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An *incomplete*

Reference Manual

Beta 6  
13th January 2025

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# Getting started

## Technical platform

You can access the Elan Beta at: <https://elan-lang.org/beta/>

Elan is designed to run within the Chrome browser; correct operation within other browsers is not guaranteed.

## Demo programs

The Beta version includes a **Demo** button that offers a menu of demonstration programs that you can run:

A screenshot of a computer

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The best way to get started with Elan is to explore these demo programs. You can edit any of them and save your own copy locally.

## Changes and additions for Beta 6

### Changes to language and standard library that could break existing code

Both the syntax and the layout for the following constructs has changed:

* if statement. See If statement
* try Statement. See Catching and throwing exceptions

The switch statement has been removed entirely. (The improved if statement means that the switch statement no longer offered any advantages over using a series of else if clauses.)

An abstract class may now define concrete members, but such members may not be overridden (modified) by sub-classes. See Abstract class

## Still to be implemented..

The following lists a few of the *stand-out* items that are not yet implemented. (For a much longer list you are welcome to browse all the open items on our development project planning system – <https://github.com/elan-language/IDE/issues>. However, please bear in mind that those items are written by and for the development team – rather than for public discussion.)

### Editor

* **Debugger**. Ability to insert breakpoints, pause, single-step, and read the state of variables
* **Navigate** directly from use of an identifier to its definition
* **Renaming** of identifiers (variables, constants, parameters, function & procedure names)
* **Profile** configuration (exists as a proof of concept only at present). In future release you will be able to define multiple profiles and then assign a profile to each user name.
* Ability to switch-on **anti-plagiarism** option (exists as a proof of concept only at present)
* Ability to perform all navigation and *actions* by keyboard or mouse (except entering code into fields, which must be done through the keyboard)

## If you have programmed in another language, the key differences to be aware of…

### Types

* Elan is a statically typed language. Basic types are Int, Float, Boolean, and String.There are ready-made data structures types Array, List, Dictionary. Elan supports user defined classes and enums, and there are several ready-made classes in the standard library such as BlockGraphics, File, Set, Stack, Queue, Tree, Graph … (only the first of these is in the Beta 6).

### Variables

* Variables are defined by a variable statement, and re-assigned with a set statement
* Variable names (indeed all names in Elan) must begin with a lower-case letter
* Variables must be initialised with a literal value or an expression that yields a value, and the type of that value determines the type of the variable.
* There is no such thing as a global variable in Elan – variables are defined within main, or within a function or procedure and are visible only within that scope.

### Constants

* A constant is only ever defined at global level and is set to a literal value of an *immutable* type: for example any of the four basic types or a List, but not an Array (see below).

### Let statement

* A let statement may be thought of as being between a constant and a variable. Like a variable a let may be defined only within a routine, but unlike a variable it may not be re-assigned once defined. It is recommended that you always use a let in preference to a variable unless you *need* to be able to re-assign it.

### Arrays

* An Array is a mutable data structure – as it is in most languages.
* It may be initialised to a specific size, with each element set to an initial value (e.g. 0 for a Int or Float), but it may also be extended dynamically with the append or prepend method.
* A 2D array may also be created, accessed with a double index e.g. a[2][3]

### Testing for equality

* Elan tests for equality *by value* (not equality by reference) using the keywords is (for example if x is y) and isnt. The comparisons, >, <. >=, <= apply to numeric types (Int and Float) only. (There are methods for String comparison – see Dot methods on a String )

### Methods

* There are several types of method in Elan: standalone function, standalone procedure, instance function and instance procedure (both defined on a class), and system methods. These are expanded below.
* Elan does not support **overloaded** method names (methods with the same name, but different number or type of parameters). Every freestanding method must have a unique name distinct also from those in the standard library; instance methods must be unique within a class – but the same name may be used within different classes.

### Function

* An Elan **function** (whether standalone or an instance method on a class) must be *pure* function. It must return a value that is derived, solely and deterministically, from the arguments supplied as parameters. A function contains one, and only one, return statement which must be the last (or only) statement in the function body.
* A function may not generate side-effects, for example it may *not*:
  + Contain any print statements
  + Use any system method within its expressions
  + Make a call to any procedure (since procedures are not pure)
  + Assign-to or mutate any parameter

### Procedure

* An Elan procedure may be thought of as a ‘command’. Like a function it may define parameters, but it does not return a value – because a procedure, necessarily makes changes: changes to one or more of the parameters (if the parameter definition is prefixed by out), and/or changes to the *system* by calling print or any of the system methods.
* A procedure exits after executing the last statement in the body – there is (deliberately) no mechanism to exit ‘early’ – thereby enforcing structured programming.
* A procedure is always executed via a call statement: either standalone, or as a ‘dot method’ on a named instance.

### System method

* System methods are all defined as part of the standard Elan library. Some are *like* procedures, returning no value, and are hence executed via the call statement. Others are *similar to* functions in that they return a value and are evaluated within an expression. However, unlike functions these system methods either have side-effects or external dependencies (or both). For that reason, no system method – whether resembling a procedure or a function – may be used within a user-defined function (nor within a test). They may only be used within main or a procedure.

### Object-oriented techniques

* The name given to a class must follow the rules for any Type name i.e. it must *start* with a capital letter.
* Every (concrete) class has a constructor – which is automatically added when you define a class. But it is not essential to define any code within that constructor.
* A property may be assigned (set) a new value within the constructor, or within a procedure method defined on the class or the sub-class. But a property may never be assigned by code outside the class. If you require this capability, you can write your own procedure methods (commonly called ‘setter’ methods) to do this. A function method may read properties, but not write to them.
* Whenever you wish to access a property from within a method (or from within the constructor) on the same class, then the name of the property must be prefixed with the ‘qualifier’: property. (‘property-dot’). This applies whether you are reading or setting the property. By this means you can have a method parameter with the same name as a property, but they are unambiguous, because the property must be prefixed. A common pattern is to use the same name in a ‘setter’ method, for example:  
  procedure setName(name as String)  
   set property.name to name  
  end procedure
* The property. qualifier is neither required, nor allowed, when accessing a property on an instance of the class because the instance name acts as the qualifier.
* A concrete class may inherit from *one or more* abstract classes, but may not inherit from another concrete class. (This enforces the widely-recognised OOP design principle that ‘all classes should be abstract or final (not inheritable)’.)
* An abstract class may define abstract members (property, function, procedure) – which must always be implemented by any concrete sub-class. It may also define private members (property, function, procedure), which are visible to any concrete sub-class, but not visible from code outside the class hierarchy.

### Functional techniques

* Elan has very strong support for the functional programming paradigm, building on the foundation of its rigorous definition of a function. In addition:
* The standard library defines several ‘higher-order functions’ (HoFs) including map, filter and reduce that apply to any type that is ‘iterable’ (including String, Array and List).
* Any user-defined or standard library function may be passed as an argument into a parameter, or associated with a name using a variable or let statement – by preceding the name of the function with the keyword function.
* You may also define a lambda, inline as an argument in a function call, or assigned to a named value.
* Although pure functions, including HoFs, may work with mutable data structures (without actually mutating them), *immutable* data structures are considered a better fit for functional programming. Elan provides many *immutable*standard data structures, including String (immutable in most languages) and List (in contrast to many languages), and record – which is like an immutable form of a class, without encapsulated methods.

# The Elan editor – quick reference

## Navigation – using the keyboard

**Note**: For *Apple Mac* users: commands use of the **Ctrl** key in this reference, should be replaced by the **Cmd**key.

|  |  |  |  |
| --- | --- | --- | --- |
| **Keystroke** |  | **On a selected Frame** | **On a selected Field** |
| **Home** |  | First *peer-level* frame. | Move text-cursor to start of field. |
| **End** |  | Last *peer-level* frame. | Move text-cursor to end of field. |
| **Tab** |  | First *field* in frame. | Select next field within frame. Or from last field in a frame, select the frame itself.  (If the field has a selected option in the auto-complete popup list then Tab will use that option – the same as **Enter**) |
| **↑** |  | Select previous frame  (within peer-level only). | Select previous *frame*  (in tab order). |
| **↓** |  | Select next frame (within peer-level only). | Select next *frame*  (in tab order). |
| **←** |  | Select *parent* frame (if any). | Move text-cursor left within field. |
| **→** |  | Select first *child* frame (if any). | Move text-cursor right within field. |
| **Shift-↑** |  | *Add* prev. frame (peer-level) to current selection. | If auto-complete options are offered (drop-down list), move the selection *down* one in the list. (See also **Enter**) |
| **Shift-↓** |  | *Add* next frame (peer-level) to current selection. | If auto-complete options are offered (drop-down list), move the selection *up* one in the list. (See also **Enter**) |
| **Esc** | Escape from the code editor, and put focus on the first Button in the IDE | | |
|  | | | |
| **Ctrl-o** |  | Toggle (expand/collapse) outlining on selected frame. | Toggle (expand/collapse) outlining on the frame enclosing this field. |
| **Ctrl-O**  (Ctrl-Shift-o) |  | Toggle (expand/collapse) outlining on *all* frames. | Toggle (expand/collapse) outlining on *all* frames. |

## Editing – using the keyboard

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Keystroke** |  | **On a selected Frame** | **On a selected Field** | |
| **Alt-t** |  | Remove all ‘new code’ selections *that can be removed.*  This is equivalent to clicking on the **Trim** button.  (This cannot be **Ctrl-t** as that is defined and executed by the browser). | | |
| **Backspace** |  | On any ‘new code’ selector: delete the selector. (Note that *all* ‘new code’ selectors can be removed with the **+/-** button above the code pane).  On a new, unmodified, frame, or from any unedited field within that new frame: delete the whole frame and go back to the selector. This capability is to facilitate deleting a frame created unintentionally. As soon as any field has been edited, or any child frame added – the frame can only be deleted using Ctrl-Delete (see below). | Delete character to the left of the cursor. | |
| **Delete** |  |  | Delete the character to the right of the cursor. | |
| **Ctrl-Delete** or  **Ctrl-d** |  | Delete the selected frame, including any frames within it. |  | |
| **Enter** |  | Insert a selector-frame (‘new code’) *below* selected, at peer level – if permissible. | If auto-complete options are offered (as a drop-down list), enter the selected option into the field.  Otherwise, move to the next field (in the same frame) – like Tab.   For last field in frame only: insert ‘new code’ *after* this field. | |
| **Shift-Enter** |  | Insert a selector-frame (‘new code’) *above* selected, at peer level – if permissible | - | |
| **Ctrl-↑** |  | Move selected frame(s) up, *within peer level.* | - | |
| **Ctrl -↓** |  | Move selected frame(s) down, *within peer level.* | - | |
| **Ctrl-→** |  |  | Move the cursor to the end of the next ‘word’ or other transition | |
| **Ctrl -←** |  |  | Move the cursor to the end of the next ‘word’ or other transition | |
| **Ctrl-x** |  | Cut selected frame(s) into the scratchpad | Cut any selected text from the field | |
| **Ctrl-v** |  | - | | Paste text from the clipboard into the field, at the cursor.  On a selected ‘new code’ field: Paste the frame(s) added to the scratchpad in place of the ‘new code’ field. If any of the frames to be added is not compatible with the content of the ‘new code’ field then no action will take place. |
| **Ctrl-z** | Undo last edit  Takes you back to the next most-recent version *that parsed successfully.* (Any changes made that did not result in a successful parse will be lost.) | | | |
| **Ctrl-y** | Redo last undo – provided that the code you undid from was parsing. | | | |

## Mouse operation – quick reference

* To select a *frame*, click on the *keyword* at the start the frame. (You can successfully click in several other places within the frame, but the simplest rule to remember is click on the starting keyword).
* To select an additional frame (‘multi-select’), hold down the **Shift** key on the keyboard and click on the frame to add to the current selection. Note that all the multi-selected frames must be at peer-level (the same level of indentation) and, unless global frames, must be within the same ‘parent’ frame.
* To select a field, click on the text (or, if empty, the prompt) shown for that field. Having selected the field, you may then click again at a particular place within the text to position the text cursor. (By default, when a field is selected the text cursor will be at the right-hand end of any existing text).
* To collapse a multi-line frame, double-click on the keyword at the start of the frame
* To expand a collapsed frame, double-click on the keyword at the start of the frame (or the ‘+’ symbol in front of it)

NOT YET IMPLEMENTED

* To move selected frame, or frames, up or down *within the same peer level* hold down the **Ctrl** key and drag the mouse, or move the scroll wheel
* Scrolling of options within the ‘autocomplete’ popup using the mouse wheel.

