

# Introduction to Bash scripting language

## Day 1

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# Topics of the day



Prelude

1

Inception and philosophy

2

Commands and arguments

3

Strings and types of commands

4

Quoting and special characters

5

Variables and special parameters

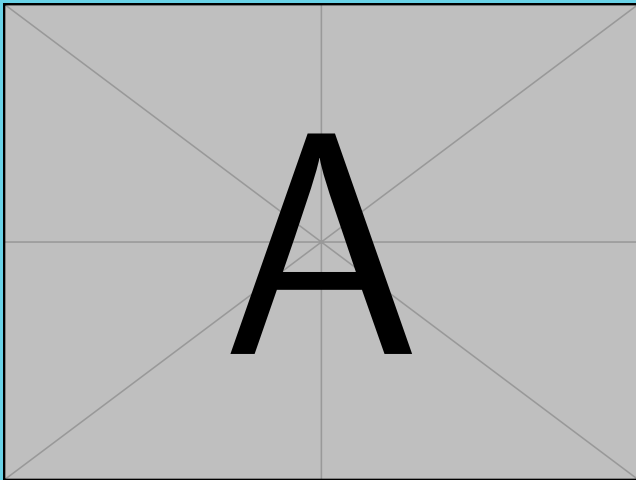
6

Shell expansion

7

Globs and filename expansion

# Inception and philosophy



Northern Light from the lighthouse of Reykjavík at  $-8^{\circ}\text{C}$

## An often mistreated language

- Everybody uses Bash
- It is easy to know a bit of many commands
- Not so many Bash users (have time to) go deeply into the details

### The nature of Bash

As with many tools, it is common to just get stuff working, no matter how

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## The nature of Bash

As with many tools, it is common to just get stuff working, no matter how

## Important aspects to always keep in mind

- Use a clear, readable layout
- Avoid unnecessary commands
- A small, trivial script today might become large and complex tomorrow

# An often mistreated language

- Everybody uses Bash
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## The nature of Bash

As with many tools, it is common to just get stuff working, no matter how

## Before you get too excited

It is key that you remember, bash is a tool, a single tool in a huge toolbox of programs. Bash alone will only let you do basic things with files and other programs. You will need to understand all the other tools in the toolbox of your system. This knowledge is vast and will come slowly, it is important that you take the time to learn them well rather than try to get the basic idea of most and break a leg tomorrow (or more likely, your music archive or collection of family pictures).

Greg's Wiki

# Using Bash

Bash in interactive mode: A prompt and a command line

Bash in non-interactive mode: Executing scripts

## The prompt

`cool-prompt$` ← shell compatible with the Bourne shell  
`cool-prompt%` ← C-shell (which is not covered here)  
`cool-prompt#` ← shell run as superuser (root)

# Using Bash

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```
1 $ man man          # Learn how to use and read the manual*
2 $ man apropos
3 $ help              # Get help for builtin commands
4 $ help echo
```

\* Use  to quit the manual



# Using Bash

Bash in interactive mode: A prompt and a command line

Bash in non-interactive mode: Executing scripts

## The prompt

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## Manual SYNOPSIS

**bold text**

type exactly as shown.

*italic text*

replace with appropriate argument.

`[-abc]`

any or all arguments within `[]` are optional.

`-a|-b`

options delimited by `|` cannot be used together.

`argument ...`

argument is repeatable.

`[ expression ] ...`

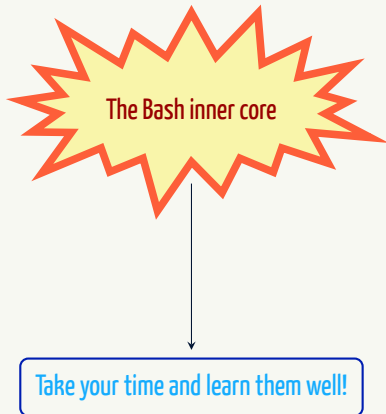
entire expression within `[]` is repeatable.

# The goal of the day

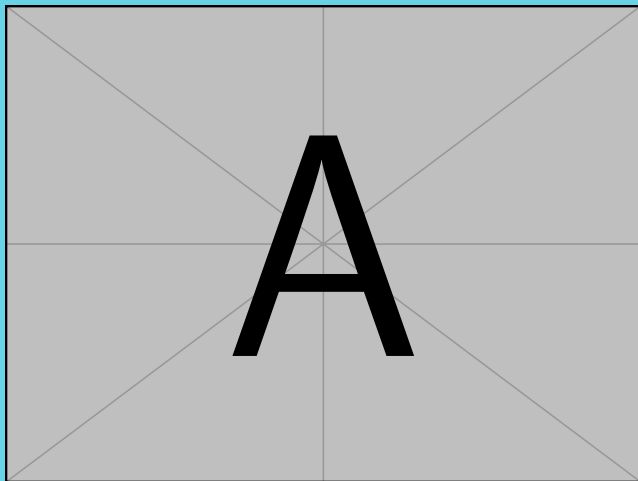
- Arguments
- Quotes
- Shell parameters
- Special variables (e.g. `IFS`)
- Shell expansion
  - Brace expansion
  - Parameters expansion
  - ...
  - Word splitting
  - Filename expansion
- Globbing

# The goal of the day

- Arguments
- Quotes
- Shell parameters
- Special variables (e.g. IFS)
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  - Brace expansion
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# Commands and arguments



The Skaftafell natural park: Approaching the Vatnajökull

# How does Bash interpret a line of code?

Spaces and Tabs

- Bash divides each line into words that are demarcated by a **whitespace character**\*.
- The **first word** of the line is the name of **the command** to be executed.
- All the remaining words become **arguments** to that command (options, filenames, etc.).

```
1 $ command arg1 arg2   arg3       arg4
2 $ command arg1 arg2 arg3 arg4
```

The amount of whitespace between arguments does not matter!

```
1 $ echo I am Clark Kent
2 I am Clark Kent           # <- Same output
3 $ echo I    am  Clark      Kent
4 I am Clark Kent           # <- as here!
```

# The first hurdle: spaces

How can such an innocent, invisible character hurt me? ...well...

- To a shell, whitespace is incredibly important
- Don't be fooled into thinking a space or tab more or less won't make much of a difference
- Whitespace is **vital** to allowing your shell to understand you

```
1 $ ls -l
2 The secret voice.mp3
3 secret
4 $ rm The secret voice.mp3 # rm gets 3 arguments, not 1!
5 rm: cannot remove 'The': No such file or directory
6 rm: cannot remove 'voice.mp3': No such file or directory
7 $ ls
8 The secret voice.mp3      # Where's your file 'secret'!?
```

`ls` and `rm` are commands to list the present working directory content and to remove files, respectively.

We will go more deeply into **Word splitting** later!

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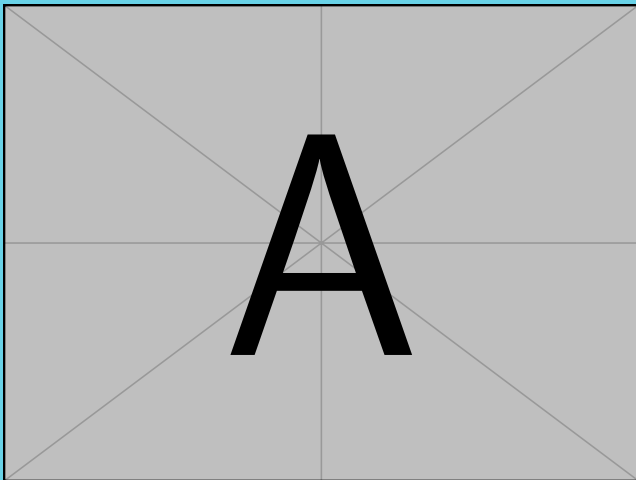
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## Side remark

Whitespaces in filenames should be avoided and replaced by underscores.  
Everything would be much easier. But they are allowed... so deal with it!

# Strings and types of commands



A must in the Golden Circle: Gullfoss



After all it is simple...



# Strings, strings everywhere

The term string refers to a sequence of characters which is treated as a single unit:

- The command's name is a string
- Each argument of a command is a string
- Variable names are strings
- The contents of variables are strings as well
- A filename is a string
- Most files contain strings

Strings do not have any intrinsic meaning

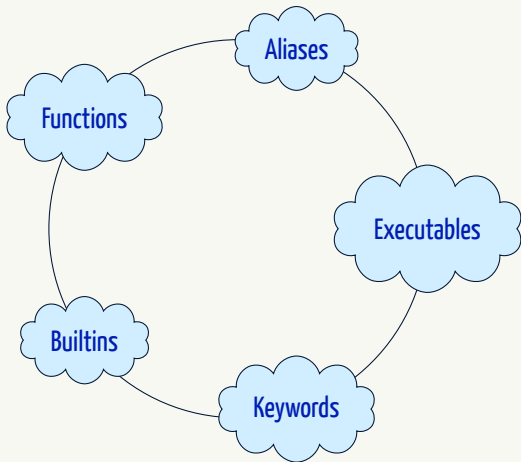
Their meaning is defined by how and where they are used.

We have all the responsibility

We need to be sure everything that needs to be separated is separated properly, and everything that needs to stay together stays together properly!

## Types of commands

There are basically 5 different classes of commands



# Types of commands

## 1 Aliases    2 Functions    3 Builtins    4 Keywords    5 Executables

- An alias is a rudimentary way of shortening a command
- It is a word that is mapped to a certain string
- They are only used in **interactive** shells and **not** in scripts
- They are limited in power; the replacement only happens in the first word
- An alias should effectively not do more than change the default options of a command
- For more complex tasks and more flexibility, use a function

```
1 $ help alias
2 alias: alias [-p] [name[=value] ... ]
3     Define or display aliases.

