# Python and Friends

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# Python (programming language)

## Python

| | |
|---|---|
| **Paradigm(s)** | Multi-paradigm: object-oriented, imperative, functional, procedural, reflective |
| **Appeared in** | 1991 |
| **Designed by** | Guido van Rossum |
| **Developer** | Python Software Foundation |
| **Stable release** | 3.3.2 /<br>15 May 2013<br>2.7.5 /<br>15 May 2013 |
| **Typing discipline** | duck, dynamic, strong |
| **Major implementations** | CPython, PyPy, IronPython, Jython |
| **Dialects** | Cython, RPython, Stackless Python |
| **Influenced by** | ABC,[] ALGOL 68,[] C,[] C++,[] Dylan,[] Haskell,[] Icon,[] Java,[] Lisp,[] Modula-3,[] Perl |
| **Influenced** | Boo, Cobra, D, Falcon, Go, Groovy, JavaScript, F#, Nimrod, Ruby[] |
| **OS** | Cross-platform |
| **License** | Python Software Foundation License |
| **Usual filename extensions** | .py, .pyw, .pyc, .pyo, .pyd |
| • Official website [1]<br>• Python Programming at Wikibooks | |

**Python** is a widely used general-purpose, high-level programming language.[][2][3] Its design philosophy emphasizes code readability, and its syntax allows programmers to express concepts in fewer lines of code than would be possible in languages such as C.[][4] The language provides constructs intended to enable clear programs on both a small and large scale.[]

Python supports multiple programming paradigms, including object-oriented, imperative and functional programming or procedural styles. It features a dynamic type system and automatic memory management and has a large and comprehensive standard library.[5]

Like other dynamic languages, Python is often used as a scripting language, but is also used in a wide range of non-scripting contexts. Using third-party tools, Python code can be packaged into standalone executable programs. Python interpreters are available for many operating systems.

CPython, the reference implementation of Python, is free and open source software and has a community-based development model, as do nearly all of its alternative implementations. CPython is managed by the non-profit Python Software Foundation.

## History

Guido van Rossum, the creator of Python

Python was conceived in the late 1980s[] and its implementation was started in December 1989[] by Guido van Rossum at CWI in the Netherlands as a successor to the ABC language (itself inspired by SETL)[] capable of exception handling and interfacing with the Amoeba operating system.[] Van Rossum is Python's principal author, and his continuing central role in deciding the direction of Python is reflected in the title given to him by the Python community, *Benevolent Dictator for Life* (BDFL).

Python 2.0 was released on 16 October 2000, with many major new features including a full garbage collector and support for Unicode. With this release the development process was changed and became more transparent and community-backed.[]

Python 3.0 (also called Python 3000 or py3k), a major, backwards-incompatible release, was released on 3 December 2008[] after a long period of testing. Many of its major features have been backported to the backwards-compatible Python 2.6 and 2.7.[]

## Features and philosophy

Python is a multi-paradigm programming language: object-oriented programming and structured programming are fully supported, and there are a number of language features which support functional programming and aspect-oriented programming (including by metaprogramming[] and by magic methods).[] Many other paradigms are supported using extensions, including design by contract[][] and logic programming.[]

Python uses dynamic typing and a combination of reference counting and a cycle-detecting garbage collector for memory management. An important feature of Python is dynamic name resolution (late binding), which binds method and variable names during program execution.

The design of Python offers only limited support for functional programming in the Lisp tradition. The language has map(), reduce() and filter() functions, comprehensions for lists, dictionaries, and sets, as well as generator expressions. The standard library has two modules (itertools and functools) that implement functional tools borrowed from Haskell and Standard ML.[]

The core philosophy of the language is summarized by the document "PEP 20 (The Zen of Python)", which includes aphorisms such as:[]

- Beautiful is better than ugly.
- Explicit is better than implicit.
- Simple is better than complex.
- Complex is better than complicated.
- Readability counts.

Rather than requiring all desired functionality to be built into the language's core, Python was designed to be highly extensible. Python can also be embedded in existing applications that need a programmable interface. This design of a small core language with a large standard library and an easily extensible interpreter was intended by Van Rossum from the very start because of his frustrations with ABC (which espoused the opposite mindset).[]

While offering choice in coding methodology, the Python philosophy rejects exuberant syntax, such as in Perl, in favor of a sparser, less-cluttered grammar. As Alex Martelli put it: "To describe something as clever is *not* considered a compliment in the Python culture."[6] Python's philosophy rejects the Perl "there is more than one way to do it" approach to language design in favor of "there should be one—and preferably only one—obvious way to do

it".[]

Python's developers strive to avoid premature optimization, and moreover, reject patches to non-critical parts of CPython which would offer a marginal increase in speed at the cost of clarity.[7] When speed is important, Python programmers use PyPy, a just-in-time compiler, or move time-critical functions to extension modules written in languages such as C. Cython is also available which translates a Python script into C and makes direct C level API calls into the Python interpreter.

An important goal of the Python developers is making Python fun to use. This is reflected in the origin of the name which comes from Monty Python[8], and in an occasionally playful approach to tutorials and reference materials, for example using spam and eggs instead of the standard foo and bar.[9]

A common neologism in the Python community is *pythonic*, which can have a wide range of meanings related to program style. To say that code is pythonic is to say that it uses Python idioms well, that it is natural or shows fluency in the language, that it conforms with Python's minimalist philosophy and emphasis on readability. In contrast, code that is difficult to understand or reads like a rough transcription from another programming language is called *unpythonic*.

Users and admirers of Python—most especially those considered knowledgeable or experienced—are often referred to as *Pythonists*, *Pythonistas*, and *Pythoneers*.[][]

## Syntax and semantics

Python is intended to be a highly readable language. It is designed to have an uncluttered visual layout, frequently using English keywords where other languages use punctuation. Furthermore Python has a smaller number of syntactic exceptions and special cases than C or Pascal.[]

### Indentation

Python uses whitespace indentation, rather than curly braces or keywords, to delimit blocks; a feature also termed the off-side rule. An increase in indentation comes after certain statements; a decrease in indentation signifies the end of the current block.[] While most consider this to significantly enhance readability,[10] others have criticized it.[]

### Statements and control flow

Python's statements include (among others):

- The `if` statement, which conditionally executes a block of code, along with `else` and `elif` (a contraction of else-if).
- The `for` statement, which iterates over an iterable object, capturing each element to a local variable for use by the attached block.
- The `while` statement, which executes a block of code as long as its condition is true.
- The `try` statement, which allows exceptions raised in its attached code block to be caught and handled by `except` clauses; it also ensures that clean-up code in a `finally` block will always be run regardless of how the block exits.
- The `class` statement, which executes a block of code and attaches its local namespace to a class, for use in object-oriented programming.
- The `def` statement, which defines a function or method.
- The `with` statement (from Python 2.5), which encloses a code block within a context manager (for example, acquiring a lock before the block of code is run and releasing the lock afterwards, or opening a file and then closing it), allowing RAII-like behavior.
- The `pass` statement, which serves as a NOP. It is syntactically needed to create an empty code block.
- The `assert` statement, used during debugging to check for conditions that ought to apply.

- The `yield` statement, which returns a value from a generator function. From Python 2.5, `yield` is also an operator. This form is used to implement coroutines.
- The `import` statement, which is used to import modules whose functions or variables can be used in the current program.

Python does not support tail-call optimization or first-class continuations, and, according to Guido van Rossum, it never will.[][] However, better support for coroutine-like functionality is provided in 2.5, by extending Python's generators.[] Prior to 2.5, generators were lazy iterators; information was passed unidirectionally out of the generator. As of Python 2.5, it is possible to pass information back into a generator function, and as of Python 3.3, the information can be passed through multiple stack levels.[]

## Expressions

Python expressions are similar to languages such as C and Java:

- In Python 2, the `/` operator on integers does integer division; it truncates the result to an integer. Floating-point division on integers can be achieved by converting one of the integers to a float (e.g. `float(x) / y`). In Python 3, the result of `/` is always a floating-point value. This behaviour can be enabled in Python 2.2+ using `from __future__ import division`. In both Python 2.2+ and Python 3, `//` can be used to do integer division.
- In Python, `==` compares by value, in contrast to Java, where it compares by reference. (Value comparisons in Java use the `equals()` method.) Python's `is` operator may be used to compare object identities (comparison by reference). Comparisons may be chained, for example `a <= b <= c`.
- Python uses the words `and`, `or`, `not` for its boolean operators rather than the symbolic `&&`, `||`, `!` used in Java and C.
- Python has a type of expression termed a *list comprehension*. Python 2.4 extended list comprehensions into a more general expression termed a *generator expression*.[]
- Anonymous functions are implemented using lambda expressions; however, these are limited in that the body can only be a single expression.
- Conditional expressions in Python are written as `x if c else y`[] (different in order of operands from the `?:` operator common to many other languages).
- Python makes a distinction between lists and tuples. Lists are written as `[1, 2, 3]`, are mutable, and cannot be used as the keys of dictionaries (dictionary keys must be immutable in Python). Tuples are written as `(1, 2, 3)`, are immutable and thus can be used as the keys of dictionaries, provided all elements of the tuple are immutable. The parentheses around the tuple are optional in some contexts. Tuples can appear on the left side of an equal sign; hence a statement like `x, y = y, x` can be used to swap two variables.
- Python has a "string format" operator `%`. This functions analogous to `printf` format strings in C, e.g. `"foo=%s bar=%d" % ("blah", 2)` evaluates to `"foo=blah bar=2"`. In Python 3, this was supplemented by the `format()` method of the `str` class, e.g. `"foo={0} bar={1}".format("blah", 2)`.
- Python has various kinds of string literals:
  - Strings delimited by single or double quotation marks. Unlike in Unix shells, Perl and Perl-influenced languages, single quotation marks and double quotation marks function similarly. Both kinds of string use the backslash (`\`) as an escape character and there is no implicit string interpolation such as `"$foo"`.
  - Triple-quoted strings, which begin and end with a series of three single or double quotation marks. They may span multiple lines and function like here documents in shells, Perl and Ruby.
  - Raw string varieties, denoted by prefixing the string literal with an `r`. No escape sequences are interpreted; hence raw strings are useful where literal backslashes are common, such as regular expressions and Windows-style paths. Compare "`@`-quoting" in C#.

- Python has index and slice expressions on lists, denoted as `a[key]`, `a[start:stop]` or `a[start:stop:step]`. Indexes are zero-based, and negative indexes are relative to the end. Slices take elements from the *start* index up to, but not including, the *stop* index. The third slice parameter, called *step* or *stride*, allows elements to be skipped and reversed. Slice indexes may be omitted, for example `a[:]` returns a copy of the entire list. Each element of a slice is a shallow copy.

In Python, a distinction between expressions and statements is rigidly enforced, in contrast to languages such as Common Lisp, Scheme, or Ruby. This leads to some duplication of functionality. For example:

- List comprehensions vs. `for`-loops
- Conditional expressions vs. `if` blocks
- The `eval()` vs. `exec()` built-in functions (in Python 2, `exec` is a statement); the former is for expressions, the latter is for statements.

Statements cannot be a part of an expression and so list and other comprehensions or lambda expressions, all being expressions, cannot contain statements. A particular case of this is that an assignment statement such as `a = 1` cannot form part of the conditional expression of a conditional statement. This has the advantage of avoiding a classic C error of mistaking an assignment operator = for an equality operator == in conditions: `if (c = 1) { ... }` is valid C code but `if c = 1: ...` causes a syntax error in Python.

## Methods

Methods on objects are functions attached to the object's class; the syntax `instance.method(argument)` is, for normal methods and functions, syntactic sugar for `Class.method(instance, argument)`. Python methods have an explicit `self` parameter to access instance data, in contrast to the implicit self in some other object-oriented programming languages (for example, Java, C++ or Ruby).[]

## Typing

Python uses duck typing and has typed objects but untyped variable names. Type constraints are not checked at compile time; rather, operations on an object may fail, signifying that the given object is not of a suitable type. Despite being dynamically typed, Python is strongly typed, forbidding operations that are not well-defined (for example, adding a number to a string) rather than silently attempting to make sense of them.

Python allows programmers to define their own types using classes, which are most often used for object-oriented programming. New instances of classes are constructed by calling the class (for example, `SpamClass()` or `EggsClass()`), and the classes themselves are instances of the metaclass `type` (itself an instance of itself), allowing metaprogramming and reflection.

Prior to version 3.0, Python had two kinds of classes: "old-style" and "new-style".[] Old-style classes were eliminated in Python 3.0, making all classes new-style. In versions between 2.2 and 3.0, both kinds of classes could be used. The syntax of both styles is the same, the difference being whether the class `object` is inherited from, directly or indirectly (all new-style classes inherit from `object` and are instances of `type`).

