# OS X for UNIX Users

## The power of UNIX. The simplicity of Mac.

Technology Brief
July 2011


### Features

**Open source UNIX foundation**

- POSIX-compliant, Open Brand UNIX 03 Registered Product
- Open source kernel based on FreeBSD and Mach 3.0
- 64-bit OS using LP64 data model
- Support for multiple CPU and GPU cores via Grand Central Dispatch and OpenCL
- Hand-tuned, standards-compliant scalar and vector math libraries

**Standards-based networking**

- Complete IP-based architecture supporting IPv4, IPv6, and L2TP/IPSec VPN
- Rich zero-configuration discovery and naming via Bonjour and Dynamic DNS
- Interoperable file serving via NFS, AFP, SMB/CIFS, and FTP
- Powerful Apache web services
- Open Directory services built on LDAP and Kerberos for single sign-on

**Comprehensive UNIX user environment**

- Standards-based graphics built on PDF (Quartz), OpenGL, and H.264 (QuickTime)
- Full-screen terminal with xterm-256color support
- Familiar UNIX/Linux utilities (such as emacs, vim, and bash)
- Free Xcode developer tools based on Clang/LLVM

OS X version 10.7 Lion combines a proven UNIX® foundation with the easy-to-use Mac interface, bringing multicore technology and 64-bit power to the mass market. With powerful technologies such as Grand Central Dispatch (GCD), OpenCL, and IPv6, Lion unleashes the full power of your Mac computer.

There are already tens of millions of OS X users—consumers, scientists, animators, developers, system administrators, and more—making OS X the most widely used UNIX desktop operating system. In addition, OS X is the only UNIX environment that natively runs Microsoft Office, Adobe Photoshop, and thousands of other consumer applications—all side by side with traditional command-line, X11, and Java applications. Tight integration with hardware—from the sleek MacBook to the eight-core Mac Pro computer—is making OS X the platform of choice for an emerging generation of UNIX users.

## Top OS X Lion Innovations for UNIX Users

**XPC**

XPC leverages Grand Central Dispatch (GCD) and launchd to provide a lightweight mechanism for managing and messaging helper processes, including sharing out-of-band data such as file descriptors and media objects. XPC uses entitlements to segregate unsafe operations in separate processes with reduced privileges.

**Terminal**

In addition to supporting Lion's UI innovations such as a full-screen mode plus Auto Save and Resume, Terminal boasts a host of new features including icon status badges, smarter background images, Services items for opening paths and man pages, and the ability to detect and remember the current working directory.

**Versions and Auto Save**

Versions brings the benefits of revision control from source code to ordinary documents. Lion automatically and efficiently saves previous versions, making it trivial to store, compare, and restore them.

**OpenCL enhancements**

Lion includes OpenCL v1.1, which brings improved threading, expanded vector types, support for atomic operations, and enhanced data sharing with OpenGL. OpenCL in Lion uses sophisticated auto-vectorization technology to efficiently execute scalar kernels across CPU vector units—letting you use a single kernel for both GPUs and CPUs. New integration with Xcode and GCD makes OS X Lion an even more powerful platform for developing OpenCL-based applications.

**FileVault 2**

FileVault 2 provides transparent support for encrypting either internal or external drives, thanks to the new Core Storage volume format. It can even encrypt your boot volume or Time Machine drive in the background while you keep working.

**IPv6**

Apple provides best-of-breed support for IPv6, the next-generation 128-bit Internet Protocol, through full support for DHCPv6 and intelligent selection between IPv6 and IPv4 addresses when both are available.

**Updated file sharing**

OS X provides the latest in network interoperability with support for DFS failover and redirects in SMB, and client support for NFSv4.

**OS X: The desktop for open source**
Since Apple first released the Darwin code in 1999, OS X has been closely identified with the open source community. Apple worked with other pioneers to develop one of the first corporate open source licenses and has built ongoing relationships with key projects such as Apache, Python, and Ruby. Today, Apple is the largest single vendor of open source software such as PHP, SSH, and scores of other projects. To learn more, visit www.apple.com/opensource/.

## State-of-the-Art Foundation

The OS X kernel at the heart of Darwin is based on FreeBSD and Mach 3.0. Apple has extended this time-tested Mach/BSD foundation with a number of powerful new features, including:

### Process and memory management

- **Loadable kernel modules.** OS X dynamically loads appropriate kernel extensions, also known as "kexts," for file system and platform support. This leads to a slimmer kernel that users never need to recompile.
- **Kernel programming interfaces.** Rather than giving kexts direct access to kernel data structures, each version of the kernel exports a well-defined programmatic interface known as a KPI, ensuring third-party kernel extensions can still work even if the internal implementation changes.
- **Efficient kernel threads.** Each POSIX thread is queued onto a particular CPU, improving processor affinity and scalability while reducing lock contention. Threads conform to POSIX (1c), including support for cancellation and shared mutexes.
- **User-level real-time support.** Unprivileged threads can request a fixed number of high-priority cycles per millisecond, for example, for burning DVDs. The kernel ensures that such threads keep their contract.
- **Asynchronous I/O.** Both BSD select and SysV poll are implemented on top of the flexible and scalable kqueue APIs from FreeBSD 5, handling file system notifications, signals, and much more.
- **Launchd daemon management.** OS X has replaced init, cron, xinetd, and /etc/rc with launchd, an innovative service that centralizes and simplifies the configuration, management, and monitoring of system, user, and network services. Lion adds the ability to launch jobs when new devices are attached.