# Expressions

One of the most important constructs in programming is the ‘expression’. An expression is evaluated to return a value. An expression is made up of the following possible elements:

* Literal value
* Named value
* Operators (including brackets)
* Function calls

## Literal value

A literal value is where a value is written ‘literally’ in the code, such as 3.142 – in contrast to a value that is referred to by a name.

The following data types may be written as literal values (follow the links to view the form of each literal value):

Int, Float, Boolean, String, Error! Reference source not found., Error! Reference source not found., Dictionary, DictionaryImmutable, Tuple

## Named value

A named value is a value that is associated with a name rather than being defined literally in code.

There are various kinds of named value:

Constant, Let

A named-value defined in a Let statement may be thought of as somewhere between a Constant and a Variable, but also has unique characteristics:

* Like a variable and a constant, a let statement defines a new named value.
* Like a constant, but unlike a variable, the named value defined by a let may not be subsequently re-assigned.
* Unlike a constant (which may only be defined at global level) a let is defined within main or any method.
* Unlike a constant, the value specified in a let may be defined by an expression i.e. may make use of other variables and constants.

Variable, Parameter, Index, Enum

#### Identifier

For all kinds of named values, the name must follow the rules for an ‘identifier’ – it must start with a lower-case letter, followed by any combination of lower-case and upper-case letters, numeric digits, and the \_ (underscore) symbol. It may not contain spaces or other symbols. Once a named value has been defined, it can be referred to by the name.

### Scoping and name qualification

With the exception of constant (below), which is global in scope, named values are always ‘local’ – their scope confined to the method in which they are defined.

Elan allows local named values to be defined with the same name as a constant, function, or procedure defined at global level, or defined in the standard library. If so, when the name is used within the same method, then it will refer to the local definition. If you have done this, but then need to access the constant, function, or procedure with the same name then you can simply prefix the use of the name with a ‘qualifier’ prefix of either global. or library. as appropriate.  
Constant

Explanatory video: <https://www.youtube.com/watch?v=KxkCDnYWkZ0&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=10>

A constant defines a named value that cannot change.

A constant is always defined at ‘global’ level (directly within a file) and is global in scope. A constant may not be defined within any method. (However, see the Error! Reference source not found.).

The name of a constant follows the rules for any Identifier.

The value to which a constant is set must be a Literal value, of one of the following types: Int, Float, Boolean, String, Error! Reference source not found., DictionaryImmutable

Examples:

constant phi set to 1.618

constant maxHits set to 10

constant warningMsg set to "Limit reached"

constant fruit set to {"apple", "orange", "banana"}

constant black set to 0x000000

constant red set to 0xff0000 constant scrabbleValues set to {"A":1, "B":3, "C":3, "D":2, "E":1, "F":4, "G":2, "H":4, "I":1, "J":8, "K":5, "L":1, "M":3, "N":1, "O":1, "P":3, "Q":10, "R":1, "S":1, "T":1, "U":1, "V":4, "W":4, "X":8, "Y":4, "Z":10}

constant colours set to {Suit.clubs:black, Suit.diamonds:red, Suit.hearts:red, Suit.spades:black}

(In the last example above, Suit is an Enum)

### Let

A named-value defined in a Let statement may be thought of as somewhere between a Constant and a Error! Not a valid bookmark self-reference. but also has unique characteristics:

* Like a variable and a constant, a let statement defines a new named value.
* Like a constant, but unlike a variable, the named value defined by a let may not be subsequently re-assigned.
* Unlike a constant (which may only be defined at global level) a let is defined within main or any method.
* Unlike a constant, the value specified in a let may be defined by an expression i.e. may make use of other variables and constants.

### Variable

A variable is a named value where the value may change during the running of the program.

The name of a variable follows the rules for all identifiers

A variable is defined using a Variable statement and may be re-assigned using a Set statement

Elan is a statically-typed language, so that each variable always has a defined type and any value assigned to that variable must be compatible with that type.

### Parameter

* A parameter is a specific kind of variable, defined as part of a method (Function and procedure or Error! Reference source not found.) for the purpose of capturing an argument being passed into that method.
* See also Parameter passing.

### Indexed Value

If a variable is of an indexable type then an index, or an index range, may be applied to the variable within an expression. For example:

variable a set to "Hello World!"  
print a[4]  
print a[4..]

print a[..5]

print a[3..4]

See also: Using an Array, Using a Dictionary.

**Important:** unlike in many languages, in Elan, indexes (whether, single index, multiple index, or index range) are only ever used for *reading* value(s). Writing a value to a specific index location is done through a method such as:

* putAt on an Array
* withPutAt on a List
* putAtKey on a Dictionary
* withPutAtKey on a DictionaryImmutable

### Enum

Explanatory video: <https://www.youtube.com/watch?v=k0IPAnNCDh0&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=19&pp=gAQBiAQB>

An enum – short for ‘enumeration’ – is the simplest form of ‘user-defined type’ , specifying a set of values, each defined as a name, such that a variable of that type must always hold one of those values.

#### Type name

The name given to an enum (see below), which must begin with a capital, is used as the Type name, when passing a value to or from a procedure or function.

#### Defining an enum

Example

enum Status incomplete, ready, running, stopped, invalid

Further examples of enum may be seen in Error! Reference source not found..

#### Using an enum

The value is specified by the type name for the specified enum, followed by a dot and the value name, for example:

variable x set to Status.ready

#### Notes

* Enums are *read-only* – once they have been defined it is not possible to add, remove, or update the values.

Example:

enum Suit clubs, diamonds, hearts, spades

## Operator

### Arithmetic operators

Arithmetic operators can be applied to Float or Int arguments, but the result is always a Float:

* 2^3 gives 8
* 2/3 gives 0.666…
* 2\*3 gives 6
* 2 + 3 gives 5
* 2 - 3 gives -1
* 11 mod 3 gives 2
* 11 div 3 gives 3 (integer division)

Arithmetic operators follow the conventional rules for precedence i.e. ‘BIDMAS’ (or ‘BODMAS’)

**Note:** When combining div or mod with *any* other operators within an expression, *insert brackets to avoid ambiguity* e.g.:

(5 + 6) mod 3

The minus sign may also be used as a unary operator, and this takes precedence over binary operators so:

* 2\*-3 gives -6

Note the Elan editor automatically puts spaces around the + and – *binary* operators, but not around ^,/,\*. This is just to reinforce, visually, the precedence.

### Logical operators

Logical operators are applied to Boolean argument(s) and return a Boolean result.

* and and or are binary operators
* not is a unary operator.

The operator precedence is not -> and -> or.

Example:

function xor(a as Boolean, b as Boolean) returns Boolean  
 return a and not b or b and not a  
end function

Implements an ‘exclusive or’.

### Equality testing

Equality testing uses the is and isnt keywords with two arguments. The arguments may be of any type.

* a is b returns true, if a and b are both of the same type and their values are equal. The only exception is that if one argument is of type Float and the other is of type Int, then is will return true if their values are the same (i.e. are the same whole number).
* isnt returns the opposite of is

Note that equality testing in Elan is *always* ‘equality by value’. There is no such thing as ‘equality by reference’ in Elan.

**Notes**

* Where a binary operator is expected, as soon as you type is the editor will automatically insert a space after it. To enter isnt you need to delete the space (using the **Backspace** key) and then type nt

### Numeric comparison

The numeric comparison operators are:

* > for ‘greater than’
* < for ‘less than’
* >= for ‘greater than or equal to’
* <= for ‘less than or equal to’

Each is applied to two arguments of type Float, but any variable of expression that evaluates to an Int type may always be used where a Float is expected.

**Notes**

* These operators cannot be applied to strings. Use the dot methods isBefore and isAfter to compare strings alphabetically. See Dot methods On a String.
* Where a binary operator is expected, as soon as you type < or > the editor will automatically insert a space after it. To enter >= or <= you need to delete the space (using the **Backspace** key) and then type =

### Combining operators

You can combine operators of different kinds e.g. combining numeric comparison with logical operators in a single expression. However the rules of precedence between operators of different kinds are complex. It is strongly recommend that you *always* use brackets to disambiguate such expressions, for example:

(a > b) and (b < c)

(a + b) > (c -d)

## Function call

An expression may simply be a function call, or it may include one or more function calls within it. Examples:

print sinDeg(30)  
variable x set to sinDeg(30)^2 + cosDeg(30)^2  
variable name set to inputString("Your name")  
print name.upperCase()

**Notes:**

* The third example (above) is not strictly a function call, but is a ‘system method’ call. System methods may only be used within the Main routine or a procedure, because they have external dependencies or side effects.
* The fourth upperCase is a ‘dot method’ that may be applied to any instance (variable or literal) of the type String. See Dot methods on a String.

# Input/Output

*All* forms of input/output involve dependencies on, or make changes to, the system. Therefore they may only be used either within the main, or within a procedure.

## Printing plain text to the Console

Explanatory video: <https://www.youtube.com/watch?v=NGYQQeAuKAg&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=20&t=2s>

The simplest way to print is with the print statement. For example

print "Hello"  
let a be 3  
let b be 4  
print a \* b  
print "{a} times {b} equals {a\*b}"

Notes:

* The last line in the example above uses an ‘interpolated string’. Arguments placed within curly braces are evaluated before printing, and these may be separated by literal text and/or punctuation as needed. This is one recommended way to print more than one value on a line. The other way is to use…

### print procedures

If you wish to have more control over the printing then, as an alternative to using a print *statement*, you may call any of these three standard library *procedures*:

printLine(arg as String)

printNoLine(arg as String)

printTab(tabPosition as Int, arg as String)

for example:

for i from 1 to 10 step 1  
 call printNoLine("{i}")  
end for

**Notes**

* For all three methods, the item to be printed must be a String – but you can convert other types into a String by using the dot-method .asString()
* printLine prints the item with a newline afterwards, in the same way that the ordinary print statement does. (The only purpose of having this procedure is so that you *may* choose to do all printing via these *methods* rather than mixing them in with print *statements*).
* printNoLine does not automatically add a newline at the end, so you may subsequently print something else on the same line (unless you choose to include \n within the string).
* printTab helps in the layout of information printed to the console, in particular, when printing of columns of data. printTab requires an additional argument specifying the tab position (number of characters from the left of the display). For example:

call printTab(0, "No.")  
call printTab(10, "Square")  
call printTab(20, "Cube\n")  
for x from 1 to 10 step 1  
 call printTab(0, x.asString()  
 call printTab(10, "{x^2}")  
 call printTab(20, "{x^3}\n")  
end for

## Print Html to the Console

As well as plain text, it is also possible to print Html to the console, which will be correctly formatted. For example:



Will produce:

A blue and white screen

Description automatically generated

**Notes**

* For specifying style, or other attributes within Html tags, the attribute value(s) should be enclosed in single quotation marks ' as shown. Html will recognise single or double quotation marks, but entering double quotation marks would terminate the Elan string.
* It is not necessary to put individual lines of Html into separate print statements – you can print a string of any length – but putting tags into separate print statements can improve the readability of your code.