### Summary of Python 3's built-in types

| Type | Description | Syntax example |
|---|---|---|
| `str` | A character string: an immutable sequence of Unicode codepoints. | `'Wikipedia'`<br>`"Wikipedia"`<br>`"""Spanning multiple lines"""` |
| `bytearray` | A mutable sequence of bytes. | `bytearray(b'Some ASCII')`<br>`bytearray(b"Some ASCII")`<br>`bytearray([119, 105, 107, 105])` |
| `bytes` | An immutable sequence of bytes. | `b'Some ASCII'`<br>`b"Some ASCII"`<br>`bytes([119, 105, 107, 105])` |
| `list` | Mutable list, can contain mixed types. | `[4.0, 'string', True]` |
| `tuple` | Immutable, can contain mixed types. | `(4.0, 'string', True)` |
| `set`, `frozenset` | Unordered set, contains no duplicates. A `frozenset` is immutable. Either can contain mixed types as long as they are immutable. | `{4.0, 'string', True}`<br>`frozenset([4.0, 'string', True])` |
| `dict` | A mutable associative array (or dictionary) of key and value pairs. Can contain mixed types (keys and values). Keys must be an immutabe type. | `{'key1': 1.0, 3: False}` |
| `int` | An immutable integer of unlimited magnitude.[] | `42` |
| `float` | An immutable floating point number (system-defined precision). | `3.1415927` |
| `complex` | An immutable complex number with real and imaginary parts. | `3+2.7j` |
| `bool` | An immutable boolean value. | `True`<br>`False` |

## Mathematics

In contrast with some programming languages, integer division is defined to round towards minus infinity. Therefore `7 // 3` is 2, but `(−7) // 3` is −3. This is uniform and consistent: for instance, it means that the equation `(a+b) // b == a // b + 1` is always true, whereas in languages such as C, `(-6+7) / 7 == -6 / 7`. It also means that the equation `b * (a // b) + a % b == a` is valid for both positive and negative values of `a`. However, maintaining the validity of this equation means that while the result of `a % b` is, as expected, in the half-open interval [0,*b*), where `b` is a positive integer, it has to lie in the interval (*b*,0] when `b` is negative.[]

Python provides a `round` function for rounding floats to integers. Versions before 3 use round-away-from-zero: `round(0.5)` is 1.0, `round(-0.5)` is −1.0.[] Python 3 uses round-to-even: `round(1.5)` is 2.0, `round(2.5)` is 2.0.[] The `Decimal` type/class in module `decimal` (since version 2.4) provides exact numerical representation and several rounding modes.

Python allows boolean expressions with multiple equality relations in a manner that is consistent with general usage in mathematics. For example, the expression `a < b < c` tests whether `a` is less than `b` and `b` is less than `c`. C-derived languages interpret this expression differently: in C, the expression would first evaluate `a < b`, resulting in 0 or 1, and that result would then be compared with `c`.[11]Wikipedia:Citing sources

## Libraries

Python has a large standard library, commonly cited as one of Python's greatest strengths,[] providing tools suited to many tasks. This is deliberate and has been described as a "batteries included"[5] Python philosophy. For Internet-facing applications, a large number of standard formats and protocols (such as MIME and HTTP) are supported. Modules for creating graphical user interfaces, connecting to relational databases, arithmetic with arbitrary precision decimals,[] manipulating regular expressions, and doing unit testing are also included. For software testing, the standard library provides the `unittest` and `doctest` modules.

Some parts of the standard library are covered by specifications (for example, the WSGI implementation `wsgiref` follows PEP 333[]), but the majority of the modules are not. They are specified by their code, internal documentation, and test suite (if supplied). However, because most of the standard library is cross-platform Python code, there are only a few modules that must be altered or completely rewritten by alternative implementations.

The standard library is not essential to run Python or embed Python within an application. Blender 2.49 for instance omits most of the standard library.

The Python Package Index, which is the official repository of third-party software for Python, contains over 25,000 "packages" covering a wide range of functionality, including:

- graphical user interface, web framework, multimedia, databases, networking and communications
- test frameworks, documentation tools, system administration
- scientific computing, text processing, image processing

## Development environments

Most Python implementations (including CPython) can function as a command line interpreter, for which the user enters statements sequentially and receives the results immediately. In short, Python acts as a shell.

Other shells add capabilities beyond those in the basic interpreter, including IDLE and IPython. While generally following the visual style of the Python shell, they implement features like auto-completion, retention of session state, and syntax highlighting.

In addition to standard desktop Python IDEs (integrated development environments), there are also browser-based IDEs, Sage, (intended for developing science and math-related Python programs), and a hosted IDE, pythonAnywhere.

## Implementations

The main Python implementation, named *CPython*, is written in C meeting the C89 standard.[] It compiles Python programs into intermediate bytecode,[] which is executed by the virtual machine.[] CPython is distributed with a large standard library written in a mixture of C and Python. It is available in versions for many platforms, including Microsoft Windows and most modern Unix-like systems. CPython was intended from almost its very conception to be cross-platform.[]

PyPy is a fast, compliant[] interpreter of Python 2.7. Its just-in-time compiler brings a significant speed improvement over CPython.[] A version taking advantage of multi-core processors using software transactional memory is in the works.[]

Stackless Python is a significant fork of CPython that implements microthreads; it does not use the C memory stack, thus allowing massively concurrent programs. PyPy also has a stackless version.[12]

Other just-in-time compilers have been developed in the past, but are now unsupported:

- Google started a project called Unladen Swallow in 2009 with the aims of increasing the speed of the Python interpreter by 5 times by using the LLVM and improving its multithreading ability to scale to thousands of cores.[] Later the project lost Google's backing and its main developers. As of 1 February 2012[13], the modified

interpreter was about 2 times faster than CPython.[citation needed]

- Psyco is a specialising just in time compiler that integrates with CPython and transforms bytecode to machine code at runtime. The produced code is specialised for certain data types and is faster than standard Python code.

In 2005 Nokia released a Python interpreter for the Series 60 mobile phones called PyS60. It includes many of the modules from the CPython implementations and some additional modules for integration with the Symbian operating system. This project has been kept up to date to run on all variants of the S60 platform and there are several third party modules available. The Nokia N900 also supports Python with GTK widget libraries, with the feature that programs can be both written and run on the device itself.[citation needed]

There are several compilers to high-level object languages, with either unrestricted Python, a restricted subset of Python, or a language similar to Python as the source language:

- Jython compiles into Java byte code, which can then be executed by every Java Virtual Machine implementation. This also enables the use of Java class library functions from the Python program.
- IronPython follows a similar approach in order to run Python programs on the .NET Common Language Runtime.
- The RPython language can be compiled to C, Java bytecode or Common Intermediate Language, and is used to build the PyPy interpreter of Python;
- Pyjamas compiles Python to JavaScript;
- Shed Skin compiles Python to C++;
- Cython and Pyrex compile to C.

## Development

Python's development is conducted largely through the Python Enhancement Proposal (PEP) process. The PEP process is the primary mechanism for proposing major new features, for collecting community input on an issue, and for documenting the design decisions that have gone into Python.[] Outstanding PEPs are reviewed and commented upon by the Python community and by Van Rossum, the Python project's Benevolent Dictator for Life (leader / language architect).[]

Enhancement of the language goes along with development of the CPython reference implementation. The mailing list python-dev is the primary forum for discussion about the language's development; specific issues are discussed in the Roundup bug tracker maintained at python.org.[] Development takes place on a self-hosted source code repository running Mercurial.[citation needed]

CPython's public releases come in three types, distinguished by which part of the version number is incremented:

- Backwards-incompatible versions, where code is expected to break and must be manually ported. The first part of the version number is incremented. These releases happen infrequently—for example, version 3.0 was released 8 years after 2.0.
- Major or "feature" releases, which are largely compatible but introduce new features. The second part of the version number is incremented. These releases are scheduled to occur roughly every 18 months, and each major version is supported by bugfixes for several years after its release.[]
- Bugfix releases, which introduce no new features but fix bugs. The third and final part of the version number is incremented. These releases are made whenever a sufficient number of bugs have been fixed upstream since the last release, or roughly every 3 months. Security vulnerabilities are also patched in bugfix releases.[]

A number of alpha, beta, and release-candidates are also released as previews and for testing before the final release is made. Although there is a rough schedule for each release, this is often pushed back if the code is not ready. The development team monitor the state of the code by running the large unit test suite during development, and using the BuildBot continuous integration system.[]

The community of Python developers has also contributed over 25,000 software modules to the Python Package Index (called pypi), the official repository of third-party libraries for python.

The major academic conference on Python is named PyCon. There are special mentoring programmes like the Pyladies.

## Naming

Python's name is derived from the television series *Monty Python's Flying Circus*,[] and it is common to use Monty Python references in example code.[] For example, the metasyntactic variables often used in Python literature are *spam* and *eggs*, instead of the traditional *foo* and *bar*.[][]

The prefix *Py-* is used to show that something is related to Python. Examples of the use of this prefix in names of Python applications or libraries include Pygame, a binding of SDL to Python (commonly used to create games); PyS60, an implementation for the Symbian S60 operating system; PyQt and PyGTK, which bind Qt and GTK, respectively, to Python; and PyPy, a Python implementation written in Python.

## Use

Since 2008, Python has consistently ranked in the top eight most popular programming languages as measured by the TIOBE Programming Community Index.[] It is the third most popular language whose grammatical syntax is not predominantly based on C, e.g. C++, C#, Objective-C, Java. Python does borrow heavily, however, from the expression and statement syntax of C, making it easier for programmers to transition between languages.

An empirical study found that, for a programming problem involving string manipulation and search in a dictionary, scripting languages such as Python were more productive than conventional languages such as C and Java. Memory consumption was often "better than Java and not much worse than C or C++".[14] Large organizations that make use of Python include Google,[] Yahoo!,[] CERN,[] NASA,[], and some smaller ones like ILM,[] and ITA.[]

Python is used as a scripting language for web applications, e.g., via mod_wsgi for the Apache web server.[] With Web Server Gateway Interface, a standard API has been developed to facilitate these applications. Web application frameworks like Django, Pylons, Pyramid, TurboGears, web2py, Tornado, Flask and Zope support developers in the design and maintenance of complex applications. Pyjamas and IronPython can be used to develop the client-side of Ajax-based applications. SQLAlchemy can be used as data mapper to a relational database. Twisted is a framework to program communications between computers, and is used for example by Dropbox.

Libraries like NumPy, SciPy and Matplotlib allow Python to be used effectively in scientific computing. Sage is a mathematical software with a "notebook" programmable in python: its library covers many aspects of mathematics, including algebra, combinatorics, numerical mathematics, number theory, and calculus.

Python has been successfully embedded in a number of software products as a scripting language, including in finite element method software such as Abaqus, 3D animation packages such as Blender, Cinema 4D, Lightwave, Houdini, Maya, modo, MotionBuilder, Softimage, the visual effects compositor Nuke, and 2D imaging programs like GIMP[15] , Inkscape, Scribus and Paint Shop Pro.[16] GNU Debugger uses Python as a pretty printer to show complex structures such as C++ containers. Esri is now promoting Python as the best choice for writing scripts in ArcGIS.[] It has even been used in several video games,[][] and has been adopted as first of the three available programming languages in Google App Engine, the other two being Java and Go.[]

Python has also been used in artificial intelligence tasks.[][][17][] Thanks to being a scripting language with module architecture, syntax simplicity and rich text processing tools, Python is often used for natural language processing tasks.[18]

For many operating systems, Python is a standard component; it ships with most Linux distributions, AmigaOS 4, FreeBSD, NetBSD, OpenBSD and OS X, and can be used from the terminal. A number of Linux distributions use installers written in Python: Ubuntu uses the Ubiquity installer, while Red Hat Linux and Fedora use the Anaconda installer. Gentoo Linux uses Python in its package management system, Portage. Pardus uses it for administration and during system boot.[19]

Python has also seen extensive use in the information security industry, including exploit development.[20]

Most of the Sugar software for the One Laptop per Child XO, now developed at Sugar Labs, is written in Python.[]

The Raspberry Pi single-board computer project has adopted Python as its principal user programming language.

LibreOffice included Python and intends to replace Java with Python. Python Scripting Provider is a core feature[21] since Version 4.0 from 7 February 2013

## Impact

Python's design and philosophy have influenced several programming languages, including:

- Boo uses indentation, a similar syntax, and a similar object model. However, Boo uses static typing and is closely integrated with the .NET Framework.[]
- Cobra uses indentation and a similar syntax. Cobra's "Acknowledgements" document lists Python first among languages that influenced it.[] However, Cobra directly supports design-by-contract, unit tests and optional static typing.[]
- ECMAScript borrowed iterators, generators, and list comprehensions from Python.[]
- Go is described as incorporating the "development speed of working in a dynamic language like Python".[]
- Groovy was motivated by the desire to bring the Python design philosophy to Java.[]
- OCaml has an optional syntax, called twt (The Whitespace Thing), inspired by Python and Haskell.[]
- Ruby's creator, Yukihiro Matsumoto, has said: "I wanted a scripting language that was more powerful than Perl, and more object-oriented than Python. That's why I decided to design my own language."[]

Python's development practices have also been emulated by other languages. The practice of requiring a document describing the rationale for, and issues surrounding, a change to the language (in Python's case, a PEP) is also used in Tcl[] and Erlang[] because of Python's influence.