**Block objects**
Block objects are extensions to C, Objective-C, and C++ that make it easy for programmers to define self-contained units of works, and are used heavily in Grand Central Dispatch. These types of "closures" are common in dynamically typed interpreted languages, but they have never before been widely available to C programmers.

Apple has published both the Blocks Language Specification and its implementation as open source under the MIT license, added blocks support to GCC 4 and Clang/LLVM, and submitted them for consideration as part of the next version of the C programming language.

- **Grand Central Dispatch.** GCD combines an easy-to-use programming model with highly efficient system services to radically simplify the code needed for parallel and asynchronous processing across multiple cores.
- **XPC.** XPC leverages GCD and launchd to provide a lightweight mechanism for managing and messaging helper processes, including sharing out-of-band data such as file descriptors and media objects.
- **DTrace.** Apple has integrated the DTrace open source project and D language from Solaris into OS X, enabling highly detailed, low-level reports of system and application behavior in languages including C, C++, Objective-C, Java, Perl, Python, and Ruby.
- **Unified memory mapping.** OS X maps both virtual memory and files using the same buffer cache, reducing the total amount of wired memory while improving performance.
- **Virtual video RAM (VRAM).** The GPU's VRAM can be backed by main memory, allowing simpler data transfer and the use of larger data sets.
- **POSIX spawn.** OS X natively implements the posix_spawn system call, which reduces memory requests and improves performance compared with vfork + exec.

LP64 data type sizes (in bytes)

| Type | 32-bit size | 64-bit size |
|---|---|---|
| `char` | 1 | 1 |
| `short` | 2 | 2 |
| `int` | 4 | 4 |
| `long` | 4 | 8 |
| `long long` | 8 | 8 |
| `float` | 4 | 4 |
| `double` | 8 | 8 |
| `long double` | 16 | 16 |
| `void *` | 4 | 8 |
| `void (*)(void)` | 4 | 8 |
| `size_t` | 4 | 8 |
| `off_t` | 8 | 8 |

## 64-bit services

Building on a time-tested open source foundation, OS X gives consumers a comprehensive 64-bit computing experience via the following features:

- **64-bit system applications.** Virtually all built-in applications and services—from the Finder and Mail to Safari and Spotlight—run as 64-bit processes on capable hardware.
- **Single operating system installation.** OS X is installed as a single, universal operating system that natively runs both 32-bit and 64-bit applications, so you can easily access your existing applications alongside those optimized for 64-bit processors.
- **Device compatibility.** Thanks to the universal nature of OS X, 64-bit applications work well with your existing printers, storage devices, and expansion cards.
- **Massive memory capacity.** You get all the benefits of 64-bit memory addressing: a theoretical address space of 16 exabytes, direct access to 128 terabytes of virtual memory, and use of all the physical RAM supported by the hardware.
- **Universal binaries.** Universal binaries contain both 32-bit and 64-bit versions of applications and libraries, with the system dynamically loading whichever is appropriate.
- **Enhanced security.** OS X incorporates numerous modern security techniques into the 64-bit runtime, making applications more resistant to attack.
- **Improved performance.** With the shift to 64-bit applications, OS X delivers dramatic performance improvements by taking advantage of the wider data paths and additional registers available to 64-bit processes on modern Intel processors. For example, Safari runs JavaScript 50 percent faster with a 64-bit process.
- **64-bit kernel.** Lion uses a 64-bit kernel on capable hardware. The larger address space enables much faster system calls, which dramatically boosts the performance of network services and other I/O-intensive applications.

## Hardware I/O

I/O Kit is the device driver subsystem of OS X. This powerful, object-oriented architecture in embedded C++ helps device manufacturers rapidly create drivers that run safely in a multiprocessing, preemptive, hot-pluggable environment.

Key technologies supported by I/O Kit include:

- **Power management.** Power management APIs and notification orderings ensure that devices power down only after their dependent systems have been appropriately notified.
- **Video.** The IOVideo family is designed to support professional video cards and adds a new IOVideoDevice class for writing video capture device drivers. It is based on the IOStream class, which provides a high-level API for managing DMAs and other high-bandwidth data transfers without the need to worry about different hardware architectures and optimal caching strategies.
- **USB.** Apple jump-started the market for plug-and-play USB peripherals in 1998 and still leads the industry with built-in support for USB drives, cameras, game inputs, audio, MIDI, and printers. You may never have to download another driver.
- **FireWire.** Apple's award-winning FireWire (IEEE 1394) is a boon to professional audio and video production. OS X provides a comprehensive suite of drivers that take full advantage of the hot pluggability, daisy chaining, and power management capabilities of FireWire.
- **Thunderbolt.** A revolutionary I/O technology, Thunderbolt supports high-resolution displays and high-performance data devices through a single, compact port. It sets new standards for speed, flexibility, and simplicity.

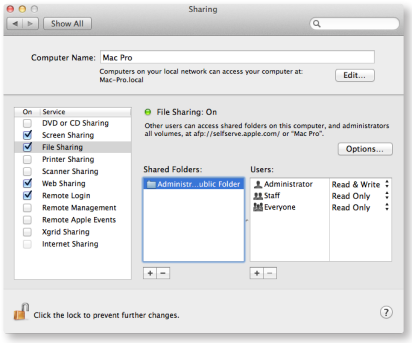
Apple's AirPort brought Wi-Fi to the mass market.