### Using an embedded stylesheet

If you want styles to be applied to multiple tags you can embed a stylesheet. For example, the following stylesheet will set the font for all text, and some further details for all h1 headings:

<style>

h1, p {

font-family: Helvetica;

}

h1 {

color: blue;

font-size: 24pt;

}

</style>

This may be safely coalesced into a single line and many spaces removed:

<style> h1, p {font-family:Helvetica;} h1{color: blue;font-size:24pt;}</style>

The only problem is the curly braces - {} – as *within a literal string* Elan will interpret these as defining an ‘interpolation’ clause (see Interpolated string). There are several ways around this, but a recommended pattern is to define the stylesheet in a literal string using square brackets instead of curly braces, and then to replace the characters. If you need to do this in more than one place, it pays to define a function to do that specific replacement, for example as shown below:

main

let stylesheet be "<style> h1, p [font-family:Helvetica;] h1[color: blue;font-size:24pt;]</style>")  
 print replaceBrackets(stylesheet)

print "<h1>A heading</h1>"

print "<p>Some text</p>"

end main

function replaceBrackets(original as String) returns String

return original.replace("[", unicode(123)).replace("]", unicode(125))

end function

Here is the result:

A screenshot of a computer

Description automatically generated

**Notes:**

* If you define an embedded stylesheet in the manner described above, then this should be printed first, and will then be applied to any subsequent printing of Html within the program. However …
* If the console is c*leared*, either by the **Clear** button on the UI, or by programmatically using call clearConsole(), then the stylesheet will be removed also – but you can print the stylesheet again before printing further content if you wish. In this case it can be a good idea to define the stylesheet as a (global) constant.
* In general you should avoid using \* to define the applicability of a style, since this could mess up the styling of the Elan IDE, and even render it unusable. (If this happens, refresh the browser and correct the stylesheet definition). If you want a style to apply to all elements that you are printing you may specify #console \* - this means ‘all elements within the element with id = 'console'

## Inputting data from the keyboard

The primary

Explanatory video: <https://www.youtube.com/watch?v=ziYfalHJ9q4&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=21>

Also the readKey system method on BlockGraphics

## Block graphics

Block graphics provides a simple way to create low resolution graphics, ideal for simple but engaging games for example. The graphics are displayed on a grid that is 40 blocks wide by 30 blocks deep. Each block may be rendered as a solid colour – either one of a small number of standard colours (black, grey, white, red, green, blue, yellow, brown) or any one of 16 million 24-bit colours specified in ‘RGB’ components – as used in Html/CSS, for example. Each block may alternatively hold a symbol – either one of the standard text characters, or any Unicode symbol – in each case with a foreground and a background colour.

Example of use (produces an attractive, but rapidly changing, pattern of coloured blocks):

main

variable gr set to new BlockGraphics()

while true

let x be randomInt(0, 39)

let y be randomInt(0, 29)

let colour be randomInt(0, 2^24 - 1)

set gr to gr.withBlock(x, y, colour)

call gr.display()

end while

end main

**Notes:**

* Making changes to the instance of BlockGraphics (gr above) – for example by calling withBlock above – does not *of itself* result in anything appearing in the **Graphics** screen. The **Graphics** screen changes only when the display() procedure is called. This is convenient, as sometimes you want to make many changes to the graphics and then have them appear all at once (when draw is called). It is even possible to create, and modify, multiple instances of BlockGraphics, and switch instantly between them by calling draw on different instances.
* The coordinates must be in the range 0-39 for the column, and 0-29 for the row. Using values outside this range will result in a run-time error.
* Colour is always specified as an integer value in the range 0 – 16,777,215 (224 -1). Note that when defining your own colours it can be helpful to use the hexadecimal notation, for example: constant lightBlue set to 0x80abff
* The withBlock method, does *not* change the instance of BlockGraphics on which it is called – it returns a new instance of BlockGraphics based on the original, but with the change specified. However this new instance may be re-assigned to the same variable – as is the case in the code above.
* In addition to withBlock there are these function methods for updating the graphics:
  + withText(x as Int, y as Int, text as String, foreground as Int, background as Int) returns BlockGraphics. If the text argument is more than one character long, the characters will be placed in successive blocks - wrapping onto the next line if necessary. (If the string is too long to fit, from the starting coordinates specified, you will get a runtime error).
  + withUnicode(x as Int, y as Int, unicode as Int, foreground as Int,   
    background as Int) returns BlockGraphics   
    is used to specify a single symbol/character using the Unicode value.
  + withBackground(backgroundColour as Int) returns BlockGraphics  
    will paint the background colour for the whole grid, leaving any existing characters (and their foreground colours) unchanged.
* There are also function methods on a **BlockGraphics** instance for reading the existing character or colours of a specified block:  
    
  getChar(x as Int, y as Int) returns String

getForeground(x as Int, y as Int) returns Int

getBackground x as Int, y as Int) returns Int

## Turtle graphics

Example code:

main

let t be new Turtle()

call t.show()

for i from 1 to 4 step 1

call t.turn(90)

call t.move(100)

call t.pause(500)

end for

end main

Output:

A screenshot of a computer

Description automatically generated

**Notes:**

* moveand turn are the two most commonly-used methods. To move backwards, specify a negative value. The value passed into turn is interpreted as degrees: a positive value turns clockwise; a negative value, anti-clockwise. These two methods take a numeric value, which may be an Int or a Float.
* Scaling:the argument provided to the move procedure is specified in ‘turtle-units’. The **Graphics** pane on the screen (i.e. the ‘paper’ on which the Turtle draws) is 100 turtle units wide by 75 turtle units high. If the turtle is moved outside these boundaries it will not cause an error, but the location of the turtle and any lines outside the boundaries will not be visible.
* show causes the turtle to be displayed (the small green circle with a black radius showing the direction it is pointing); hide does the opposite. You can move and turn the turtle, causing lines to be drawn, whether or not the turtle is shown.
* To move the turtle without drawing a line call penUp, then penDown when you are ready to draw lines again.
* penColour takes an integer argument specifying the colour. You may use one of the standard colour constants (which are just integer values themselves): black, grey, white, red, green, blue, yellow, brown, or you may specify a custom colour in hexadecimal RGB format such as 0xf74b80. penWidth specifies the width of the line drawn by the turtle – which must be an integer value with 1 as the default, and minimum, width.
* You can specify the start position of the turtle in x,y coordinates (0,0 being the top-left of the **Graphics** pane) with placeAt, which may also be used to reposition the turtle (without drawing a connecting line) during the program run. You may specify the heading absolutely with turnTo, where 0 would cause the turtle to face the top of the screen.
* The current location and heading of the turtle may be read using the x, y, and heading properties.
* There is no difference in effect between call t.pause(500) and call pause(500) (see pause ) – the former option is provided as a convenience, because most instructions in a Turtle program take the form call t.something. Both versions take an integer argument, being the length of the pause in milliseconds.
* Apart from the penColour and pause methods, both of which require an integer value, all other procedure methods on the Turtle can take integer or floating-point values.

Here is a more sophisticated example, using a procedure and recursion:

main

variable t set to new Turtle()

call t.placeAt(10, 60)

call t.turn(90)

call t.show()

for i from 1 to 3 step 1

call drawSide(160, t)

call t.turn(120)

end for

end main

procedure drawSide(length as Float, out t as Turtle)

if (length > 3) then

let third be length/3

call drawSide(third, t)

call t.turn(-60)

call drawSide(third, t)

call t.turn(120)

call drawSide(third, t)

call t.turn(-60)

call drawSide(third, t)

else

call t.move(length)

end if

end procedure

to produce a *fractal* snowflake:

A screenshot of a computer

Description automatically generated

## Vector graphics

Example:

main

  variable vg set to new VectorGraphics()

  let circ be new CircleVG() with cx to 35, cy to 35, r to 5, stroke to red, strokeWidth to 2, fill to green

  set vg to vg.add(circ)

  call vg.display()

end main

Output:

A blue and white flag

Description automatically generated

**Notes:**

* Elan vector graphics are displayed using SVG (Scalable Vector Graphics) that are a part of the Html specification. The names of the shapes broadly correspond to the names of SVG tags: CircleVG for <circle../>, LineVG for <line../>, and RectangleVG for <rect../>. The properties of the Elan VG shapes, match the names of the attributes used in the SVG tags, except that the stroke-width attribute is changed to strokeWidth to make it a valid Elan identifier.
* The ‘canvas’ on which vector graphics are drawn (the **Graphics** pane in the user interface) is 100 units wide, by 75 units high .All numeric values specified for attributes of vector graphic shapes may be integer or floating point.
* All Elan ...VG shapes have default values for all attributes, and so will show up even if no attributes have been specified. You can specify as many of the attributes as you wish when creating the shape using the new .. with syntax, as shown in the example above.
* As with Block graphics the screen is not updated until the display method is called – allowing you to make multiple changes before updating the screen. Similarly, the method to add a shape returns a new instance of the VectorGraphicswhich must be assigned either to an existing variable, or to a new let.
* As with the way that SVG works within Html, the shapes are drawn in the order in which they are added into the VectorGraphics instance, with later shapes overwriting earlier shapes.
* The colour (for stroke and fill properties) may be specified using the small number of standard colours (e.g. red) or as a 24-bit colour code, specified in hexadecimal format e.g. 0xfe3ba0. The fill colour only may also be specified as ‘transparent’ by specifying the value as any negative value, though we suggest using fill to -1
* VectorGraphics also has methods removeLast(no parameters),remove (which takes a shape as a parameter, and replace which takes an existing shape and a new shape as parameters. The new shape may be a modified version of an existing shape (created using copy..with), thereby enabling animation. The following simple example creates a circle that changes between red and green every second:

main

variable vg set to new VectorGraphics()

let greenCirc be new CircleVG() with cx to 50, cy to 37, r to 30, fill to green

let redCirc be copy greenCirc with fill to red

set vg to vg.add(greenCirc)

while true

call vg.display()

call pause(1000)

set vg to vg.replace(greenCirc, redCirc)

call vg.display()

call pause(1000)

set vg to vg.replace(redCirc, greenCirc)

end while

end main

## Reading keys ‘on the fly’

In some applications – especially in games, for example – you want the program to react to a key pressed by the user, but without holding up the program to wait for value to be input.

Whether your application makes use graphics, or just uses the *Console* for text, reading keystrokes ‘on the fly’ is done via one of two methods:

let key be getKey()

let key, modifier be getKeyWithModifier()

**Notes:**

* When the getKey is called, the system *does not wait for a response*. If a key has been pressed then that will be returned as a **String** e.g. "a".
* Non-printable keys will be returned in the form: **"Backspace"**,"**Enter"**,**"ArrowDown"**,..
* If no key has been pressed (since the last time the method was called), it will return an empty string "".
* Pressing *just* the **Shift**, **Ctrl**, or **Alt** keys will not be detected by getKey. To read those keys use…
* getKeyWithModifier returns a 2-tuple, containing the key pressed, and secondly any ‘modifier’ key such a Shift, Ctrl, or Alt (or an empty string if no modifier key is pressed).
* Both of these get methods are System methods, because they have a dependency on the system, so may only be used within a procedure or main.

The procedure method clearKeyBuffer() if you want to enforce that the user cannot get too far ahead of the program by hitting keys in very rapid succession.

waitForAnyKey

pauses the execution of the program until the user presses *any* single key. The identity of the key is not captured though. Example of use:

print "Press any key to continue.."  
call waitForAnyKey()  
call clearConsole()

print "Next page"

## Reading textual data from a file

Reading a whole file in one go:

let file be openFileForReading()

let text be file.readWholeFile()

call file.close()

print text

Reading a file line by line:

let file be openFileForReading()

variable lines set to empty Array<of String>

while not file.endOfFile()

let line be file.readLine()

call lines.append(line)

end while

call file.close()

**Notes:**

* openFileForReading will present the user with a dialog to select the file.
* readWholeFilereturns a String containing every character in the file, without any trimming. It automatically closes the file after the read.
* readLine reads as far as the next newline character (\n) and then automatically trims the line to remove any spaces and/or carriage-returns (which some file systems insert after the newline automatically) from the resulting line returned as a String. If this behaviour is not desired, the programmer may use readWholeFile, which does no trimming and then parse the resulting string into separate lines.
* Calling file.close() after reading line by line is strongly recommended to avoid any risk of leaving the file locked. It is *not necessary* to call it after using readWholeFile() because that method automatically closes the file.
* Calling any method on a file that is already closed will result in a runtime error.