4 # [More information]

5 $ alias ls='ls --color=auto'
6 $ ls # The command executed is, instead:  ls --color=auto
```

# Types of commands

- 1 Aliases
- 2 Functions
- 3 Builtins
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Functions are tricky!

They will be covered in depth later in the course

For the moment, a few hints:

- Functions in Bash are more powerful than aliases and they are often the way to go
- Unlike aliases, they can be used in scripts, i.e. in non-interactive mode
- A function contains shell commands, and acts very much like a small script
- They can even take arguments and create local variables
- When a function is called, the commands in it are executed

# Types of commands

- 1 Aliases
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- Builtins are basic commands that Bash has built into it
- They can be thought as functions that are already provided
- We will learn about (or at least mention) most of them
- Keywords which are provided as builtins are nevertheless highlighted as keywords

:	complete	export	let	shift	umask
.	compgen	false	local	shopt	unalias
[	continue	fc	logout	source	unset
alias	declare	fg	popd	suspend	until
bg	dirs	getopts	printf	test	wait
bind	disown	hash	pushd	times	while
break	echo	help	pwd	trap	
builtin	enable	history	read	true	
case	eval	if	readonly	type	
cd	exec	jobs	return	typeset	
command	exit	kill	set	ulimit	

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# Types of commands

- 1 Aliases
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Keywords are like builtins, but **special parsing rules apply to them**

- Flow control constructs is achieved thanks to keywords
- We will explore all of them in detail {except `coproc`}

```
if      elif    esac    while    done    time    !      coproc
then    fi      for     until    in      {        [[
else    case    select  do      function }       ]]
```

For example:

```
1 $ [ a < b ] # Oops, < means here input redirection!
2 -bash: b: No such file or directory
3 $ [[ a < b ]] # The meaning of < changes within [[ ]]
```

# Types of commands

- 1 Aliases
- 2 Functions
- 3 Builtins
- 4 Keywords
- 5 Executables

- Executables are the last type of command that Bash can execute
- They are also known as external commands or applications
- They are typically invoked by their name, on the constraint that Bash is able to find them
- When a command is specified without a file path and it is **not an alias, a function, a builtin or a keyword**, Bash searches through the directories contained in the variable `PATH`
- The search is done from left to right and the first executable found is run

```
1 $ ls /home/sciarra/.local/bin
2 ... g++ ... # Version 8.3.0
3 $ ls /usr/bin
4 ... g++ ... # Version 5.4.0
5 $ echo ${PATH}
6 /home/sciarra/.local/bin:/usr/bin:/bin
7 $ g++ -dumpversion
8 8.3.0
```

# Bash scripts

- A script is a sequence of Bash commands in a file
- The commands are read and processed **in order**
- A new command is processed after the previous has **ended** { unless differently required }
- The first line of a script should be reserved for an **interpret directive** also called **hashbang** or **shebang**. This is used when the kernel executes a non-binary file. Use one of the two following alternatives:

```
#!/bin/bash
```

or, preferably,

```
#!/usr/bin/env bash
```

The right directive has the benefit of looking for whatever the default version of the program is in your current **environment** (i.e. in **PATH**).

- Please, **do not use** `#!/bin/sh` as shebang, even if you might see it around on the web!
- Avoid giving your scripts a **.sh** extension. Do not use one or use **.bash**!

**Sh is NOT Bash!**

**Bash** itself is a **sh-compatible** shell however, the opposite is not true!

# Bash scripts

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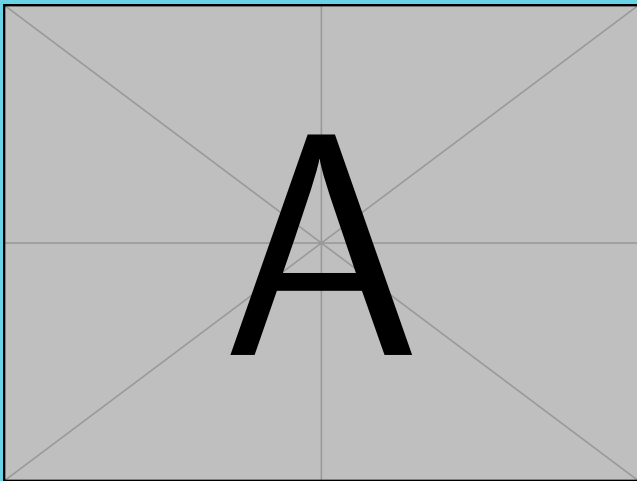
- Execute the script in either of the following ways:

```
1 $ bash myscript    #The shebang is treated as a comment!
```

or

```
1 $ chmod +x myscript # Make the file executable
2 $ ./myscript        # Execute it, the shebang is used!
```

# Quoting and special characters



The Þingvellir national park: Oxararfoss

# Types of quoting

**Single quotes** Everything inside single quotes becomes a literal string

{ The only character that you can't safely enclose in single quotes is a single quote. }

**Double quotes** Performed actions:

- Every substitution that begins with a dollar sign \$
- Backslash escaping
- The legacy ``...`` (backticks) command substitution

**No word splitting or filename expansion is performed!**

**Backticks** ``...`` is the legacy command substitution syntax

**Deprecated in favor of \$ (...)**

**Backslash** Putting `\` in front of a metacharacter removes its special meaning

{ This works inside double quotes, or in the absence of quotes. It does not work inside single quotes. }

**\$ ' ... '** A Bash extension that prevents everything except backslash escaping  
It also allows special backslash escape sequences like `\n` for newline

**\$ " ... "** Bash extension used for  **localisation support** , not covered here

## Examples about quoting

```
1 $ echo I      am  Clark      Kent
  I am Clark Kent
3 $ echo I"      "am"    "Clark"      "Kent      # Not nice
  I      am  Clark      Kent
5 $ echo I\ \ \ \ am\ \ Clark\ \ \ \ \ \ \ Kent # Really!?!
  I      am  Clark      Kent
7 $ echo 'I      am  Clark      Kent'
  I      am  Clark      Kent
9 $ echo "I      am  Clark      Kent"
  I      am  Clark      Kent
```

```
11 $ echo 'PATH contains ${PATH}'
    PATH contains ${PATH}
13 $ echo "PATH contains ${PATH}"
    PATH contains /home/sciarra/.local/bin:/usr/bin:/bin
15 $ echo "PATH contains \${PATH}"
    PATH contains ${PATH}
```

## Examples about quoting

```
17 $ ls *.tex
    Day_1.tex    Day_2.tex    Day_3.tex
19 $ ls '*.tex'
ls: cannot access '*.tex': No such file or directory
21 $ ls "*.tex"
ls: cannot access '*.tex': No such file or directory
23 $ echo "Hello\nWorld"
Hello\nWorld
25 $ echo '$Hello\nWorld'
Hello
27 World
```

I'm Too Lazy to Read, Just Tell Me What to Do