Python has been awarded a TIOBE Programming Language of the Year award twice (in 2007 and 2010), which is given to the language with the greatest growth in popularity over the course of a year, as measured by the TIOBE index.[]

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[2] Programming Language Trends - O'Reilly Radar (http://radar.oreilly.com/2006/08/programming-language-trends.html). Radar.oreilly.com (2006-08-02). Retrieved on 2013-07-17.

[3] The RedMonk Programming Language Rankings: January 2013 – tecosystems (http://redmonk.com/sogrady/2013/02/28/language-rankings-1-13/). Redmonk.com (2013-02-28). Retrieved on 2013-07-17.

[4] Code Complete, p. 100 (http://books.google.at/books?id=3JfE7TGUwvgC&pg=PT100)

**[5]** , second section "Fans of Python use the phrase "batteries included" to describe the standard library, which covers everything from asynchronous processing to zip files."

[6] Alex Martelli, *Python Cookbook* (2nd ed., p. 230)

[7] (http://www.python.org/dev/culture/)

[10] http://programmers.stackexchange.com/questions/66755/do-python-programmers-find-the-whitespace-issue-inconvenient

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[13] http://en.wikipedia.org/w/index.php?title=Python_(programming_language)&action=edit

[14] http://page.mi.fu-berlin.de/prechelt/Biblio/jccpprt_computer2000.pdf

[16] (http://www.jasc.com/support/customercare/articles/psp9components.asp)

[17] PyAIML 0.8.5 : Python Package Index (http://pypi.python.org/pypi/PyAIML). Pypi.python.org. Retrieved on 2013-07-17.

[18] http://www.nltk.org

[20] http://www.immunitysec.com/products-immdbg.shtml http://oss.coresecurity.com/

## Further reading


- Downey, Allen B (Version 1.6.6 - May 2012). *Think Python: How to Think Like a Computer Scientist* (http://www.greenteapress.com/thinkpython/html/). ISBN 978-0-521-72596-5.
- Hamilton, Naomi (5 August 2008). "The A-Z of Programming Languages: Python" (http://www.computerworld.com.au/index.php/id;66665771). *Computerworld*. Retrieved 31 March 2010.
- Lutz, Mark (2009). *Learning Python* (4th ed.). O'Reilly Media. ISBN 978-0-596-15806-4.
- Pilgrim, Mark (2004). *Dive Into Python* (http://diveintopython.net). Apress. ISBN 978-1-59059-356-1.
- Pilgrim, Mark (2009). *Dive Into Python 3* (http://diveintopython3.net). Apress. ISBN 978-1-4302-2415-0.
- Summerfield, Mark (2009). *Programming in Python 3* (http://www.qtrac.eu/py3book.html) (2nd ed.). Addison-Wesley Professional. ISBN 978-0-321-68056-3.


## External links

- Official website (http://www.python.org)
- [news://comp.lang.python Python (programming language)] newsgroup on Usenet ( alternative free web access (http://groups.google.com/group/comp.lang.python) using Google Groups)
- Python development list (http://mail.python.org/mailman/listinfo/python-list)
- Python (http://www.dmoz.org/Computers/Programming/Languages/Python/) at the Open Directory Project

# Raspberry Pi

**Raspberry Pi**

"Raspberry Pi" Computer Model-B Rev1

| | |
|---|---|
| **Developer** | Raspberry Pi Foundation |
| **Type** | Single-board computer |
| **Release date** | 29 February 2012[1] |
| **Introductory price** | US$ 25 (model A) and US$ 35 (model B) |
| **Operating system** | Linux (Raspbian, Debian GNU/Linux, Fedora, and Arch Linux ARM)[2] RISC OS, FreeBSD, NetBSD, Plan 9 |
| **Power** | 2.5 W (model A), 3.5 W (model B) |
| **CPU** | ARM1176JZF-S (armv6**k**) 700 MHz,[] Raspberry Pis can dynamically increase clockspeeds, and some can temporarily reach speeds up to 1 GHz.[] |
| **Storage capacity** | SD card slot<br>(SD or SDHC card) |
| **Memory** | 256 MByte (Model A)<br>512 MByte (Model B rev 2)[3]<br>256 MByte (Model B rev 1) |
| **Graphics** | Broadcom VideoCore IV[] |
| **Website** | www.raspberrypi.org [4] |

The **Raspberry Pi** is a credit-card-sized single-board computer developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools.[][][5][6][7]

The Raspberry Pi is manufactured through licensed manufacturing deals with Element 14/Premier Farnell, RS Components and Egoman. All of these companies sell the Raspberry Pi online.[8] Egoman produce a version that is only able to be distributed in China and Taiwan and can be distinguished from other Pis as they are Red and do not have the FCC/CE marks. All of the hardware is the same.

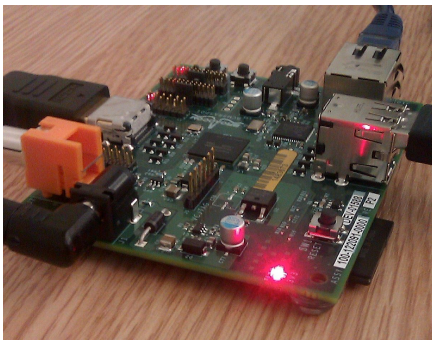
The Raspberry Pi has a Broadcom BCM2835 system on a chip (SoC),[] which includes an ARM1176JZF-S 700 MHz processor (The firmware includes a number of "Turbo" modes so that the user can attempt overclocking, up to 1 GHz, without affecting the warranty),[] VideoCore IV GPU,[] and was originally shipped with 256 megabytes of RAM, later upgraded to 512 MB.[] It does not include a built-in hard disk or solid-state drive, but uses an SD card for

booting and long-term storage.[] The Foundation's goal was to offer two versions, priced at US$25 and US$35. They started accepting orders for the higher priced model B on 29 February 2012,[9] and the lower cost model A on 4 February 2013.[10]

The Foundation provides Debian and Arch Linux ARM distributions for download.[] Also planned are tools for supporting Python as the main programming language,[][] with support for BBC BASIC,[] (via the RISC OS image or the "Brandy Basic" clone for Linux),[11] C,[] and Perl.[]

On 17 December 2012 the Raspberry Pi Foundation, in collaboration with IndieCity and Velocix, opened the "Pi Store", as a "one-stop shop for all your Raspberry Pi (software) needs". Using an application included in Raspbian, users can browse through several categories and download what they want. Software can also be uploaded for moderation and release.[12]

## History



An early alpha-test board in operation. Its layout is different from the beta and production boards.

In 2006, early concepts of the Raspberry Pi were based on the Atmel ATmega644 microcontroller. Its schematics and PCB layout are available for public download.[] Foundation trustee Eben Upton assembled a group of teachers, academics and computer enthusiasts to devise a computer to inspire children.[] The computer is inspired by Acorn's BBC Micro of 1981.[] The first ARM prototype version of the computer was mounted in a package the same size as a USB memory stick.[13] It had a USB port on one end and a HDMI port on the other.

### Pre-launch

In August 2011, fifty Alpha boards were manufactured. These boards were functionally identical to the planned model B,[14] but were physically larger to accommodate debug headers. Demonstrations of the board showed it running the LXDE desktop on Debian, *Quake 3* at 1080p,[15] and Full HD MPEG-4 video over HDMI.[16]

In October 2011, a version of RISC OS 5 was demonstrated in public, and following a year of development the port was released for general consumption in November 2012.[][][][]

In December 2011, twenty-five model B Beta boards were assembled and tested[17] from one hundred unpopulated PCBs.[18] The component layout of the Beta boards was the same as on production boards. A single error was discovered in the board design where some pins on the CPU were not held high; it was fixed for the first production run.[19] The Beta boards were demonstrated booting Linux, playing a 1080p movie trailer and the Rightware Samurai OpenGL ES benchmark.[20]

Certificate of Authenticity

This certifies that this Raspberry Pi Computer is one of ten beta Model B pre-release development boards.

Serial # ...7.....

Certified by: RDMullins

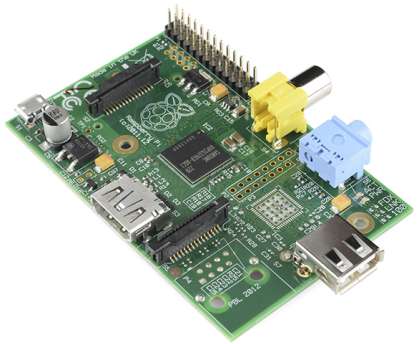
Robert Mullins
Co-founder and Trustee of the Raspberry Pi Foundation

Date: 11.1.2012

Certificate of authenticity for an auctioned board

During the first week of 2012, the first 10 boards were put up for auction on eBay.[21][] One was bought anonymously and donated to the museum at The Centre for Computing History in Suffolk, England.[][] The ten boards (with a total retail price of £220) together raised over £16,000,[22] with the last to be auctioned, serial number No. 01, raising £3,500.[23] In advance of the anticipated launch at the end of February 2012, the Foundation's servers struggled to cope with the load placed by watchers repeatedly refreshing their browsers.[]

## Launch



Raspberry Pi Model A

The first batch of 10,000 boards was manufactured in Taiwan and China,[][] rather than in the UK. This is in part because import duty is payable on individual components but not on finished products. Chinese manufacturers also quoted a lead time of four weeks, compared to twelve weeks in the UK.

Shipping delays for the first batch were announced in March 2012, as the result of installation of an incorrect Ethernet port.[][] But the Foundation expects that manufacturing quantities of future batches can be increased with little difficulty if required.[]

> "We have ensured we can get them [the Ethernet connectors with magnetics] in large numbers and Premier Farnell and RS Components [the two distributors] have been fantastic at helping to source components," Upton said.

Initial sales commenced 29 February 2012[] at 06:00 UTC;. At the same time, it was announced that the Model A, originally to have had 128 MB of RAM, was to be upgraded to 256 MB before release.[9] The Foundation's website also announced "Six years after the project's inception, we're nearly at the end of our first run of development – although it's just the beginning of the Raspberry Pi story."[] The web-shops of the two licensed manufacturers selling Raspberry Pi's within the United Kingdom, Premier Farnell and RS Components, had their websites stalled by heavy web traffic immediately after the launch.[] At one point the webmaster pleaded, "Guys – can you please stop hitting F5 on our website quite so often? You're bringing the server to its knees."[] Although as yet unconfirmed, reports suggest that there are over two million expressions of interest or pre-orders.[24] The official Raspberry Pi Twitter account reported that Premier Farnell sold out within a few minutes of the initial launch, while RS Components took over 100,000 pre orders on day one.[9] As of September 2012[25], about 500,000 boards have been sold.[]

Manufacturers were reported in March 2012 to be taking a "healthy number" of pre-orders.[]

## Post-launch

On 16 April 2012 reports started to appear from the first buyers who had received their Raspberry Pi.[26][27] As of 22 May 2012 over 20,000 units have been shipped.[28] On 16 July 2012 it was announced that 4000 units were being manufactured per day, allowing Raspberry Pis to be bought in bulk.[][29] On 5 September the Raspberry Pi Foundation announced a second revision of the Model B Raspberry Pi.[30] On 6 September 2012 it was announced that in future the bulk of Raspberry Pi units would be manufactured in the UK, at Sony's manufacturing facility in Pencoed, Wales. The Foundation estimates the plant will produce 30,000 units per month, and will create about 30 new jobs.[][31] In October 2012 it was reported that some customers of one of the two main distributors had been waiting more than six months for their orders. This was reported to be due to difficulties in sourcing the CPU and conservative sales forecasting by this distributor.[]

## Hardware

Initial sales are of the Model B, with plans to release the Model A in early 2013. Model A has one USB port and no Ethernet controller, and will cost less than the Model B with two USB ports and a 10/100 Ethernet controller.[]

Though the Model A doesn't have an 8P8C (RJ45) Ethernet port, it can connect to a network by using a user-supplied USB Ethernet or Wi-Fi adapter. There is in reality no difference between a model A with an external Ethernet adapter and a model B with one built in, because the Ethernet port of the model B is actually a built-in USB Ethernet adapter. As is typical of modern computers, generic USB keyboards and mice are compatible with the Raspberry Pi.[]

The Raspberry Pi does not come with a real-time clock,[] so an OS must use a network time server, or ask the user for time information at boot time to get access to time and date for file time and date stamping. However, a real-time clock (such as the DS1307) with battery backup can be added via the I²C interface.

