

## Command Interpreters

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A *command interpreter* is a program that executes other programs.

Aim: allow users to execute the commands provided on a computer system.

Command interpreters come in two flavours:

- graphical (e.g. Windows or Mac desktop)
  - advantage: easy for naive users to start using system
- command-line (e.g. Unix shell)
  - advantage: programmable, powerful tool for expert users

On Unix/Linux, `bash` has become defacto standard shell.

## What Shells Do

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All Unix shells have the same basic mode of operation:

```
loop
  if (interactive) print a prompt
  read a line of user input
  apply transformations to line
  split line into words (/s+/)
  use first word in line as command name
  execute that command,
    using other words as arguments
end loop
```

Note that "line of user input" could be a line from a file. In that case, the shell is reading a "script" of commands and acting as a kind of programming language interpreter.

## What Shells Do

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The "transformations" applied to input lines include:

- variable expansion ... e.g. `$1 ${x-20}`
- file name expansion ... e.g. `*.c enr.07s?`

To "execute that command" the shell needs to:

- find file containing named program (PATH)
- start new process for execution of program

## Command Search PATH

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If we have a script called `bling` in the current directory, we might be able to execute it with any of these:

```
$ sh bling    # file need not be executable
$ ./bling     # file must be executable
$ bling       # file must be executable and . in PATH
```

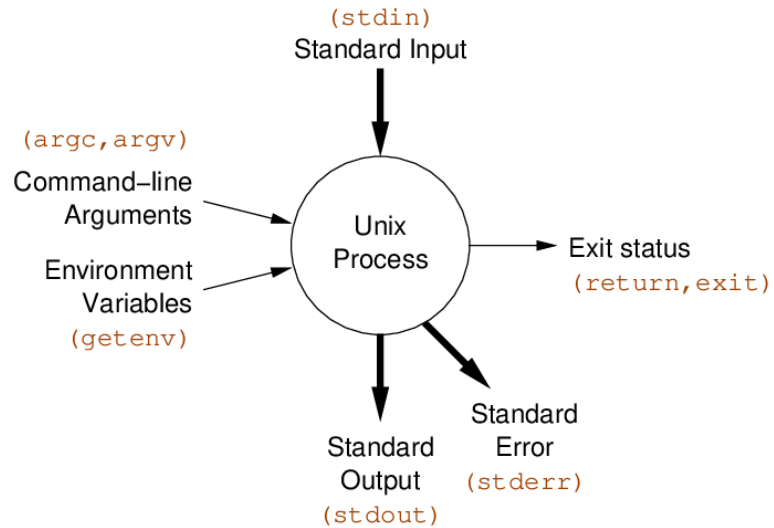
Shell searches for programs to run using the colon-separated list of directories in the variable `PATH`. Beware: only append the current directory to end of your path, e.g:

```
$ PATH=.:$PATH
$ cat >cat <<eof
#!/bin/sh
echo miaou
eof
$ chmod 755 cat
$ cat /home/cs2041/public_html/index.html
miaou
$
```

Note `./cat` is being run rather `/bin/cat`.  
Much hard to discover if it happens with another shell script which runs `cat`. Safer still: don't put `.` in your `PATH`.

## Unix Processes

A Unix process executes in this environment



## Unix Processes: C Program View

Components of process environment (C programmer's view):

- `char *argv[]` - command line "words"
- `int argc` - size of `argv[]`
- `char *env[]` - name=value pairs from shell
- `FILE *stdin` - input byte-stream, e.g. `getchar()`
- `FILE *stdout` - output byte-stream, e.g. `putchar()`
- `FILE *stderr` - output byte-stream, e.g. `fputc(c, stderr)`
- `exit(int)` - terminate program, set exit status
- `return int` - terminate `main()`, set exit status

## Shell as Interpreter

The shell can be viewed as a programming language interpreter.

