

# **Cygwin/X User's Guide**

**Harold L Hunt, II**

**Jon Turney**

## **Cygwin/X User's Guide**

by Harold L Hunt, II

by Jon Turney

Copyright (c) 2000 Harold L Hunt II. Copyright (C) 2009 Jon Turney. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.1 or any later version published by the Free Software Foundation; with no Invariant Sections, with no Front-Cover Texts, and with no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

# Table of Contents

<b>1. Cygwin/X Overview .....</b>	<b>1</b>
<b>2. Setting Up Cygwin/X .....</b>	<b>2</b>
Cygwin/X Contents .....	2
Installing Cygwin/X .....	2
<b>3. Configuring Cygwin/X.....</b>	<b>13</b>
Configuration Overview .....	13
Command Line Parameters .....	13
<b>4. Using Cygwin/X .....</b>	<b>18</b>
Starting Cygwin/X .....	18
startxwin.bat .....	18
startxwin.sh.....	18
startx .....	18
Switching Out of Cygwin/X .....	18
Stopping Cygwin/X.....	19
Window Managers .....	19
Windows Clipboard Integration .....	19
Shared Memory Support (MIT-SHM Extension).....	19
Remote Sessions via XDMCP .....	20
Displaying Remote Clients .....	20
Secure ssh .....	20
Unsecure Telnet .....	21
<b>A. GNU Free Documentation License.....</b>	<b>22</b>
0. PREAMBLE .....	22
1. APPLICABILITY AND DEFINITIONS .....	22
2. VERBATIM COPYING.....	23
3. COPYING IN QUANTITY .....	23
4. MODIFICATIONS.....	24
5. COMBINING DOCUMENTS.....	25
6. COLLECTIONS OF DOCUMENTS .....	25
7. AGGREGATION WITH INDEPENDENT WORKS.....	26
8. TRANSLATION .....	26
9. TERMINATION.....	26
10. FUTURE REVISIONS OF THIS LICENSE.....	26
How to use this License for your documents .....	27

# List of Tables

3-1. Parameter Descriptions.....	14
----------------------------------	----

# Chapter 1. Cygwin/X Overview

Cygwin/X is a port of the X Window System to Cygwin; Cygwin provides a UNIX-like API on the Win32 platform.

# Chapter 2. Setting Up Cygwin/X

## Cygwin/X Contents

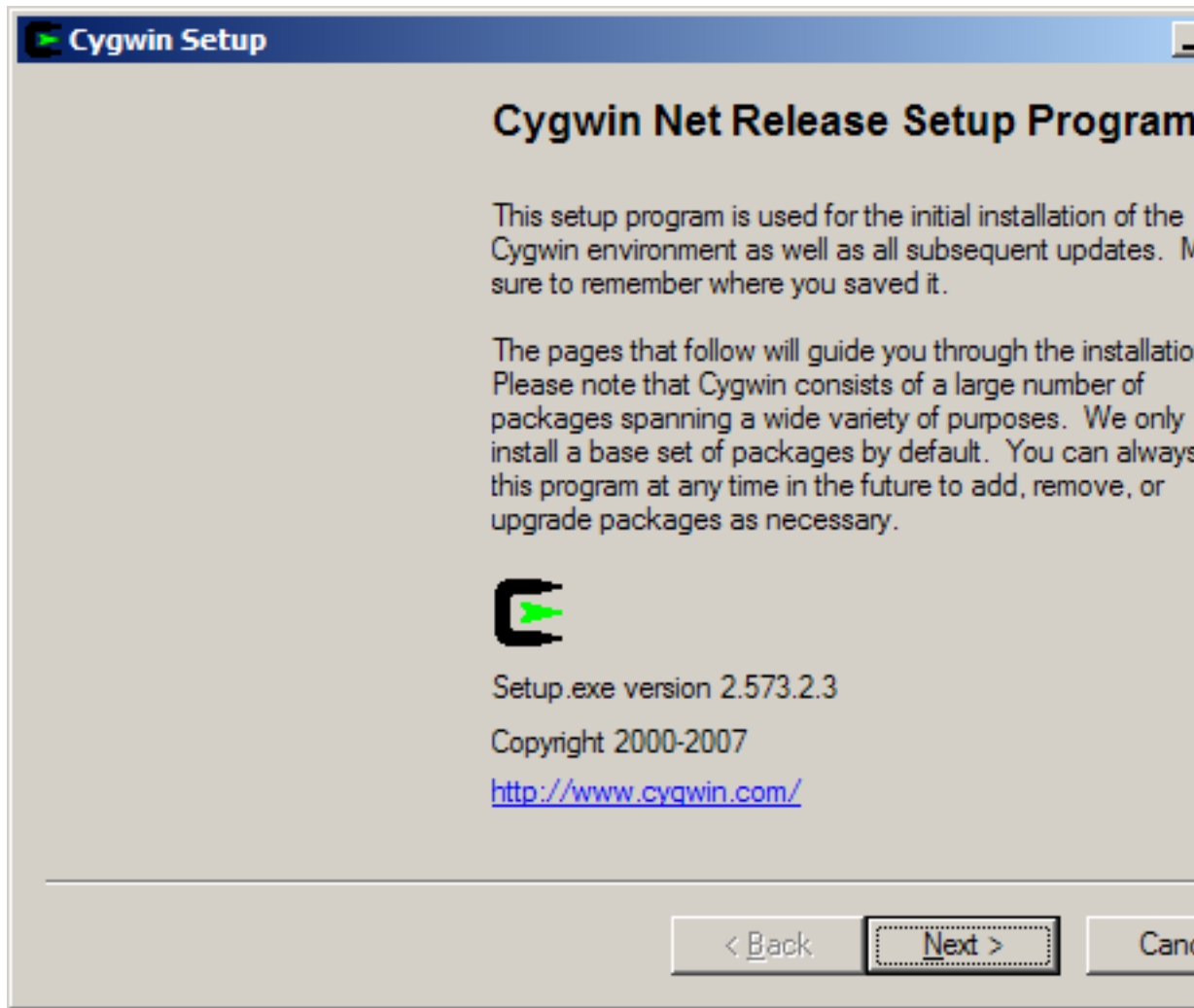
Cygwin/X consists of two parts: Cygwin, a port of the GNU tools to Win32, and Cygwin/X, a port of the X Window System to Win32. Both parts of Cygwin/X are needed to successfully run an X Server on a Win32 platform.