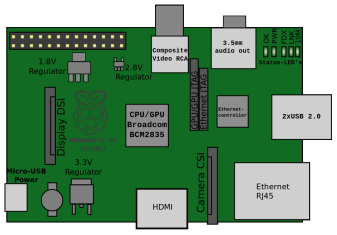
On 20 April 2012 the schematics for the Model-A and Model-B were released by the Raspberry Pi Foundation.[32]

Hardware accelerated video (H.264) encoding became available on 24 August 2012 when it became known that the existing license also covered encoding. Previously it was thought that encoding would be added with the release of the announced camera module.[33][34] However, for the time being, there is no stable software support for hardware H.264 encoding.[35]

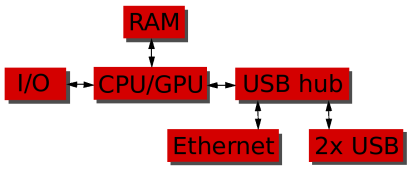
At the same time the Raspberry Pi Foundation released two additional codecs that can be bought separately, MPEG-2 and Microsoft's VC-1. Also it was announced that the Pi will support CEC, enabling it to be controlled with the television's remote control.[]

On 5 September 2012, a revision 2.0 board was announced, with a number of minor corrections and improvements.[36]

On 15 October 2012, the Raspberry Pi foundation announced that all new Raspberry Pi model B's would be fitted with 512 MB instead of 256 MB RAM.[]

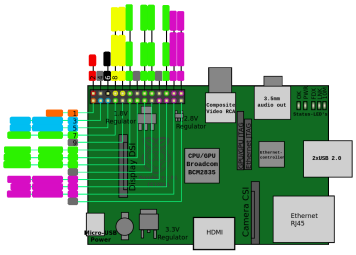



Location on the PCB of connectors and major ICs




Block diagram of the Model-B; in a Model-A the lowest two blocks and the rightmost block are missing (note that these three blocks are in a chip that actually contains a three-port USB hub, with a USB Ethernet adapter connected to one of its ports). In the Model-A the USB port is connected directly to the SoC.

A Raspberry Pi system running an X server



Pinout-diagram for Rev. 1 Board

## Specifications

| | Model A | Model B |
|---|---|---|
| **Target price:**[] | US$ 25 | US$ 35[37] |
| **SoC:**[] | Broadcom BCM2835 (CPU, GPU, DSP, SDRAM, and single USB port)[] | |
| **CPU:** | 700 MHz ARM1176JZF-S core (ARM11 family, ARMv6 instruction set)[] | |
| **GPU:** | Broadcom VideoCore IV @ 250 MHz[38][39]<br>OpenGL ES 2.0 (24 GFLOPS)<br>MPEG-2 and VC-1 (with license[]), 1080p30 h.264/MPEG-4 AVC high-profile decoder and encoder[] | |
| **Memory (SDRAM):** | 256 MB (shared with GPU) | 512 MB (shared with GPU) as of 15 October 2012 |
| **USB 2.0 ports:**[] | 1 (direct from BCM2835 chip) | 2 (via the built in integrated 3-port USB hub)[] |
| **Video input:** | A CSI input connector allows for the connection of a RPF designed camera module[] | |
| **Video outputs:**[] | Composite RCA (PAL and NTSC), HDMI (rev 1.3 & 1.4),[] raw LCD Panels via DSI[][40] 14 HDMI resolutions from 640×350 to 1920×1200 plus various PAL and NTSC standards.[] | |
| **Audio outputs:**[] | 3.5 mm jack, HDMI, and, as of revision 2 boards, I²S audio[41] (also potentially for audio input) | |
| **Onboard storage:**[] | SD / MMC / SDIO card slot (3,3V card power support only) | |
| **Onboard network:**[][] | None | 10/100 Ethernet (8P8C) USB adapter on the third port of the USB hub[] |
| **Low-level peripherals:** | 8 × GPIO,[42] UART, I²C bus, SPI bus with two chip selects, I²S audio[43] +3.3 V, +5 V, ground[38][44] | |
| **Power ratings:** | 300 mA (1.5 W)[45] | 700 mA (3.5 W) |
| **Power source:**[] | 5 volt via MicroUSB or GPIO header | |
| **Size:** | 85.60 mm × 53.98 mm (3.370 in × 2.125 in)[46] | |
| **Weight:** | 45 g (1.6 oz)[47] | |
| **Operating systems:** | Arch Linux ARM,[2] Debian GNU/Linux, Fedora, FreeBSD, NetBSD, Plan 9, Raspbian OS, RISC OS,[]Slackware Linux[] | |

Notes

1. **Model A** and **Model B** are cultural references[] to the original models of the British educational BBC Micro computer, developed by Acorn Computers, who originally developed the ARM processors (the architecture of the Raspberry Pi) and operating system RISC OS, which will also be able to be run on the Raspberry Pi (version 5.17).[]
2. On the older beta model B boards, 128 MB was allocated by default to the GPU, leaving 128 MB for the CPU.[48] On the first 256 MB release model B (and Model A), three different splits were possible. The default split was 192 MB (CPU RAM), which should be sufficient for standalone 1080p video decoding, or for simple 3D, but probably not for both together. 224 MB was for Linux only, with just a 1080p framebuffer, and was likely to fail for any video or 3D. 128 MB was for heavy 3D, possibly also with video decoding (e.g. XBMC).[49] Comparatively the Nokia 701 uses 128 MB for the Broadcom VideoCore IV.[50] For the new model B with 512 MB RAM initially there were new standard memory split files released( arm256_start.elf, arm384_start.elf, arm496_start.elf) for 256 MB, 384 MB and 496 MB CPU RAM (and 256 MB, 128 MB and 16 MB video RAM).

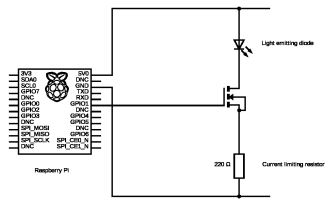
But a week or so later the RPF released a new version of start.elf that could read a new entry in config.txt (gpu_mem=xx) and could dynamically assign an amount of RAM (from 16 to 256 MB in 8 MB steps) to the GPU, so the older method of memory splits became obsolete, and a single start.elf worked the same for 256 and 512 MB Pis.[51]

3. Level 2 Cache is 128 kB, used primarily by the GPU, not the CPU.
4. The ARM11 is based on version 6 of the ARM architecture (ARMv6), which due to its age is no longer supported by several popular versions of Linux, including Ubuntu which dropped support for processors below ARMv7 in 2009.[52]
5. The Raspberry Pi also contains a 15-pin MIPI camera interface (CSI) connector, which is used with the Raspberry Pi Camera Addon.[53][54]
6. Support for raw LCD panels is available in hardware through the available DSI connector from the Mobile Industry Processor Interface (MIPI) Alliance.[] Software support is being planned.
7. Supported digital video resolutions are: 640 × 350 EGA; 640 × 480 VGA; 800 × 600 SVGA; 1024 × 768 XGA; 1280×720 720p HDTV; 1280 × 768 WXGA Variant; 1280 × 800 WXGA Variant; 1280 × 1024 SXGA; 1366 × 768 WXGA Variant; 1400 × 1050 SXGA+; 1600 × 1200 UXGA; 1680 × 1050 WXGA+; 1920 × 1080 1080p HDTV; 1920 × 1200 WUXGA.[] Also to be supported are the generation of 576i and 480i composite video signals for PAL-BGHID, PAL-M, PAL-N, NTSC and NTSC-J[]
8. Newer versions of the firmware contain the option to choose between five overclock ("turbo") presets that when turned on try to get the most performance out of the SoC without impairing the lifetime of the Pi. This is done by monitoring the core temperature of the chip, and the CPU load, and dynamically adjusting clock speeds and the core voltage. So when there is a low demand on the CPU, or it is getting too hot, the performance is throttled down, but if the CPU has much to do, and the chip's temperature allows it, performance is temporarily increased, with clock speeds up to 1 GHz, depending on the individual board, and on which of the "turbo" settings is used. The five settings currently are:
   1. "None"; 700 MHz ARM, 250 MHz core, 400 MHz SDRAM, 0 overvolt,
   2. "Modest"; 800 MHz ARM, 250 MHz core, 400 MHz SDRAM, 0 overvolt,
   3. "Medium" 900 MHz ARM, 250 MHz core, 450 MHz SDRAM, 2 overvolt,
   4. "High"; 950 MHz ARM, 250 MHz core, 450 MHz SDRAM, 6 overvolt,
   5. "Turbo"; 1000 MHz ARM, 500 MHz core, 600 MHz SDRAM, 6 overvolt[][]

In the highest ("turbo") preset the SDRAM clock was originally 500 MHz, but this was later changed to 600 MHz because 500 MHz sometimes causes SD card corruption. Simultaneously in "High" mode the core clock speed was lowered from 450 to 250 MHz, and in "medium" mode from 333 to 250 MHz.

## Accessories

The Foundation reported on its blog in May 2012 about a prototype camera module they have tested. The prototype used a 14 megapixel module, while the released version will be 5 megapixels.



Using GPIO pins to control an LED

On 14 May 2013 the foundation and the distributors RS Components & Premier Farnell/Element 14 launched the camera board with updated firmware to support the camera board. The camera board is shipped with a flexible flat cable that plugs into the CSI connector located between the Ethernet and HDMI ports. In Raspbian support can be enabled by the installing or upgrading to the latest version of the OS and then running Raspi-config and selecting the camera option. The cost of the camera module is 20 EUR in Europe (2013-06-09).[] and supports 1080p, 720p, 640x480p video. The footprint dimensions are 25 x 20 x 9 mm.[]

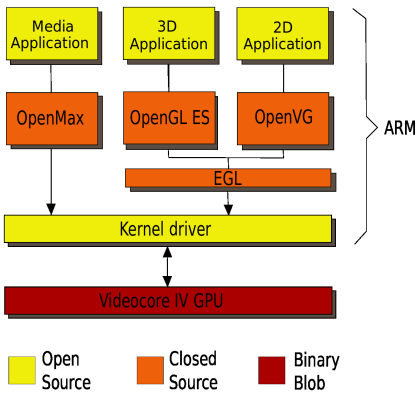
A number of Raspberry Pi specific peripheral devices and cases are available from third-party suppliers.[] These include the Raspberry Pi Foundation sanctioned Gertboard, which is designed for educational purposes, and expands the Raspberry Pi's GPIO pins to allow interface with and control of LEDs, switches, analog signals, sensors and other devices. It also includes an optional Arduino compatible controller to interface with the Pi.[]

## Software

### Driver API

The Raspberry Pi uses Linux kernel-based operating systems.

The GPU hardware is accessed via a firmware image which is loaded into the GPU at boot time from the SD-card. The firmware image is known as the binary blob, while the associated ARM coded Linux drivers were initially closed source.[] this part of the driver code was later released,[], however much of the actual driver work is done using the closed source GPU code. Application software uses calls to closed source run-time libraries (Open Max, OpenGL ES or open VG) which in turn calls an open source driver inside the Linux kernel, which then calls the closed source Videocore IV GPU driver code. The API of the kernel driver is specific for these closed libraries. Video applications use OpenMAX, 3D applications use OpenGL ES and 2D applications use OpenVG which both in turn use EGL. OpenMAX and EGL use the open source kernel driver in turn.[55]



Visual diagram of API connections

### Raspbian

After cycling through several recommendations since just before the hardware was first made available, the Raspberry Pi Foundation created the New Out Of Box System (NOOBS) installer, and as of July 2013[25] suggests using it to install the Debian-derived Raspbian.[] The Foundation intends to create an application store website for people to exchange programs.[]

Raspbian is a Debian-based free operating system optimized for the Raspberry Pi hardware. It is the current recommended system, and was officially released in July 2012,[] although it is still in development. It is free software and maintained independently of the Raspberry Pi Foundation;[]. It is based on ARM hard-float (armhf)-Debian 7 'Wheezy' architecture port with the LXDE desktop environment, but optimized for the ARMv6 instruction set of the Raspberry Pi. It provides some available deb software packages, pre-compiled software bundles.[] A minimum size of 2 GB SD card is required for Raspbian, but a 4 GB SD card or above is recommended. The downloaded Raspbian "wheezy" image file has to be unzipped and then written to a suitable SD card, formatting it for use.[]

**History**

On 19 February 2012, the Raspberry Pi Foundation released its first proof of concept SD card image that could be loaded onto an SD card to produce a preliminary operating system. The image was based upon Debian 6.0 (Squeeze), with the LXDE desktop and the Midori browser, plus various programming tools. The image also runs on QEMU allowing the Raspberry Pi to be emulated on various other platforms.[56][]

On 8 March 2012 The Raspberry Pi Foundation released Raspberry Pi Fedora Remix, at the time its recommended Linux distribution,[57] which was developed at Seneca College in Canada.[]

The Debian port was initiated by Mike Thompson, the former CTO of Atomz, in March 2012, a week after the Raspberry Pi's launch. The effort was largely carried out by Thompson and Peter Green, a volunteer Debian developer, with some support from the Raspberry Pi Foundation, who tested the resulting binaries that the two produced during the early stages. (Neither Thompson nor Green had physical access to the hardware, as boards were not widely accessible at the time due to demand.)[] While the preliminary proof of concept image distributed by the Foundation before launch had also been Debian-based, it differed from Thompson and Green's Raspbian effort in a couple ways.

The POC image was based on then-stable Debian Squeeze, while Raspbian aimed to track then-upcoming Debian Wheezy packages.[][] Aside from the updated packages that would come with the new release, Wheezy was also set to introduce the armhf architecture,[] which became the *raison d'être* for the Raspbian effort.