```
$ cp $file $destination          # WRONG
$ cp -- "$file" "$destination"  # Right
```

When in doubt, **double-quote every expansion** in your shell commands.  
Generally use **double quotes** unless it makes more sense to use single quotes.



# Special characters

## Just a brief overview

{a space, tab, newline, carriage return, vertical tab or form feed}

- A **whitespace** is used by Bash to determine where words begin and end  
The first word is the command name and additional words become arguments

\$ It introduces various types of **expansion**:

- parameter expansion    `${var}`
- command substitution    `$(command)`
- arithmetic expansion    `$((expression))`

' '	Single quotes	} Already discussed on slide 14
" "	Double quotes	
\	Escape symbol	

# It introduced a **comment** that extends to the end of the line.  
Text after it is ignored by the shell. { In single and double quotes, # is just a #. }

! The **negate keyword** reverses a test or an exit status

# Special characters

## Just a brief overview

- = The **assignment** symbol is used to assign a value to a variable  
Whitespace is not allowed on either side of the = character
- [ [ ] ] This **testing keyword** allows to evaluate a conditional expression to determine whether it is “true” or “false”
- > >> < **Redirection** of a command's output or input to a file
  - | The **pipeline** sends the output from one command to the input of another command
  - ;  
**Command separator** of multiple commands that are on the same line
  - { } An **inline group** allows to treat multiple commands as if they were one command  
Convenient to be uses when Bash syntax requires only one command
  - ( ) Another way to group commands, but in a **subshell group**  
However, commands in ( ) are executed in a subshell (a new process) and this is often the way to avoid side effects on the current shell

# Special characters

## Just a brief overview

the 4 characters

+ - \* /

**(( ))** Within an **arithmetic expression**, mathematical operators are used for calculations

They can be used for

- variable assignments `(( a = 1 + 4 ))`
- tests evaluation `(( a < b ))`

**\$( ( ))** Comparable to `(( ))`, but the expression is replaced with the result of its evaluation

**\* ?** **Globbering** characters are wildcards which match parts of filenames

**~** The tilde is a representation of a **home directory**

When alone or followed by a `/`, it means the current user's home directory

Otherwise, a username must be specified: `ls ~john/`

**&** When used at the end of a command, run the command in the **background**

The shell does not wait for it to complete

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**&** When used at the end of a command, run the command in the **background**

The shell does not wait for it to complete

More details later

We will come back to these special instructions with details and examples

# Deprecated special character

``` Command substitution - **use `$ ( )` instead**   Advanced reading

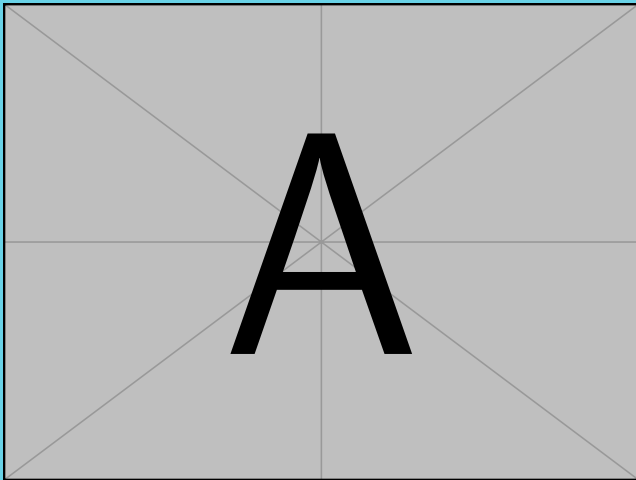
`[ ]` An alias for the old `test` command  
Commonly used in POSIX shell scripts  
**Lacks many features of `[ [ ]`**   Advanced reading

`$ [ ]` Arithmetic expression - **use `$ ( ( ) )` instead**  
Simply do not use it, it dates back to 1990s!!!

## Legacy code and portability

Unless you have very special requirement, try to stick to modern Bash features!

# Variables and special parameters

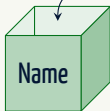


Seljalandsfoss: A 360° cascade

# The first building block

Parameters come in two flavours:

- **Variables (i.e. parameters with a name)**
  - Created and updated by the user
  - Available in the environment
- **Special parameters (later)**
  - Read-only and pre-set by Bash



Content:

- ★ strings
- ★ integers
- ★ indexed arrays
- ★ associative arrays
- ★ references

The variable name (also referred to as an **identifier**)

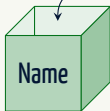
A word consisting only of

- letters, digits and underscores
- and beginning with a letter or an underscore

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## Assignment

```
$ variableName=variableContent
```

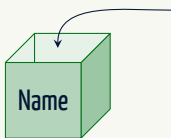
- If not existing, the **global** variable `variableName` is created, and the content `variableContent` is put into it
- If existing, the content of `variableName` is set to `variableContent`
- If `variableName` exists and it is read-only, an error occurs



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## Accessing the content: the **parameter expansion**

Use the `$` special character to tell Bash that you want to use the content of a variable

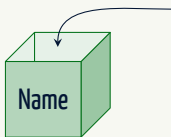
```
$ prefix='Day_'  
$ day='Monday'  
$ echo "$prefix1.pdf are the slides for ${day}"  
.pdf are the slides for Monday  
$ echo "${prefix}1.pdf are the slides for ${day}"  
Day_1.pdf are the slides for Monday
```

**Always** using curly braces `${...}` can be considered **good programming practice!**

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## Expanding undeclared variable

Variables in Bash do not have to be declared, as they do in languages like C!  
If you try to read an undeclared variable, the result is the empty string.

```
$ invisibleVariable='Hello'
$ echo _${invisibleVariable}_
-- # Is this magic?! Well, no...
```

**By default, you get no warnings or errors!**

## Variables types

Bash is not a typed language

It does have a few different types of variables, though!  
It is more about activate particular rules when acting on variables.

**Array:** `declare -a variableName`

The variable is an array of strings

**Associative array:** `declare -A variableName`

The variable is an associative array of strings (v4.0 or higher)

**Integer:** `declare -i variableName`

The variable holds an integer

Assigning values to this variable automatically triggers Arithmetic Evaluation

**Read only:** `declare -r variableName`

The variable can no longer be modified or unset

**Export:** `declare -x variableName`

The variable is marked for export, i.e. it will be inherited by any child process

# Variables types

```
1 $ aVar=5; aVar+=2; echo "${aVar}"; unset aVar
52
3 $ aVar=5; let aVar+=2; echo "${aVar}"; unset aVar
7
5 $ declare -i aVar=5; aVar+=2; echo "${aVar}"; unset aVar
7
7 $ aVar=5+2; echo "${aVar}"; unset aVar
5+2
9 $ declare -i aVar=5+2; echo "${aVar}"; unset aVar
7
11 $ declare -i aVar=5; aVar+=aVar; echo "${aVar}"; unset aVar
10
13 $ declare -i aVar=5; aVar+='foo'; echo "${aVar}"; unset aVar
5
15 # "foo" refers to the variable foo in arithmetic evaluation
```

The use of integer variables is exceedingly rare!

Most experienced shell programmers prefer to use explicit arithmetic commands (with `((...))` or `let`) when they want to perform arithmetic!

# Crucial to know (I)

...and not to forget!

```
# This is WRONG
$ variableName_=_variableContent    # spaces around = sign!
bash: variableName: command not found
```

- 1 Bash will not know that you are attempting to assign something
- 2 The parser will see `variableName` with no `=` and treat it as a command name
- 3 `=` and `variableContent` are then passed to it as arguments

If you think about it for a moment, it makes sense!

## Crucial to know (II)

...and not to forget!

### Attention!

After parameter expansion, Bash may still perform additional manipulations on the result!

```
1 $ today=Monday
2 $ echo "Today is ${today}"
3 Today is Monday
4 # Bash takes the content of the variable today
5 # and replaces ${today} by Monday. It seems equivalent to:
6 $ echo Today is Monday
7 Today is Monday
```

Everything seems to work as expected... but:

## Crucial to know (II)

...and not to forget!

### Attention!

After parameter expansion, Bash may still perform additional manipulations on the result!

```
1 $ today=Monday
2 $ echo "Today is ${today}"
3 Today is Monday
4 # Bash takes the content of the variable today
5 # and replaces ${today} by Monday. It seems equivalent to:
6 $ echo Today is Monday
7 Today is Monday
```

Everything seems to work as expected... but:

```
1 #This is probably not what you would like to do
2 $ song="My song.mp3"
3 $ rm ${song}
4 rm: My: No such file or directory
5 rm: song.mp3: No such file or directory
```

## Crucial to know (II)

...and not to forget!

### Attention!

After parameter expansion, Bash may still perform additional manipulations on the result!

Why did it not work?

```
1 #This is probably not what you would like to do
2 $ song="My song.mp3"
3 $ rm ${song}
4 rm: My: No such file or directory
5 rm: song.mp3: No such file or directory
```



## Crucial to know (II)

...and not to forget!

### Attention!

After parameter expansion, Bash may still perform additional manipulations on the result!

Why did it not work?

- 1 Bash replaced `${song}` by its content
- 2 Word splitting occurred before the command was executed!
- 3 `rm` was run with 2 arguments (there is white space between them and it is not quoted!)

```
$ rm My song.mp3
```

```
1 #This is probably not what you would like to do
2 $ song="My song.mp3"
3 $ rm ${song}
4 rm: My: No such file or directory
5 rm: song.mp3: No such file or directory
```

## Crucial to know (II)

...and not to forget!

