# Shell Scripting with Bash

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# Intro

# What is a Script?

- A sequence of Bash commands
- A Bash program
- Stored as a text file
  - *Interpreted* by the Bash shell

# Why Write Scripts

- Convenience
- Sequences of oft-performed operations can be placed in a script, executed as a single command
- Shell provides access to many useful utilities
- I have scripts for simple tasks, and scripts for some fairly complex tasks:
  - Rename all files of the form `DSC`*nnnn*`.JPG` to *nnnn*`.jpeg`
  - Organise the flat directory of heavily decorated filenames downloaded from Blackboard into subdirectories by student, restoring the original filenames
  - A testing framework, for grading student programs. Calls individual test cases (themselves scripts) for each program to grade

# Shell Scripts vs. C-like Languages

- Shells are built for comfort. This comes at a cost
- Shell scripts are generally not as well-suited to large tasks
  - They run more slowly, are more resource-intensive
  - Scripts do not give the programmer nearly the same control over resources
- Languages such as C allow for much more structured programs
- Shell scripts are more difficult to harden against security attacks

# Hello, Script!

# Our First Bash Script

Consider the following file, `hello`

```
#!/bin/bash
echo "Hello, $USER"
exit 0  # success
```

- `#!/bin/bash` – sha-bang
  - First line
  - Identifies the interpreter who is to execute this script
- *Always* quote variables in scripts
  - If you don't think you need to, *quote it anyway!*
- `exit 0` – The return value (status) of the script
- `# success` – Line comment

# Running a Script

- Can be given explicitly to Bash as a simple input text file:

```
$ bash hello
Hello, kschmidt
```

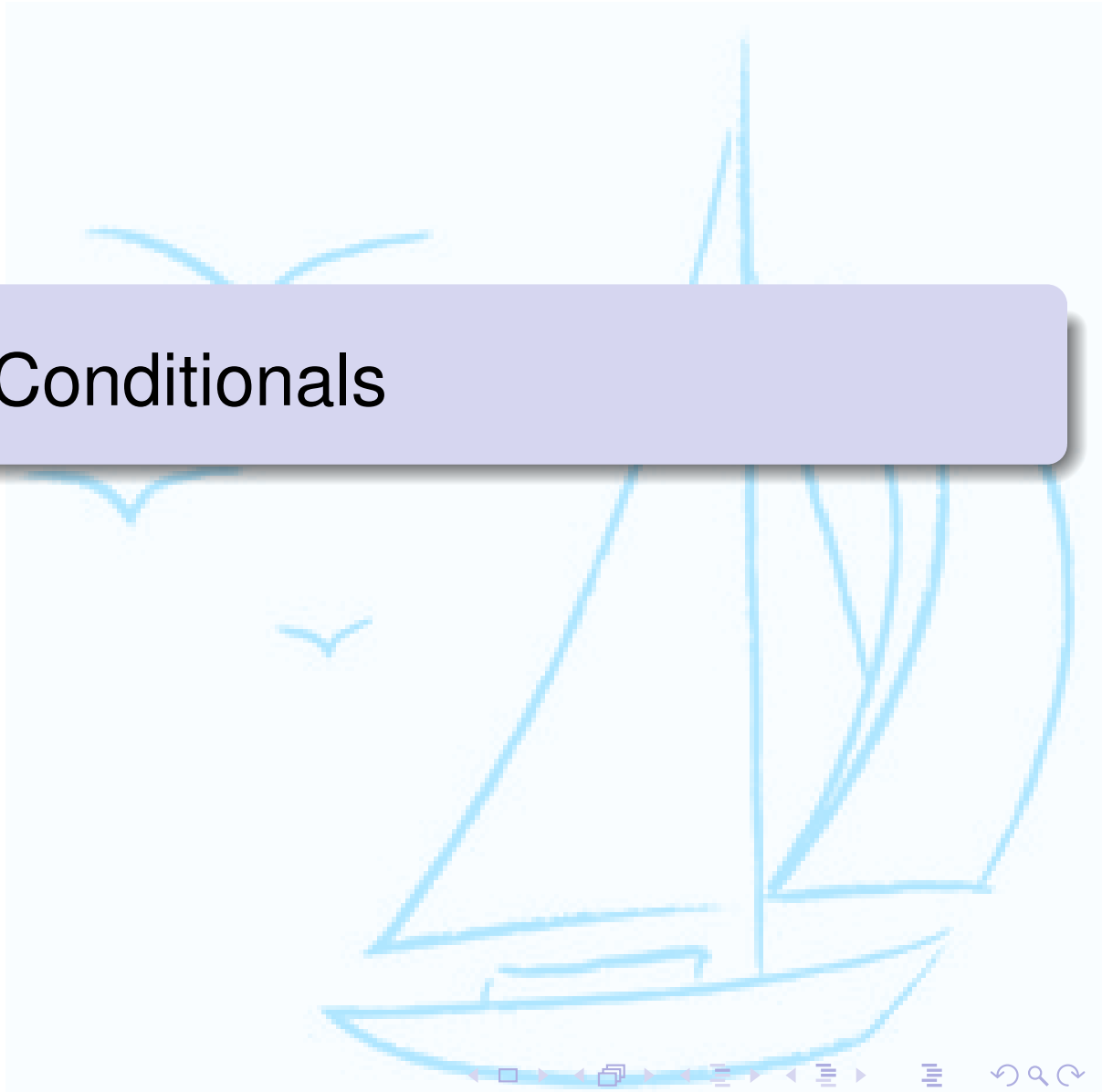
- Or, we can give it execute permissions, run it as any other utility:

```
$ chmod +x hello
$ hello
hello: command not found
```

