

# **Cygwin User's Guide**

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# Table of Contents

<b>1. Cygwin Overview .....</b>	<b>1</b>
1.1. What is it? .....	1
1.2. Are the Cygwin tools free software? .....	1
1.3. A brief history of the Cygwin project .....	1
1.4. Expectations for UNIX Programmers.....	2
1.5. Expectations for Windows Programmers.....	2
1.6. Highlights of Cygwin Functionality .....	2
1.6.1. Introduction.....	3
1.6.2. Supporting both Windows NT and 9x .....	3
1.6.3. Permissions and Security .....	4
1.6.4. File Access .....	4
1.6.5. Text Mode vs. Binary Mode .....	6
1.6.6. ANSI C Library.....	6
1.6.7. Process Creation.....	6
1.6.8. Signals.....	7
1.6.9. Sockets .....	8
1.6.10. Select.....	8
<b>2. Setting Up Cygwin .....</b>	<b>10</b>
2.1. Internet Setup .....	10
2.1.1. Download Source.....	10
2.1.2. Selecting an Install Directory.....	11
2.1.3. Local Package Directory .....	11
2.1.4. Connection Method.....	11
2.1.5. Choosing Mirrors .....	12
2.1.6. Choosing Packages .....	12
2.1.7. Download and Installation Progress .....	13
2.1.8. Icons .....	13
2.1.9. Post-Install Scripts .....	13
2.2. Environment Variables .....	13
2.3. Changing Cygwin's Maximum Memory .....	14
2.4. NT security and the ntsec usage .....	15
2.4.1. NT security.....	16
2.4.2. Process privileges.....	19
2.4.3. File permissions .....	19
2.4.4. New since Cygwin release 1.1 .....	21
2.4.5. The mapping leak.....	23
2.4.6. New acl API.....	25

2.4.7. New setuid concept .....	26
2.4.8. New since Cygwin release 1.3.3 .....	28
2.4.9. Special values of user and group ids .....	29
2.5. Customizing bash .....	30
<b>3. Using Cygwin.....</b>	<b>32</b>
3.1. Mapping path names .....	32
3.1.1. Introduction .....	32
3.1.2. The Cygwin Mount Table .....	32
3.1.3. Additional Path-related Information .....	34
3.2. Text and Binary modes .....	34
3.2.1. The Issue .....	34
3.2.2. The default Cygwin behavior .....	35
3.2.3. Example .....	36
3.2.4. Binary or text? .....	36
3.2.5. Programming .....	37
3.3. File permissions .....	37
3.4. Special filenames .....	38
3.4.1. DOS devices .....	38
3.4.2. POSIX devices .....	38
3.4.3. The .exe extension .....	41
3.4.4. The @pathnames .....	41
3.5. The CYGWIN environment variable .....	42
3.6. Cygwin Utilities .....	44
3.6.1. cygcheck .....	44
3.6.2. cygpath .....	46
3.6.3. dumper .....	47
3.6.4. getfacl .....	48
3.6.5. kill .....	49
3.6.6. mkgroup .....	51
3.6.7. mkpasswd .....	52
3.6.8. mount .....	54
3.6.8.1. Using mount .....	54
3.6.8.2. Cygdrive mount points .....	56
3.6.8.3. Limitations .....	57
3.6.9. passwd .....	57
3.6.10. ps .....	59
3.6.11. regtool .....	60
3.6.12. setfacl .....	62
3.6.13. ssp .....	64
3.6.14. strace .....	67

3.6.15. umount .....	68
3.7. Using Cygwin effectively with Windows .....	69
3.7.1. Pathnames .....	69
3.7.2. Console Programs .....	70
3.7.3. Cygwin and Windows Networking .....	70
3.7.4. The cygutils package.....	71
3.7.5. Creating shortcuts with cygutils.....	71
3.7.6. Printing with cygutils .....	72
<b>4. Programming with Cygwin.....</b>	<b>73</b>
4.1. Using GCC with Cygwin.....	73
4.1.1. Console Mode Applications.....	73
4.1.2. GUI Mode Applications.....	73
4.2. Debugging Cygwin Programs .....	76
4.3. Building and Using DLLs .....	77
4.3.1. Building DLLs .....	78
4.3.2. Linking Against DLLs .....	79
4.4. Defining Windows Resources .....	79

# List of Examples

2-1. /etc/passwd.....	20
2-2. /etc/group.....	21
2-5. /etc/passwd.....	23
2-6. /etc/group.....	23
3-1. Displaying the current set of mount points.....	33
3-2. Using @pathname .....	41
3-3. Example cygpath usage .....	47
3-4. Using the kill command.....	50
3-5. Setting up the groups file for local accounts.....	52
3-6. Setting up the passwd file for local accounts.....	53
3-7. Using an alternate home root.....	53
3-8. Displaying the current set of mount points.....	54
3-9. Adding mount points .....	55
3-10. Changing the default prefix .....	57
4-1. Building Hello World with GCC .....	73
4-2. Compiling with -g.....	76
4-3. "break" in gdb.....	77
4-4. Debugging with command line arguments .....	77

# Chapter 1. Cygwin Overview

## 1.1. What is it?

The Cygwin tools are ports of the popular GNU development tools and utilities for Windows NT and 9x. They function through the use of the Cygwin library which provides the UNIX system calls and environment that these programs require.

With the tools installed, programmers may write Win32 console or GUI applications that make use of the standard Microsoft Win32 API and/or the Cygwin API. As a result, it is possible to easily port many significant UNIX programs without the need for extensive changes to the source code. This includes configuring and building most of the available GNU software (including the development tools included with the Cygwin distributions). Even if the compiler tools are of little to no use to you, you may have interest in the many standard UNIX utilities. They can be used both from the bash shell (provided) or from the command.com.

## 1.2. Are the Cygwin tools free software?

Yes. Parts are GNU software (gcc, gas, ld, etc...), parts are covered by the standard X11 license, some of it is public domain, some of it was written by Red Hat and placed under the GPL. None of it is shareware. You don't have to pay anyone to use it but you should be sure to read the copyright section of the FAQ for more information on how the GNU General Public License may affect your use of these tools. If you intend to port a proprietary application using the Cygwin library, you may want the Cygwin proprietary-use license. For more information about the proprietary-use license, please go to <http://www.redhat.com/software/tools/cygwin/>. Customers of the native Win32 GNUPro should feel free to submit bug reports and ask questions through the normal channels. All other questions should be sent to the project mailing list <cygwin@cygwin.com>.

## 1.3. A brief history of the Cygwin project

The first thing done was to enhance the development tools (gcc, gdb, gas, et al) so that they could generate/interpret Win32 native object files.

The next task was to port the tools to Win NT/9x. We could have done this by rewriting large portions of the source to work within the context of the Win32 API. But this would have meant spending a huge amount of time on each and every tool. Instead, we took a substantially different approach by writing a shared library (the Cygwin DLL) that adds the necessary UNIX-like functionality missing from the Win32 API (fork, spawn, signals, select, sockets, etc.). We call this new interface the Cygwin API. Once written, it was possible to build working Win32 tools using UNIX-hosted cross-compilers, linking against this library.

From this point, we pursued the goal of producing native tools capable of rebuilding themselves under Windows 9x and NT (this is often called self-hosting). Since neither OS ships with standard UNIX user tools (fileutils, textutils, bash, etc...), we had to get the GNU equivalents working with the Cygwin API. Most of these tools were previously only built natively so we had to modify their configure scripts to be compatible with cross-compilation. Other than the configuration changes, very few source-level changes had to be made. Running bash with the development tools and user tools in place, Windows 9x and NT look like a flavor of UNIX from the perspective of the GNU configure mechanism. Self hosting was achieved as of the beta 17.1 release.

## **1.4. Expectations for UNIX Programmers**

Developers coming from a UNIX background will find a set of utilities they are already comfortable using, including a working UNIX shell. The compiler tools are the standard GNU compilers most people will have previously used under UNIX, only ported to the Windows host. Programmers wishing to port UNIX software to Windows NT or 9x will find that the Cygwin library provides an easy way to port many UNIX packages, with only minimal source code changes.

## **1.5. Expectations for Windows Programmers**

Developers coming from a Windows background will find a set of tools capable of writing console or GUI executables that rely on the Microsoft Win32 API. The linker and dlltool utility may be used to write Windows Dynamically Linked Libraries (DLLs). The resource compiler "windres" is also provided with the native Windows GNUPro tools. All tools may be used from the Microsoft command line prompt, with full support for normal Windows pathnames.

## 1.6. Highlights of Cygwin Functionality

### 1.6.1. Introduction

When a binary linked against the library is executed, the Cygwin DLL is loaded into the application's text segment. Because we are trying to emulate a UNIX kernel which needs access to all processes running under it, the first Cygwin DLL to run creates shared memory areas that other processes using separate instances of the DLL can access. This is used to keep track of open file descriptors and assist fork and exec, among other purposes. In addition to the shared memory regions, every process also has a `per_process` structure that contains information such as process id, user id, signal masks, and other similar process-specific information.

The DLL is implemented using the Win32 API, which allows it to run on all Win32 hosts. Because processes run under the standard Win32 subsystem, they can access both the UNIX compatibility calls provided by Cygwin as well as any of the Win32 API calls. This gives the programmer complete flexibility in designing the structure of their program in terms of the APIs used. For example, they could write a Win32-specific GUI using Win32 API calls on top of a UNIX back-end that uses Cygwin.

Early on in the development process, we made the important design decision that it would not be necessary to strictly adhere to existing UNIX standards like POSIX.1 if it was not possible or if it would significantly diminish the usability of the tools on the Win32 platform. In many cases, an environment variable can be set to override the default behavior and force standards compliance.

### 1.6.2. Supporting both Windows NT and 9x

While Windows 95 and Windows 98 are similar enough to each other that we can safely ignore the distinction when implementing Cygwin, Windows NT is an extremely different operating system. For this reason, whenever the DLL is loaded, the library checks which operating system is active so that it can act accordingly.

In some cases, the Win32 API is only different for historical reasons. In this situation, the same basic functionality is available under Windows 9x and NT but the method used to gain this functionality differs. A trivial example: in our implementation of `uname`, the library examines the `sysinfo.dwProcessorType` structure member to figure out the processor type under Windows 9x. This field is not supported in NT, which has its own operating system-specific structure member called `sysinfo.wProcessorLevel`.

Other differences between NT and 9x are much more fundamental in nature. The best example is that only NT provides a security model.

### 1.6.3. Permissions and Security

Windows NT includes a sophisticated security model based on Access Control Lists (ACLs). Cygwin maps Win32 file ownership and permissions to the more standard, older UNIX model by default. Cygwin version 1.1 introduces support for ACLs according to the system calls used on newer versions of Solaris. This ability is used when the 'ntsec' feature is switched on which is described in another chapter. The `chmod` call maps UNIX-style permissions back to the Win32 equivalents. Because many programs expect to be able to find the `/etc/passwd` and `/etc/group` files, we provide utilities that can be used to construct them from the user and group information provided by the operating system.

Under Windows NT, the administrator is permitted to `chown` files. There is no mechanism to support the `setuid` concept or API call since Cygwin version 1.1.2. With version 1.1.3 Cygwin introduces a mechanism for setting real and effective UIDs under Windows NT/W2K. This is described in the `ntsec` section.

Under Windows 9x, the situation is considerably different. Since a security model is not provided, Cygwin fakes file ownership by making all files look like they are owned by a default user and group id. As under NT, file permissions can still be determined by examining their read/write/execute status. Rather than return an unimplemented error, under Windows 9x, the `chown` call succeeds immediately without actually performing any action whatsoever. This is appropriate since essentially all users jointly own the files when no concept of file ownership exists.

It is important that we discuss the implications of our "kernel" using shared memory areas to store information about Cygwin processes. Because these areas are not yet protected in any way, in principle a malicious user could modify them to cause unexpected behavior in Cygwin processes. While this is not a new problem under Windows 9x (because of the lack of operating system security), it does constitute a security hole under Windows NT. This is because one user could affect the Cygwin programs run by another user by changing the shared memory information in ways that they could not in a more typical WinNT program. For this reason, it is not appropriate to use Cygwin in high-security applications. In practice, this will not be a major problem for most uses of the library.

## 1.6.4. File Access

Cygwin supports both Win32- and POSIX-style paths, using either forward or back slashes as the directory delimiter. Paths coming into the DLL are translated from Win32 to POSIX as needed. As a result, the library believes that the file system is a POSIX-compliant one, translating paths back to Win32 paths whenever it calls a Win32 API function. UNC pathnames (starting with two slashes) are supported.

The layout of this POSIX view of the Windows file system space is stored in the Windows registry. While the slash ( '/') directory points to the system partition by default, this is easy to change with the Cygwin mount utility. In addition to selecting the slash partition, it allows mounting arbitrary Win32 paths into the POSIX file system space. Many people use the utility to mount each drive letter under the slash partition (e.g. C:\ to /c, D:\ to /d, etc...).

The library exports several Cygwin-specific functions that can be used by external programs to convert a path or path list from Win32 to POSIX or vice versa. Shell scripts and Makefiles cannot call these functions directly. Instead, they can do the same path translations by executing the `cygpath` utility program that we provide with Cygwin.

Win32 file systems are case preserving but case insensitive. Cygwin does not currently support case distinction because, in practice, few UNIX programs actually rely on it. While we could mangle file names to support case distinction, this would add unnecessary overhead to the library and make it more difficult for non-Cygwin applications to access those files.

Symbolic links are emulated by files containing a magic cookie followed by the path to which the link points. They are marked with the System attribute so that only files with that attribute have to be read to determine whether or not the file is a symbolic link. Hard links are fully supported under Windows NT on NTFS file systems. On a FAT file system, the call falls back to simply copying the file, a strategy that works in many cases.

The inode number for a file is calculated by hashing its full Win32 path. The inode number generated by the `stat` call always matches the one returned in `d_ino` of the `dirent` structure. It is worth noting that the number produced by this method is not guaranteed to be unique. However, we have not found this to be a significant problem because of the low probability of generating a duplicate inode number.

Chroot is supported since release 1.1.3. Note that chroot isn't supported native by Windows. This implies some restrictions. First of all, the chroot call isn't a privileged call. Each user may call it. Second, the chroot environment isn't safe against native windows processes. If you want to support a chroot environment as, for example, by allowing an anonymous ftp with restricted access, you'll have to care that only native

Cygwin applications are accessible inside of the chroot environment. Since that applications are only using the Cygwin POSIX API to access the file system their access can be restricted as it is intended. This includes not only POSIX paths but Win32 paths (containing drive letter and/or backslashes) and CIFS paths (`//server/share` or `\\server\share`) as well.

### **1.6.5. Text Mode vs. Binary Mode**

Interoperability with other Win32 programs such as text editors was critical to the success of the port of the development tools. Most Red Hat customers upgrading from the older DOS-hosted toolchains expected the new Win32-hosted ones to continue to work with their old development sources.

Unfortunately, UNIX and Win32 use different end-of-line terminators in text files. Consequently, carriage-return newlines have to be translated on the fly by Cygwin into a single newline when reading in text mode.

This solution addresses the compatibility requirement at the expense of violating the POSIX standard that states that text and binary mode will be identical. Consequently, processes that attempt to lseek through text files can no longer rely on the number of bytes read as an accurate indicator of position in the file. For this reason, the `CYGWIN` environment variable can be set to override this behavior.

### **1.6.6. ANSI C Library**

We chose to include Red Hat's own existing ANSI C library "newlib" as part of the library, rather than write all of the lib C and math calls from scratch. Newlib is a BSD-derived ANSI C library, previously only used by cross-compilers for embedded systems development.

The reuse of existing free implementations of such things as the glob, regexp, and getopt libraries saved us considerable effort. In addition, Cygwin uses Doug Lea's free malloc implementation that successfully balances speed and compactness. The library accesses the malloc calls via an exported function pointer. This makes it possible for a Cygwin process to provide its own malloc if it so desires.

### **1.6.7. Process Creation**

The fork call in Cygwin is particularly interesting because it does not map well on top

of the Win32 API. This makes it very difficult to implement correctly. Currently, the Cygwin fork is a non-copy-on-write implementation similar to what was present in early flavors of UNIX.

The first thing that happens when a parent process forks a child process is that the parent initializes a space in the Cygwin process table for the child. It then creates a suspended child process using the Win32 CreateProcess call. Next, the parent process calls setjmp to save its own context and sets a pointer to this in a Cygwin shared memory area (shared among all Cygwin tasks). It then fills in the child's .data and .bss sections by copying from its own address space into the suspended child's address space. After the child's address space is initialized, the child is run while the parent waits on a mutex. The child discovers it has been forked and longjumps using the saved jump buffer. The child then sets the mutex the parent is waiting on and blocks on another mutex. This is the signal for the parent to copy its stack and heap into the child, after which it releases the mutex the child is waiting on and returns from the fork call. Finally, the child wakes from blocking on the last mutex, recreates any memory-mapped areas passed to it via the shared area, and returns from fork itself.

While we have some ideas as to how to speed up our fork implementation by reducing the number of context switches between the parent and child process, fork will almost certainly always be inefficient under Win32. Fortunately, in most circumstances the spawn family of calls provided by Cygwin can be substituted for a fork/exec pair with only a little effort. These calls map cleanly on top of the Win32 API. As a result, they are much more efficient. Changing the compiler's driver program to call spawn instead of fork was a trivial change and increased compilation speeds by twenty to thirty percent in our tests.

However, spawn and exec present their own set of difficulties. Because there is no way to do an actual exec under Win32, Cygwin has to invent its own Process IDs (PIDs). As a result, when a process performs multiple exec calls, there will be multiple Windows PIDs associated with a single Cygwin PID. In some cases, stubs of each of these Win32 processes may linger, waiting for their exec'd Cygwin process to exit.

## 1.6.8. Signals

When a Cygwin process starts, the library starts a secondary thread for use in signal handling. This thread waits for Windows events used to pass signals to the process. When a process notices it has a signal, it scans its signal bitmask and handles the signal in the appropriate fashion.