### Attention!

After parameter expansion, Bash may still perform additional manipulations on the result!

```
1 # Please, do not try to put quotes in variables!
2 $ song="\My song.mp3\"
3 $ rm ${song}
4 rm: "My: No such file or directory
5 rm: song.mp3": No such file or directory
6 # Here the quotes contained in the variable song
7 # are literal characters and they are not interpreted
8 # as quotes when the rm command is run!!
```

How do we fix this?

## Crucial to know (II)

...and not to forget!

### Attention!

After parameter expansion, Bash may still perform additional manipulations on the result!

```
1 # Please, do not try to put quotes in variables!
2 $ song="\My song.mp3\"
3 $ rm ${song}
4 rm: "My: No such file or directory
5 rm: song.mp3": No such file or directory
6 # Here the quotes contained in the variable song
7 # are literal characters and they are not interpreted
8 # as quotes when the rm command is run!!

9 # CORRECT WAY TO DO IT:
10 $ rm "${song}"
```

### How do we fix this?

Remember to put double quotes around every parameter expansion!

# Available variables

## Bash manual v5.2 section 5

```
# Bourne Shell Variables (For some, Bash sets a default)
CDPATH  HOME  IFS  MAIL  MAILPATH  OPTARG  OPTIND  PATH  PS1  PS2

# Bash Variables (i.e. variables that are set or used by Bash)
BASH          COMP_POINT      HISTFILESIZE    OSTYPE
BASHOPTS      COMP_TYPE      HISTIGNORE      PIPESTATUS
BASHPID       COMP_KEY       HISTSIZE        POSIXLY_CORRECT
BASH_ALIASES  COMP_WORDBREAKS HISTTIMEFORMAT  PPID
BASH_ARGC     COMP_WORDS     HOSTFILE        PROMPT_COMMAND
BASH_ARGV     COMPREPLY      HOSTNAME        PROMPT_DIRTRIM
BASH_ARGVO    COPROC         HOSTTYPE        PS0
BASH_CMDS     DIRSTACK       IGNOREEOF       PS3
BASH_COMMAND  EMACS          INPUTRC         PS4
BASH_COMPAT   ENV            INSIDE_EMACS    PWD
BASH_ENV      EPOCHREALTIME LANG             RANDOM
BASH_EXECUTION_STRING EPOCHSECONDS LC_ALL          READLINE_LINE
BASH_LINENO   EUID           LC_COLLATE      READLINE_POINT
BASH_LOADABLES_PATH EXECIGNORE     LC_CTYPE        REPLY
BASH_REMATCH  FCEDIT         LC_MESSAGES     SECONDS
BASH_SOURCE   FIGNORE        LC_NUMERIC      SHELL
BASH_SUBSHELL FUNCNAME       LC_TIME         SHELLOPTS
BASH_VERSION  FUNCNEST       LINENO          SHLVL
BASH_VERSION  GLOBIGNORE     LINES           TIMEFORMAT
BASH_XTRACEFD GROUPS         MACH_TYPE       TMOUT
CHILD_MAX     histchars      MAILCHECK       TMPDIR
COLUMNS      HISTCMD        MAPFILE         UID
COMP_CWORD    HISTCONTROL    OLDPWD          # And few more
COMP_LINE     HISTFILE       OPTERR
```

# The Internal Field Separator

A very important Bash special variable { More on it later when we discuss word splitting in detail }

- By default, `IFS` is unset and acts as if it were set to `<space><tab><newline>`

```
#The following two lines have the same effect
$ IFS=$' \t\n'
$ unset IFS
```

- It is used to determine what characters to use as word splitting delimiters
- Therefore, you can use any of these forms of white space to delimit words
- The `IFS` variable comes into play also in special parameter `$*` expansion!

## Attention

It is crucial to understand the role of the `IFS` variable!

# The Internal Field Separator

A very important Bash special variable { More on it later when we discuss word splitting in detail }

- By default, `IFS` is unset and acts as if it were set to `<space><tab><newline>`

```
#The following two lines have the same effect
$ IFS=$' \t\n'
$ unset IFS
```

- It is used to determine what characters to use as word splitting delimiters
- Therefore, you can use any of these forms of white space to delimit words
- The `IFS` variable comes into play also in special parameter `$*` expansion!

## When and why not to use a custom IFS

It is important that you understand the danger of changing the way the shell behaves. If you modify `IFS`, word splitting will happen in a non-default manner henceforth. Some will recommend you save `IFS` and reset it to the default later on. Others will recommend to unset `IFS` after you're done with your custom word splitting. Personally, I prefer to recommend you **to NOT modify `IFS` on the script level. Ever!**

Greg's wiki

# The Special Parameters

 Bash manual v5.0 section 3.4.2

- 0 Contains the name, or the path, of the script. Do not rely on it or read the manual carefully!
- 1 2 ... **Positional Parameters** contain the arguments passed to the current script or function
  - \* Expands each positional parameter to a separate word  
Double quoted, "\$\*", expands to "\$1c\$2c...c\$N"  
where c is the first character of the IFS variable
  - @ Expands each positional parameter to a separate word  
Double quoted, "\$@", expands to "\$1" "\$2" ... "\$N"
  - # Expands to the number of positional parameters that are currently set
    - Expands to the current shell option flags
  - ? Expands to the exit code of the most recently completed foreground command
  - \$ Expands to the PID (process ID number) of the current shell
  - ! Expands to the PID of the command most recently executed in the background
  - \_ Expands to the last argument of the last command that was executed

# The Special Parameters

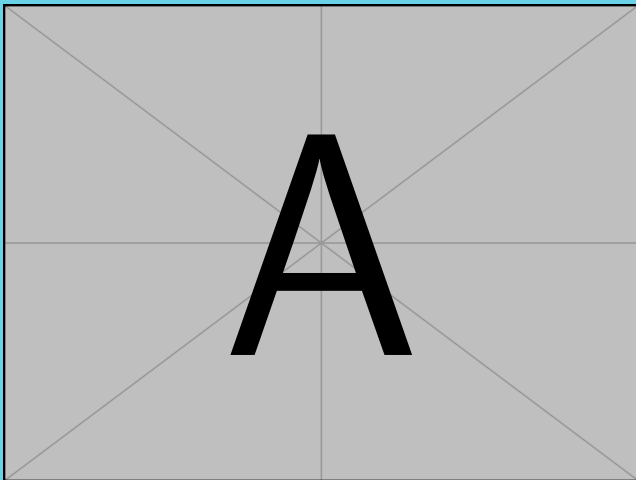
 Bash manual v5.0 section 3.4.2

- 0 Contains the name, or the path, of the script. Do not rely on it or read the manual carefully!
- 1 2 ... **Positional Parameters** contain the arguments passed to the current script or function
  - \* Expands each positional parameter to a separate word  
Double quoted, "\$\*", expands to "\$1c\$2c...c\$N"  
where c is the first character of the IFS variable
  - @ Expands each positional parameter to a separate word  
Double quoted, "\$@", expands to "\$1" "\$2" ... "\$N"
  - # Expands to the number of positional parameters that are currently set
  - Expands to the current shell option flags
  - ? Expands to the exit code of the most recently completed foreground command
  - \$ Expands to the PID (process ID number) of the current shell
  - ! Expands to the PID of the command most recently executed in the background
  - \_ Expands to the last argument of the last command that was executed

Exercise  
Sheet 1



# Shell expansion



Danger: Sneaker waves!

# Several kind of expansions


 Bash manual v5.2 section 3.5

A line is split into tokens using unquoted metacharacters:

`□ \t \n | & ; ( ) < >`



Expansion is performed on the command line after it has been split into tokens:

- Brace expansion  **1**
  - Parameter and variable expansion
  - Tilde expansion
  - Arithmetic expansion
  - Process substitution { Done only from v5.1 when  Bash in POSIX Mode (item 30) }
  - Command substitution
  - Word splitting  **3**
  - Filename expansion  **4**
- 2** **At the same time!**

## Quote removal

After the preceding expansions, all unquoted occurrences of the characters `\`, `'`, and `"` that did not result from one of the above expansions are removed.

## Brace expansion

- It comes in two forms:
  - 1 `[prefix]{comma separated list}[postfix]`
  - 2 `[prefix]{X..Y[..increment]}[postfix]`
- `[prefix]` and `[postfix]` are optional and might contain other brace expansions
- Brace expansions can be nested and, if so, they work from the outside in
- X and Y are either characters or numbers
- `increment` is an optional integer (if omitted, it is +1 or -1 as appropriate)
- If X and Y are numbers, leading 0 are respected to force each term to have the same width
- If the brace expansion syntax is not respected, then brace expansion is not performed!