- Whoops! The current directory isn't in my PATH (nor should it be). Tell the shell where it is:

```
$ ./hello
Hello, kschmidt
```

# Conditionals



# Tests for Branches and Loops

We need tests for branches and loops

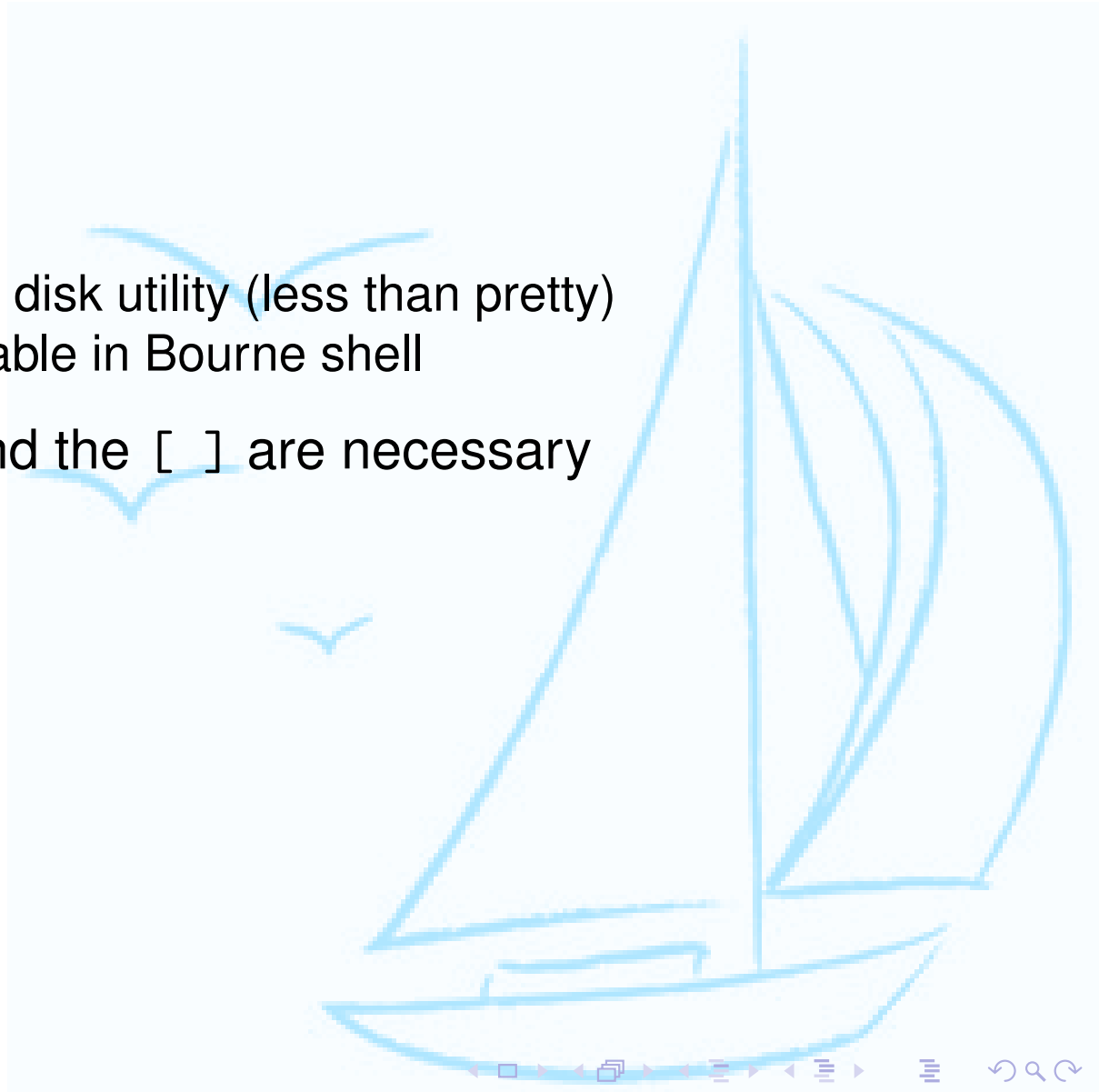
- We've already seen the return value of commands
  - Zero (`0`) is *true* (success)
  - All else is false (signals some failure)
  - Can be negated using `!` before
- There are special utilities and Bash built-ins to provide various tests

| | |
|---|---|
| `test`, `[ ]` | Provides string, numeric, and file tests |
| `[[ ]]` | Similar to `[ ]`, but gentler syntax |
| `let`, `(())` | Provides numeric tests and arithmetic |

# [ ] – String Tests

`[ expr ]`

- Built into Bash
  - But behaves like the disk utility (less than pretty)
  - Only such test available in Bourne shell
- Note, the spaces around the `[ ]` are necessary
- Provides:
  - String tests
  - File tests
  - Numeric tests
  - Logical operators



# [ ] – String Tests

- We have the normal binary, relational operators

< = != >

```
$ [ a = b ] || echo false
false
$ [ jaga < kurt ] && echo true
bash: kurt: No such file or directory
```

- Whoops! < is a shell metacharacter. Needs to be escaped

```
$ [ jaga \< kurt ] && echo true
true
```

# [ ] – String Tests

We have unary tests for strings

| | |
|---|---|
| `-z` | True if string is empty |
| `-n` | True if string is not empty |

```
[ -z "$1" ] && echo "Script requires a filename as an argument"
[ -n "$1" ] || echo "Script requires a filename as an argument"
```

# [ ] – File Tests

Many unary tests for files. Here are a few:[1]

| | |
|---|---|
| `-e` *file* | True if *file* exists |
| `-d` *file* | True if *file* is a directory |
| `-f` *file* | True if *file* is a regular file |
| `-L` *file* | True if *file* is a symbolic link |
| `-r` *file* | True if *file* is readable by you |
| `-w` *file* | True if *file* is writable by you |
| `-x` *file* | True if *file* is executable by you |
| `-O` *file* | True if *file* is effectively owned by you |

