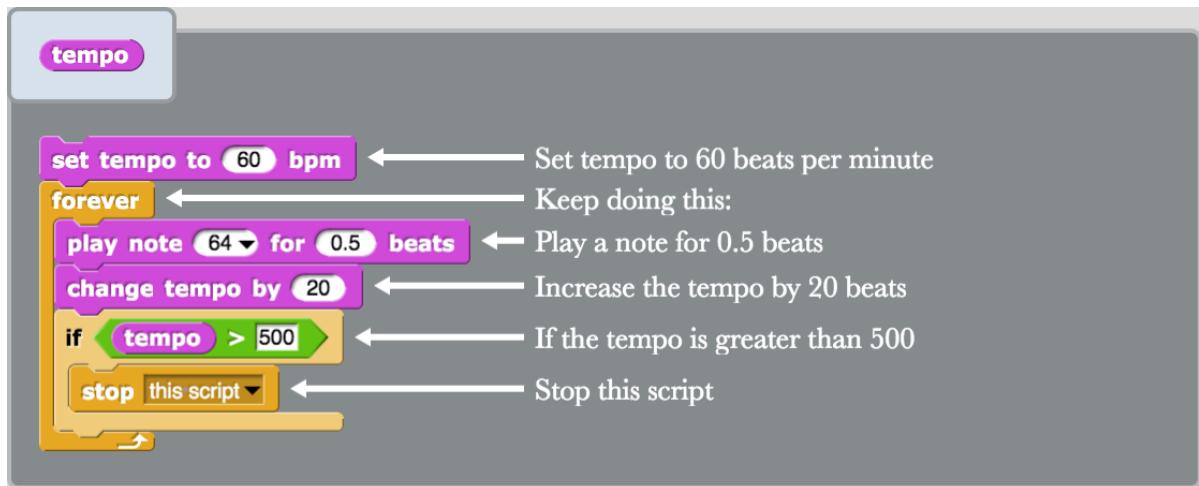
Example Projects

No examples yet.

Tempo

Complete Me

tempo



Tempo is the speed (bpm = beats per minute) at which Snap! notes and drums play. The larger the tempo value, the faster the notes and drums will play.

play note [60] for [0.5] beats ← 0.5 beats = 0.5 seconds at 60 bpm

play note [48] for [0.2] beats ← 0.2 beats = 0.1 seconds at 120 bpm

Example Images

No examples yet.

Example Projects

No examples yet.

Change Volume

Complete Me

change volume by 10

change volume by

Change volume for sounds.

100% is the maximum sound possible. 50% is already quite soft!

Each sprite has its own volume, which can be inherited by clones.

Example Images

No examples yet.

Example Projects

No examples yet.

Set Volume

Complete Me

set volume to %

set volume to %

Set volume for sounds.

100% is the maximum sound possible. 50% is already quite soft!

Each sprite has its own volume, which can be inherited by clones.

Example Images

No examples yet.

Example Projects

No examples yet.

Volume

Complete Me

volume

volume

Change volume for sounds.

100% is the maximum sound possible. 50% is already quite soft!

Each sprite has its own volume, which can be inherited by clones.

Example Images

No examples yet.

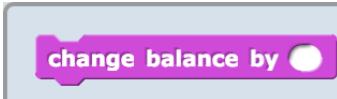
Example Projects

No examples yet.

Change Balance

Complete Me

change balance by 10



Change balance for sounds.

0 is normal. -100 is left channel only; 100 is right channel only.

Each sprite has its own balance, which can be inherited by clones.

Example Images

No examples yet.

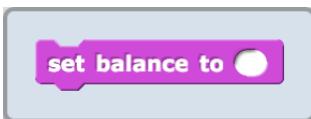
Example Projects

No examples yet.

Set Balance To

Complete Me

`set balance to [0]`



Set balance for sounds.

0 is normal. -100 is left channel only; 100 is right channel only.

Each sprite has its own balance, which can be inherited by clones.

Example Images

No examples yet.

Example Projects

No examples yet.

Report Balance

Complete Me

balance

balance

Report stereo balance for sounds.

0 is normal. -100 is left channel only; 100 is right channel only.

Each sprite has its own balance, which can be inherited by clones.

Example Images

No examples yet.

Example Projects

No examples yet.

Play Frequency Hz

Complete Me

play frequency 440 Hz

play frequency 440 Hz

Play a tone until stopped.

This block starts playing a tone (pure sine wave) at the given frequency until stopped.

Use stop frequency to stop it.

440 Hz is A above middle C, note number 69.
Middle C, note number 60, is 256 Hz.

Example Images

No examples yet.

Example Projects

No examples yet.

Stop Frequency

Complete Me

stop frequency



Example Images

No examples yet.

Example Projects

No examples yet.

Part IV.

Pen Blocks

clear

Complete Me

A Scratch script consisting of a single green `clear` hat block. To the right of the script, a note is displayed in a light blue box:

Note: The pen marks and stamps are not part of the background costume. Therefore, when they are cleared, the background costume remains unchanged.

Example Images

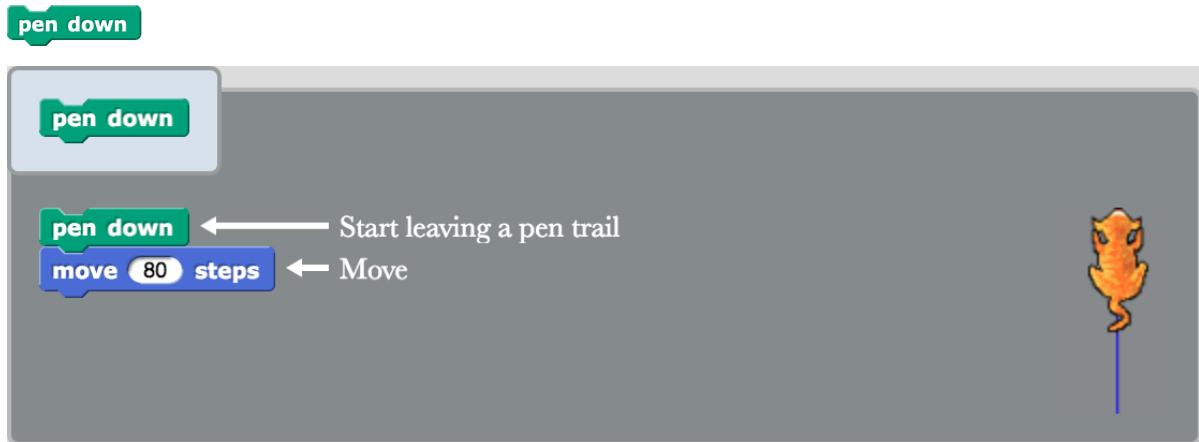
No examples yet.

Example Projects

No examples yet.

pen down

Complete Me



Example Images

No examples yet.

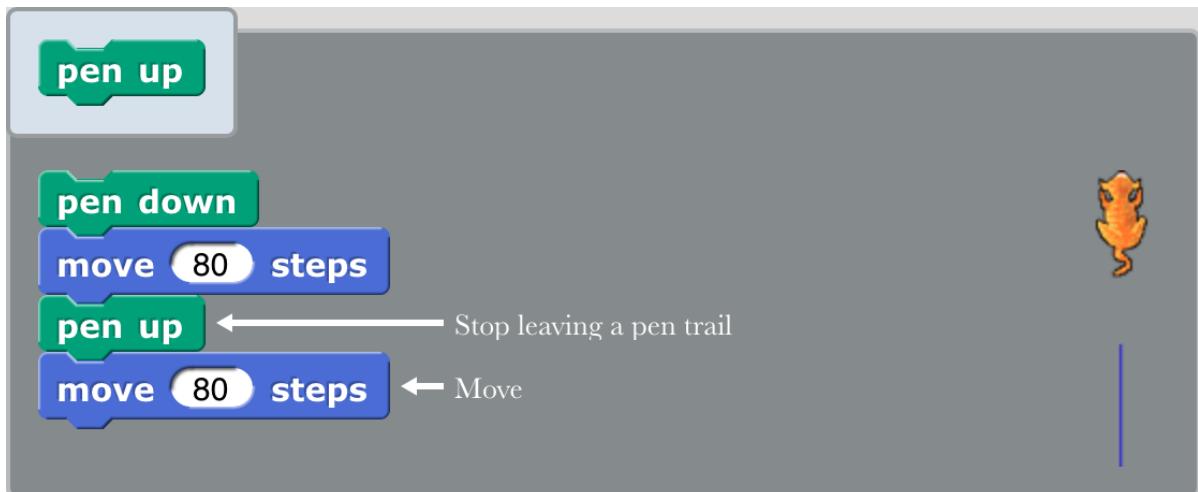
Example Projects

No examples yet.

pen up

Complete Me

pen up



Example Images

No examples yet.

Example Projects

No examples yet.

pen down?

Complete Me

pen down?

pen down?

Report true if sprite's pen is down.

The sprite draws as it moves if its pen is down.

Use pen down to put the pen down.

Use pen up to pick the pen up.

Example Images

No examples yet.

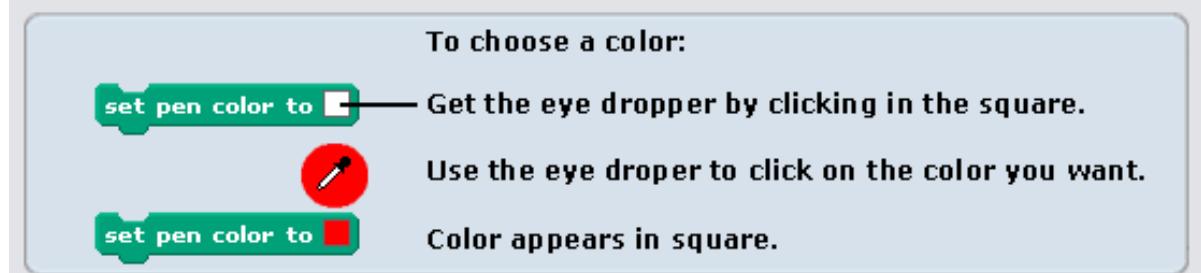
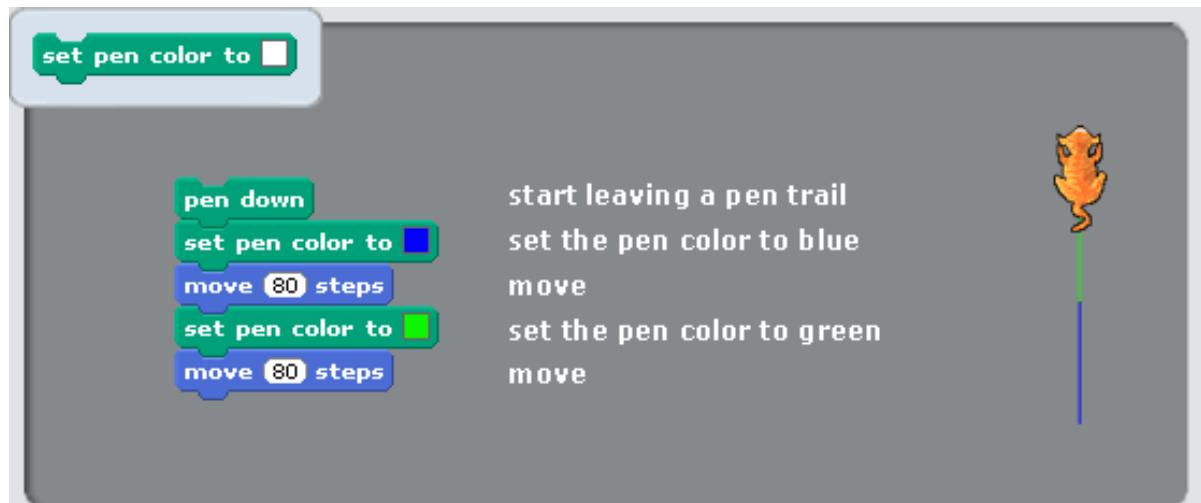
Example Projects

No examples yet.

set pen color to

Complete Me

set pen color to 



Example Images

No examples yet.

Example Projects

No examples yet.

change pen by

Complete Me

change pen hue by 10



Example Images

No examples yet.

Example Projects

No examples yet.

set pen to

Complete Me

set pen hue to 50



Example Images

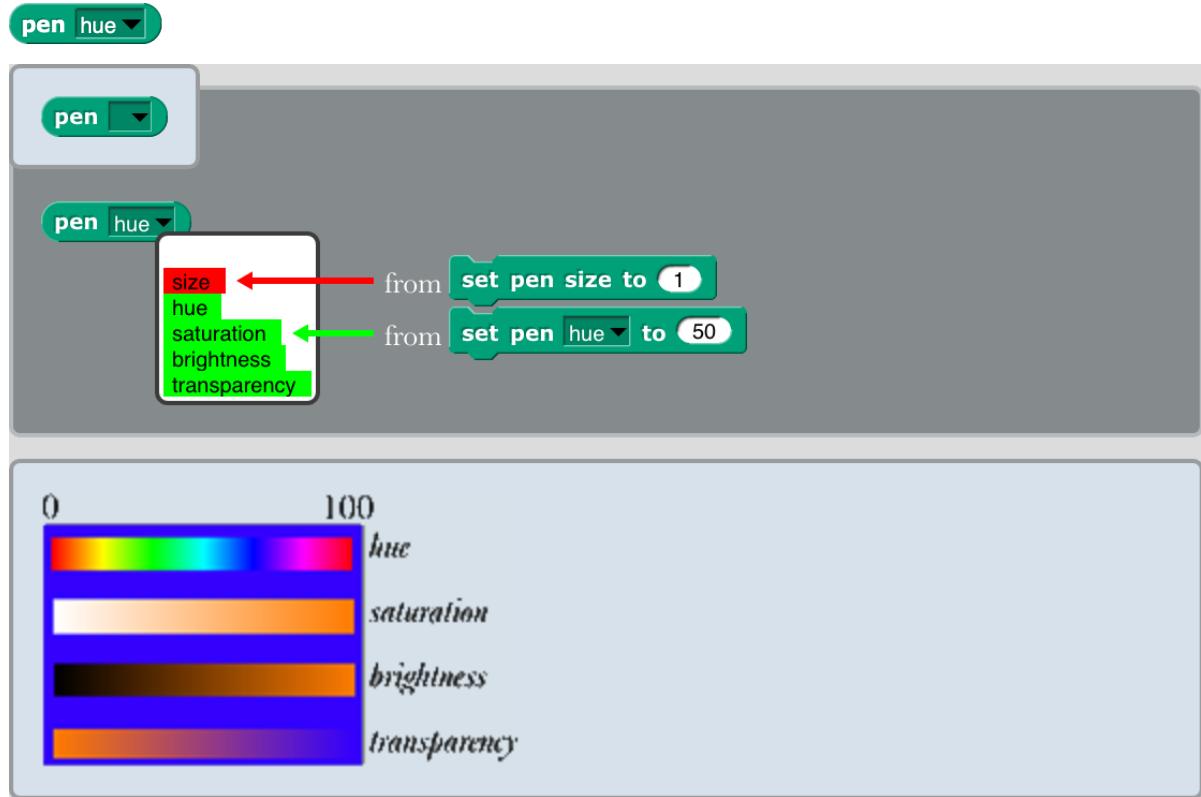
No examples yet.

Example Projects

No examples yet.

pen

Complete Me



Example Images

No examples yet.

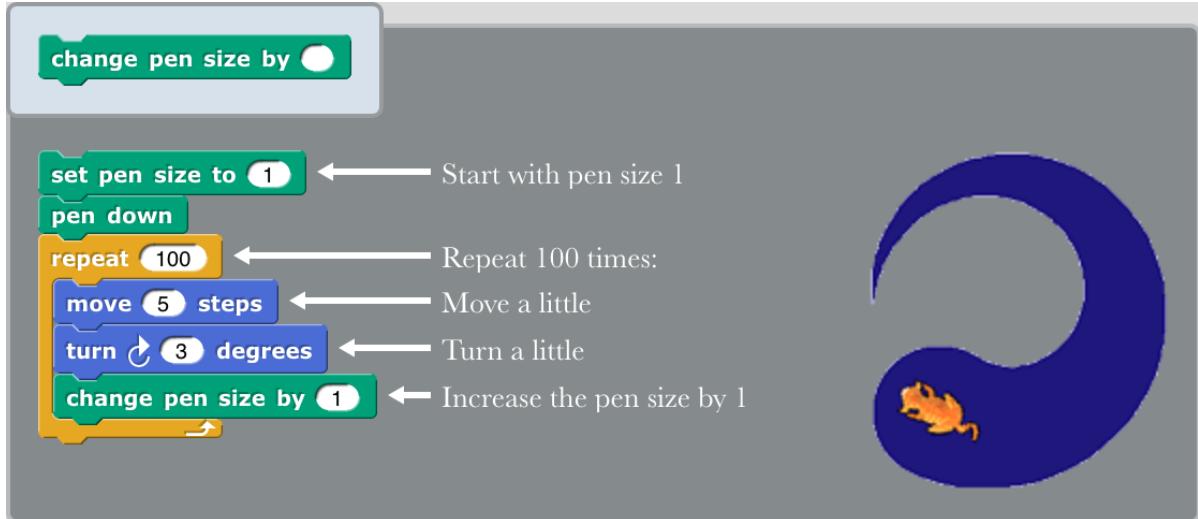
Example Projects

No examples yet.

change pen size by

Complete Me

change pen size by 1



Example Images

No examples yet.

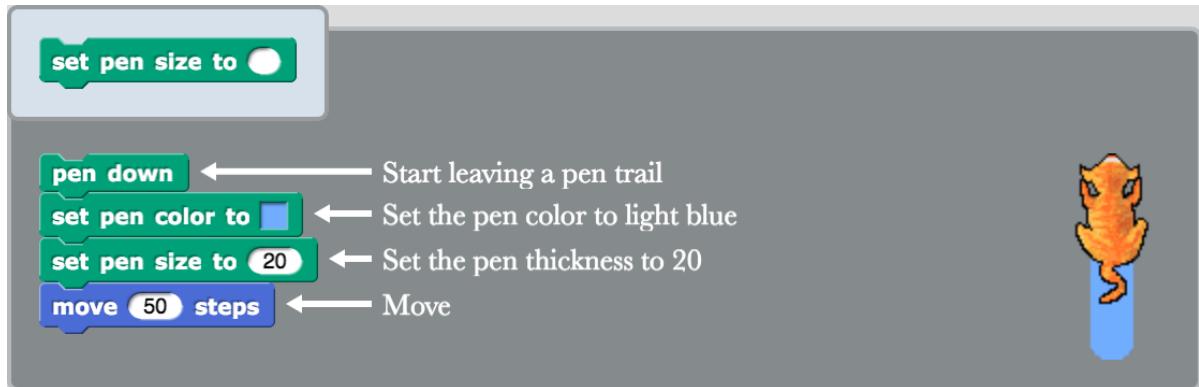
Example Projects

No examples yet.

set pen size to

Complete Me

set pen size to 1



Example Images

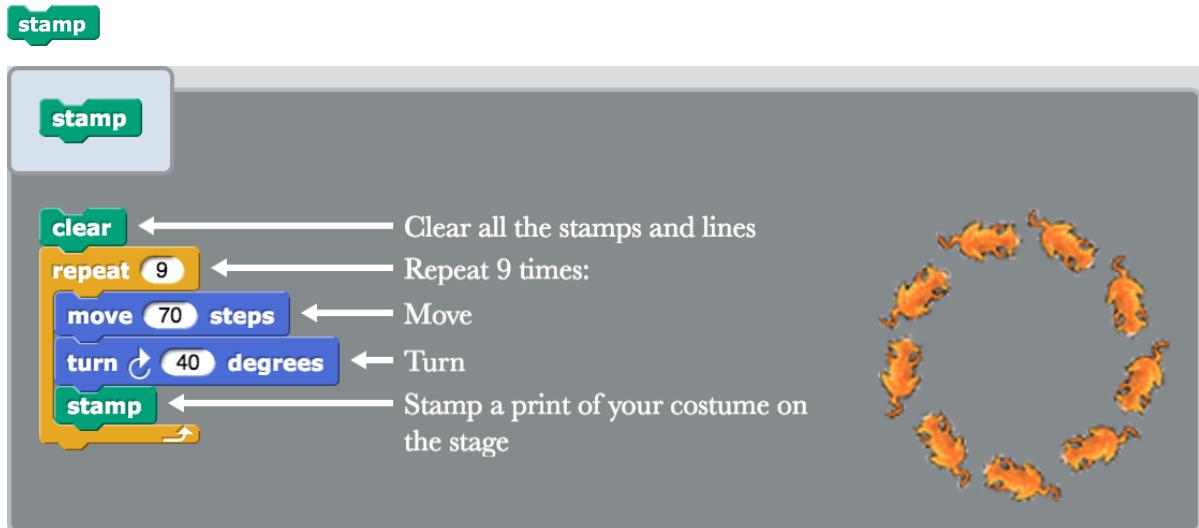
No examples yet.

Example Projects

No examples yet.

stamp

Complete Me



Example Images

No examples yet.

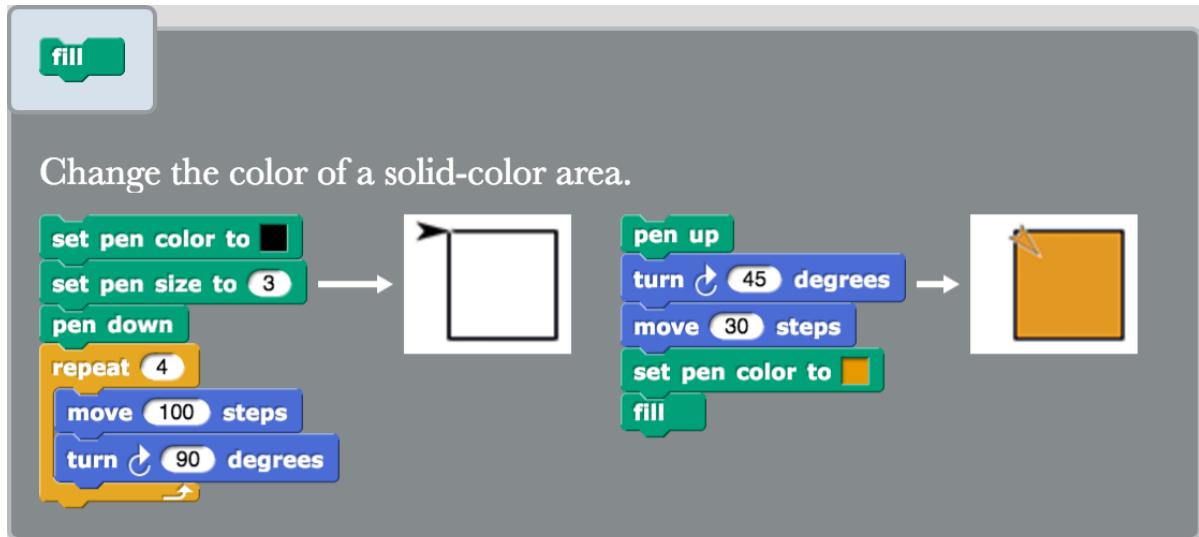
Example Projects

No examples yet.

fill

Complete Me

fill



Fill first determines the color of the stage pixel under the sprite. Then it changes every adjacent pixel with that color to be the current pen color. So it's important to pick the pen up before moving to the inside of the region to be colored. If the color under the sprite is the border color, just the border will be filled.

Example Images

No examples yet.

Example Projects

No examples yet.

write size

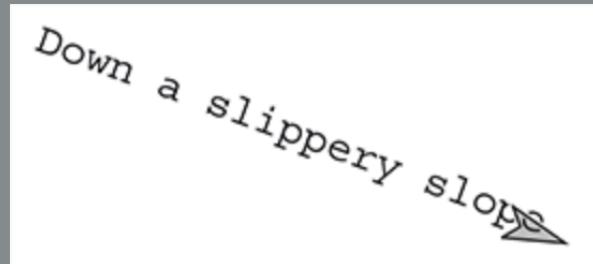
Complete Me

```
write Hello! size 12
```

```
write Hello! size 12
```

The text slope follows the sprite's direction. The sprite is left at the end of the text so that you can find out how long it is.