## Installing Cygwin/X

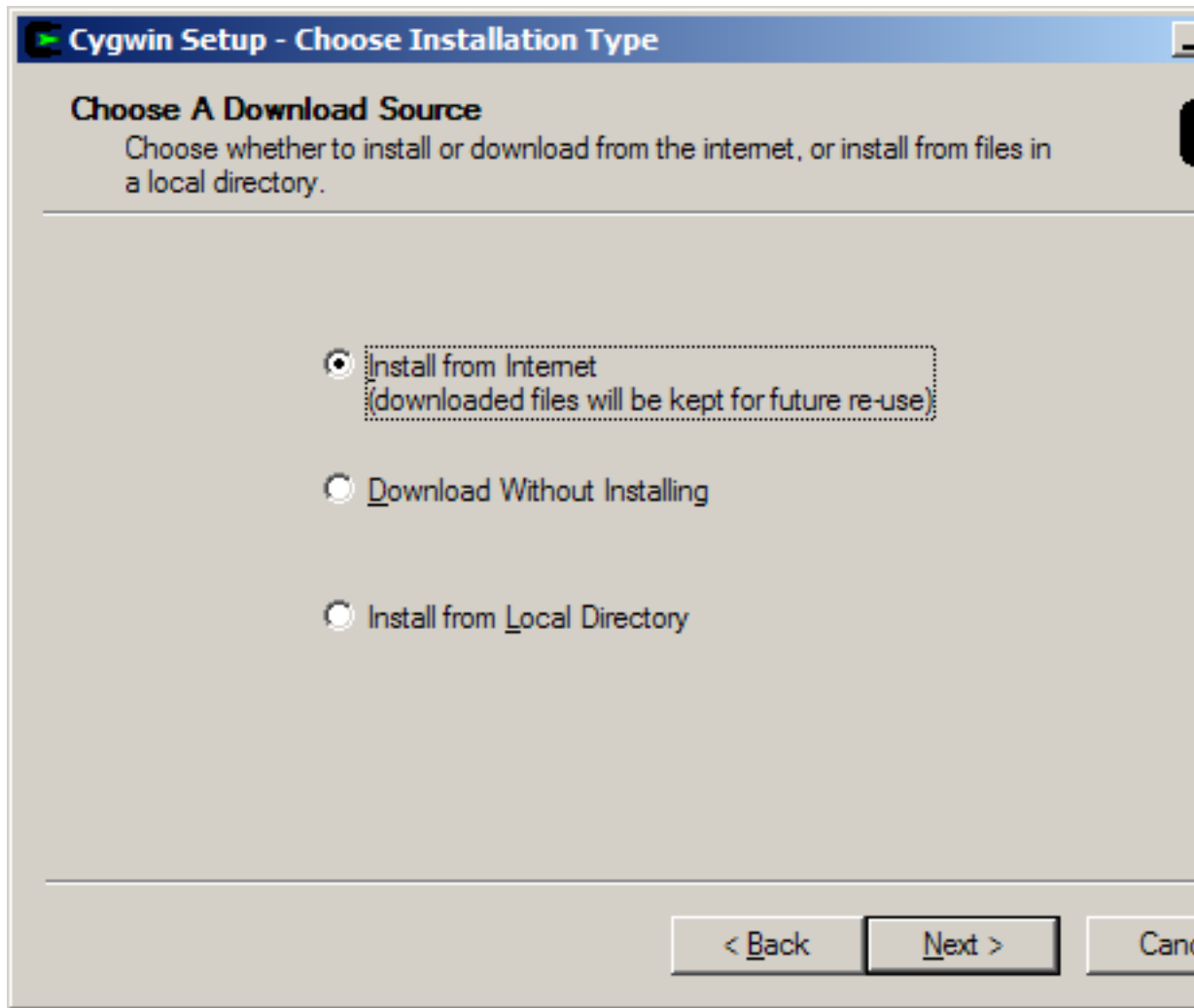
Cygwin tools are, in the words of the Cygwin development homepage, <http://cygwin.com/>, “ports of the popular GNU development tools and utilities for Windows 95, 98, and NT. They function by using the Cygwin library which provides a UNIX-like API on top of the Win32 API.” Cygwin allows the compilation of the X Window System source on Win32; several patches were made to the X Window System source to make it actually compile and run under Cygwin.

Cygwin has a nice setup program that downloads and installs the necessary Cygwin packages for you.

1. Open the Cygwin, <http://cygwin.com/> page in your web browser
2. Click the “Install Cygwin Now” (<http://cygwin.com/setup.exe>) link in the upper-right hand corner of the page. This link downloads `setup.exe` from the primary Cygwin server; save `setup.exe` to the directory that you would like to store the downloaded packages in (e.g. `c:\download`); do not save `setup.exe` to `c:\cygwin`, as that is the default directory for the extraction and installation of the downloaded packages.
3. Run `setup.exe`, you will see the welcome screen:

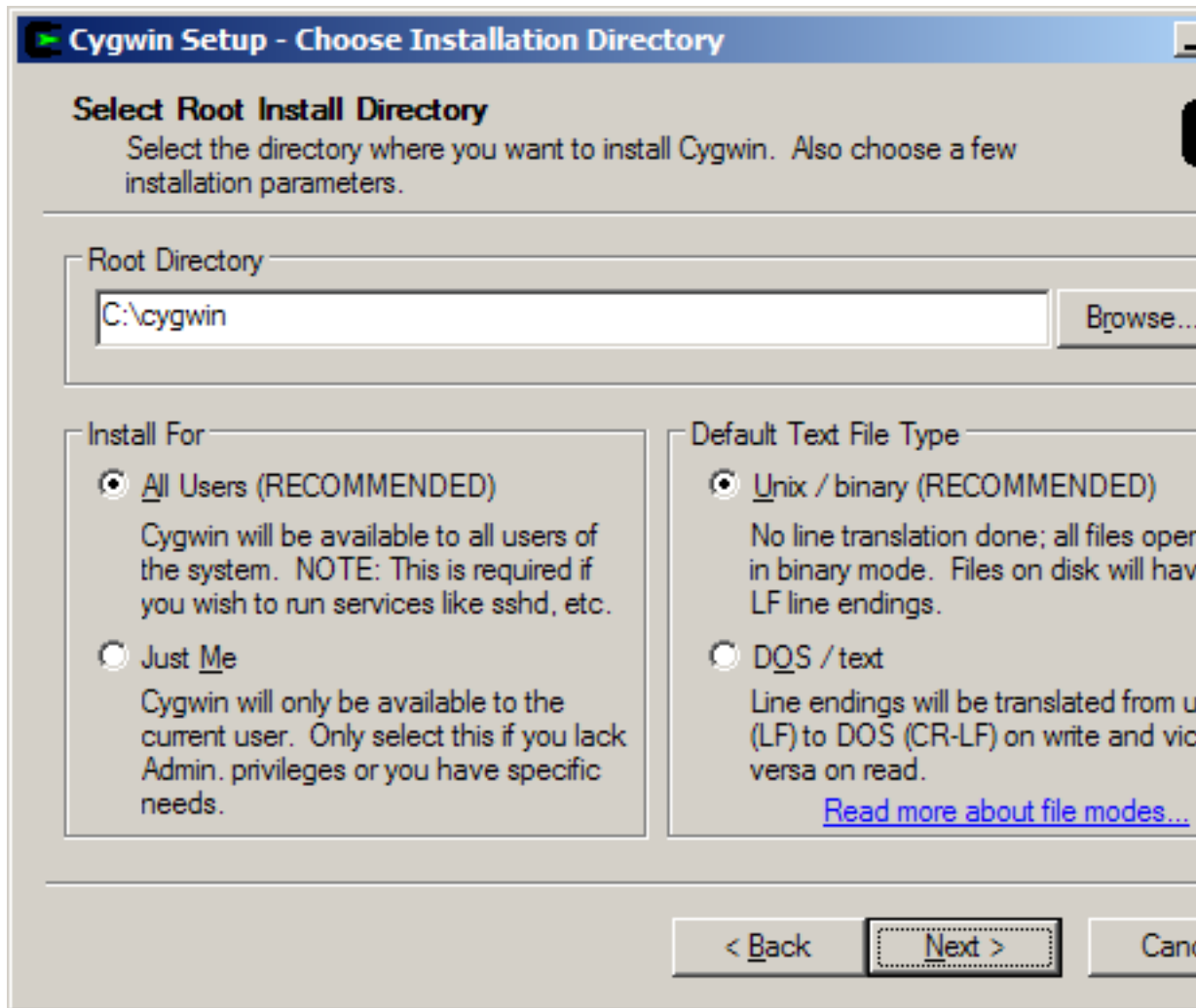


4. Click **Next** to proceed to the next screen.
5. Choose, **Install from Internet**, this will still save the package files to your download directory so that you can install Cygwin on any number of machines:

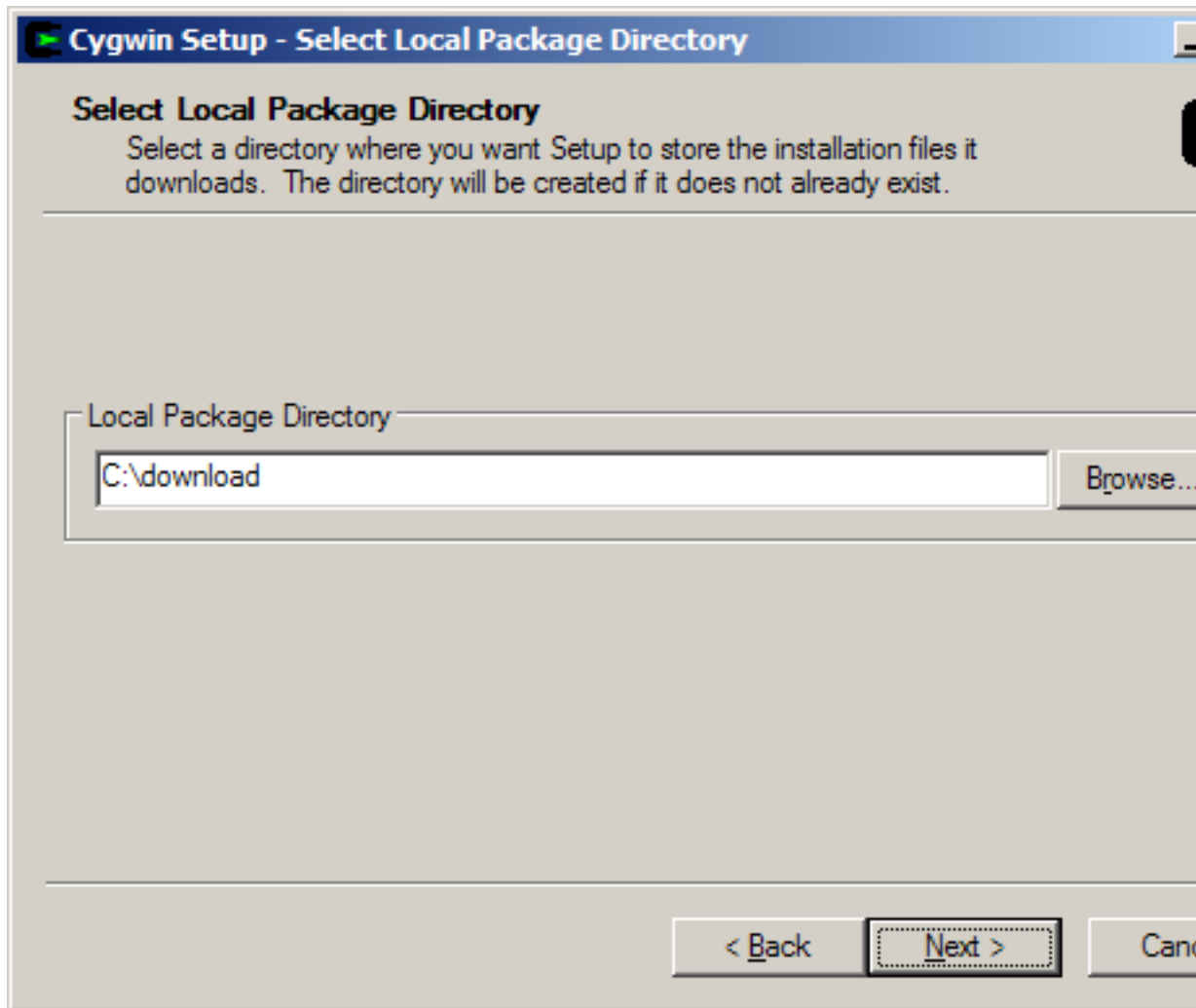


6. Click **Next** to proceed to the next screen.
7. The default **Install Root** is `c:\cygwin`; this should be fine for most installations. Leave **Default Text File Type** as **UNIX**. Leave **Install For** set to **All** unless you lack local administrative privileges.