Several complications in the implementation arise from the fact that the signal handler

operates in the same address space as the executing program. The immediate consequence is that Cygwin system functions are interruptible unless special care is taken to avoid this. We go to some lengths to prevent the `sig_send` function that sends signals from being interrupted. In the case of a process sending a signal to another process, we place a mutex around `sig_send` such that `sig_send` will not be interrupted until it has completely finished sending the signal.

In the case of a process sending itself a signal, we use a separate semaphore/event pair instead of the mutex. `sig_send` starts by resetting the event and incrementing the semaphore that flags the signal handler to process the signal. After the signal is processed, the signal handler signals the event that it is done. This process keeps intraprocess signals synchronous, as required by POSIX.

Most standard UNIX signals are provided. Job control works as expected in shells that support it.

### **1.6.9. Sockets**

Socket-related calls in Cygwin simply call the functions by the same name in Winsock, Microsoft's implementation of Berkeley sockets. Only a few changes were needed to match the expected UNIX semantics - one of the most troublesome differences was that Winsock must be initialized before the first socket function is called. As a result, Cygwin has to perform this initialization when appropriate. In order to support sockets across fork calls, child processes initialize Winsock if any inherited file descriptor is a socket.

Unfortunately, implicitly loading DLLs at process startup is usually a slow affair. Because many processes do not use sockets, Cygwin explicitly loads the Winsock DLL the first time it calls the Winsock initialization routine. This single change sped up GNU configure times by thirty percent.

### **1.6.10. Select**

The UNIX `select` function is another call that does not map cleanly on top of the Win32 API. Much to our dismay, we discovered that the Win32 `select` in Winsock only worked on socket handles. Our implementation allows `select` to function normally when given different types of file descriptors (sockets, pipes, handles, and a custom `/dev/windows` Windows messages pseudo-device).

Upon entry into the select function, the first operation is to sort the file descriptors into the different types. There are then two cases to consider. The simple case is when at least one file descriptor is a type that is always known to be ready (such as a disk file). In that case, select returns immediately as soon as it has polled each of the other types to see if they are ready. The more complex case involves waiting for socket or pipe file descriptors to be ready. This is accomplished by the main thread suspending itself, after starting one thread for each type of file descriptor present. Each thread polls the file descriptors of its respective type with the appropriate Win32 API call. As soon as a thread identifies a ready descriptor, that thread signals the main thread to wake up. This case is now the same as the first one since we know at least one descriptor is ready. So select returns, after polling all of the file descriptors one last time.

# Chapter 2. Setting Up Cygwin

## 2.1. Internet Setup

To install the Cygwin net release, go to <http://cygwin.com/> and click on "Install Cygwin Now!" (<http://cygwin.com/>). This will download a GUI installer called **setup.exe** which can be run to download a complete cygwin installation via the internet. Follow the instructions on each screen to install Cygwin.

The **setup.exe** installer is designed to be easy for new users to understand while remaining flexible for the experienced. The volunteer development team is constantly working on **setup.exe**; before requesting a new feature, check the wishlist in the CVS README (<http://sources.redhat.com/cgi-bin/cvsweb.cgi/setup/README?cvsroot=cygwin-apps&rev=2>). It may already be present in the CVS version!

Since the default value for each option is the logical choice for most installations, you can get a working minimal Cygwin environment installed by simply clicking the `Next` button at each page. The only exception to this is choosing a Cygwin mirror, which you can choose by experimenting with those listed at <http://cygwin.com/mirrors.html>. For more details about each of page of the **setup.exe** installation, read on below. Please note that this guide assumes that you have a basic understanding of Unix (or a Unix-like OS). If you are new to Unix, you will also want to make use of other resources (<http://www.google.com/search?q=new+to+unix>).

### 2.1.1. Download Source

Cygwin uses packages to manage installing various software. When the default `Install from Internet` option is chosen, **setup.exe** creates a local directory to store the packages before actually installing the contents. `Download from Internet` performs only the first part (storing the packages locally), while `Install from Local Directory` performs only the second (installing the contents of the packages).

The `Download from Internet` option is mainly for creating a base Cygwin package tree on one computer for installation on several machines with `Install from Local Directory`; copy the entire local package tree to another machine with the directory tree intact. For example, you might create a `C:\cache\` directory and place **setup.exe** in it. Run **setup.exe** to `Install from Internet` or `Download from Internet`,

then copy the whole `C:\cache\` to each machine and instead choose `Install` from `Local Directory`. Unfortunately **setup.exe** does not yet support unattended installs.

Though this provides some basic mirroring functionality, if you are managing a wide Cygwin installation, to keep up to date we recommend using a mirroring tool such as **wget**. A helpful user on the Cygwin mailing list created a simple demonstration script to accomplish this; search the list for **mkcygwget** for ideas.

## 2.1.2. Selecting an Install Directory

The `Root Directory` for Cygwin (default `C:\cygwin`) will become `/` within your Cygwin installation. You must have write access to the parent directory, and any ACLs on the parent directory will determine access to installed files.

The `Install For` options of `All Users` or `Just Me` should always be left on the default `All Users`, unless you do not have write access to `HKEY_LOCAL_MACHINE` in the registry or the All Users Start Menu. This is true even if you are the only user planning to use Cygwin on the machine. Selecting `Just Me` will cause problems for programs such as **crond** and **sshd**. If you do not have the necessary permissions, but still want to use these programs, consult the Cygwin mailing list archives about others' experiences.

The `Default Text File Type` should be left on `Unix` (that is, `\n`) unless you have a very good reason to switch it to `DOS` (that is, `\r\n`).

## 2.1.3. Local Package Directory

The `Local Package Directory` is the cache where **setup.exe** stores the packages before they are installed. The cache must not be the same folder as the Cygwin root. Within the cache, a separate directory is created for each Cygwin mirror, which allows **setup.exe** to use multiple mirrors and custom packages. After installing Cygwin, the cache is no longer necessary, but you may want to retain the packages as backups, for installing Cygwin to another system, or in case you need to reinstall a package.

## 2.1.4. Connection Method

The `Direct Connection` method of downloading will directly download the packages, while the `IE5` method will leverage your IE5 cache for performance. If your organisation uses a proxy server or auto-configuration scripts, the `IE5` method also uses

these settings. If you have a proxy server, you can manually type it into the `Use Proxy` section. Unfortunately, **setup.exe** does not currently support password authorization for proxy servers.

## 2.1.5. Choosing Mirrors

Since there is no way of knowing from where you will be downloading Cygwin, you need to choose at least one mirror site. Cygwin mirrors are geographically distributed around the world; check the list at <http://cygwin.com/mirrors.html> to find one near you. You can select multiple mirrors by holding down `CTRL` and clicking on each one. If you have the URL of an unlisted mirror (for example, if your organization has an internal Cygwin mirror) you can add it.

## 2.1.6. Choosing Packages

For each selected mirror site, **setup.exe** downloads a small text file called `setup.bz2` that contains a list of packages available from that site along with some basic information about each package which **setup.exe** parses and uses to create the chooser window. For details about the format of this file, see <http://sources.redhat.com/cygwin-apps/setup.html> (<http://sources.redhat.com/cygwin-apps/setup.html#setup.ini>).

The chooser is the most complex part of **setup.exe**. Packages are grouped into categories, and one package may belong to multiple categories (assigned by the volunteer package maintainer). Each package can be found under any of those categories in the heirarchical chooser view. By default **setup.exe** will install only the packages in the `Base` category and their dependencies, resulting in a minimal Cygwin installation. However, this will not include many commonly used tools such as **gcc** (which you will find in the `Devel` category).

You can change **setup.exe**'s view style, which is helpful if you know the name of a package you want to install but not which category it is in. Click on the `View` button and it will rotate between `Category` (the default), `Full` (all packages), and `Partial` (only packages to be upgraded). If you are familiar with Unix, you will probably want to at least glance through the `Full` listing for your favorite tools.

Once you have an existing Cygwin installation, the **setup.exe** chooser is also used to manage your Cygwin installation. Information on installed packages is kept in the `/etc/setup/` directory of your Cygwin installation; if **setup.exe** cannot find this directory it will act just like you had no Cygwin installation. If **setup.exe** finds a newer

version of an installed package available, it will automatically mark it to be upgraded. To `Uninstall`, `Reinstall`, or get the `Source` for an existing package, click on `Keep` to toggle it. Also, to avoid the need to reboot after upgrading, make sure to close all Cygwin windows and stop all Cygwin processes before **setup.exe** begins to install the upgraded package.

The final feature of the **setup.exe** chooser is for `Previous` and `Experimental` packages. By default the chooser shows only the current version of each package, though mirrors have at least one previous version and occasionally there is a testing or beta version of a package available. To see these package, click on the `Prev` or `Exp` radio button. Be warned, however, that the next time you run **setup.exe** it will try to replace old or experimental versions with the latest.

## 2.1.7. Download and Installation Progress

First, **setup.exe** will download all selected packages to the local directory chosen earlier. Before installing, **setup.exe** performs a checksum on each package. If the local directory is a slow medium (such as a network drive) this can take a long time. During the download and installation, **setup.exe** show progress bars for the current task and total remaining disk space.

## 2.1.8. Icons

You may choose to install shortcuts on the Desktop and/or Start Menu to start a bash shell. If you prefer to use a different shell or the native Windows version of `rxvt`, you can use these shortcuts as a guide to creating your own.

## 2.1.9. Post-Install Scripts

Last of all, **setup.exe** will run any post-install scripts to finish correctly setting up installed packages. Since each script is run separately, several windows may pop up. If you are interested in what is being done, see the Cygwin Package Contributor's Guide at <http://cygwin.com/setup.html> When the last post-install script is completed, **setup.exe** will display a box announcing the completion. A few packages, such as the OpenSSH server, require some manual site-specific configuration. Relevant documentation can be found in the `/usr/doc/Cygwin/` directory.

## 2.2. Environment Variables

Before starting bash, you may set some environment variables. A .bat file is provided where the most important ones are set before bash is launched. This is the safest way to launch bash initially. The .bat file is installed in the root directory that you specified during setup and pointed to in the Start Menu under the "Cygwin" option. You can edit it this file your liking.

The CYGWIN variable is used to configure many global settings for the Cygwin runtime system. Initially you can leave CYGWIN unset or set it to `tty` (e.g. to support job control with `^Z` etc...) using a syntax like this in the DOS shell, before launching bash.

```
C:\> set CYGWIN=tty notitle glob
```

The PATH environment variable is used by Cygwin applications as a list of directories to search for executable files to run. This environment variable is converted from Windows format (e.g. `C:\WinNT\system32;C:\WinNT`) to UNIX format (e.g., `/WinNT/system32:/WinNT`) when a Cygwin process first starts. Set it so that it contains at least the `x:\cygwin\bin` directory where "x:\cygwin" is the "root" of your cygwin installation if you wish to use cygwin tools outside of bash.

The HOME environment variable is used by many programs to determine the location of your home directory and we recommend that it be defined. This environment variable is also converted from Windows format when a Cygwin process first starts. Set it to point to your home directory before launching bash.

The TERM environment variable specifies your terminal type. It is automatically set to `cygwin` if you have not set it to something else.

The LD\_LIBRARY\_PATH environment variable is used by the Cygwin function `dlopen ( )` as a list of directories to search for .dll files to load. This environment variable is converted from Windows format to UNIX format when a Cygwin process first starts. Most Cygwin applications do not make use of the `dlopen ( )` call and do not need this variable.

## 2.3. Changing Cygwin's Maximum Memory

By default no Cygwin program can allocate more than 384 MB of memory (program+data). You should not need to change this default in most circumstances. However, if you need to use more real or virtual memory in your machine you may add

an entry in either the `HKEY_LOCAL_MACHINE` (to change the limit for all users) or `HKEY_CURRENT_USER` (for just the current user) section of the registry.

Add the `DWORD` value `heap_chunk_in_mb` and set it to the desired memory limit in decimal MB. It is preferred to do this in Cygwin using the **regtool** program included in the Cygwin package. (For more information about **regtool** or the other Cygwin utilities, see Section 3.6 or use each the `--help` option of each util.) You should always be careful when using **regtool** since damaging your system registry can result in an unusable system. This example sets memory limit to 1024 MB:

```
regtool -i set /HKLM/Software/Cygnus\ Solutions/Cygwin/heap_chunk_in_mb 1024
regtool -v list /HKLM/Software/Cygnus\ Solutions/Cygwin
```

Exit all running Cygwin processes and restart them. Memory can be allocated up to the size of the system swap space minus any the size of any running processes. The system swap should be at least as large as the physically installed RAM and can be modified under the System category of the Control Panel.

Here is a small program written by DJ Delorie that tests the memory allocation limit on your system:

```
main()
{
    unsigned int bit=0x40000000, sum=0;
    char *x;

    while (bit > 4096)
    {
        x = malloc(bit);
        if (x)
            sum += bit;
        bit >>= 1;
    }
    printf("%08x bytes (%.1fMb)\n", sum, sum/1024.0/1024.0);
    return 0;
}
```

You can compile this program using:

```
gcc max_memory.c -o max_memory.exe
```

Run the program and it will output the maximum amount of allocatable memory.

## 2.4. NT security and the ntsec usage

The design goal of ntsec is to get a more UNIX like permission structure based upon the security features of Windows NT. To describe the changes, I will give a short overview of NT security in chapter one.

Chapter two discusses the changes in ntsec related to privileges on processes.

Chapter three shows the basics of UNIX like setting of file permissions.

Chapter four talks about the advanced settings introduced in release 1.1

Chapter five illustrates the permission mapping leak of Windows NT.

Chapter six describes the new support of a setuid concept introduced with release 1.1.3.

Chapter six describes in short the new acl API since release 1.1

The setting of UNIX like object permissions is controlled by the new CYGWIN variable setting `(no)ntsec`.

### 2.4.1. NT security

The NT security allows a process to allow or deny access of different kind to ‘objects’. ‘Objects’ are files, processes, threads, semaphores, etc.

The main data structure of NT security is the ‘security descriptor’ (SD) structure. It explains the permissions, that are granted (or denied) to an object and contains information, that is related to so called ‘security identifiers’ (SID).

A SID is a unique identifier for users, groups and domains. SIDs are comparable to UNIX UIDs and GIDs, but are more complicated because they are unique across networks. Example:

SID of a system ‘foo’:

```
S-1-5-21-165875785-1005667432-441284377
```

SID of a user ‘johndoe’ of the system ‘foo’:

```
S-1-5-21-165875785-1005667432-441284377-1023
```

The above example shows the convention for printing SIDs. The leading ‘S’ should show that it is a SID. The next number is a version number which is always 1. The next number is the so called ‘top-level authority’ that identifies the source that issued the SID.

While each system in a NT network has it's own SID, the situation is modified in NT domains: The SID of the domain controller is the base SID for each domain user. If an NT user has one account as domain user and another account on his local machine, this accounts are under any circumstances DIFFERENT, regardless of the usage of the same user name and password!

SID of a domain 'bar':

S-1-5-21-186985262-1144665072-740312968

SID of a user 'johndoe' in the domain 'bar':

S-1-5-21-186985262-1144665072-740312968-1207

The last part of the SID, the so called 'relative identifier' (RID), is by default used as UID and/or GID under cygwin. As the name and the above example implies, this id is unique only relative to one system or domain.

Note, that it's possible, that an user has the same RID on two different systems. The resulting SIDs are nevertheless different, so the SIDs are representing different users in an NT network.

There is a big difference between UNIX IDs and NT SIDs, the existence of the so called 'well known groups'. For example UNIX has no GID for the group of 'all users'. NT has an SID for them, called 'Everyone' in the English versions. The SIDs of well-known groups are not unique across an NT network but their meanings are unmistakable. Examples of well-known groups:

everyone	S-1-1-0
creator/owner	S-1-3-0
batch process (via 'at')	S-1-5-3
authenticated users	S-1-5-11
system	S-1-5-18

The last important group of SIDs are the 'predefined groups'. This groups are used mainly on systems outside of domains to simplify the administration of user permissions. The corresponding SIDs are not unique across the network so they are interpreted only locally:

administrators	S-1-5-32-544
users	S-1-5-32-545
guests	S-1-5-32-546
...	

Now, how are permissions given to objects? A process may assign an SD to the object. The SD of an object consists of three parts:

- the SID of the owner
- the SID of the group
- a list of SIDs with their permissions, called ‘access control list’ (ACL)

UNIX is able to create three different permissions, the permissions for the owner, for the group and for the world. In contrast the ACL has a potentially infinite number of members. Every member is a so called ‘access control element’ (ACE). An ACE contains three parts:

- the type of the ACE
- permissions, described with a DWORD
- the SID, for which the above mentioned permissions are set

The two important types of ACEs are the ‘access allowed ACE’ and the ‘access denied ACE’. The ntsec functionality only used ‘access allowed ACEs’ up to Cygwin version 1.1.0. Later versions also use ‘access denied ACEs’ to reflect the UNIX permissions as well as possible.

The possible permissions on objects are more detailed than in UNIX. For example, the permission to delete an object is different from the write permission.

With the aforementioned method NT is able to grant or revoke permissions to objects in a far more specific way. But what about cygwin? In a POSIX environment it would be fine to have the security behavior of a POSIX system. The NT security model is MOSTLY able to reproduce the POSIX model. The ntsec method tries to do this in cygwin.

You ask "Mostly? Why mostly???" Because there's a leak in the NT model. I will describe that in detail in chapter 4.

Creating explicit object security is not that easy so you will often see only two simple variations in use:

- default permissions, computed by the operating system
- each permission to everyone

For parameters to functions that create or open securable objects another data structure is used, the ‘security attributes’ (SA). This structure contains an SD and a flag that specifies whether the returned handle to the object is inherited to child processes or not. This property is not important for ntsec so in this document the difference between SDs and SAs is ignored.