### Result of the expansion

A space separated list of all combinations of `[prefix]` and `[postfix]` with the elements in the brace. In **2**, the sequence in braces is at first completed going back to **1**. Order is respected left to right. Multiple non-nested braces expand to all combinations.

## Brace expansion

- It comes in two forms:

- 1 [prefix]{comma separated list}[postfix]
- 2 [prefix]{X..Y[..increment]}[postfix]

```
1 $ echo {a,b,c}
a b c
3 $ echo {a,b,c}.tex
a.tex b.tex c.tex
5 $ echo image.{jpg,png,pdf}
image.jpg image.png image.pdf
7 $ echo {1..8}
1 2 3 4 5 6 7 8
9 $ echo {8..1}
8 7 6 5 4 3 2 1
11 $ echo {1..8..3}
1 4 7
13 $ echo {a..e}
a b c d e
15 $ echo {e..a..2}
e c a
17 $ echo file_{01..3}.pdf
file_01.pdf file_02.pdf file_03.pdf #Note leading zeros!
```

## Brace expansion

- It comes in two forms:

- 1 [prefix]{comma separated list}[postfix]
- 2 [prefix]{X..Y[..increment]}[postfix]

```
19 $ echo {A..C}{0..2}
   AO A1 A2 B0 B1 B2 C0 C1 C2
21 $ echo {A..C}_ {0..2} # Here two independent expansions!
   A B C 0 1 2
23 $ echo {in,out}{go,com}ing
   ingoing incoming outgoing outcoming
25 $ echo ${A,E,I,O,U},{0..9}
   A E I O U 0 1 2 3 4 5 6 7 8 9
27 $ echo {a..z..x}
   {a..z..x} # No brace expansion!
29 $ aVar=1; echo {$aVar..5}; unset aVar
   {1..5} # No brace expansion!
31 $ echo {b,1..5}
   b 1..5 # Not surprising, right?
33 $ echo {b,{1..5}}
   b 1 2 3 4 5
35 $ echo {b,{1..5}} # Which of the last braces is kept?
   b} 1} 2} 3} 4} 5}
```

# Parameter expansion: Overview

- It is the most used form of expansion!
- Its basic syntax consists of a single dollar sign alone
- Braces after the dollar are only sometimes necessary  
→ it is good practice to always use them: `${...}`
- Basic form: `${parameter}` → The value of parameter is substituted
- There are plenty of incredibly powerful modified forms of parameter expansion  
→ you will learn them by using, but **keep in mind they exist!**
- General form: `${ [prefix] parameter [postfix] }`
- Not all (particular) cases are discussed here immediately
- More on parameter expansion in the future
  - namerefs and indirect expansion
  - arrays and associative arrays

# Parameter expansion: Checking variables state

In each of the cases below, word is subject to tilde expansion, parameter expansion, command substitution, and arithmetic expansion!

`${parameter:-word}`

Use Default Value

Parameter unset or null: **expansion of word is substituted**

Otherwise: the value of parameter is substituted

`${parameter:=word}`

Assign Default Value

Parameter unset or null: **expansion of word is assigned to parameter**

Otherwise: the value of parameter remains unchanged

The value of parameter is then substituted

{ Positional parameters and special parameters may not be assigned to in this way }

`${parameter:?word}`

Exit with message

Parameter is null or unset: **the expansion of word to the standard error**

The shell, then, if it is not interactive, exits

Otherwise, the value of parameter is substituted

{ If word is not present, a default message is produced }

`${parameter:+word}`

Use Alternative value

Parameter is null or unset: **nothing is substituted**

Otherwise, the expansion of word is substituted

## A different variant

Omitting the colon results in a test only for a parameter that is unset.

Put another way, if the colon is omitted, the operator tests only for existence.

# Parameter expansion: Checking variables state

```
1  $ aVar="Hello"
   # The variable aVar is set and not empty/null
3  $ echo "${aVar}_"
   _Hello_
5  $ echo "${aVar-Goodbye}_" "${aVar:-Goodbye}_" # Use default Value
   _Hello_ _Hello_
7  $ echo "${aVar=Goodbye}_" "${aVar:=Goodbye}_" # Assign default Value
   _Hello_ _Hello_
9  $ echo "${aVar?Goodbye}_" "${aVar:?Goodbye}_" # Exit with message
   _Hello_ _Hello_
11 $ echo "${aVar+Goodbye}_" "${aVar:+Goodbye}_" # Use alternative value
   _Goodbye_ _Goodbye_
13 $ aVar=""
   # The variable aVar is now set BUT empty/null
15 $ echo "${aVar}_"
   --
17 $ echo "${aVar-Goodbye}_" "${aVar:-Goodbye}_"
   -- _Goodbye_
19 $ echo "${aVar=Goodbye}_" "${aVar:=Goodbye}_" ; aVar=""
   -- _Goodbye_
21 $ echo "${aVar?Goodbye}_" "${aVar:?Goodbye}_"
   bash: aVar: Goodbye # Shell STOPS at second expansion and prints message!
23 $ echo "${aVar?Goodbye}_"
   --
25 $ echo "${aVar+Goodbye}_" "${aVar:+Goodbye}_"
   _Goodbye_ --
```



## Parameter expansion: Checking variables state

```
27 $ unset aVar
   # The variable aVar is now UNSET
29 $ echo "${aVar}_"
--
31 $ echo "${aVar-Goodbye}_   ${aVar:-Goodbye}_"
   _Goodbye_   _Goodbye_
33 $ echo "${aVar=Goodbye}_"; unset aVar
   _Goodbye_
35 $ echo "${aVar:=Goodbye}_"; unset aVar
   _Goodbye_
37 $ echo "${aVar?Goodbye}_"
bash: aVar: Goodbye # Shell STOPS at expansion and prints message!
39 $ echo "${aVar:?Goodbye}_"
bash: aVar: Goodbye # Shell STOPS at expansion and prints message!
41 $ echo "${aVar+Goodbye}_   ${aVar:+Goodbye}_"
--  --
```

Ok, but is all this useful? When?

Ohhh yes! These kinds of expansion are useful e.g. when it comes to checking whether a variable is set, unset or set but empty. Sometimes there are alternatives, but sometimes you need exactly this!

# Parameter expansion: String manipulation (I)

**String Length:** `${#parameter}`

The length in characters of the value of `parameter` is substituted

**Substring Expansion:** `${parameter:offset:length}`

Expands to up to `length` characters of `parameter` starting at the character specified by `offset` (0-indexed)

If `:length` is omitted, go all the way to the end

{ If `offset` is negative, count backward from the end of `parameter` instead of forward from the beginning }

# Parameter expansion: String manipulation (I)

**String Length:** `${#parameter}`

The length in characters of the value of parameter is substituted

**Substring Expansion:** `${parameter:offset:length}`

Expands to up to length characters of parameter starting at the character specified by offset (0-indexed)

If :length is omitted, go all the way to the end

{ If offset is negative, count backward from the end of parameter instead of forward from the beginning }

```
1 $ aVar='01234567890abcdefgh'
# Let us demonstrate a bit
3 $ echo "String ${aVar} is ${#aVar} characters long"
String 01234567890abcdefgh is 19 characters long
5 $ echo "${aVar:7} and 0 length: \"${aVar:7:0}\""
7890abcdefgh and 0 length: ""
7 $ echo "${aVar:7:2} and ${aVar:7:-2}"
78 and 7890abcdef
9 $ echo "${aVar:␣-7}" # Why do you need a space?
bcdefgh
11 $ echo "${aVar: -7:2} and ${aVar: -7:0} and ${aVar: -7:-2}"
bc and and bcdef
```

## Parameter expansion: String manipulation (II)

**Remove Smallest Prefix:** `${parameter#pattern}`

The `pattern` is matched against the **beginning** of `parameter` which is expanded with the **shortest** match deleted

**Remove Largest Prefix:** `${parameter##pattern}` As the previous, but the **longest** match is deleted

**Remove Smallest Suffix:** `${parameter%pattern}`

The `pattern` is matched against the **end** of `parameter` which is expanded with the **shortest** match deleted

**Remove Largest Suffix:** `${parameter%%pattern}` As the previous, but the **longest** match is deleted

## Parameter expansion: String manipulation (II)

**Remove Smallest Prefix:** `${parameter#pattern}`

The pattern is matched against the **beginning** of parameter which is expanded with the **shortest** match deleted