The text is in monospace (Courier) font.



Hello!

If the pen is down, then the text will be underlined.

Example Images

No examples yet.

Example Projects

No examples yet.

pen trails

Complete Me

pen trails



The reported value does not include the stage background or the sprite itself, just the lines drawn with the pen.

What can you do with the reported costume?

Add it to your costumes.

add pen trails to my costumes

Modify it.



```
switch to costume
stretch
map
  [if item 4 of [ ] > 0 then [255 in front of [all but first of [ ]] else
    [ ]]
  ]
over [pixels v] of costume pen trails
x: [width v] of costume pen trails y: [height v] of costume pen trails %
```

Example Images

No examples yet.

Example Projects

No examples yet.

paste on

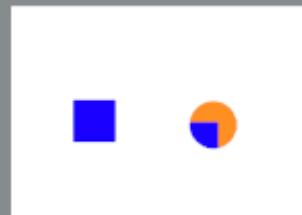
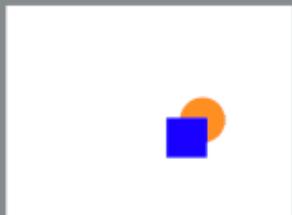
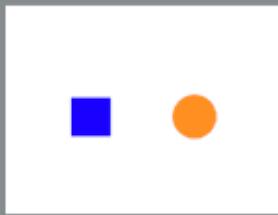
Complete Me

paste on 

paste on 

Stamps this sprite onto another sprite.

The affected sprite (the orange ball)'s costume changes depending on where the pasting sprite (the square) is overlapping.



The PASTE ON block pastes onto the affected sprite's costume. This means you can reverse its effect by changing the affected sprite's costume back to what it was before, not by using the CLEAR block.

Example Images

No examples yet.

Example Projects

No examples yet.

cut from

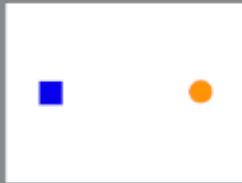
Complete Me

cut from 

cut from 

Use your sprite to cut off another sprite's costume.

Part of the affected sprite (the orange ball) gets removed depending on where the cutting sprite is overlapping.



The CUT FROM block cuts from the affected sprite's costume. This means you can reverse the effect by setting the affected sprite's costume back to what it was before, not by using the CLEAR block.

Example Images

No examples yet.

Example Projects

No examples yet.

Color

Complete Me

color 



Example Images

No examples yet.

Example Projects

No examples yet.

Color Attribute

Complete Me

hue ▾ of color 



Example Images

No examples yet.

Example Projects

No examples yet.

new color

Complete Me

new color hue 0 



Example Images

No examples yet.

Example Projects

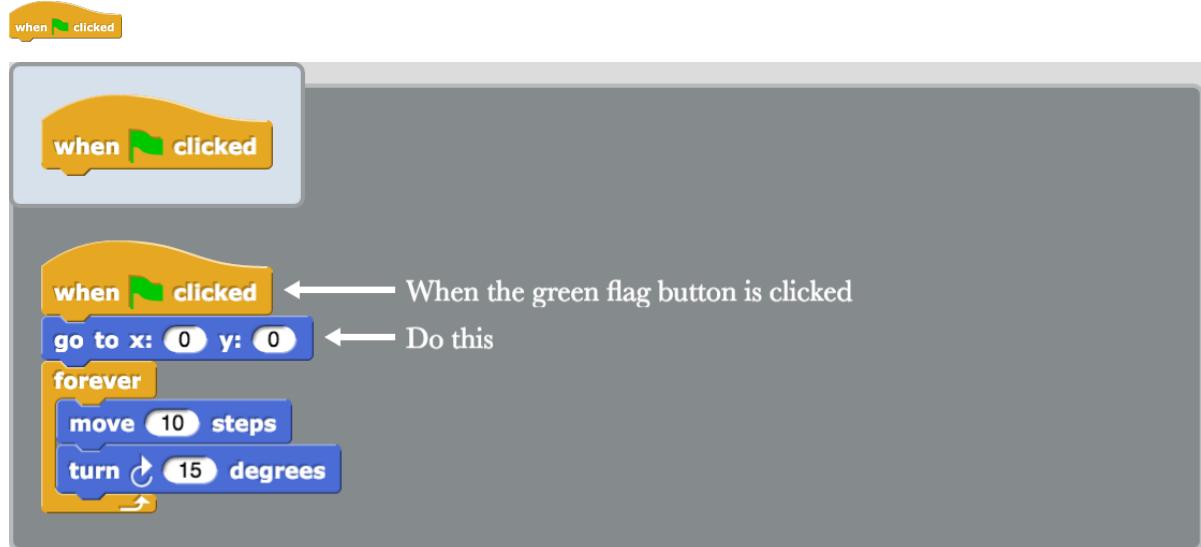
No examples yet.

Part V.

Control Blocks

When Green Flag Clicked

Complete Me



Example Images

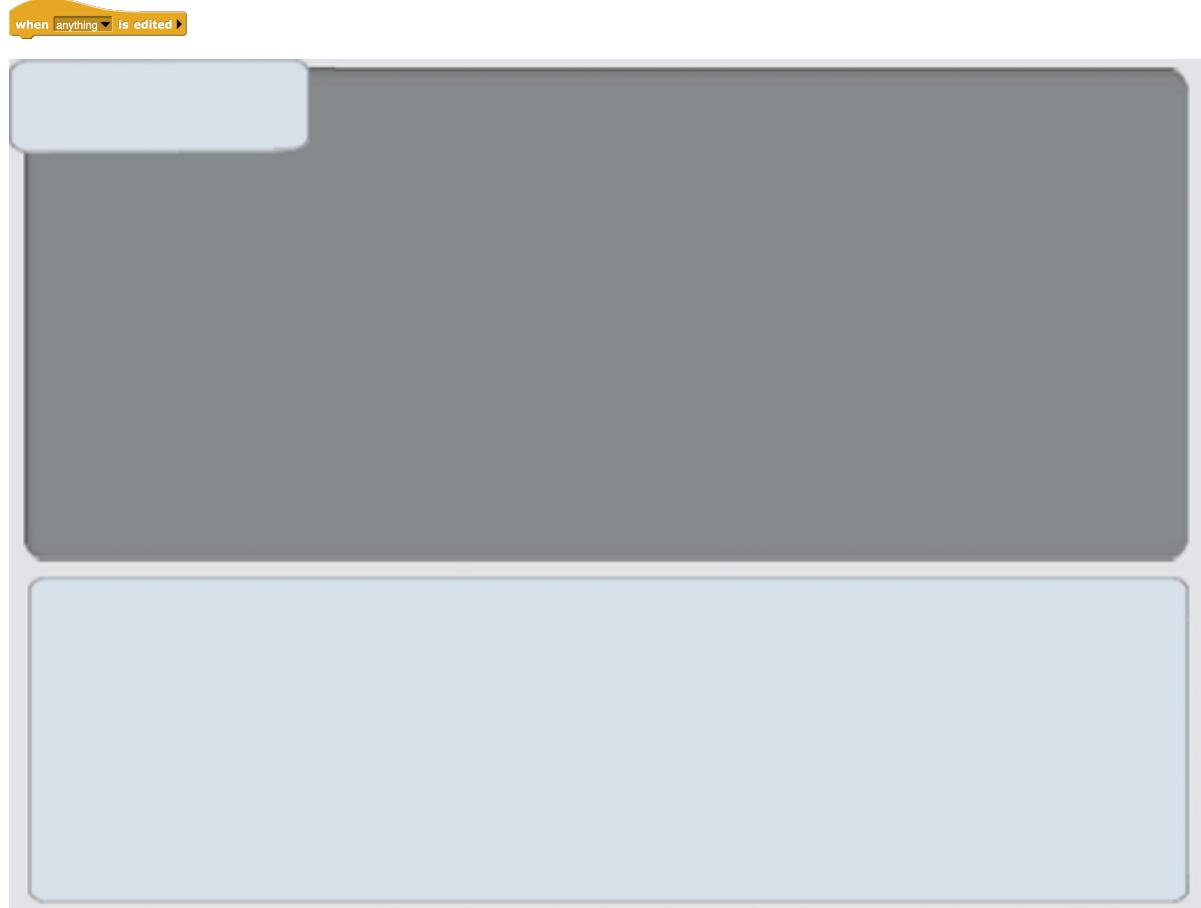
No examples yet.

Example Projects

No examples yet.

when is edited

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

when I start as a clone

Complete Me

when I start as a clone

Clone initialization script

```
when I start as a clone
repeat (3)
  create a clone of [Sprite v]
end
```

(because the original and all three copies are in the same place and the same color)

```
when I start as a clone
set pen hue to [pick random 1 to 100]
set pen saturation to [100]
set pen brightness to [100]
go to x: [pick random -50 to 50] y: [pick random -50 to 50]

when green flag clicked
repeat (3)
  create a clone of [Sprite v]
end
```

Note: Snap! clones are not copies of the sprite; they actually share information, so a change in the original may be seen in the clones. See the “Object Oriented Programming with Sprites” chapter in the Snap! Reference Manual.

when I start as a clone

Example Images

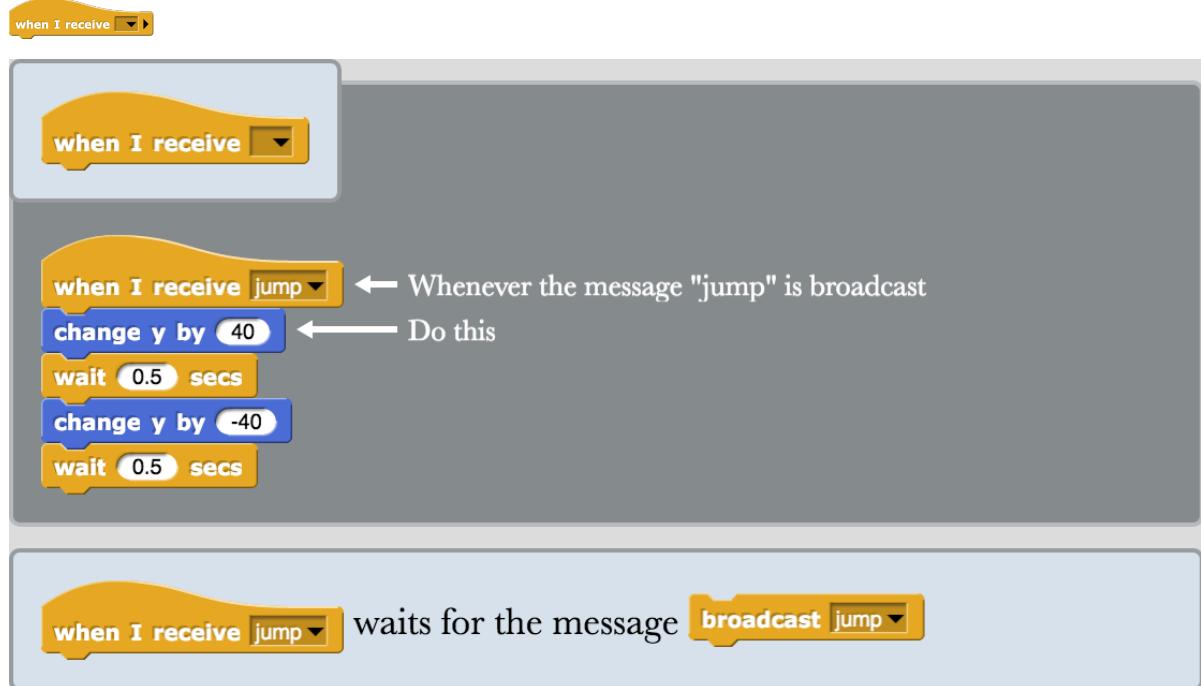
No examples yet.

Example Projects

No examples yet.

when I receive

Complete Me



Example Images

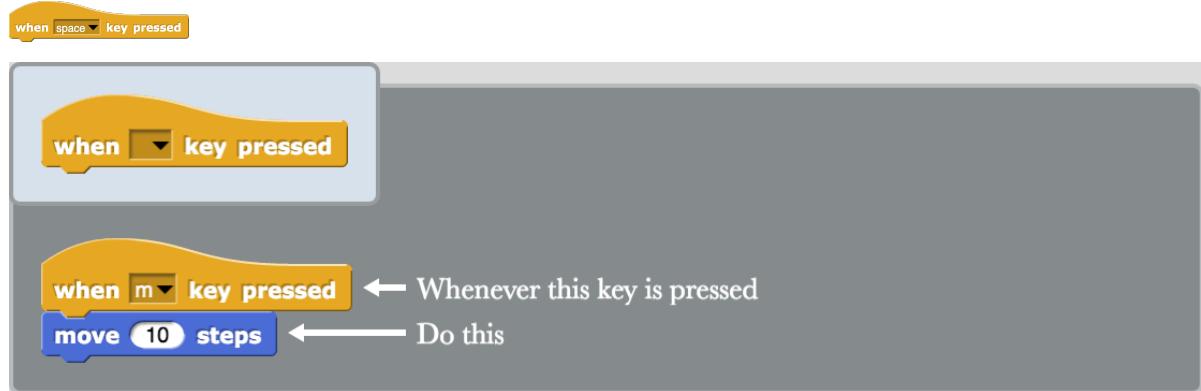
No examples yet.

Example Projects

No examples yet.

when key pressed

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

when

Complete Me

The image shows a Scratch script starting with a generic **when green flag clicked** hat block. Inside, there are three specific **when** blocks:

- when answer = parrot**: A green **when** block with a blue **answer** variable set to "parrot".
- when mouse down?**: A blue **when** block.
- when y position < 0**: A green **when** block with a blue **y position** variable set to less than 0.

say [You win \$50!!] **for** (2) **secs**: A purple **say** block with the message "You win \$50!!" and a duration of 2 seconds.

Note: This generic hat block slows down Snap! more than the specific hat blocks, because your script is always running, in the equivalent of a FOREVER [IF...] loop. Therefore, to prevent an inescapable slowdown, clicking the Stop button disables the generic hat block tests until some other script is running.

When a test is True, the script under the hat block is guaranteed to start (but not necessarily to finish) before any other script runs.

Example Images

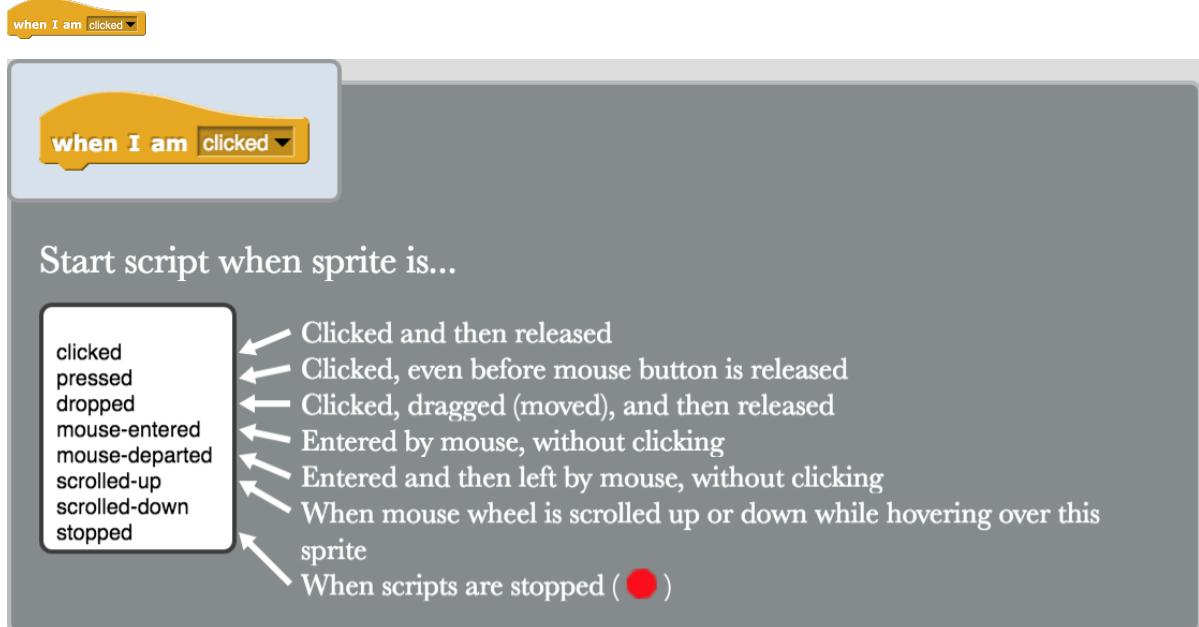
No examples yet.

Example Projects

No examples yet.

when I am

Complete Me



Example Images

No examples yet.

Example Projects

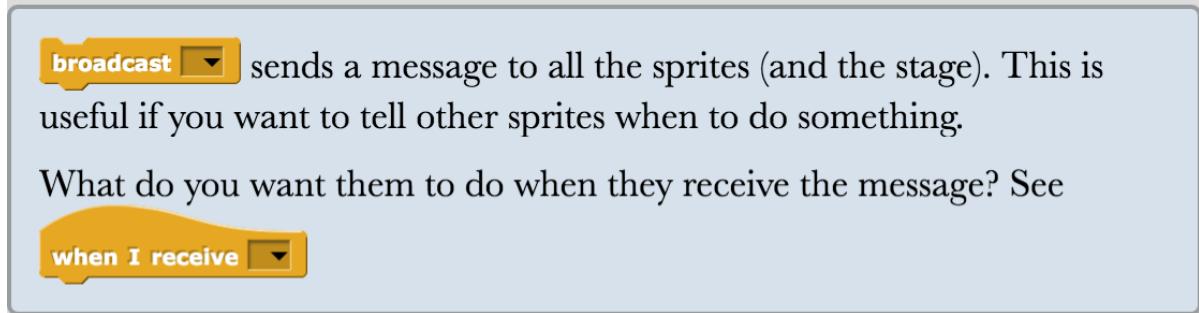
No examples yet.

broadcast

Complete Me



← Sends the message "jump" to all sprites



Example Images

No examples yet.

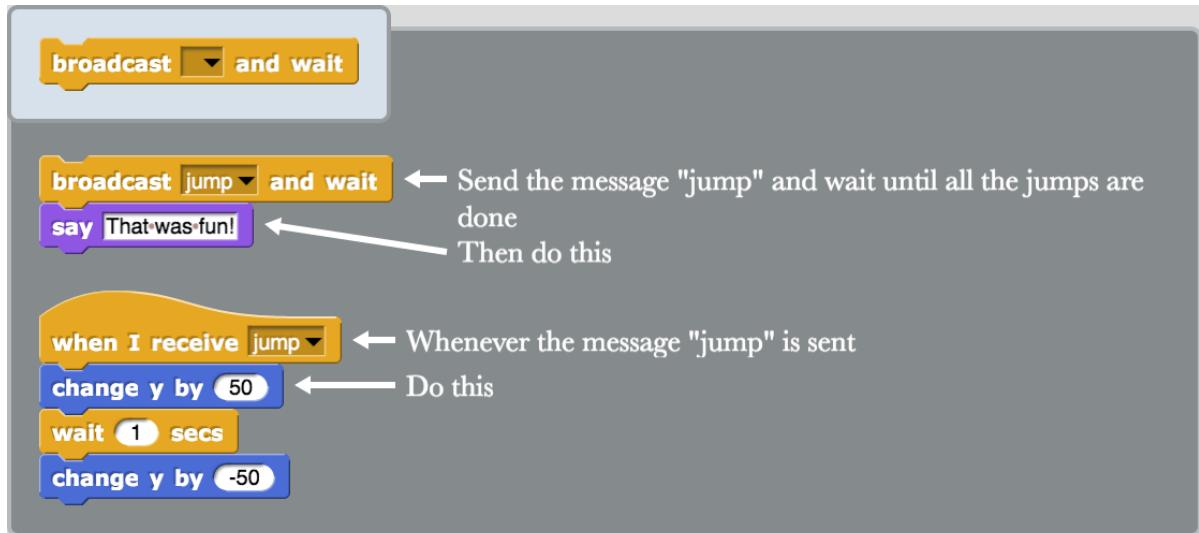
Example Projects

No examples yet.

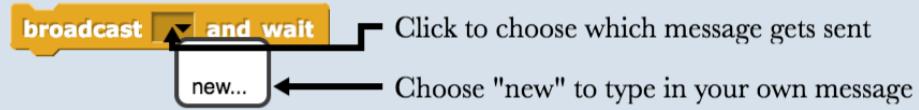
broadcast and wait

Complete Me

broadcast [] and wait



You can use **broadcast [] and wait** to send a message to all sprites to tell them to do something, and wait until they all finish before continuing.



Example Images

No examples yet.

Example Projects

No examples yet.

Warp

Complete Me



Run fast; don't draw intermediate steps.

```
repeat (4)
  move (100) steps
  turn (90) degrees
```



```
warp
repeat (4)
  move (100) steps
  turn (90) degrees
```



Other scripts can't run until the warp is finished.

If your warped script has a bug and keeps running forever, hold down the stop sign in the top right corner of the window until it stops.



Example Images

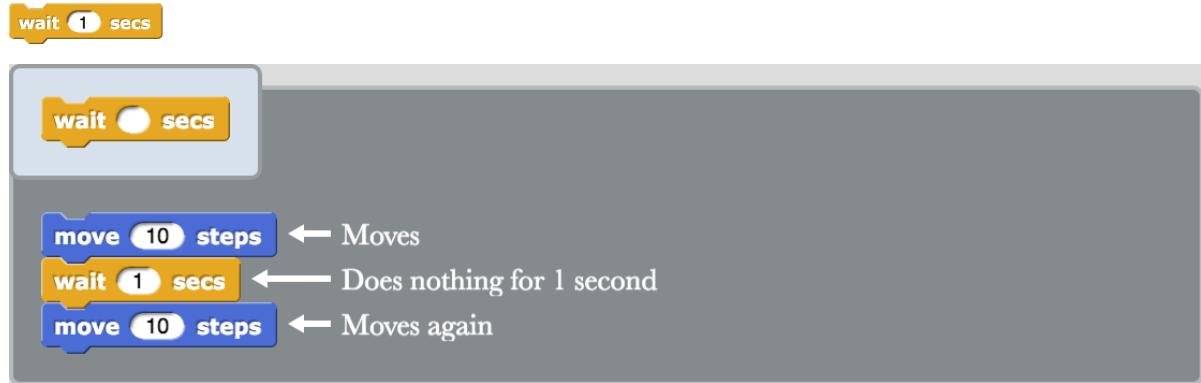
No examples yet.

Example Projects

No examples yet.

wait secs

Complete Me



Example Images

No examples yet.

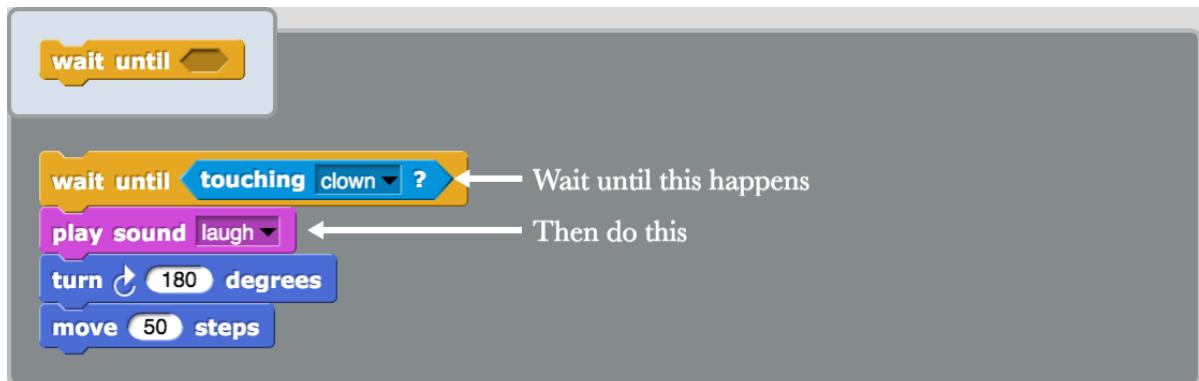
Example Projects

No examples yet.

wait until

Complete Me

wait until 



This whole stack will just run once. If you want **wait until**  to keep checking, put the whole stack inside a forever block.