[1] Do a `help test`, or `man test` for more

# [ ] – File Tests, 2

There are some binary operators for files:

| | |
|---|---|
| *f1* `-nt` *f2* | True if *f1* is newer than *f2* |
| *f1* `-ot` *f2* | True if *f1* is older than *f2* |
| *f1* `-ef` *f2* | True if *f1* is a hard link to *f2* (they are the same file) |

```
[ -f "$log" ] && echo "Next status line" >> "$log"
[ -r "$input" ] || echo "I can't read $input"
[ "$f1" -ef "$f2" ] &&
  echo "I can remove $f1 and $f2 will still be there"
```

# [ ] – Arithmetic Tests

- We have different relational operators for arithmetic[1]
  - All parameter values are just strings
  - Shell can't tell from context which comparison is meant

`-lt -le -eq -ne -ge -gt`

```
$ [ 13 \< 2 ] && echo true
true
$ [ 13 -lt 2 ] || echo false
false
```

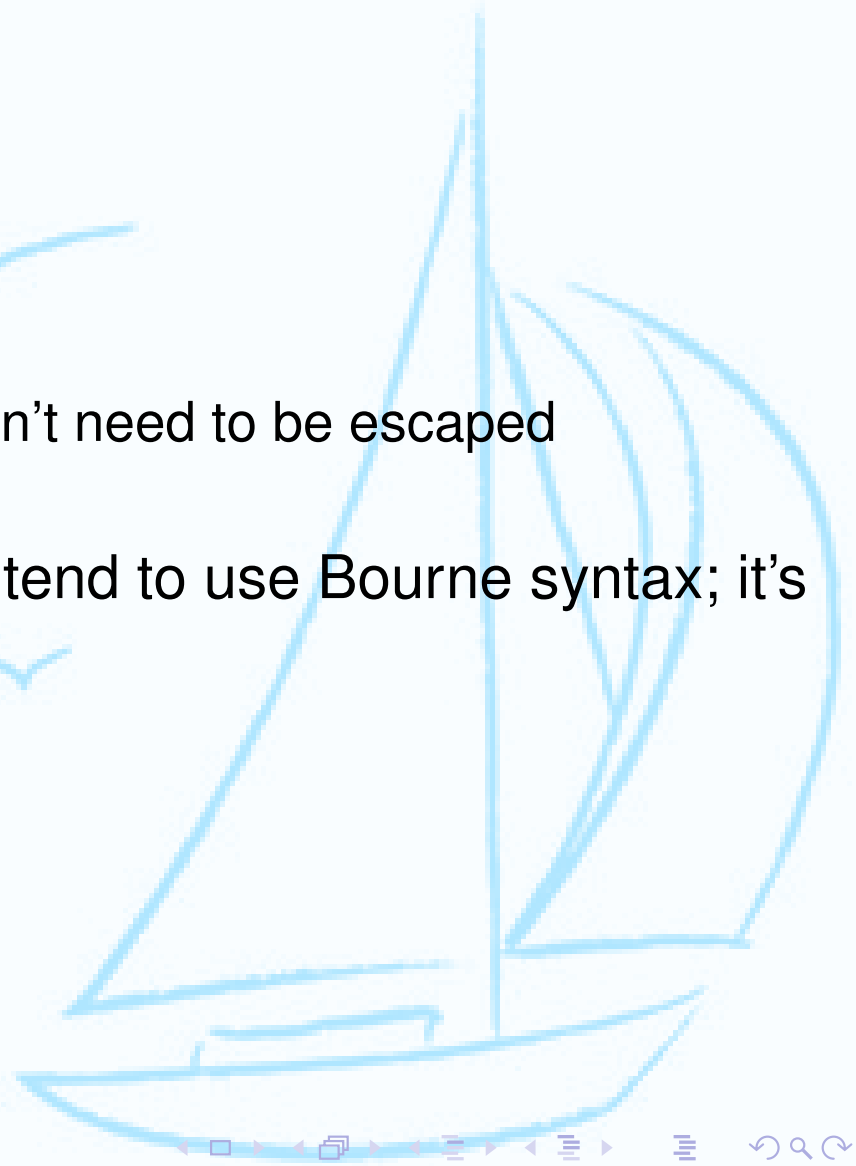
[1] The `let` utility makes this prettier