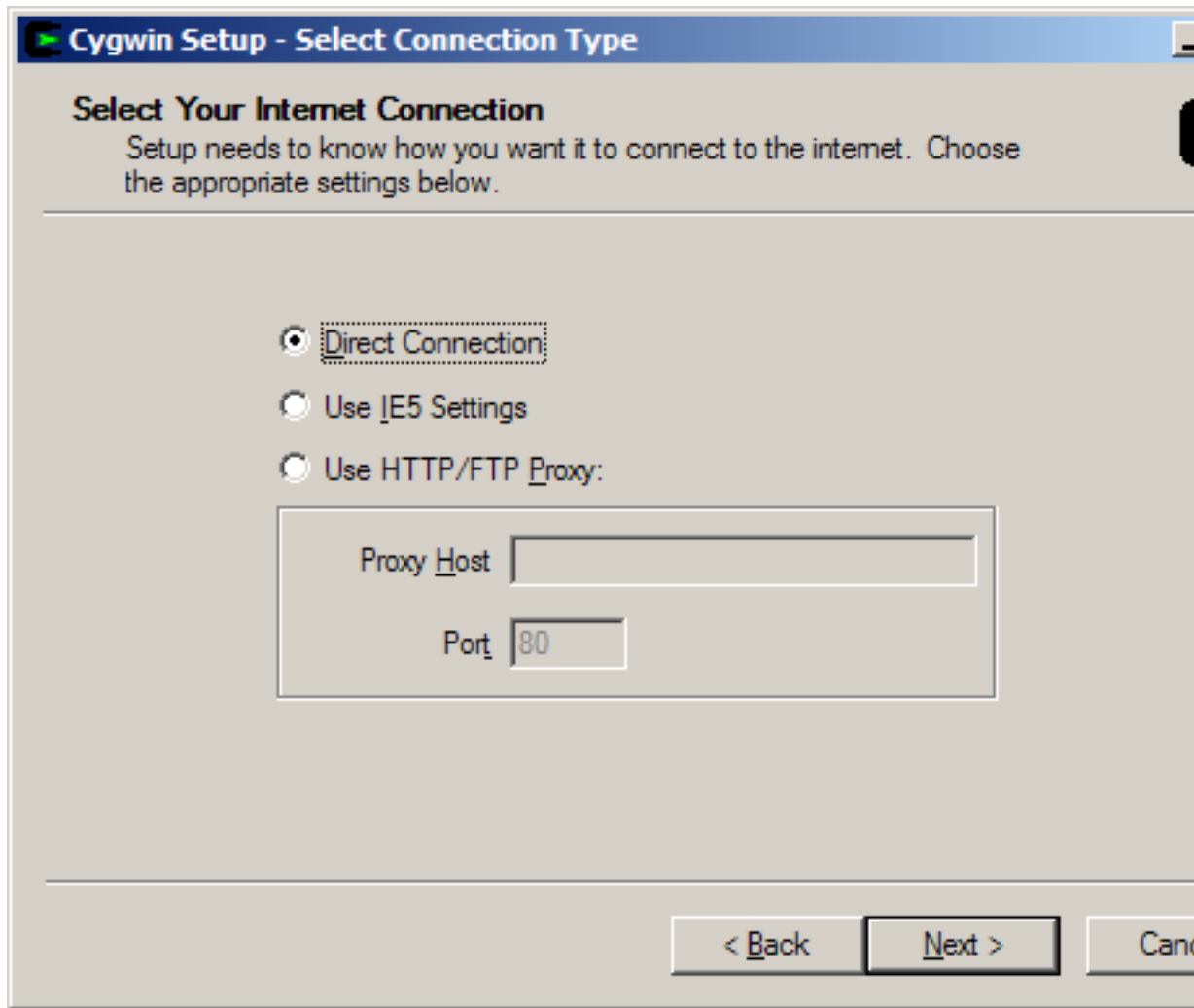




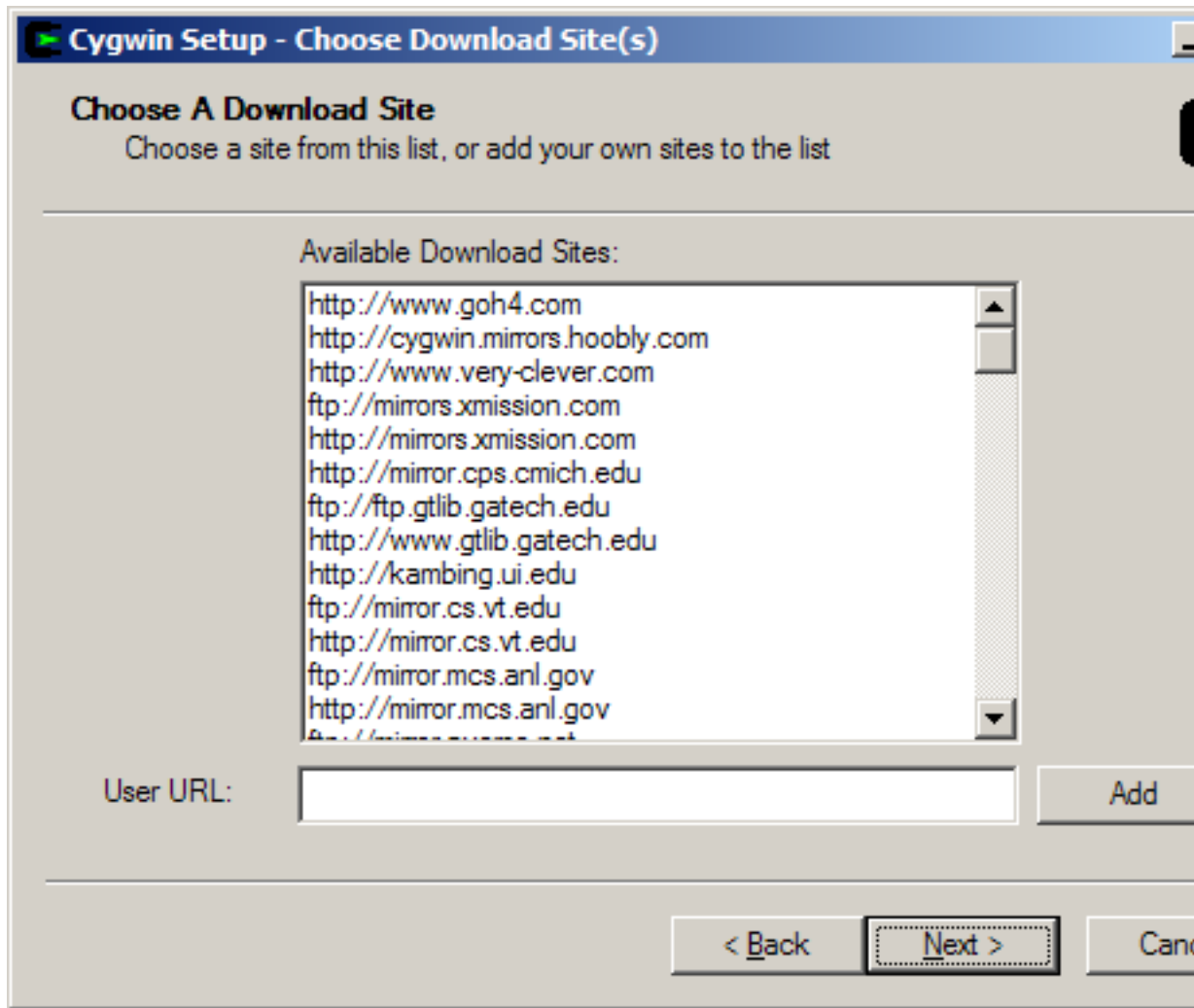
8. Click Next to proceed to the next screen.
9. Local Package Directory should default to the directory that you ran `setup.exe` from:



10. Click **Next** to proceed to the next screen.
11. Choose your proxy setup, or, just choose **Direct Connection** if no proxy is needed:



12. Click **Next** to proceed to the next screen.
13. Select your nearest mirror for downloading:

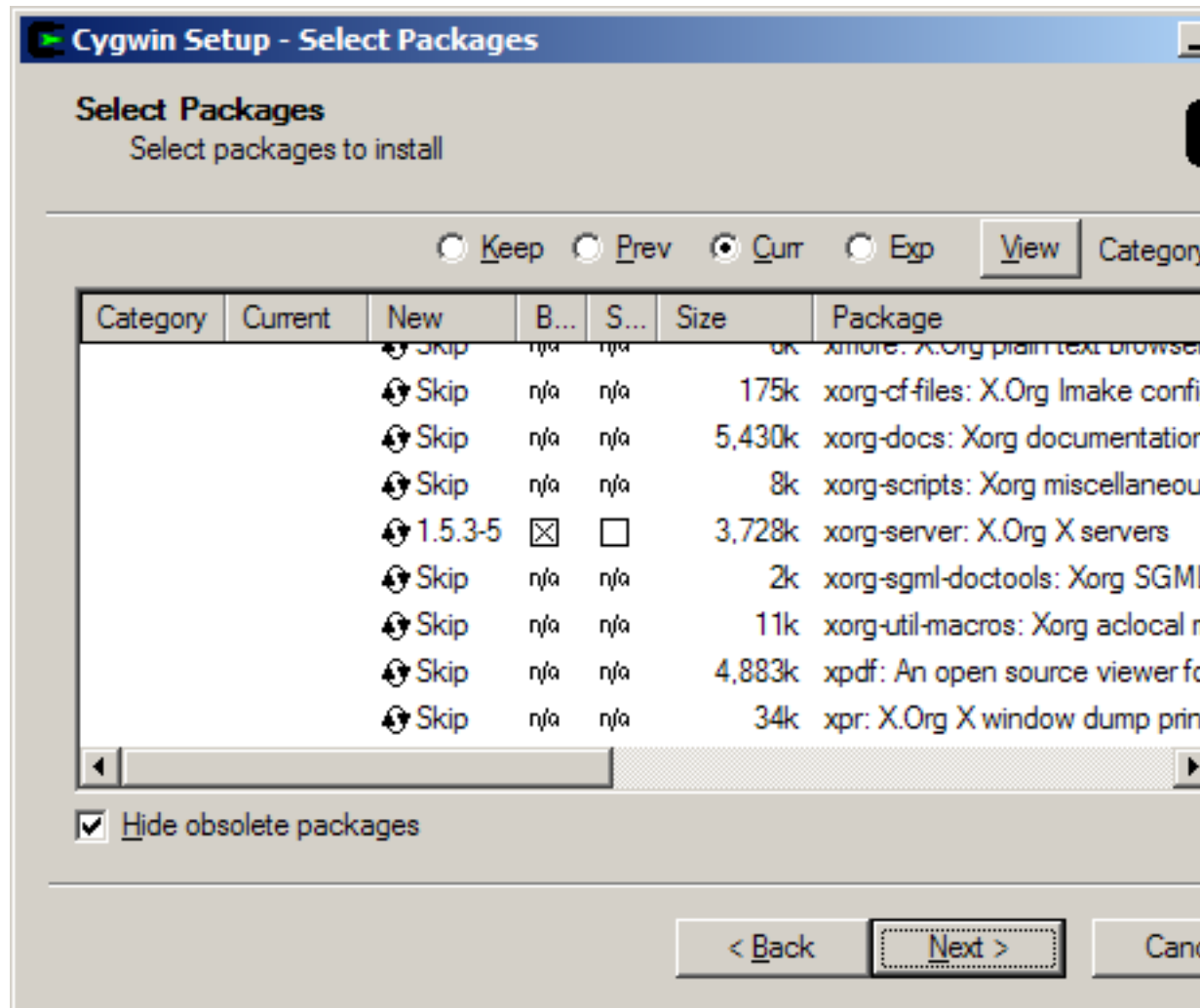


14. Click **Next** to proceed to the next screen; setup will download a list of available packages as it moves to the next screen.
15. On the next screen you will select the packages that will be downloaded and installed. A listing of the Cygwin/X packages is given below; a listing of the general Cygwin packages would be beyond the scope of this document.