Example Images

No examples yet.

Example Projects

No examples yet.

forever

Runs the scripts in a loop until the stop button is clicked.



Example Images

No examples yet.

Example Projects

No examples yet.

repeat

Complete Me



Example Images

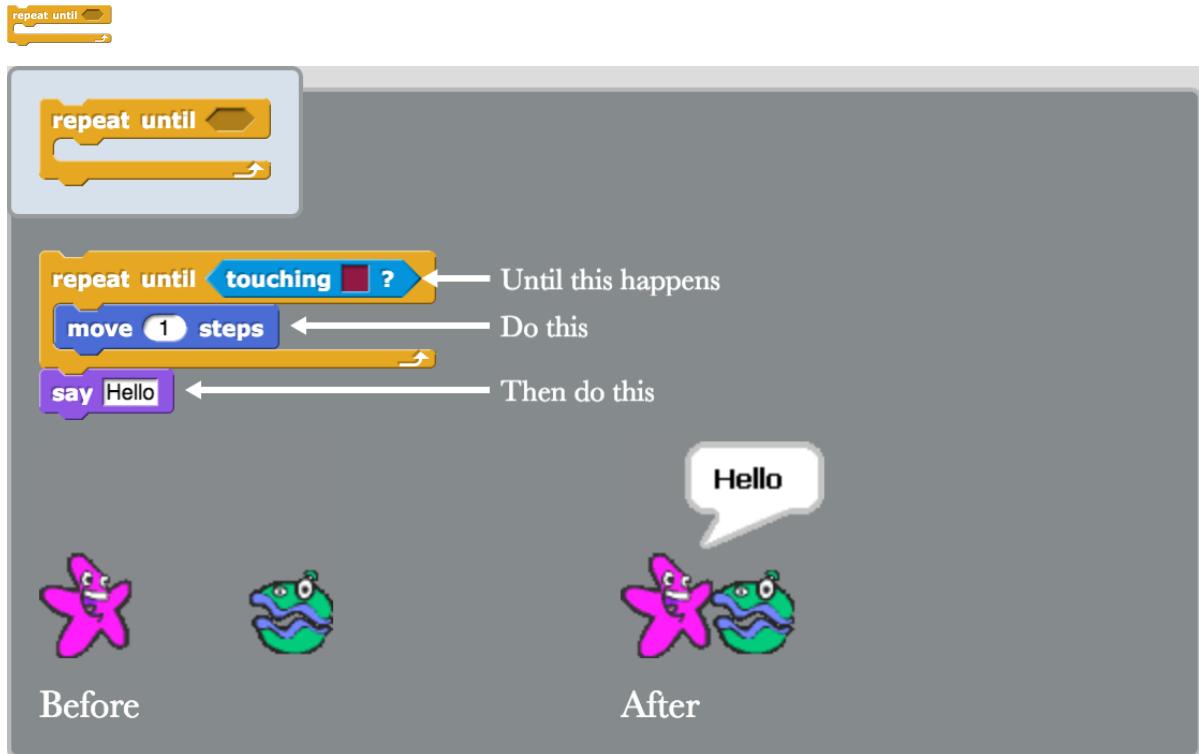
No examples yet.

Example Projects

No examples yet.

repeat until

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

for _ = to

The **for** block lets you make a loop with a new variable (**i**) that starts at 1 and increments by 1 value, up to 10.

The image shows two Scratch script examples. The top example, titled "Run a script repeatedly, keeping count.", features a yellow **for** loop block with **i** as the iterator, ranging from 1 to 10. Inside the loop, there are two blue **move** and **turn** blocks. To the right is a spiral drawing. Below it, another **for** loop block is shown with **i** as the iterator, ranging from 1 to 200, with the same **move** and **turn** blocks. A pink arrow points from the spiral drawing to the expanded loop blocks. The bottom example shows a nested loop structure. It has an outer **for** loop with **outer** as the iterator, ranging from 1 to 10. Inside it is an inner **for** loop with **inner** as the iterator, ranging from 20 to 7. Both loops contain blue **move** and **turn** blocks. A green circle highlights the **outer** variable in the outer loop, and a purple circle highlights the **count** variable in the inner loop. A blue arrow points from the inner loop's **count** variable to the text: "Click on the variable without dragging to change its name. That lets you nest **for** blocks!"

Example Images

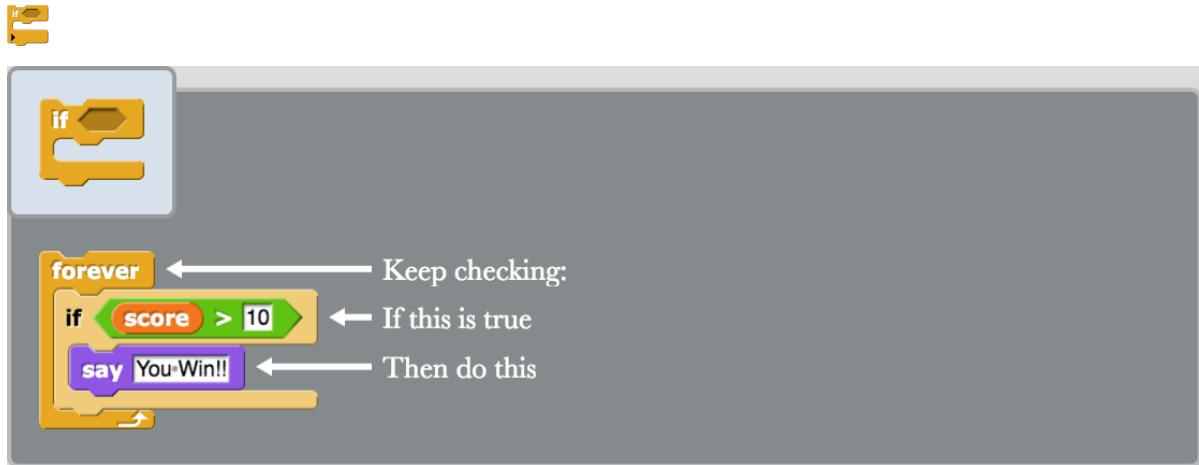
No examples yet.

Example Projects

No examples yet.

if

Complete Me



Example Images

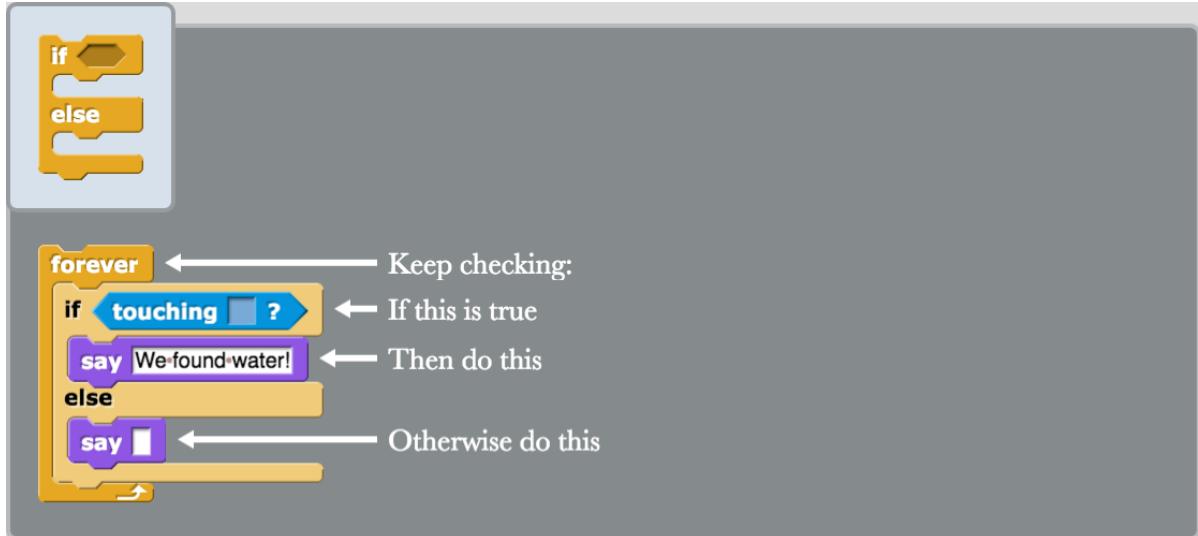
No examples yet.

Example Projects

No examples yet.

if else

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

if then else

Complete Me

if [] then [] else []

Choose which of two values to report.

No
if [2 = 3] then [Yes] else [No]

Yes
if [2 < 3] then [Yes] else [No]

+ factorial + [n #] +

report if [n = 0] then [1] else [n × factorial [n - 1]]

Example Images

No examples yet.

Example Projects

No examples yet.

report

Complete Me

report []

The image shows a Scratch script within a custom block. The script starts with a green `+ absolute + value + of + num +` hat block. It then branches into two parallel orange `if < num < 0` blocks. The first parallel branch contains a yellow `report [- num]` reporter block. The second parallel branch contains a yellow `report [num]` reporter block. A callout bubble points to the first reporter block with the text: "If this `report []` runs because the number is negative, then that ends the custom block, and so this `report []` block (or whatever else comes later in the block's script) doesn't happen." Below the parallel blocks is a yellow `7.5` reporter block. At the bottom of the script is a green `absolute value of -7.5` reporter block.

Report a value from a custom block to its caller.

```
+ absolute + value + of + num +
if < num < 0
  report [ - num ]
  report [ num ]
7.5
absolute value of -7.5
```

If this `report []` runs because the number is negative, then that ends the custom block, and so this `report []` block (or whatever else comes later in the block's script) doesn't happen.

+ empty? + data : +
report [data = list]

`report []` works for predicate custom blocks too; just drag a hexagonal true/false reporter into its input slot.

Example Images

No examples yet.

Example Projects

No examples yet.

stop

Complete Me

stop all ▾



Stop some or all running scripts.

stop ▾

all
this script
this block
all but this script
other scripts in sprite

stop all: like pushing the red button.

stop this script: stops the top-level script even if this block is inside a custom block definition.

stop this block: stops the innermost call to the custom block that's running now (maybe leaving outer recursive calls still running).

all but this script: stops scripts of all sprites.

other scripts in sprite: stops scripts in this sprite only.

This block changes shape depending on the option selected. All, this script, and this block stop the script containing the block, so no other block can go beneath it. (In Scratch terms, this is a “cap block.”) The bottom two options allow this script to keep running, so it has a tab at the bottom. (It's a “stack block.”)

stop all ▾

stop all but this script ▾

Example Images

No examples yet.

Example Projects

No examples yet.

run

Complete Me



Run a command script.

This script makes this custom block.

The run block runs whatever you put in this slot.

for *i* = 1 to 10
action λ
set *i* to start
repeat until *i* > end
run action
change *i* by 1

for *i* = 1 to 10

for *i* = 1 to 200
move *i* steps
turn 92 degrees

run say [x × 3] with inputs [5]

15

Example Images

No examples yet.

Example Projects

No examples yet.

launch

Complete Me



Run another script independently of this script.

The Scratch script editor shows a script starting with a **when green flag clicked** hat. It contains a **launch** control block, which triggers a **forever** loop. Inside this loop are **pen down**, **move (5) steps**, **pen up**, and **move (5) steps** blocks. Below the **forever** loop is another **forever** loop with a **turn (10) degrees** block. Two arrows point from text labels to these loops: one arrow points to the inner **forever** loop with the text "The move-and-dra script runs in parallel with", and another arrow points to the outer **forever** loop with the text "the turn script." To the right of the script is a preview window showing a dashed circle with an arrow at the top, indicating the direction of the turn.

Example Images

No examples yet.

Example Projects

No examples yet.

call

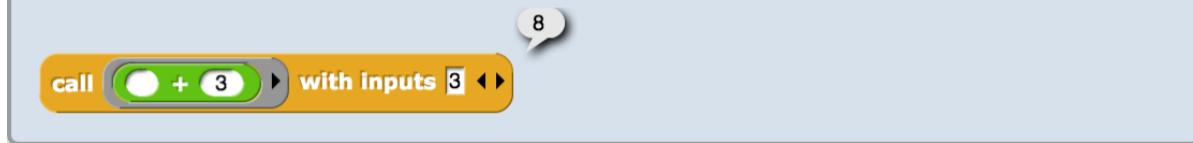
Complete Me



Call a reporter or predicate block.



The CALL block has a ring for its first input slot because it expects a reporter or predicate as its input. Almost always, though, you'll use a variable to provide the input value, as in the example above. When you put a variable in a ringed input slot, the ring disappears because it's the value of the variable that gives the function to call. If you drag anything but a variable into the ring, the ring remains around the input:



Example Images

No examples yet.

call

Example Projects

No examples yet.

pipe →

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

tell to

Complete Me

The screenshot shows the Scratch script editor with two scripts. The top script is a single **tell [] to []** block. Below it is a more complex script:

```
tell [Sprite(3)] to [show]
for each [sprite] in [my other sprites]
  tell [ ] to [go to center]
```

Annotations explain the functions of these blocks:

- The first block is annotated with "Tell a particular other sprite to show itself."
- The second block is annotated with "Tell all sprites except myself to move to the center of the stage. (Each sprite is used, one at a time, to fill the empty slot highlighted in green.)"

The script is run in the environment of the other object, so it uses that object's local variables and methods. If you want to use one of the sender's variables inside the script, leave an empty input slot in the script, click the right arrowhead at the end of the TELL block, and use the sender's variable as input to TELL.



In this example, "his variable" is defined in Sprite(2), so it can be used inside the script. "My variable" is defined in the sending sprite, so it can't be used inside the script. Instead it is used as input to TELL, which fills the empty slot in the MOVE block with it.

Example Images

No examples yet.

tell to

Example Projects

No examples yet.

ask for

Complete Me



ask for



Ask another object a question.

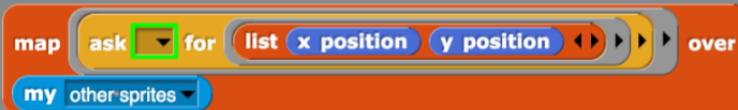
Ask a particular sprite where it is:

1	156	-
2	20	-
+ length: 2		



Ask all sprites except myself where they are:

2	A	B
1	-177	-76
2	156	20



(Each sprite is used, one at a time, to fill the empty slot circled in green.)

The expression is evaluated in the environment of the other object, so it uses that object's local variables and methods. If you want to use one of the sender's variables inside the script, leave an empty input slot in the script, click the right arrowhead at the end of the ASK, and use the sender's variable as input to ASK.



In this example, “its variable” is defined in Sprite(3), so it can be used inside the expression. “My variable” is defined in the asking sprite, so it can't be used inside the expression. Instead it is used as input to ASK, which fills the empty slot in the LIST block with it.

Example Images

No examples yet.

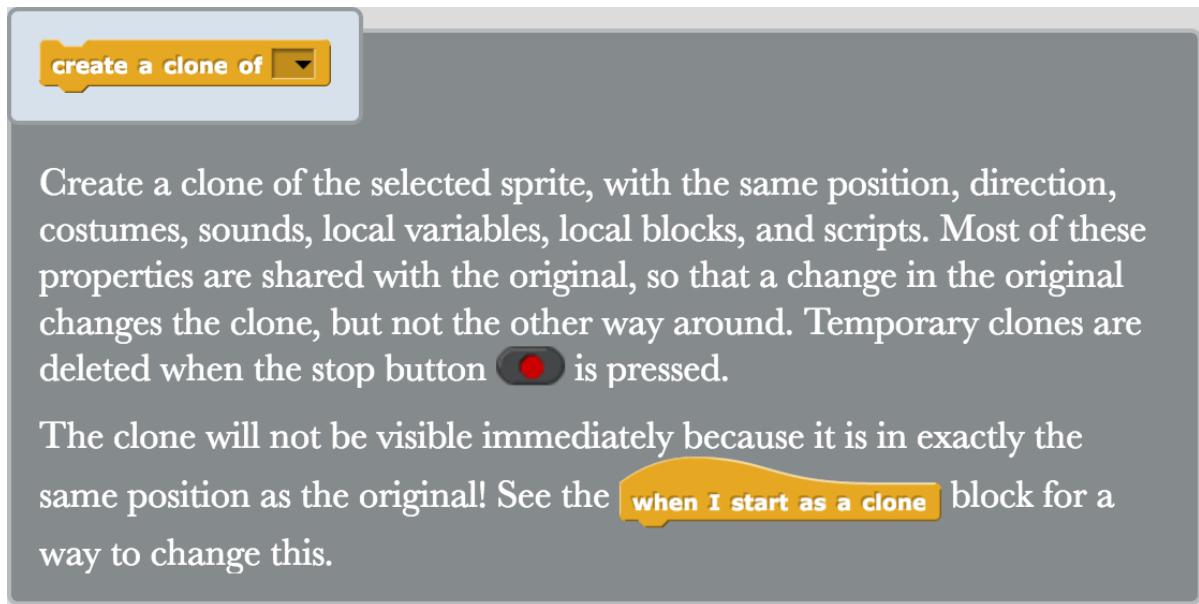
Example Projects

No examples yet.

create a clone of

Complete Me

create a clone of myself ▾



The screenshot shows the Scratch programming interface. A yellow **create a clone of** block is selected and highlighted with a yellow border. To its right is a dropdown menu with "myself" selected. In the background, there is a grey text area containing explanatory text about clones.

Create a clone of the selected sprite, with the same position, direction, costumes, sounds, local variables, local blocks, and scripts. Most of these properties are shared with the original, so that a change in the original changes the clone, but not the other way around. Temporary clones are deleted when the stop button  is pressed.

The clone will not be visible immediately because it is in exactly the same position as the original! See the **when I start as a clone** block for a way to change this.

Note: Snap! clones are not copies of the sprite; they actually share information, so a change in the original may be seen in the clones. See the “Object Oriented Programming with Sprites” chapter in the Snap! Reference Manual.

Example Images

No examples yet.

Example Projects

No examples yet.

a new clone of

Complete Me

a new clone of myself ▾

a new clone of myself ▾

Report a new clone of the selected sprite, with the same position, direction, costumes, sounds, local variables, local blocks, and scripts. Most of these properties are shared with the original, so that a change in the original changes the clone, but not the other way around. Temporary clones are deleted when the stop button  is pressed.

The clone will not be visible immediately because it is in exactly the same position as the original! See the **when I start as a clone** block for a way to change this.

Note: Snap! clones are not copies of the sprite; they actually share information, so a change in the original may be seen in the clones. See the “Object Oriented Programming with Sprites” chapter in the Snap! Reference Manual.

Example Images

No examples yet.

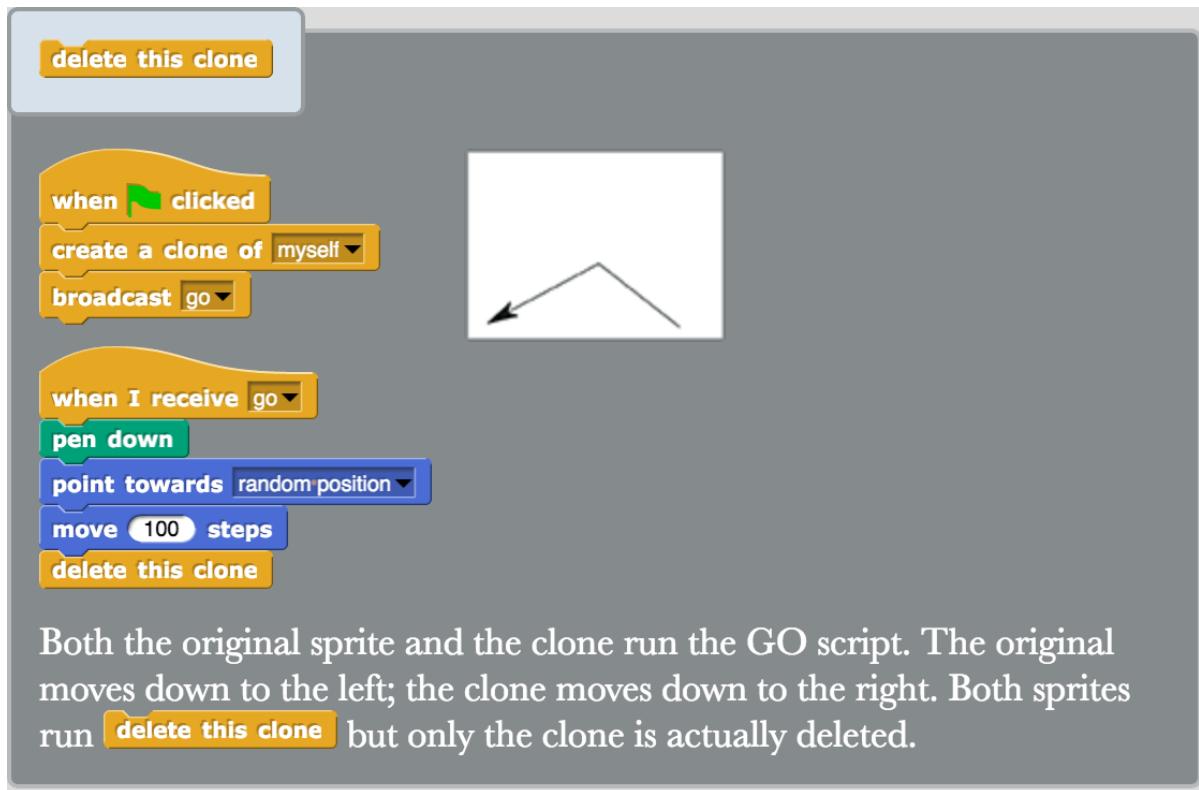
Example Projects

No examples yet.

delete this clone

Complete Me

delete this clone



Both the original sprite and the clone run the GO script. The original moves down to the left; the clone moves down to the right. Both sprites run **delete this clone** but only the clone is actually deleted.

Note: Snap! clones are not copies of the sprite; they actually share information, so a change in the original may be seen in the clones. See the “Object Oriented Programming with Sprites” chapter in the Snap! Reference Manual.

Example Images

No examples yet.

delete this clone

Example Projects

No examples yet.

pause all

Complete Me



Pause all running scripts.

Running this block is like pushing the pause button  in the top right corner of the screen. It pauses all running scripts until you push the pause button (which will have turned into a play button ).

The main purpose of this block is for use in debugging, as a way to set a breakpoint in a script.



Example Images

No examples yet.

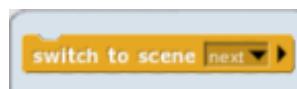
Example Projects

No examples yet.

switch to scene

Complete Me

switch to scene [next ▾]



A scene is a project included with others in a super-project.
Using the dropdown will switch to one of the scenes:



Clicking the arrowhead once or twice gives the long versions of this block. The second input sends a message to the scene you selected like with BROADCAST, and the third sends data with the message.

switch to scene [next ▾] and send [message] with data [list 1 ▶◀]



Example Images

No examples yet.