## Writing textual data to a file

Writing a whole file in one go:

A close up of text

Description automatically generated

Writing a file line by line:

A computer code with text

Description automatically generated with medium confidence

**Notes:**

* writeLine adds the string it is passed onto the end of any text previously written, with a newline character (\n) automatically appended.
* When execution reaches file.saveAndClose() the user will be presented with a dialog to confirm (or edit) the given filename and location where it is to be saved.
* It is not therefore strictly *necessary* to specify a filename when creating the file, since it can be specified by the user in the dialog – in which pass an empty string "" into createFileForWriting
* writeWholeFile puts the string it is given into the file and then *automatically* saves the file – so the user will be presented with the same dialog as if saveAndClose had been called.
* Calling any method on a file that has already been closed (by calling either saveAndClose or by writeWholeFile) will result in a runtime error.
* If the user were to hit **Cancel**on the dialog, then the program will exit with an error. If you want to guard against this possibility (if, for example, it might mean the loss of important data) then you should perform the save and close within a try..catch perhaps like this:

try

call file.saveAndClose()

catch exception in e

print "File save cancelled"

end try

or you could make the code offer the user options: to save again, or to continue without saving.

# Procedural programming

## Main routine

Explanatory video: <https://www.youtube.com/watch?v=Tg1SKYcrF4E&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=8>

A file must have a main method *if it is intended to be run as program*. (You may however develop and test code that does *not* have a main method – either as a coding exercise, or for subsequent use within another program).

The main method defines the start point when a program is run.

The main method does not have to be at the top of the file, but this is a good convention to follow.

There may *not* be more than one main method in a file – and the global selector (above) will not show the main option when one already exists in the file.

Example:

main

variable li set to [3, 6, 1, 0, 99, 4, 67]

call inPlaceRippleSort(li)

print li

end main

## Using variables

Explanatory video: <https://www.youtube.com/watch?v=g6Byq0vhYw8&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=9&t=34s>

### Variable statement

The variable statement is used to define, and initialise, a new variable.

The name given to the variable must follow the rules for an Identifier.

The value to which the new variable is initialised may be a literal value, or a more complex expression. Either way, the resulting value defines the type for that variable.

### Set statement

The set statement is used to assign a new value to an existing variable. The new value must be of the same type (or a type compatible with) that of the variable.

A set statement may not assign a new value to a parameter – see Parameter passing.

## Conditions & selection

### If statement

Example1:

if head is apple then

call setAppleToRandomPosition(apple, body)

else

call body.removeAt(0)

end if

Example 2:

if item is value then

set result to true

else if item.isBefore(value) then

set result to binarySearch(list[..mid], item)

else

set result to binarySearch(list[mid + 1..], item)

end if

**Notes:**

* The else clause is optional
* You can add as many else if clauses as you wish, but only one *unconditional* else (which, if present, must be the last clause).

### If expression

Elan also supports the If expression, which, although often thought of as a Functional programming technique, may be used within procedural programming also – within any expression.

## Loops & iteration

### For loop

Explanatory video: <https://www.youtube.com/watch?v=D8HF3386FtI&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=12&pp=gAQBiAQB>

**Notes**

* The three defining values (from, to, and step) must all be integers – positive or negative.
* They may be defined by literal integers, variables of integer type, or expressions that evaluate to an integer.
* However, if you require a *negative* step then the literal value, variable, or expression *must start with a negative sign* – as this is needed at compile time to determine the nature of the exit condition. So if you have a variable s that holds a negative value to be used as the step, then you will need to write something like the following:

variable s set to -3

for i from 100 to 0 step -(-s)

...

end for

### Each loop

Explanatory video: <https://www.youtube.com/watch?v=kTMfiH7wXOs&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=14&pp=gAQBiAQB>

### While loop

Explanatory video: <https://www.youtube.com/watch?v=Uwp_7Eh2P88&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=15&pp=gAQBiAQB>

### Repeat loop

Explanatory video: <https://www.youtube.com/watch?v=b-kD417YopM&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=16&pp=gAQBiAQB>

## Function and procedures

The main routine may delegate work to one or more functions or procedures

### Function

* Parameter passing).

### Procedure

Like a function, a procedure is a named piece of behaviour that may define parameters; unlike a function, a procedure does not return a value. However, unlike a function, a procedure can have ‘side effects’ - indeed it *must* have side-effects otherwise there would be no point in calling it! For this reason the statements within a procedure can:

* Include print statements (or methods).
* include input methods or other ‘system’ methods (such as random number generation).
* call other procedures (or itself if ‘recursion’ is required).
* Re-assign a parameter, provided that parameter definition is preceded by the keyword out Example:

procedure inPlaceRippleSort(out list as Array<of Int>)

variable lastComp set to list.length() - 2

repeat

set changes to false

for i from 0 to lastComp step 1

if list[i] > list[i + 1] then

variable temp set to list[i]

set list[i] to list[i + 1]

set list[i + 1] to temp

set changes to true

end if

end for

set lastComp to lastComp - 1

end repeat when not changes

end procedure

Procedures are used within a call statement, for example:

main

variable li set to [3, 6, 1, 0, 99, 4, 67]

call inPlaceRippleSort(li)

print li

end main

**Notes**:

* Parameters for a procedure are defined exactly the same way as for a function – each parameter definition taking the form <name> as <Type> - for example age as Int

### Parameter passing

The arguments provided to a method (function or procedure) are passed ‘by value’ and not ‘by reference’. If you wish to be able to *re-assign* the value associated with a parameter, such that that change would be visible to the code that calls the procedure, then you can precede the parameter definition with the out keyword. This is useful when you are passing in, say, an Int that refers to an index, and you want the procedure to update which index number it is pointing to.

Note, however, that *mutating* an instance of a reference type held in a variable is not the same thing as re-assigning the variable to a different instance. The first changes the contents of the thing, the second changes the thing for another thing!

Therefore, *if*

* the method is a procedure AND
* the type of the argument is a ‘reference type’ AND
* that type is *mutable* such as an Array, Dictionary, Stack, Queue, or a user-defined class

then it is possible to *mutate* the parameter that holds that argument within the procedure, such that any reference to the argument outside the procedure will ‘see’ the changes.

A good example of this is an ‘in-place sort’ procedure. In the following code the arr parameter is mutated in the two highlighted lines:

procedure inPlaceRippleSort(arr as Array<of Int>)

variable changes set to true

variable lastComp set to arr.length() - 2

repeat

set changes to false

for i from 0 to lastComp step 1

if arr [i] > arr [i + 1] then

variable temp set to arr [i]

set arr[i] to arr[i + 1]

set arr[i + 1] to temp

set changes to true

end if

end for

set lastComp to lastComp - 1

end repeat when not changes

end procedure

Note however that:

* In a function you may not mutate *any* parameter
* In a procedure you may not *re-assign* any parameter

## Catching and throwing exceptions

An exception may be deliberately generated by the programmer when a specific circumstance is identified with a throw statement, for example:

throw exception "something has happened"

Where another piece of code might throw an exception – for example when calling a System method that is dependent upon external conditions - it may be executed within a try statement, for example:

try

call foo()

print "not caught"

catch exception in e

print e

end try

The variable holding the exception (by default named e, but this may be changed by the programmer) is of type String. The programmer may compare the exception message to one or more expected messages, and if the message does not match an expected exception may choose to throw the exception ‘up’, for example:

try

call foo()

print "not caught"

catch exception in e

if e isnt "An expected message" then

throw exception e

end if

end try

## Generating random numbers

Random numbers may be created by calling one of these two standard methods:

* random() returnss a Float in the range 0-1
* randomInt(min, max) returnss an Int in the range min to max *inclusive*

For example:

let probability be random()  
print probability

for I from 1 to 10 step 1  
 print randomInt(1, 6)  
end for

**Notes**

* These two methods are both System methods so they may be used only within main or a procedure. However, the resulting Int or Float may then be used as an argument to pass *into* a function.
* Elan provides a separate mechanism for generating random numbers within a function. See Error! Reference source not found..

## Comments

Explanatory video: <https://www.youtube.com/watch?v=Vv2hD3EobKU&list=PLhZaBW7EbafOPO4YyuovGI1prCViAeVKM&index=11>

Comments:

* may be added at global level – as well as within other constructs.
* always start with a # followed by a space and then free-form text. The text field may be left empty
* are a single line, though if the text is long enough the line may be wrapped within the editor
* are always on their own line. It is it not possible to add a comment after, or within, a line of code.

# Object-oriented programming

## Class

A class is user-defined type – offering far richer capability than an enum.

(A record is in some ways similar to a class but simpler: it defines properties, but has no constructor and no methods. See Working with records).

### Definition

Here is an example of class definition – taken from the *Snake OOP* demo program:

class Apple

constructor(board as Board)

set property.board to board

end constructor

property board as Board

property location as Square

procedure newRandomPosition(snake as Snake)

repeat

variable ranX set to randomInt(0, board.width - 1)

variable ranY set to randomInt(0, board.height - 1)

set location to new Square(ranX, ranY)

end repeat when not snake.bodyCovers(location)

end procedure

function updateGraphics(gr as BlockGraphics) returns BlockGraphics

return gr.withBlock(location.x, location.y, red)

end function

end class

**Notes:**

A class *must* have:

* A name that, like any other type, must begin with a capital letter.

A class *may* define:

* One or more propertys – see Property
* function methods – see Function method
* procedure methods – see Procedure method
* A constructor which may be used for setting up the values of properties. The constructormay, optionally, define parameters – to force the calling code to provide initial values. However, it is not necessary to add a constructor if you have no need to initialise properties. Code in the constructor may make use of any functions – and follows the same constraints as a function (i.e. may not call any procedure, whether defined on the class or outside).

### Inheritance

A regular (concrete) class may inherit from one or more abstractclass – see Abstract class. The concrete class must define for itself a concrete version of every abstract property and abstract method defined in the abstract class, or classes, that it inherits from.

### Using a class

A class is instantiated using the keyword new followed by the class name and brackets, which should enclose the comma-separated arguments required to match the parameters (if any) defined on the constructor (if any) for that class. For example (also from the *Snake OOP* demo):

variable board set to new Board(40, 30)

variable currentDirection set to Direction.up

variable snake set to new Snake(board, currentDirection)

variable apple set to new Apple(board)

The created instance may then be used within expressions, like any other variable.

## Abstract class

An abstract class may not be instantiated (and hence may not define a constructor). It *may* define *concrete* members i.e.:

* a property
* a function
* a procedure

As on a concrete class, any of these members may be made private after the corresponding frame has been added, by selecting on that member frame and pressing **Ctrl‑p**.

These concrete members are automatically inherited by any sub-class, *but they may not be overridden* (modified) by the sub-class. Therefore you should define concrete members only if they are intended to work identically on every sub-class.

You may also define abstract methods on an abstract classes i.e. abstract property, abstract function, abstract procedure. Such methods define only the signature of the method, not the implementation. Therefore they have no end statement. For example:

abstract function calculateDiscount() as Float

Every concrete class must implement each abstract member that is defined on any of its (abstract) super-classes, by defining a method with the same signature (without the abstract) and – if it is a method – defining the body of the method also.

Different super-classes may define abstract members with identical signatures, in which case a single implementation in the concrete sub-class will cover them all. However, a class may not inherit from two or more abstract classes that define the same *concrete* member, since that would result in two separate members with the same signature.