## 2.4.2. Process privileges

Any process started under control of cygwin has a semaphore attached to it, that is used for signaling purposes. The creation of this semaphore can be found in `sigproc.cc`, function `'getsem'`. The first parameter to the function call `'CreateSemaphore'` is an SA. Without `ntsec` this SA assigns default security to the semaphore. There is a simple disadvantage: Only the owner of the process may send signals to it. Or, in other words, if the owner of the process is not a member of the administrators' group, no administrator may kill the process! This is especially annoying, if processes are started via service manager.

`Ntsec` now assigns an SA to the process control semaphore, that has each permission set for the user of the process, for the administrators' group and for `'system'`, which is a synonym for the operating system itself. The creation of this SA is done by the function `'sec_user'`, that can be found in `'shared.cc'`. Each member of the administrators' group is now allowed to send signals to any process created in cygwin, regardless of the process owner.

Moreover, each process now has the appropriate security settings, when it is started via `'CreateProcess'`. You will find this in function `'spawn_guts'` in module `'spawn.cc'`. The security settings for starting a process in another user context have to add the sid of the new user, too. In the case of the `'CreateProcessAsUser'` call, `sec_user` creates an SA with an additional entry for the sid of the new user.

## 2.4.3. File permissions

If `ntsec` is turned on, file permissions are set as in UNIX. An SD is assigned to the file containing the owner and group and ACEs for the owner, the group and `'Everyone'`.

The complete settings of UNIX like permissions can be found in the file `'security.cc'`. The two functions `'get_nt_attribute'` and `'set_nt_attribute'` are the main code. The reading and writing of the SDs is done by the functions `'read_sd'` and `'write_sd'`. `'write_sd'` uses the function `'BackupRead'` instead of the simpler function `'SetFileSecurity'` because the latter is unable to set owners different from the caller.

If you are creating a file `'foo'` outside of cygwin, you will see something like the following on `ls -ln`:

If your login is member of the administrators' group:

```
rw-rw-rwx 1 544 513 ... foo
```

if not:

```
rw-rw-rw- 1 1000 513 ... foo
```

Note the user and group IDs. 544 is the UID of the administrators' group. This is a 'feature' :-P of WinNT. If one is a member of the administrators' group, every file, that he has created is owned by the administrators' group, instead by him.

The second example shows the UID of the first user, that has been created with NT's the user administration tool. The users and groups are sequentially numbered, starting with 1000. Users and groups are using the same numbering scheme, so a user and a group don't share the same ID.

In both examples the GID 513 is of special interest. This GID is a well known group with different naming in local systems and domains. Outside of domains the group is named 'None' ('Kein' in German, 'Aucun' in French, etc.), in domains it is named 'Domain Users'. Unfortunately, the group 'None' is never shown in the user admin tool outside of domains! This is very confusing but this seems to have no negative consequences.

To work correctly, ntsec depends on the files `/etc/passwd/` and `/etc/group`. In cygwin release 1.0 the names and the IDs must correspond to the appropriate NT IDs! The IDs used in cygwin are the RID of the NT SID, as mentioned earlier. An SID of e.g. the user 'corinna' on my NT workstation:

```
S-1-5-21-165875785-1005667432-441284377-1000
```

Note the last number: It's the RID 1000, the cygwin's UID.

Unfortunately, workstations and servers outside of domains are not able to set primary groups! In these cases, where there is no correlation of users to primary groups, NT returns 513 (None) as primary group, regardless of the membership to existing local groups.

When using **mkpasswd -l -g** on such systems, you have to change the primary group by hand if 'None' as primary group is not what you want (and I'm sure, it's not what you want!)

Look at the following examples, which were parts of my files before storing SIDs in `/etc/passwd` and `/etc/group` had been introduced (See next chapter for details). With the exception of my personal user entry, all entries are well known entries.

### Example 2-1. `/etc/passwd`

```
everyone:*:0:0:::
system:*:18:18:::
administrator::500:544::/home/root:/bin/bash
```

```

guest:*:501:546:::
administrators:*:544:544:::/home/root:
corinna::1000:547:Corinna Vinschen:/home/corinna:/bin/tcsh

```

### Example 2-2. /etc/group

```

everyone::0:
system::18:
none::513:
administrators::544:
users::545:
guests::546:
powerusers::547:

```

As you can see, I changed my primary group membership from 513 (None) to 547 (powerusers). So all files I created inside of Cygwin were now owned by the powerusers group instead of None. This is the way I liked it.

Groups may be mentioned in the passwd file, too. This has two advantages:

- Because NT assigns them to files as owners, a **ls -l** is often more readable.
- Moreover it's possible to assigned them to files as owners with cygwin's **chown**.

The group 'system' is the aforementioned synonym for the operating system itself and is normally the owner of processes, that are started through service manager. The same is true for files, that are created by processes, which are started through service manager.

## 2.4.4. New since Cygwin release 1.1

In Cygwin release 1.1 a new technique of using the `/etc/passwd` and `/etc/group` is introduced.

Both files may now contain SIDs of users and groups. They are saved in the last field of `pw_gecos` in `/etc/passwd` and in the `gr_passwd` field in `/etc/group`.

This has the following advantages:

- `ntsec` works better in domain environments.
- Accounts (users and groups) may get another name in cygwin than their NT account name. The name in `/etc/passwd` or `/etc/group` is transparently used by cygwin applications (eg. **chown**, **chmod**, **ls**):

```
root::500:513::/home/root:/bin/sh
```

instead of

```
adminstrator::500:513::/home/root:/bin/sh
```

Caution: If you like to use the account as login account via **telnet** etc. you have to remain the name unchanged or you have to use the special version of **login** which is part of the standard Cygwin distribution since 1.1.

- Cygwin UIDs and GIDs are now not necessarily the RID part of the NT SID:

```
root::0:513:S-1-5-21-54355234-56236534-345635656-500:/home/root:/bin/sh
```

instead of

```
root::500:513::/home/root:/bin/sh
```

- As in U\*X systems UIDs and GIDs numbering scheme now don't influence each other. So it's possible to have same Id's for a user and a group:

#### Example 2-3. /etc/passwd:

```
root::0:0:S-1-5-21-54355234-56236534-345635656-500:/home/root:/bin/sh
```

#### Example 2-4. /etc/group:

```
root:S-1-5-32-544:0:
```

The tools **mkpasswd** and **mkgroup** create the needed entries by default. If you don't want that you can use the options `-s` or `--no-sids`. I suggest not to do this since `ntsec` works better when having the SIDs available.

Please note that the `pw_gecos` field in `/etc/passwd` is defined as a comma separated list. The SID has to be the last field!

As aforementioned you are able to use cygwin account names different from the NT account names. If you want to login thru 'telnet' or something else you have to use the special **login**. You may then add another field to `pw_gecos` which contains the NT user name including it's domain. So you are able to login as each domain user. The syntax is easy: Just add an entry of the form `U-ntdomain\ntusername` to the `pw_gecos` field. Note that the SID must still remain the last field in `pw_gecos`!

```
the_king::1:1:Elvis Presley,U-STILLHERE\elvis,S-1-5-21-1234-5678-9012-1000:/
```

For a local user just drop the domain:

```
the_king::1:1:Elvis Presley,U-elvis,S-1-5-21-1234-5678-9012-1000:/bin/sh
```

In either case the password of the user is taken from the NT user database, NOT from the passwd file!

As in the previous chapter I give my personal `/etc/passwd` and `/etc/group` as examples. Please note that I've changed these files heavily! There's no need to change them that way, it's just for testing purposes and... for fun.

### Example 2-5. `/etc/passwd`

```
root:*:0:0:Administrators group,S-1-5-32-544::  
SYSTEM:*:18:18:,S-1-5-18:/home/system:/bin/bash  
admin:*:500:513:,S-1-5-21-1844237615-436374069-1060284298-500:/home/Administ  
corinna:*:100:0:Corinna Vinschen,S-1-5-21-1844237615-436374069-1060284298-10  
Guest:*:501:546:,S-1-5-21-1844237615-436374069-1060284298-501:/home/Guest:/b
```

### Example 2-6. `/etc/group`

```
root:S-1-5-32-544:0:  
local:S-1-2-0:2:  
network:S-1-5-2:3:  
interactive:S-1-5-4:4:  
authenticatedusers:S-1-5-11:5:  
SYSTEM:S-1-5-18:18:  
local_svc:S-1-5-19:19:  
netwrk_svc:S-1-5-20:20:  
none:S-1-5-21-1844237615-436374069-1060284298-513:513:  
bckup_op:S-1-5-32-551:551:  
guests:S-1-5-32-546:546:  
pwrusers:S-1-5-32-547:547:  
replicator:S-1-5-32-552:552:  
users:S-1-5-32-545:545:
```

If you want to do similar changes to your files, please do that only if you're feeling comfortably with the concepts. Otherwise don't be surprised if some stuff doesn't work anymore. If you screwed up things, revert to files created by `mkpasswd` and `mkgroup`. Especially don't change the uid or the name of user `SYSTEM`. Even if that works mostly, some Cygwin applications running as local service under that account could behave strangely suddenly.

## 2.4.5. The mapping leak

Now its time to point out the leak in the NT permissions. The official documentation explains in short the following:

- access allow ACEs are accumulated regarding to the group membership of the caller.
- The order of ACEs is important. The system reads them in sequence until either any needed right is denied or all needed rights are granted. Later ACEs are then not taken into account.
- All access denied ACEs *should* precede any access allowed ACE.

Note that the last rule is a preference, not a law. NT will correctly deal with the ACL regardless of the sequence order. The second rule is not modified to get the ACEs in the preferred order.

Unfortunately the security tab of the NT4 explorer is completely unable to deal with access denied ACEs while the explorer of W2K rearranges the order of the ACEs before you can read them. Thank God, the sort order remains unchanged if one presses the Cancel button.

You still ask "Where is the leak?" NT ACLs are unable to reflect each possible combination of POSIX permissions. Example:

```
rw-r-xrw-
```

1st try:

```
UserAllow:   110
GroupAllow:  101
OthersAllow: 110
```

Hmm, because of the accumulation of allow rights the user may execute because the group may execute.

2st try:

```
UserDeny:    001
GroupAllow:  101
OthersAllow: 110
```

Now the user may read and write but not execute. Better? No! Unfortunately the group may write now because others may write.

3rd try:

```
UserDeny:    001
GroupDeny:  010
GroupAllow: 001
OthersAllow: 110
```

Now the group may not write as intended but unfortunately the user may not write anymore, too. How should this problem be solved? According to the official rules a UserAllow has to follow the GroupDeny but it's easy to see that this can never be solved that way.

The only chance:

```
UserDeny:    001
UserAllow:   010
GroupDeny:  010
GroupAllow: 001
OthersAllow: 110
```

Again: This works for both, NT4 and W2K. Only the GUIs aren't able to deal with that order.

## 2.4.6. New acl API

For dealing with ACLs Cygwin now has the acl API as it's implemented in newer versions of Solaris. The new data structure for a single ACL entry (ACE in NT terminology) is defined in `sys/acl.h` as:

```
typedef struct acl {
    int      a_type; /* entry type */
    uid_t    a_id;   /* UID | GID */
    mode_t   a_perm; /* permissions */
} aclent_t;
```

The `a_perm` member of the `aclent_t` type contains only the bits for read, write and execute as in the file mode. If eg. read permission is granted, all read bits (`S_IRUSR`, `S_IRGRP`, `S_IROTH`) are set. `CLASS_OBJ` or `MASK` ACL entries are not fully implemented yet.

The new API calls are

```
acl(2), facl(2)
aclcheck(3),
aclsort(3),
```

```
acltomode(3), aclfrommode(3),
acltopbits(3), aclfrompbits(3),
acltotext(3), aclfromtext(3)
```

Like in Solaris, Cygwin has two new commands for working with ACLs on the command line: **getfacl** and **setfacl**.

Online man pages for the aforementioned commands and API calls can be found on eg. <http://docs.sun.com>

## 2.4.7. New setuid concept

UNIX applications which have to switch the user context are using the **setuid** and **seteuid** calls which are not part of the Windows API. Nevertheless these calls are supported under Windows NT/W2K since Cygwin release 1.1.3. Because of the nature of NT security an application which needs the ability has to be patched, though.

NT uses so called 'access tokens' to identify a user and its permissions. To switch the user context the application has to request such an 'access token'. This is typically done by calling the NT API function **LogonUser**. The access token is returned and either used in **ImpersonateLoggedOnUser** to change user context of the current process or in **CreateProcessAsUser** to change user context of a spawned child process. An important restriction is that the application using **LogonUser** must have special permissions:

```
"Act as part of the operating system"
"Replace process level token"
"Increase quotas"
```

Note that administrators do not have all these user rights set by default.

Two new Cygwin calls are introduced to support porting **setuid** applications with a minimum of effort. You only give Cygwin the right access token and then you can call **seteuid** or **setuid** as usual in POSIX applications. The call to **sexec** is not needed anymore. Porting a **setuid** application is illustrated by a short example:

```
/* First include all needed cygwin stuff. */
#ifdef __CYGWIN__
#include <windows.h>
#include <sys/cygwin.h>
/* Use the following define to determine the Windows version */
#define is_winnt      (GetVersion() < 0x80000000)
#endif
```

```

[...]
```

```

    struct passwd *user_pwd_entry = getpwnam (username);
    char *cleartext_password = getpass ("Password:");

[...]
```

```

#ifdef __CYGWIN__
    /* Patch the typical password test. */
    if (is_winnt)
    {
        HANDLE token;

        /* Try to get the access token from NT. */
        token = cygwin_logon_user (user_pwd_entry, cleartext_password);
        if (token == INVALID_HANDLE_VALUE)
            error_exit;
        /* Inform Cygwin about the new impersonation token.
           Cygwin is able now, to switch to that user context by
           setuid or seteuid calls. */
        cygwin_set_impersonation_token (token);
    }
    else
#endif /* CYGWIN */
    /* Use standard method for W9X as well. */
    hashed_password = crypt (cleartext_password, salt);
    if (!user_pwd_entry ||
        strcmp (hashed_password, user_pwd_entry->pw_password))
        error_exit;

[...]
```

```

    /* Everything else remains the same! */

    setegid (user_pwd_entry->pw_gid);
    seteuid (user_pwd_entry->pw_uid);
    execl ("/bin/sh", ...);

```

The new Cygwin call to retrieve an access token is defined as follows:

```

#include <windows.h>
#include <sys/cygwin.h>

```

```
HANDLE
cygwin_logon_user (struct passwd *pw, const char *cleartext_password)
```

You can call that function as often as you want for different user logons and remember the access tokens for further calls to the second function.

```
#include <windows.h>
#include <sys/cygwin.h>

void
cygwin_set_impersonation_token (HANDLE hToken);
```

is the call to inform Cygwin about the user context to which further calls to **setuid/seteuid** should switch to. While you need always the correct access token to do a **setuid/seteuid** to another users context, you are always able to use **setuid/seteuid** to return to your own user context by giving your own uid as parameter.

If you have remembered several access tokens from calls to **cygwin\_logon\_user** you can switch to different user contexts by observing the following order:

```
    cygwin_set_impersonation_token (user1_token);
    seteuid (user1_uid);

[...]
```

```
    seteuid (own_uid);
    cygwin_set_impersonation_token (user2_token);
    seteuid (user2_uid);

[...]
```

```
    seteuid (own_uid);
    cygwin_set_impersonation_token (user1_token);
    seteuid (user1_uid);

etc.
```

## 2.4.8. New since Cygwin release 1.3.3

Since Cygwin release 1.3.3, applications having the **Create a process level token** user right can switch user context without giving a password by just calling the usual **setuid**, **seteuid**, **setgid** and **setegid** functions. This is typically only given to the SYSTEM user.

However, this now allows to switch the user context using e. g. rhosts authentication or (when running sshd under SYSTEM account as service) public key authentication.

An important restriction of this method is, that a process started under SYSTEM account can't access network shares which require authentication. This also applies to the subprocesses which switched the user context without a password. People using network home drives are typically not able to access it when trying to login using ssh or rsh without password.

## 2.4.9. Special values of user and group ids

If the current user is not present in `/etc/passwd`, that user's user id is set to a special value of 400. The user name for the current user will always be shown correctly. If another user (or a Windows group, treated as a user) is not present in `/etc/passwd`, the user id of that user will have a special value of -1 (which would be shown by `ls` as 65535). The user name shown in this case will be '????????'.

If the current user is not present in `/etc/passwd`, that user's login group id is set to a special value of 401. If another user is not present in `/etc/passwd`, that user's login group id is set to a special value of -1. If the user is present in `/etc/passwd`, but that user's group is not in `/etc/group` and is not the login group of that user, the group id is set to a special value of -1. The name of this group (id -1) will be shown as '????????'. In releases of Cygwin before 1.3.20, the group id 401 had a group name 'None'. Since Cygwin release 1.3.20, the group id 401 is shown as 'mkpasswd', indicating the command that should be run to alleviate the situation.

Also, since Cygwin release 1.3.20, if the current user is present in `/etc/passwd`, but that user's login group is not present in `/etc/group`, the group name will be shown as 'mkgroup', again indicating the appropriate command.

To summarize:

- If the current user doesn't show up in `/etc/passwd`, it's *group* will be named 'mkpasswd'.
- Otherwise, if the login group of the current user isn't in `/etc/group`, it will be named 'mkgroup'.
- Otherwise a group not in `/etc/group` will be shown as '????????' and a user not in `/etc/passwd` will be shown as "????????".

Note that, since the special user and group names are just indicators, nothing prevents you from actually having a user named 'mkpasswd' in `/etc/passwd` (or a group

named 'mkgroup' in `/etc/group`). If you do that, however, be aware of the possible confusion.

## 2.5. Customizing bash

To set bash up so that cut and paste work properly, click on the "Properties" button of the window, then on the "Misc" tab. Make sure that "Quick Edit" is checked and "Fast Pasting" isn't. These settings will be remembered next time you run bash from that shortcut. Similarly you can set the working directory inside the "Program" tab. The entry "%HOME%" is valid.