# [ ] – Logical Operators

| | |
|---|---|
| `!` *expr* | NOT - True when *expr* is false, false otherwise |
| *exp1* `-a` *exp2* | AND - True when both *exp1* and *exp2* are true, false otherwise |
| *exp1* `-o` *exp2* | OR - False when both *exp1* and *exp2* are false, true otherwise |

# [[ ]]

- Supports all the same tests as `[ ]`
- Is a built-in, so, syntax is gentler
  - Shell metacharacters <, >, etc., don't need to be escaped
  - Shell knows it's in a test
- Mind, install scripts (and makefiles) tend to use Bourne syntax; it's the default for all Unix systems



# [[ ]] – New Features

- Familiar logical operators
  - ! && ||
- == = both test for equality
- == != treat the right operand as a pattern (glob)

```
$ [[ abcde.f == a*e.? ]] && echo true
true
```

- New operator, =~, treats the right operand as an extended regular expression

```
$ [[ abcde.f =~ a.*e\..? ]] && echo true
true
```

# `(( ))` – `let`, Relational Operators

- `let` is a Bash built-in
- Bash provides syntactic sugar: `(( ))`[1]
- Treats values stored in parameters as integers[2]
  - *N.B* – Only does integer arithmetic (division)
- Allows you to evaluate relational expressions
  - Same logical operators

`<  <=  ==  !=  >=  >`

```
$ x=13 ; y=87
$ (( x > 7 )) && echo true
true
$ (( x!=0 && y/x >= 6 )) && echo true
true
```

[1] Note, the `$[ ]` form is deprecated

[2] For float arithmetic, see the `bc` utility

# `(( ))` – `let`, Arithmetic Operators

`let` can be used to evaluate arithmetic exceptions

- Arithmetic: `** * / % + -`
- Bit-wise: `~ << >> ^ & |`
- Pre- and post-fix increment/decrement: `++ --`
- A C-like ternary operator: `?:`
- Assignment (=), and the usual operator/assignment operators: `+= -= &=`, etc.

# (( )) – Examples

```
$ x=13
$ echo $(( x+15 ))
28
$ echo $x
13
$ (( y = x*4 ))
$ echo $y
52
$ (( y-=1 ))
$ echo $y
51
$ echo $((x>>2))
3
$ (( 5 && 2 )) && echo true
true
$ (( 5 & 2 )) || echo false
false
$ # Same as in C, Python, etc.  Why?
```