- **Ethernet.** OS X supports everything from 10BASE-T to 10 gigabits, including automatic link detection, duplex matching, IEEE 802.3ad link aggregation, jumbo frames, and TCP segment offloading.
- **AirPort.** Every Mac is designed to work seamlessly with 802.11b/g/a/n networks, such as those provided by the AirPort Extreme Base Station. Thanks to Wide-Area Bonjour and NAT-PMP support, you can even access your home printer and drives from the public Internet.
- **Bluetooth.** Built-in support for a wide range of Bluetooth devices is closely integrated with OS X Sync Services, so information can be shared seamlessly among devices and one or more Mac computers.
- **Fibre Channel.** OS X provides built-in support for Apple's Fibre Channel cards, the technology of choice for high-performance storage.

## TCP/IP networking

The OS X TCP/IP implementation is based on the original BSD networking stack, but over the years, Apple has added numerous powerful enhancements:

- **Self-tuning TCP.** OS X sets the initial max TCP window according to the local resources and connection type, enabling TCP to do a better job of optimizing performance on high-bandwidth/high-latency networks.
- **Multithreading.** The networking stack is fully multithreaded, with at least one input queue per network interface and distinct pools of output message buffers (mbufs) for each CPU, to minimize the need for shared locks.
- **Configuration API.** Rather than manually editing multiple configuration files, developers can use a high-level C API to programmatically set advanced network preferences.
- **IPv6.** Apple provides best-of-breed support for IPv6, the next-generation 128-bit Internet Protocol, including dynamic selection of IPv6 vs. IPv4 addressing, anonymous addressing, and both stateless and stateful Dynamic Host Configuration Protocol (DHCP) support.




Enable file and Internet sharing with a single click.

- **Internet sharing.** A single click allows your Mac to share its Internet connection over any other interface to one or more computers using Network Address Translation (NAT) and DHCP. This works with a Mac, a PC, and even a virtual system.
- **Captive network support.** Like iOS, OS X will now automatically detect the presence of a captive network and prompt for the authentication necessary to reach the public Internet.
- **Apache HTTP.** OS X uses Apache for both personal file sharing and high-end web serving.

## File system architecture

Apple's dynamic implementation of BSD's virtual file system layer (VFS) allows OS X to load numerous local and remote file systems on demand, including:

### Disk file systems

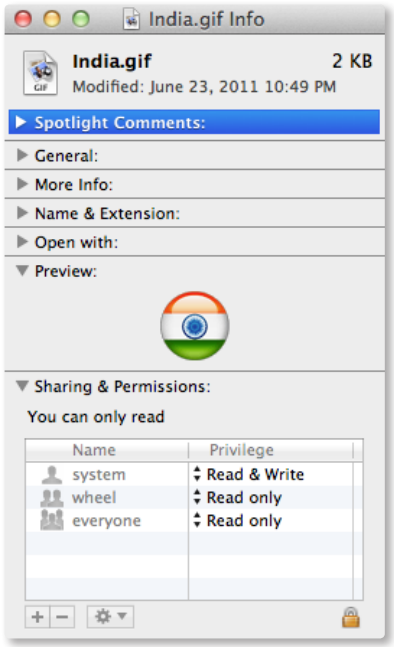
- **HFS+**, the default, provides fast Btree-based lookups, robust aliases, and rich metadata (including fine-grained access controls and extended attributes). It supports compression and has journaled (HFSJ) and case-sensitive (HFSX) variants.
- **ISO 9660**, the standard CD-ROM format.
- **UDF 2.5**, the Universal Disk Format, is fully read/write and works with standard block storage (flash, hard drive) as well as optical (CD, DVD) devices.
- **FAT32**, the standard Windows interchange format.
- **NTFS**, a read-only implementation of the high-end Windows file system format.

### Network file systems

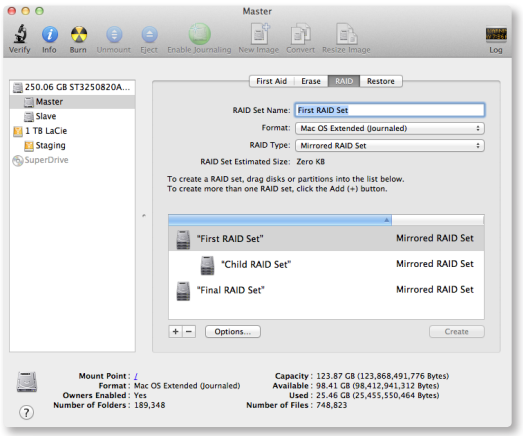
- **AFP**, the Apple Filing Protocol.
- **NFS**, the Network File System standard for UNIX, supporting NFSv3 clients and servers as well as NFSv4 clients.
- **SMB/CIFS**, Microsoft's Server Message Block/Common Internet File System file service for Windows, including support for DFS.
- **FTP (read-only)**, the File Transfer Protocol file system.

## File system features

- **Core Storage.** This new volume format makes it easy to add new storage features (such as full disk encryption) without modifying HFS+.
- **Extended attributes.** The xattr routines support arbitrary attributes and a high-level copyfile API that automatically transfers all metadata and permissions.
- **Boot root.** OS X automatically creates a special HFSJ partition containing the last three known good copies of the bootloader, kernel, and essential kexts to enable the use of nonbootable "root" partitions (such as NTFS).
- **Access control lists (ACLs).** The Finder can set read and write permissions for files and folders on both a per-user and per-group basis. The underlying kauth subsystem can also limit:
  - Read/write/execute/append for either data or extended attributes
  - Read/write (regular) attributes
  - Read/write security settings or change ownership
  - Add/delete files, directories, or children
  - Search/list directories
- **File locking.** OS X provides unified file locking across AFP, CIFS (SMB), and NFS volumes, simplifying resharing and reducing the risk of data corruption.
- **Network home directories.** OS X supports AFP, SMB, and NFS network home directories, which can all be automatically synced with OS X Server.
- **RAID.** In addition to striping (RAID 0) and mirroring (RAID 1), Apple's built-in software RAID supports combined 0+1 and 1+0 when using four or more disks, providing greater fault tolerance and higher performance.