Your home directory should contain three initialization files that control the behavior of bash. They are `.profile`, `.bashrc` and `.inputrc`. These initialization files will only be read if HOME is defined before starting bash.

`.profile` (other names are also valid, see the bash man page) contains bash commands. It is executed when bash is started as login shell, e.g. from the command **bash --login** (the provided `.bat` file does not set the switch). This is a useful place to define and export environment variables and bash functions that will be used by bash and the programs invoked by bash. It is a good place to redefine PATH if needed. We recommend adding a ":" to the end of PATH to also search the current working directory (contrary to DOS, the local directory is not searched by default). Also to avoid delays you should either **unset** MAILCHECK or define MAILPATH to point to your existing mail inbox.

`.bashrc` is similar to `.profile` but is executed each time an interactive bash shell is launched. It serves to define elements that are not inherited through the environment, such as aliases. If you do not use login shells, you may want to put the contents of `.profile` as discussed above in this file instead.

```
shopt -s nocaseglob
```

will allow bash to glob filenames in a case-insensitive manner. Note that `.bashrc` is not called automatically for login shells. You can source it from `.profile`.

`.inputrc` controls how programs using the readline library (including bash) behave. It is loaded automatically. The full details are in the `readline.info`. Due to a bug in the current readline version, `.inputrc` cannot contain `\r`, even on text mounted systems. Consider the following settings:

```
# Make Bash 8bit clean
```

```
set meta-flag on
set convert-meta off
set output-meta on
# Ignore case while completing
set completion-ignore-case on
```

The first three commands allow bash to display 8-bit characters, useful for languages with accented characters. The last line makes filename completion case insensitive, which can be convenient in a Windows environment.

# Chapter 3. Using Cygwin

This chapter explains some key differences between the Cygwin environment and traditional UNIX systems. It assumes a working knowledge of standard UNIX commands.

## 3.1. Mapping path names

### 3.1.1. Introduction

Cygwin supports both Win32- and POSIX-style paths, where directory delimiters may be either forward or back slashes. UNC pathnames (starting with two slashes and a network name) are also supported.

POSIX operating systems (such as Linux) do not have the concept of drive letters. Instead, all absolute paths begin with a slash (instead of a drive letter such as "c:") and all file systems appear as subdirectories (for example, you might buy a new disk and make it be the `/disk2` directory).

Because many programs written to run on UNIX systems assume the existence of a single unified POSIX file system structure, Cygwin maintains a special internal POSIX view of the Win32 file system that allows these programs to successfully run under Windows. Cygwin uses this mapping to translate between Win32 and POSIX paths as necessary.

### 3.1.2. The Cygwin Mount Table

The **mount** utility program is used to map Win32 drives and network shares into Cygwin's internal POSIX directory tree. This is a similar concept to the typical UNIX mount program. For those people coming from a Windows background, the **mount** utility is very similar to the old DOS **join**, in that it makes your drive letters appear as subdirectories somewhere else.

The mapping is stored in the current user's Cygwin *mount table* in the Windows registry so that the information will be retrieved next time the user logs in. Because it is sometimes desirable to have system-wide as well as user-specific mounts, there is also a system-wide mount table that all Cygwin users inherit. The system-wide table may

only be modified by a user with the appropriate privileges (Administrator privileges in Windows NT).

The current user's table is located under "HKEY\_CURRENT\_USER/Software/Cygnus Solutions/Cygwin/mounts v<version>" where <version> is the latest registry version associated with the Cygwin library (this version is not the same as the release number). The system-wide table is located under the same subkeys under HKEY\_LOCAL\_SYSTEM.

By default, the POSIX root / points to the system partition but it can be relocated to any directory in the Windows file system using the **mount** command. Whenever Cygwin generates a POSIX path from a Win32 one, it uses the longest matching prefix in the mount table. Thus, if C: is mounted as /c and also as /, then Cygwin would translate C:/foo/bar to /c/foo/bar.

Invoking **mount** without any arguments displays Cygwin's current set of mount points. In the following example, the C drive is the POSIX root and D drive is mapped to /d. Note that in this case, the root mount is a system-wide mount point that is visible to all users running Cygwin programs, whereas the /d mount is only visible to the current user.

### Example 3-1. Displaying the current set of mount points

```
c:\> mount
f:\cygwin\bin on /usr/bin type system (binmode)
f:\cygwin\lib on /usr/lib type system (binmode)
f:\cygwin on / type system (binmode)
e:\src on /usr/src type system (binmode)
c: on /cygdrive/c type user (binmode,noumount)
e: on /cygdrive/e type user (binmode,noumount)
```

You can also use the **mount** command to add new mount points, and the **umount** to delete them. See Section 3.6.8 and Section 3.6.15 for more information on how to use these utilities to set up your Cygwin POSIX file system.

Whenever Cygwin cannot use any of the existing mounts to convert from a particular Win32 path to a POSIX one, Cygwin will automatically default to an imaginary mount point under the default POSIX path /cygdrive. For example, if Cygwin accesses z:\foo and the Z drive is not currently in the mount table, then z:\ would be automatically converted to /cygdrive/z. The default prefix of /cygdrive may be changed (see the Section 3.6.8 for more information).

It is possible to assign some special attributes to each mount point. Automatically mounted partitions are displayed as "auto" mounts. Mounts can also be marked as either

"textmode" or "binmode" -- whether text files are read in the same manner as binary files by default or not (see Section 3.2 for more information on text and binary modes).

### 3.1.3. Additional Path-related Information

The **cygpath** program provides the ability to translate between Win32 and POSIX pathnames in shell scripts. See Section 3.6.2 for the details.

The HOME, PATH, and LD\_LIBRARY\_PATH environment variables are automatically converted from Win32 format to POSIX format (e.g. from `c:\cygwin\bin` to `/bin`, if there was a mount from that Win32 path to that POSIX path) when a Cygwin process first starts.

Symbolic links can also be used to map Win32 pathnames to POSIX. For example, the command **ln -s //pollux/home/joe/data /data** would have about the same effect as creating a mount point from `//pollux/home/joe/data` to `/data` using **mount**, except that symbolic links cannot set the default file access mode. Other differences are that the mapping is distributed throughout the file system and proceeds by iteratively walking the directory tree instead of matching the longest prefix in a kernel table. Note that symbolic links will only work on network drives that are properly configured to support the "system" file attribute. Many do not do so by default (the Unix Samba server does not by default, for example).

## 3.2. Text and Binary modes

### 3.2.1. The Issue

On a UNIX system, when an application reads from a file it gets exactly what's in the file on disk and the converse is true for writing. The situation is different in the DOS/Windows world where a file can be opened in one of two modes, binary or text. In the binary mode the system behaves exactly as in UNIX. However in text mode there are major differences:

- a. On writing in text mode, a NL (`\n`, `^J`) is transformed into the sequence CR (`\r`, `^M`) NL.
- b. On reading in text mode, a CR followed by an NL is deleted and a `^Z` character signals the end of file.

This can wreak havoc with the seek/fseek calls since the number of bytes actually in the file may differ from that seen by the application.

The mode can be specified explicitly as explained in the Programming section below. In an ideal DOS/Windows world, all programs using lines as records (such as **bash**, **make**, **sed** ...) would open files (and change the mode of their standard input and output) as text. All other programs (such as **cat**, **cmp**, **tr** ...) would use binary mode. In practice with Cygwin, programs that deal explicitly with object files specify binary mode (this is the case of **od**, which is helpful to diagnose CR problems). Most other programs (such as **cat**, **cmp**, **tr**) use the default mode.

### 3.2.2. The default Cygwin behavior

The Cygwin system gives us some flexibility in deciding how files are to be opened when the mode is not specified explicitly. The rules are evolving, this section gives the design goals.

- a. If the file appears to reside on a file system that is mounted (i.e. if its pathname starts with a directory displayed by **mount**), then the default is specified by the mount flag. If the file is a symbolic link, the mode of the target file system applies.
- b. If the file appears to reside on a file system that is not mounted (as can happen when the path contains a drive letter), the default is text.
- c. Pipes and non-file devices are opened in binary mode, except if the CYGWIN environment variable contains `nobinmode`.

#### **Warning!**

In b20.1 of 12/98, a file will be opened in binary mode if any of the following conditions hold:

1. binary mode is specified in the open call
2. CYGWIN contains `binmode`
3. the file resides in a binary mounted partition
4. the file is not a disk file

- d. When a Cygwin program is launched by a shell, its standard input, output and error are in binary mode if the `CYGWIN` variable contains `tty`, else in text mode, except if they are piped or redirected.

When redirecting, the Cygwin shells uses rules (a-c). For these shells the relevant value of `CYGWIN` is that at the time the shell was launched and not that at the time the program is executed. Non-Cygwin shells always pipe and redirect with binary mode. With non-Cygwin shells the commands **`cat filename | program`** and **`program < filename`** are not equivalent when `filename` is on a text-mounted partition.

### 3.2.3. Example

To illustrate the various rules, we provide scripts to delete CRs from files by using the `tr` program, which can only write to standard output. The script

```
#!/bin/sh
# Remove \r from the file given as argument
tr -d '\r' < "$1" > "$1".nocr
```

will not work on a text mounted systems because the `\r` will be reintroduced on writing. However scripts such as

```
#!/bin/sh
# Remove \r from the file given as argument
tr -d '\r' | gzip | gunzip > "$1".nocr
```

and the `.bat` file

```
REM Remove \r from the file given as argument
@echo off
tr -d \r < %1 > %1.nocr
```

work fine. In the first case (assuming the pipes are binary) we rely on **`gunzip`** to set its output to binary mode, possibly overriding the mode used by the shell. In the second case we rely on the DOS shell to redirect in binary mode.

### 3.2.4. Binary or text?

UNIX programs that have been written for maximum portability will know the difference between text and binary files and act appropriately under Cygwin. For those programs, the text mode default is a good choice. Programs included in official Cygwin distributions should work well in the default mode.

Text mode makes it much easier to mix files between Cygwin and Windows programs, since Windows programs will usually use the CRLF format. Unfortunately you may still have some problems with text mode. First, some of the utilities included with Cygwin do not yet specify binary mode when they should, e.g. **cat** will not work with binary files (input will stop at ^Z, CRs will be introduced in the output). Second, you will introduce CRs in text files you write, which can cause problems when moving them back to a UNIX system.

If you are mounting a remote file system from a UNIX machine, or moving files back and forth to a UNIX machine, you may want to access the files in binary mode. The text files found there will normally be in UNIX NL format, and you would want any files put there by Cygwin programs to be stored in a format understood by UNIX. Be sure to remove CRs from all Makefiles and shell scripts and make sure that you only edit the files with DOS/Windows editors that can cope with and preserve NL terminated lines.

Note that you can decide this on a disk by disk basis (for example, mounting local disks in text mode and network disks in binary mode). You can also partition a disk, for example by mounting `c:` in text mode, and `c:\home` in binary mode.

### 3.2.5. Programming

In the `open()` function call, binary mode can be specified with the flag `O_BINARY` and text mode with `O_TEXT`. These symbols are defined in `fcntl.h`.

In the `fopen()` function call, binary mode can be specified by adding a `b` to the mode string. There is no direct way to specify text mode.

The mode of a file can be changed by the call `setmode(fd, mode)` where `fd` is a file descriptor (an integer) and `mode` is `O_BINARY` or `O_TEXT`. The function returns `O_BINARY` or `O_TEXT` depending on the mode before the call, and `EOF` on error.

## 3.3. File permissions

On Windows 9x systems, files are always readable, and Cygwin uses the native read-only mode to determine if they are writable. Files are considered to be executable if the filename ends with `.bat`, `.com` or `.exe`, or if its content starts with `#!`. Consequently `chmod` can only affect the "w" mode, it silently ignores actions involving the other modes. This means that `ls -l` needs to open and read files. It can thus be relatively slow.

Under NT, file permissions default to the same behavior as Windows 9x but there is optional functionality in Cygwin that can make file systems behave more like on UNIX systems. This is turned on by adding the "ntea" option to the CYGWIN environment variable.

When the "ntea" feature is activated, Cygwin will start with basic permissions as determined above, but can store POSIX file permissions in NT Extended Attributes. This feature works quite well on NTFS partitions because the attributes can be stored sensibly inside the normal NTFS filesystem structure. However, on a FAT partition, NT stores extended attributes in a flat file at the root of the partition called `EA DATA . SF`. This file can grow to extremely large sizes if you have a large number of files on the partition in question, slowing the system to a crawl. In addition, the `EA DATA . SF` file can only be deleted outside of Windows because of its "in use" status. For these reasons, the use of NT Extended Attributes is off by default in Cygwin. Finally, note that specifying "ntea" in CYGWIN has no effect under Windows 9x.

Under NT, the test "`[ -w filename ]`" is only true if filename is writable across the board, e.g. `chmod +w filename`.

## 3.4. Special filenames

### 3.4.1. DOS devices

Windows filenames invalid under Windows are also invalid under Cygwin. This means that base filenames such as `AUX`, `COM1`, `LPT1` or `PRN` (to name a few) cannot be used in a regular Cygwin Windows or POSIX path, even with an extension (`prn.txt`). However the special names can be used as filename extensions (`file.aux`). You can use the special names as you would under DOS, for example you can print on your default printer with the command `cat filename > PRN` (make sure to end with a Form Feed).

### 3.4.2. POSIX devices

There is no need to create a POSIX `/dev` directory as it is simulated within Cygwin automatically. It supports the following devices: `/dev/null`, `/dev/zero`, `/dev/tty`, `/dev/ttyX`, `/dev/ptmx`, `/dev/comX` (the serial ports), `/dev/windows` (the windows message queue), `/dev/random` and `/dev/urandom`. These devices cannot be seen with the command `ls /dev` although commands such as `ls /dev/tty` work fine.

Windows NT/W2K/XP additionally support raw devices like floppies, disks, partitions and tapes. These are accessed from Cygwin applications using POSIX device names which are supported in two different ways. Up to 1.3.3, Cygwin only uses Win32 device names, since 1.3.4 it additionally uses NT internal device names.

Up to Cygwin 1.3.3 the only way to access those devices is to mount the Win32 device names to a POSIX device name.

The Win32 device name for a partition is the drive letter with leading `\\. \\.`, so the floppy would be `\\. \\A:`, the first partition typically `\\. \\C:`. Complete drives (except floppies and CD-ROMS which are supported as partitions only) are named `\\. \\PHYSICALDRIVE $x$` . The  $x$  is the drive number which you can check in the disk manager. Each drive line has prepended the text "Disk  $x$ ".

To access tape drives the Win32 file name `\\. \\TAPE $x$`  is used. For example the first installed tape device is named `\\. \\tape0`.

The naming convention is simple: The name of the POSIX device has to begin with `/dev/` and the rest is as you like. The only exception are tape devices. To identify if the tape device is used as a rewind or a no-rewind device the name must not begin with `n` (rewind) or has to begin with `n` (no-rewind).

Some examples:

```
mount -b //./A: /dev/fd0           # mount floppy as raw block special
mount -b //./physicaldrive1 /dev/hdb # mount "Disk 1"
mount -b //./tape0 /dev/st0       # mount first tape as the rewind device
mount -b //./tape0 /dev/nst0     # ...and as the no-rewind device
```

Note the usage of the `-b` option. It is best to include the `-b` option when mounting these devices to ensure that all file I/O is in "binary mode".

Since Cygwin 1.3.4 raw devices are accessible from inside of Cygwin processes using fixed POSIX device names. That means, you don't have to mount the devices anymore which results in a more cleaner mount table.

These new fixed POSIX device names are generated using a direct conversion from the POSIX namespace to the internal NT namespace. E.g. the first harddisk is the NT

internal device `\device\harddisk0\partition0` or the first partition on the third harddisk is `\device\harddisk2\partition1`. The first floppy in the system is `\device\floppy0`, the first CD-ROM is `\device\cdrom0` and the first tape drive is `\device\tape0`.

The new fixed POSIX names are mapped to NT internal devices as follows:

```
/dev/st0 \device\tape0, rewind
/dev/nst0 \device\tape0, no-rewind
/dev/st1 \device\tape1
...

/dev/fd0 \device\floppy0
/dev/fd1 \device\floppy1
...

/dev/scd0 \device\cdrom0
/dev/scd1 \device\cdrom1
...

/dev/sda \device\harddisk0\partition0 (whole disk)
/dev/sda1 \device\harddisk0\partition1 (first partition)
...
/dev/sda15 \device\harddisk0\partition15 (fifteenth partition)

/dev/sdb \device\harddisk1\partition0
/dev/sdb1 \device\harddisk1\partition1

[up to]

/dev/sd1 \device\harddisk11\partition0
/dev/sd11 \device\harddisk11\partition1
...
/dev/sd115 \device\harddisk11\partition15
```

if you don't like these device names, feel free to create symbolic links as they are created on Linux systems for convenience:

```
ln -s /dev/scd0 /dev/cdrom
ln -s /dev/st0 /dev/tape
...
```

Note that you can't use the mount table to map from fixed device name to your own device name or to map from internal NT device name to your own device name. The following two examples will not work:

```
mount -s -f -b /dev/st0 /dev/tape
mount -s -f -b /device/tape0 /dev/tape
```

### 3.4.3. The .exe extension

Executable program filenames end with `.exe` but the `.exe` need not be included in the command, so that traditional UNIX names can be used. However, for programs that end in `".bat"` and `".com"`, you cannot omit the extension.

As a side effect, the `ls filename` gives information about `filename.exe` if `filename.exe` exists and `filename` does not. In the same situation the function call `stat("filename",..)` gives information about `filename.exe`. The two files can be distinguished by examining their inodes, as demonstrated below.

```
C:\> ls *
a      a.exe      b.exe
C:\> ls -i a a.exe
445885548 a          435996602 a.exe
C:\> ls -i b b.exe
432961010 b          432961010 b.exe
```

If a shell script `myprog` and a program `myprog.exe` coexist in a directory, the program has precedence and is selected for execution of **myprog**.