**Remove Largest Prefix:** `${parameter##pattern}` As the previous, but the **longest** match is deleted

**Remove Smallest Suffix:** `${parameter%pattern}`

The pattern is matched against the **end** of parameter which is expanded with the **shortest** match deleted

**Remove Largest Suffix:** `${parameter%%pattern}` As the previous, but the **longest** match is deleted

```
1 $ aVar='b1.2345_s0000_s1111'
  # Let us demonstrate a bit (* matches any characters)
3 $ echo "${aVar#*_} and ${aVar##*_}"
  s0000_s1111 and s1111
5 $ echo "${aVar%_*} and ${aVar%%_*}"
  b1.2345_s0000 and b1.2345
7 $ echo "${aVar#NoMatch} and ${aVar%NoMatch}"
  b1.2345_s0000_s1111 and b1.2345_s0000_s1111
```

## Parameter expansion: String manipulation (III)

**Replace first:** `${parameter/pattern/string}`

Results in the expanded value of `parameter` with the first (unanchored) match of `pattern` replaced by `string`

{ Assume null string when the `/string` part is absent }

**Replace all:** `${parameter//pattern/string}`

As the previous, but **every** match is replaced

**Replace at start:** `${parameter/#pattern/string}`

As the first, but matched against the **beginning**

**Replace at end:** `${parameter/%pattern/string}`

As the first, but matched against the **end**

## Parameter expansion: String manipulation (III)

**Replace first:** `${parameter/pattern/string}`

Results in the expanded value of `parameter` with the first (unanchored) match of `pattern` replaced by `string`

{ Assume null string when the `/string` part is absent }

**Replace all:** `${parameter//pattern/string}`

As the previous, but **every** match is replaced

**Replace at start:** `${parameter/#pattern/string}`

As the first, but matched against the **beginning**

**Replace at end:** `${parameter/%pattern/string}`

As the first, but matched against the **end**

```
1 $ aVar='123aa000aa321'
   # Let us demonstrate a bit
3 $ echo "${aVar/aa/_}" and "${aVar//aa/_}"
   123_000aa321 and 123_000_321
5 $ echo "${aVar/#1/_}" and "${aVar/%1/_}"
   _23aa000aa321 and 123aa000aa32_
7 $ echo "${aVar/#/prefix}" and "${aVar/%/postfix}"
   prefix123aa000aa321 and 123aa000aa321postfix
```

## Parameter expansion: String manipulation (IV)

Since Bash v4.0 (2009)

**First uppercase:** `${parameter^pattern}`

Results in the expanded value of `parameter` with the first character capitalised

**All uppercase:** `${parameter^^pattern}`

As the previous, but all characters are capitalised

**First lowercase:** `${parameter,pattern}`

Results in the expanded value of `parameter` with the first character to lowercase

**All lowercase:** `${parameter,,pattern}`

As the previous, but all characters are transformed to lowercase

### Pattern matching

The pattern is expanded to produce a pattern just as in filename expansion. Each character in the expanded value of `parameter` is tested against `pattern`, and, if it matches the pattern, its case is converted. **The pattern should not attempt to match more than one character.**

If `pattern` is omitted, it is treated like a `?`, which matches every character.



## Parameter expansion: String manipulation (IV)

Since Bash v4.0 (2009)

**First uppercase:** `${parameter^pattern}`

Results in the expanded value of `parameter` with the first character capitalised

**All uppercase:** `${parameter^^pattern}`

As the previous, but all characters are capitalised

**First lowercase:** `${parameter,pattern}`

Results in the expanded value of `parameter` with the first character to lowercase

**All lowercase:** `${parameter,,pattern}`

As the previous, but all characters are transformed to lowercase

```
1 $ aVar='hELLO, World!'
   # Let us demonstrate a bit
3 $ echo "${aVar^} - ${aVar^^}"
   HELLO, World! - HELLO, WORLD!
5 $ echo "${aVar,} - ${aVar,,} - ${aVar,,[LW]}"
   hELLO, World! - hello, world! - hEllo, world!
```

# Parameter expansion: String manipulation (V) and reflection (I)

Since Bash v4.4 (2016)

**Syntax:** `${parameter@operator}`

The expansion is either a transformation of the value of `parameter` or information about `parameter` itself, depending on the value of `operator`.

## Each operator is a single letter:

- a** The expansion is a string consisting of flag values representing `parameter`'s attributes.
- A** The expansion is a string in the form of an assignment statement or `declare` command that, if evaluated, will recreate `parameter` with its attributes and value.
- E** The expansion is a string that is the value of `parameter` with backslash escape sequences expanded as with the `$'...'` quoting mechanism.
- P** The result of expanding the value of `parameter` as if it were a prompt string.
- Q** The value of `parameter` quoted in a format that can be reused as input.

# Parameter expansion: String manipulation (V) and reflection (I)

Since Bash v4.4 (2016)

**Syntax:** `${parameter@operator}`

The expansion is either a transformation of the value of `parameter` or information about `parameter` itself, depending on the value of `operator`.

```
1 $ declare -i aVar=5
   # Retrieve information about the variable
3 $ echo "${aVar@a}"
   i
5 $ echo "${aVar@A}"; unset aVar
   declare -i aVar='5'
7 $ aVar='Hello\tworld!'; echo "${aVar@E}"
   Hello    world!
9 $ aVar='\d \t'; echo "${aVar@P}"
   Wed Sep 13 16:04:11
11 $ echo "${IFS@Q}"
   $' \t\n'
```

## Parameter expansion: String manipulation (VI) and reflection (II)

Since Bash v5.1 (2020)

### Further operators introduced more recently:

- U** The expansion is a string that is the value of `parameter` with lowercase alphabetic characters converted to uppercase.
- u** The expansion is a string that is the value of `parameter` with the first character converted to uppercase, if it is alphabetic.
- L** The expansion is a string that is the value of `parameter` with uppercase alphabetic characters converted to lowercase.
- K** Produces a possibly-quoted version of the value of `parameter`, except that it prints the values of indexed and associative arrays as a sequence of quoted key-value pairs
- k** Like the `K` transformation, but expands the keys and values of indexed and associative arrays to separate words after word splitting. { Since Bash v5.2 }

We will see examples of `@k` and `@K` expansions when discussing arrays

## Parameter expansion: String manipulation (VI) and reflection (II)

Since Bash v5.1 (2020)

### Further operators introduced more recently:

- U** The expansion is a string that is the value of `parameter` with lowercase alphabetic characters converted to uppercase.
- u** The expansion is a string that is the value of `parameter` with the first character converted to uppercase, if it is alphabetic.
- L** The expansion is a string that is the value of `parameter` with uppercase alphabetic characters converted to lowercase.

```
1 $ aVar="hello WoRLd!"  
  # Let us demonstrate  
3 $ echo "${aVar@U}"      # Equivalent to ${aVar^^}  
  HELLO WORLD!  
5 $ echo "${aVar@u}"      # Equivalent to ${aVar^}  
  Hello WoRLd!  
7 $ echo "${aVar@L}"      # Equivalent to ${aVar,,}  
  hello world!
```

## Parameter expansion: Summary

### Good practice:

You may be tempted to use external applications such as `sed`, `awk`, `cut`, `perl` or others to modify your strings. Be aware that all of these require an extra process to be started, which in some cases can cause slowdowns.

**Parameter Expansions are the perfect alternative!**



# Tilde expansion in its basic version

- 1 If a word begins with an unquoted tilde character ~
    - ⇒ all of the characters up to the first unquoted slash are considered a **tilde-prefix**.  
{ all characters are considered, if there is no unquoted slash }
  - 2 If none of the characters in the tilde-prefix are quoted
    - ⇒ the characters in the tilde-prefix following the tilde are treated as a possible **login name**.
  - 3 If this login name is the null string
    - ⇒ the tilde is replaced with the value of the **HOME** shell variable,  
or with the home directory of the user executing the shell, if **HOME** is unset.
- Otherwise
- ⇒ the **tilde-prefix** is replaced with the home directory associated with the specified **login name**.
- 4 If the login name is invalid the word is left unchanged.

# Tilde expansion in its basic version

## 1 If a word begins with an unquoted tilde character ~

⇒ all of the characters up to the first unquoted slash are considered a **tilde-prefix**.

{ all characters are considered, if there is no unquoted slash }

## 2 If none of the characters in the tilde-prefix are quoted

⇒ the characters in the tilde-prefix following the tilde are treated as a possible **login name**.

## 3 If this login name is the null string

⇒ the tilde is replaced with the value of the `HOME` shell variable,  
or with the home directory of the user executing the shell, if `HOME` is unset.