Control exactly who is allowed to access your files.




Easily create redundant arrays of inexpensive disks.

- **Error checking.** The system will perform automatic "fsck" checks on reboot.
- **fsevents.** User processes can be notified whenever files are added, removed, or modified.

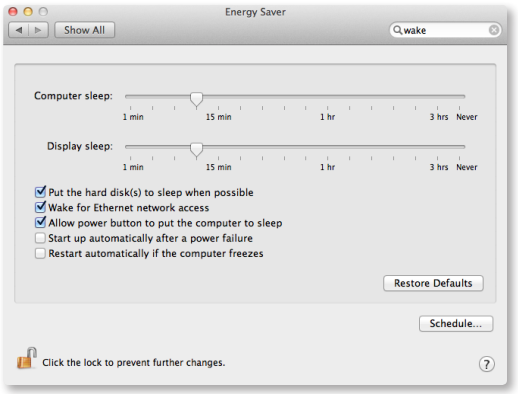
## System Services

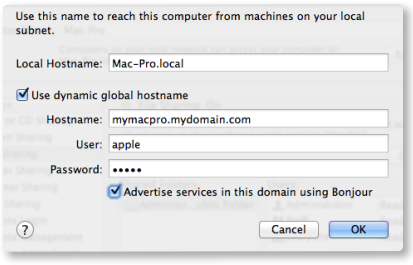
OS X integrates mobility, directory services, and security throughout the system in order to bring the openness and flexibility of UNIX to the mass market while still ensuring a safe, user-friendly environment.

### Mobility

The ability to deal with a constantly changing physical and network environment is one of the key features that distinguishes OS X from other UNIX systems. Beneath the friendly interface for configuring and switching networks lies a very powerful infrastructure.

- **Notifications.** Notify is a comprehensive systemwide service for communicating both kernel-to-application and application-to-application events. This reduces the reliance on signals and other legacy UNIX mechanisms previously used for this purpose.
- **configd.** This configuration daemon notifies the system to automatically reroute Internet traffic when either wired or wireless connections come and go, to help affected services maintain connectivity.
- **Safe disconnect.** OS X is the first system to gracefully mount and unmount NFS, DAV, and SMB/CIFS volumes based on changes to network status or available directory services, providing an uninterrupted experience from either the GUI or the command line.
- **Power management.** Tight integration with the underlying hardware allows OS X to minimize power consumption while preserving responsiveness. This includes safe sleep to preserve data even if the battery runs out, and a low-power wake that runs background services without lighting the display.




Sharing Preferences let you configure Dynamic DNS for Bonjour over wide area networks.

### Directory services

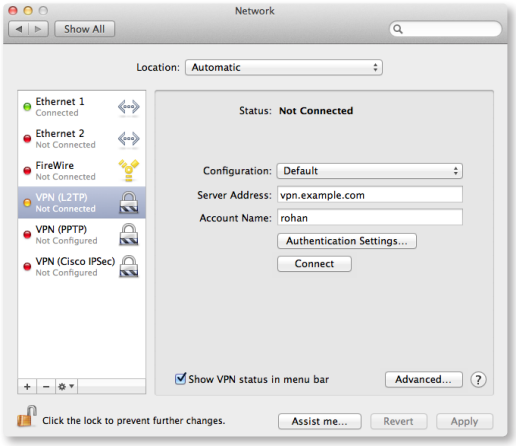
OS X is designed to minimize configuration effort by automatically pulling information from a variety of sources, including:

- **Open Directory.** Apple's Open Directory is a unified architecture for managing user and system information across the network. While primarily designed for use with LDAP v2/v3 (the IETF standard Lightweight Directory Access Protocol), Open Directory also supports Microsoft's Active Directory and Sun's Network Information System (NIS).
- **Bonjour.** Bonjour uses industry-standard zero-configuration networking to help you automatically find printers, file servers, and other network services on your local network. Bonjour also works across NAT gateways and can help you access your home machines from across the Internet.
- **DNS (Domain Name Services).** OS X Server uses mDNSResponder, the technology underlying Bonjour, to provide name lookup services, including Dynamic DNS and Secure DNS for automatic updates of IP addresses.

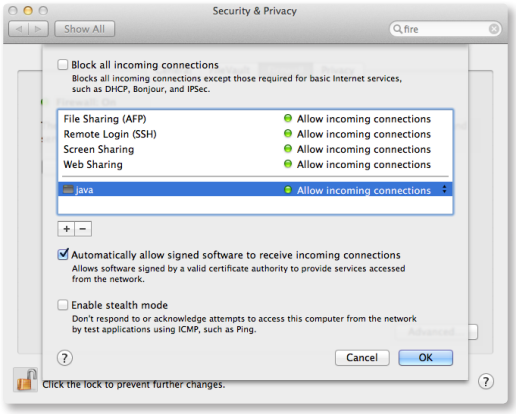
- **Wake on Demand.** Wake on Demand allows your computer to sleep yet still advertise available services via a Bonjour Sleep Proxy (typically an AirPort Extreme Base Station) located on your network. The proxy will automatically wake your machine when clients attempt to access it; your computer will even periodically do a "maintenance wake" to renew its DHCP address and other leases.