The **gcc** compiler produces an executable named `filename.exe` when asked to produce `filename`. This allows many makefiles written for UNIX systems to work well under Cygwin.

Unfortunately, the **install** and **strip** commands do distinguish between `filename` and `filename.exe`. They fail when working on a non-existing `filename` even if `filename.exe` exists, thus breaking some makefiles. This problem can be solved by writing **install** and **strip** shell scripts to provide the extension `".exe"` when needed.

### 3.4.4. The @pathnames

To circumvent the limitations on shell line length in the native Windows command shells, Cygwin programs expand their arguments starting with `"@"` in a special way. If a file `pathname` exists, the argument `@pathname` expands recursively to the content of `pathname`. Double quotes can be used inside the file to delimit strings containing blank space. Embedded double quotes must be repeated. In the following example compare the behaviors of the bash built-in **echo** and of the program `/bin/echo`.

**Example 3-2. Using @pathname**

```

bash$ echo 'This is "a long" line' > mylist
bash$ echo @mylist
@mylist
c:\> c:\cygwin\bin\echo @mylist
This is a long line

```

## 3.5. The CYGWIN environment variable

The CYGWIN environment variable is used to configure many global settings for the Cygwin runtime system. It contains the options listed below, separated by blank characters. Many options can be turned off by prefixing with `no`.

- *(no)binmode* - if set, non-disk (e.g. pipe and COM ports) file opens default to binary mode (no CRLF translation) instead of text mode. Defaults to set (binary mode). By default, devices are opened in binary mode, so this option has little effect on normal cygwin operations. It does affect two things, however. For non-NTFS filesystems, this option will control the line endings for standard output/input/error for redirection from the Windows command shell. It will also affect the default translation mode of a pipe, although most shells set the pipe to binary by default.

### Warning!

If set in 12/98 b20.1, all files always open in binary mode.

- *check\_case:level* - Controls the behaviour of Cygwin when a user tries to open or create a file using a case different from the case of the path as saved on the disk. `level` is one of `relaxed`, `adjust` and `strict`.
  - *relaxed* which is the default behaviour simply ignores case. That's the default for native Windows applications as well.
  - *adjust* behaves mostly invisible. The POSIX input path is internally adjusted in case, so that the resulting DOS path uses the correct case throughout. You can see the result when changing the directory using a wrong case and calling `/bin/pwd` afterwards.

- *strict* results in a error message if the case isn't correct. Trying to open a file `FOO` while a file `fOo` exists results in a "no such file or directory" error. Trying to create a file `BAR` while a file `Bar` exists results in a "Filename exists with different case" error.
- *codepage:[ansi/oem]* - Windows console applications can use different character sets (codepages) for drawing characters. The first setting, called "ansi", is the default. This character set contains various forms of latin characters used in European languages. The name originates from the ANSI Latin1 (ISO 8859-1) standard, used in Windows 1.0, though the character sets have since diverged from any standard. The second setting selects an older, DOS-based character set, containing various line drawing and special characters. It is called "oem" since it was originally encoded in the firmware of IBM PCs by original equipment manufacturers (OEMs). If you find that some characters (especially non-US or 'graphical' ones) do not display correctly in Cygwin, you can use this option to select an appropriate codepage.
- *(no)envcache* - If set, environment variable conversions (between Win32 and POSIX) are cached. Note that this is may cause problems if the mount table changes, as the cache is not invalidated and may contain values that depend on the previous mount table contents. Defaults to set.
- *(no)export* - if set, the final values of these settings are re-exported to the environment as `$CYGWIN` again.
- *error\_start:filepath* - if set, runs `filepath` when cygwin encounters a fatal error. This is useful for debugging. `filepath` is usually set to the path to the `gdb` program.
- *(no)glob[:ignorecase]* - if set, command line arguments containing UNIX-style file wildcard characters (brackets, question mark, asterisk, escaped with `\`) are expanded into lists of files that match those wildcards. This is applicable only to programs running from a DOS command line prompt. Default is set.  
  
This option also accepts an optional `[no]ignorecase` modifier. If supplied, wildcard matching is case insensitive. The default is `noignorecase`
- *(no)nfea* - if set, use the full NT Extended Attributes to store UNIX-like inode information. This option only operates under Windows NT. Defaults to not set.

### Warning!

This may create additional *large* files on non-NTFS partitions.

- *(no)ntsec* - if set, use the NT security model to set UNIX-like permissions on files and processes. The file permissions can only be set on NTFS partitions. FAT doesn't support the NT file security. For more information, read the documentation in [ntsec.sgml].
- *(no)smbntsec* - if set, use 'ntsec' on remote drives as well (this is the default). If you encounter problems with NT shares or Samba drives, setting this to 'nosmbntsec' could help. In that case the permission and owner/group information is faked as on FAT partitions. A reason for a non working ntsec on remote drives could be insufficient permissions of the users. Since the needed user rights are somewhat dangerous (SeRestorePrivilege) it's not always an option to grant that rights to users. However, this shouldn't be a problem in NT domain environments.
- *(no)reset\_com* - if set, serial ports are reset to 9600-8-N-1 with no flow control when used. This is done at open time and when handles are inherited. Defaults to set.
- *(no)strip\_title* - if set, strips the directory part off the window title, if any. Default is not set.
- *(no)title* - if set, the title bar reflects the name of the program currently running. Default is not set. Note that under Win9x the title bar is always enabled and it is stripped by default, but this is because of the way Win9x works. In order not to strip, specify `title` or `title nostrip_title`.
- *(no)tty* - if set, Cygwin enables extra support (i.e., termios) for UNIX-like ttys. It is not compatible with some Windows programs. Defaults to not set, in which case the tty is opened in text mode with ^Z as EOF. Note that this has been changed such that ^D works as expected instead of ^Z, and is settable via stty. This option must be specified before starting a Cygwin shell and it cannot be changed in the shell.
- *(no)winsymlinks* - if set, Cygwin creates symlinks as Windows shortcuts with a special header and the R/O attribute set. If not set, Cygwin creates symlinks as plain files with a magic number, a path and the system attribute set. Defaults to set.

## 3.6. Cygwin Utilities

Cygwin comes with a number of command-line utilities that are used to manage the UNIX emulation portion of the Cygwin environment. While many of these reflect their UNIX counterparts, each was written specifically for Cygwin. You may use the long or short option names interchangeably; for example, `--help` and `-h` function identically. All of the Cygwin command-line utilities support the `--help` and `--version` options.

### 3.6.1. cygcheck

Usage: `cygcheck [OPTIONS] [program ...]`

Check system information or PROGRAM library dependencies

```
-c, --check-setup  check packages installed via setup.exe
-s, --sysinfo      system information (not with -k)
-v, --verbose      verbose output (indented) (for -s or programs)
-r, --registry     registry search (requires -s)
-k, --keycheck     perform a keyboard check session (not with -s)
-h, --help         give help about the info (not with -c)
-V, --version      output version information and exit
```

You must at least give either `-s` or `-k` or a program name

The **cygcheck** program is a diagnostic utility that examines your system and reports the information that is significant to the proper operation of Cygwin programs. It can give information about specific programs or libraries you are trying to run, general system information, or both. If you list one or more programs on the command line, it will diagnose the runtime environment of that program or programs, providing the names of DLL files on which the program depends. If you specify the `-s` option, it will give general system information. If you specify `-s` and list one or more programs on the command line, it reports on both.

The `-h` option prints additional helpful messages in the report, at the beginning of each section. It also adds table column headings. While this is useful information, it also adds some to the size of the report, so if you want a compact report or if you know what everything is already, just leave this out.

The `-v` option causes the output to be more verbose. What this means is that additional information will be reported which is usually not interesting, such as the internal version numbers of DLLs, additional information about recursive DLL usage, and if a file in one directory in the PATH also occurs in other directories on the PATH.

The `-r` option causes **cygcheck** to search your registry for information that is relevant to Cygwin programs. These registry entries are the ones that have "Cygwin" in the name. If you are paranoid about privacy, you may remove information from this report, but please keep in mind that doing so makes it harder to diagnose your problems.

The `-c` option causes the arguments to be interpreted as package names. **cygcheck** will report the current version of the package that you specify, or with no arguments, on all packages.

The **cygcheck** program should be used to send information about your system for troubleshooting when requested. When asked to run this command save the output so

that you can email it, for example:

```
C:\cygwin> cygcheck -s -v -r -h > cygcheck_output.txt
```

## 3.6.2. cygpath

```
Usage: cygpath (-d|-m|-u|-w|-t TYPE) [-c HANDLE] [-f FILE] [options] NAME
       cygpath [-ADHPSW]
```

Convert Unix and Windows format paths, or output system path information

Output type options:

-d, --dos	print DOS (short) form of NAME (C:\PROGRA~1\)
-m, --mixed	like --windows, but with regular slashes (C:/WINNT)
-u, --unix	(default) print Unix form of NAME (/cygdrive/c/winnt)
-w, --windows	print Windows form of NAME (C:\WINNT)
-t, --type TYPE	print TYPE form: 'dos', 'mixed', 'unix', or 'windows'

Path conversion options:

-a, --absolute	output absolute path
-l, --long-name	print Windows long form of NAME (with -w, -m only)
-p, --path	NAME is a PATH list (i.e., '/bin:/usr/bin')
-s, --short-name	print DOS (short) form of NAME (with -w, -m only)

System information:

-A, --allusers	use 'All Users' instead of current user for -D, -P
-D, --desktop	output 'Desktop' directory and exit
-H, --homeroot	output 'Profiles' directory (home root) and exit
-P, --smprograms	output Start Menu 'Programs' directory and exit
-S, --sysdir	output system directory and exit
-W, --windir	output 'Windows' directory and exit

The **cygpath** program is a utility that converts Windows native filenames to Cygwin POSIX-style pathnames and vice versa. It can be used when a Cygwin program needs to pass a file name to a native Windows program, or expects to get a file name from a native Windows program. Alternatively, **cygpath** can output information about the location of important system directories in either format.

The `-u` and `-w` options indicate whether you want a conversion to UNIX (POSIX) format (`-u`) or to Windows format (`-w`). Use the `-d` to get DOS-style (8.3) file and path names. The `-m` option will output Windows-style format but with forward slashes instead of backslashes. This option is especially useful in shell scripts, which use backslashes as an escape character.

In combination with the `-w` option, you can use the `-l` and `-s` options to use normal (long) or DOS-style (short) form. The `-d` option is identical to `-w` and `-s` together.

Caveat: The `-l` option does not work if the `check_case` parameter of `CYGWIN` is set to `strict`, since Cygwin is not able to match any Windows short path in this mode.

The `-p` option means that you want to convert a path-style string rather than a single filename. For example, the `PATH` environment variable is semicolon-delimited in Windows, but colon-delimited in UNIX. By giving `-p` you are instructing **cygpath** to convert between these formats.

The `-i` option suppresses the print out of the usage message if no filename argument was given. It can be used in make file rules converting variables that may be omitted to a proper format. Note that **cygpath** output may contain spaces (C:\Program Files) so should be enclosed in quotes.

### Example 3-3. Example cygpath usage

```
#!/bin/sh
if [ "${1}" = "" ];
then
  XPATH=".";
else
  XPATH="$(cygpath -w "${1}")";
fi
explorer $XPATH &
```

The capital options `-D`, `-H`, `-P`, `-S`, and `-W` output directories used by Windows that are not the same on all systems, for example `-S` might output `C:\WINNT\SYSTEM32` or `C:\WINDOWS\SYSTEM`. The `-H` shows the Windows profiles directory that can be used as root of home. The `-A` option forces use of the "All Users" directories instead of the current user for the `-D` and `-P` options. On Win9x systems with only a single user, `-A` has no effect; `-D` and `-AD` would have the same output. By default the output is in UNIX (POSIX) format; use the `-w` or `-d` options to get other formats.

### 3.6.3. dumper

```
Usage: dumper [OPTION] FILENAME WIN32PID
Dump core from WIN32PID to FILENAME.core
```

```
-d, --verbose    be verbose while dumping
-h, --help       output help information and exit
```

```
-q, --quiet      be quiet while dumping (default)
-v, --version    output version information and exit
```

The **dumper** utility can be used to create a core dump of running Windows process. This core dump can be later loaded to **gdb** and analyzed. One common way to use **dumper** is to plug it into cygwin's Just-In-Time debugging facility by adding

```
error_start=x:\path\to\dumper.exe
```

to the *CYGWIN* environment variable. Please note that `x:\path\to\dumper.exe` is Windows-style and not cygwin path. If `error_start` is set this way, then **dumper** will be started whenever some program encounters a fatal error.

**dumper** can be also be started from the command line to create a core dump of any running process. Unfortunately, because of a Windows API limitation, when a core dump is created and **dumper** exits, the target process is terminated too.

To save space in the core dump, **dumper** doesn't write those portions of target process' memory space that are loaded from executable and dll files and are unchangeable, such as program code and debug info. Instead, **dumper** saves paths to files which contain that data. When a core dump is loaded into **gdb**, it uses these paths to load appropriate files. That means that if you create a core dump on one machine and try to debug it on another, you'll need to place identical copies of the executable and dlls in the same directories as on the machine where the core dump was created.

### 3.6.4. getfacl

```
Usage: getfacl [-adn] FILE [FILE2...]
```

Display file and directory access control lists (ACLs).

```
-a, --all        display the filename, the owner, the group, and
                 the ACL of the file
-d, --dir        display the filename, the owner, the group, and
                 the default ACL of the directory, if it exists
-h, --help      output usage information and exit
-n, --noname     display user and group IDs instead of names
-v, --version    output version information and exit
```

When multiple files are specified on the command line, a blank line separates the ACLs for each file.

For each argument that is a regular file, special file or directory, **getfacl** displays the owner, the group, and the ACL. For directories **getfacl** displays additionally the default ACL. With no options specified, **getfacl** displays the filename, the owner, the group, and both the ACL and the default ACL, if it exists. For more information on Cygwin and Windows ACLs, see Section 2.4 in the Cygwin User's Guide. The format for ACL output is as follows:

```
# file: filename
# owner: name or uid
# group: name or uid
user::perm
user:name or uid:perm
group::perm
group:name or gid:perm
mask:perm
other:perm
default:user::perm
default:user:name or uid:perm
default:group::perm
default:group:name or gid:perm
default:mask:perm
default:other:perm
```

### 3.6.5. kill

```
Usage: kill [-f] [-signal] [-s signal] pid1 [pid2 ...]
       kill -l [signal]
Send signals to processes
```

```
-f, --force      force, using win32 interface if necessary
-l, --list       print a list of signal names
-s, --signal     send signal (use kill --list for a list)
-h, --help      output usage information and exit
-v, --version    output version information and exit
```

The **kill** program allows you to send arbitrary signals to other Cygwin programs. The usual purpose is to end a running program from some other window when **^C** won't work, but you can also send program-specified signals such as **SIGUSR1** to trigger actions within the program, like enabling debugging or re-opening log files. Each program defines the signals they understand.

You may need to specify the full path to use **kill** from within some shells, including **bash**, the default Cygwin shell. This is because **bash** defines a **kill** builtin function; see the **bash** man page under *BUILTIN COMMANDS* for more information. To make sure you are using the Cygwin version, try

```
$ /bin/kill --version
```

which should give the Cygwin **kill** version number and copyright information.

Unless you specify the **-f** option, the "pid" values used by **kill** are the Cygwin pids, not the Windows pids. To get a list of running programs and their Cygwin pids, use the Cygwin **ps** program. **ps -W** will display *all* windows pids.

The **kill -l** option prints the name of the given signal, or a list of all signal names if no signal is given.

To send a specific signal, use the **-signN** option, either with a signal number or a signal name (minus the "SIG" part), like these examples:

#### Example 3-4. Using the kill command

```
$ kill 123
$ kill -1 123
$ kill -HUP 123
$ kill -f 123
```

Here is a list of available signals, their numbers, and some commentary on them, from the file `<sys/signal.h>`, which should be considered the official source of this information.

SIGHUP	1	hangup
SIGINT	2	interrupt
SIGQUIT	3	quit
SIGILL	4	illegal instruction (not reset when caught)
SIGTRAP	5	trace trap (not reset when caught)
SIGABRT	6	used by abort
SIGEMT	7	EMT instruction
SIGFPE	8	floating point exception
SIGKILL	9	kill (cannot be caught or ignored)
SIGBUS	10	bus error
SIGSEGV	11	segmentation violation
SIGSYS	12	bad argument to system call
SIGPIPE	13	write on a pipe with no one to read it
SIGALRM	14	alarm clock
SIGTERM	15	software termination signal from kill

SIGURG	16	urgent condition on IO channel
SIGSTOP	17	sendable stop signal not from tty
SIGTSTP	18	stop signal from tty
SIGCONT	19	continue a stopped process
SIGCHLD	20	to parent on child stop or exit
SIGTTIN	21	to readers pgrp upon background tty read
SIGTTOU	22	like TTIN for output if (tp->t_local&LTOSTOP)
SIGPOLL	23	System V name for SIGIO
SIGXCPU	24	exceeded CPU time limit
SIGXFSZ	25	exceeded file size limit
SIGVTALRM	26	virtual time alarm
SIGPROF	27	profiling time alarm
SIGWINCH	28	window changed
SIGLOST	29	resource lost (eg, record-lock lost)
SIGUSR1	30	user defined signal 1
SIGUSR2	31	user defined signal 2

### 3.6.6. mkgroup

Usage: mkgroup [OPTION]... [domain]...  
 Prints /etc/group file to stdout

Options:

-l,--local	print local group information
-c,--current	print current group, if a domain account
-d,--domain	print global group information (from current domain if no domains specified).
-o,--id-offset offset	change the default offset (10000) added to gids in domain accounts.
-s,--no-sids	don't print SIDs in pwd field (this affects ntsec)
-u,--users	print user list in gr_mem field
-h,--help	print this message
-v,--version	print version information and exit

One of '-l' or '-d' must be given on NT/W2K.