Example Projects

No examples yet.

define

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

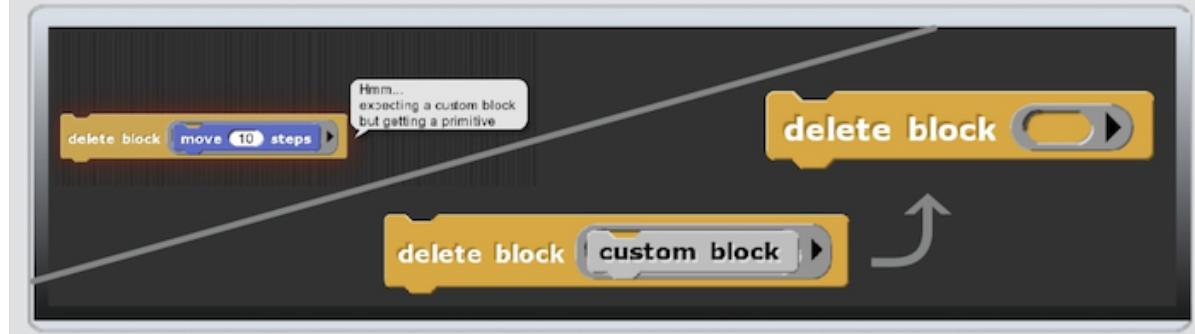
delete block

Complete Me



Delete a custom block's definition.

Running this block deletes all instances of the custom block and its definition. If the block is saved in a variable, the definition will be preserved, except for instances of the deleted block in its own definition, which will still be removed. Dragging the block from the variable lets you use it normally, although the block will be gone from the palette.



Example Images

No examples yet.

Example Projects

No examples yet.

set [label] of block [] to []

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

Attribute Of Block

Complete Me

definition ▾ **of block** ➔



Example Images

No examples yet.

Example Projects

No examples yet.

this

Complete Me

this script ▾



Example Images

No examples yet.

Example Projects

No examples yet.

set slot to

Complete Me

set slot  to 



Example Images

No examples yet.

Example Projects

No examples yet.

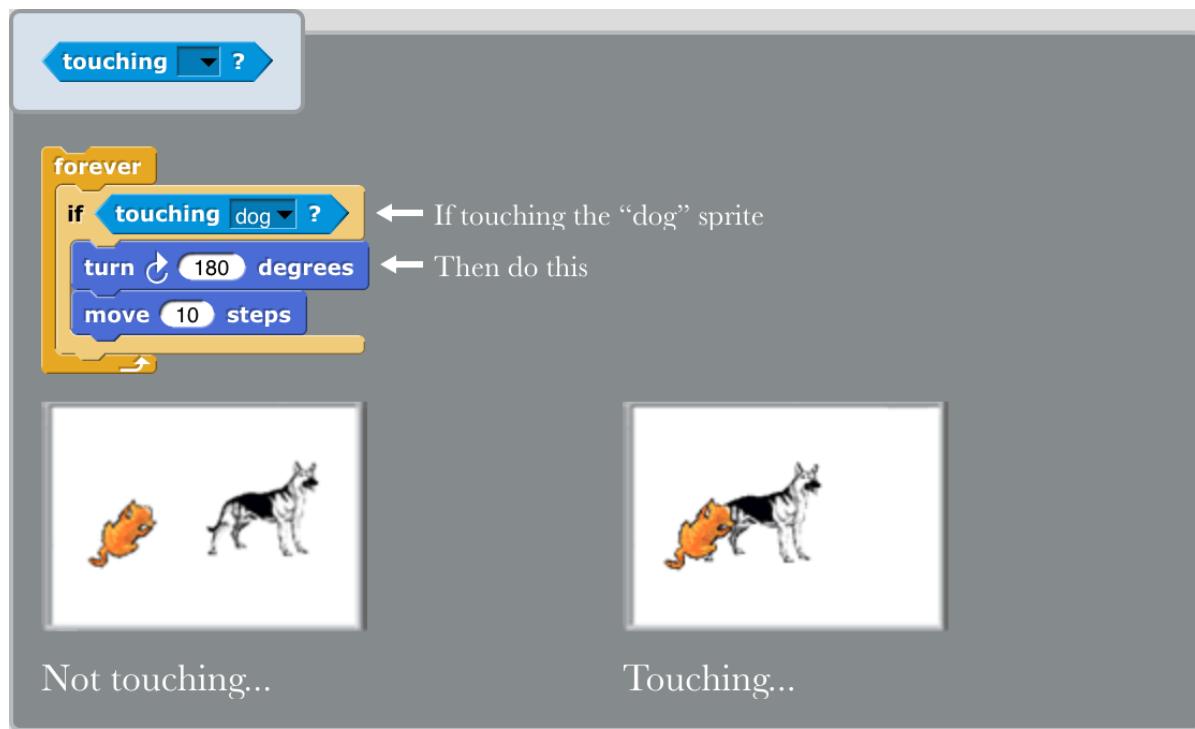
Part VI.

Sensing Blocks

touching ?

Complete Me

touching [mouse-pointer ▾ ?]



You can use the **touching** [dog ▾ ?] block in three different ways. Select from the dropdown menu to choose. You can check if the sprite is:

touching [mouse-pointer ▾ ?] ← Touching the mouse-pointer (cursor)?

touching [edge ▾ ?] ← Touching the edge of the screen?

touching [Sprite(2) ▾ ?] ← Touching another sprite?

Example Images

No examples yet.

touching ?

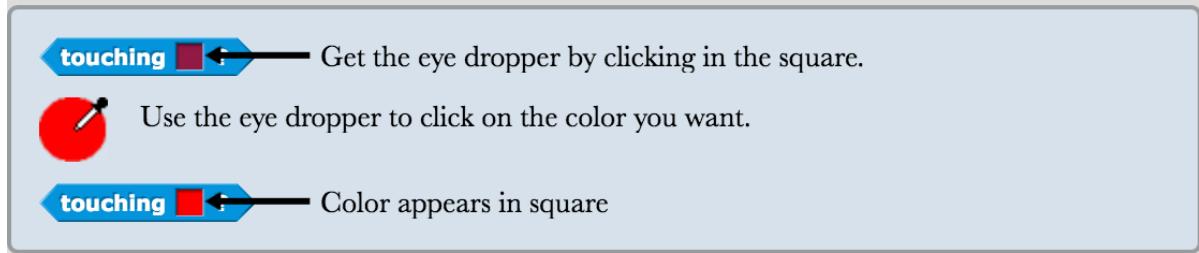
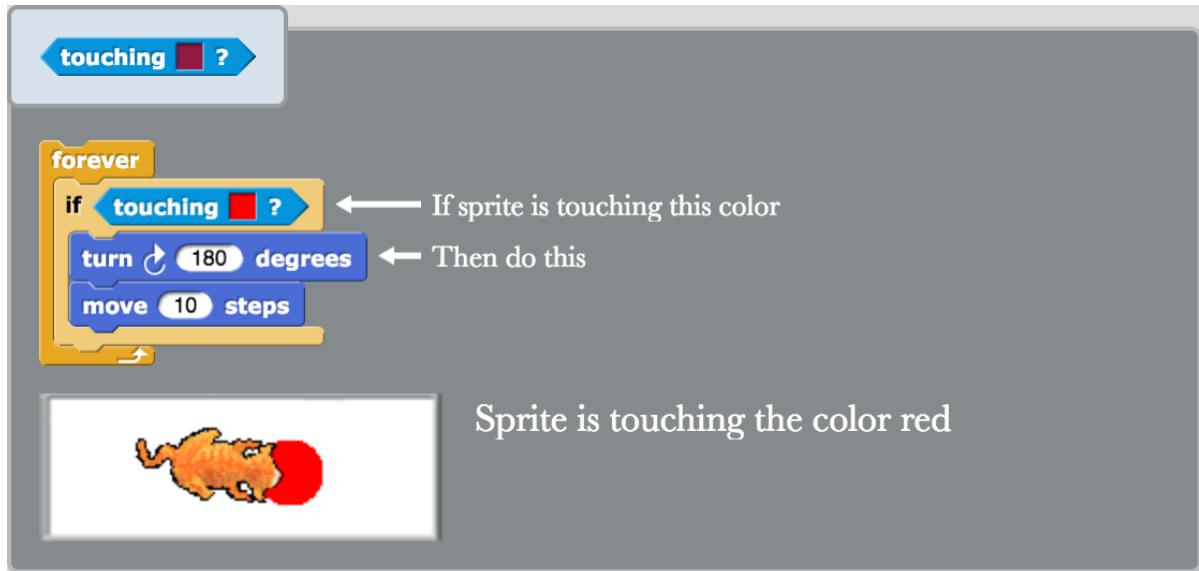
Example Projects

No examples yet.

touching ?

Complete Me

touching [] ?



Example Images

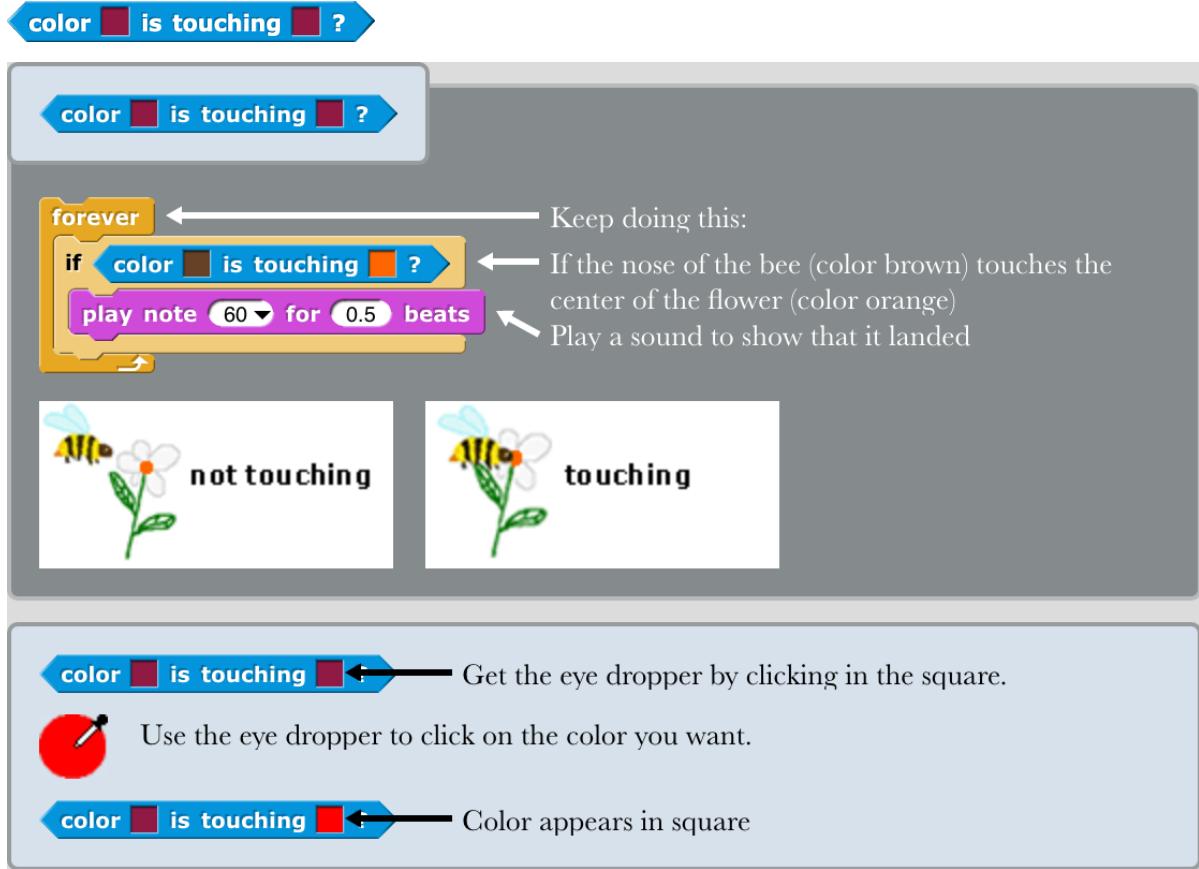
No examples yet.

Example Projects

No examples yet.

color is touching ?

Complete Me



The image shows a Scratch script consisting of the following blocks:

- A **forever** loop.
- An **if [color is touching [orange v] ?** control block.
- A **play note [60 v] for [0.5] beats** sound block.

Below the script are two images illustrating the color sensing:

- not touching**: A bee is above a flower, but the flower is white.
- touching**: The flower is orange, and the bee's nose is touching it.

Annotations explain the script:

- Keep doing this: Points to the **forever** loop.
- If the nose of the bee (color brown) touches the center of the flower (color orange): Points to the **if [color is touching [orange v] ?** block.
- Play a sound to show that it landed: Points to the **play note [60 v] for [0.5] beats** sound block.

Below the script are three more blocks:

- color [red v] is touching [red v]**: Get the eye dropper by clicking in the square.
- eye dropper icon**: Use the eye dropper to click on the color you want.
- color [red v] is touching [red v]**: Color appears in square

Example Images

No examples yet.

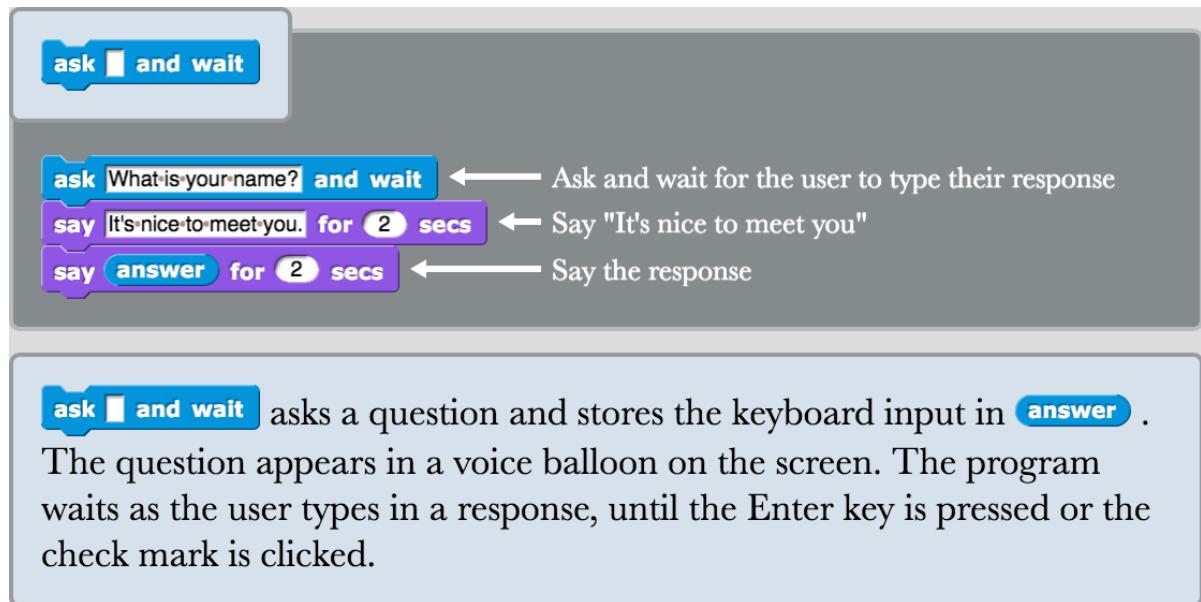
Example Projects

No examples yet.

ask and wait

Complete Me

ask [what's your name? and wait



The image shows a Scratch script consisting of three blocks:

- An **ask [] and wait** hat block.
- A **say [It's nice to meet you.] for [2] secs** control block.
- A **say [answer] for [2] secs** control block.

Annotations explain the purpose of each block:

- The first block is labeled "Ask and wait for the user to type their response".
- The second block is labeled "Say 'It's nice to meet you'".
- The third block is labeled "Say the response".

ask [] and wait asks a question and stores the keyboard input in **answer**. The question appears in a voice balloon on the screen. The program waits as the user types in a response, until the Enter key is pressed or the check mark is clicked.

Example Images

No examples yet.

Example Projects

No examples yet.

answer

Complete Me

answer

The image shows a Scratch script for the **answer** block. It begins with an **ask [Do you want an apple or orange?] and wait** block. This is followed by two nested **if [answer = [apple]] then** blocks. Each branch contains a **switch to costume [holding an apple]** block. After these, there are two more nested **if [answer = [orange]] then** blocks, each containing a **switch to costume [holding an orange]** block. Arrows point from the explanatory text to the corresponding blocks in the script.

ask [Do you want an apple or orange?] and wait ← Asks question and waits for person to type in an answer
If the answer is “apple”
switch to costume [holding an apple] ← Do this

if [answer = [orange]] then ← If the answer is “orange”
switch to costume [holding orange] ← Do this

ask [] and wait asks a question and stores the keyboard input in **answer**. If you want to save the current answer, you can store it in a variable or list. For example: **set [your name] to [answer]**

Example Images

No examples yet.

Example Projects

No examples yet.

mouse position

Complete Me

mouse position



Example Images

No examples yet.

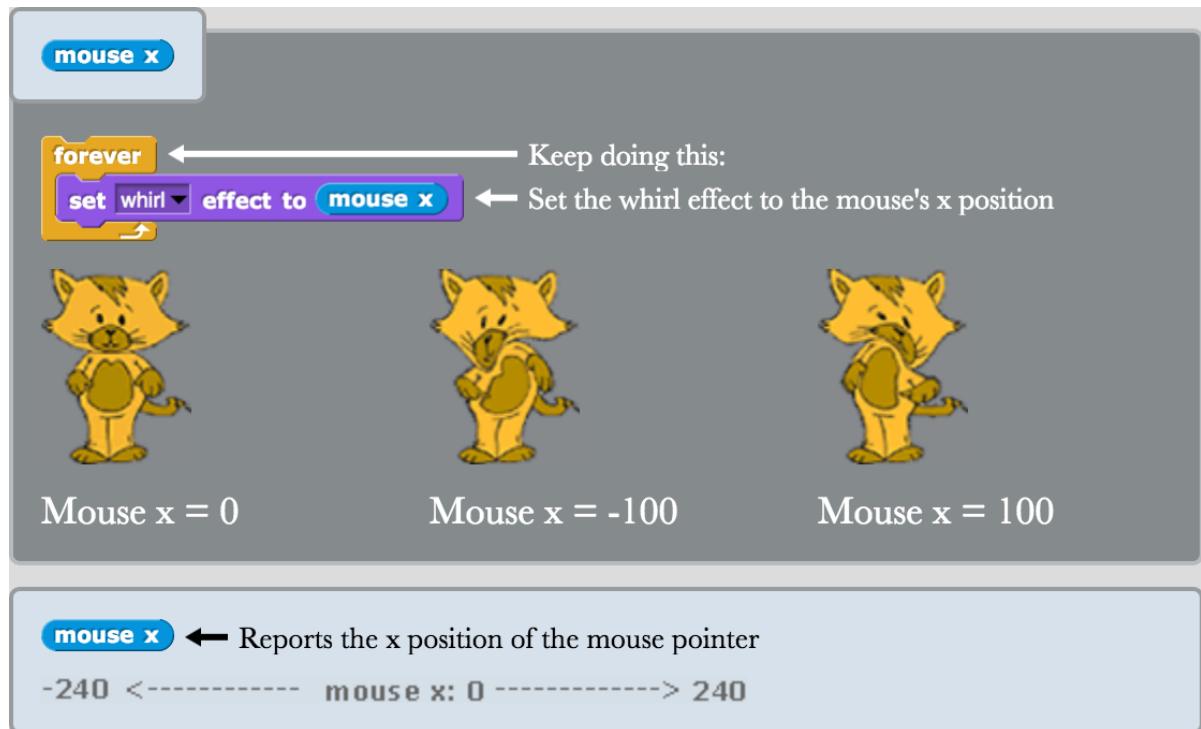
Example Projects

No examples yet.

mouse x

Complete Me

mouse x



A Scratch script titled "mouse x" is shown. It starts with a "forever" loop. Inside the loop is a "set whirl effect to [mouse x]" block. To the left of the script, three small yellow cat images are shown in different poses, representing the effect of the whirl effect at different mouse x positions. Below each image is a label: "Mouse x = 0", "Mouse x = -100", and "Mouse x = 100".

mouse x ← Reports the x position of the mouse pointer
-240 <----- **mouse x: 0** -----> 240

Example Images

No examples yet.

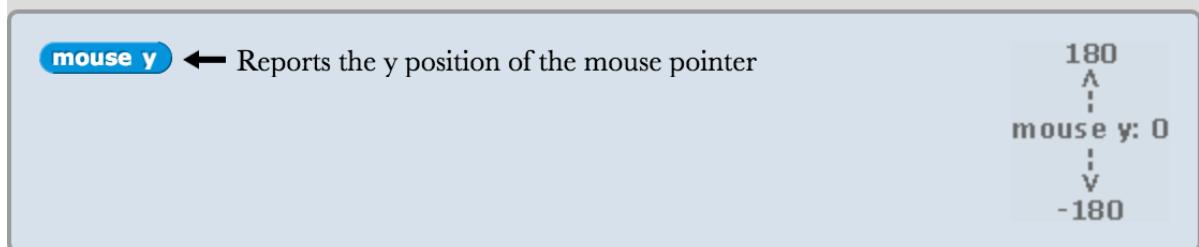
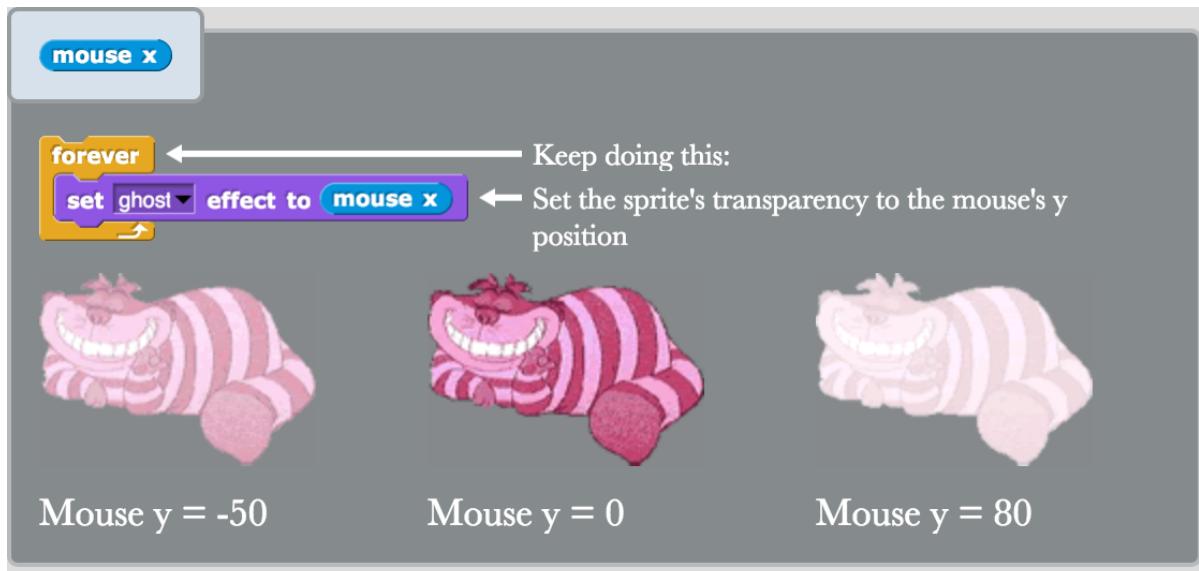
Example Projects

No examples yet.

mouse y

Complete Me

mouse y



Example Images

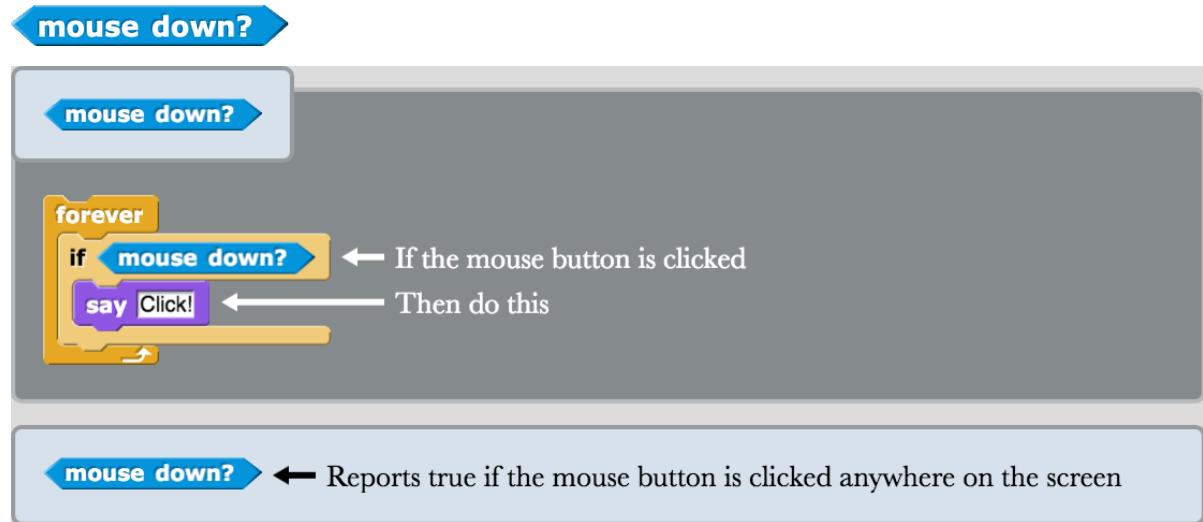
No examples yet.