Also a class may not inherit from two or more abstract classes that have conflicting definitions of abstract and/or concrete members – for example methods with the same name, but defining different parameters or return *type*.

If you wish to have several sub-classes of an abstract class that share a common implementation for a method, but require that *some* of the sub-classes can define a different implementation, then you should:

* Define the method as abstract on the superclass
* Define a concrete implementation on the superclass with a similar, but slightly different name e.g. having a prefix such as: default…
* Each sub-class must then define its implementation of the abstract method, but the ones needing a common implementation can be just one line, *delegating* responsibility up to the ‘default’ method on the superclass.

## Property

Examples:

property height as Int

property board as Board

property head as Square

property body as [Square]

* A property is defined on a Class and must specify a name (conforming to Identifier rules) and a Type.
* A property may be marked private – in which case it is visible only by code within the class and, *if defined on an* abstract class, within its sub-classes. This is done by selecting the property frame and then pressing **Ctrl-p**. (Pressing these keys *again* will remove the private modifier).
* If not marked private, a property may be read – but may not be written. Properties may only be modified from outside the class by means of a Procedure method.
* A property may be given an initial value in the constructor.
* If the property is not initialised within the constructor then it will automatically be given the empty value for that type. You may test whether a property contains this default value by writing e.g.:

if head is empty Square

* Whenever you wish to access a property from within a method (or from within the constructor) on the same class, then the name of the property must be prefixed with the ‘qualifier’: property. (‘property-dot’). This applies whether you are reading or setting the property. By this means you can have a method parameter with the same name as a property, but they are unambiguous, because the property must be prefixed. A common pattern is to use the same name in a ‘setter’ method, for example:

constructor(board as Board)

set property.board to board

end constructor

procedure setHeight(height as Int)

set property.height to height

end procedure

## Function method

A function method follows the same syntax and rules as a freestanding (global) function. The differences are:

* A function method is always referenced (used) by code outside the class using ‘dot-syntax’ on an instance.
* A function method may directly reference (read only) any property defined on the class as though it were a variable/parameter.
* A function method may be marked private – in which case it is visible only by code within the class and, *if defined on an* abstract class, within its sub-classes. This is done by selecting the property frame and then pressing **Ctrl-p**. (Pressing these keys *again* will remove the private modifier).
* asString() method
* asString method. This is just a regular function method with a specific name, no parameters and returning a String. If defined for a class, then if an instance of the class is printed, the asString function method will automatically be used. Typically asString will return a string made up of one or more of the property values, perhaps with additional text, or the results of function calls.

## Procedure method

A ‘procedure method’ follows the same syntax and rules as a freestanding (global) procedure. The differences are:

* A procedure method, like a function method, is always referenced (used) by code outside the class using ‘dot-syntax’ on an instance.
* A procedure method may read, or write to, any property defined on the class.
* A procedure method may be marked private – in which case it is visible only by code within the class and, *if defined on an* abstract class, within its sub-classes. This is done by selecting the property frame and then pressing **Ctrl-p**. (Pressing these keys *again* will remove the private modifier).

# Functional programming

Elan is designed to support the ‘functional programming’ paradigm.

Unlike in most ‘mixed-paradigm’ programming languages, *all* functions in Elan are ‘pure functions’: Elan does not permit any function to create ‘side-effects’, and enforces that the returned value is derived solely, and deterministically, from the values passed into the function’s parameters. This applies whether or not you are actively seeking to write code according to the functional programming approach.

When writing code according to the functional programming paradigm the aim is to write as much as possible of the program’s logic and behaviour within pure functions; to use the Main routine and Function and procedure calls solely for implementing input/output; and to keep both main and procedures ‘as thin as possible’. Elan’s in-built support for character-mapped BlockGraphics is a good example of this pattern: almost all the work can be done using the in-built *functions*, such as withBlock, which may be used within your own user-defined functions. Only the draw method – which is the only one that actually changes the display - is a procedure, and this must be called from within main, or a procedure. (See Error! Reference source not found..)

*Although it is not a requirement to do so*, adopting the functional programming paradigm also means that, wherever possible, functions should avoid using procedural code constructs: sequence, loop, and branch. Here are some examples of functions that *don’t* use any of those procedural code constructs:

function w(c as Int) returns Int

return if (c mod 40) > 0 then c - 1 else c + 39

end function

function possibleAnswersAfterAttempt(prior as List<of String>, attempt as String, mark as String) returns List<of String>

return prior.filter(lambda w as String => markAttempt(attempt, w) is mark).asList()

end function

function nextGeneration(cells as [Boolean]) returns [Boolean]

let cellRange be range(0, cells.length() - 1)

let next be cellRange.map(lambda n as Int => nextCellValue(cells, n))

return next.asArray()

end function

In the examples above we can see several patterns/techniques that are widely used in functional programming in place of procedural code constructs:

* (Top example) Use of an If expression, instead of using an If statement.
* (Middle example) Use of Higher order functions – in this case, filter – together with a Passing a function as a reference

If you are passing a reference to a freestanding function as an argument into a HoF (as distinct from defining a lambda) then you provide the name of that function, but precede it with the keyword function. For example:

...

variable passes set to allPupils.filter(function passedMathsTest)

...

function passedMathsTest(p as Pupil) as Boolean

return p.mathsPercent > 35

end function

**Notes:**

* When passing in a reference function passMathsTest, the name is preceded by function, and that no parameters (or brackets) are added to the name as they would have been if you were *evaluating* (calling) the function at that point.
* Lambda, instead of writing a loop
* Use of a Let statement (instead of the Variable statement) to calculate intermediate values.

These are explained below.

## If expression

The ‘if expression’ is *in certain respects* similar to an If statement, but with the following differences:

* It is written entirely within a single expression. This is possible because the if expression always returns a value.
* There is always a single then and a single else clause, and each clause contains just a single expression. The if expression returns the result of evaluating one of these two expressions, according to whether the condition evaluates to true or false.

Here are three examples:

return if c < 1160 then c + 40

else c – 1160

return if isGreen(attempt, target, n) then setChar(attempt, n, "\*")

else attempt

return if attempt[n] is "\*" then attempt

else if isYellow(attempt, target, n) then setChar(attempt, n, "+")

else setChar(attempt, n, "\_"))

**Notes:**

* When the if expression is being entered, or edited, it is presented as a single editable line, which may be scrolled horizontally. As soon as the entry/edit field is exited, the expression will be re-formatted as shown above, with each else clause starting on a new line, indented by one character. Note that each of the three examples above is still a single *statement* – not a sequence of statements.
* The else keyword may be followed by a further if expression – as in the second example above. It is possible to form a long ‘*chain’* of these else if clauses, in which case there is only ever one unconditional else clause at the very end.
* If you wish to have another if expression *within* the then clause, then this ‘nested’ if expression must be surrounded by brackets – to avoid ambiguity. However, nesting if expressions in this way - rather than chaining else if statements (above) – since *nested* if expressions are hard to read.

## Let statement

A let statement may be used only within a function, where its purpose is to calculate an intermediate result for use within one or more subsequent expressions. This may be for any of the following reasons:

* To avoid duplicating code, where the same sub-expression would otherwise be written more than one
* To break up a complex expression just for clarity or readability

Here is an example of let statements in use:

let wordCounts be allRemainingWordCounts(possAnswers, possAttempts)

let best be wordCounts.reduce(wordCounts.head(), lambda bestSoFar as WordCount, newWord as WordCount => betterOf(bestSoFar, newWord, possAnswers))

return best.word

You are never *required* to use a let statement: you may always use a variable instead. But if you are willing to use let where you can, it is considered a good practice in functional programming. let may be thought of as somewhere between a Constant and a Let

A named-value defined in a Let statement may be thought of as somewhere between a Constant and a Error! Not a valid bookmark self-reference. but also has unique characteristics:

* Like a variable and a constant, a let statement defines a new named value.
* Like a constant, but unlike a variable, the named value defined by a let may not be subsequently re-assigned.
* Unlike a constant (which may only be defined at global level) a let is defined within main or any method.
* Unlike a constant, the value specified in a let may be defined by an expression i.e. may make use of other variables and constants.

Variable but also has unique characteristics:

* Like a variable and a constant, a let statement defines a new named value.
* Like a constant, but unlike a variable, the named value defined by a let may not be subsequently re-assigned.
* Unlike a constant (which may only be defined at global level) a let is defined within main or any method.
* Unlike a constant, the value specified in a let may be defined by an expression i.e. may make use of other variables and constants.

## Higher order functions (HoFs)

A ‘higher order function’ is one that takes in a reference to another function as a parameter, or (less commonly) that returns a reference to another function as its result.

### Standard HoFs

The Elan standard library contains several HoFs that are widely recognised and used within functional programming. See On any Iterable - Higher order functions (HoFs).

### Passing a function as a reference

On most occasions when you write the name of an existing function elsewhere in code your intent is to *evaluate* the function – and to do so you write the name of the function, followed by brackets, containing such arguments as are required by the function. For this reason if you forget to add the brackets, you will get an error, for example:



The second sentence in the error message is for when your intention is *not* to evaluate the function, but to create a *reference* to the function. This is a valid thing to do in functional programming, but is not generally done in procedural programming. As the error message says, to create a reference to a function you need to precede it by ref and the name of the function should *not* be followed by brackets (or any arguments). For example:

...

variable passes set to allPupils.filter(ref passedMathsTest)

...

function passedMathsTest(p as Pupil) as Boolean

return p.mathsPercent > 35

end function

### Lambda

A lambda is lightweight means to define a function ‘in line’. You typically define a lambda:

* If the functionality it defines is needed only in one location - typically for a particular call to a HoF.
* If you need to capture a local variable in the implementation. (This is called ‘closing around a variable’)

The syntax for a lambda is as follows:

* Start with the keyword lambda
* Parameter definitions, comma-separated, follow the same form as parameter definitions in a function or procedure – but with no surrounding brackets.
* The => symbol, which is usually articulated as ‘returns’ or ‘yields’ or even ‘fat arrow’.
* An expression that makes use of the parameter(s) – and may also make use of other variables in scope.

Example:

function liveNeighbours(cells as [Boolean], c as Int) returns Int

let neighbours be neighbourCells(c)

let live be neighbours.filter(lambda i as Int => cells[i])

return live.length()

end function

**Notes**:

* Although a lambda is commonly defined ‘inline’ (as shown above) it is possible to assign a lambda to a variable and hence to re-use it within the scope of that variable.
* Although a lambda will *usually* define at least one parameter, it is possible to define a lambda with no parameter, just returning an expression – in which case it acts just like a locally defined variable, but with the advantage (useful in rare circumstances) that the expression is evaluated ‘lazily’ i.e. only when the lambda is *used*. The following example uses both these techniques within a function:

function safeSquareRoot(x as Float) returns Float  
 let root be lambda => sqrt(x)  
 return if x < 0 then 0 else root()  
end function

### Defining your own HoFs

TODO

The Iterable type

The Func type

## Working with records

You may pass an instance a Class, into a function. However, you may not call any procedure on, not otherwise mutate the instance.

But if you are wanting to learn to write code according to the functional programming paradigm, it is better to try to work exclusively with *immutable* types. Elan provides very good support for these, both in the form of standard immutable data structures (such as List) and user-defined ‘record’ type. Here is an example:

A close up of words

Description automatically generated

A record is a user-defined data structure that is given a type name – Square, above – that must begin with a capital letter. The record defines one or more properties, each of which has a name (starting lower case) and a type. The type of a property may be any simple value type (as in the example above), or a List, another type of record (or even the same type of record). What distinguishes a record type from a List is that its members may be of different types, and what distinguished a record type from a Tuple is that each member has a specific name.

Having defined a record type, such as Square above, you can create as many instances as you wish using the following syntax to specify the values:

let sq1 be new Square() with x to 3.5, y to 4.0, size to 1.0, colour to blue

Notice that you are not *required* provide a value for each property – because where a property is not specified in the ‘with clause’ (as above), that property will be given the empty (default) value of the correct type.