As with all interpreters, the shell has:

- a state (collection of variables and their values)
- control (current location, execution flow)

Different to most interpreters, the shell:

- modifies the program code before finally executing it
- has an infinitely extendible set of basic operations

## Shell as Interpreter

Basic operations in shell scripts are a sequence of *words*.

`CommandName Arg1 Arg2 Arg3 ...`

A *word* is defined to be any sequence of:

- non-whitespace characters (e.g. `x`, `y1`, `aVeryLongWord`)
- characters enclosed in double-quotes (e.g. `"abc"`, `"a b c"`)
- characters enclosed in single-quotes (e.g. `'abc'`, `'a b c'`)

We discuss the different kinds of quote later.

## Shell Scripts

Consider a file called "hello" containing

```
#!/bin/sh
```

```
echo Hello, World
```

How do we execute it?

```
$ sh hello          # execute the script
```

or

```
$ chmod +x hello    # make the file executable
```

```
$ ./hello           # execute the script
```

## Shell Variables

More on shell variables:

- no need to declare shell variables; simply use them
- are local to the current execution of the shell.
- all variables have type string
- initial value of variable = empty string
- note that `x=1` is equivalent to `x="1"`

Examples:

```
$ x=5
$ y="6"
$ z=abc
$ echo $(( $x + $y ))
11
$ echo $(( $x + $z ))
5
```

## Shell Scripts

The next simplest shell program: "Hello, *YourName*"

```
#!/bin/sh
```

```
echo -n "Enter your name: "
```

```
read name
```

```
echo Hello, $name
```

Shell variables:

```
$ read x          # read a value into variable x
```

```
$ y=John          # assign a value to variable y
```

```
$ echo $x         # display the VALUE of variable x
```

```
$ z="$y $y"       # assign two copies of y to variable z
```

Note: spaces matter ... do *not* put spaces around the = symbol.

## Shell Variables

```
$ x=1
$ y=fred
$ echo $x$y
1fred
$ echo $xy        # the aim is to display "1y"

$ echo "$x"y
1y
$ echo ${x}y
1y
$ echo ${j-10}     # give value of j or 10 if no value
10
$ echo ${j=33}     # set j to 33 if no value (and give $j)
33
$ echo ${x:?No Value} # display "No Value" if $x not set
1
$ echo ${xx:?No Value} # display "No Value" if $xx not set
-bash: xx: No Value
```

## Shell Scripts

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Some shell built-in variables with pre-assigned values:

- \$0 the name of the command
- \$1 the first command-line argument
- \$2 the second command-line argument
- \$3 the third command-line argument
- \$# count of command-line arguments
- \$\* all of the command-line arguments (together)
- @ all of the command-line arguments (separately)
- \$? exit status of the most recent command
- \$\$ process ID of this shell

The last one is useful for generating unique filenames.

## Shell Pathname Expansion

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If a string contains any of \* ? [] it is matched against pathnames.

- \* matches zero or more of any character
- ? matches any one character
- [] matches any one character between the []

The string is replaced with all matching pathnames.

If no matches the string is left unchanged (usually configurable)

## Shell Scripts

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Tip: debugging for shell scripts

- the shell transforms commands before executing
- can be useful to know what commands are executed
- can be useful to know what transformations produced
- set -x shows each command after transformation

i.e. execution trace

## Quoting

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Quoting can be used for three purposes in the shell:

- to group a sequence of words into a single "word"
- to control the kinds of transformations that are performed
- to capture the output of commands (back-quotes)

The three different kinds of quotes have three different effects:

single-quote (')	grouping, turns off all transformations
double-quote (")	grouping, no transformations except \$ and `
backquote (`)	no grouping, capture command results

## Quoting

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Single-quotes are useful to pass shell meta-characters in args: e.g.  
`grep 'S.*[0-9]+$' < myfile`

Use double-quotes to

- construct strings using the values of shell variables  
e.g. `"x=$x, y=$y"` like Java's `("x=" + x + ", y=" + y)`
- prevent empty variables from "vanishing"  
e.g. use `test "$x" = "abc"` rather than `test $x = "abc"`  
in case `$x` is empty
- for values obtained from the command line or a user  
e.g. use `test -f "$1"` rather than `test -f $1` in case  
`$1` contains a path with spaces e.g. `C:/Program Files/app/data`

## Back-quotes

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Back-quotes capture the output of commands as shell values.