# Integer Literals

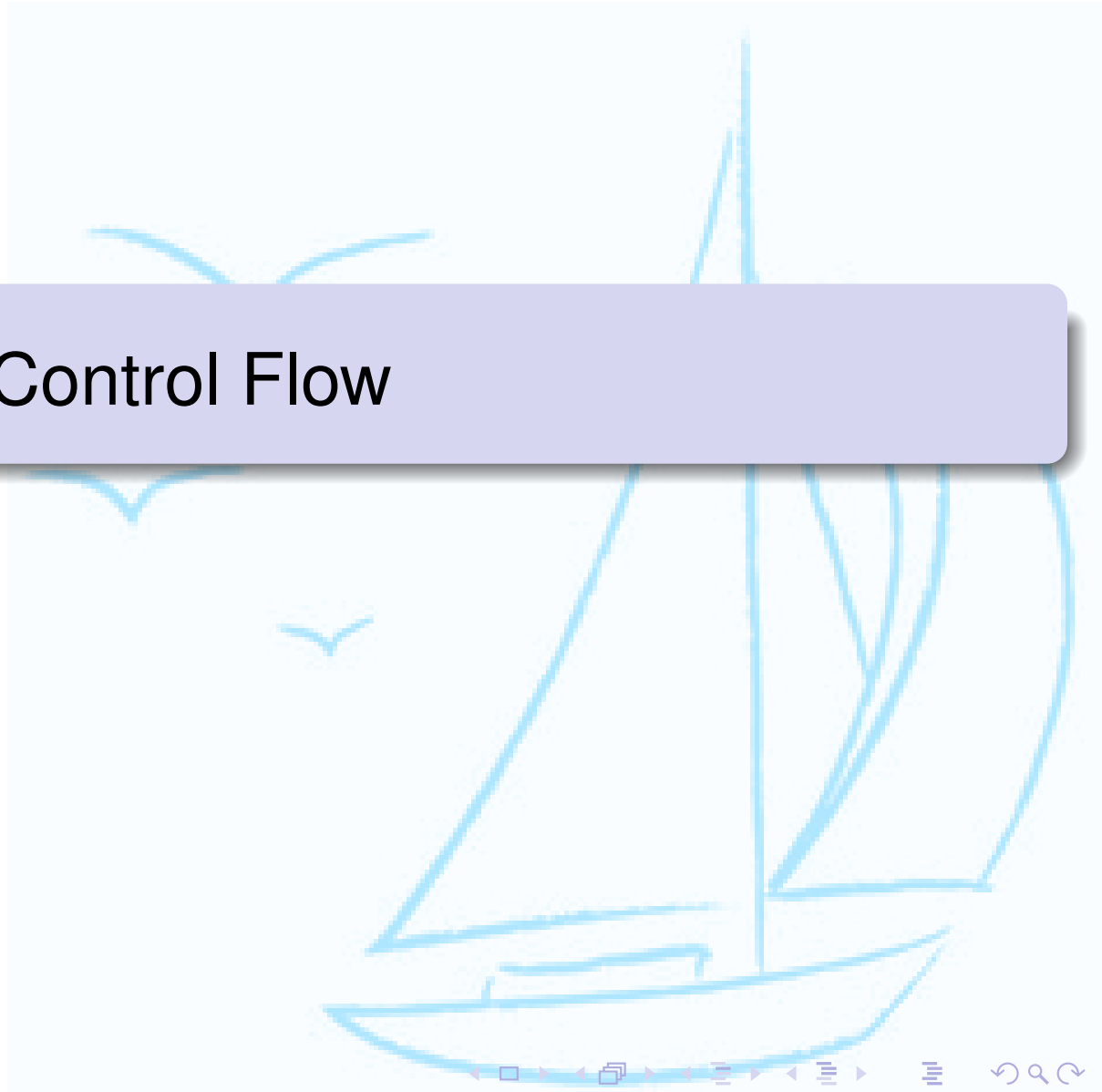
## Integer Literals

Be careful. Try the following out.

```
$ echo $(( 012 ))
10
$ echo $(( 0x23 ))
35
```

This is not an odd artifact of Bash, nor of `let`. You will find similar behavior in C, AWK, Python2, Java, etc.