The **mkgroup** program can be used to help configure your Windows system to be more UNIX-like by creating an initial /etc/group. Its use is essential on the NT series (Windows NT, 2000, and XP) to include Windows security information. It can also be used on the Win9x series (Windows 95, 98, and Me) to create a file with the correct

format. To initially set up your machine if you are a local user, you'd do something like this:

### Example 3-5. Setting up the groups file for local accounts

```
$ mkdir /etc
$ mkgroup -l > /etc/group
```

Note that this information is static. If you change the group information in your system, you'll need to regenerate the group file for it to have the new information.

The `-d` and `-l` options allow you to specify where the information comes from, the local machine or the domain (default or given), or both. With the `-d` option the program contacts the Domain Controller, which may be unreachable or have restricted access. An entry for the current domain user can then be created by using the option `-c` together with `-l`, but `-c` has no effect when used with `-d`. The `-o` option allows for special cases (such as multiple domains) where the GIDs might match otherwise. The `-s` option omits the NT Security Identifier (SID). For more information on SIDs, see Section 2.4 in the Cygwin User's Guide. The `-u` option causes **mkgroup** to enumerate the users for each group, placing the group members in the `gr_mem` (last) field. Note that this can greatly increase the time for **mkgroup** to run in a large domain. Having `gr_mem` fields is helpful when a domain user logs in remotely while the local machine is disconnected from the Domain Controller.

## 3.6.7. mkpasswd

Usage: `mkpasswd [OPTION]... [domain]...`

Prints `/etc/passwd` file to stdout

Options:

<code>-l,--local</code>	print local user accounts
<code>-c,--current</code>	print current account, if a domain account
<code>-d,--domain</code>	print domain accounts (from current domain if no domains specified)
<code>-o,--id-offset offset</code>	change the default offset (10000) added to uids in domain accounts.
<code>-g,--local-groups</code>	print local group information too if no domains specified
<code>-m,--no-mount</code>	don't use mount points for home dir
<code>-s,--no-sids</code>	don't print SIDs in GCOS field (this affects ntsec)

```

-p,--path-to-home path    use specified path and not user account home dir
-u,--username username    only return information for the specified user
-h,--help                  displays this message
-v,--version                version information and exit

```

One of '-l', '-d' or '-g' must be given on NT/W2K.

The **mkpasswd** program can be used to help configure your Windows system to be more UNIX-like by creating an initial `/etc/passwd` from your system information. Its use is essential on the NT series (Windows NT, 2000, and XP) to include Windows security information, but the actual passwords are determined by Windows, not by the content of `/etc/passwd`. On the Win9x series (Windows 95, 98, and Me) the password field must be replaced by the output of **crypt your\_password** if remote access is desired. To initially set up your machine if you are a local user, you'd do something like this:

### Example 3-6. Setting up the passwd file for local accounts

```

$ mkdir /etc
$ mkpasswd -l > /etc/passwd

```

Note that this information is static. If you change the user information in your system, you'll need to regenerate the passwd file for it to have the new information.

The `-d` and `-l` options allow you to specify where the information comes from, the local machine or the domain (default or given), or both. With the `-d` option the program contacts the Domain Controller, which may be unreachable or have restricted access. An entry for the current domain user can then be created by using the option `-c` together with `-l`, but `-c` has no effect when used with `-d`. The `-o` option allows for special cases (such as multiple domains) where the UIDs might match otherwise. The `-g` option creates a local user that corresponds to each local group. This is because NT assigns groups file ownership. The `-m` option bypasses the current mount table so that, for example, two users who have a Windows home directory of H: could mount them differently. The `-s` option omits the NT Security Identifier (SID). For more information on SIDs, see Section 2.4 in the Cygwin User's Guide. The `-p` option causes **mkpasswd** to use the specified prefix instead of the account home dir or `/home/`. For example, this command:

### Example 3-7. Using an alternate home root

```

$ mkpasswd -l -p "$(cygpath -H)" > /etc/passwd

```

would put local users' home directories in the Windows 'Profiles' directory. On Win9x machines the `-u` option creates an entry for the specified user. On the NT series it restricts the output to that user, greatly reducing the amount of time it takes in a large domain.

## 3.6.8. mount

Usage: `mount [OPTION] [<win32path> <posixpath>]`

Display information about mounted filesystems, or mount a filesystem

<code>-b, --binary</code>	(default)	text files are equivalent to binary files (newline = \n)
<code>-c, --change-cygdrive-prefix</code>		change the cygdrive path prefix to <posixpath>
<code>-f, --force</code>		force mount, don't warn about missing mount point directories
<code>-h, --help</code>		output usage information and exit
<code>-m, --mount-commands</code>		write mount commands to replace user and system mount points and cygdrive prefixes
<code>-o, --options X[,X...]</code>		specify mount options
<code>-p, --show-cygdrive-prefix</code>		show user and/or system cygdrive path prefix
<code>-s, --system</code>	(default)	add system-wide mount point
<code>-t, --text</code>		text files get \r\n line endings
<code>-u, --user</code>		add user-only mount point
<code>-v, --version</code>		output version information and exit
<code>-x, --executable</code>		treat all files under mount point as executables
<code>-E, --no-executable</code>		treat all files under mount point as non-executables
<code>-X, --cygwin-executable</code>		treat all files under mount point as cygwin executables

The **mount** program is used to map your drives and shares onto Cygwin's simulated POSIX directory tree, much like as is done by mount commands on typical UNIX systems. Please see Section 3.1.2 for more information on the concepts behind the Cygwin POSIX file system and strategies for using mounts. To remove mounts, use **umount**

### 3.6.8.1. Using mount

If you just type **mount** with no parameters, it will display the current mount table for you.

**Example 3-8. Displaying the current set of mount points**

```
c:\cygwin\> mount
c:\cygwin\bin on /usr/bin type system (binmode)
c:\cygwin\lib on /usr/lib type system (binmode)
c:\cygwin on / type system (binmode)
c: on /c type user (binmode,noumount)
d: on /d type user (binmode,noumount)
```

In this example, c:\cygwin is the POSIX root and D drive is mapped to /d. Note that in this case, the root mount is a system-wide mount point that is visible to all users running Cygwin programs, whereas the /d mount is only visible to the current user.

The **mount** utility is also the mechanism for adding new mounts to the mount table. The following example demonstrates how to mount the directory \\pollux\home\joe\data to /data.

**Example 3-9. Adding mount points**

```
c:\cygwin\> ls /data
ls: /data: No such file or directory
c:\cygwin\> mount \\pollux\home\joe\data /data
mount: warning - /data does not exist!
c:\cygwin\> mount
\\pollux\home\joe\data on /data type sytem (binmode)
c:\cygwin\bin on /usr/bin type system (binmode)
c:\cygwin\lib on /usr/lib type system (binmode)
c:\cygwin on / type system (binmode)
c: on /c type user (binmode,noumount)
d: on /d type user (binmode,noumount)
```

Note that **mount** was invoked from the Windows command shell in the previous example. In many Unix shells, including bash, it is legal and convenient to use the forward "/" in Win32 pathnames since the "\" is the shell's escape character.

The **-s** flag to **mount** is used to add a mount in the system-wide mount table used by all Cygwin users on the system, instead of the user-specific one. System-wide mounts are displayed by **mount** as being of the "system" type, as is the case for the / partition in the last example. Under Windows NT, only those users with Administrator privileges are permitted to modify the system-wide mount table.

Note that a given POSIX path may only exist once in the user table and once in the global, system-wide table. Attempts to replace the mount will fail with a busy error. The

`-f` (force) flag causes the old mount to be silently replaced with the new one. It will also silence warnings about the non-existence of directories at the Win32 path location.

The `-b` flag is used to instruct Cygwin to treat binary and text files in the same manner by default. Binary mode mounts are marked as "binmode" in the Flags column of **mount** output. By default, mounts are in text mode ("textmode" in the Flags column).

Normally, files ending in certain extensions (.exe, .com, .bat, .cmd) are assumed to be executable. Files whose first two characters begin with '#!' are also considered to be executable. The `-x` flag is used to instruct Cygwin that the mounted file is "executable". If the `-x` flag is used with a directory then all files in the directory are executable. This option allows other files to be marked as executable and avoids the overhead of opening each file to check for a '#!'. The `-x` option is very similar to `-x`, but also prevents Cygwin from setting up commands and environment variables for a normal Windows program, adding another small performance gain. The opposite of these flags is the `-E` flag, which means that no files should be marked as executable.

The `-m` option causes the **mount** utility to output a series of commands that could recreate both user and system mount points. You can save this output as a backup when experimenting with the mount table. It also makes moving your settings to a different machine much easier.

The `-o` option is the method via which various options about the mount point may be recorded. The following options are available (note that most of the options are duplicates of other mount flags):

```

user          - mount lives user-specific mount
system        - mount lives in system table (default)
binary        - files default to binary mode (default)
text          - files default to CRLF text mode line endings
exec          - files below mount point are all executable
notexec       - files below mount point are not executable
cygexec       - files below mount point are all cygwin executables
nosuid        - no suid files are allowed (currently unimplemented)
managed       - directory is managed by cygwin. Mixed case and special
                characters in filenames are allowed.
```

### 3.6.8.2. Cygdrive mount points

Whenever Cygwin cannot use any of the existing mounts to convert from a particular Win32 path to a POSIX one, Cygwin will, instead, convert to a POSIX path using a default mount point: `/cygdrive`. For example, if Cygwin accesses `z:\foo` and the `z` drive is not currently in the mount table, then `z:\` will be accessible as `/cygdrive/z`.

The **mount** utility can be used to change this default automount prefix through the use of the "--change-cygdrive-prefix" option. In the following example, we will set the automount prefix to /:

### Example 3-10. Changing the default prefix

```
c:\cygwin\> mount --change-cygdrive-prefix /
```

Note that if you set a new prefix in this manner, you can specify the `-s` flag to make this the system-wide default prefix. By default, the `cygdrive-prefix` applies only to the system-wide setting. You can always see the user and system `cygdrive` prefixes with the `-p` option. Using the `-b` flag with `--change-cygdrive-prefix` makes all new automounted filesystems default to binary mode file accesses.

### 3.6.8.3. Limitations

Limitations: there is a hard-coded limit of 30 mount points. Also, although you can mount to pathnames that do not start with "/", there is no way to make use of such mount points.

Normally the POSIX mount point in Cygwin is an existing empty directory, as in standard UNIX. If this is the case, or if there is a place-holder for the mount point (such as a file, a symbolic link pointing anywhere, or a non-empty directory), you will get the expected behavior. Files present in a mount point directory before the mount become invisible to Cygwin programs.

It is sometimes desirable to mount to a non-existent directory, for example to avoid cluttering the root directory with names such as `a`, `b`, `c` pointing to disks. Although **mount** will give you a warning, most everything will work properly when you refer to the mount point explicitly. Some strange effects can occur however. For example if your current working directory is `/dir`, say, and `/dir/mtpt` is a mount point, then `mtpt` will not show up in an **ls** or **echo \*** command and **find .** will not find `mtpt`.

## 3.6.9. passwd

```
Usage: passwd (-l|-u|-S) [USER]
        passwd [-i NUM] [-n MINDAYS] [-x MAXDAYS] [-L LEN]
Change USER's password or password attributes
```

## User operations:

```
-l, --lock      lock USER's account
-u, --unlock    unlock USER's account
-S, --status    display password status for USER (locked, expired, etc.)
```

## System operations:

```
-i, --inactive  set NUM of days before inactive accounts are disabled
                (inactive accounts are those with expired passwords)
-n, --minage    set system minimum password age to MINDAYS
-x, --maxage    set system maximum password age to MAXDAYS
-L, --length    set system minimum password length to LEN
```

## Other options:

```
-h, --help      output usage information and exit
-v, --version    output version information and exit
```

**passwd** changes passwords for user accounts. A normal user may only change the password for their own account, but administrators may change passwords on any account. **passwd** also changes account information, such as password expiry dates and intervals.

**Password changes:** The user is first prompted for their old password, if one is present. This password is then encrypted and compared against the stored password. The user has only one chance to enter the correct password. The administrators are permitted to bypass this step so that forgotten passwords may be changed.

The user is then prompted for a replacement password. **passwd** will prompt twice for this replacement and compare the second entry against the first. Both entries are required to match in order for the password to be changed.

After the password has been entered, password aging information is checked to see if the user is permitted to change their password at this time. If not, **passwd** refuses to change the password and exits.

**Account maintenance:** User accounts may be locked and unlocked with the `-l` and `-u` flags. The `-l` option disables an account. The `-u` option re-enables an account.

The account status may be given with the `-S` option. The status information is self-explanatory.

Administrators can also use **passwd** to change system-wide password expiry and length requirements with the `-i`, `-n`, `-x`, and `-L` options. The `-i` option is used to disable an account after the password has been expired for a number of days. After a user account has had an expired password for *NUM* days, the user may no longer sign on to the account. The `-n` option is used to set the minimum number of days before a password

may be changed. The user will not be permitted to change the password until *MINDAYS* days have elapsed. The `-x` option is used to set the maximum number of days a password remains valid. After *MAXDAYS* days, the password is required to be changed. Allowed values for the above options are 0 to 999. The `-L` option sets the minimum length of allowed passwords for users who don't belong to the administrators group to *LEN* characters. Allowed values for the minimum password length are 0 to 14. In any of the above cases, a value of 0 means 'no restrictions'.

Limitations: Users may not be able to change their password on some systems.

### 3.6.10. ps

Usage: `ps [-aefls] [-u UID]`

Report process status

```
-a, --all          show processes of all users
-e, --everyone    show processes of all users
-f, --full        show process uids, pids
-h, --help        output usage information and exit
-l, --long        show process uids, pids, pgids, winpids
-s, --summary     show process summary
-u, --user        list processes owned by UID
-v, --version     output version information and exit
-W, --windows     show windows as well as cygwin processes
```

With no options, `ps` outputs the long format by default

The **ps** program gives the status of all the Cygwin processes running on the system (`ps = "process status"`). Due to the limitations of simulating a POSIX environment under Windows, there is little information to give.

The PID column is the process ID you need to give to the **kill** command. The PPID is the parent process ID, and PGID is the process group ID. The WINPID column is the process ID displayed by NT's Task Manager program. The TTY column gives which pseudo-terminal a process is running on, or a '?' for services. The UID column shows which user owns each process. STIME is the time the process was started, and COMMAND gives the name of the program running.

By default **ps** will only show processes owned by the current user. With either the `-a` or `-e` option, all user's processes (and system processes) are listed. There are historical UNIX reasons for the synonymous options, which are functionally identical. The `-f` option outputs a "full" listing with usernames for UIDs. The `-l` option is the default display mode, showing a "long" listing with all the above columns. The other display

option is `-s`, which outputs a shorter listing of just PID, TTY, STIME, and COMMAND. The `-u` option allows you to show only processes owned by a specific user. The `-w` option causes `ps` show non-Cygwin Windows processes as well as Cygwin processes. The WINPID is also the PID, and they can be killed with the Cygwin `kill` command's `-f` option.

### 3.6.11. regtool

Usage: `regtool.exe [OPTION] (add | check | get | list | remove | unset) KEY`  
View or edit the Win32 registry

Actions:

<code>add KEY\SUBKEY</code>	add new SUBKEY
<code>check KEY</code>	exit 0 if KEY exists, 1 if not
<code>get KEY\VALUE</code>	prints VALUE to stdout
<code>list KEY</code>	list SUBKEYs and VALUEs
<code>remove KEY</code>	remove KEY
<code>set KEY\VALUE [data ...]</code>	set VALUE
<code>unset KEY\VALUE</code>	removes VALUE from KEY

Options for 'list' Action:

<code>-k, --keys</code>	print only KEYS
<code>-l, --list</code>	print only VALUEs
<code>-p, --postfix</code>	like <code>ls -p</code> , appends <code>'\'</code> postfix to KEY names

Options for 'set' Action:

<code>-e, --expand-string</code>	set type to REG_EXPAND_SZ
<code>-i, --integer</code>	set type to REG_DWORD
<code>-m, --multi-string</code>	set type to REG_MULTI_SZ
<code>-s, --string</code>	set type to REG_SZ

Options for 'set' and 'unset' Actions:

<code>-K&lt;c&gt;, --key-separator[=]&lt;c&gt;</code>	set key separator to <c> instead of <code>'\'</code>
---	--

Other Options:

<code>-h, --help</code>	output usage information and exit
<code>-q, --quiet</code>	no error output, just nonzero return if KEY/VALUE missing
<code>-v, --verbose</code>	verbose output, including VALUE contents when applicable
<code>-V, --version</code>	output version information and exit

KEY is in the format `[host]\prefix\KEY\KEY\VALUE`, where host is optional remote host in either `\\hostname` or `hostname:` format and prefix is any of:

root	HKCR	HKEY_CLASSES_ROOT (local only)
config	HKCC	HKEY_CURRENT_CONFIG (local only)
user	HKCU	HKEY_CURRENT_USER (local only)
machine	HKLM	HKEY_LOCAL_MACHINE
users	HKU	HKEY_USERS

You can use forward slash ( '/' ) as a separator instead of backslash, in that case backslash is treated as escape character

Example: `regtool.exe get '\user\software\Microsoft\Clock\iFormat'`

The **regtool** program allows shell scripts to access and modify the Windows registry. Note that modifying the Windows registry is dangerous, and carelessness here can result in an unusable system. Be careful.

The `-v` option means "verbose". For most commands, this causes additional or lengthier messages to be printed. Conversely, the `-q` option suppresses error messages, so you can use the exit status of the program to detect if a key exists or not (for example).

You must provide **regtool** with an *action* following options (if any). Currently, the action must be `add`, `set`, `check`, `get`, `list`, `remove`, `set`, or `unset`.

The `add` action adds a new key. The `check` action checks to see if a key exists (the exit code of the program is zero if it does, nonzero if it does not). The `get` action gets the value of a value of a key, and prints it (and nothing else) to stdout. Note: if the value doesn't exist, an error message is printed and the program returns a non-zero exit code. If you give `-q`, it doesn't print the message but does return the non-zero exit code.