For '*Command*', the shell:

1. performs variable-substitution (as for double-quotes)
2. executes the resulting command and arguments
3. captures the standard output from the command
4. converts it to a single string
5. uses this string as the value of the expression

## Back-quotes

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Example: convert GIF files to PNG format.

Original and converted files share the same prefix

(e.g. `/x/y/abc.gif` is converted to `/x/y/abc.png`)

```
#!/bin/sh
# ungif - convert gifs to PNG format

for f in "$@"
do
    dir='dirname "$f"'
    prefix='basename "$f" .gif'
    outfile="$dir/$prefix.png"
    giftopnm "$f" | pnmtopng > "$outfile"
done
```

## Connecting Commands

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The shell provides *I/O redirection* to allow us to change where processes read from and write to.

<code>&lt; infile</code>	connect stdin to the file <code>infile</code>
<code>&gt; outfile</code>	connect stdout to the file <code>outfile</code>
<code>» outfile</code>	append stdout to the file <code>outfile</code>
<code>2&gt; outfile</code>	connect stderr to the file <code>outfile</code>
<code>2&gt;&amp;1 &gt; outfile</code>	connect stderr+stdout to <code>outfile</code>

Beware: `>` truncates file before executing command.

Always have backups!

## Connecting Commands

Many commands accept list of input files:

E.g. `cat file1 file2 file3`

These commands also typically adopt the conventions:

- read contents of `stdin` if no filename arguments
- treat the filename `-` as meaning `stdin`

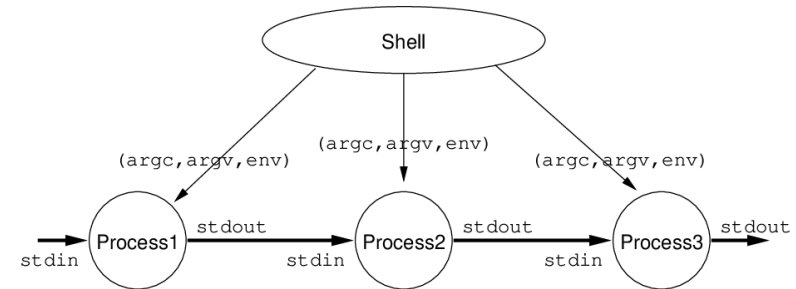
E.g. `cat -n < file` and `cat a - b - c`

If a command does not allow the use of multiple files as input, use:

E.g. `cat file1 file2 file3 | Command`

## Connecting Commands

The shell sets up the environment for each command in a pipeline and connects them together:



## Exit Status and Control

Process exit status is used for control in shell scripts:

- zero exit status means command successful  $\rightarrow$  true
- non-zero exit status means error occurred  $\rightarrow$  false

Mostly, exit status is simply ignored (e.g. when interactive)

One application of exit statuses:

- AND lists `cmd1 && cmd2 && ... && cmdn`  
(`cmdi+1` is executed only if `cmdi` succeeds (zero exit status))
- OR lists `cmd1 || cmd2 || ... || cmdn`  
(`cmdi+1` is executed only if `cmdi` fails (non-zero exit status))

## Testing

The test command performs a test or combination of tests and:

- returns a zero exit status if the test succeeds
- returns a non-zero exit status if the test fails

Provides a variety of useful testing features:

- string comparison (`=` `!=`)
- numeric comparison (`-eq` `-ne` `-lt`)
- checks on files (`-f` `-x` `-r`)
- boolean operators (`-a` `-o` `!`)