## Secure networking

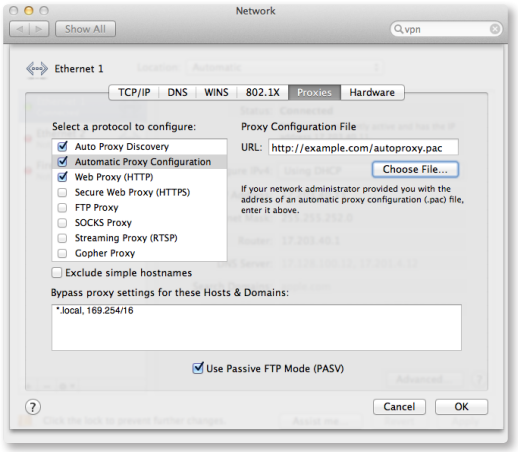
- **VPN via L2TP/IPSec or PPTP.** OS X includes a virtual private network (VPN) client that supports the Internet standard Layer 2 Tunneling Protocol (L2TP) over IPSec (the secure version of IPv4), as well as the older Point-to-Point Tunneling Protocol (PPTP).




- **SSH (Secure Shell).** OS X allows OpenSSH to store and retrieve private key pass phrases from a keychain, reducing the need to type a pass phrase. The ssh-agent is launched on demand on login, allowing it to be accessed from any process—for example, multiple terminal windows.
- **Built-in firewall.** In addition to the ipfw2-based systemwide firewall, OS X includes an application firewall that can be configured to allow only incoming access to preapproved applications and services.



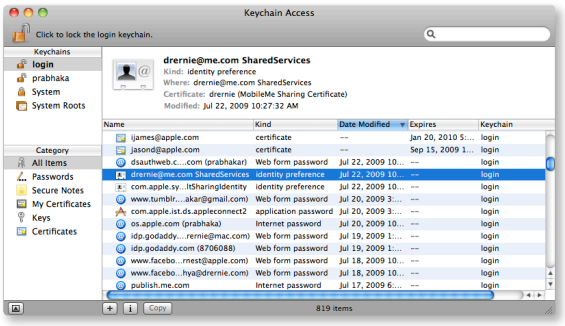
- **Proxy auto-configuration.** The networking APIs of OS X support PAC files, including locating them using the Web Proxy Autodiscovery Protocol (WPAD). This means that applications such as Safari will automatically route requests via any site-specific proxy services.




## Authentication

OS X provides a state-of-the-art security infrastructure based on modern, standards-based technologies for authenticating who you are and authorizing what you can do. Key technologies include:

- **Systemwide keychains.** In OS X, certificates and user passwords (for example, for mail accounts and websites) are stored in a secure keychain, which provides them only to verified, preauthorized applications.




- **Password assistant.** To further reduce the risk of compromised accounts, OS X warns users about choosing an easily guessed password and encourages stronger alternatives.
- **Certificates.** Public key infrastructure (PKI) authentication is integrated throughout OS X. PKI keys and other X.509 certificates can be stored in smart cards, keychains, Address Book, or LDAP directories.
- **Unified authentication service.** A single security daemon (securityd) processes authentication requests from both GUI and command-line applications to simplify the implementation, adoption, and auditing of new forms of authentication.
- **Kerberos single sign-on.** Apple has adopted the MIT-developed, IETF-specified Kerberos v5 protocol for systemwide single sign-on, allowing users to authenticate against multiple services without retyping passwords or sending them over the network. Every system automatically generates its own principals, allowing it to vend secure services that are fully compatible with other Kerberos-based implementations. The Lion implementation is based on the new Heimdal server.

- **Pluggable Authentication Modules.** The PAM library is an industry-standard API used by numerous UNIX programs and OS X services. It enables them to dynamically load shared authentication modules for everything from Open Directory to Kerberos.

## System security

Apple used its deep understanding of user experience to build security into OS X from the ground up in order to provide a safe environment with minimal inconvenience. Some of the key advantages of OS X are as follows:

- **Role-based administration.** OS X does not require users to use the Administrator or root account to manage the system. Instead, the initial user (or other authorized user) can authenticate into the Administrator role, which allows one specific privileged operation at a time.
- **Strict filesystem permissions.** Most folders in /System and /Library are only writable by root, reducing the risk of them being modified accidentally or maliciously.
- **Network services off by default.** Unlike many systems, OS X defaults to having very few open ports. This approach avoids unnecessary exposure, yet authorized users can still enable precisely the services they need with a single click.
- **Secure launch services.** To minimize the risk of invisibly activating rogue software, the OS X gatekeeper warns users before launching mail attachments, adding new Safari handlers, or opening an unknown application.
- **Sandboxing.** The sandbox facility limits a process's access to system resources, minimizing the scope of damage even if a vulnerability were to be exploited.
- **Privilege separation.** XPC makes it easy to use sandboxing to factor applications into isolated components with varying privilege levels, with specific permissions granted implicitly in response to user actions.
- **Fast user switching.** As a multiuser operating system, UNIX has made it possible to give users their own accounts with appropriate privileges and strict separation between them. OS X makes it easy and convenient for any family to do the same, so they can easily set up individual user accounts (for example, with specific parental controls) and then quickly and safely switch between them on shared computers.
- **FileVault 2.** If you're worried about sensitive data, enabling FileVault 2 will encrypt your entire disk. The password will be securely stored in the user's keychain, which can only be unlocked by a personal password or a site-specific master password. Core Storage makes it easy to encrypt your boot disk in the background while you continue working.

- **Fast, reliable security updates.** Apple is committed to providing rapid-response software updates to address vulnerabilities identified by CERT/FIRST or other groups. The user is periodically prompted to install updates, which OS X Server can limit to only those preapproved at that site. Administrators can also use Apple Remote Desktop to proactively push essential updates onto systems.