Otherwise

⇒ the **tilde-prefix** is replaced with the home directory associated with the specified **login name**.

## 4 If the login name is invalid the word is left unchanged.

```
1 $ echo ~ ~palao
/home/sciarra /home/palao
3 $ echo ~"sciarra" ~sciar"ra" ~sciarra""
~sciarra ~sciarra ~sciarra
5 $ echo ~NotExistentUser # Invalid login name
~NotExistentUser
```

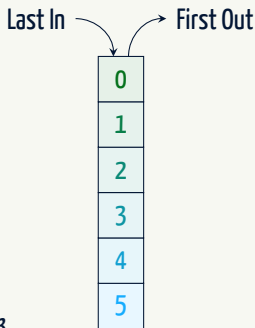


# The Directory Stack

 Bash manual v5.2 section 6.8

## Intuitive definition of stack

An abstract data type or data structure based on the principle of last in first out.



- The directory stack is a list of recently-visited directories
- The `dirs` builtin **displays** the contents of the directory stack
- The current directory is always the “top” of the directory stack
- The `pushd` builtin **adds** directories to the stack as it changes the current directory
- The `popd` builtin **removes** specified directories from the stack and changes the current directory to the new top directory
- Both `pushd` and `popd` accept a `-n` option to avoid changing directory

## The Directory Stack: An example usage

```
1 $ cd ~; pwd; dirs -v
2 /home/sciarra
3 0 ~
4 $ cd ~/Documents/Seminars/BashCourse_2020; dirs -v
5 0 ~/Documents/Seminars/BashCourse_2020
6 $ pushd /myBackupDisk/University/Seminars/BashCourse_2020
7 # Stack automatically displayed on one line
8 $ dirs -v
9 0 /myBackupDisk/University/Seminars/BashCourse_2020
10 1 ~/Documents/Seminars/BashCourse_2020
11 $ pushd ~; pwd
12 # Stack automatically displayed on one line
13 /home/sciarra
14 $ dirs -v
15 0 ~
16 1 /myBackupDisk/University/Seminars/BashCourse_2020
17 2 ~/Documents/Seminars/BashCourse_2020
18 $ cd Documents; dirs -v
19 0 ~/Documents
20 1 /myBackupDisk/University/Seminars/BashCourse_2020
21 2 ~/Documents/Seminars/BashCourse_2020
22 $ popd; pwd # Stack automatically displayed on one line
23 /myBackupDisk/University/Seminars/BashCourse_2020
```

## Tilde expansion and its advanced usage

If the tilde-prefix matches the following forms, a special expansion is done:

- `~+` `${PWD}` is substituted.
- `~-` The value of the shell variable `OLDPWD`, if it is set, is substituted.  
→ `${OLDPWD- '~-'}`
- `~N` The string that would be displayed by `dirs +N` is substituted.
- `~+N` The string that would be displayed by `dirs +N` is substituted.
- `~-N` The string that would be displayed by `dirs -N` is substituted.

If the tilde expansion fails, the word is left unchanged!

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- `~-` The value of the shell variable `OLDPWD`, if it is set, is substituted.  
→ `${OLDPWD- '~- '}`
- `~N` The string that would be displayed by `dirs +N` is substituted.
- `~+N` The string that would be displayed by `dirs +N` is substituted.
- `~-N` The string that would be displayed by `dirs -N` is substituted.

If the tilde expansion fails, the word is left unchanged!


You can then take advantage of the Directory Stack!

## Tilde expansion and its advanced usage

```
1 $ dirs -v
2 0 ~
3 1 /scratch/latticeqcd/sciarra
4 2 /home/latticeqcd/public
5 3 /arc01/archive/latticeqcd/sciarra
6 4 /arc02/archive/latticeqcd/sciarra
7 $ cd ~2; pwd
8 /home/latticeqcd/public
9 $ cd ~-0; pwd; cd ~4; pwd
10 /arc02/archive/latticeqcd/sciarra
11 /arc02/archive/latticeqcd/sciarra
12 # Of course you can use them for any operation, e.g.
13 $ cp -r ~3/Results ~4/Results_backup
14 $ ls ~5
15 ls: cannot access ~5: No such file or directory
```

You can then take advantage of the Directory Stack!

## Arithmetic expansion

- Arithmetic expansion syntax is `$ ( ... )` and it can be nested
- **Bash is only capable of integer arithmetic**
- If you need to do a lot of non-integer arithmetic, then Bash is the wrong tool!
- Shell variables are allowed as operands
  - parameter expansion is performed before the expression is evaluated!
- Within an expression, shell variables may also be referenced by name without `${...}`
  - ⇒ strings are recursively interpreted as variable name until an integer value is found!
- A shell variable that is null or unset evaluates to
  - 0 when referenced by name **without using** the parameter expansion syntax
  - '' when referenced by name **using** the parameter expansion syntax
- Overflow is not checked but division by 0 gives an error
- Operators and their precedence are the same as in the C language
  -  Bash manual v5.2 section 6.5

# Arithmetic expansion

```
1 $ echo $(( 22 / 3 ))
7
3 $ aVar=22; echo $(( ${aVar} / 3 )); unset aVar
7
5 $ aVar=22; echo $(( aVar / 3 )); unset aVar
7
7 $ echo $(( aVar / 3 ))      # aVar is unset, no ${} => 0 is used: $((0/3))
0
9 $ echo $(( ${aVar} / 3 ))  # aVar is unset, with ${} => ' ' is used: $(( /3))
bash: / 3 : syntax error: operand expected (error token is "/ 3 ")
11 $ echo $(( ))
0
13 $ aVar='Hello'; echo $(( aVar )) $(( ${aVar} )); unset aVar
0 0 # No variable 'Hello' existing
15 $ aVar='bVar'; bVar=5; echo $(( aVar )) $(( ${aVar} )); unset aVar bVar
5 5 # aVar is expanded to bVar, which is defined to 5
17 $ aVar='HelloMyLove'; echo $(( aVar )) $(( ${aVar} )); unset aVar
0 0 # No variable 'HelloMyLove' existing
19 $ aVar='Hello <3'; echo $(( aVar )) $(( ${aVar} )); unset aVar
1 1 # It makes sense, doesn't it?
21 $ echo $(( 2**51 * 4096 ))
-9223372036854775808 # No error, no overflow check!
```

# Word splitting

...the evil of Bash!

## When does it occur?

The shell scans the results of parameter expansion, command substitution, and arithmetic expansion that did not occur within double quotes for word splitting!

- The shell treats each character of `IFS` as a delimiter, and splits the results of the other expansions into words using these characters as **field terminators** (these are all dropped)
- Whitespace characters `␣\t\n` contained in `IFS` are called **IFS whitespaces**
- **IFS whitespaces at the beginning/end** of the results of previous expansions **are ignored**
- **Adjacent IFS whitespaces** are considered all together as **single field terminator**
- **Any other character** in `IFS` that is not an IFS whitespace **always delimits a field**
- If the value of `IFS` is null, no word splitting occurs
- Implicit null arguments, resulting from the expansion of empty parameters, are removed
- **Note that if no expansion occurs, no splitting is performed**



# Word splitting

...the evil of Bash!

```
1  # The args command puts the arguments it gets in <...>
   # NOT standard, I implemented it!
3  $ args Hello world "I am Alessandro"
   3 args: <Hello> <world> <I am Alessandro>
5  $ aVar="This is a variable"; args ${aVar}
   4 args: <This> <is> <a> <variable>
7  $ args "${aVar}"
   1 args: <This is a variable>
9  $ ls
   Day1.tex  Day2.tex  Day3.tex
11 $ args $(ls)
   3 args: <Day1.tex> <Day2.tex> <Day3.tex>
13 $ aVar="      This is a variable  "; args ${aVar}
   4 args: <This> <is> <a> <variable>
15 $ aVar="      This   is a   variable   "; args ${aVar}
   4 args: <This> <is> <a> <variable>
17 $ aVar="/home/sciarra/Documents/Seminars/"; args ${aVar}
   1 args: </home/sciarra/Documents/Seminars/>
19 $ IFS='/'; args ${aVar}; unset IFS
   5 args: <> <home> <sciarra> <Documents> <Seminars>
21 # Why is there an empty argument at the beginning?
   # Why isn't there one at the end?
```

# Word splitting

...the evil of Bash!

```
23 # Let us have a look to more complex situations
$ aVar="/home/sciarra/Documents/Seminars"
25 $ IFS='/'; args ${aVar}; unset IFS
5 args: < > <home> <sciarra> <Documents> <Seminars >
27 $ IFS='␣/'; args ${aVar}; unset IFS # Note the space in IFS
5 args: <> <home> <sciarra> <Documents> <Seminars>
29 # Remember '$\n' special quoting to allow backslash escaping
$ aVar=$'\n \n xxx \t \t xx \t'
31 $ args ${aVar}
2 args: <xxx> <xx>
33 $ IFS=''; args ${aVar}; unset IFS
1 args: <
35
xxx          xx      >
37 $ IFS=$'\n'; args ${aVar}; unset IFS
2 args: < > < xxx          xx >
39 $ IFS=$'\n\t'; args ${aVar}; unset IFS
4 args: < > < xxx > < > < xx >
41 $ IFS=$'\n\t x'; args ${aVar}; unset IFS
5 args: <> <> <> <> <>
43 $ IFS=': '; args aaa:bbb; unset IFS aVar
1 args: <aaa:bbb> # It makes sense, right?
```

## Word splitting: conclusion

When does NOT it occur?