Example Projects

No examples yet.

mouse down?

Complete Me



Example Images

No examples yet.

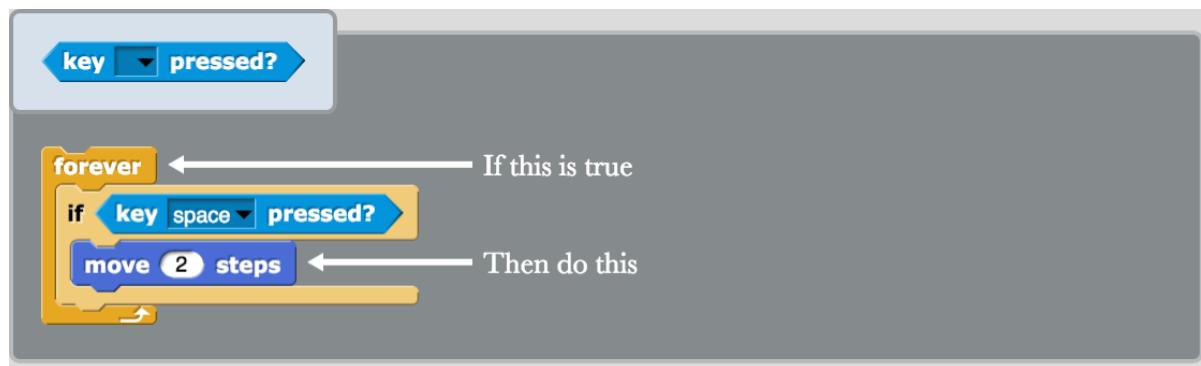
Example Projects

No examples yet.

key pressed?

Complete Me

key space ▾ pressed?



Use **key space ▾ pressed?** instead of **when space ▾ key pressed** when you want to keep, for example, the space key pressed continuously.

Example Images

No examples yet.

Example Projects

No examples yet.

Distance To

Complete Me

`distance ▾ to mouse-pointer ▾`

A Scratch script attached to a cat sprite:

- A `distance ▾ to [mouse-pointer ▾]` sensor block.
- An `forever` loop:
 - An `if <distance to [dog v.] < 20>` control block.
 - Inside the if-block:
 - A `switch to costume [scared cat v.]` control block.
- A `distance ▾ to []` reporter block with `distance direction` selected.

Annotations explain:

- The `if` condition: ← If distance to the dog sprite is less than 20
- The `switch to costume` action: ← Then do this
- The `distance direction` reporter: ← Can also report what `direction` to face in order to be facing toward the other sprite.

Select from the dropdown menu to choose:

`distance ▾ to mouse-pointer ▾` ← Reports the distance from this sprite to the pointer (☞)

`distance ▾ to [Sprite(2) ▾]` ← Reports the distance to another sprite

Example Images

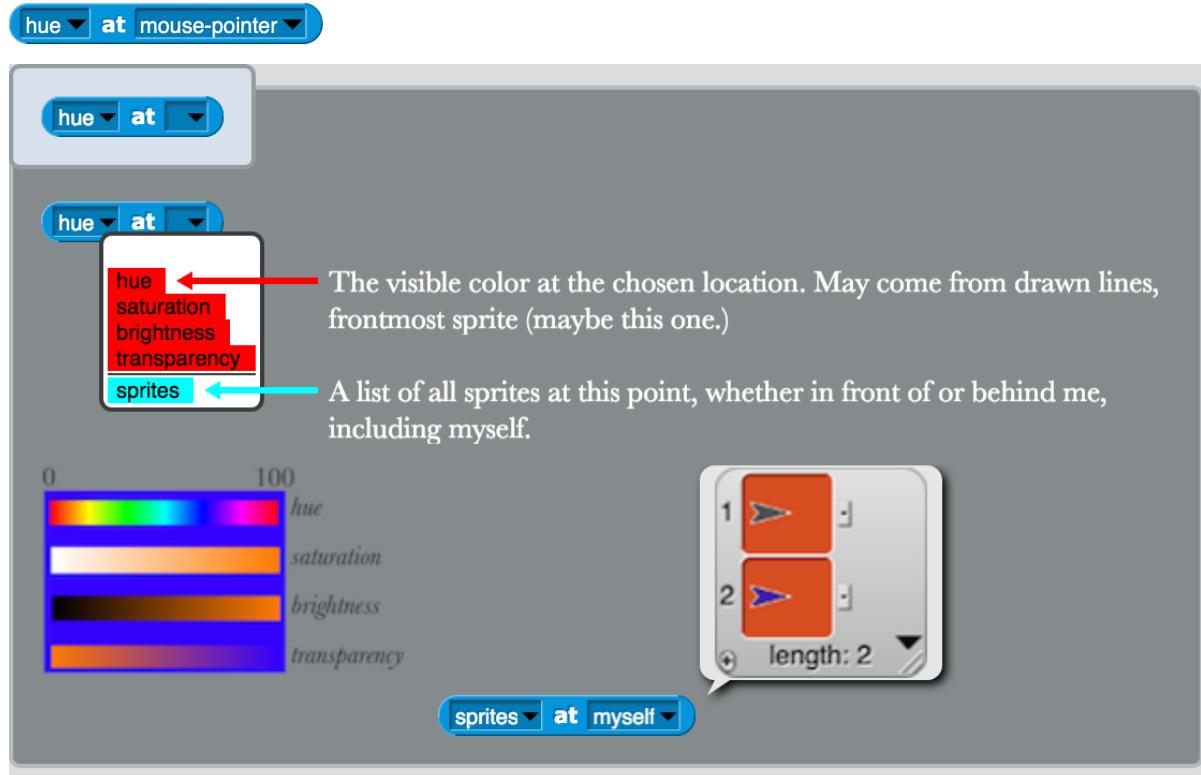
No examples yet.

Example Projects

No examples yet.

Color at Location

Complete Me



The value (color or sprites) is measured at the rotation center of the given sprite.

Instead of choosing from the right menu, you can drop an (x,y) coordinate pair into that slot.

Example Images

No examples yet.

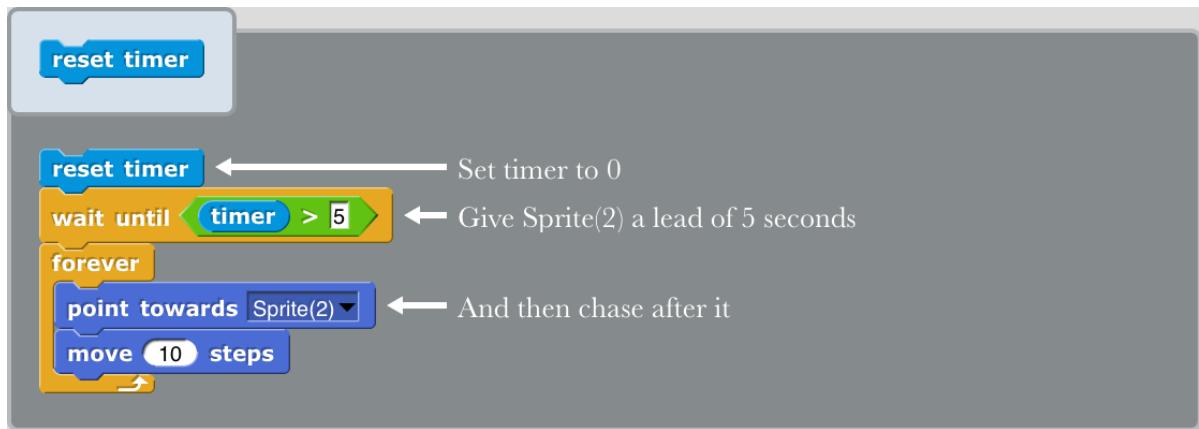
Example Projects

No examples yet.

reset timer

Complete Me

reset timer



Example Images

No examples yet.

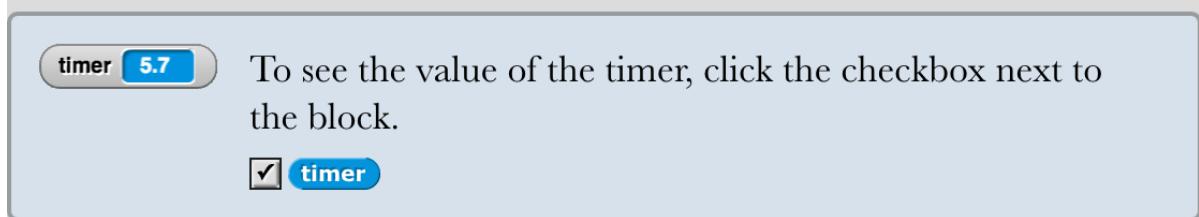
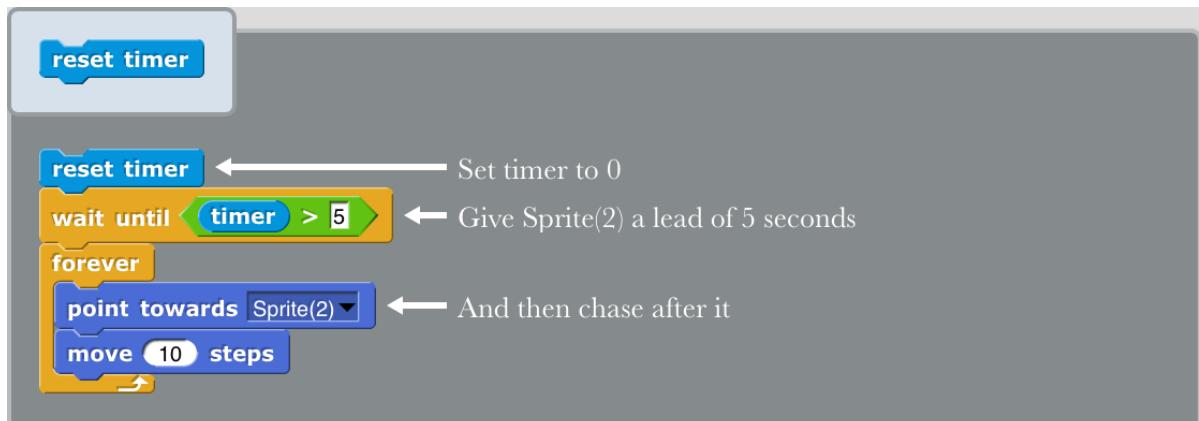
Example Projects

No examples yet.

timer

Complete Me

timer



Example Images

No examples yet.

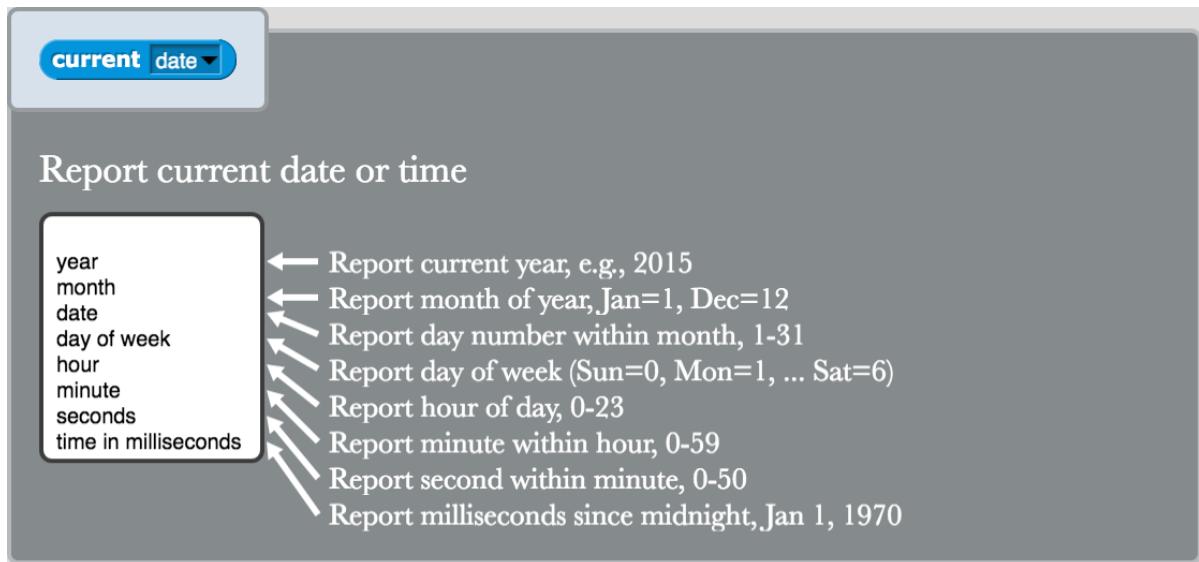
Example Projects

No examples yet.

current

Complete Me

current date



A Scratch script consisting of a single **current date** block. The script is titled "Report current date or time". To the left of the script is a list of variables: year, month, date, day of week, hour, minute, seconds, and time in milliseconds. Arrows point from each variable to its corresponding description on the right.

Variable	Description
year	Report current year, e.g., 2015
month	Report month of year, Jan=1, Dec=12
date	Report day number within month, 1-31
day of week	Report day of week (Sun=0, Mon=1, ... Sat=6)
hour	Report hour of day, 0-23
minute	Report minute within hour, 0-59
seconds	Report second within minute, 0-50
time in milliseconds	Report milliseconds since midnight, Jan 1, 1970

All reported values are numbers; you can write blocks to convert week days or months into words. Note that date numbers start at 1, as in conventional written notation (7/20/2015 or 20-7-2015 for July 20th), but time numbers start at 0, as in 24-hour clock notation (15:49:20 is 3:49pm plus 20 seconds).

5/25/2015

join **current month** **current date** **current year**

Example Images

No examples yet.

Example Projects

No examples yet.

Attribute Of

Complete Me

costume # ▾ of ▾

Report an attribute of an object.

x-position ▾ of Sprite(2) ▾ (The attributes available in the left pulldown are different for different objects, e.g., the stage has no x position.)

Sprite(2) my variable something
my variables ▾ of Sprite(2) ▾ If a sprite has a “for this sprite only” variable, it will appear in the left pulldown, so one sprite can examine the variables of another.



By putting a script in a grey ring and dragging it over the left pulldown, you can even let one sprite control the actions of another sprite!

Example Images

No examples yet.

Example Projects

No examples yet.

my

Complete Me

my neighbors ▾

my neighbors ▾

Reports properties of this sprite and its family.

my neighbors ▾

neighbors
self
other sprites
clones
other clones
parts
anchor
stage
children
parent
temporary?
name
costume
costumes
sounds
dangling?
draggable?
width
height
rotation style
rotation x
rotation y
center x
center y

● Reports an object



my self ▾

-115

my rotation-x ▾

false

my dangling? ▾



my neighbors ▾

● Reports a number

● Reports a Boolean

● Reports a list

ask Sprite(3) ▾ for my self ▾ ▶▶

ask my parent ▾ for my name ▾ ▶▶

For more details on what each option means, read the Reference Manual, Chapter VII.

my

Example Images

No examples yet.

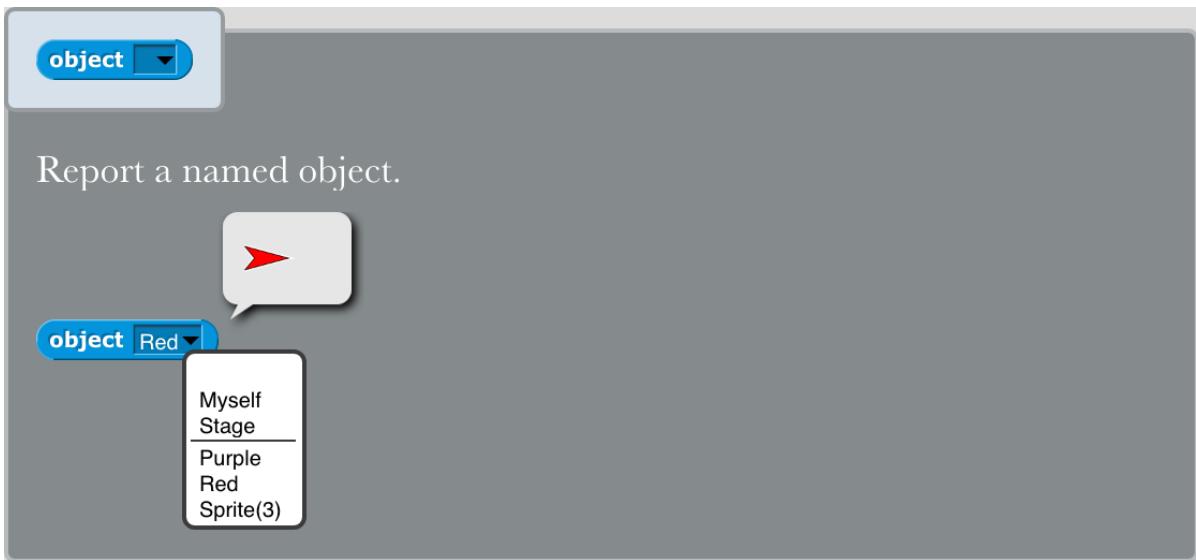
Example Projects

No examples yet.

object

Complete Me

object myself ▾



Example Images

No examples yet.

Example Projects

No examples yet.

url

Complete Me

url snap.berkeley.edu

url snap.berkeley.edu

Report web page text.

```
<html>
<head>
<meta name="snap-cloud-domain" location="https://snap.berkeley.edu:443">
<meta charset="UTF-8">
<title>Snap! Build Your Own Blocks</title>
<meta name="description" content="The Snap! social platform">
<meta name="author" content="Bernat Romagosa">
<meta name="snap-cloud-domain" location="https://snap.berkeley.edu">
<link rel="icon" href="favicon.ico">
<meta name="viewport" content="width=device-width, initial-scale=1">
...

```

url snap.berkeley.edu

Hint: Use SPLIT to see the result as a list of lines.



split url snap.berkeley.edu by line ▾

Note: Many websites won't work with this block because of an Internet security feature built into browsers, called "Cross Origin Resource Sharing." There's nothing Snap! can do about this; you should try to get the provider of the website to allow cross-origin requests from everyone, or at least for your Internet domain. You can also look for a "CORS proxy," which is a website that funnels requests for arbitrary pages regardless of CORS status.

url

Example Images

No examples yet.

Example Projects

No examples yet.

microphone

Complete Me

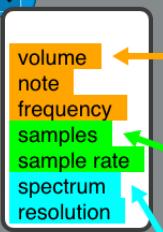
microphone [volume ▾]

microphone [volume ▾]

Report data from microphone.

This block collects and analyzes a short (0.01 to 0.1 second) burst of sound.

microphone [volume ▾]



The first three options report a single number characterizing the sound as a whole average volume, dominant note number, and frequency.

The next two options are time domain information: a list of instantaneous volumes and a number representing the number of samples per second (sampling rate).

The last two options are frequency domain information: a histogram of frequencies and the number of buckets in the histogram.

“Time domain” means that the list items are the instantaneous volume at each moment, measured thousands of times per second. “Frequency domain” means that the list items are the volume over the entire burst of sound at each note frequency.



Tuning fork (pure sine wave)



Simple musical instrument with harmonics

microphone

Example Images

No examples yet.

Example Projects

No examples yet.

video on

Complete Me

video motion ▾ on myself ▾

video motion ▾ on myself ▾

Reports information from video capture.

The second input is a menu of sprites, and restricts the block's attention to the part of the stage taken up by the chosen sprite. ("Stage" uses the entire stage area.)

The first input specifies what information you want:

video motion ▾ on myself ▾

snap
motion
direction

- ← Reports a snapshot of the video as a costume.
- ← Reports a number, the speed of a detected moving object in the video.
- ← Reports a number, the direction in which the object is moving, suitable for use as input in POINT IN DIRECTION.

Example Images

No examples yet.

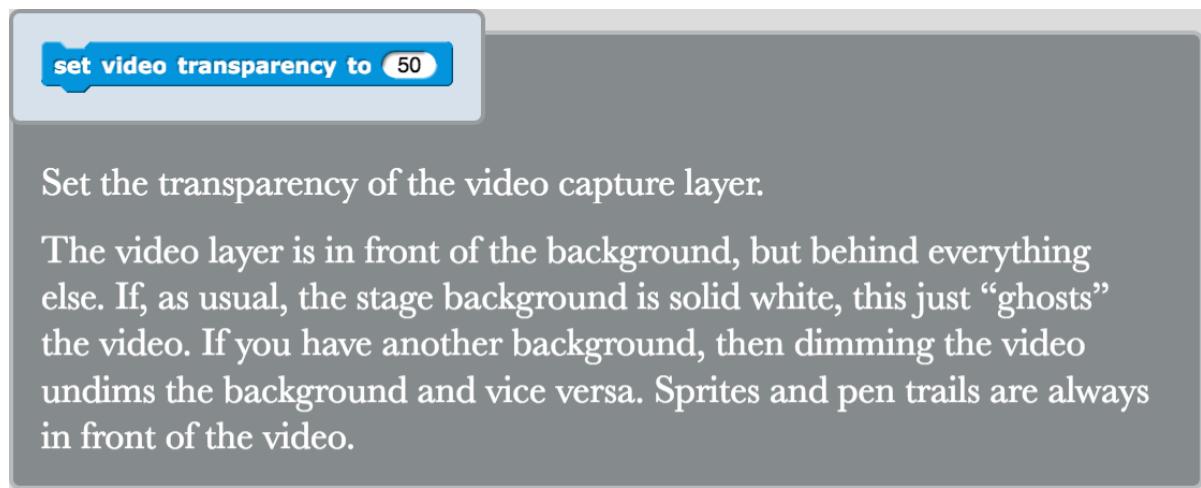
Example Projects

No examples yet.

set video transparency to

Complete Me

set video transparency to 50



A Scratch script consisting of a single green flag button labeled "set video transparency to 50". The script is enclosed in a light blue rounded rectangle.

Set the transparency of the video capture layer.

The video layer is in front of the background, but behind everything else. If, as usual, the stage background is solid white, this just “ghosts” the video. If you have another background, then dimming the video undims the background and vice versa. Sprites and pen trails are always in front of the video.

Example Images

No examples yet.

Example Projects

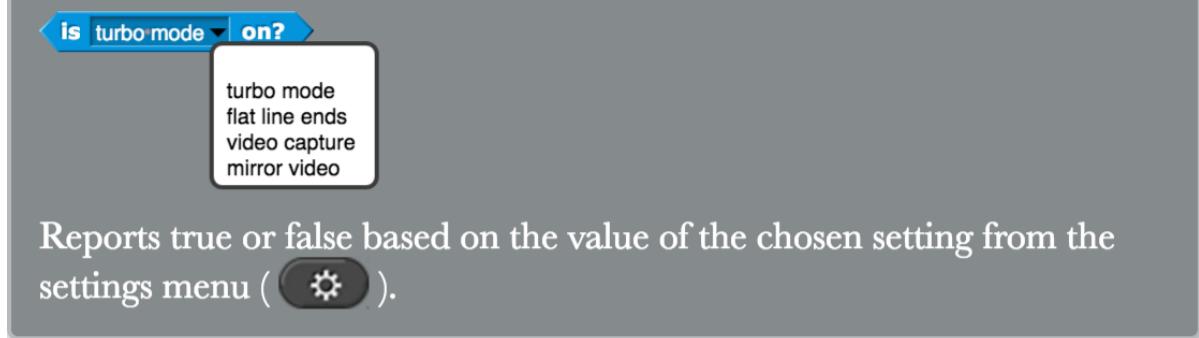
No examples yet.

is on?