You can then read the values from the properties using ‘dot syntax’ for example:

print sq1.size

record types are *immutable*: the properties on an instance may not be changed, directly. However, you can easily create another instance that is a copy of the original, with all the same property values except for any specific changes as specified in another ‘with clause’. The newly-minted copy (with changes) must be assigned to a new named value. For example:

let sq1 be new Square() with x to 3.5, y to 4.0, size to 1.0

let sq2 be copy sq1 with size to 2.0, colour to red

Or even to the same name if that name is a variable:

variable a set to new Square() with x to 3.5, y to 4.0, size to 1.0

set a to copy a with size to 2.0, colour to red

Note that a record type has some similarity to a class:

* Both are user-define data structures
* Both are given a ‘type name’
* Both may define one or more properties, each with a name and type

However a record is *different* from a class in that:

* A record does *not* define a constructor
* A record cannot define any methods
* A record is *immutable* (like a List or String) – you can create a copy with specified differences but you cannot modify a property on a given instance.
* A record instance may be created or copied using a with clause; with may not be used on a class instance.

### Record deconstruction

A record may be ‘deconstructed’ – its properties read into separate variables – using the same syntax as for deconstructing a tuple. For example, assuming that Square is a record defined as in the example above then:

let x, y, size, colour be mySquare

will read the properties into the four names defined.

**Notes**

* When deconstructing, the *names* of the values must match the names of the properties of the record. However, the ordering of the names does not have match the order in which the properties are defined in the record.

## Generating random numbers within a function

It is *not* possible to use the system methods random() or randomInt(…) within a function - because they create unseen side effects. (You *may* use those system methods outside the function and pass the resulting random number (as an Int or a Float) as an argument *into* a function.  
  
It *is possible* to create and use random numbers *within a function*, but it requires a different approach and is a little more complex, using a special *type* named Random (note that the R is capitalised).

Example of use:

main

  variable rnd set to new Random()  
 call rnd.initialiseFromClock()

  variable dice set to 0

  for i from 1 to 10 step 1

    set dice, rnd to rollDice(rnd)

print dice

  end for

end main

function rollDice(rnd as Random) returns (Int, Random)

  return rnd.nextInt(1, 6)

end function

The Random type defined two `function methods` - next, and nextInt.

Both of them return a 2-Tuple consisting of the random value (as either a Float or an Int respectively) plus a new Random. The *new* (returned) Random must be used for generating the subsequent random number (if more are required). If you call next repeatedly on the same instance of Random, you will always get the same value.

As shown in the example, when *first created* you should call initialiseWithClock() on it. If you remove that call statement from the code above, the program will still generate a sequence of randomised values – *but the sequence will be exactly the same each time you run the program.* Initialising from the clock ensures that you get a different sequence each run. Using Random *without* so initialising, however, can be extremely useful for testing purpose, since the results are repeatable.

# Tests

Example of a test method:

A screen shot of a computer code

Description automatically generated

**Notes:**

* Elan tests are designed to test functions only. It is not possible to call a procedure or main routine within a test. Nor is it possible to use any System method (the same rule as within a function).
* A test may be given a name and/or description – which is free-form text, just like a comment. This name/description is optional – it does not play any role in the execution of the test. You might give the test the same name as a function that it is testing. Or you might describe a particular scenario that is being tested.
* test methods may be written anywhere in the code, at the global (file) level.
* A test method may contain multiple assert statements. When tests are run, the test runner (part of the Elan IDE) will attempt to run all assert statements and show the pass/fail outcome alongside each one. However, if the test hits a run-time error (as distinct from an assert failure) then execution of the test will stop and remaining asserts will be shown as Not run.
* In addition to assert statements a test may contain any other statements that may be added into a function (except return).

### Testing for run-time errors

If the expression you are testing causes a run-time error then the error will be displayed in the fail message:

A green and red rectangle with white text

Description automatically generated

You can also test for the error message successfully, for example:

A close-up of a logo

Description automatically generated

It is not possible to test for stack overflow exceptions – causes, for example, by writing a recursive method with incorrect (or missing) exit conditions. A stack overflow will cause the test runner to ‘time out’ and all tests will be marked ‘Not Run’:

A screenshot of a computer

Description automatically generated

If this occurs ‘ignore’ (see below) tests that you added since the last successful test run, and then un-ignore them one-by-one until the cause is identified and can be fixed.

### Marking a test with ‘ignore’

It is possible to mark a test with the ignore keyword, by selecting the test frame and then hitting **Ctrl-i** for example:

A screen shot of a computer screen

Description automatically generated

When a test is marked with ignore, that test will not be executed when the tests are run, and its result will be shown as ‘Not Run’. The overall test status will also show in the ‘warning’ status (amber colour) – even if all the tests that did run passed. This is to discourage you from leaving a test marked ignore for long.

The principal reason for marking a test ignore, is if either the test code, or code in any function being called, would not terminate – typically meaning that there is a loop (or a recursive call) with no exit condition, or where the exit condition is never met.

If you do create such code without realising it, then when the tests are executed the test runner will ‘time out’ after a few seconds (most tests will pass in milliseconds) – and an error message will be shown on the Console. The test that caused the time-out will *automatically* then be marked ignore.

You priority should then be to identify the cause of the time-out and attempt to fix it before then ‘un-ignoring’ the test by selecting the test frame and hitting Ctrl-i i.e. the same command as for *setting* ignore manually.

# Types

## Int

An integer is a whole number i.e. with no ‘fractional’ component.

### Type name

Int

### Defining a literal integer

variable meaningOfLife set to 42

### Default value

0

### Constraints

* Maximum value: 253 – 1 which is just over 9 x 1015
* Minimum value: – (253 – 1)

If either limit is exceeded the number will automatically be represented as a Float, with possible loss of precision.

### Notes

* An Int may always be passed as an argument into a method that requires a Float.

## Float

Float is short for ‘floating-point number’ – a number that may have both an integer and fractional part.

### Type name

Float

### Defining literal floating-point value

variable a set to 1.618

### Constraints

Since Elan compiles to JavaScript, the constraints on floating point numbers are those of JavaScript:

* Maximum value: just over 1 x 10308
* Minimum value: approx. 5 x 10-324

For greater detail, refer to the official JavaScript documentation

### Notes

* A variable that has been defined as being of type Float may not be passed as an argument into a method that requires an Int, nor as an index into an Array, *even if the variable contains no fractional part*. However, it may be converted into an Int before passing, using the functions floor() (the integer value left by removing any fractional part) or ceiling() (if the Float value *does* have a fractional part, the ‘ceiling’ will the lowest integer greater than the Float value).
* If you wish to define a variable to be of type Float but initialise it with a whole number then add .0 on the end of the whole number, for example: variable a set to 3.0.

## Boolean

A Boolean value is either true or false.

### Type name

Boolean

### Defining a literal Boolean

variable a set to true

true and false must be written lower-case

### Default value

false

## String

A String represents ‘text’ – a sequence of zero or more characters.

### Type name

String

### Defining a literal string value

variable a set to "Hello"

String are always delineated by double-quote marks

### Default value

"" – known as ‘empty string’.

### Notes

* As on most programming languages, strings are *immutable*. When you apply any operation or function with the *intent* of modifying an existing string, the existing string is never modified. Instead the function or operation will return a *new* string that is based on the original, but with the specified differences.
* Strings may be appended using the plus operator, for example print "Hello" + " " + "World".
* A newline may be inserted within a string as \n, for example: print "Hello\nWorld".
* You may insert single-quote marks – ' – within a string.

### Interpolated string

* Elan strings are automatically interpolated: you may insert the values of variables, or simple expressions within a string, by enclosing them in curly braces. For example (assuming that the variables a and b are already defined as integers) :  
   print "{a} times {b} equals {a\*b}."
* It is not *currently* possible to include ", {, or } *directly* within a literal string. However they can be inserted into a string by creating the character from the Unicode, for example:  
  print "This is a double quote mark: " + **unicode**(34)

Or even by inserting the unicode within curly braces:

print "{**unicode**(123)} and {**unicode**(125)}"

### Dot methods on a String

Note: There is no ‘substring’ method in Elan, because you can use to index range get a substring e.g. s[3..7] **.** See Indexed Value.

upperCase() returns String

Returns a new string based on the input with all alpha-characters in upper-case.

lowerCase() returns String

Returns a new string based on the input with all alpha-characters in upper-case.

contains(partString as String) returns Boolean

Takes a single parameter of type String, and returns a Boolean value indicating whether or not that argument string is contained within the string on which contained was called. Usage:

variable a set to "Hello World!"  
print a.contains("ello")

prints true

replace(match as String, replacement as String) returns String

Returns a new string where all occurrence of the match string are replaced with the replacement string.

trim() returns String

returns a new string based on the string on which the method is called, but with any leading or trailing spaces removed.

indexOf(partString as String) returns Int

The following methods are used for comparing strings alphabetically – for example in a sort routine.

isBefore(otherString as String) returns Boolean

isAfter(otherString as String) returns Boolean

isBeforeOrSameAs(otherString as String) returns Boolean

isAfterOrSameAs(otherString as String) returns Boolean

asUnicode() returns Int

Returns the Unicode (integer) value for a character. If the string is more than one character long, the Unicode value returned is that for the *first* character in the string only. Note that the opposite method – to create a single-character string from its numeric Unicode value is e.g. unicode(123) which returns "{"

## Arrays and Lists

### Quick reference

|  |  |  |
| --- | --- | --- |
|  | **Array** | **List** |
| Type form | Array<of String>  Array2D<of String> | List<of String> |
| Literal | ["plum", "pear"] | {"plum", "pear"} |
| Literal empty | empty Array<of String> | empty List<of String> |
| Initial size (filled with default values) | variable a set to  createArray(10, "x")  createArray2D(8, 8, "")  In each case, the last argument is the value to which each element is initialised, and defines the type of elements in the Array | Not applicable |
| Read from position | a[3]  2D: **board[3][4]** | a[3] |
| Read range | a[5..9] | A[5..9)] |
| Put a value | call a.putAt(3, "pear")  2D: **call board.putAt2D(3,4,"K")** | set a to a.withPutAt(3, "pear) |
| Append/Prepend | call a.append("pear")  call a.prepend("pear")  call a.appendList(anotherList)  call a.prependList(anotherList) | Note that + appends a *list* to a list. To append/prepend a single *item,* it should be enclosed in square brackets. Append: set a to a + {"pear"}  Prepend: set a to {"pear"} + a  Append/prepend a list:  set x to listA + listb |
| Insert | call a.insertAt(3, "pear") | set a to a.withInsertAt(3, "pear) |
| Remove by index | call a.removeAt(3) | set a to a.withRemoveAt(3) |
| Remove by value | call a.removeFirst("pear")  call a.removeAll("pear") | set a to a.withRemoveFirst ("p")  set a to a.withRemoveAll ("p") |
| Deconstruction into head (first element) and tail (all the rest) | Not applicable | variable x:xs set to myList  set h:t to myList  discarding either the head or tail: variable \_:tail set to myList variable head:\_ set t myList |

### List

A List is a simple data structure that holds multiple elements of the same type.

A list – just like a String – is *immutable*. You can still insert, delete, or change elements in a List, but the methods for these operations do not modify the input list: they return a new list based on the input list but with the specified differences.