The Squeeze-based POC image was limited to the armel architecture,[] which was, at the time of Squeeze's release, the latest attempt by the Debian project to support the newest ARM EABI.[] The armhf architecture in Wheezy intended to support the ARM VFP hardware floating-point unit, while armel was limited to emulating floating point operations in software.[][][] Since the Raspberry Pi included a VFP, being able to make use of the hardware unit would result in performance gains and reduced power usage for floating point operations.[] The armhf effort in mainline Debian, however, was orthogonal to the work surrounding the Pi and only intended to support ARMv7 at a minimum, which would mean the Pi, an ARMv6 device, would not benefit.[] As a result, Thompson and Green set out to build the 19,000 Debian packages for the device using a custom build cluster.[]

On 3 June 2013 the Raspberry Pi foundation introduced a new tool called "New Out Of Box Software" or "NOOBS" which makes taking the Raspberry Pi to use much easier by simplifying the installing of an operating system on it. Instead of using specific software to "burn an SD card", now all you have to do is to unzip a file and copy the contents over to a FAT formatted (4 GB or bigger) SD card. Then you can boot that card on the Raspberry Pi and are presented with a choice of six operating systems you can choose to install on the card. The system also contains a recovery partition that allows for the quick restoration of the OS you have chosen to install, tools to modify the config.txt and an online help button and web browser which directs to the Raspberry Pi Forums.[]

The operating systems the NOOBS installer is tailored for are:

- Archlinux ARM
- OpenELEC
- Pidora (Fedora Remix)
- Raspbmc
- Raspbian (recommended)
- RISC OS

## Third-party system software

A server computer systems oriented edition of Raspbian, the *Raspbian Server Edition (RSEv2.4)*,[] is a stripped version of Raspbian with other software packages bundled as compared to the usual desktop computer oriented Raspbian.[]

Slackware ARM (formally ARMedslack) version 13.37 and later runs on the Raspberry Pi without modification.[58][59][60][61] The 128–496 MB of available memory on the Raspberry Pi is twice the minimum requirement of 64 MB needed to run Slackware Linux on an ARM or i386 system.[62] (Whereas the majority of Linux systems boot into a graphical user interface, Slackware's default user environment is the textual shell / command line interface.[63]) The Fluxbox window manager running under the X Window System requires an additional 48 MB of RAM.[64]

In addition, work is being done on system-specific light Linux distributions such as IPFire,[65] OpenELEC,[] Raspbmc[66] and the XBMC open source digital media center.[]

Trustee Eben Upton publicly approached the RISC OS Open community in July 2011 to enquire about assistance with a potential port.[] Adrian Lees at Broadcom has since worked on the port,[][] with his work being cited in a discussion regarding the graphics drivers.[]

On 24 October 2012 the Raspberry Pi Foundation announced that "all of the VideoCore driver code which runs on the ARM" had been released as free software under a BSD-style license, making it "the first ARM-based multimedia SoC with fully-functional, vendor-provided (as opposed to partial, reverse engineered) fully open-source drivers", although this claim has not been universally accepted.[]

On 25 May 2013 the Raspberry Pi foundation pre-announced that (initially) for Raspbian they would switch from using the X Window System to the Wayland display server protocol. This would enable the efficient use of the GPU for hardware accelerated GUI drawing functions.[]

## List of operating systems

This is a list of operating systems running, ported or in the process of being ported to Raspberry Pi.

- **Full OS:**
  - AROS
  - GEORGE 3 - within an emulator [67].
  - Haiku[68]
  - Linux
    - Android
      - Android 2.3 (Gingerbread)[69]
      - Android 4.0 (Ice Cream Sandwich)
    - Arch Linux ARM
    - R_Pi Bodhi Linux[70]
    - Debian ARM architecture ports, but not the Debian ARMhf architecture ports (introduced with Debian 7 Wheezy), since these are compiled for ARMv7 and the Raspberry Pi CPU is ARMv6
      - Raspbian[71] (Debian 7 Wheezy ARMhf backported for ARMv6)
    - Firefox OS
    - Puppy Linux
    - Gentoo Linux[72]
    - Google Chromium OS
    - PiBang Linux[73]
    - Raspberry Pi Fedora Remix
    - Slackware ARM (formerly ARMedslack)

    - QtonPi a cross-platform application framework based Linux distribution based on the Qt framework
    - WebOS
        - Open webOS[74]
  - Plan 9 from Bell Labs[75][76]
  - RISC OS
  - Unix
    - FreeBSD[77]
    - NetBSD[78][]
- **Multi-purpose light distributions:**
  - Moebius operating system, a light ARM HF distribution based on Debian. It uses Raspbian repository, but it fits in a 1 GB SD card. It has just minimal services and its memory usage is optimized to keep a small footprint.
  - Minibian, another light ARM HF distribution based on Raspbian repository.
  - OpenWrt "Attitude Adjustment" 12.09
  - Squeezed Arm Puppy, a version of Puppy Linux (Puppi) for the ARMv6 (sap6) specifically for the Raspberry Pi.[79]
- **Single-purpose light distributions:**
  - IPFire
  - OpenELEC
  - Raspbmc
  - XBian
  - RasPlex
  - Raspberry Digital signage, former Instant WebKiosk for Raspberry Pi, a browser-only distribution based on Raspbian for digital signage purposes.

## Reception and use

Technology writer Glyn Moody described the project in May 2011 as a "potential BBC Micro 2.0", not by replacing PC compatible machines but by supplementing them.[] In March 2012 Stephen Pritchard echoed the "BBC Micro successor" sentiment in *ITPRO*.[] Alex Hope, co-author of the Next Gen report, is hopeful that the computer will engage children with the excitement of programming.[] Co-author Ian Livingstone suggested that the BBC could be involved in building support for the device, possibly branding it as the "BBC Nano".[] Chris Williams, writing in The Register sees the inclusion of programming languages such as Kids Ruby, Scratch and BASIC as a "good start" to equip kids with the skills needed in the future – although it remains to be seen how effective their use will be.[] The Centre for Computing History strongly supports the Raspberry Pi project, feeling that it could "usher in a new era".[] Before release, the board was showcased by ARM's CEO Warren East at an event in Cambridge outlining Google's ideas to improve UK science and technology education.[]

Harry Fairhead, however, suggests that more emphasis should be put on improving the educational software available on existing hardware, using tools such as Google App Inventor to return programming to schools, rather than adding new hardware choices.[] Simon Rockman, writing in a ZDNet blog, was of the opinion that teens will have "better things to do", despite what happened in the 1980s.[]

In October 2012 the Raspberry Pi won T3's "Innovation of the Year" award,[80] and futurist Mark Pesce cited a (borrowed) Raspberry Pi as the inspiration for his ambient device project MooresCloud.[81] In October 2012 the BCS reacted to the announcement of enhanced specifications by stating, "it's definitely something we'll want to sink our teeth into."[]

### Community

The Raspberry Pi community was described by Jamie Ayre of FLOSS software company AdaCore as one of the most exciting parts of the project.[] Community blogger Russell Davis said that the community strength allows the Foundation to concentrate on documentation and teaching.[] The community is developing fanzines around the platform, such as *The MagPi*.[82] A series of community *Raspberry Jam* events have been held across the UK[] and further afield,[] led by Alan O'Donohoe,[][][] principal teacher of ICT at Our Lady's High School, Preston,[][] and a teacher-led community from RaspberryJam has started building an crowdsourced Scheme of Work.[]

### Use in education

As of January 2012[25], enquiries about the board in the United Kingdom have been received from schools in both the state and independent sectors, with around five times as much interest from the latter. It is hoped that businesses will sponsor purchases for less advantaged schools.[] The CEO of Premier Farnell said that the government of a country in the Middle East has expressed interest in providing a board to every schoolgirl, in order to enhance her employment prospects.[][83]

The Raspberry Pi Foundation and Oxford, Cambridge and RSA Examinations launched a beta of the Cambridge GCSE Computing Online course or "MOOC (Massive Open Online Course)" based around the current GCSE Computing syllabus. The MOOC will comprise of videos, animations and interactive tasks on every part of the curriculum presented by UK teachers. The beta is currently presented by Clive Beale who is the Head of Educational Development. All tasks will be supported by written materials & audio and text transcripts available for disabled students. The first MOOC will be linked to a formal GCSE qualification. [84]

Oxford, Cambridge and RSA Examinations also provide resources to use with a Raspberry Pi for teachers who would like to use the device in their lessons including Getting started, Singing Jelly Baby and other features about the Raspberry Pi. The resources can be found at http://www.ocr.org.uk/qualifications/by-subject/computing/raspberry-pi/?utm_source=external&utm_medium=short&utm_campaign=nurpi_140513

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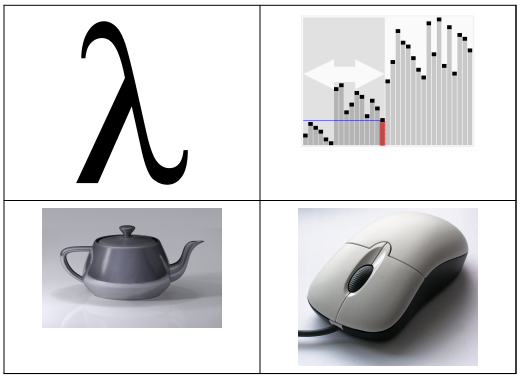
## External links

- Raspberry Pi Foundation official website and forums (http://www.raspberrypi.org)
- Raspberry Pi Wiki, supported by the RPF (http://elinux.org/RaspberryPiBoard)
- Raspberry Pi unofficial Q&A site on StackExchange (http://raspberrypi.stackexchange.com)
- Raspberry Pi Resources at the IET (http://mycommunity.theiet.org/communities/home/368)

# Computer science

**Computer science** or **computing science** (abbreviated **CS** or **CompSci**) is the scientific and practical approach to computation and its applications. A computer scientist specializes in the theory of computation and the design of computational systems.[1]

Its subfields can be divided into a variety of theoretical and practical disciplines. Some fields, such as computational complexity theory (which explores the fundamental properties of computational problems), are highly abstract, while fields such as computer graphics emphasize real-world visual applications. Still other fields focus on the challenges in implementing computation. For example, programming language theory considers various approaches to the description of computation, whilst the study of computer programming itself investigates various aspects of the use of programming language and complex systems. Human-computer interaction considers the challenges in making computers and computations useful, usable, and universally accessible to humans.



Computer science deals with the theoretical foundations of information and computation, together with practical techniques for the implementation and application of these foundations

## History

The earliest foundations of what would become computer science predate the invention of the modern digital computer. Machines for calculating fixed numerical tasks such as the abacus have existed since antiquity but they only supported the human mind, aiding in computations as complex as multiplication and division.

Charles Babbage is credited with inventing the first mechanical computer.

Blaise Pascal designed and constructed the first working mechanical calculator, Pascal's calculator, in 1642. Two hundred years later, Thomas de Colmar launched the mechanical calculator industry[2] when he released his simplified arithmometer, which was the first calculating machine strong enough and reliable enough to be used daily in an office environment. Charles Babbage started the design of the first *automatic mechanical calculator*, his difference engine, in 1822, which eventually gave him the idea of the first *programmable mechanical calculator*, his Analytical Engine.[3] He started developing this machine in 1834 and "in less than two years he had sketched out many of the salient features of the modern computer. A crucial step was the adoption of a punched card system derived from the Jacquard loom"[4] making it infinitely programmable.[5] In 1843, during the translation of a French article on the *analytical engine*, Ada Lovelace wrote, in one of the many notes she included, an algorithm to compute the Bernoulli numbers, which is considered to be the first computer program.[6] Around 1885, Herman Hollerith invented the tabulator which used punched cards to process statistical information; eventually his company became part of IBM. In 1937, one hundred years after Babbage's impossible dream, Howard Aiken convinced IBM, which was making all kinds of punched card equipment and was also in the calculator business[7] to develop his giant programmable calculator, the ASCC/Harvard Mark I, based on Babbage's *analytical engine*, which itself used cards and a central computing unit. When the machine was finished, some hailed it as "Babbage's dream come true".[8]

Ada Lovelace is credited with writing the first algorithm intended for processing on a computer.

During the 1940s, as new and more powerful computing machines were developed, the term *computer* came to refer to the machines rather than their human predecessors.[9] As it became clear that computers could be used for more than just mathematical calculations, the field of computer science broadened to study computation in general. Computer science began to be established as a distinct academic discipline in the 1950s and early 1960s.[][10] The world's first computer science degree program, the Cambridge Diploma in Computer Science, began at the University of Cambridge Computer Laboratory in 1953. The first computer science degree program in the United States was formed at Purdue University in 1962.[11] Since practical computers became available, many applications of computing have become distinct areas of study in their own right.