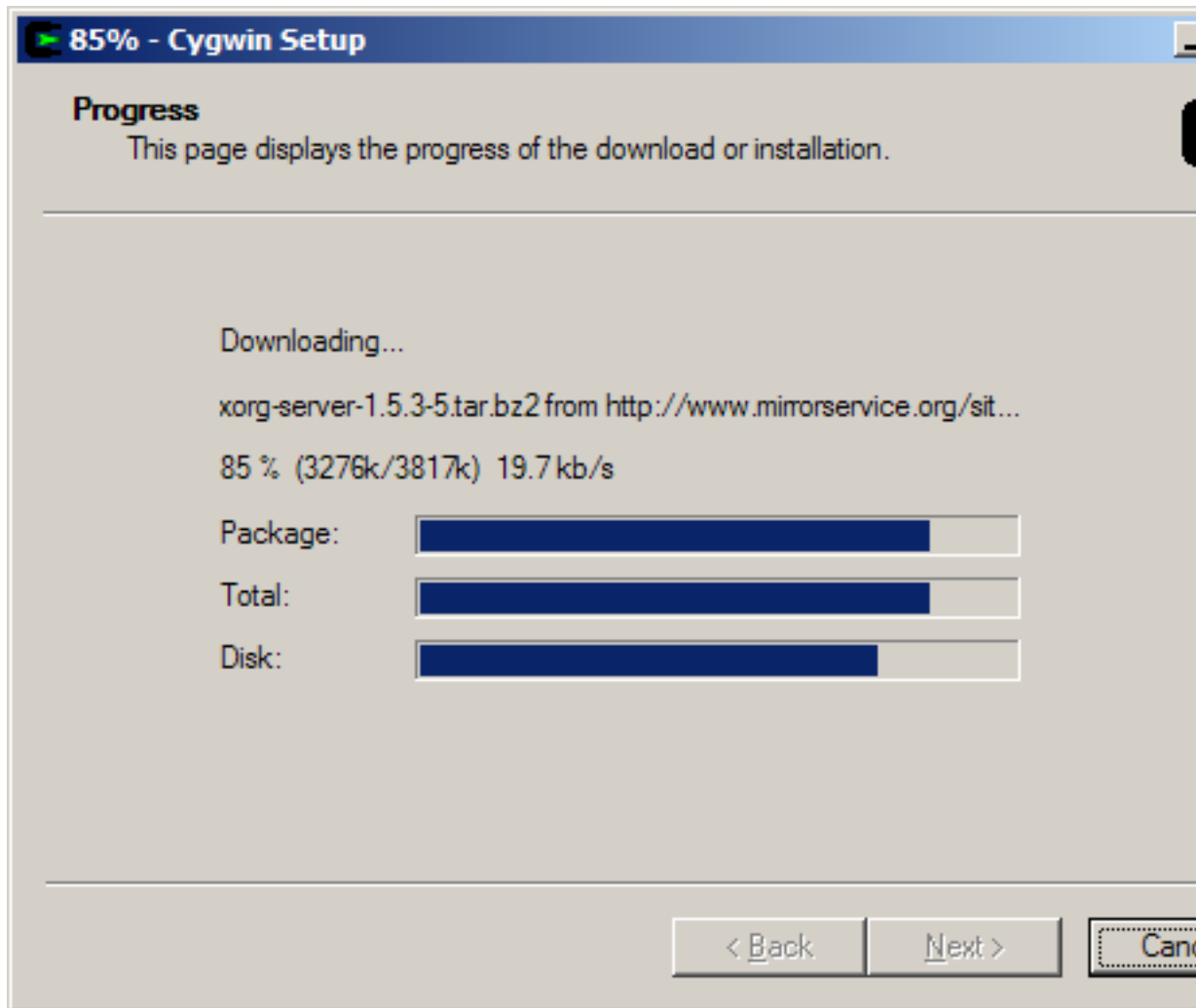
Cygwin/X packages are located in the `x11` category.

- `xorg-server` (required, the Cygwin/X X Server)
- `xinit` (required, scripts for starting the X server: **`xinit`**, **`startx`**, **`startwin.sh`**, **`startxwin.bat`** (and a shortcut on the Start Menu to run it), **`startxdmcp.bat`** )
- `xorg-docs` (optional, **`man`** pages)
- `x-start-menu-icons` (optional, adds icons for X Clients to the Start menu)
- You may also select any X client programs you want to use, and any fonts you would like to have available.

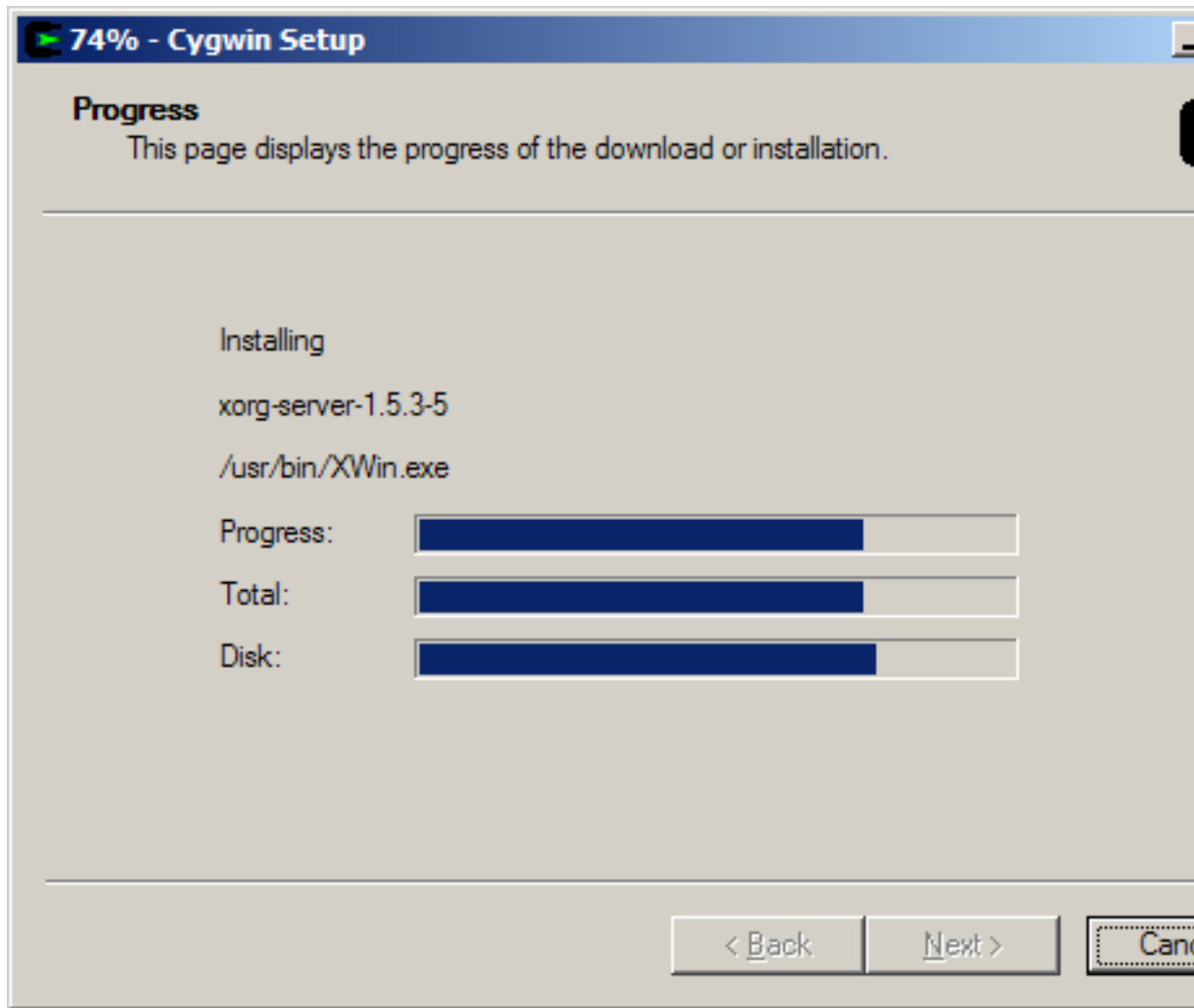
- You may also want to ensure that the `inetutils` or `openssh` packages are selected if you wish to use **telnet** or **ssh** connections to run remote X clients.