Word splitting is not performed

- on expansions inside Bash keywords such as `[[ ... ]]` and `case`;
- on expansions in assignments.

Thus, one does not need to quote anything in a command like these:

```
aVar=${bVar}; aVar=$(date)
PATH=/usr/local/bin:${PATH}
```

Quoting anyway will not break anything, so **if in doubt, quote!**

Remember:

**Word Splitting is performed *after* Parameter Expansion has been performed!**

That means that it is absolutely vital that we quote our Parameter Expansions, in case they may expand values that contain syntactical whitespace which will then be word-split.

## Other expansions

### Before Word Splitting:

**Command substitution:** It occurs when a command is enclosed as `$ (...)`

Do not use the deprecated syntax ``...``

Still too early to be discussed → [Bash manual v5.2 section 3.5.4](#)

`{ $ (...)` is substituted by the standard output of the command (executed in a subshell), with any trailing newlines deleted. }

**Process substitution:** Useful, but not discussed here → [Bash manual v5.2 section 3.5.6](#)

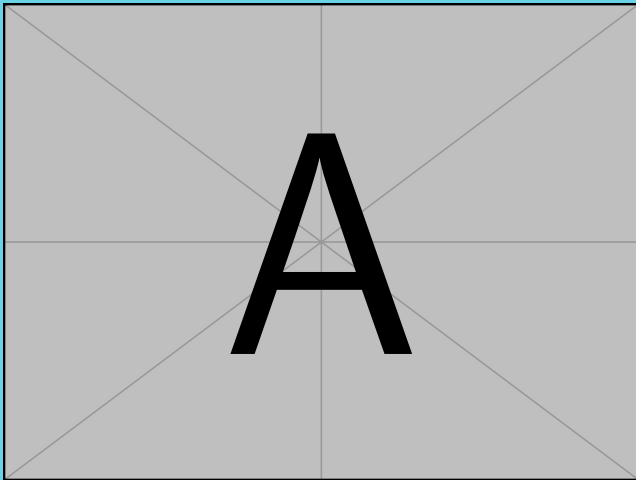
It takes the form `< (...)` or `> (...)`

It will be discussed in the section about redirection

### After Word Splitting:

**Filename expansion:** Discussed in the next section about globbing

# Globs and filename expansion



One of the edges of the Vatnajökull (the largest glacier in Europe)

# Patterns in Bash

## Definition

A pattern is a string with a special format designed to match filenames, or to check, classify or validate data strings.

Bash offers three different kinds of **pattern matching**:

- |                                     |                                                  |   |                                                        |
|-------------------------------------|--------------------------------------------------|---|--------------------------------------------------------|
| <b>1</b> <b>Globs</b>               | { Used also in patterns of Parameter Expansion } | } | <b>Pattern matching done<br/>in Filename expansion</b> |
| <b>2</b> <b>Extended Globbs</b>     |                                                  |   |                                                        |
| <b>3</b> <b>Regular expressions</b> | { Since Bash v3.0 }                              | ← | { Cannot be used to select filenames! }                |

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| <b>3</b> <b>Regular expressions</b> | { Since Bash v3.0 }                              | ← | { Cannot be used to select filenames! }                |

↑  
We will discuss this tomorrow with conditional blocks

# Filename expansion

## Glob patterns


### How does it work?

If a character among `*`, `?`, `[` appears, then the word is regarded as a pattern, and replaced with an alphabetically sorted list of filenames matching the pattern

- Metacharacters which might be used in glob patterns and undergo Filename Expansion:
  - \* Matches any string, including the null string
  - ? Matches any single character
  - [...] Matches any one of the enclosed characters
- Globbs are implicitly **anchored at both ends**, i.e. **a glob must match a whole string**
- When matching filenames, the `*` and `?` characters cannot match a slash (`/`)
- When matching patterns, the `/` restriction is removed



## The [...] pattern

- There are some special rules which might be interesting to know
- A pair of characters separated by a hyphen denotes a range expression  
→ any character that falls between those two characters, inclusive, is matched
- If the first character following the [ is a ! or a ^ then any character not enclosed is matched
- A - may be matched by including it as the first or last character in the set
- A ] may be matched by including it as the first character in the set
- Within [...], character classes can be specified using the syntax [:class:], where class is one of the  character classes defined in the POSIX standard:

alnum	ascii	cntrl	graph	print	space	word
alpha	blank	digit	lower	punct	upper	xdigit

For example, [:digit:] or [:blank:]

# Globs examples

```
1 $ ls
   Bash.pdf    Day_1.tex    Day_2.tex    Day_3.tex    Day_extra.tex
3 $ echo *
   Bash.pdf Day_1.tex Day_2.tex Day_3.tex Day_extra.tex
5 $ echo Day*
   Day_1.tex Day_2.tex Day_3.tex Day_extra.tex
7 $ echo *.pdf
   Bash.pdf
9 $ echo *_?.tex
   Day_1.tex Day_2.tex Day_3.tex
11 $ echo *_[12]*
   Day_1.tex Day_2.tex
13 $ echo *_[0-9]*
   Day_1.tex Day_2.tex Day_3.tex
15 $ echo *_[[:digit:]]*
   Day_1.tex Day_2.tex Day_3.tex
17 $ echo '*' # As already said, quotes prevent globbing
   *
19 $ echo "*_[[:digit:]]*"
   *_[[:digit:]]*
```

## Globs examples

```
21 $ aVar='Day3_Day2_Day1'; echo "${aVar#[12]}"; unset aVar
    _Day1
23 $ aVar='Day3_Day2_Day1'; echo "${aVar%[123]*}"; unset aVar
    Day
25 $ echo */bin      # For filenames, * does not match /
    /usr/bin
27 $ echo */*/bin
    /usr/local/bin
29 $ aVar='/home/sciarra/Documents'; echo "${aVar##*/}"
    Documents      # For strings, it does!
31 $ echo "${aVar%/*}"; unset aVar
    /home/sciarra
33 # This different behaviour is quite natural, indeed
```

### Good practice:

You should always use globs instead of `ls` (or similar) to enumerate files. Globs will always expand safely and minimise the risk for bugs. You can sometimes end up with some very weird filenames. Most scripts aren't tested against all the odd cases that they may end up being used with. Don't let your script be one of those!

Greg's Wiki

## Globs examples

```
33 # Bash performs Filename Expansions AFTER Word Splitting
34 # => filenames generated by a glob will not be split!
35 $ touch "a b.txt"; ls -l
a b.txt
36 $ rm *; ls # Here * is expanded into "a b.txt"
# => rm run correctly with one argument only!
37 $ touch "a b.txt"; rm $(ls) # WRONG!
rm: cannot remove 'a': No such file or directory
41 rm: cannot remove 'b.txt': No such file or directory
# Please, do not be tempted by using quotes here...
43 $ rm "$(ls)" # AAAARGHH! It works, but try this:
$ touch "a b.txt" c.txt; rm "$(ls)"
45 rm: cannot remove 'a b.txt'$'\n''c.txt': No such file or dir
```

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Greg's Wiki

## Extended Globs

This feature is turned off by default (in scripts)

You can turn it on with the `shopt` command, which is used to toggle **shell options**:

```
$ shopt -s extglob
```

In the following description, a **pattern-list** is a list of one or more patterns separated by a `|`:

- `?(pattern-list)` Matches zero or one occurrence of the given patterns
- `*(pattern-list)` Matches zero or more occurrences of the given patterns
- `+(pattern-list)` Matches one or more occurrences of the given patterns
- `@(pattern-list)` Matches one of the given patterns
- `!(pattern-list)` Matches anything except one of the given patterns

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- `!(pattern-list)` Matches anything except one of the given patterns

```
1 $ ls
   names.txt    tokyo.jpg     california.bmp
3 $ echo !(*jpg|*bmp)
   names.txt
```