## Numerical Libraries

OS X includes a robust suite of standard math libraries manually optimized for specific processor models, plus high-performance, state-of-the-art libraries for digital signal processing, image processing, and linear algebra. While these libraries work on every Mac, they are tuned to take advantage of native hardware capabilities, including 64-bit pointers, vector engines, and multicore CPUs.

### Math libraries

The standard C math library in OS X (libm, part of libSystem) complies with both C99 and IEEE 754. In addition to the traditional double-precision operations, it supports very fast single-precision functions, as well as long double and complex functions.


OpenCL is an open standard for parallel programming managed by the Khronos Group.

### OpenCL

OpenCL is a powerful API, language, and runtime that lets any application tap into the vast computing power of the GPU using IEEE-754 arithmetic, opening up incredible performance opportunities. In Lion, OpenCL kernels can be written as separate files, then run as blocks on the GPU or CPU using a special Grand Central Dispatch queue.

### Accelerate

Apple has a unique Accelerate framework that provides:

- **Vector digital signal processing (vDSP).** Optimized Fast Fourier Transforms (FFTs), convolutions, vector arithmetic, and other common video and audio processing tasks for both single- and double-precision data.
- **Vector image processing (vImage).** Optimized routines for convolutions, compositing, color correction, and other image processing tasks, even for gigapixel images.
- **vForce.** vForce is designed to wring optimal efficiency from modern hardware by specifying multiple operands at once, allowing only default IEEE-754 exception handling.
- **LAPACK (Linear Algebra Package).** Written on top of BLAS, LAPACK provides industry-standard APIs for solving common linear algebra problems.
- **BLAS (Basic Linear Algebra Subprograms) Levels I, II, and III.** These high-quality "building block" routines perform basic vector and matrix operations using standard APIs.
- **vMathLib.** This vectorized version of libm provides transcendental operations, enabling you to perform standard math functions on many operands at once.

## The UNIX User Experience Redefined

UNIX users will quickly recognize the full BSD command-line environment in OS X, with the usual editors (for example, emacs, vim, and nano), utilities (ls, cp, bsdtar, and so on), and shells (bash/sh, tcsh/csh, zsh, and ksh). But there's much more to OS X—not only friendly applications for productivity and the digital lifestyle, but also powerful services, utilities, and tools that will improve the workflow of any command-line user.

### Next-generation services

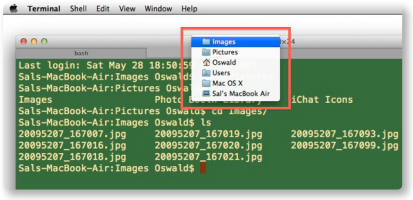
OS X includes several breakthrough technologies that promise to dramatically expand the capabilities of the UNIX command line.

- **Spotlight.** Spotlight is a lightning-fast way to find anything on your computer—documents, email, and so on—based on their metadata (for example, keywords and properties). The command-line tool mdfind returns a list of pathnames whose metadata match a given string, rather like a systemwide grep, while mdls displays metadata associated with a file. Spotlight can also remotely search mounted AFP volumes.
- **Xgrid.** Xgrid in OS X makes it easy to run virtually any command-line program (such as a scientific computation or a multimedia renderer) on a grid of Mac computers.
- **Quick Look.** The Quick Look API enables the system to quickly display preview images of documents in Time Machine, the Dock, or the Finder. It supports common Internet formats, Microsoft Office documents, and even source code.
- **Time Machine.** Time Machine automatically maintains archival copies of all your documents, applications, and personal information on a second hard drive. Even better, it provides a beautiful, intuitive interface for discovering and recovering deleted items.

### Terminal environment

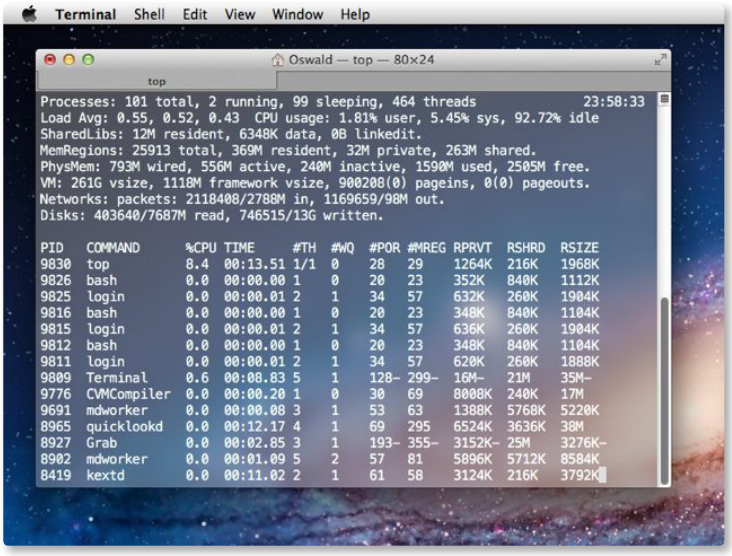
Terminal is an xterm-compliant shell with full international support, a Safari style tabbed interface, and streamlined preferences for easy access to the UNIX command line. Lion brings a host of new features, including:

- **Colored output.** The default TERM value is now xterm-256color, supporting colorized output (for example, "ls -G") and BCE (background color erase) beyond the traditional 16 colors.
- **Enhanced drag-and-drop support.** In a Terminal window, the proxy icon in the window is an alias to the current directory. You can drag it from the window title bar into a session or tab to insert a reference to the current directory or file. Also, if you drag a folder from the Finder onto the Terminal icon, a new Terminal session to the dragged-on directory will be created.
- **Full-screen support.** Like other applications, Terminal windows use disappearing scroll bars and an optional full-screen mode.
- **New status controls.** These include display in tabs and minimized windows, as well as the showing of live content, with unread text, busy, and bell count indicators.
- **Session support.** Terminal tabs automatically update to show the current process and working directory. New tabs and windows can be set to open in the current working directory. On restart, Terminal will not only reopen your previous tabs, but also show their prior contents.
- **Built-in systemwide services.** Using services, you can create new Terminal sessions or man page lookups based on selections of Finder folders or text in any application.