Although many initially believed it was impossible that computers themselves could actually be a scientific field of study, in the late fifties it gradually became accepted among the greater academic population.[] It is the now well-known IBM brand that formed part of the computer science revolution during this time. IBM (short for International Business Machines) released the IBM 704[12] and later the IBM 709[13] computers, which were widely used during the exploration period of such devices. "Still, working with the IBM [computer] was frustrating...if you had misplaced as much as one letter in one instruction, the program would crash, and you would have to start the whole process over again".[] During the late 1950s, the computer science discipline was very much in its developmental stages, and such issues were commonplace.

Time has seen significant improvements in the usability and effectiveness of computing technology. Modern society has seen a significant shift in the users of computer technology, from usage only by experts and professionals, to a near-ubiquitous user base. Initially, computers were quite costly, and some degree of human aid was needed for efficient use - in part from professional computer operators. As computer adoption became more widespread and affordable, less human assistance was needed for common usage.

## Major achievements

Despite its short history as a formal academic discipline, computer science has made a number of fundamental contributions to science and society - in fact, along with electronics, it is a founding science of the current epoch of human history called the Information Age and a driver of the Information Revolution, seen as the third major leap in human technological progress after the Industrial Revolution (1750-1850 CE) and the Agricultural Revolution (8000-5000 BCE).

The German military used the Enigma machine (shown here) during World War II for communication they thought to be secret. The large-scale decryption of Enigma traffic at Bletchley Park was an important factor that contributed to Allied victory in WWII.[14]

These contributions include:

- The start of the "digital revolution," which includes the current Information Age and the Internet.[15]
- A formal definition of computation and computability, and proof that there are computationally unsolvable and intractable problems.[16]
- The concept of a programming language, a tool for the precise expression of methodological information at various levels of abstraction.[17]
- In cryptography, breaking the Enigma code was an important factor contributing to the Allied victory in World War II.[14]
- Scientific computing enabled practical evaluation of processes and situations of great complexity, as well as experimentation entirely by software. It also enabled advanced study of the mind, and mapping of the human genome became possible with the Human Genome Project.[15] Distributed computing projects such as Folding@home explore protein folding.
- Algorithmic trading has increased the efficiency and liquidity of financial markets by using artificial intelligence, machine learning, and other statistical and numerical techniques on a large scale.[18] High frequency algorithmic trading can also exacerbate volatility.[19]
- Computer graphics and computer-generated imagery have become almost ubiquitous in modern entertainment, particularly in television, cinema, advertising, animation and video games. Even films that feature no explicit CGI are usually "filmed" now on digital cameras, or edited or postprocessed using a digital video editor. [*citation needed*]
- Simulation of various processes, including computational fluid dynamics, physical, electrical, and electronic systems and circuits, as well as societies and social situations (notably war games) along with their habitats, among many others. Modern computers enable optimization of such designs as complete aircraft. Notable in electrical and electronic circuit design are SPICE, as well as software for physical realization of new (or modified) designs. The latter includes essential design software for integrated circuits.[*citation needed*]
- Artificial intelligence is becoming increasingly important as it gets more efficient and complex. There are many applications of the AI, some of which can be seen at home, such as robotic vacuum cleaners. It is also present in video games and on the modern battlefield in drones, anti-missile systems, and squad support robots.

## Philosophy

A number of computer scientists have argued for the distinction of three separate paradigms in computer science. Peter Wegner argued that those paradigms are science, technology, and mathematics.[20] Peter Denning's working group argued that they are theory, abstraction (modeling), and design.[21] Amnon H. Eden described them as the "rationalist paradigm" (which treats computer science as a branch of mathematics, which is prevalent in theoretical computer science, and mainly employs deductive reasoning), the "technocratic paradigm" (which might be found in engineering approaches, most prominently in software engineering), and the "scientific paradigm" (which approaches computer-related artifacts from the empirical perspective of natural sciences, identifiable in some branches of artificial intelligence).[22]

### Name of the field

The term "computer science" appears in a 1959 article in Communications of the ACM,[23] in which Louis Fein argues for the creation of a *Graduate School in Computer Sciences* analogous to the creation of Harvard Business School in 1921, justifying the name by arguing that, like management science, it is applied and interdisciplinary in nature, yet at the same time, has all the characteristics of an academic discipline.[24] His efforts, and those of others such as numerical analyst George Forsythe, were rewarded: universities went on to create such programs, starting with Purdue in 1962.[25] Despite its name, a significant amount of computer science does not involve the study of computers themselves. Because of this, several alternative names have been proposed.[26] Certain departments of major universities prefer the term *computing science*, to emphasize precisely that difference. Danish scientist Peter Naur suggested the term *datalogy*,[27] to reflect the fact that the scientific discipline revolves around data and data treatment, while not necessarily involving computers. The first scientific institution to use the term was the Department of Datalogy at the University of Copenhagen, founded in 1969, with Peter Naur being the first professor in datalogy. The term is used mainly in the Scandinavian countries. Also, in the early days of computing, a number of terms for the practitioners of the field of computing were suggested in the *Communications of the ACM* – *turingineer*, *turologist*, *flow-charts-man*, *applied meta-mathematician*, and *applied epistemologist*.[28] Three months later in the same journal, *comptologist* was suggested, followed next year by *hypologist*.[29] The term *computics* has also been suggested.[30] In Europe, terms derived from contracted translations of the expression "automatic information" (e.g. "informazione automatica" in Italian) or "information and mathematics" are often used, e.g. *informatique* (French), *Informatik* (German), *informatica* (Italy), *informática* (Spain, Portugal) or *informatika* (Slavic languages) are also used and have also been adopted in the UK (as in *the School of Informatics of the University of Edinburgh*).[31]

A folkloric quotation, often attributed to—but almost certainly not first formulated by—Edsger Dijkstra, states that "computer science is no more about computers than astronomy is about telescopes."[32] The design and deployment of computers and computer systems is generally considered the province of disciplines other than computer science. For example, the study of computer hardware is usually considered part of computer engineering, while the study of commercial computer systems and their deployment is often called information technology or information systems. However, there has been much cross-fertilization of ideas between the various computer-related disciplines. Computer science research also often intersects other disciplines, such as philosophy, cognitive science, linguistics, mathematics, physics, statistics, and logic.

Computer science is considered by some to have a much closer relationship with mathematics than many scientific disciplines, with some observers saying that computing is a mathematical science.[] Early computer science was strongly influenced by the work of mathematicians such as Kurt Gödel and Alan Turing, and there continues to be a useful interchange of ideas between the two fields in areas such as mathematical logic, category theory, domain theory, and algebra.

The relationship between computer science and software engineering is a contentious issue, which is further muddied by disputes over what the term "software engineering" means, and how computer science is defined.[33]

David Parnas, taking a cue from the relationship between other engineering and science disciplines, has claimed that the principal focus of computer science is studying the properties of computation in general, while the principal focus of software engineering is the design of specific computations to achieve practical goals, making the two separate but complementary disciplines.[34]

The academic, political, and funding aspects of computer science tend to depend on whether a department formed with a mathematical emphasis or with an engineering emphasis. Computer science departments with a mathematics emphasis and with a numerical orientation consider alignment with computational science. Both types of departments tend to make efforts to bridge the field educationally if not across all research.

## Areas of computer science

As a discipline, computer science spans a range of topics from theoretical studies of algorithms and the limits of computation to the practical issues of implementing computing systems in hardware and software.[][35] CSAB, formerly called *Computing Sciences Accreditation Board* – which is made up of representatives of the Association for Computing Machinery (ACM), and the IEEE Computer Society (IEEE-CS)[36] – identifies four areas that it considers crucial to the discipline of computer science: *theory of computation*, *algorithms and data structures*, *programming methodology and languages*, and *computer elements and architecture*. In addition to these four areas, CSAB also identifies fields such as software engineering, artificial intelligence, computer networking and communication, database systems, parallel computation, distributed computation, computer-human interaction, computer graphics, operating systems, and numerical and symbolic computation as being important areas of computer science.[]

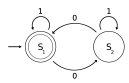
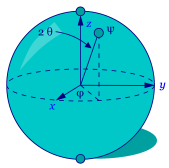
### Theoretical computer science

The broader field of theoretical computer science encompasses both the classical theory of computation and a wide range of other topics that focus on the more abstract, logical, and mathematical aspects of computing.

#### Theory of computation

According to Peter J. Denning, the fundamental question underlying computer science is, *"What can be (efficiently) automated?"*[] The study of the theory of computation is focused on answering fundamental questions about what can be computed and what amount of resources are required to perform those computations. In an effort to answer the first question, computability theory examines which computational problems are solvable on various theoretical models of computation. The second question is addressed by computational complexity theory, which studies the time and space costs associated with different approaches to solving a multitude of computational problems.

The famous "P=NP?" problem, one of the Millennium Prize Problems,[37] is an open problem in the theory of computation.

|  | | **P = NP** ? | **GNITIRW-TERCES** |  |
|---|---|---|---|---|
| Automata theory | Computability theory | Computational complexity theory | Cryptography | Quantum computing theory |

### Information and coding theory

Information theory is related to the quantification of information. This was developed by Claude E. Shannon to find fundamental limits on signal processing operations such as compressing data and on reliably storing and communicating data. Coding theory is the study of the properties of codes (systems for converting information from one form to another) and their fitness for a specific application. Codes are used for data compression, cryptography, error detection and correction, and more recently also for network coding. Codes are studied for the purpose of designing efficient and reliable data transmission methods.

### Algorithms and data structures

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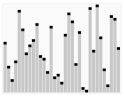
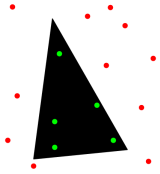
| $O(n^2)$ |  |  |  |
| Analysis of algorithms | Algorithms | Data structures | Computational geometry |

### Programming language theory

Programming language theory (PLT) is a branch of computer science that deals with the design, implementation, analysis, characterization, and classification of programming languages and their individual features. It falls within the discipline of computer science, both depending on and affecting mathematics, software engineering and linguistics. It is an active research area, with numerous dedicated academic journals.

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| Type theory | Compiler design | Programming languages |

### Formal methods

Formal methods are a particular kind of mathematically based technique for the specification, development and verification of software and hardware systems. The use of formal methods for software and hardware design is motivated by the expectation that, as in other engineering disciplines, performing appropriate mathematical analysis can contribute to the reliability and robustness of a design. They form an important theoretical underpinning for software engineering, especially where safety or security is involved. Formal methods are a useful adjunct to software testing since they help avoid errors and can also give a framework for testing. For industrial use, tool support is required. However, the high cost of using formal methods means that they are usually only used in the development of high-integrity and life-critical systems, where safety or security is of utmost importance. Formal methods are best described as the application of a fairly broad variety of theoretical computer science fundamentals, in particular logic calculi, formal languages, automata theory, and program semantics, but also type systems and algebraic data types to problems in software and hardware specification and verification.

## Applied computer science

Applied Computer Science aims at identifying certain Computer Science concepts that can be used directly in solving real world problems.

### Artificial intelligence

This branch of computer science aims to or is required to synthesise goal-orientated processes such as problem-solving, decision-making, environmental adaptation, learning and communication which are found in humans and animals. From its origins in cybernetics and in the Dartmouth Conference (1956), artificial intelligence (AI) research has been necessarily cross-disciplinary, drawing on areas of expertise such as applied mathematics, symbolic logic, semiotics, electrical engineering, philosophy of mind, neurophysiology, and social intelligence. AI is associated in the popular mind with robotic development, but the main field of practical application has been as an embedded component in areas of software development which require computational understanding and modeling such as finance and economics, data mining and the physical sciences. The starting-point in the late 1940s was Alan Turing's question "Can computers think?", and the question remains effectively unanswered although the "Turing Test" is still used to assess computer output on the scale of human intelligence. But the automation of evaluative and predictive tasks has been increasingly successful as a substitute for human monitoring and intervention in domains of computer application involving complex real-world data.

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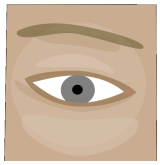
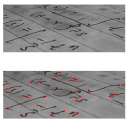
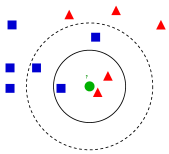
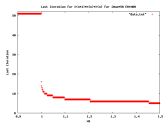
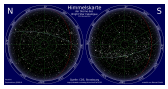
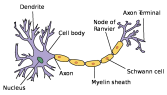
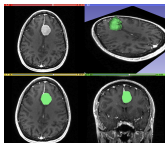
| |  |  |  |
| Machine learning | Computer vision | Image processing | Pattern recognition |
| |  |  | |
| Cognitive science | Data mining | Evolutionary computation | Information retrieval |
|  | abcdefghijk<br>lmnopqrstuvwxyz<br><br>ABCDEFGHIJKLMN<br>OPQRSTUVWXYZ | |  |
| Knowledge representation | Natural language processing | Robotics | Medical Image Computing |

### Computer architecture and engineering

Computer architecture, or digital computer organization, is the conceptual design and fundamental operational structure of a computer system. It focuses largely on the way by which the central processing unit performs internally and accesses addresses in memory. The field often involves disciplines of computer engineering and electrical engineering, selecting and interconnecting hardware components to create computers that meet functional, performance, and cost goals.