The `list` action lists the subkeys and values belonging to the given key. With `list`, the `-k` option instructs **regtool** to print only KEYS, and the `-l` option to print only VALUES. The `-p` option postfixes a '/' to each KEY, but leave VALUES with no postfix. The `remove` action removes a key. Note that you may need to remove everything in the key before you may remove it, but don't rely on this stopping you from accidentally removing too much.

The `set` action sets a value within a key. `-e` means it's an expanding string (REG\_EXPAND\_SZ) that contains embedded environment variables. `-i` means the value is an integer (REG\_DWORD). `-m` means it's a multi-string (REG\_MULTI\_SZ). `-s` means the value is a string (REG\_SZ). If you don't specify one of these, **regtool** tries to guess the type based on the value you give. If it looks like a number, it's a DWORD. If it starts with a percent, it's an expanding string. If you give multiple values, it's a multi-string. Else, it's a regular string. The `unset` action removes a value from a key.

By default, the last "\" or "/" is assumed to be the separator between the key and the value. You can use the `-K` option to provide an alternate key/value separator character.

### 3.6.12. setfacl

```
Usage: setfacl [-r] (-f ACL_FILE | -s acl_entries) FILE...
       setfacl [-r] ([-d acl_entries] [-m acl_entries]) FILE...
Modify file and directory access control lists (ACLs)
```

```
-d, --delete      delete one or more specified ACL entries
-f, --file        set ACL entries for FILE to ACL entries read
                  from a ACL_FILE
-m, --modify      modify one or more specified ACL entries
-r, --replace     replace mask entry with maximum permissions
                  needed for the file group class
-s, --substitute  substitute specified ACL entries for the
                  ACL of FILE
-h, --help        output usage information and exit
-v, --version     output version information and exit
```

At least one of (-d, -f, -m, -s) must be specified

For each file given as parameter, **setfacl** will either replace its complete ACL (-s, -f), or it will add, modify, or delete ACL entries. For more information on Cygwin and Windows ACLs, see Section 2.4 in the Cygwin User's Guide.

Acl\_entries are one or more comma-separated ACL entries from the following list:

```
u[ser]::perm
u[ser]:uid:perm
g[roup]::perm
g[roup]:gid:perm
m[ask]::perm
o[ther]::perm
```

Default entries are like the above with the additional default identifier. For example:

```
d[efault]:u[ser]:uid:perm
```

*perm* is either a 3-char permissions string in the form "rwx" with the character '-' for no permission or it is the octal representation of the permissions, a value from 0 (equivalent to "---") to 7 ("rwx"). *uid* is a user name or a numerical uid. *gid* is a group name or a numerical gid.

The following options are supported:

`-d` Delete one or more specified entries from the file's ACL. The owner, group and others entries must not be deleted. Acl\_entries to be deleted should be specified without permissions, as in the following list:

```
u[ser]:uid
g[roup]:gid
d[efault]:u[ser]:uid
d[efault]:g[roup]:gid
d[efault]:m[ask]:
d[efault]:o[ther]:
```

`-f` Take the Acl\_entries from ACL\_FILE one per line. Whitespace characters are ignored, and the character "#" may be used to start a comment. The special filename "-" indicates reading from stdin. Note that you can use this with **getfacl** and **setfacl** to copy ACLs from one file to another:

```
$ getfacl source_file | setfacl -f - target_file
```

Required entries are: one user entry for the owner of the file, one group entry for the group of the file, and one other entry.

If additional user and group entries are given: a mask entry for the file group class of the file, and no duplicate user or group entries with the same uid/gid.

If it is a directory: one default user entry for the owner of the file, one default group entry for the group of the file, one default mask entry for the file group class, and one default other entry.

`-m` Add or modify one or more specified ACL entries. Acl\_entries is a comma-separated list of entries from the same list as above.

`-r` Causes the permissions specified in the mask entry to be ignored and replaced by the maximum permissions needed for the file group class.

`-s` Like `-f`, but substitute the file's ACL with Acl\_entries specified in a comma-separated list on the command line.

While the `-d` and `-m` options may be used in the same command, the `-f` and `-s` options may be used only exclusively.

Directories may contain default ACL entries. Files created in a directory that contains default ACL entries will have permissions according to the combination of the current umask, the explicit permissions requested and the default ACL entries

Limitations: Under Cygwin, the default ACL entries are not taken into account currently.

### 3.6.13. ssp

Usage: ssp [options] low\_pc high\_pc command...

Single-step profile COMMAND

```

-c, --console-trace  trace every EIP value to the console. *Lots* slower.
-d, --disable        disable single-stepping by default; use
                    OutputDebugString ("ssp on") to enable stepping
-e, --enable        enable single-stepping by default; use
                    OutputDebugString ("ssp off") to disable stepping
-h, --help          output usage information and exit
-l, --dll           enable dll profiling. A chart of relative DLL usage
                    is produced after the run.
-s, --sub-threads   trace sub-threads too. Dangerous if you have
                    race conditions.
-t, --trace-eip     trace every EIP value to a file TRACE.SSP. This
                    gets big *fast*.
-v, --verbose       output verbose messages about debug events.
-V, --version       output version information and exit

```

Example: ssp 0x401000 0x403000 hello.exe

#### SSP - The Single Step Profiler

Original Author: DJ Delorie

The SSP is a program that uses the Win32 debug API to run a program one ASM instruction at a time. It records the location of each instruction used, how many times that instruction is used, and all function calls. The results are saved in a format that is usable by the profiling program **gprof**, although **gprof** will claim the values are seconds, they really are instruction counts. More on that later.

Because the SSP was originally designed to profile the cygwin DLL, it does not automatically select a block of code to report statistics on. You must specify the range of memory addresses to keep track of manually, but it's not hard to figure out what to specify. Use the "objdump" program to determine the bounds of the target's ".text" section. Let's say we're profiling cygwin1.dll. Make sure you've built it with debug symbols (else **gprof** won't run) and run objdump like this:

```
$ objdump -h cygwin1.dll
```

It will print a report like this:

```
cygwin1.dll:      file format pei-i386

Sections:
Idx Name          Size      VMA      LMA      File off  Algn
  0 .text          0007ea00 61001000 61001000 00000400 2**2
                  CONTENTS, ALLOC, LOAD, READONLY, CODE, DATA
  1 .data          00008000 61080000 61080000 0007ee00 2**2
                  CONTENTS, ALLOC, LOAD, DATA
  . . .
```

The only information we're concerned with are the VMA of the `.text` section and the VMA of the section after it (sections are usually contiguous; you can also add the Size to the VMA to get the end address). In this case, the VMA is `0x61001000` and the ending address is either `0x61080000` (start of `.data` method) or `0x0x6107fa00` (VMA+Size method).

There are two basic ways to use SSP - either profiling a whole program, or selectively profiling parts of the program.

To profile a whole program, just run **ssp** without options. By default, it will step the whole program. Here's a simple example, using the numbers above:

```
$ ssp 0x61001000 0x61080000 hello.exe
```

This will step the whole program. It will take at least 8 minutes on a PII/300 (yes, really). When it's done, it will create a file called "gmon.out". You can turn this data file into a readable report with **gprof**:

```
$ gprof -b cygwin1.dll
```

The "-b" means 'skip the help pages'. You can omit this until you're familiar with the report layout. The **gprof** documentation explains a lot about this report, but **ssp** changes a few things. For example, the first part of the report reports the amount of time spent in each function, like this:

Each sample counts as 0.01 seconds.

%	cumulative	self		self	total	
time	seconds	seconds	calls	ms/call	ms/call	name
10.02	231.22	72.43	46	1574.57	1574.57	strcspn
7.95	288.70	57.48	130	442.15	442.15	strncasematch

The "seconds" columns are really CPU opcodes, 1/100 second per opcode. So, "231.22" above means 23,122 opcodes. The ms/call values are 10x too big; 1574.57 means 157.457 opcodes per call. Similar adjustments need to be made for the "self" and "children" columns in the second part of the report.

OK, so now we've got a huge report that took a long time to generate, and we've identified a spot we want to work on optimizing. Let's say it's the time() function. We can use SSP to selectively profile this function by using OutputDebugString() to control SSP from within the program. Here's a sample program:

```
#include <windows.h>
main()
{
    time_t t;
    OutputDebugString("ssp on");
    time(&t);
    OutputDebugString("ssp off");
}
```

Then, add the `-d` option to `ssp` to default to *\*disabling\** profiling. The program will run at full speed until the first `OutputDebugString`, then step until the second. You can then use **gprof** (as usual) to see the performance profile for just that portion of the program's execution.

There are many options to `ssp`. Since step-profiling makes your program run about 1,000 times slower than normal, it's best to understand all the options so that you can narrow down the parts of your program you need to single-step.

`-v` - verbose. This prints messages about threads starting and stopping, `OutputDebugString` calls, DLLs loading, etc.

`-t` and `-c` - tracing. With `-t`, *\*every\** step's address is written to the file "trace.ssp". This can be used to help debug functions, since it can trace multiple threads. Clever use of scripts can match addresses with disassembled opcodes if needed. Warning: creates *\*huge\** files, very quickly. `-c` prints each address to the console, useful for debugging key chunks of assembler. Use `addr2line -C -f -s -e foo.exe < trace.ssp > lines.ssp` and then `perl cvttrace` to convert to symbolic traces.

`-s` - subthreads. Usually, you only need to trace the main thread, but sometimes you need to trace all threads, so this enables that. It's also needed when you want to profile a function that only a subthread calls. However, using `OutputDebugString` automatically enables profiling on the thread that called it, not the main thread.

-l - dll profiling. Generates a pretty table of how much time was spent in each dll the program used. No sense optimizing a function in your program if most of the time is spent in the DLL. I usually use the -v, -s, and -l options:

```
$ ssp -v -s -l -d 0x61001000 0x61080000 hello.exe
```

### 3.6.14. strace

Usage: strace.exe [OPTIONS] <command-line>

Usage: strace.exe [OPTIONS] -p <pid>

Trace system calls and signals

-b, --buffer-size=SIZE	set size of output file buffer
-d, --no-delta	don't display the delta-t microsecond timestamp
-f, --trace-children	trace child processes (toggle - default true)
-h, --help	output usage information and exit
-m, --mask=MASK	set message filter mask
-n, --crack-error-numbers	output descriptive text instead of error numbers for Windows errors
-o, --output=FILENAME	set output file to FILENAME
-p, --pid=n	attach to executing program with cygwin pid n
-S, --flush-period=PERIOD	flush buffered strace output every PERIOD seconds
-t, --timestamp	use an absolute hh:mm:ss timestamp instead of the default microsecond timestamp. Implies -d
-T, --toggle	toggle tracing in a process already being traced. Requires -p <pid>
-v, --version	output version information and exit
-w, --new-window	spawn program under test in a new window

MASK can be any combination of the following mnemonics and/or hex values (0x is optional). Combine masks with '+' or ',' like so:

```
--mask=wm+system,malloc+0x00800
```

Mnemonic	Hex	Corresponding Def	Description
all	0x00001	(_STRACE_ALL)	All strace messages.
flush	0x00002	(_STRACE_FLUSH)	Flush output buffer after each message.
inherit	0x00004	(_STRACE_INHERIT)	Children inherit mask from parent.
uhoh	0x00008	(_STRACE_UHOH)	Unusual or weird phenomenon.
syscall	0x00010	(_STRACE_SYSCALL)	System calls.

startup	0x00020	(_STRACE_STARTUP)	argc/envp printout at startup.
debug	0x00040	(_STRACE_DEBUG)	Info to help debugging.
paranoid	0x00080	(_STRACE_PARANOID)	Paranoid info.
termios	0x00100	(_STRACE_TERMIOS)	Info for debugging termios stuff.
select	0x00200	(_STRACE_SELECT)	Info on ugly select internals.
wm	0x00400	(_STRACE_WM)	Trace Windows msgs (enable <code>_strace_wm</code> )
sigp	0x00800	(_STRACE_SIGP)	Trace signal and process handling.
minimal	0x01000	(_STRACE_MINIMAL)	Very minimal strace output.
exitdump	0x04000	(_STRACE_EXITDUMP)	Dump strace cache on exit.
system	0x08000	(_STRACE_SYSTEM)	Serious error; goes to console and log.
nomutex	0x10000	(_STRACE_NOMUTEX)	Don't use mutex for synchronization.
malloc	0x20000	(_STRACE_MALLOC)	Trace malloc calls.
thread	0x40000	(_STRACE_THREAD)	Thread-locking calls.

The **strace** program executes a program, and optionally the children of the program, reporting any Cygwin DLL output from the program(s) to stdout, or to a file with the `-o` option. With the `-w` option, you can start an strace session in a new window, for example:

```
$ strace -o tracing_output -w sh -c 'while true; do echo "tracing..."; done'
```

This is particularly useful for **strace** sessions that take a long time to complete.

Note that **strace** is a standalone Windows program and so does not rely on the Cygwin DLL itself (you can verify this with **cygcheck**). As a result it does not understand POSIX pathnames or symlinks. This program is mainly useful for debugging the Cygwin DLL itself.

### 3.6.15. umount

Usage: `umount.exe [OPTION] [<posixpath>]`

Unmount filesystems

<code>-A, --remove-all-mounts</code>	remove all mounts
<code>-c, --remove-cygdrive-prefix</code>	remove cygdrive prefix
<code>-h, --help</code>	output usage information and exit
<code>-s, --system</code>	remove system mount (default)
<code>-S, --remove-system-mounts</code>	remove all system mounts
<code>-u, --user</code>	remove user mount
<code>-U, --remove-user-mounts</code>	remove all user mounts
<code>-v, --version</code>	output version information and exit

The **umount** program removes mounts from the mount table. If you specify a POSIX path that corresponds to a current mount point, **umount** will remove it from the system registry area. (Administrator privileges are required). The `-u` flag may be used to specify removing the mount from the user-specific registry area instead.

The **umount** utility may also be used to remove all mounts of a particular type. With the extended options it is possible to remove all mounts (`-A`), all cygdrive automatically-mounted mounts (`-c`), all mounts in the current user's registry area (`-U`), or all mounts in the system-wide registry area (`-S`) (with Administrator privileges).

See Section 3.6.8 for more information on the mount table.

## 3.7. Using Cygwin effectively with Windows

Cygwin is not a full operating system, and so must rely on Windows for accomplishing some tasks. For example, Cygwin provides a POSIX view of the Windows filesystem, but does not provide filesystem drivers of its own. Therefore part of using Cygwin effectively is learning to use Windows effectively. Many Windows utilities provide a good way to interact with Cygwin's predominately command-line environment. For example, **ipconfig.exe** provides information about network configuration, and **net.exe** views and configures network file and printer resources. Most of these tools support the `/?` switch to display usage information.

Unfortunately, no standard set of tools included with all versions of Windows exists. If you are unfamiliar with the tools available on your system, here is a general guide. Windows 95, 98, and ME have very limited command-line configuration tools. Windows NT 4.0 has much better coverage, which Windows 2000 and XP expanded. Microsoft also provides free downloads for Windows NT 4.0 (the Resource Kit Support Tools), Windows 2000 (the Resource Kit Tools), and XP (the Windows Support Tools). Additionally, many independent sites such as download.com (<http://download.com.com>), simtel.net (<http://simtel.net>), and sysinternals.com (<http://sysinternals.com>) provide command-line utilities. A few Windows tools, such as **find.exe** and **sort.exe**, may conflict with the Cygwin versions; make sure that you use the full path (`/usr/bin/find`) or that your Cygwin `bin` directory comes first in your `PATH`.

### 3.7.1. Pathnames

Windows programs do not understand POSIX pathnames, so any arguments that

reference the filesystem must be in Windows (or DOS) format or translated. Cygwin provides the **cygpath** utility for converting between Windows and POSIX paths. A complete description of its options and examples of its usage are in Section 3.6.2, including a shell script for starting Windows Explorer in any directory. The same format works for most Windows programs, for example

```
notepad.exe "$(cygpath -aw "Desktop/Phone Numbers.txt")"
```

A few programs require a Windows-style, semicolon-delimited path list, which **cygpath** can translate from a POSIX path with the `-p` option. For example, a Java compilation from **bash** might look like this:

```
javac -cp "$(cygpath -pw "$CLASSPATH")" hello.java
```

Since using quoting and subshells is somewhat awkward, it is often preferable to use **cygpath** in shell scripts.

### 3.7.2. Console Programs

Another issue is receiving output from or giving input to the console-based Windows programs. Unfortunately, interacting with Windows console applications is not a simple matter of using a translation utility. Windows console applications are designed to run under **command.com** or **cmd.exe**, and some do not deal gracefully with other situations. Cygwin can receive console input only if it is also running in a console (DOS box) since Windows does not provide any way to attach to the backend of the console device. Another traditional Unix input/output method, ptys (pseudo-terminals), are supported by Cygwin but not entirely by Windows. The basic problem is that a Cygwin pty is a pipe and some Windows applications do not like having their input or output redirected to pipes.

To help deal with these issues, Cygwin supports customizable levels of Windows versus Unix compatibility behavior. To be most compatible with Windows programs, use a DOS prompt, running only the occasional Cygwin command or script. Next would be to run **bash** with the default DOS box. To make Cygwin more Unix compatible in this case, set `CYGWIN=tty` (see Section 3.5). Alternatively, the optional **rxvt** package provides a native-Windows version of the popular X11 terminal emulator (it is not necessary to set `CYGWIN=tty` with **rxvt**). Using **rxvt.exe** provides the most Unix-like environment, but expect some compatibility problems with Windows programs.

### 3.7.3. Cygwin and Windows Networking

Many popular Cygwin packages, such as **ncftp**, **lynx**, and **wget**, require a network connection. Since Cygwin relies on Windows for connectivity, if one of these tools is not working as expected you may need to troubleshoot using Windows tools. The first test is to see if you can reach the URL's host with **ping.exe**, one of the few utilities included with every Windows version since Windows 95. If you chose to install the **inetutils** package, you may have both Windows and Cygwin versions of utilities such as **ftp** and **telnet**. If you are having problems using one of these programs, see if the alternate one works as expected.