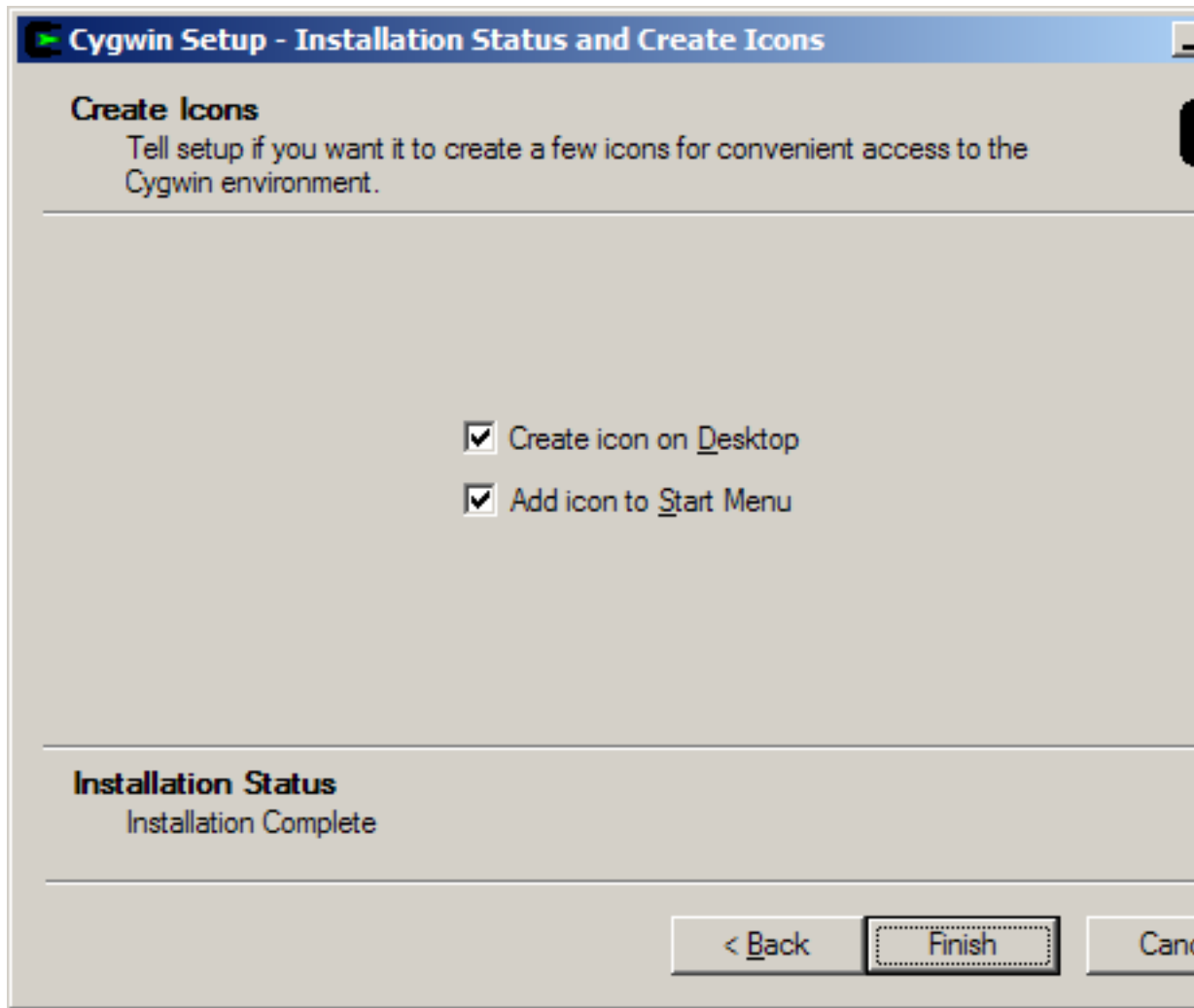
- Click Next to begin the download process, you may want to try another mirror if you see a "Connecting" message on this screen for a long period of time:



17. After the packages are downloaded, setup will automatically begin to install them:



18. I highly recommend allowing Cygwin Setup to create Desktop and Start Menu icons for you; these icons simply launch a bash shell:



19. Click Finish to close the setup program.

You have now successfully installed Cygwin/X. Proceed to Chapter 4 for instructions on how to use Cygwin/X.



# Chapter 3. Configuring Cygwin/X

## Configuration Overview

Cygwin/X settings are configured primarily through command-line parameters passed to `XWin.exe`. Cygwin/X comes with a file called `startxwin.bat` that launches an X Server, a terminal, and a window manager.

## Command Line Parameters

Cygwin/X, by default, runs in windowed mode with the largest window that will fit on your Windows desktop, using the best performing engine that is installed on your system; you do not need to pass any parameters to **XWin.exe** to use the default behavior. Below is the syntax for **XWin.exe** parameters.

### **XWin.exe**

```
[-help]
[-clipboard [-nunicodeclipboard] ]
[-clipupdates clip_updates_above_n ]
[-emulate3buttons timeout_in_milliseconds ]
[-engine engine_number ]
[-fullscreen [-depth depth_in_bits_per_pixel ] [-refresh refresh_rate_in_hertz ] ]
[-ignoreinput]
[-lesspointer]
[-multiwindow]
[-multimonitors]
[-nodecoration]
[-rootless]
[-screen screen_number width height ...]
[-scrollbars]
[-[no]trayicon]
[-[no]unixkill]
[-[no]winkill]
[-[no]keyhook]
[-swcursor]
[-xkbrules XKBRules ]
[-xkbmodel XKBModel ]
[-xkblayout XKBLayout ]
[-xkbvariant XKBVariant ]
[-xkboptions XKBOptions ]
[-logfile path_to_logfile ]
[-logverbose verbosity_level ]
```

Below is an example command line for **XWin.exe**.

```
XWin.exe -screen 0 800 600 -fullscreen -depth 32 -refresh 85 -emulate
100 -nowinkill -unixkill
```

```
3buttons
```

Table 3-1. Parameter Descriptions

Parameter	Description
<code>[-help]</code>	Print a list of supported commandline options and their description similar to this list.
<code>[-clipboard [-nunicodeclipboard] ]</code>	Enables the integrated version of <b>xwinclip</b> , which provides integration between the Cygwin/X clipboard and Windows clipboard. Do not use in conjunction with the <b>xwinclip</b> program.  <code>-nunicodeclipboard</code> disables Unicode clipboard even if Cygwin/X is running on a NT-based platform
<code>[-clipupdates <i>clip_updates_above_n</i> ]</code>	Groups together the regions in each update to the screen when there are more than the specified number of regions in an update. This works by fitting a clipping region around the updated regions, then transferring that entire region of the shadow frame buffer to the screen, rather than making many individual calls to transfer small portions of the shadow frame buffer to the screen. This has a diminished effect on NT-based platforms because they already group GDI operations together in a batch, which has a similar effect.
<code>[-emulate3buttons <i>timeout_in_milliseconds</i> ]</code>	Note: scroll wheel mice often allow you to click the scroll wheel for middle mouse button functionality. Thus, most users with a scroll wheel mouse will not need to use this parameter. This option allows users with a two-button mouse to emulate a third mouse button by pressing both mouse buttons within the optional timeout specified in milliseconds. The default timeout is 50 milliseconds.