# Control Flow



# Bash Control Structures

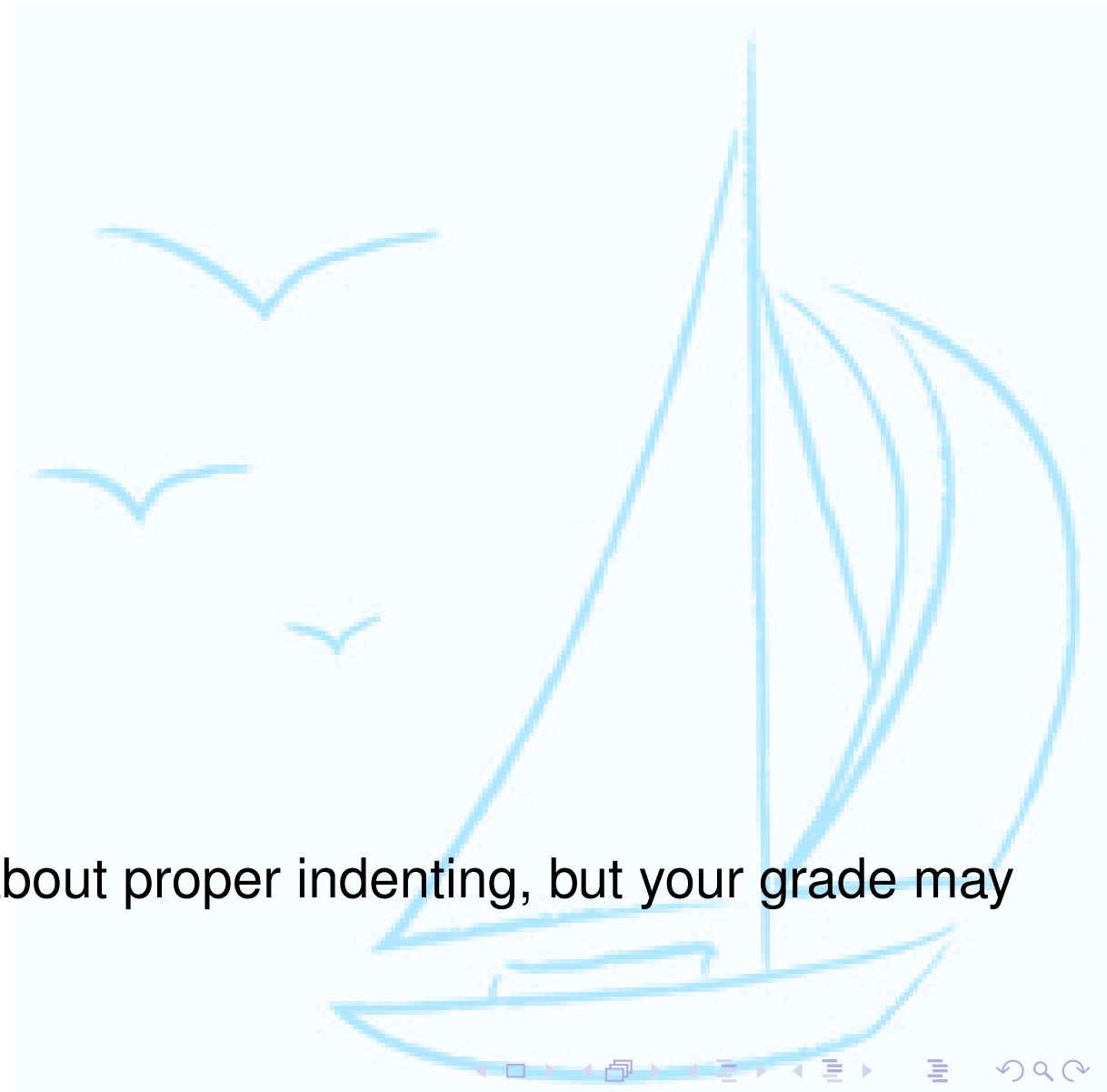
We have branching:

- `if`
- `if-else`
- `if-elif-else`
- `case`

And loops:

- `while`
- `until`
- `for`
- `select`

**Note:** Bash may not care about proper indenting, but your grade may well care



# if

`if` *`tests`*`; then` *`cmds`*`; fi`

- *`tests`* is executed
- If the exit status is 0 (success), *`cmds`* is executed

```
if grep Waldo * &> /dev/null ; then
  echo "Found Waldo!"
fi
```

```
if [[ -d "$paris" && -r "$paris" ]] ; then
  echo "I see $paris"'!'
fi
```

```
if (( cats > 3 )) ; then
  echo "Too many cats"
  echo "People will talk"
fi
```