Complete Me

 is [turbo mode v] on?


Report global flag.


turbo mode
flat line ends
video capture
mirror video

Reports true or false based on the value of the chosen setting from the settings menu ().

(Note: The particular settings available in the menu of this block are just the ones Jens has needed for some project of his. If you'd like to be able to read and set all the settings in your project, load the “Provide getters and setters for all GUI controls” library.)

“Anything you can do from the GUI, you should be able to do from the programming language, and vice versa.” — Mike Eisenberg, d. 3/12/2019 RIP

Example Images

No examples yet.

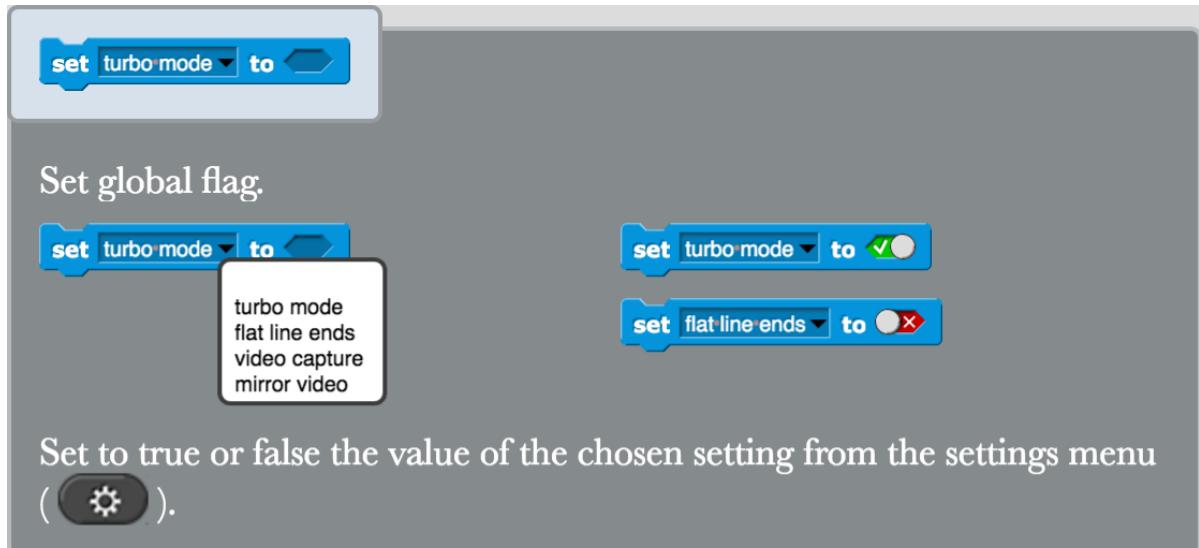
Example Projects

No examples yet.

set to

Complete Me

`set [video capture] to []`



Set to true or false the value of the chosen setting from the settings menu ().

(Note: The particular settings available in the menu of this block are just the ones Jens has needed for some project of his. If you'd like to be able to read and set all the settings in your project, load the “Provide getters and setters for all GUI controls” library.)

“Anything you can do from the GUI, you should be able to do from the programming language, and vice versa.” — Mike Eisenberg, d. 3/12/2019 RIP

Example Images

No examples yet.

Example Projects

No examples yet.

Part VII.

Operators Blocks

Command Ring

Complete Me



Reports a script or block as a value.

All rings are oval on the outside because a ring reports a value.
The inside shape tells whether this ring expects a command script, a reporter, or a predicate block.

Some blocks have rings built in. These are input slots that expect a script or block as the input value.



This slot in the CALL block takes a reporter as the input.



Example Images

No examples yet.

Example Projects

No examples yet.

Reporter Ring

Complete Me



Reports a script or block as a value.

A Scratch script consisting of three blocks: a green **math** block with values 2 and 3, a blue **control** block with a **repeat** loop containing a **math** block with values 2 and 3, and a blue **control** block with a **repeat** loop containing a **pen down** block followed by a **move 10 steps** block. Each of these blocks has a reporter ring attached to its right side. The first two reporter rings are green and contain the value 5, while the third one is blue and contains the value 8. Arrows point from the text descriptions to the reporter rings on the blocks.

All rings are oval on the outside because a ring reports a value.
The inside shape tells whether this ring expects a command script, a reporter, or a predicate block.

Some blocks have rings built in. These are input slots that expect a script or block as the input value.

This slot in the CALL block takes a reporter as the input.

8

Example Images

No examples yet.

Example Projects

No examples yet.

Predicate Ring

Complete Me



The image shows a Scratch script editor window. At the top are three control blocks: a green flag, a red stop, and a yellow wait. Below them is a grey reporter block labeled "Report [5]" with a green +3 block inside. To the right is a blue command block labeled "pen down" with a blue move 10 steps block inside. A grey oval ring with a black border and a white center is attached to the right side of the "Report [5]" block. An arrow points from this ring to a text box containing the following explanation:

All rings are oval on the outside because a ring reports a value.
The inside shape tells whether this ring expects a command script, a reporter, or a predicate block.

Some blocks have rings built in. These are input slots that expect a script or block as the input value.



This slot in the CALL block takes a reporter as the input.



Example Images

No examples yet.

Example Projects

No examples yet.

Sum +

Complete Me



- $6 + 2$ gives the result of 6 plus 2
- $6 - 2$ gives the result of 6 minus 2
- $6 * 2$ gives the result of 6 times 2
- $6 / 2$ gives the result of 6 divided by 2

Example Images

No examples yet.

Example Projects

No examples yet.

Subtract -

Complete Me

The image shows a digital calculator interface. At the top, there is a green button with a minus sign (-). Below it is a light blue panel containing four buttons arranged in a 2x2 grid: addition (+), multiplication (x), subtraction (-), and division (/). To the right of the panel is a large, dark grey input field. Below the input field, there are four examples of operations with their results and descriptions:

- 6 + 2** ← Gives the result of 6 plus 2
- 6 - 2** ← Gives the result of 6 minus 2
- 6 x 2** ← Gives the result of 6 times 2
- 6 / 2** ← Gives the result of 6 divided by 2

Example Images

No examples yet.

Example Projects

No examples yet.

Product ×

Complete Me



The image shows a Scratch script consisting of a grey stage and a green script area. In the top-left corner of the stage, there is a green script icon with four operators arranged in a 2x2 grid: addition (+), subtraction (-), multiplication (*), and division (/). Below the stage, the green script area contains four corresponding blocks: **[6 + (2)]**, **[6 - (2)]**, **[6 * (2)]**, and **[6 / (2)]**. Each block is followed by its description: "gives the result of 6 plus 2", "gives the result of 6 minus 2", "gives the result of 6 times 2", and "gives the result of 6 divided by 2".

- [6 + (2)]** gives the result of 6 plus 2
- [6 - (2)]** gives the result of 6 minus 2
- [6 * (2)]** gives the result of 6 times 2
- [6 / (2)]** gives the result of 6 divided by 2

Example Images

No examples yet.

Example Projects

No examples yet.

Divide ÷

Complete Me



+ ×
 - ÷

6 + 2 ← Gives the result of 6 plus 2

6 - 2 ← Gives the result of 6 minus 2

6 × 2 ← Gives the result of 6 times 2

6 ÷ 2 ← Gives the result of 6 divided by 2

Example Images

No examples yet.

Example Projects

No examples yet.

Power of Number

Complete Me



Exponentiation (power) function.

$$3 \wedge 4 \rightarrow 81$$

$\leftarrow 3 \times 3 \times 3 \times 3$

$$3 \wedge 0.5 \rightarrow 1.7320508075688772$$

$\leftarrow \sqrt{3}$

$$3 \wedge -1 \rightarrow 0.3333333333333333$$

$\leftarrow \frac{1}{3}$

$$-3 \wedge 0.5 \rightarrow \text{NaN}$$

$\leftarrow \sqrt{-3}$

$$-3 \wedge 0.5 \rightarrow 1.0605752387249068e-16 + 1.7320508075688772i$$

$\leftarrow \approx 0 + \sqrt{3}i$

Would you prefer this answer? Then load the “infinite precision integers” library and do this:

USE BIGNUMS

Example Images

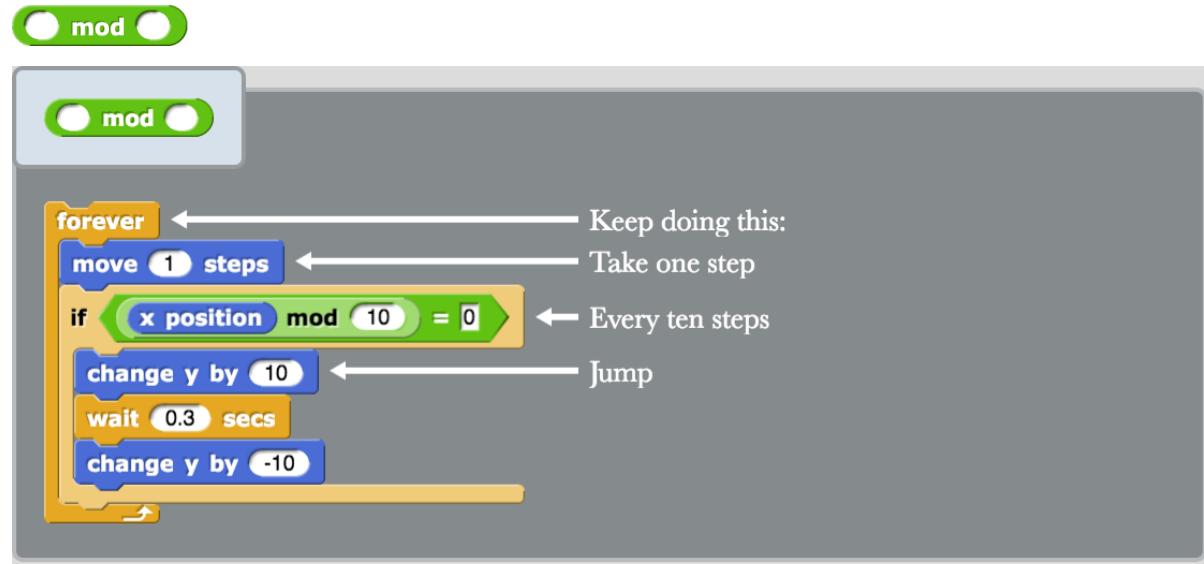
No examples yet.

Example Projects

No examples yet.

Mod

Complete Me



mod gives the remainder of the division of the two numbers.

For example, $143 \text{ mod } 6$ is 5 (143 divided 6 is 23 and the remainder is 5).

Example Images

No examples yet.

Example Projects

No examples yet.

min

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

max

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

round

Complete Me

The image shows a Scratch script consisting of a green **round** control block and a yellow **forever** control block. Inside the **forever** loop is a purple **say round timer** control block. A callout box points to the **forever** loop with the text "Keep doing this forever:" and another callout box points to the **say round timer** block with the text "Say how many seconds is on the timer (rounded to the nearest whole number)".

round gives the rounded value of a number. That means it turns a decimal number into the nearest whole number.

For example: **round 5.1** is 5, and **round 5.6** is 6.

Example Images

No examples yet.

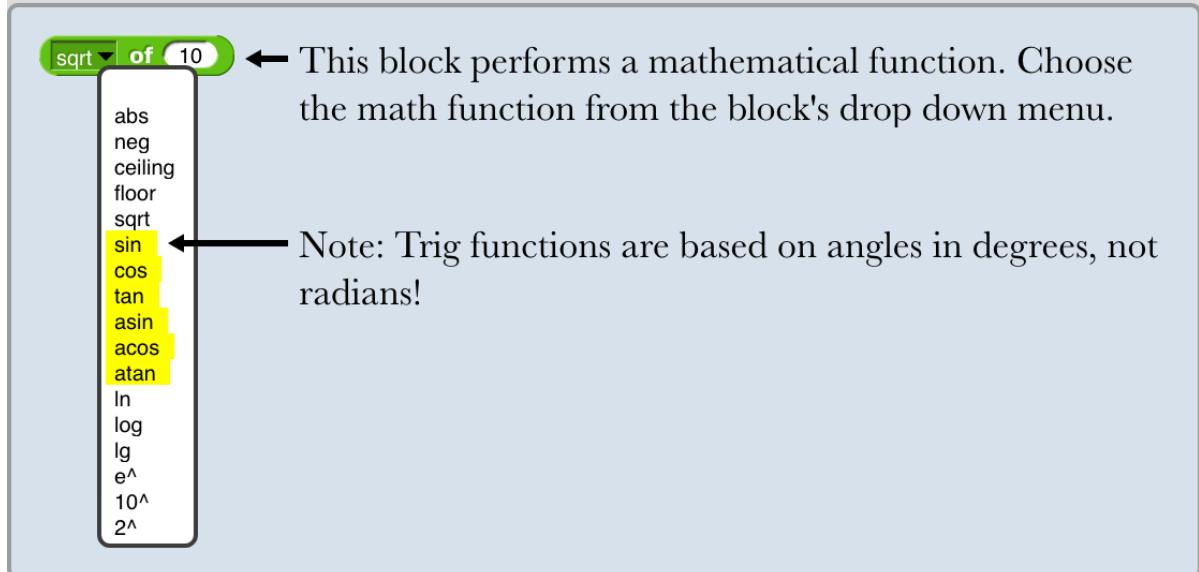
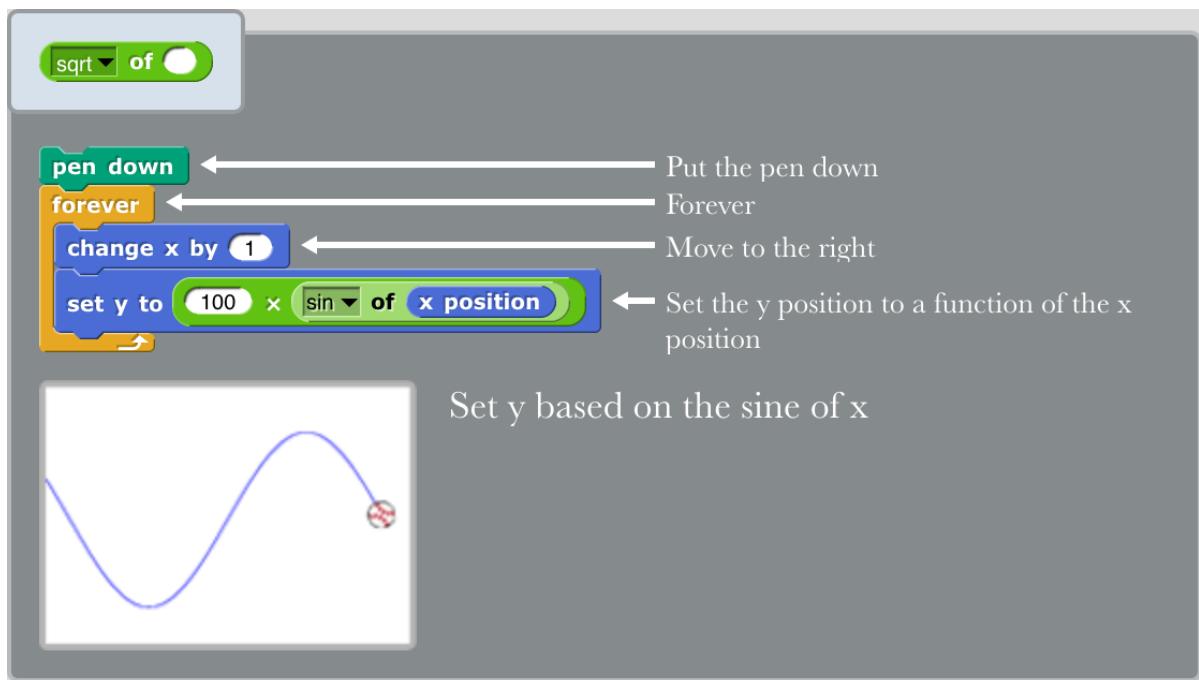
Example Projects

No examples yet.

Math Functions

Complete Me

sqrt ▾ of 10



Example Images

No examples yet.

Example Projects

No examples yet.

atan2 ÷

Complete Me

atan2  ÷ 



Example Images

No examples yet.

Example Projects

No examples yet.

pick random to

Complete Me

pick random 1 to 10

set x to [pick random -240 to 240] ← Set sprite's position to a random point anywhere on the stage

set y to [pick random -180 to 180]

This can be abbreviated with **go to random position**

pick random 1 to 10 ← Picks a random number from 1 and 10.

say [pick random 1 to 10] ← Click to have a sprite say a random number. Click again to get another random number.

pick random 1 to 5.3 ← If either input isn't an integer, then the result can be any value between the input values, not just whole numbers.

Example Images

No examples yet.

Example Projects

No examples yet.

<

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

-

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

>

Complete Me



Example Images

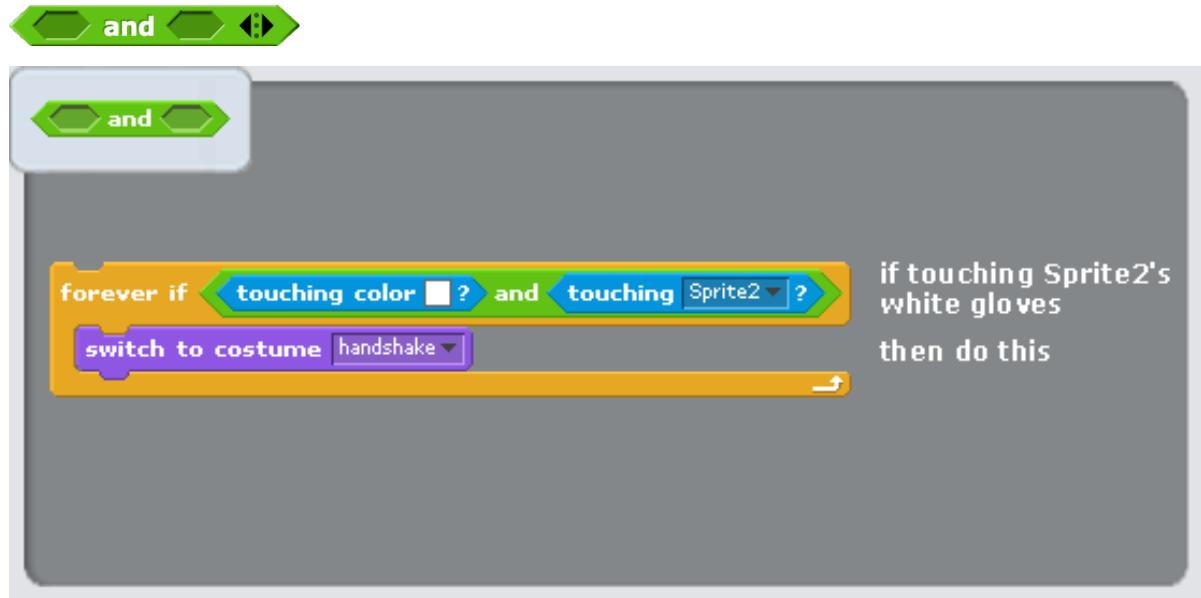
No examples yet.

Example Projects

No examples yet.

—

Complete Me



Example Images

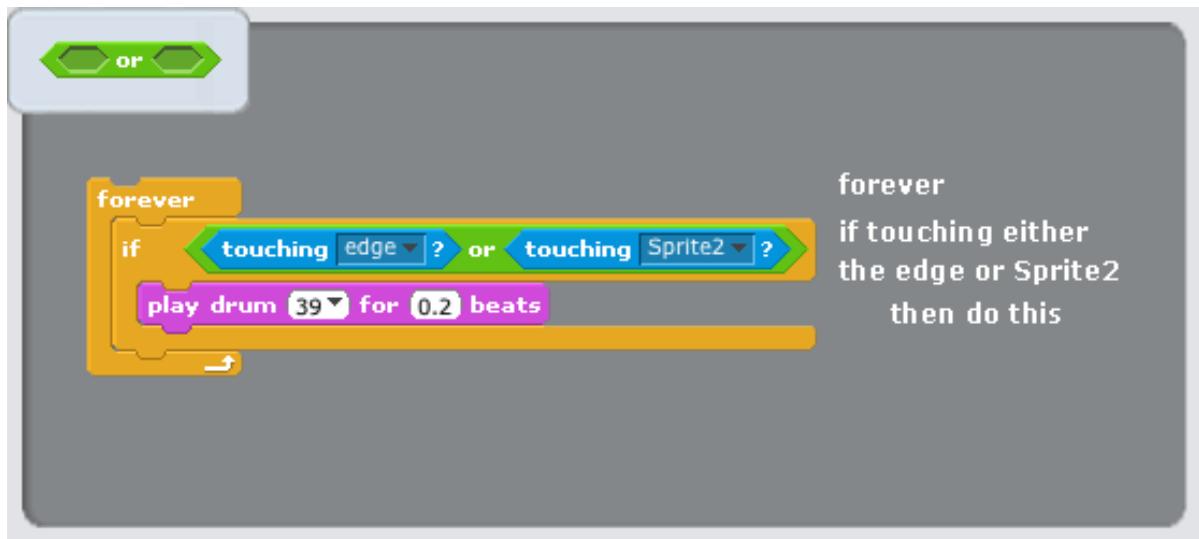
No examples yet.

Example Projects

No examples yet.

or

Complete Me



Example Images

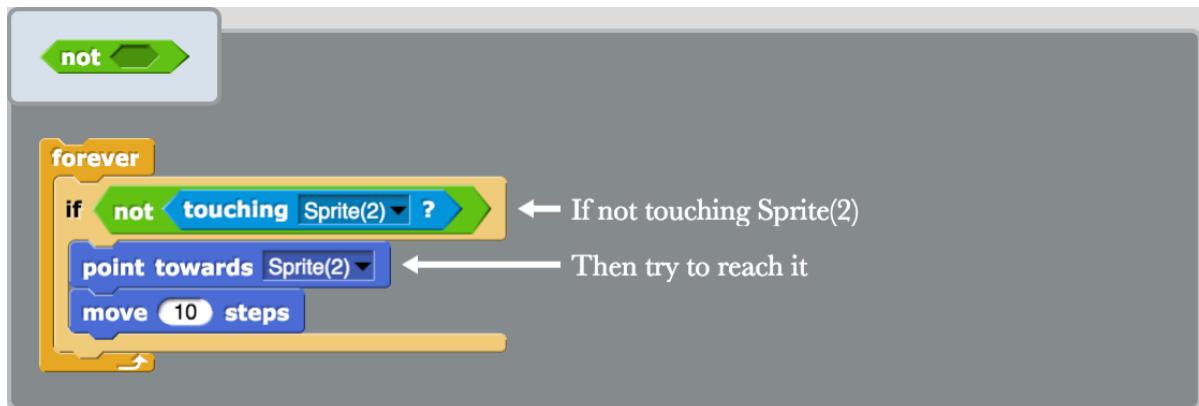
No examples yet.

Example Projects

No examples yet.

not

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

Complete Me

The image shows a Scratch script consisting of the following blocks:

- A green **reporter** block labeled "true" is at the top.
- An orange **control** loop:
 - Condition: **if pen down**
 - Action:
 - pen down**
 - repeat (4)**:
 - move (size) steps**
 - turn (90) degrees**- Two blue **control** blocks:
 - square (100)** with a checkmark icon (indicated by a green arrow).
 - square (100)** with a red X icon (indicated by a red arrow).