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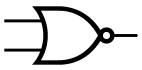
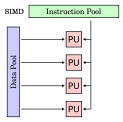
|  | |   | |
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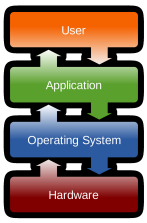
|   | | | |
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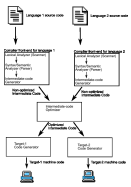
| | |  | |
| Ubiquitous computing | Systems architecture | Compiler design | Programming languages |

### Computer graphics and visualization

Computer graphics is the study of digital visual contents, and involves synthese and manipulations of image data. The study is connected to many other fields in computer science, including computer vision, image processing, and computational geometry, and is heavily applied in the fields of special effects and video games.

### Computer security and cryptography

Computer security is a branch of computer technology, whose objective includes protection of information from unauthorized access, disruption, or modification while maintaining the accessibility and usability of the system for its intended users. Cryptography is the practice and study of hiding (encryption) and therefore deciphering (decryption) information. Modern cryptography is largely related to computer science, for many encryption and decryption algorithms are based on their computational complexity.

### Computational science

Computational science (or scientific computing) is the field of study concerned with constructing mathematical models and quantitative analysis techniques and using computers to analyze and solve scientific problems. In practical use, it is typically the application of computer simulation and other forms of computation to problems in various scientific disciplines.

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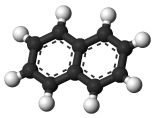
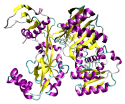
| | |  |  |
| Numerical analysis | Computational physics | Computational chemistry | Bioinformatics |

### Computer Networks

This branch of computer science aims to manage networks between computers worldwide.

### Concurrent, parallel and distributed systems

Concurrency is a property of systems in which several computations are executing simultaneously, and potentially interacting with each other. A number of mathematical models have been developed for general concurrent computation including Petri nets, process calculi and the Parallel Random Access Machine model. A distributed system extends the idea of concurrency onto multiple computers connected through a network. Computers within the same distributed system have their own private memory, and information is often exchanged amongst themselves to achieve a common goal.

### Databases and information retrieval

A database is intended to organize, store, and retrieve large amounts of data easily. Digital databases are managed using database management systems to store, create, maintain, and search data, through database models and query languages.

### Health Informatics

Health Informatics in computer science deals with computational techniques for solving problems in health care.

### Information science

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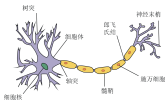
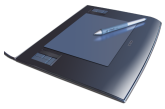
| |  | abcdefghijk<br>lmnopqrstuvwxyz<br><br>ABCDEFGHIJKLMN<br>OPQRSTUVWXYZ |  |
| Information retrieval | Knowledge representation | Natural language processing | Human–computer interaction |

### Software engineering

Software engineering is the study of designing, implementing, and modifying software in order to ensure it is of high quality, affordable, maintainable, and fast to build. It is a systematic approach to software design, involving the application of engineering practices to software. Software engineering deals with the organizing and analyzing of software— it doesn't just deal with the creation or manufacture of new software, but its internal maintenance and arrangement. Both computer applications software engineers and computer systems software engineers are projected to be among the fastest growing occupations from 2008 and 2018.

## Academia

### Conferences

Conferences are strategic events of the Academic Research in computer science. During those conferences, researchers from the public and private sectors present their recent work and meet. Proceedings of these conferences are an important part of the computer science literature.

## Education

Some universities teach computer science as a theoretical study of computation and algorithmic reasoning. These programs often feature the theory of computation, analysis of algorithms, formal methods, concurrency theory, databases, computer graphics, and systems analysis, among others. They typically also teach computer programming, but treat it as a vessel for the support of other fields of computer science rather than a central focus of

high-level study. The ACM/IEEE-CS Joint Curriculum Task Force "Computing Curriculum 2005" (and 2008 update) [38] gives a guideline for university curriculum.

Other colleges and universities, as well as secondary schools and vocational programs that teach computer science, emphasize the practice of advanced programming rather than the theory of algorithms and computation in their computer science curricula. Such curricula tend to focus on those skills that are important to workers entering the software industry. The process aspects of computer programming are often referred to as software engineering.

While computer science professions increasingly drive the U.S. economy, computer science education is absent in most American K-12 curricula. A report entitled "Running on Empty: The Failure to Teach K-12 Computer Science in the Digital Age" [39] was released in October 2010 by Association for Computing Machinery (ACM) [40] and Computer Science Teachers Association (CSTA) [41], and revealed that only 14 states have adopted significant education standards for high school computer science. The report also found that only nine states count high school computer science courses as a core academic subject in their graduation requirements. In tandem with "Running on Empty", a new non-partisan advocacy coalition - Computing in the Core (CinC) [42] - was founded to influence federal and state policy, such as the Computer Science Education Act [43], which calls for grants to states to develop plans for improving computer science education and supporting computer science teachers.

Within the United States a gender gap in computer science education has been observed as well. Research conducted by the WGBH Educational Foundation and the Association for Computing Machinery (ACM) revealed that more than twice as many high school boys considered computer science to be a “very good” or “good” college major than high school girls.[44] In addition, the high school Advanced Placement (AP) exam for computer science has displayed a disparity in gender. Compared to other AP subjects it has the lowest number of female participants, with a composition of about 15 percent women.[45] This gender gap in computer science is further witnessed at the college level, where 31 percent of undergraduate computer science degrees are earned by women and only 8 percent of computer science faculty consists of women.[46] According to an article [47] published by the Epistemic Games Group [48] in August 2012, the number of women graduates in the computer science field has declined to 13 percent.

## Notes

**[2]** In 1851

[4] Anthony Hyman, *Charles Babbage, pioneer of the computer*, 1982

**[5]** "The introduction of punched cards into the new engine was important not only as a more convenient form of control than the drums, or because programs could now be of unlimited extent, and could be stored and repeated without the danger of introducing errors in setting the machine by hand; it was important also because it served to crystallize Babbage's feeling that he had invented something really new, something much more than a sophisticated calculating machine." Bruce Collier, 1970

**[7]** "In this sense Aiken needed IBM, whose technology included the use of punched cards, the accumulation of numerical data, and the transfer of numerical data from one register to another", Bernard Cohen, p.44 (2000)

**[8]** Brian Randell, p.187, 1975

[9] The Association for Computing Machinery (ACM) was founded in 1947.

[11] Computer science pioneer Samuel D. Conte dies at 85 (http://www.cs.purdue.edu/feature/conte.html) July 1, 2002

[13] http://archive.computerhistory.org/resources/text/IBM/IBM.709.1957.102646304.pdf

[14] David Kahn, The Codebreakers, 1967, ISBN 0-684-83130-9.

[15] http://www.cis.cornell.edu/Dean/Presentations/Slides/bgu.pdf

[18] Black box traders are on the march (http://www.telegraph.co.uk/money/main.jhtml?xml=/money/2006/08/27/ccsoft27.xml) The Telegraph, August 26, 2006

**[24]** id., p. 11

[25] Donald Knuth (1972). *"George Forsythe and the Development of Computer Science"* (http://www.stanford.edu/dept/ICME/docs/history/forsythe_knuth.pdf). Comms. ACM.

[26] Matti Tedre (2006). The Development of Computer Science: A Sociocultural Perspective (http://epublications.uef.fi/pub/urn_isbn_952-458-867-6/urn_isbn_952-458-867-6.pdf), p.260

**[28]** Communications of the ACM 1(4):p.6

**[29]** Communications of the ACM 2(1):p.4

**[30]** IEEE Computer 28(12):p.136

[31] P. Mounier-Kuhn, *L'Informatique en France, de la seconde guerre mondiale au Plan Calcul. L'émergence d'une science*, Paris, PUPS, 2010, ch. 3 & 4.
[32] See the entry "Computer science" on Wikiquote for the history of this quotation.
[33] M. Tedre (2011) Computing as a Science: A Survey of Competing Viewpoints (http://www.springerlink.com/content/v66j682n57602453/), Minds and Machines 21(3), 361-387
[34] , p. 19: "Rather than treat software engineering as a subfield of computer science, I treat it as an element of the set, Civil Engineering, Mechanical Engineering, Chemical Engineering, Electrical Engineering, [...]"
[37] Clay Mathematics Institute (http://www.claymath.org/millennium/P_vs_NP/) P=NP
[39] http://www.acm.org/runningonempty/
[40] http://www.acm.org/
[41] http://csta.acm.org/
[42] http://www.computinginthecore.org/
[43] http://www.govtrack.us/congress/bill.xpd?bill=h111-5929&tab=summary
[44] http://www.acm.org/membership/NIC.pdf
[47] http://edgaps.org/gaps/number-of-women-in-computer-science-fields-shrinking-can-epistemic-games-help-solve-the-problem/
[48] http://edgaps.org/gaps/

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## Further reading

Overview

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  - "Within more than 70 chapters, every one new or significantly revised, one can find any kind of information and references about computer science one can imagine. [...] all in all, there is absolute nothing about Computer Science that can not be found in the 2.5 kilogram-encyclopaedia with its 110 survey articles [...]." (Christoph Meinel, *Zentralblatt MATH*)
- van Leeuwen, Jan (1994). *Handbook of Theoretical Computer Science*. The MIT Press. ISBN 0-262-72020-5.
  - "[...] this set is the most unique and possibly the most useful to the [theoretical computer science] community, in support both of teaching and research [...]. The books can be used by anyone wanting simply to gain an understanding of one of these areas, or by someone desiring to be in research in a topic, or by instructors wishing to find timely information on a subject they are teaching outside their major areas of expertise." (Rocky Ross, *SIGACT News*)
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  - "Since 1976, this has been the definitive reference work on computer, computing, and computer science. [...] Alphabetically arranged and classified into broad subject areas, the entries cover hardware, computer systems, information and data, software, the mathematics of computing, theory of computation, methodologies, applications, and computing milieu. The editors have done a commendable job of blending historical perspective and practical reference information. The encyclopedia remains essential for most public and academic library reference collections." (Joe Accardin, Northeastern Illinois Univ., Chicago)
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  - "Covering a period from 1966 to 1993, its interest lies not only in the content of each of these papers — still timely today — but also in their being put together so that ideas expressed at different times complement each other nicely." (N. Bernard, *Zentralblatt MATH*)

Articles

- Peter J. Denning. *Is computer science science?* (http://portal.acm.org/citation.cfm?id=1053309&coll=&dl=ACM&CFID=15151515&CFTOKEN=6184618), Communications of the ACM, April 2005.
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- Research evaluation for computer science, Informatics Europe report (http://www.informatics-europe.org/docs/research_evaluation.pdf)Wikipedia:Link rot. Shorter journal version: Bertrand Meyer, Christine Choppy, Jan van Leeuwen and Jorgen Staunstrup, *Research evaluation for computer science*, in Communications of the ACM, vol. 52, no. 4, pp. 31–34, April 2009.

Curriculum and classification

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- Norman Gibbs, Allen Tucker. "A model curriculum for a liberal arts degree in computer science". *Communications of the ACM*, Volume 29 Issue 3, March 1986.


## External links

| Library resources |
| --- |
| **About Computer science** |
| • Resources in your library (http://tools.wmflabs.org/ftl/cgi-bin/ftl?st=wp&su=Computer+science)<br>• Resources in other libraries (http://tools.wmflabs.org/ftl/cgi-bin/ftl?st=wp&su=Computer+science&library=0CHOOSE0) |

- Computer science (http://www.dmoz.org/Computers/Computer_Science//) at the Open Directory Project
- Scholarly Societies in Computer Science (http://www.lib.uwaterloo.ca/society/compsci_soc.html)
- Best Papers Awards in Computer Science since 1996 (http://jeffhuang.com/best_paper_awards.html)
- Photographs of computer scientists (http://se.ethz.ch/~meyer/gallery/) by Bertrand Meyer
- EECS.berkeley.edu (http://www.eecs.berkeley.edu/department/history.shtml)

Bibliography and academic search engines

- CiteSeer$^{x}$ (http://citeseerx.ist.psu.edu/) (article): search engine, digital library and repository for scientific and academic papers with a focus on computer and information science.
- DBLP Computer Science Bibliography (http://dblp.uni-trier.de/) (article): computer science bibliography website hosted at Universität Trier, in Germany.
- The Collection of Computer Science Bibliographies (http://liinwww.ira.uka.de/bibliography/) (article)

Professional organizations

- Association for Computing Machinery (http://www.acm.org/)
- IEEE Computer Society (http://www.computer.org/)
- Informatics Europe (http://www.informatics-europe.org/)

Misc

- Computer Science - Stack Exchange (http://cs.stackexchange.com/) a community run Question and Answer site for Computer Science

# STEM fields

| Part of a series on |
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| **Science** |
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| • **Outline**<br>• **Portal**<br>• **Category** |

**STEM fields** or **STEM education** is an acronym for the fields of study in the categories of science, technology, engineering, and mathematics in the United States.[1] The term is typically used in addressing education policy and curriculum choices in schools from kindergarten through college to improve the nation's competitiveness in technology development. It has implications for workforce development, national security concerns and immigration policy.[1]