Parameter	Description
<code>[-engine <i>engine_number</i> ]</code>	<p>Do not use this parameter unless you are a Cygwin/X developer or are instructed by a Cygwin/X developer to do so.</p> <p>Cygwin/X's default behavior is to determine if DirectDraw or DirectDraw4 are present, then to examine the <code>-depth</code> and <code>-fullscreen</code> parameters to determine the engine with optimum performance that supports the specified depth and window configuration.</p>
<code>[-fullscreen [-depth <i>depth_in_bits_per_pixel</i> ] [-refresh <i>refresh_rate_in_hertz</i> ] ]</code>	<p>The <code>-fullscreen</code> parameter tells Cygwin/X to open a given screen in fullscreen mode.</p> <p>The <code>-depth</code> parameter can only be used with <code>-fullscreen</code> and a DirectDraw based engine to specify the display depth that should be used for the fullscreen Cygwin/X screen.</p> <p>The <code>-refresh</code> parameter can only be used with <code>-fullscreen</code> and a DirectDraw based engine to specify the refresh rate that should be used for the fullscreen Cygwin/X screen.</p>
<code>[-ignoreinput]</code>	Ignore keyboard and mouse input. This is usually only use for testing and debugging purposes.
<code>[-lesspointer]</code>	Hide the Windows mouse cursor when the mouse is over any Cygwin/X window (regardless of whether that window is active or inactive). This prevents the Windows mouse cursor from being placed overtop of the X cursor.
<code>[-multimonitors]</code>	Create a root window that covers all monitors on a system with multiple monitors.
<code>[-multiwindow]</code>	Start the integrated Windows-based window manager, which launches each top-level X window in its own Windows window. Not to be used together with <code>-rootless</code> nor <code>-fullscreen</code> .
<code>[-nodecoration]</code>	Do not give the Cygwin/X window a Windows window border, title bar, etc. This parameter only applies to windowed mode screens, i.e., this parameter is ignored when the <code>-fullscreen</code> parameter is specified.
<code>[-rootless]</code>	Use a transparent root window with an external window manager (such as <b>twm</b> ). Not to be used with <code>-multiwindow</code> nor with <code>-fullscreen</code> .

Parameter	Description
<code>[-screen <i>screen_number</i> <i>width</i> <i>height</i> ...]</code>	<p>This parameter does not have to be specified. Cygwin/X's default behavior is to create a single screen that is roughly the size of the current Windows display area.</p> <p>This parameter may be used to specify the screen number, height, and width of one or several Cygwin/X screens; each Cygwin/X screen will be opened in its own window. When using multiple screens, be sure not to duplicate any screen numbers. Do note that, as of 2002-01-08, using multiple screens is not fully implemented; there are several bugs that must be fixed by someone that uses the multiple screens feature.</p> <p>Screen specific parameters, such as <code>-fullscreen</code>, can be applied as a default to all screens by placing those screen specific parameters before any <code>-screen</code> parameter. Screen specific parameters placed after the first <code>-screen</code> parameter will apply only to the immediately preceeding <code>-screen</code> parameter.</p>
<code>[-scrollbars]</code>	Enable resizing of the server display window. Do not use in conjunction with <code>-multiwindow</code> nor with <code>-rootless</code> .
<code>[-[no]trayicon]</code>	Enable or disable the tray icon; the default is to enable the tray icon.
<code>[-[no]unixkill]</code>	Enable or disable the <b>Ctrl-Alt-Backspace</b> key combo as a signal to exit Cygwin/X. The <b>Ctrl-Alt-Backspace</b> key combo is disabled by default.
<code>[-[no]winkill]</code>	Enable or disable the <b>Alt-F4</b> key combo as a signal to exit Cygwin/X. The <b>Alt-F4</b> key combo is enabled by default.
<code>[-[no]keyhook]</code>	Enable or disable grabbing of special windows keys like the <b>Menu</b> key or <b>Alt-Tab</b> . This is disabled by default.
<code>[-swcursor]</code>	Disable the use of the windows cursor and use the X11 software cursor instead.
<code>[-xkbrules <i>XKBrules</i> ]</code>	Set the rules to use for XKB. This defaults to <code>xorg</code> .
<code>[-xkbmodel <i>XKBmodel</i> ]</code>	Set the model to use for XKB. This defaults to <code>pc105</code> .

Parameter	Description
<code>[-xkblayout <i>XKBLayout</i> ]</code>	Set the layout to use for XKB. This defaults to a layout matching your current layout from windows or <code>us</code> if no matching layout was found.
<code>[-xkbvariant <i>XKBVariant</i> ]</code>	Set the variant to use for XKB. This defaults to not set.
<code>[-xkboptions <i>XKBOptions</i> ]</code>	Set the options to use for XKB. This defaults to not set.
<code>[-logfile <i>path_to_logfile</i> ]</code>	Set the location of the logfile. This defaults to <code>/tmp/Win.log</code> .
<code>[-logverbose <i>verbosity_level</i> ]</code>	Set the level of logging verbosity. Currently only a few log messages respect this setting.

# Chapter 4. Using Cygwin/X

## Starting Cygwin/X

There are several methods of starting the Cygwin/X X Server with a startup script that optionally starts initial clients and loads keyboard modifier maps. Several startup methods are described below.

### startxwin.bat

Use a MS-DOS batch file as the startup script. An example `startxwin.bat` is included in `xorg-xinit`, which is installed by following the instructions in the Section called *Installing Cygwin/X* in Chapter 2. Run `/usr/bin/startxwin.bat` by using the "XWin Server" shortcut under "Cygwin-X" on the Start Menu, or starting it from a MS-DOS shell, or double-clicking it in Windows Explorer.

### startxwin.sh

Use a `sh` shell script as the startup script. An example `startxwin.sh` is included in `xorg-xinit`, which is installed by following the instructions in the Section called *Installing Cygwin/X* in Chapter 2. Run `/usr/bin/startxwin.sh` in a Cygwin shell:

```
Username@CygwinHost ~  
$ sh /usr/bin/startxwin.sh
```

### startx

Use the standard X Window System `startx` script with its attendant `~/.xinitrc` configuration file. Run `startx` in a Cygwin shell:

```
Username@CygwinHost ~  
$ startx
```

You may create a `~/.xinitrc` from the template in `/etc/X11/xinit/` and then customize `~/.xinitrc` as required

```
Username@CygwinHost ~  
$ cp /etc/X11/xinit/xinitrc ~/.xinitrc
```

## Switching Out of Cygwin/X

Press **Alt-Tab** to switch from Cygwin/X to your Windows desktop or other running Windows applications.

## Stopping Cygwin/X

When you are done using Cygwin/X, press **Alt-F4** to shutdown the X Server; this is the default key combination to shutdown the X Server. The `-[no]winkill` and `-[no]unixkill` parameters can change the set of key combinations that will shutdown the X Server. Using the `-unixkill` allows the **Ctrl-Alt-Backspace** key combination to shutdown the X Server, in addition to the default **Alt-F4** key combination.

## Window Managers

Cygwin/X works with window managers in a couple of different ways:

- Internal window manager (a.k.a. MultiWindow Mode) that creates a Windows window for each top-level X window. The internal window manager is launched using the `-multiwindow` command-line parameter to **XWin.exe**. See the Section called *Command Line Parameters* in Chapter 3 for more information on the `-multiwindow` command-line parameter.
- External local window managers (e.g. **twm**, **mwm** (part of the lesstif package)). These local window managers must be installed on Cygwin; they are run locally and cannot be used together with the internal window manager.
- Remote window managers via an XDMCP session, which you can read more about in the Section called *Remote Sessions via XDMCP*.
- Remote window manager launched through an **ssh** tunnel. This is not Cygwin/X-specific, so you should be able to find information about launching remote window managers from other sources. See the Section called *Secure ssh* for more information on using **ssh**.