#### Type name

The type is specified in the following form:

List<of String> for a list of type String

List<of Int> for a list of type Int

{List<of Int>} for a list of lists of type Int

#### Defining a literal

variable fruit set to {"apple", "orange", "pear"}

### Dot methods on a List

**Important**: in Elan, a List is *immutable.* Methods never *modify* the List on which they are called: instead they return a *new* List based on the original but with the specified differences – the same as happens for an ordinary String. And the dot-methods on a list are all functions.

myList.contains(item) returnss true or false

myList.asArray() returns a new Array with the same contents as myList

The following functions all return a new List, copied from the list on which the function was called, but with the differences specified by the function:

myList.withInsertAt(4, "cherry")

myList.withPutAt(2, "grape")

myList.withRemoveAt(3)

myList.withRemoveFirst("apple")

myList.withRemoveAll("apple")

Try these examples:

variable fruit set to empty List<of String>

print fruit

set fruit to fruit + "apple"

set fruit to fruit + "pear"

print fruit

set fruit to "orange" + pear

print fruit[0]

print fruit.length()

print fruit[fruit.length() -1]

variable head:tail set to fruit

print head

print tail

### Array

An ‘Array’ is a simple data structure that holds multiple elements of the same type.

Unlike a list, an Array is *mutable* – meaning that the elements within the data structure can be altered without creating a new Array from the old.

The type is specified in the following form:

Array<of String> for an Array of type String

Array<of Int> for an Array of type Int

Where, in this example, String represents the type of each element. The element type could be any value type – Int, Boolean, Float, String – or the name of a specific class such as Player or an enum such as Direction. It may also be another data structure, including another Array, (sometimes referred to as a ‘nested array’).

#### Creating an Array

An Array may be defined in ‘literal’ form, ‘delimited’ by square brackets, and with all the required elements are separated by commas. The elements may be literal values (but must be all of the same type):

variable fruit set to ["apple", "orange", "pear"]

including ‘nested arrays’:

variable coordinates set to [[3.4, 0.1, 7.8], [1, 0, 1.5], [10, -1.5, 25]]

or variables (provided they are all of the same type):

variable values set to [x, y, z]

or a mixture of literal values and variables (all of the same type):

variable values set to [3.1, y, z]

where y and z are existing variables of type Float.

You may also define an array of a specified size, with each element initialised to the same value, for example:

variable fruit set to createArray(20, "")

will create an Array of type String with exactly 20 elements, each initialised to an empty String and:

variable scores set to createArray(12, 100.0)

will create an Array of type Float with exactly 12 elements, each initialised to 100.0.

### Dot methods on an Array

**Functions:**

myArray.contains(item) returnss true or false

myArray.asList() returnss a List containing the same elements as the Array on which the method was called. This is often used to permit an Array to be passed into a function that has been designed to accept a List.

**Procedures:**

call fruit.append("banana")  
call fruit.appendList(anotherList)  
call fruit.insertAt(4, "cherry")  
call fruit.prepend("melon")  
call fruit.prependList(anotherList)  
call fruit.putAt(2, "grape")  
call fruit.removeAll("apple")  
call fruit.removeAt(3)  
call fruit.removeFirst("apple")

### **Using an Array**

Elements are read using an index in square brackets – the *first* element being element [0]. The last element of an Array of size 10 will therefore be accessed by the index [9].

Attempting to read an element *by index*, where that element does not exist, will result in an ‘Index out of range’ run-time error.

Unlike in many programming you may *not* modify data by index: elements are *modified* by calling the putAt procedure on the array.

Try these examples (the last one will produce an error – make sure you understand why):

variable a set to createArray(10, 0)

print a

print a.length()

call a.putAt(0, 3)

call a.putAt(1, 7)

print a

print a[0]

print a[a.length() -1]

print a[a.length()]

Unlike in some languages, Elan Arrays may be dynamically extended, using append and prepend methods.

variable a set to createArray(3, 0)

variable b set to createArray(3, 10)

print a

print b

a.append(3)

b.prepend(7)

print a

print b

a.appendArray(b)

print a

### 2-dimensional Array

In Elan, as in many languages, a ‘2-dimensional array’ is just an Array of Arrays. However, Elan provides a couple of convenient short-cut methods for working with such data structures:

variable board set to createArray2D(8, 8, "")

will create an Array of Arrays with a total of 64 elements each of type String, and initialised to an empty String. The type is determined by the type of the third parameter, which might be an Int, Boolean, or user-defined type. It need not be an empty value. The Array2D need not be square – it may be rectangular.  
It is *possible* to create an 2-dimensional array with no elements, for example by:

let a be new Array2D<of Int>()

However, this is *not recommended* as subsequently adding elements takes a lot of care and effort. It is recommended that you always use the method createArray2D to create a 2-dimensional array initialised to the desired size. That way you can modify individual elements in the initialised array with e.g.:

call board.putAt2D(3,4,"K")

and you can read individual elements with a double index, for example:

for col from 0 to 7 step 1

for row from 0 to 7 step 1

print board[col][row]

end for

end for

If you want to define a function or procedure with a parameter that should be a 2-dimensional array, the type is specified as Array2D, for example:

**Array2D<of String>**   
**Array2D<of Int>**

## Dictionaries

There are two forms of dictionary in Elan: an ordinary Dictionary (which is mutable) and a DictionaryImmutable.

### Quick reference

|  |  |  |
| --- | --- | --- |
|  | **Dictionary** | **DictionaryImmutable** |
| Type form | Dictionary<of String,Int> | DictionaryImmutable<of String,Int> |
| Literal | ["a":1, "b":4] | {"a":1, "b":4} |
| Literal empty | empty Dictionary<of String,Int> | empty DictionaryImmutable<of String,Int> |
| Read the value for a given key | d["a"] | d["a"] |
| Get all keys, or all values | d.keys() and d.values() Both return an immutable list of the appropriate type | |
| Define (or change) a value associated with a key | Call d.putAtKey("c", 7) | set d to d.withPutAtKey("c", 7) |
| Remove both key and value | call d.removeAtKey("c") | set d to d.withRemoveAtKey("c") |

### Dictionary

#### Type name

In the following example, Int is the type of the ‘key’ and String is the type of the value associated with a specific key:

Dictionary<of String,Int>

Important: For both Dictionary and DictionaryImmutable the value type can be any type, including e.g. a specific type of class, a List, another Dictionary or another data structure. However, the *key* type must be one of: Int, Float, String, Boolean, or a specific type of enum.

#### Defining a literal

A literal Dictionary is defined as a comma-separated list of ‘key:value pairs’ surrounded by square brackets e.g:

variable scrabbleValues set to ["a":1, "b":3, "c":3, "d":2]

#### 

#### Using a Dictionary

Try these examples:

variable dict set to new Dictionary<of String,Int>()

print dict

call dict.putAtKey("a", 3)

print dict["a"]

call dict.removeAtKey("a")

print dict

Constraints

* Key values must be unique
* There is no difference in syntax between *adding* an entry with a new key, and setting a new value for an existing key: if the key does not exist in the dictionary, it will be added.

### Dot methods on a Dictionary

See also: Dictionaries - Quick reference

putAtKey

removeAtKey

keys

values

### DictionaryImmutable

An immutable dictionary may be defined in a constant. For examples, see Error! Reference source not found. and Error! Reference source not found..

#### Type name

Type name takes the following form:

#### **DictionaryImmutable<of String,Int>**

#### Defining a literal

A literal Dictionary is defined as a comma-separated list of ‘key:value pairs’ surrounded by curly braces e.g:

variable scrabbleValues set to {"a":1, "b":3, "c":3, "d":2}

#### Using an Immutable Dictionary

Try these examples:

variable immD set to new DictionaryImmutable<of String,Int>()

print immD

set immD to immD.withPutAtKey("a", 3)

print immD["a"]

set immD to immD.withRemoveAtKey("a")

print immD

### Dot methods on a DictionaryImmutable

See also: Dictionaries - Quick reference

hasKey

withPutAtKey

withRemoveAtKey

## Tuple

A tuple is a way of holding a small number values of *different* types together as a single reference. A common usage scenarios include:

* Holding a pair of x and y coordinates (each a floating point number) as a single unit.
* Allowing a function could pass back a result, together with, say a string message and/or a Boolean flag indicating whether the operation was successful

A tuple is considered a ‘lightweight’ alternative to defining a specific class *for some purposes*.

### Type name

Written as a comma-separated list of the type of each member, surrounded by round brackets:

(Int, Int, Int)

(String, Boolean)

### Defining a literal tuple

A tuple is defined, where it is needed, by a number of elements – each being a variable or literal values - separated by commas and surrounded by round brackets, for example:

let foo be (3.769, 4.088, true, 5, "correct")

### Using a tuple

* You may pass a tuple into a function, or return one from a function, for example:

variable d set to distanceBetween(point1, (12.34, 20.0))

* An existing tuple (for example point1 below) may be ‘deconstructed’ into new variables or named values (where the number of variables/names must match the number of elements in the tuple):

let x, y set to point1

or

variable x, y set to point1

or into existing variables of the correct type:

variable a set to 3

variable b set to 4

set a, b to point1

* The ‘discard’ symbol \_ (underscore) may also be used when deconstructing a tuple, if there is no need to capture one (or more) specific elements:  
    
  variable x, \_ set to point1

### Constraints

* As in most languages, Elan tuples are *immutable*. Once defined they are effectively ‘read only’: you cannot alter any of the elements in a tuple, nor (unlike an List for example) can you create a new tuple from an existing one with specified differences
* You cannot deconstruct a tuple into a *mixture* of new and existing variables

## Func

A function may be passed as an argument into another function (or a procedure), or returned as the result of calling another function. This pattern is known as ‘higher order function’, and is a key idea in the functional programming paradigm. To define a function that takes in another function as a parameter, or returns a function, you need to specify the *type* of the function, just as you would specify the *type* of every parameter and the return type for the function.

### Type name

The *type* of any function starts with the word Func, followed by angle brackets defining type of each parameter, and the return type for that function, following this syntax:

Func<of String, String, Int => Boolean>

The example above defines the type for a function that defines *three* parameters, of type **String**, **String**, and **Int** respectively, and returns a **Boolean** value. For example this type would match that of a function definition that started:

Function charactersMatchAt(a as String, b as String, position as Int) returns Boolean

# Standard Library

## Standalone functions

Standalone functions always return a value and are therefore used in contexts that expect a value, such as in the right-hand side of a variable declaration (var) or assignment (set), either on their own or within a more complex expression. All standalone *library* functions require at least one argument to be passed in brackets – corresponding to the parameters defined for that function.

### unicode

unicode(code as Int) returns String

Converts a Unicode value (expressed in decimal or hexadecimal notation) into a single character string. For example:

function hearts() return string

return unicode(0x2655)

end function

### parseAsInt and parseAsFloat

parseAsInt(inp as String) returns (Boolean, Int)  
parseAsFloat(inp as String) returns (Boolean, Float)

parseAsInt attempts to parse the input String as an Int. Returns a 2-tuple, the first value of which is Boolean, with true indicating whether or not the parse has succeeded, and the second value being the resulting Int. parseAsFloat does the equivalent for floating point. Usage:

print parseAsInt("31") yields (true, 31)

print parseAsFloat("31") yields (true, 31)

print parseAsInt("31.2") yields (false, 0)

print parseAsFloat("31.2") yields (true, 31.2)

print parseAsInt("0") yields (true, 0)

print parseAsInt("0") yields (true, 0)

Notes:

* Any string that parses as an Int will also parse as a Float
* If the parse has failed the second value will default to zero – so you should always check the first value to see if this is a correct parse, or just the default.
* You can ‘deconstruct’ the tuple into two variables e.g  
  variable (outcome, value) = parseAsInt(myString)
* One usage for these parsing methods is for validating inputs, but note that there is an easier way to do this – see Error! Reference source not found..