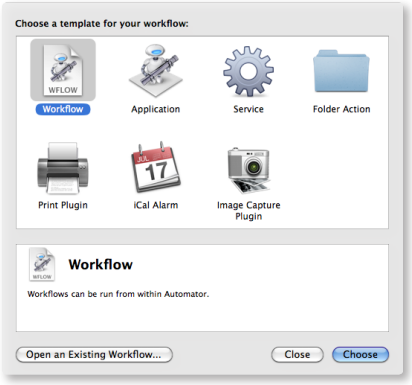



In Lion, the proxy icon in a Terminal window is an alias to the current directory, whose path hierarchy can be displayed by clicking the title bar while holding down the Command (⌘) key.

- **Richer background images.** Terminal windows now support multiple background images (including randomized images from folders) and a new translucent view that blurs the background when activated.

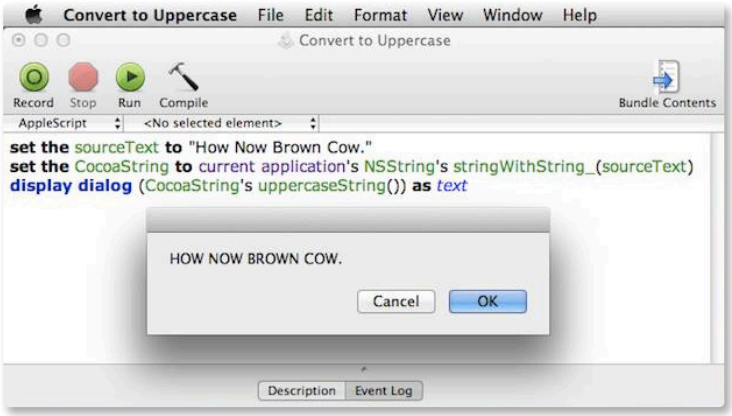



## Scripting and automation



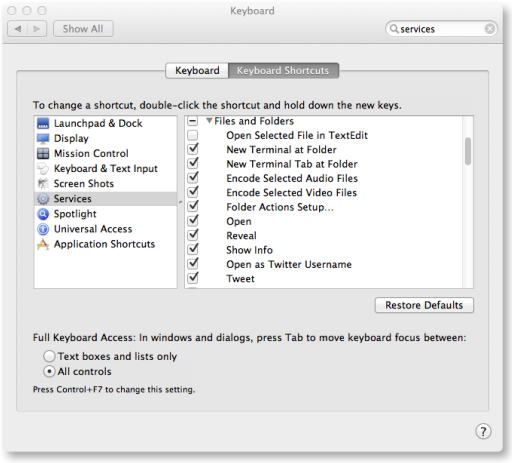

Automator comes with templates for many kinds of workflows.

- **AppleScript** is Apple's native language for application automation. Its English-like syntax generates Apple events, which use a scripting dictionary (provided by most Mac applications) to programmatically create, edit, or transform their documents.
- The **AppleScript Editor** makes it easy to create, edit, and run AppleScripts. In Lion, it can create and edit lightweight Cocoa-AppleScript applications that provide Cocoa user interfaces from within AppleScript code.




- **Open Scripting Architecture (OSA) scripts** including AppleScript can be activated by contextual menus, user interface elements, iCal events, and folder actions (on drag and drop).
- **Automator** provides a graphical environment for assembling Actions (typically built from AppleScript or shell scripts) into sophisticated workflows, which can be saved as standalone applications or a wide range of plug-ins.
- The **BridgeSupport framework** enhances bridges by providing additional metadata and stubs for inline functions; almost every Cocoa framework in OS X has complete bridge data for use by AppleScript, Python, Ruby, or any other BridgeSupport-enabled language.

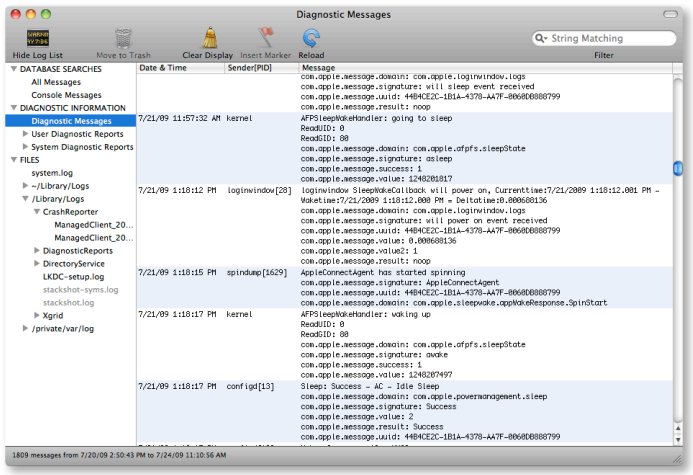
- The **AppleEventBridge framework** provides an elegant way for Cocoa applications (including bridged scripting languages) to generate Apple events based on an application's dictionary, even generating appropriate header files if necessary.
- **Services menu** lets you focus on only those actions relevant to your current selection, whether in the menu bar, the Finder action menu, or a contextual menu. They can also be disabled and assigned shortcuts from the Keyboard pane in System Preferences.