## Windows Clipboard Integration

The X Window System, and thus Cygwin/X, uses its own internal clipboard system that is distinct from the clipboard system used by Windows. Copying and pasting text between these two clipboard systems requires a clipboard integration program that watches for updates to either clipboard and copies data between them when either one is updated.

Cygwin/X has an internal clipboard integration system that is invoked via the `-clipboard` command-line parameter. See the Section called *Command Line Parameters* in Chapter 3 for more information on the `-clipboard` command-line parameter.

## Shared Memory Support (MIT-SHM Extension)

Shared memory is provided by the **cygserver** service. On Windows NT, Windows 2000 and Windows XP cygserver can be installed as a windows service.

To install cygserver run the **cygserver-config** script. It will install the service.

XWin.exe will not use Shared Memory if the *CYGWIN* does not contain the *server* keyword. Starting **XWin.exe** with

```
CYGWIN=server XWin.exe
```

will enable Shared Memory support if the cygserver service is running.

## Remote Sessions via XDMCP

Cygwin/X can be used login to one or several remote sessions using XDMCP (X Display Manager Control Protocol).

Start Cygwin/X with a command similar to the following to login to a single remote session using XDMCP:

```
XWin.exe -query remote_hostname_or_ip_address
```

You may login to several remote sessions with a single or multiple hosts using XDMCP. Each session will need a separate display number, specified by the *:display\_number* parameter, such as *:0*. A display number is not the same as a screen number, as a single display can have multiple screens associated with it. Each display listens on a different network port number, so each display can connect to multiple machines. Start Cygwin/X with command lines similar to the following to login to several remote sessions using XDMCP:

```
XWin.exe :0 -query remote_hostname_or_ip_address_0
```

```
XWin.exe :1 -query remote_hostname_or_ip_address_1
```

Note that the *:display\_number* parameter is a general X Server parameter, not specific to Cygwin/X. Further documentation of the *:display\_number* parameter can be found in the X Server manual page (<http://freedesktop.org/~xorg/X11R6.7.0/doc/Xserver.1.html>). XDMCP is a complex system that is not specific to Cygwin/X; further discussion of XDMCP is beyond the scope of this document. You may wish to read the Linux XDMCP HOWTO (<http://en.tldp.org/HOWTO/XDMCP-HOWTO/>) or the X Server XDMCP Options (<http://freedesktop.org/~xorg/X11R6.7.0/doc/Xserver.1.html#sect6>) for more information.

## Displaying Remote Clients

Displaying remote X clients with Cygwin/X is nearly identical to displaying remote X clients with any other X Server. You may use the secure **ssh** method, or the unsecure **telnet** method (not recommended).

### Secure ssh

On your Windows machine:

1. Make sure you have the openssh package installed.
2. Launch Cygwin/X



3. Run the following in an X terminal:

```
Username@CygwinHost ~
$ ssh -Y -l username remote_hostname_or_ip_address
```

4. Enter your password when prompted by **ssh**.
5. Your **ssh** session should now show you a shell prompt for your remote machine.
6. You can now launch remote X clients in your **ssh** session, for example, ~~xterm~~ will launch an xterm running on your remote host that will display on your Cygwin/X screen.
7. Launch other remote clients in the same manner. I recommend starting the remote clients in the background, by appending & to the command name, so that you don't have to open several **ssh** sessions.

## Unsecure Telnet

On your Windows machine:

1. Make sure you have the `inetutils` package installed.
2. Launch Cygwin/X
3. In an X terminal type `/usr/bin/xhost remote_hostname_or_ip_address`
4. In an X terminal type `/usr/bin/telnet remote_hostname_or_ip_address`. Use the explicit path to ensure that Cygwin's **telnet** is run instead of Microsoft's **telnet**; Microsoft's **telnet** will crash on startup when run from Cygwin/X.
5. Login to your remote machine via your **telnet** session
6. In your **telnet** session type, `DISPLAY= windows_hostname_or_ip_address :0.0`
7. In your **telnet** session type, `export DISPLAY`
8. You can now launch remote X clients in your **telnet** session, for example, ~~xterm~~ will launch an xterm running on your remote host that will display on your Cygwin/X screen.
9. Launch other remote clients in the same manner; I recommend starting the remote clients in the background, by appending & to the command name, so that you don't have to open several **telnet** sessions.

# Appendix A. GNU Free Documentation License

Version 1.1, March 2000

Copyright (C) 2000 Free Software Foundation, Inc. 59 Temple Place, Suite 330, Boston, MA 02111-1307 USA  
Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

## 0. PREAMBLE

The purpose of this License is to make a manual, textbook, or other written document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondly, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

## 1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. The "Document", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "you".

A "Modified Version" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A "Secondary Section" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (For example, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The "Invariant Sections" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License.

The "Cover Texts" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, whose contents can be viewed and edited directly and straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup has been designed to thwart or discourage subsequent modification by readers is not Transparent. A copy that is not "Transparent" is called "Opaque".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML designed for human modification. Opaque formats include PostScript, PDF, proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML produced by some word processors for output purposes only.

The "Title Page" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

## **2. VERBATIM COPYING**

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

## **3. COPYING IN QUANTITY**

If you publish printed copies of the Document numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a publicly-accessible computer-network location containing a complete Transparent copy of the Document, free of added material, which the general network-using public has access to download

anonymously at no charge using public-standard network protocols. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

## **4. MODIFICATIONS**

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

- A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.
- B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has less than five).
- C. State on the Title page the name of the publisher of the Modified Version, as the publisher.
- D. Preserve all the copyright notices of the Document.
- E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
- F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
- G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
- H. Include an unaltered copy of this License.
- I. Preserve the section entitled "History", and its title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.
- J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.

- K. In any section entitled "Acknowledgements" or "Dedications", preserve the section's title, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
- L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
- M. Delete any section entitled "Endorsements". Such a section may not be included in the Modified Version.
- N. Do not retitle any existing section as "Endorsements" or to conflict in title with any Invariant Section.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties--for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

## **5. COMBINING DOCUMENTS**

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections entitled "History" in the various original documents, forming one section entitled "History"; likewise combine any sections entitled "Acknowledgements", and any sections entitled "Dedications". You must delete all sections entitled "Endorsements."

## **6. COLLECTIONS OF DOCUMENTS**

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

## **7. AGGREGATION WITH INDEPENDENT WORKS**

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, does not as a whole count as a Modified Version of the Document, provided no compilation copyright is claimed for the compilation. Such a compilation is called an "aggregate", and this License does not apply to the other self-contained works thus compiled with the Document, on account of their being thus compiled, if they are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one quarter of the entire aggregate, the Document's Cover Texts may be placed on covers that surround only the Document within the aggregate. Otherwise they must appear on covers around the whole aggregate.

## **8. TRANSLATION**

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License provided that you also include the original English version of this License. In case of a disagreement between the translation and the original English version of this License, the original English version will prevail.

## **9. TERMINATION**

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

## 10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See <http://www.gnu.org/copyleft/>.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

## How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

Copyright (c) YEAR YOUR NAME. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.1 or any later version published by the Free Software Foundation; with the Invariant Sections being LIST THEIR TITLES, with the Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST. A copy of the license is included in the section entitled "GNU Free Documentation License".

If you have no Invariant Sections, write "with no Invariant Sections" instead of saying which ones are invariant. If you have no Front-Cover Texts, write "no Front-Cover Texts" instead of "Front-Cover Texts being LIST"; likewise for Back-Cover Texts.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.