Text annotations explain the blocks:

- "Reports “true” or “false.”"
- "true" ← Click the block to change the value.
- "square (100)" with checkmark ← This says, “draw a square with side 200 steps, after putting the pen down first.”
- "square (100)" with red X ← This says, “draw a square with side 100 steps, and don't put the pen down first.”

Programming style tip:

The image shows two Scratch scripts illustrating programming style:

- The first script uses nested conditionals and reporters:
 - if** **foo = 0**
 - report** **true**
 - else**
 - report** **false**
- The second script is a simplified version:
 - report** **foo = 0**

Text annotations explain the scripts:

- "Instead of this" points to the first script.
- "you can just say this" points to the second script.

Example Images

No examples yet.

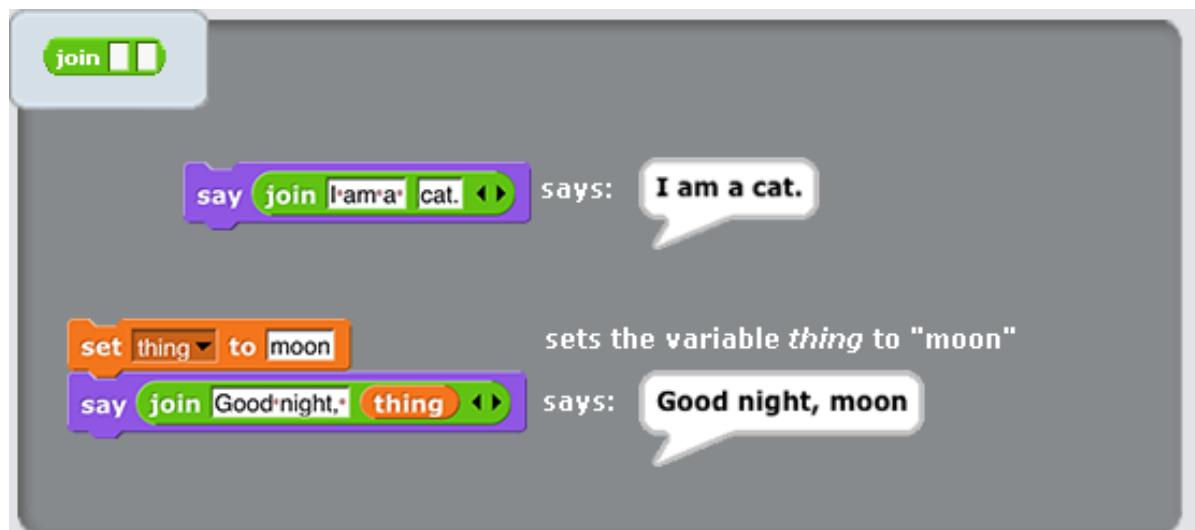
Example Projects

No examples yet.

join

Complete Me

join [hello world] ◀▶



join [I am a cat.] ◀▶

The raised brown dots represent spaces in the text. They're only in the input slot, not the actual text. They're so you can tell the difference between [] and [].

Example Images

No examples yet.

Example Projects

No examples yet.

split by

Complete Me

split by

`split by`

Report list of text split into words or lines.

`split hello-world by space`

Splitting on a character (space, in this example) can result in empty list elements if the character appears several times in a row in the text.

`split nowhere::man by whitespace`

Choosing “whitespace” from the pulldown menu will treat any number of spaces, tabs, or newlines as a single separator, to make a list of words.

`split Yakko by letter`

Split a text into individual characters (including spaces, newlines, and punctuation as list items).

`split url snap.berkeley.edu by line`

Split a multiline text into lines. (The newline character, the carriage return character, or the combination CR, NL all count as a single line break in the text.)

`split banana by an`

It's not often useful, but you can use a multi-character string as the separator. In this example, we get an empty list item because “an” appears twice in a row in “banana.”

Example Images

No examples yet.

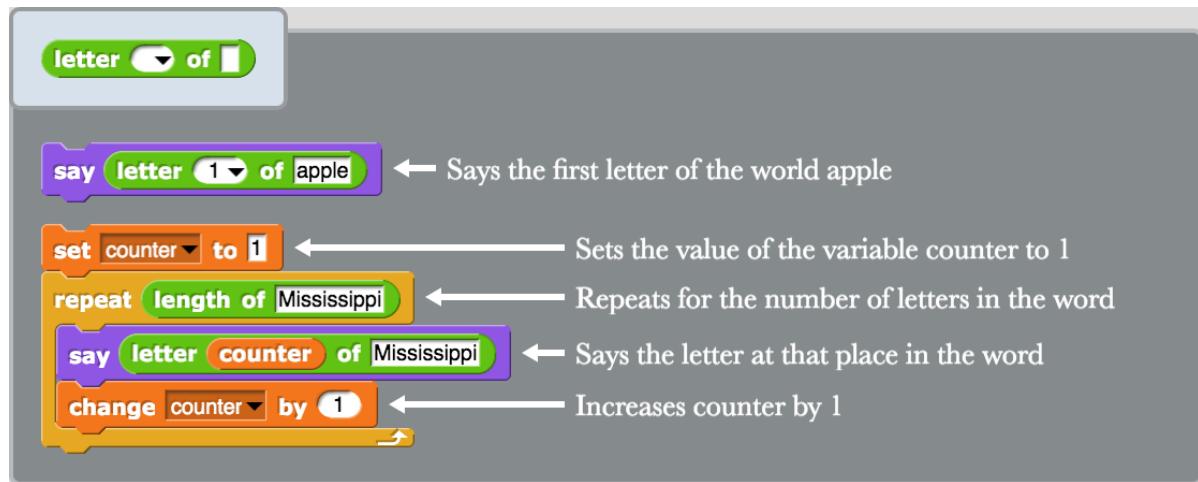
Example Projects

No examples yet.

letter of

Complete Me

letter 1 of world



Example Images

No examples yet.

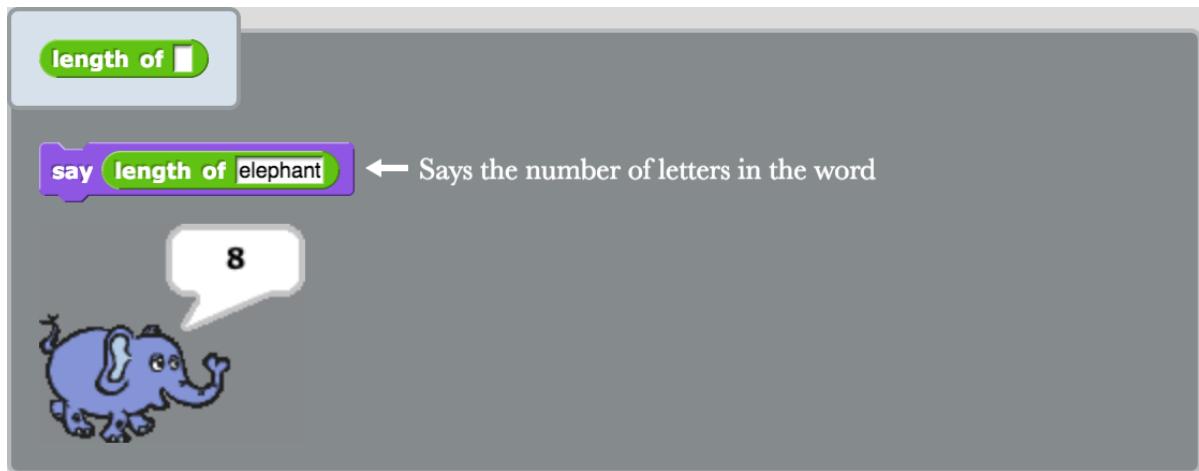
Example Projects

No examples yet.

Attribute of Text

Complete Me

length ▾ of text word



Example Images

No examples yet.

Example Projects

No examples yet.

unicode of

Complete Me

unicode of `a`

unicode of `a`

Reports the Unicode value of a letter.

Letters and other characters are represented inside the computer using a numeric code called Unicode. Type or paste a single character into the input to get its Unicode number.

97
unicode of `a`

55
unicode of `7`

32
unicode of `  `

960
unicode of `  `

8804
unicode of `  `

8734
unicode of `  `

Some Unicode values:

48-57: digits 0-9
65-90: capital letters A-Z
97-122: lower case letters
32: space

See the complete official Unicode chart at
<http://www.unicode.org/charts/>

There are also unofficial Unicode values for fictional languages such as Tengwar (Elvish) and Klingon at
<http://www.evertype.com/standards/csue/conscript-table.html>

Example Images

No examples yet.

Example Projects

No examples yet.

unicode as letter

Complete Me

unicode 65 as letter

unicode 65 as letter

Reports the letter with a given code.

Letters and other characters are represented inside the computer using a numeric code called Unicode. Give a Unicode number as input to find out what character it represents.

A

unicode 65 as letter

π

unicode 960 as letter

女

unicode 12069 as letter

⌚

unicode 9775 as letter

Some Unicode values:

48-57: digits 0-9

65-90: capital letters A-Z

97-122: lower case letters

32: space

See the complete official Unicode chart at

<http://www.unicode.org/charts/>

There are also unofficial Unicode values for fictional languages such as Tengwar (Elvish) and Klingon at

<http://www.evertype.com/standards/csuri/conscript-table.html>

Example Images

No examples yet.

Example Projects

No examples yet.

is a ?

Complete Me

is [5] a [number ▾] ?

is [5] a [number ▾] ?

Reports true if input is a given type.

All of these are true:

is [-5.37] a [number ▾] ?

is [] a [text ▾] ?

is [(3) + (4)] a [number ▾] ?

is [true] a [text ▾] ?

is [(3) + (4)] a [reporter ▾] ?

is [true] a [Boolean ▾] ?

is [pen up] a [command ▾] ?

is [true] a [predicate ▾] ?

The possible types are number, text, Boolean (true or false), list, sprite, costume, sound (object-oriented types), command (a script or jigsaw-shaped command block), reporter (an oval block that reports a value), and predicate (a hexagonal block that reports true or false).

Every value has exactly one of these types.

is [] a [number ▾] ?

number
text
Boolean
list
sprite
costume
sound
command
reporter
predicate

Example Images

No examples yet.

Example Projects

No examples yet.

is ?

Complete Me

The image shows a Scratch script editor window with several examples of the 'is identical to' operator. The examples are:

- `is [] identical to [] ?` (true)
- `is [3] identical to [3] ?` (true)
- `is [3] identical to [3.0] ?` (false)
- `is [a] identical to [a] ?` (true)
- `is [a] identical to [A] ?` (false)
- `is [list 1 2] identical to [list 1 2] ?` (false)

A note at the bottom left states: "Two variables need to have the same list for identical to report true with them. You can go to chapter I, part G of the manual for more information."

Example Images

No examples yet.

Example Projects

No examples yet.

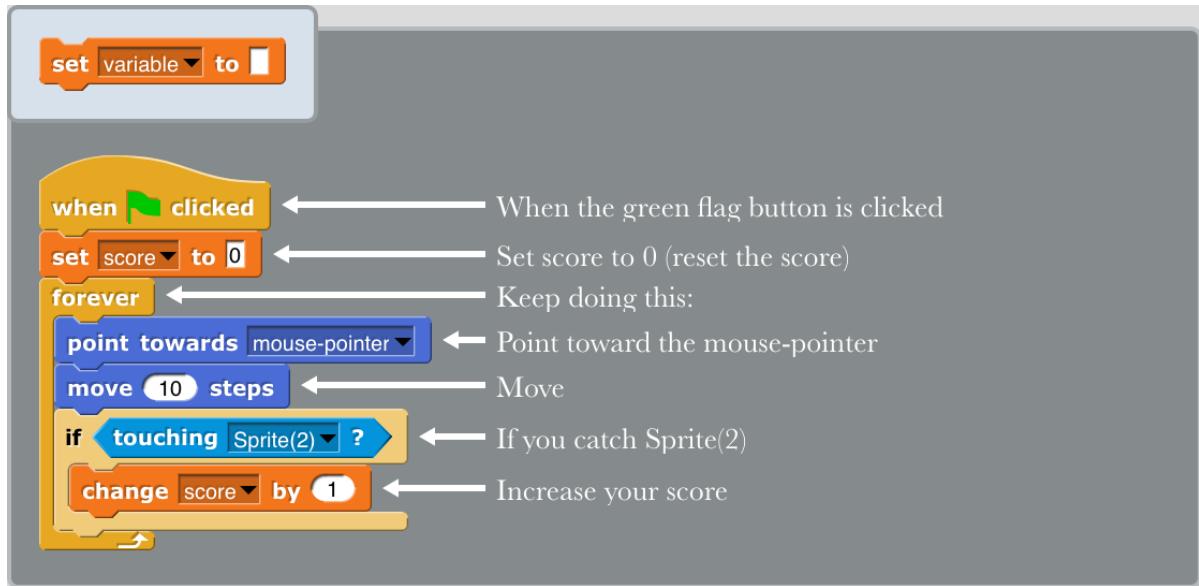
Part VIII.

Variables Blocks

set to

Complete Me

set [variable] to 0



Example Images

No examples yet.

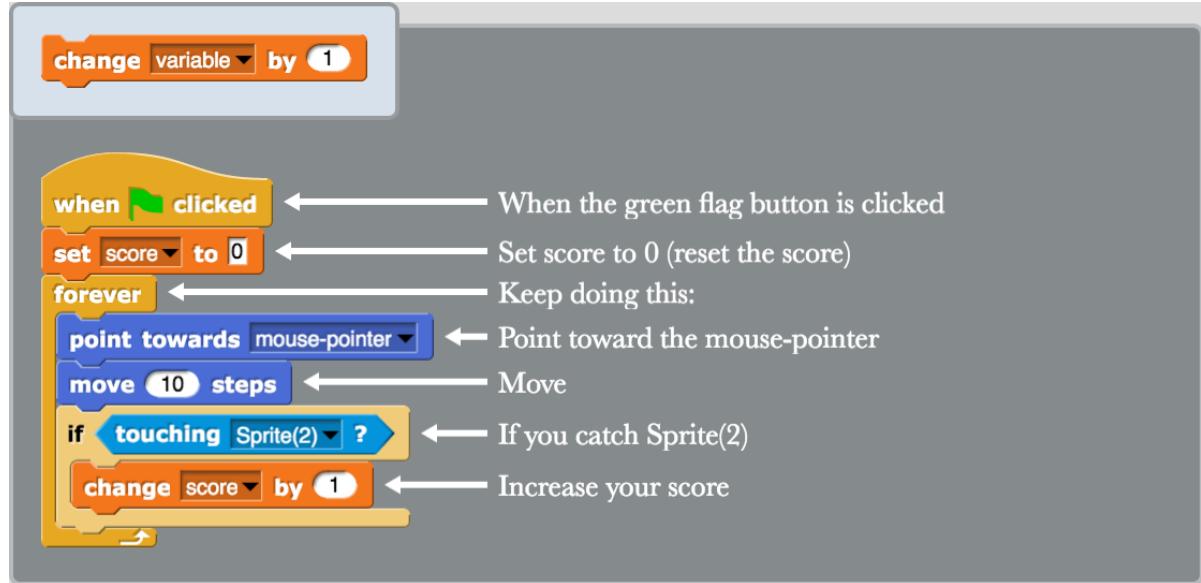
Example Projects

No examples yet.

change by

Complete Me

change [] by 1



Example Images

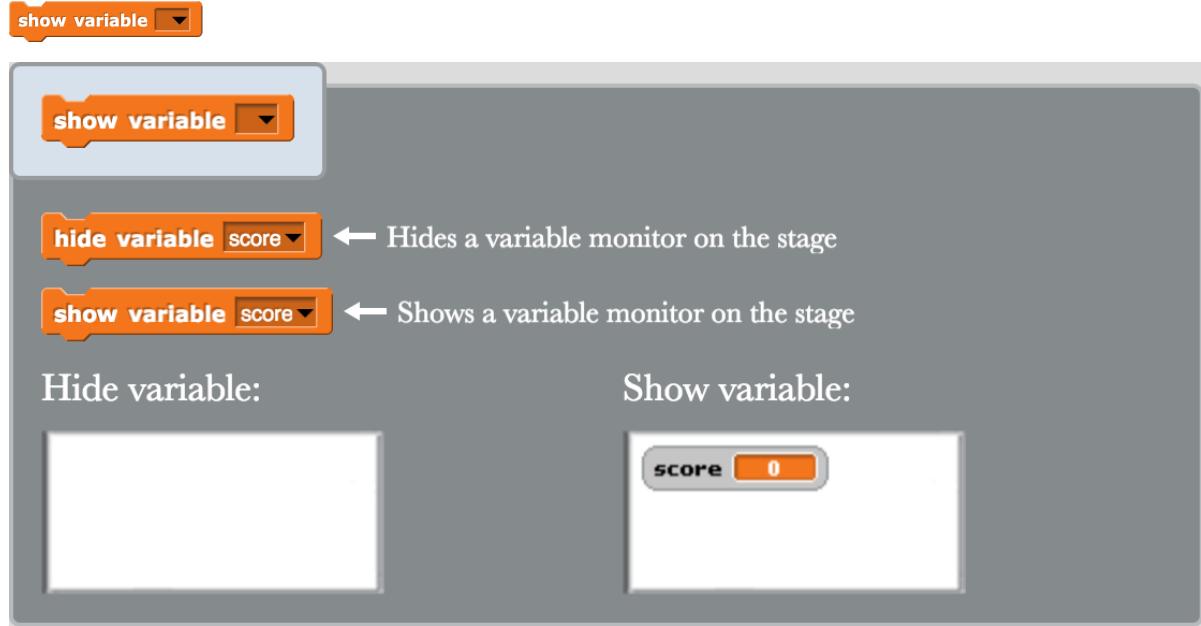
No examples yet.

Example Projects

No examples yet.

show variable

Complete Me



Example Images

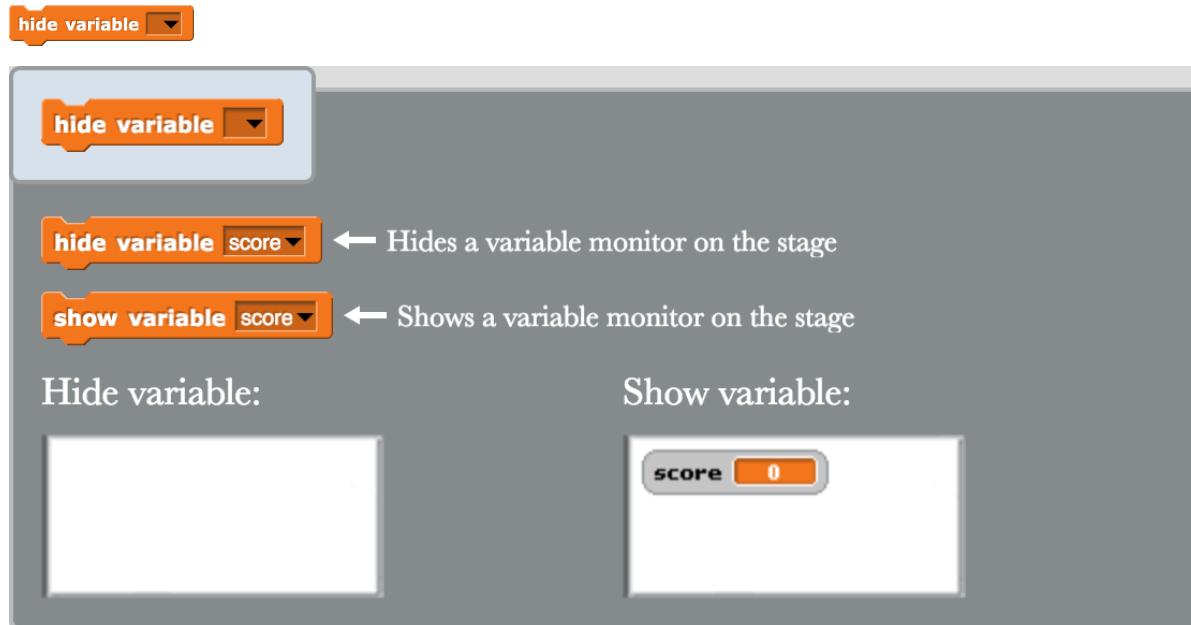
No examples yet.

Example Projects

No examples yet.

hide variable

Complete Me



Example Images

No examples yet.

Example Projects

No examples yet.

Script variables

Complete Me

A Scratch script titled "script variables a" containing the following blocks:

- + swap + items + [index1 #] + and + [index2 #] + in + [list ::] +
- script variables [temp]
- set [temp v] to [item [index1] of [list]]
- replace item [index1] of [list] with [item [index2] of [list]]
- replace item [index2] of [list] with [temp]

Annotations explain the use of a temporary variable:

- An arrow points from the "script variables temp" block to the "temp" variable in the "set" block.
- A callout box states: "Every time this block is called, it makes a new temporary variable **temp**. Click (don't drag) to change name."

Text below the script:
Script variables don't clutter up your palette, and you can be sure no other block changes their value. This works for scripting area scripts, too, not just custom blocks.

A Scratch script titled "Object Oriented Programming:" containing the following blocks:

- + new + counter +
- script variables [count]
- set [count v] to [0]
- report [change [count v] by [1]]
- report [count]

Text to the right:
If a reporter reports a script, and that script uses a script variable created outside the reported script (such as the use of **count** in the script that **new counter** reports) then the script variable isn't temporary!

Below the text are two additional blocks:

- set [my counter v] to [new counter]
- say [call [my counter] for 2 secs] → 1
- say [call [my counter] for 2 secs] → 2

Example Images

No examples yet.

Example Projects

No examples yet.

inherit

Complete Me



Share a property with your parent. (This only works for clones.)

BEFORE Run AFTER

Pale background in palette for inherited property.

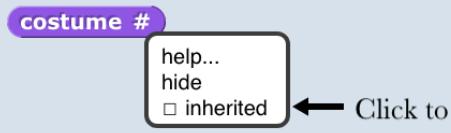
Clone's x position is now tied to parent's.

Inheritable properties include these:



(and more... See Reference Manual Chapter VII.)

You can also control inheritance through the user interface. Right-click on a shareable thing in the palette and see this:



Example Images

No examples yet.

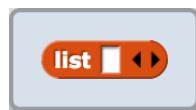
inherit

Example Projects

No examples yet.

list

Complete Me



Reports a newly created list with the given items.

list ← Use the arrows to change the number of inputs.



Make an empty list.

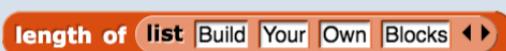


The list items can be anything; text, numbers, blocks, scripts, and even other lists!

You can put a list in a rectangular input slot:



and also in a lists-only input slot:



Example Images

No examples yet.

list

Example Projects

No examples yet.

numbers from to

Complete Me

numbers from 1 to 10

numbers from to

numbers from 1 to 10

Report a list of consecutive numbers.

numbers from 3 to 6

numbers from -2 to 1

numbers from 5 to 1

(Range must be ascending.)

The Scratch script displays three lists of consecutive numbers. The first list, "numbers from 1 to 10", shows values 1 through 10. The second list, "numbers from 3 to 6", shows values 3 through 6. The third list, "numbers from -2 to 1", shows values -2 through 1. Below each list is a message indicating its length: "length: 4" for the -2 to 1 list and "length: 6" for the other two lists. A note at the bottom states "(Range must be ascending.)".

+prime? + value # +

report is keep items [value mod (blank) = 0 from numbers from 2 to value - 1] empty?

true

false

prime? 7

prime? 7

numbers from 1.3 to 5

A number n is prime if the list of its factors in the range [2,n-1] is empty.

The Scratch script defines a function "+prime? + value # +" which returns true if the value is prime and false otherwise. It uses a "keep items" loop to collect factors of the input value. If the list is empty, it returns true; otherwise, it returns false. An example check for 7 shows no factors, so it returns true. Another check for 1.3 shows factors 1.3 and 2.3, so it returns false. A list of factors for 1.3 is shown below the script.