There are a variety of other programs available for specific situations. If your system does not have an always-on network connection, you may be interested in **rasdial.exe** (or alternatives for Windows 95, 98, and ME) for automating dialup connections. Users who frequently change their network configuration can script these changes with **netsh.exe** (Windows 2000 and XP). For proxy users, the open source NTLM Authorization Proxy Server (<http://apserver.sourceforge.net>) or the no-charge Hummingbird SOCKS Proxy (<http://www.hummingbird.com/products/nc/socks/index.html>) may allow you to use Cygwin network programs in your environment.

### 3.7.4. The cygutils package

The optional **cygutils** package contains miscellaneous tools that are small enough to not require their own package. It is not included in a default Cygwin install; select it from the Utils category in **setup.exe**. Several of the **cygutils** tools are useful for interacting with Windows.

One of the hassles of Unix-Windows interoperability is the different line endings on text files. As mentioned in Section 3.2, Unix tools such as **tr** can convert between CRLF and LF endings, but **cygutils** provides several dedicated programs: **conv**, **d2u**, **dos2unix**, **u2d**, and **unix2dos**. Use the `--help` switch for usage information.

### 3.7.5. Creating shortcuts with cygutils

Another problem area is between Unix-style links, which link one file to another, and Microsoft **.lnk** files, which provide a shortcut to a file. They seem similar at first glance but, in reality, are fairly different. By default, Cygwin uses a mechanism that creates symbolic links that are compatible with standard Microsoft **.lnk** files. However, they do

not include much of the information that is available in a standard Microsoft shortcut, such as the working directory, an icon, etc. The `cygutils` package includes a **mkshortcut** utility for creating standard Microsoft `.lnk` files.

If Cygwin handled these native shortcuts like any other symlink, you could not archive Microsoft `.lnk` files into **tar** archives and keep all the information in them. After unpacking, these shortcuts would have lost all the extra information and would be no different than standard Cygwin symlinks. Therefore these two types of links are treated differently. Unfortunately, this means that the usual Unix way of creating and using symlinks does not work with Windows shortcuts.

### 3.7.6. Printing with `cygutils`

There are several options for printing from Cygwin, including the **lpr** found in `cygutils` (not to be confused with the native Windows **lpr.exe**). The easiest way to use `cygutils`' **lpr** is to specify a default device name in the `PRINTER` environment variable. You may also specify a device on the command line with the `-d` or `-P` options, which will override the environment variable setting.

A device name may be a UNC path (`\\server_name\printer_name`), a reserved DOS device name (`prn`, `lpt1`), or a local port name that is mapped to a printer share. Note that forward slashes may be used in a UNC path (`//server_name/printer_name`), which is helpful when using **lpr** from a shell that uses the backslash as an escape character.

**lpr** sends raw data to the printer; no formatting is done. Many, but not all, printers accept plain text as input. If your printer supports PostScript, packages such as **a2ps** and **enscript** can prepare text files for printing. The `ghostscript` package also provides some translation from PostScript to various native printer languages. Additionally, a native Windows application for printing PostScript, **gsprint**, is available from the Ghostscript website (<http://www.cs.wisc.edu/~ghost/>).

# Chapter 4. Programming with Cygwin

## 4.1. Using GCC with Cygwin

### 4.1.1. Console Mode Applications

Use `gcc` to compile, just like under UNIX. Refer to the GCC User's Guide for information on standard usage and options. Here's a simple example:

#### Example 4-1. Building Hello World with GCC

```
C:\> gcc hello.c -o hello.exe
C:\> hello.exe
Hello, World

C:\>
```

### 4.1.2. GUI Mode Applications

Cygwin allows you to build programs with full access to the standard Windows 32-bit API, including the GUI functions as defined in any Microsoft or off-the-shelf publication. However, the process of building those applications is slightly different, as you'll be using the GNU tools instead of the Microsoft tools.

For the most part, your sources won't need to change at all. However, you should remove all `__export` attributes from functions and replace them like this:

```
int foo (int) __attribute__ ((__dllexport__));

int
foo (int i)
```

The Makefile is similar to any other UNIX-like Makefile, and like any other Cygwin makefile. The only difference is that you use `gcc -mwindows` to link your program into a GUI application instead of a command-line application. Here's an example:

```
myapp.exe : myapp.o myapp.res
gcc -mwindows myapp.o myapp.res -o $@
```

```
myapp.res : myapp.rc resource.h
windres $< -O coff -o $@
```

Note the use of `windres` to compile the Windows resources into a COFF-format `.res` file. That will include all the bitmaps, icons, and other resources you need, into one handy object file. Normally, if you omitted the `"-O coff"` it would create a Windows `.res` format file, but we can only link COFF objects. So, we tell `windres` to produce a COFF object, but for compatibility with the many examples that assume your linker can handle Windows resource files directly, we maintain the `.res` naming convention. For more information on `windres`, consult the Binutils manual.

The following is a simple GUI-mode "Hello, World!" program to help get you started:

```
/*-----*/
/* hellogui.c - gui hello world */
/* build: gcc -mwindows hellogui.c -o hellogui.exe */
/*-----*/
#include <windows.h>

char glpszText[1024];

LRESULT CALLBACK WndProc(HWND, UINT, WPARAM, LPARAM);

int APIENTRY WinMain(HINSTANCE hInstance,
    HINSTANCE hPrevInstance,
    LPSTR lpCmdLine,
    int nCmdShow)
{
    sprintf(glpszText,
        "Hello World\nGetCommandLine(): [%s]\n"
        "WinMain lpCmdLine: [%s]\n",
        lpCmdLine, GetCommandLine() );

    WNDCLASSEX wcex;

    wcex.cbSize = sizeof(wcex);
    wcex.style = CS_HREDRAW | CS_VREDRAW;
    wcex.lpfnWndProc = WndProc;
    wcex.cbClsExtra = 0;
    wcex.cbWndExtra = 0;
    wcex.hInstance = hInstance;
    wcex.hIcon = LoadIcon(NULL, IDI_APPLICATION);
    wcex.hCursor = LoadCursor(NULL, IDC_ARROW);
```

```
wcex.hbrBackground = (HBRUSH)(COLOR_WINDOW+1);
wcex.lpszMenuName = NULL;
wcex.lpszClassName = "HELLO";
wcex.hIconSm = NULL;

if (!RegisterClassEx(&wcex))
    return FALSE;

HWND hWnd;
hWnd = CreateWindow("HELLO", "Hello", WS_OVERLAPPEDWINDOW,
    CW_USEDEFAULT, CW_USEDEFAULT, CW_USEDEFAULT, CW_USEDEFAULT, NULL, NULL, hI

if (!hWnd)
    return FALSE;

ShowWindow(hWnd, nCmdShow);
UpdateWindow(hWnd);

MSG msg;
while (GetMessage(&msg, NULL, 0, 0))
{
    TranslateMessage(&msg);
    DispatchMessage(&msg);
}

return msg.wParam;
}

LRESULT CALLBACK WndProc(HWND hWnd, UINT message, WPARAM wParam, LPARAM lParam)
{
    PAINTSTRUCT ps;
    HDC hdc;

    switch (message)
    {
        case WM_PAINT:
            hdc = BeginPaint(hWnd, &ps);
            RECT rt;
            GetClientRect(hWnd, &rt);
            DrawText(hdc, glpszText, strlen(glpszText), &rt, DT_TOP | DT_LEFT);
            EndPaint(hWnd, &ps);
            break;
        case WM_DESTROY:
            PostQuitMessage(0);
    }
}
```

```

    break;
default:
    return DefWindowProc(hWnd, message, wParam, lParam);
}
return 0;
}

```

## 4.2. Debugging Cygwin Programs

When your program doesn't work right, it usually has a "bug" in it, meaning there's something wrong with the program itself that is causing unexpected results or crashes. Diagnosing these bugs and fixing them is made easy by special tools called *debuggers*. In the case of Cygwin, the debugger is GDB, which stands for "GNU DeBugger". This tool lets you run your program in a controlled environment where you can investigate the state of your program while it is running or after it crashes. Crashing programs sometimes create "core" files. In Cygwin these are regular text files that cannot be used directly by GDB.

Before you can debug your program, you need to prepare your program for debugging. What you need to do is add `-g` to all the other flags you use when compiling your sources to objects.

### Example 4-2. Compiling with `-g`

```

$ gcc -g -O2 -c myapp.c
$ gcc -g myapp.c -o myapp

```

What this does is add extra information to the objects (they get much bigger too) that tell the debugger about line numbers, variable names, and other useful things. These extra symbols and debugging information give your program enough information about the original sources so that the debugger can make debugging much easier for you.

In Windows versions of GNUPro, GDB comes with a full-featured graphical interface. In Cygwin Net distributions, GDB is only available as a command-line tool. To invoke GDB, simply type **`gdb myapp.exe`** at the command prompt. It will display some text telling you about itself, then `(gdb)` will appear to prompt you to enter commands. Whenever you see this prompt, it means that `gdb` is waiting for you to type in a command, like **`run`** or **`help`**. Oh :- ) type **`help`** to get help on the commands you can

type in, or read the [GDB User's Manual] for a complete description of GDB and how to use it.

If your program crashes and you're trying to figure out why it crashed, the best thing to do is type **run** and let your program run. After it crashes, you can type **where** to find out where it crashed, or **info locals** to see the values of all the local variables. There's also a **print** that lets you look at individual variables or what pointers point to.

If your program is doing something unexpected, you can use the **break** command to tell gdb to stop your program when it gets to a specific function or line number:

#### Example 4-3. "break" in gdb

```
(gdb) break my_function
(gdb) break 47
```

Now, when you type **run** your program will stop at that "breakpoint" and you can use the other gdb commands to look at the state of your program at that point, modify variables, and **step** through your program's statements one at a time.

Note that you may specify additional arguments to the **run** command to provide command-line arguments to your program. These two cases are the same as far as your program is concerned:

#### Example 4-4. Debugging with command line arguments

```
$ myprog -t foo --queue 47

$ gdb myprog
(gdb) run -t foo --queue 47
```

## 4.3. Building and Using DLLs

DLLs are Dynamic Link Libraries, which means that they're linked into your program at run time instead of build time. There are three parts to a DLL:

- the exports
- the code and data
- the import library

The code and data are the parts you write - functions, variables, etc. All these are merged together, like if you were building one big object files, and put into the dll. They are not put into your .exe at all.

The exports contains a list of functions and variables that the dll makes available to other programs. Think of this as the list of "global" symbols, the rest being hidden. Normally, you'd create this list by hand with a text editor, but it's possible to do it automatically from the list of functions in your code. The `dlltool` program creates the exports section of the dll from your text file of exported symbols.

The import library is a regular UNIX-like .a library, but it only contains the tiny bit of information needed to tell the OS how your program interacts with ("imports") the dll. This information is linked into your .exe. This is also generated by `dlltool`.

### 4.3.1. Building DLLs

This page gives only a few simple examples of gcc's DLL-building capabilities. To begin an exploration of the many additional options, see the gcc documentation and website, currently at <http://gcc.gnu.org/>

Let's go through a simple example of how to build a dll. For this example, we'll use a single file `myprog.c` for the program (`myprog.exe`) and a single file `mydll.c` for the contents of the dll (`mydll.dll`).

Fortunately, with the latest gcc and binutils the process for building a dll is now pretty simple. Say you want to build this minimal function in `mydll.c`:

```
#include <stdio.h>

int
hello()
{
    printf ("Hello World!\n");
}
```

First compile `mydll.c` to object code:

```
gcc -c mydll.c
```

Then, tell gcc that it is building a shared library:

```
gcc -shared -o mydll.dll mydll.o
```

That's it! To finish up the example, you can now link to the dll with a simple program:

```
int
main ()
{
    hello ();
}
```

Then link to your dll with a command like:

```
gcc -o myprog myprog.ca -L./ -lmydll
```

However, if you are building a dll as an export library, you will probably want to use the complete syntax:

```
gcc -shared -o cyg${module}.dll \
    -Wl,--out-implib=lib${module}.dll.a \
    -Wl,--export-all-symbols \
    -Wl,--enable-auto-import \
    -Wl,--whole-archive ${old_lib} \
    -Wl,--no-whole-archive ${dependency_libs}
```

Where `${module}` is the name of your DLL, `${old_lib}` are all your object files, bundled together in static libs or single object files and the `${dependency_libs}` are import libs you need to link against, e.g. `'-lpng -lz -L/usr/local/special -lmyspeciallib'`.

## 4.3.2. Linking Against DLLs

If you have an existing DLL already, you need to build a Cygwin-compatible import library. If you have the source to compile the DLL, see Section 4.3.1 for details on having `gcc` build one for you. If you do not have the source or a supplied working import library, you can get most of the way by creating a `.def` file with these commands (you might need to do this in `bash` for the quoting to work correctly):

```
echo EXPORTS > foo.def
nm foo.dll | grep ' T _' | sed 's/.* T _//>' >> foo.def
```

Note that this will only work if the DLL is not stripped. Otherwise you will get an error message: "No symbols in foo.dll".

Once you have the `.def` file, you can create an import library from it like this:

```
dlltool --def foo.def --dllname foo.dll --output-lib foo.a
```

## 4.4. Defining Windows Resources

`windres` reads a Windows resource file (`*.rc`) and converts it to a `res` or `coff` file. The syntax and semantics of the input file are the same as for any other resource compiler, so please refer to any publication describing the Windows resource format for details. Also, the `windres` program itself is fully documented in the Binutils manual. Here's an example of using it in a project:

```
myapp.exe : myapp.o myapp.res
    gcc -mwindows myapp.o myapp.res -o $@

myapp.res : myapp.rc resource.h
    windres $< -O coff -o $@
```

What follows is a quick-reference to the syntax `windres` supports.

```
id ACCELERATORS suboptions
BEG
"^C" 12
"Q" 12
65 12
65 12 , VIRTKEY ASCII NOINVERT SHIFT CONTROL ALT
65 12 , VIRTKEY, ASCII, NOINVERT, SHIFT, CONTROL, ALT
(12 is an acc_id)
END
```

SHIFT, CONTROL, ALT require VIRTKEY

```
id BITMAP memflags "filename"
memflags defaults to MOVEABLE
```

```
id CURSOR memflags "filename"
memflags defaults to MOVEABLE,DISCARDABLE
```

```
id DIALOG memflags exstyle x,y,width,height styles BEG controls END
id DIALOGEX memflags exstyle x,y,width,height styles BEG controls END
id DIALOGEX memflags exstyle x,y,width,height,helpid styles BEG controls END
```

```
memflags defaults to MOVEABLE
exstyle may be EXSTYLE=number
styles: CAPTION "string"
```

```
CLASS id
STYLE FOO | NOT FOO | (12)
EXSTYLE number
FONT number, "name"
FONT number, "name",weight,italic
MENU id
CHARACTERISTICS number
LANGUAGE number,number
VERSIONK number
controls:
AUTO3STATE params
AUTOCHECKBOX params
AUTORADIOBUTTON params
BEDIT params
CHECKBOX params
COMBOBOX params
CONTROL ["name",] id, class, style, x,y,w,h [,exstyle] [data]
CONTROL ["name",] id, class, style, x,y,w,h, exstyle, helpid [data]
CTEXT params
DEFPUSHBUTTON params
EDITTEXT params
GROUPBOX params
HEDIT params
ICON ["name",] id, x,y [data]
ICON ["name",] id, x,y,w,h, style, exstyle [data]
ICON ["name",] id, x,y,w,h, style, exstyle, helpid [data]
IEDIT params
LISTBOX params
LTEXT params
PUSHBOX params
PUSHBUTTON params
RADIOBUTTON params
RTEXT params
SCROLLBAR params
STATE3 params
USERBUTTON "string", id, x,y,w,h, style, exstyle
params:
["name",] id, x, y, w, h, [data]
["name",] id, x, y, w, h, style [,exstyle] [data]
["name",] id, x, y, w, h, style, exstyle, helpid [data]

[data] is optional BEG (string|number) [,(string|number)] (etc) END
```

```
id FONT memflags "filename"
memflags defaults to MOVEABLE|DISCARDABLE

id ICON memflags "filename"
memflags defaults to MOVEABLE|DISCARDABLE

LANGUAGE num,num

id MENU options BEG items END
items:
  "string", id, flags
  SEPARATOR
  POPUP "string" flags BEG menuitems END
flags:
  CHECKED
  GRAYED
  HELP
  INACTIVE
  MENUBARBREAK
  MENUBREAK

id MENUEX suboptions BEG items END
items:
  MENUITEM "string"
  MENUITEM "string", id
  MENUITEM "string", id, type [,state]
  POPUP "string" BEG items END
  POPUP "string", id BEG items END
  POPUP "string", id, type BEG items END
  POPUP "string", id, type, state [,helpid] BEG items END

id MESSAGETABLE memflags "filename"
memflags defaults to MOVEABLE

id RCDATA suboptions BEG (string|number) [,(string|number)] (etc) END

STRINGTABLE suboptions BEG strings END
strings:
  id "string"
  id, "string"

(User data)
id id suboptions BEG (string|number) [,(string|number)] (etc) END
```

```
id VERSIONINFO stuffs BEG verblocks END
stuffs: FILEVERSION num,num,num,num
        PRODUCTVERSION num,num,num,num
        FILEFLAGSMASK num
        FILEOS num
        FILETYPE num
        FILESUBTYPE num
verblocks:
        BLOCK "StringFileInfo" BEG BLOCK BEG vervals END END
        BLOCK "VarFileInfo" BEG BLOCK BEG vertrans END END
vervals: VALUE "foo","bar"
vertrans: VALUE num,num
```

```
suboptions:
        memflags
        CHARACTERISTICS num
        LANGUAGE num,num
        VERSIONK num
```

memflags are MOVEABLE/FIXED PURE/IMPURE PRELOAD/LOADONCALL DISCARDABLE