## Utility applications

In addition to the dozens of rich GUI applications for end users, OS X ships several advanced applications (primarily in /Applications/Utilities) of particular interest to developers, administrators, and UNIX enthusiasts, including:

- **Activity Monitor,** to monitor the resource consumption (CPU, memory, disk, networking, and so on) of all processes on the system.
- **Console,** to search the system and crash log databases.



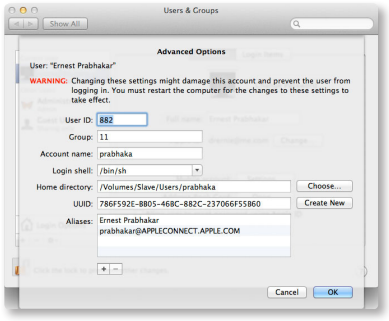

- **Directory,** so you can manage shared contacts and resources, particularly for use with OS X Server.
- **Disk Utility,** to create and repair volumes, partitions, and disk images.
- **Grapher,** to visualize 2D and 3D mathematical functions.
- **Keychain Access,** so you can create and manage all your passwords and certificates.

- **Migration Assistant,** which lets you transfer your files and important settings from an older Mac or PC to a new Mac.
- **Network Utility,** a unified graphical front end to several common diagnostic tools, for example, netstat, ping, lookup, traceroute, and whois.
- **Podcast Capture** and **Podcast Publisher,** which let you easily capture high-quality video and audio from a camera or the screen then publish it to a server.
- **RAID Utility,** for configuring hardware RAID cards (for example, on a Mac Pro) to improve performance and reliability.
- **System Preferences,** enabling you to graphically manage network settings, user accounts, sharing, and other functionality.
- **System Information,** which provides information about your computer, such as the hardware and software installed, the serial number and operating system, how much memory is installed, and what peripheral devices are connected. This can be very useful when troubleshooting any problems that might occur.

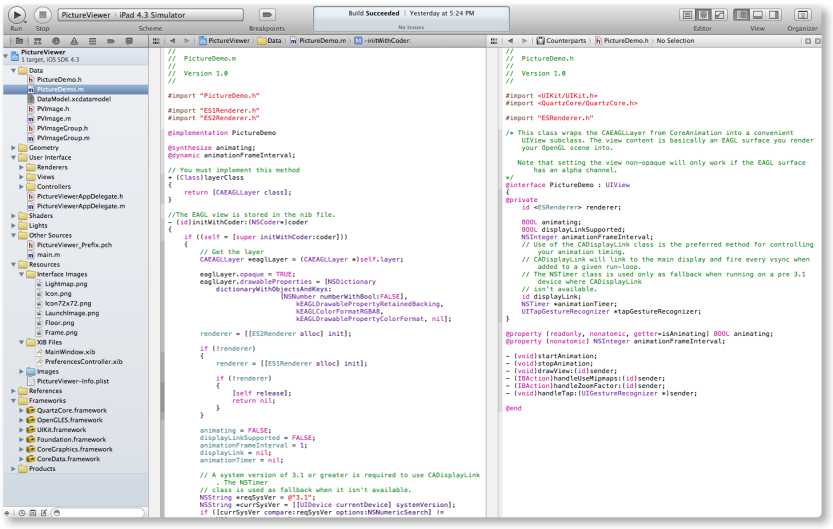
## Integrated developer tools

The same Xcode developer tools used by Apple engineers to build OS X are available for free on the Mac App Store.*

- **Xcode.** Xcode 4 is Apple's trailblazing integrated development environment (IDE) for OS X, designed to streamline Cocoa and Cocoa Touch development.




Use the Advanced Options contextual menu to configure low-level details in System Information after creating a local user account.



Xcode shows your errors, warnings, and data values as you debug, all within the same editor window.

- **Interface Builder.** Interface Builder is a graphical editor for designing user interface components for both Carbon and Cocoa applications. It makes creating an application's user interface easy, and it supports core animation for dynamic effects. Interface Builder files can also be validated and examined using the ibtool command-line utility.
- **Instruments.** This time-based analysis tool provides a GarageBand-like track interface for aggregating data from DTrace and other "instruments."
- **LLVM.** A powerful compiler designed for modularity and efficiency, LLVM enables fast compilation, sophisticated optimizations, rich static analyses, and tight integration with Xcode.

- **Dynamic linker.** dyld is the dynamic link editor for loading and linking dynamic libraries written in Apple's native MACH-O format, which for compatibility with other UNIX systems supports standard dlopen/dlclose calls and semantics.
- **IORegistryExplorer.** IORegistryExplorer provides beautiful diagrams of the various dependencies between IOKit components and devices.
- **FileMerge.** FileMerge enables you to graphically view changes between files (analogous to that from the UNIX diff command), which is particularly useful when refactoring in Xcode.

## For More Information

Now that you've been introduced to the robust UNIX functionality of OS X, here are several resources to help you find out more about specific topics.

- OS X overview: www.apple.com/macosx
- Open source projects in OS X: www.apple.com/opensource
- Scientific computing: www.apple.com/science
- Open source code releases: opensource.apple.com
- Developing on OS X: developer.apple.com/mac
- Open source collaborations: macosforge.org

*The Mac App Store is available only to persons age 13 or older in the U.S. and many other countries. Requires compatible hardware and software, and Internet access. An Apple ID is required to make purchases from the Mac App Store.

 July 2011 L425835A