Example Images

No examples yet.

Example Projects

No examples yet.

In Front Of

Complete Me

 in front of 

in front of []

Report a list that extends another list with one new item.

The list you want to extend
New item (can be anything!)

7 in front of [list 8 1 <>]

Note: The new list shares structure with the old one!

set foo to [list 8 1 <>]
set baz to [7 in front of foo]

true

is foo identical to all but first of baz ?

+ Initials + [data : +]
if is data empty?

report [letter 1 of item 1 of data] in front of initials [all but first of data]

some function [item 1 of foo] in front of
recursive call [all but first of foo]

initials [list Three Letter Acronym <>]

in front of [] is most useful in writing recursive reporters like this one, to build up a list element by element.

Example Images

No examples yet.

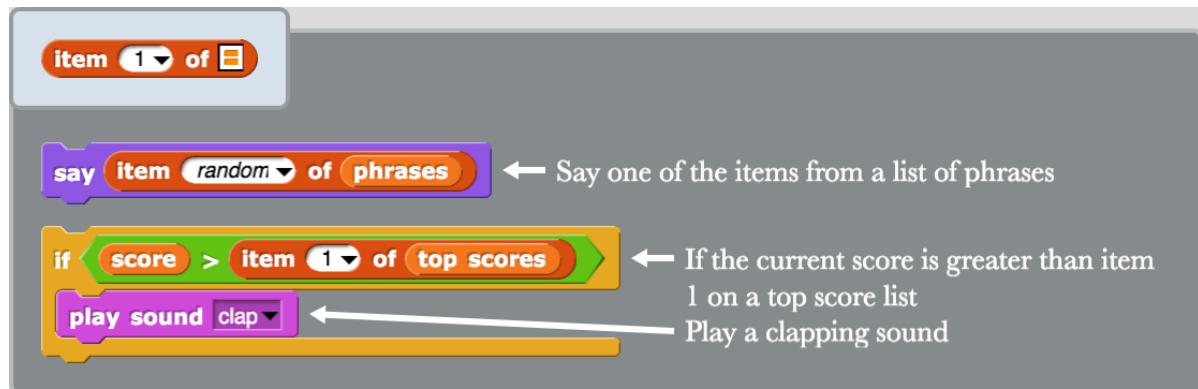
Example Projects

No examples yet.

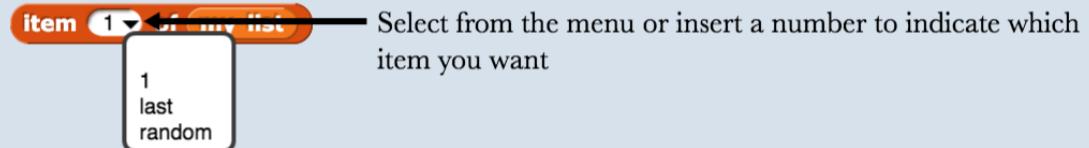
item of

Complete Me

item 1 of



The item block reports the value of the item at the specified place on a list.



You can fit an item block into other blocks, for example: say, switch to costume, play sound, or broadcast.

Example Images

No examples yet.

Example Projects

No examples yet.

all but first of

Complete Me

all but first of []

A Scratch script demonstrating the 'all but first of' block. The script consists of the following blocks:

- A control block: **when green flag clicked**
- An 'all but first of' reporter block: **all but first of** [list 7 8 1 <-->]
- A say block: **say** (the value of the 'all but first of' block)

The 'all but first of' block has a parameter slot containing the list [list 7 8 1 <-->]. A callout box shows the list's contents: [1] 8 [] [2] 1 [] with a note below it: **length: 2**.

The new list shares structure with the old one; it's not a copy. If the input list was made with the list reporter blocks **[] in front of** [] **item** [1] **of** [] **all but first of** [] then **all but first of** [] is very fast; it doesn't have to copy the items or the list structure. If you use list commands such as **insert** [thing] **at** [1] **of** [] on a list, then it will be a dynamic array rather than a linked list, so this block has to convert to linked form.

The list reporters are good for writing recursive list reporters that build up a result list item by item.

Example Images

No examples yet.

Example Projects

No examples yet.

Report List Attribute

Complete Me

length ▾ of ⚡

length ▾ of ⚡

Reports an attribute of the list

length ▾ of list a b c d ↺ ↻

4

It gives the number of items in the *outermost* list:

length ▾ of list a b list c d ↺ ↻ e ↺ ↻

4

Here are the possible attributes:

length
rank
dimensions
flatten
columns
reverse

LENGTH is described above
RANK reports the LENGTH OF DIMENSIONS OF its input
DIMENSIONS reports how long the list is in each dimension
FLATTEN reports each non-list item, even those from sublists.
E.g., FLATTEN OF (a (b c) d e (f (g))) gives (a b c d e f g)
COLUMNS, given ((a b c) (d e f)), reports ((a d) (b e) (c f))
REVERSE, given (a b (c d e) f), reports (f (c d e) b a)

These three report texts, not lists:

LINES joins each item with a newline
CSV takes a 2D list and gives the spreadsheet equivalent
JSON takes an arbitrarily deep list, often with key-value pairs, and gives the JSON equivalent

lines
csv
json

Example Images

No examples yet.

Example Projects

No examples yet.

index of in

Complete Me

index of [thing] in [list]

The image shows a Scratch script consisting of the following blocks:

- A yellow **when green flag clicked** hat block.
- An orange **set list [] to [list a b c d e f g <-->]** control block, which initializes a list variable containing the letters a through g.
- A purple **say [index of [d] in [list]]** control block, which outputs the index of the letter "d" from the list.

The output of the script is shown in a white window with a grey border. It displays the text "Say item number reported by the **index of [thing] in [list]** block". A speech bubble arrow points from this text to the **say** block. Inside the speech bubble is the number "4", indicating that the script will output the index of the letter "d" (which is 4).

Example Images

No examples yet.

Example Projects

No examples yet.

List Contains

Complete Me

The image shows a Scratch script consisting of the following blocks:

- A green **when green flag clicked** hat block.
- An orange **if [my list contains banana] then** control block with a yellow **else** branch.
- Inside the if-block:
 - A blue **say [You have a banana.]** control block.
 - A blue **else** control block.
 - Inside the else-block:
 - A blue **say [You do not have a banana.]** control block.

Annotations explain the code:

- The first **contains** block is labeled "If list contains this item".
- The **say** block is labeled "Says this".
- The **else** block is labeled "If not, says this".

In the bottom text box, the **contains** block is described as follows:

[list] contains [thing] reports whether an item is in a list. If the item matches exactly, then it reports true. If not, it reports false.

Example Images

No examples yet.

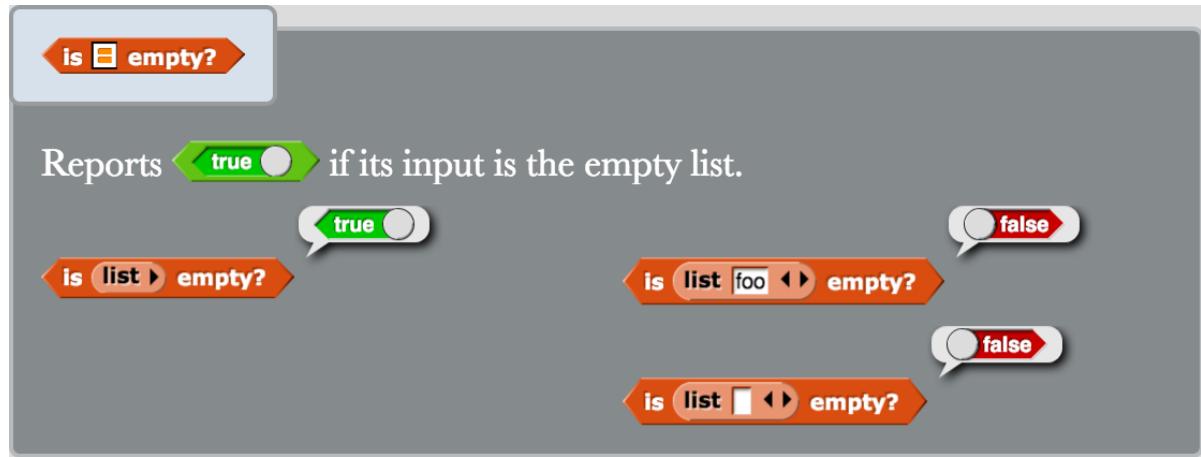
Example Projects

No examples yet.

is empty?

Complete Me

is empty?



Example Images

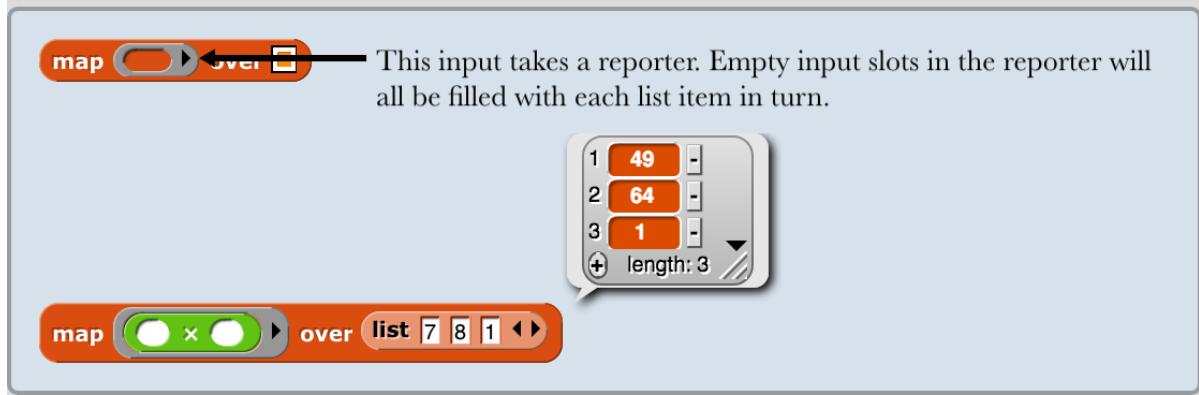
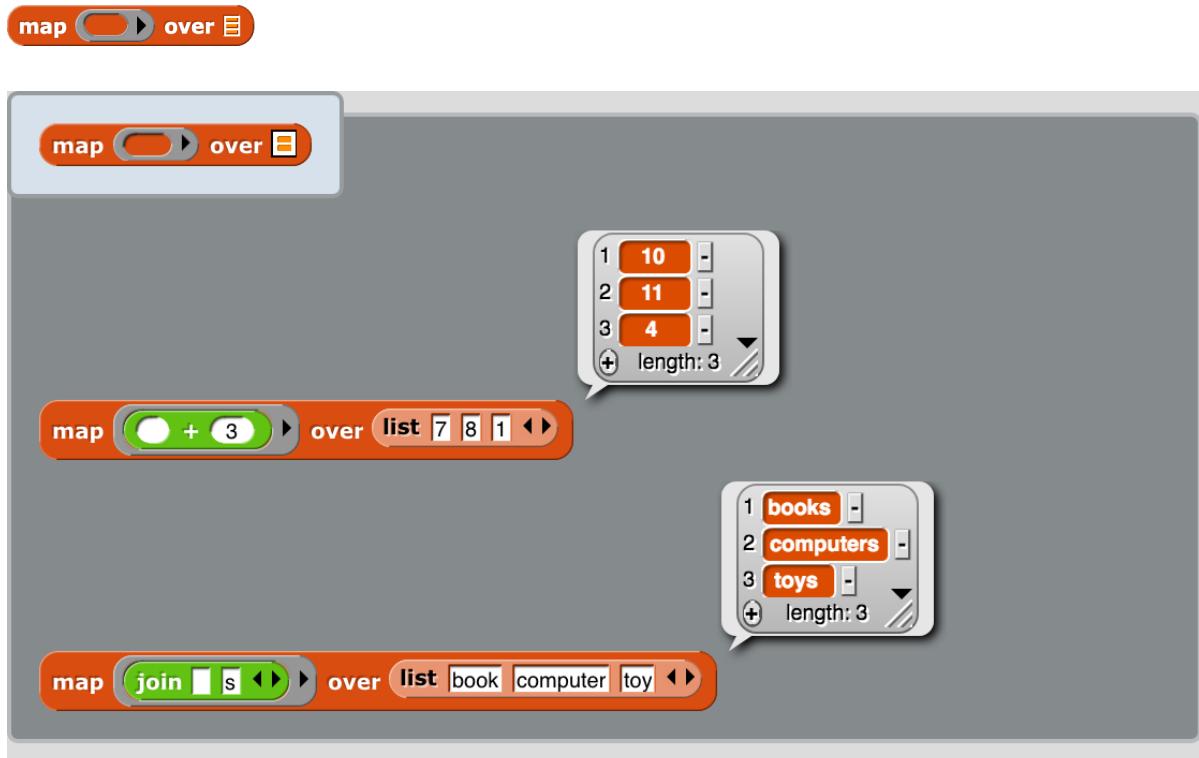
No examples yet.

Example Projects

No examples yet.

map over

Complete Me



Example Images

No examples yet.

map over

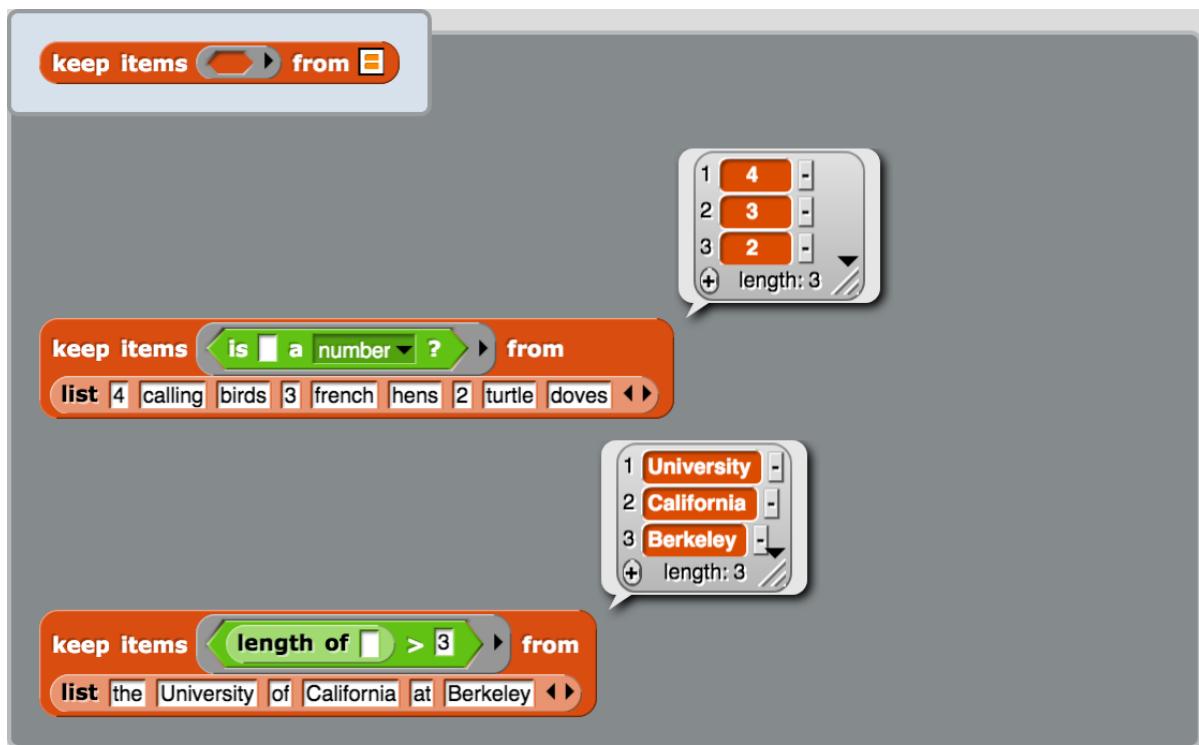
Example Projects

No examples yet.

keep items from

Complete Me

keep items  from 



Each list item is put into the empty input slot of the predicate block. If the predicate reports  then that item is included in the result list. Note that if the predicate has a default input value, you have to clear the slot to use it with KEEP, e.g., this won't work:

keep items  from list 

KEEP makes a new list; the original list is not modified.

Example Images

No examples yet.

keep items from

Example Projects

No examples yet.

find first item in

Complete Me

find first item  **in** 

find first item in

A Scratch script demonstrating two ways to find the first item in a list that matches a predicate.

The top part shows a **find first item** block with a **length of [] > 3** control block nested inside it. The **in** parameter is set to a list containing "the", "University", "of", "California", and "at Berkeley". A speech bubble labeled "University" points to the third item in the list. The bottom part shows a **keep items** block with a **length of [] > 3** control block nested inside it. The **from** parameter is set to the same list.

A Scratch script demonstrating the behavior of **find first item** when no item matches the predicate.

The top part shows a **find first item** block with a **[] = 3** control block nested inside it. The **in** parameter is set to a list containing "the", "University", "of", "California", and "at Berkeley". A speech bubble labeled "false" indicates that no item matches the predicate. The bottom part shows a **keep items** block with a **[] = 3** control block nested inside it. The **from** parameter is set to the same list.

Example Images

No examples yet.

Example Projects

No examples yet.

combine using

Complete Me

combine using

combine using

Combine all list items into one.

16

combine list [7 8 1] using +

combine list University of California using join words

University of California

99% of the time, you'll use one of these six blocks in the first input slot of combine using :

+ x
 join join words
 and or

It has to have exactly two empty input slots, and be associative.

join hello world
 join words

Example Images

No examples yet.

Example Projects

No examples yet.

for each in

Complete Me

```
for each item in [ ]
```



Do something for each item of a list.



There are two equivalent ways to represent the list item inside the script. They're equally good; different people have their own preference.



Example Images

No examples yet.

Example Projects

No examples yet.

add to

Complete Me

A Scratch script demonstrating the use of the `add` blocks. It starts with a `say` block: `say [item random of my list]`. Above it is a `add [] to []` control block. To its right is a `my list` variable containing three items: `rock`, `paper`, and `scissors`. Below the `say` block is another `add` block: `add [rock to my list]`. This is followed by two more `add` blocks: `add [paper to my list]` and `add [scissors to my list]`.

Use this block to add an item to the end of a list.

Four examples of `add` blocks:

- `add [781 to my list]`
- `add [list alpha beta gamma to my list]`
- `add [+ to my list]`
- `add [a new clone of myself to my list]`

Make an empty list: `set [my list] to [list]`

Example Images

No examples yet.

Example Projects

No examples yet.

delete of

Complete Me

delete 1 ▾ of ☐

Before:

The list 'supplies' contains the following items:

- 1 water
- 2 piece of fruit
- 3 biscuits

length: 3

After:

The list 'supplies' contains the following items:

- 1 water
- 2 piece of fruit

length: 2

← Says the last item from the list
← Deletes the last item from the list

You can specify the number of the item you want to delete. For example:

delete 2 ▾ of my list

To delete the last item in the list, choose "last" from the dropdown menu:

delete last ▾ of my list

You can also choose to delete everything in the list:

delete all ▾ of my list

Example Images

No examples yet.

delete of

Example Projects

No examples yet.

insert at of

Complete Me

The image shows a Scratch script with the following components:

- A **when I am clicked** hat block.
- An **insert lamp at 1 of my list** control block.
- A **my list** variable containing one item: "compass".
- The variable's value is shown as "length: 1".
- After the script runs, the **my list** variable contains two items: "lamp" and "compass".
- The variable's value is shown as "length: 2".

Below the script, two examples of the **insert** block are shown:

- insert score at 2 of scoreboard** ← Inserts item at the specified place in the list
- insert Hello, world! at random of greetings** ← Inserts item at a random place in the list

Example Images

No examples yet.

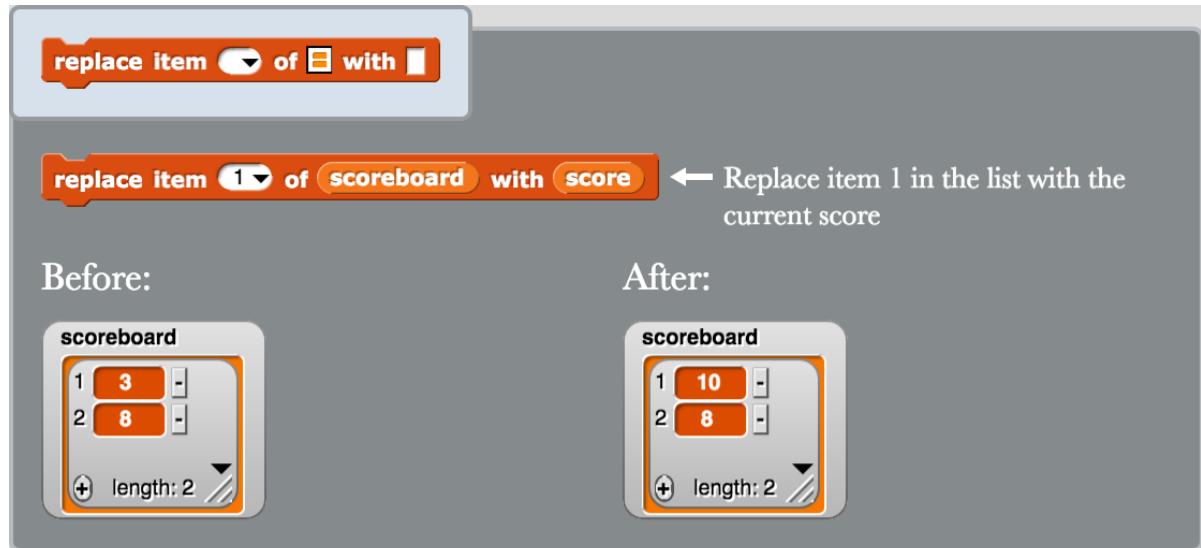
Example Projects

No examples yet.

replace item of with

Complete Me

replace item 1 of [] with [thing]



A Scratch script consisting of two blocks: "replace item 1 of [scoreboard v] with [score v]" and "scoreboard". The "scoreboard" hat block shows a list with two items: 1 (3) and 2 (8). A callout points to the first item with the text "← Replace item 1 in the list with the current score".

Before:



After:



You can choose where in a list to put an item. For example:

replace item 2 of [race times v] with [timer v] ← Replaces item 2 in the list

replace item [last v] of [questions v] with [How are you?] ← Replaces last item in the list

Example Images

No examples yet.

Example Projects

No examples yet.

append

Complete Me

append [list] [list]

append [list] [list]

Joins two lists together.

APPEND reports a new list containing the items from the input lists, in order.

Comparison:

Append

append [list] [a b c] [list] [1 2 3]

List

1	a
2	b
3	c
4	1
5	2
6	3
[+]	length: 6

list

[list] [a b c] [list] [1 2 3]

2	A	B	C
1	a	b	c
2	1	2	3

Example Images

No examples yet.

Example Projects

No examples yet.

reshape to

Complete Me

reshape  to 4 3 

reshape  to 4 3 

Reshapes a list to the provided dimensions

Examples:

5	A	B
1	1	2
2	3	4
3	5	6
4	7	8
5	9	10

reshape numbers from 1 to 10 to 5 2 

If the dimensions multiply to a number larger than the length of the list, it starts over with the beginning of the list:

4	A	B	C	D
1	1	2	3	4
2	5	6	7	8
3	9	10	1	2
4	3	4	5	6

reshape numbers from 1 to 10 to 4 4 

You can use a simple scalar input (number or text string) too:

4	A	B	C
1	5	5	5
2	5	5	5
3	5	5	5
4	5	5	5

reshape join 5  to 4 3 

And with no dimensions, it returns a scalar:

reshape numbers from 1 to 10 to 

reshape to

Example Images

No examples yet.

Example Projects

No examples yet.

combinations

Complete Me

combinations ☰ ☱



Example Images

No examples yet.

Example Projects

No examples yet.

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