## Testing

Examples:

```
# does the variable msg have the value "Hello"?
test "$msg" = "Hello"

# does x contain a numeric value larger than y?
test "$x" -gt "$y"

# Error: expands to "test hello there = Hello"?
msg="hello there"
test $msg = Hello

# is the value of x in range 10..20?
test "$x" -ge 10 -a "$x" -le 20

# is the file xyz a readable directory?
test -r xyz -a -d xyz

# alternative syntax; requires closing ]
[ -r xyz -a -d xyz ]
```

Note: use of quotes, spaces around values/operators

## Sequential Execution

Combine commands in pipelines and AND and OR lists.  
Commands executed sequentially if separated by semicolon or newline.

```
cmd1 ; cmd2 ; ... ; cmdn
cmd1
cmd2
...
cmdn
```

## Grouping

Commands can be grouped using ( ... ) or { ... }  
(cmd<sub>1</sub> ; ... cmd<sub>n</sub>) are executed in a new sub-shell.  
{cmd<sub>1</sub> ; ... cmd<sub>n</sub>} are executed in the current shell.  
Exit status of group is exit status of last command.  
Beware: state of sub-shell (e.g. \$PWD, other variables) is lost after (...), hence

```
$ cd /usr/share
$ x=123
$ ( cd $HOME; x=abc; )
$ echo $PWD $x
/usr/share 123
$ { cd $HOME; x=abc; }
$ echo $PWD $x
/home/cs2041 abc
```

## If Command

The if-then-else construct allows conditional execution:

```
if testList{1}
then
    commandList{1}
elif testList{2}
then
    commandList{2}
    ...
else
    commandList{n}
fi
```

Keywords if, else etc, are only recognised at the start of a command (after newline or semicolon).

## If Command

Examples:

```
# Check whether a file is readable

if [ -r $HOME ]      # neater than:  if test -r $HOME
then
    echo "$0: $HOME is readable"
fi

# Test whether a user exists in passwd file

if grep "^$user" /etc/passwd > /dev/null
then
    # do something if they do exist ...
else
    echo "$0: $user does not exist"
fi
```

## Case command

case provides multi-way choice based on patterns:

```
case word in
pattern{1})  commandList{1} ;;
pattern{2}-2)  commandList{2}-2 ;;
...
pattern{n})  commandList{n} ;;
esac
```

The *word* is compared to each *pattern<sub>i</sub>* in turn.

For the first matching pattern, corresponding *commandList<sub>i</sub>* is executed and the statement finishes.

Patterns are those used in filename expansion ( \* ? [] ).

## Case command

Examples:

```
# Checking number of command line args

case $# in
0)  echo "You forgot to supply the argument" ;;
1)  ... process the argument ... ;;
*)  echo "You supplied too many arguments" ;;
esac

# Classifying a file via its name

case "$file" in
*.c)  echo "$file looks like a C source-code file" ;;
*.h)  echo "$file looks like a C header file" ;;
*.o)  echo "$file looks like a C object file" ;;
...
?)    echo "$file's name is too short to classify" ;;
*)    echo "I have no idea what $file is" ;;
esac
```

## Loop commands

while loops iterate based on a test command list:

```
while testList
do
    commandList
done
```

for loops set a variable to successive words from a list:

```
for var in wordList
do
    commandList # ... generally involving var
done
```



## Loop commands

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Examples of while:

```
# Check the system status every ten minutes
```

```
while true
do
    uptime ; sleep 600
done
```

```
# Interactively prompt the user to process files
```

```
echo -n "Next file: "
while read filename
do
    process < "$filename" >> results
    echo -n "Next file: "
done
```

## Loop commands

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Examples of for:

```
# Compute sum of a list of numbers from command line
```

```
sum=0
for n in "$@"    # use "$@" to preserve args
do
    sum=`expr $sum + "$n"`
done
```

```
# Process files in $PWD, asking for confirmation
```

```
for file in *
do
    echo -n "Process $file? "
    read answer
    case "$answer" in
        [yY]*) process < $file >> results ;;
        *)      ;;
    esac
done
```