## Definition

The definitions of the purview of STEM, and what is excluded, varies from organization to organization. In the broader definition, STEM degrees includes the fields of Chemistry, Computer and Information Technology Science, Engineering, Geosciences, Life Sciences, Mathematical Sciences, Physics, and STEM Education and Learning Research

## Predictors of success in STEM fields

Graduates with advanced degrees in math/CS, physical science and engineering were characterized by having greater spatial abilities than verbal abilities, but graduates with advanced degrees in biology were characterized by having greater verbal abilities than spatial abilities.[2] Moreover, math/CS, physical science and engineering graduates had 0.40 standard deviations higher "general intellectual ability" than graduates of biology.[2]

Engineering schools that take GRE verbal scores into account for admissions might be unintentionally selecting lower qualified students, because verbal ability could be a "suppressor variable" that excludes students with higher GRE math scores and/or higher spatial ability.[2]

## In the United States

In the United States, the acronym began to be used in education and immigration debates in initiatives to begin to address the perceived lack of qualified candidates for high-tech jobs. It also addresses concern that the subjects are often taught in isolation, instead of as an integrated curriculum.[] Maintaining a citizenry that is well versed in the STEM fields is a key portion of the public education agenda of the United States.[] The acronym has been widely used in the immigration debate regarding access to United States work visas for immigrants who are skilled in these fields. It has also become commonplace in education discussions as a reference to the shortage of skilled workers and inadequate education in these areas.[]

### National Science Foundation

Many organizations in the United States follow the guidelines of the National Science Foundation on what constitutes a STEM field. The NSF uses a broader category to define STEM subjects which includes subjects in the fields of Chemistry, Computer and Information Technology Science, Engineering, Geosciences, Life Sciences, Mathematical Sciences, Physics and Astronomy, Social Sciences (Anthropology, Economics, Psychology and Sociology), and STEM Education and Learning Research.[3] Eligibility for scholarship programs such as the CSM STEM Scholars Program use the NSF definition.[4]

It is the only American federal agency whose mission includes support for all fields of fundamental science and engineering, except for medical sciences.[5] Its disciplinary program areas include scholarships, grants, fellowships in fields like Biological Sciences, Computer & Information Science & Engineering, Education and Human Resources, Engineering, Environmental Research & Education, Geosciences, International Science & Engineering, Mathematical & Physical Sciences, Social, Behavioral & Economic Sciences, Cyberinfrastructure and Polar Programs.[3] A list of NSF's STEM degree fields can be found on the NSF site [6].

### Immigration policy

Although many organizations in the United States follow the guidelines of the National Science Foundation on what constitutes a STEM field, the United States Department of Homeland Security (DHS) has its own functional definition used for immigration policy.[7] In 2012, DHS or ICE announced an expanded list of science, technology, engineering, and math (STEM) designated-degree programs that qualify eligible graduates on student visas for an optional practical training (OPT) extension. Under the OPT program, international students who graduate from colleges and universities in the United States are able to remain in the country and receive training through work experience for up to 12 months. Students who graduate from a designated STEM degree program can remain for an additional 17 months on an OPT STEM extension.[8] The expanded list released by DHS in 2012 full list can be found at http://www.ice.gov/doclib/sevis/pdf/stem-list.pdf.

**STEM Eligible degrees in US Immigration** An exhaustive list of STEM disciplines does not exist because the definition varies by organization. The U.S. Immigration and Customs Enforcement lists disciplines including:[9] Physics, Actuarial Science, Chemistry, Mathematics, Applied Mathematics, Statistics, Computer Science, Computational Science, Psychology, Biochemistry, Robotics, Computer Engineering, Electrical Engineering, Electronics, Mechanical Engineering, Industrial Engineering, Information Science, Civil Engineering, Aerospace Engineering, Chemical Engineering, Astrophysics, Astronomy, Optics, Nanotechnology, Nuclear Physics, Mathematical Biology, Operations Research, Neurobiology, Biomechanics, Bioinformatics, Acoustical Engineering, Geographic Information Systems, Atmospheric Sciences, Educational/Instructional technology, Software Engineering, and Educational Research

## Education

STEM generally supports broadening the study of engineering within each of the other subjects, and beginning engineering at younger grades, even elementary school. It also brings STEM education to all students rather than only the gifted programs. In his 2012 Budget, President Obama renamed and broadened the "Mathematics and Science Partnership (MSP)" to award block grants to states for improving teacher education in those subjects.[10]

In 2006, the United States National Academies expressed their concern about the declining state of STEM education in the United States. Its Committee on Science, Engineering and Public Policy developed a list of 10 actions federal policy makers could take to advance STEM education in the United States to compete successfully in the 21st century. Their top three recommendations were to:

- increase America's talent pool by improving K–12 science and mathematics education;
- strengthen the skills of teachers through additional training in science, math and technology; and
- enlarge the pipeline of students prepared to enter college and graduate with STEM degrees.

The National Aeronautics and Space Administration also has implemented programs and curricula to advance STEM education in order to replenish the pool of scientists, engineers and mathematicians who will lead space exploration in the 21st century.

**American Competitiveness Initiative** In the State of the Union Address on January 31, 2006, United States President George W. Bush announced the American Competitiveness Initiative. Bush proposed the initiative to address shortfalls in federal government support of educational development and progress at all academic levels in the STEM fields. In detail, the initiative called for significant increases in federal funding for advanced R&D programs (including a doubling of federal funding support for advanced research in the physical sciences through DOE) and an increase in U.S. higher education graduates within STEM disciplines.

The NASA Means Business competition, sponsored by the Texas Space Grant Consortium, furthers that goal. College students compete to develop promotional plans to encourage students in middle and high school to study STEM subjects and to inspire professors in STEM fields to involve their students in outreach activities that support STEM education.

The National Science Foundation has numerous programs in STEM education, including some for K-12 students such as the ITEST Program that supports The Global Challenge Award ITEST Program. STEM programs have been implemented in some Arizona schools. They implement higher cognitive skills for students and enable them to inquire and use techniques used by professionals in the Science, Technology, Engineering and Mathematical fields.

The STEM Academy is a national non-profit status organization dedicated to improving STEM literacy for all students. It represents a recognized national next-generation high impact academic model. The practices, strategies, and programming are built upon a foundation of identified national best practices which are designed to improve under-represented minority and low-income student growth, close achievement gaps, decrease dropout rates, increase high school graduation rates and improve teacher and principal effectiveness. The STEM Academy represents a flexible use academic model which targets all schools and is for all students.[11]

Project Lead The Way (PLTW) is a leading provider of STEM education curricular programs to middle and high schools in the United States. The national non-profit organization has over 5,200 programs in over 4,700 schools in all 50 states. Programs include a high school engineering curriculum called Pathway To Engineering, a high school Biomedical Sciences program, and a middle school engineering and technology program called Gateway To Technology. PLTW provides the curriculum and the teacher professional development and ongoing support to create transformational programs in schools, districts, and communities. PLTW programs have been endorsed by President Barack Obama and U.S. Secretary of Education Arne Duncan as well as various state, national, and business leaders.

**STEM Education Coalition**

"The Science, Technology, Engineering, and Mathematics (STEM) Education Coalition[12] works to support STEM programs for teachers and students at the U. S. Department of Education, the National Science Foundation, and other agencies that offer STEM related programs." Activity of the STEM Coalition seems to have slowed since September 2009.

**Boy Scouts of America**

The Boy Scouts of America have announced the roll out of an awards program in the spring of 2012 to promote more interest and involvement in the STEM disciplines. The NOVA and SUPERNOVA awards are available to Boy Scouts, Cub Scouts and Venturers as they complete specific requirements appropriate to their program level in each of the four main STEM program areas (Science, Technology, Engineering, Mathematics).

## Legislation

America COMPETES Act of 2007: The America COMPETES Act (P.L. 110-69) became law on August 9, 2007. The act responds to concerns that the United States may not be able to compete economically with other nations in the future due to insufficient investment today in science and technology research and science, technology, engineering, and mathematics (STEM) education and workforce development. The America COMPETES Act is intended to increase the nation's investment in science and engineering research and in STEM education from kindergarten to graduate school and postdoctoral education.

The act authorizes funding increases for the National Science Foundation (NSF), National Institute of Standards and Technology (NIST) laboratories, and the Department of Energy (DOE) Office of Science over FY2008–FY2010. Robert Gabrys, Director of Education at NASA's Goddard Space Flight Center, articulated success as increased student achievement, early expression of student interest in STEM subjects, and student preparedness to enter the workforce.

## Jobs

November 2012 - White House announcement before congressional vote on STEM Jobs Act puts president in opposition to many of the Silicon Valley firms and executives who bankrolled his re-election campaign.[13] The Department of Labor identifies fourteen sectors that are "projected to add substantial numbers of new jobs to the economy or affect the growth of other industries or are being transformed by technology and innovation requiring new sets of skills for workers."[14]

Advanced Manufacturing, Automotive, Construction, Financial Services, Geospatial Technology, Homeland Security, Information Technology, Transportation, Aerospace, Biotechnology, Energy, Healthcare, Hospitality and Retail.

The Department of Commerce notes STEM fields careers are some of the best-paying and have the greatest potential for job growth in the early 21st century. The report also notes that STEM workers play a key role in the sustained growth and stability of the U.S. economy, and training in STEM fields generally results in higher wages, whether or not they work in a STEM field.[15]

## In the United Kingdom

The National STEM Centre of the UK houses the largest open collection of resources for teachers of science, design and technology, engineering and mathematics in the United Kingdom. Alongside contemporary resource materials, including print, multimedia, and practical resources, is a growing archive collection which showcases several decades of curriculum development.[*citation needed*]

Resources for use with early years to post-16 students are freely available in both physical and electronic ("eLibrary") collections. These materials include:[*citation needed*]

- Contemporary print, multimedia, interactive, and practical teaching materials
- Archive of STEM videos from TeachersTV
- Digitised archive resources drawn from recent decades
- Research publications with bearing on classroom practice
- Cross-curricular resources to aid innovative STEM teaching approaches
- The UK Space Education Office (ESERO-UK) collection of space education resources

To foster colleagues work with the resource collections, an online Community is freely available. The Community include options for teachers to collate links to resources from the eLibrary or elsewhere on the web in 'My lists', and share their own materials and ideas in 'Groups'. [*citation needed*]

Further information on how to access the eLibrary, as well as how to register with the National STEM Centre, is available from the National STEM Centre.[16]

## Proposed enhancements

Some have suggested STEM by itself is inadequate to rebuild a nation's economy, and have added additional subjects or qualifiers.

- STEAM (Art) -Some have discussed the need for product design in marketing new technologies, and point to the successes of Apple, which combines technology functionality with usability and style.[17][18][19][20][21][22]
- STEAM (Applied Math) [23]
- eSTEM (Environmental STEM) [24][25]

## References


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## External links

- U.S. News & World Report STEM Education blog (http://www.usnews.com/news/blogs/stem-education)
- LEGO Education for STEM in association with Edutech (http://lego.edutech.com/lego-education.html)
- STEM Education Blog: Blog, Resources, Articles, Interviews (http://www.stemeducation.com/)
- STEM Education Coalition (http://www.stemedcoalition.org/)
- National Defense Education Program (http://www.ndep.us)
- NASA information for educators (http://www.nasa.gov/audience/foreducators/index.html)
- National Institute of Aerospace (NIA) Education Outreach (http://www.nianet.org/resources/Education/K-12-Education-Outreach/K-12-Education.aspx)
- NASA Pre-Service Teacher Institute (http://education.jsc.nasa.gov/psti/)
- "The Gender Chip Project" A documentary by Helen De Michiel on Women in STEM Fields (http://www.genderchip.org/)
- STEM School (http://www.stemschool.com) — STEM education articles, resources, and K-12 STEM school directory
- The Global Challenge (http://www.globalchallengeaward.org) — Game-based STEM learning
- The COMETS Initiative (http://www.ocean.edu/comets.htm) — Career-Oriented Mathematics, Engineering, Technology and Science

- Sloan Career Cornerstone Center (http://www.careercornerstone.org) — Provides in-depth career information for over 190 fields in STEM
- STEM Careers (http://www.stemcareer.com/) — Provides a wide variety of information on STEM for students, counselors, and teachers
- STEM2Stern (http://www.stem2stern.org) — US Navy's program to promote STEM careers
- Boy Scouts of America (http://www.scouting.org/stem.aspx) — STEM/NOVA page
- mOway robot (http://www.moway-robot.com)
- STEM connector (http://www.stemconnector.org)
- Center for Mathematics, Science, and Technology (http://cemast.tumblr.com)
- Center for Mathematics, Science, and Technology (http://cemast.tumblr.com) — Blog and Resources from Illinois State University's Center for Mathematics, Science, and Technology
- Grandma got STEM (http://ggstem.wordpress.com) International collection of pictures and remembrances of women in STEM fields
- Engineering career path (http://www.gr8bit.ru/gr8bit_engineering.html) from DIY project GR8BIT

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