### floor, ceiling, and round

floor(inp as Float) returns Int

returns the nearest integer value *below* (or equal to) the argument value. Usage:

print floor(2.5) yields 2

ceiling(inp as Float) returns Int

returns the nearest integer value *above* (or equal to) the input value. Usage:

print ceiling(2.5) yields 3

round(inp as Float, places as Int) returns Float

Rounds the input number of decimal places specified as the second argument (an Int). Usage:

print round(3.14159, 3) yields 3.142

### Maths functions

pi -returns the constant Float value 3.141592653589793

Each of the following functions takes a single argument of type Float and returns a Float.

abs - returns the absolute value of the input.

acos - returns the arccosine of the input, as radians.

asin - returns the arcsine of the input value, as radians.

atan - returns the arctangent of the input value, as radians.

acosDeg - returns the arccosine of the input, as degrees.

asinDeg - returns the arcsine of the input, as degrees.

atanDeg - returns the arctangent of the input, as degrees.

cos - returns the cosine of input interpreted as radians.

cosDeg - returns the cosine of input interpreted as degrees.

exp - returns ex, where x is the argument, and e is Euler's number (2.718…)

logE - returns the natural logarithm of the input.

log10 - returns the base-10 logarithm of the input.

log2 - returns the base-2 logarithm of the input.

sin - returns the sine of the input interpreted as radians.

sinDeg - returns the sine of input interpreted as degrees.

sqrt - returns the positive square root of the input.

tan - returns the tangent of the input interpreted as radians.

tanDeg - returns the tangent of input interpreted as degrees.

degToRad - converts input from degrees to radians.

radToDeg - converts input from radians to degrees.

Examples of the maths functions being used:

A screenshot of a computer code

Description automatically generated

### Regular expressions

**Note:** Elan regular expressions are modelled on those of JavaScript, including the syntax for literal regular expressions. See, for example: <https://developer.mozilla.org/en-US/docs/Web/JavaScript/Guide/Regular_expressions>

More functions for using regular expressions will be added in a future release of Elan. For now…

The method testRegExp is applied to a String using dot-syntax and requires a RegExp parameter, specified as a literal or as variable. It returns a Boolean. For example:

A computer code with red and blue text

Description automatically generated

You can also convert a (valid) string to a RegExp. For example:

A computer code with red and blue text

Description automatically generated

Although it is recommended that literal regular expressions are written with the /.../ delimiters, the ability to convert a string, allows a user to enter a regular expression into a running program as an input.

### Bitwise functions

bitAnd(a as Int, b as Int) returns Int

bitOr(a as Int, b as Int) returns Int

bitXor(a as Int, b as Int) returns Int

bitNot(a as Int) returns Int

bitShiftL(a as Int, places as Int) returns Int

bitShiftR(a as Int, places as Int) returns Int

Examples of the bitwise functions being used:

A screenshot of a computer code

Description automatically generated

The result of bitNot(a), where a is 13 being -14 might be a surprise. But this is because the bitwise functions assume that the arguments are represented as 32-bit *signed* integers. So 13 is represented as 00000000000000000000000000001101, applying bitNot will give 11111111111111111111111111110010 which is the 32-bit 2s-complement of -14

### Creating Arrays of specific sizes

The following methods return an Array, of a specified size, and with all elements initialised to a specified value. Although the resulting Array *may* still be expanded subsequently (by using the add procedure), the *typical* use for these two methods is for cases that would originally have used a traditional (fixed-size) ‘array’:

createArray(size as Int, initialValue as Type) returns [Type]

where Type is one of the following types: Int, Float, Boolean, String or any type of enum.

There is also a variant of the method that creates a ‘2-dimensional’ rectangular array (actually an Array of Arrays):

createArray2D(noOfrows as Int, noOfColumns as Int, initialValue as T) returns [[Type]]

See also: Lists - Quick reference.

## Standalone procedures

All procedures are accessed via a call statement.

pause(100)

Typically used to slow down the execution of a program e.g. for a game. The argument provided to pause is in milliseconds, so pause(100) delays execution for 1/10th of a second.

clearConsole()

See Printing plain text to the Console

clearKeyBuffer()

getKey()

getKeyWithModifier()

waitForAnyKey()

See Reading keys ‘on the fly’.

## System methods

System methods *appear* to work like functions, because:

* they may require one or more arguments to be provided
* they always return a value
* they are used in expressions

However, system methods are not *pure* functions because:

* They may have a dependency on data that is not provided as an argument
* They may generate side effects, such as changing the screen display, or writing to a file.

Because of these properties, system methods may be used only within a procedure or within the main routine. System methods may *not* be used inside a function that you have defined – because to do so would mean that your function would not be pure.

System methods are all defined within the Elan standard library – you cannot write a system method yourself.

System methods are commonly associated with ‘input/output’ (see Input/Output), but note that:

* Input/output may also be performed via procedures
* Some system methods do not appear to be concerned with input/output – see list below. The reason those are system methods is that they both have a dependency on variable data that is not passed into them as argument(s).

### List of system methods

clock Returns an integer that increments every millisecond. Useful for measuring elapsed time by comparing the values returned by two such evaluations of the clock method.

random and randomInt See Generating random numbers

openFileForReading See Reading textual data from a file

All the input methods, getKey, and getKeyWithModifier See Inputting data from the keyboard

## Standard data structures

### Stack and queue

* Stack and Queue are similar data structures except that Stack is a ‘LIFO’ (last in, first out), while Queue is FIFO (first in, first out). The names of the methods for adding/removing are different, but there are also common methods, summarised here.
* Both a Stack and a Queue are defined with the type of the items that they can contain - similar to the way that Array and List have a specified item type, but different syntax. The type is specified in the form shown above e.g. Stack<of String>, Queue<of Int>, Stack<of (Float, Float)>, Queue<of Square>.
* Both Stack and Queue are dynamically extensible – like an Array or List. There is no need (or means to) specify a size limit – they will continue to expand until, eventually, the computer’s memory limit is reached.
* This same syntax is used to specify the type if you want to pass a Stack into a function, or specify it as the return type.
* Stack and Queue have some methods in common: length(), and peek() which allows you to read the next item that *would be* removed, without actually removing it.
* The names of the methods for adding or removing an item are different for Stack and Queue, summarised in this table:

|  |  |  |
| --- | --- | --- |
|  | **Stack** | **Queue** |
| Create a new instance | let s be new Stack<of Int>() | let q be new Queue<of Int>() |
| Add an item (must be of correct Type) | **call s.push(item)** | **call q.enqueue(item)** |
| Remove the next item | variable item set to s.pop() | variable item set to s.dequeue() |
| View the next item to be removed without removing it | variable item set to s.peek() | variable item set to q.peek() |
| Read the current length | s.length() | q.length() |

Example usage of a Stack:

main

  let st be new Stack<of String>()

  print st.length()

  call st.push("apple")

  call st.push("pear")

  print st.length()

  print st.peek()

  variable fruit set to st.pop()

  print fruit

  set fruit to st.pop()

  print fruit

  print st.length()

end main

Example usage of a Queue:

main

  let qu be new Queue<of String>()

  print qu.length()

  call qu.enqueue("apple")

  call qu.enqueue("pear")

  print qu.length()

  print qu.peek()

  variable fruit set to qu.dequeue()

  print fruit

  set fruit to qu.dequeue()

  print fruit

  print qu.length()

end main

### Set

A Set is a standard data structure that works somewhat like a list with the important difference that in a Set a given element may appear only once. If an item being added to a Set is identical to an existing item in the Set then the Set remains the same length as before.

This enables a Set to work like a *mathematical* set so that it is possible to perform standard set operations such as union or intersection. For the same reason, a Set is an *immutable* data structure: no methods modify the set on which they are called, but several of them (including add, remove) return a new Set that is based on the original Set or Sets, with specified differences.

Example of use:

main

  variable st set to new Set<of Int>()

  set st to st.addFromList({3, 5, 7})

  print st.length()

  set st to st.add(7)

  print st.length()

  set st to st.remove(3)

  print st.length()

  set st to st.remove(3)

  print st.length()

  print st

end main

**Notes**:

* When creating a Set, the type of the elements must be specified in the form e.g. Set<of String>. This applies both when creating a new, empty set, and when defining the type of a parameter to be a Set.
* You can add elements: individually with add, or multiple elements with, addFromList or addFromArray.
* You can create a new Set from an existing Array or List, by calling .asSet() on it.

**List of dot methods on a Set:**

  length()

  contains(item) returns Boolean

  add(item) returns Set

  addFromList(list) returns Set

  addFromArray(array) returns Set

  remove(item) returns Set

  union(anotherSet) returns Set

  difference(anotherSet) returns Set

  intersection(anotherSet) returns Set

  isDisjointFrom(anotherSet) returns Boolean

  isSubsetOf(anotherSet) returns Boolean

  isSupersetOf(anotherSet) returns Boolean

  asArray(anotherSet) returns Array

  asList(anotherSet) returns List

  asString() returns String

## Higher order functions (HoFs)

These dot methods are called on any ‘iterable’ type, which includes Array, List, and String. As ‘higher order functions’ they take either a lambda or a function reference (see Passing a function as a reference) as one of their arguments.

**Important:** Several of these methods return an abstract type named Iterable. The result may easily be turned into a form that can be printed, or passed into other functions, by appending .asList() or .asArray() at the end of the expression.

*These are not yet fully documented* but, for readers familiar with HoFs from another language, some examples are shown below.

### filter

Usage:

let matches be rules.filter(lambda r as Rule =>   
 (r.currentState is currentState) and (r.currentSymbol is tape[headPosition]))

### map

Usage:

let next be cellRange.map(lambda n as Int => nextCellValue(cells, n))

### reduce

Usage:

let d2 be possibleAnswers.reduce(d,   
 lambda dd as Dictionary<of String, Int>, possAnswer as String =>  
 incrementCount(dd, possAnswer, attempt))

### max and min

Both functions may be applied to an Iterable<of Float> e.g. an Array<of Float> or a List<of Float> and return the maximum/minimum value found therein.

variable a set to {33, 4, 0,99, 82, 55}

print "Max: {a.max()} Min: {a.min()}"

maxBy and minBy

Alternative implementations of max and min that take. Usage:

variable a set to {33, 4, 0,99, 82, 55}

print a.maxBy(lambda x as Int => x mod 10)

### any

Returns true or false indicating whether any of the members of the iterable individually pass the test defined by the lambda (which itself returns a Boolean). Usage:

variable a set to {33, 4, 0,99, 82, 55}

print a.any(lambda x as Int => x > 50)

sortBy

*Additional sort methods will be introduced in a later Beta.*

For now, sortBy takes a lambda that takes two arguments (of the same type as that of the iterable being sorted) and compares them, returning an integer with one of the values -1, 0, 1, to indicate whether the first argument should be placed before, after or just adjacent to (does not matter whether before or after) the second argument in the sorted result. Example:

variable source set to {2, 3, 5, 7, 11, 13, 17, 19, 23, 27, 31, 37}

print source.sortBy(lambda x as Int, y as Int => if x > y then 1 else -1)

The following are not HoFs, but are included here because they are most likely to be used *with* one of the HoFs listed above.

range(first as Int, last as Int) as Iterable<of Int>

returns an iterable that will produce all the integer values between the two argument values.

## Dot methods that work on many different types

.asString()

.asIterable()

.length()

.head() returns the first item in an Array or a List

# Index to keywords

abstract - see Abstract class

and - see Logical operators

as - see Function and procedures

assert – see Tests

be - see If expression

call - see Function and procedure

catch - see Catching and throwing exceptions

class - see Object-oriented programming

constant - see Constant

constructor - see Object-oriented programming

copy - see Working with records

div - see Arithmetic operators

each - see Each loop

else - see If statement and If expression

empty – creates the empty (or ‘default’) value of a specified type. See e.g. Arrays and Lists

end – (followed by another keyword) defines the end of a multi-line construct

enum - see Enum

exception - see Try statement and

false – see Boolean

for - see For loop

from - see For loop

function - see Function and Passing a function as a reference

global – see Scoping and name qualification

if - see If statement and If expression

import – (Not yet implemented)

in - see Each loop

inherits - see Inheritance

is - see Equality testing

isnt - see Equality testing

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let - Let statement

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main - see Main routine

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