# if-else

**if *tests*; then *cmds*; else *cmds*; fi**

```
if grep Waldo * &> /dev/null ; then
  echo "Found Waldo!"
else
  echo "Dude's a slippery one"
fi
```

```
if [[ -d "$paris" && -r "$paris" ]] ; then
  echo "I see $paris"'!'
else
  echo "Might be on the wrong continent"
fi
```

```
if (( cats > 3 )) ; then
  echo "Too many cats"
  echo "People will talk"
else
  echo "You might yet be sane"
fi
```

# if-elif-else

**if *tests*; then *cmds*; {elif cmds;} else *cmds*; fi**

```
read grade
if (( grade >= 90 )) ; then
  echo "A"
elif (( grade >= 80 )) ; then
  echo "B"
elif (( grade >= 70 )) ; then
  echo "C"
elif (( grade >= 60 )) ; then
  echo "D"
else
  echo "F"
fi
```

# `while` Loop

**`while` *`tests`*`; do` *`cmds`*`; done`**

- *`tests`* is executed
- If the exit status is 0 (success), *`cmds`* is executed
- Execution returns back to *`tests`*, start again

```
i=0
while (( i<=12 )) ; do
  echo $i
  (( i+=1 ))
done
```

```
cat list | while read f ; do
  # Assume list contains one filename per line
  stat "$f"
done
```

# `for` Loop

**`for` *`name`* `[in` *`list`*`]; do` *`cmds`* `; done`**

- Executes *`cmds`* for each member in *`list`*
- `"$@"` used if *`list`* isn't there

```
$ for i in a b c ; do
>   echo $i
> done
a
b
c
```

```
for id in $(cat userlist) ; do
    # assumes no spaces in userIDs
  echo "Mailing $id..."
  mail -s "Good subject" "$id"@someschool.edu < msg
done
```

# Reading Files in Directory

## Use `read` to Preserve Spaces

- You must be aware of filenames with spaces
- Consider the different approaches:

```
$ ls -1
'a space'
nospace
$ for f in $(ls -1) ; do
> echo $f
> done
a
space
nospace
$ ls -1 | while read f ; do
> echo $f
> done
a space
nospace
```

# Counting `for` Loop

- Bash has a C-like for loop:

```
$ for (( i=0; i<3; ++i )) ; do
>   echo $i
> done
0
1
2
```

```
$ for (( i=12; i>0; i-=4 )) ; do
>   echo $i
> done
12
8
4
```

# {x..y} – Brace Expansion

## {x..y[..inc]}

- Generates sequences in a natural way

```
$ echo {5..13}
5 6 7 8 9 10 11 12 13
```

```
$ echo {a..g}
a b c d e f g
$
```

- Brace expansion will pad numbers on the left[1]

```
$ for i in {000..010..2} ; do  echo -n "$i " ; done
000 002 004 006 008 010
```

- This is quite handy in loops:

```
for i in {00..05} ; do
  \rm proc${i}.log
done
```

[1] YMMV, depending on your platform

# Loops – `continue`, `break`

- `break` exits a loop
- `continue` shortcircuits the loop, resumes at the next iteration of the loop

```
$ for i in {1..42} ; do
>   (( i%2 == 0 )) && continue
>   (( i%9 == 0 )) && break
>   echo $i
> done
1
3
5
7
$
```

# case

`case` *word* `in` {*pattern* `)` *cmds* `;;`} `esac`

- Selectively execute *cmds* if *word* matches the corresponding *pattern* (glob)
- Commands are separated by `;`
- Cases are separated by `;;`

```
case $opt in
  n ) DRY_RUN=1 ;;
  x ) ECHO=1 ;;
  \? | h | H ) usage() ; exit 1 ;;
  ?) echo "Unkown character ;;
esac
```

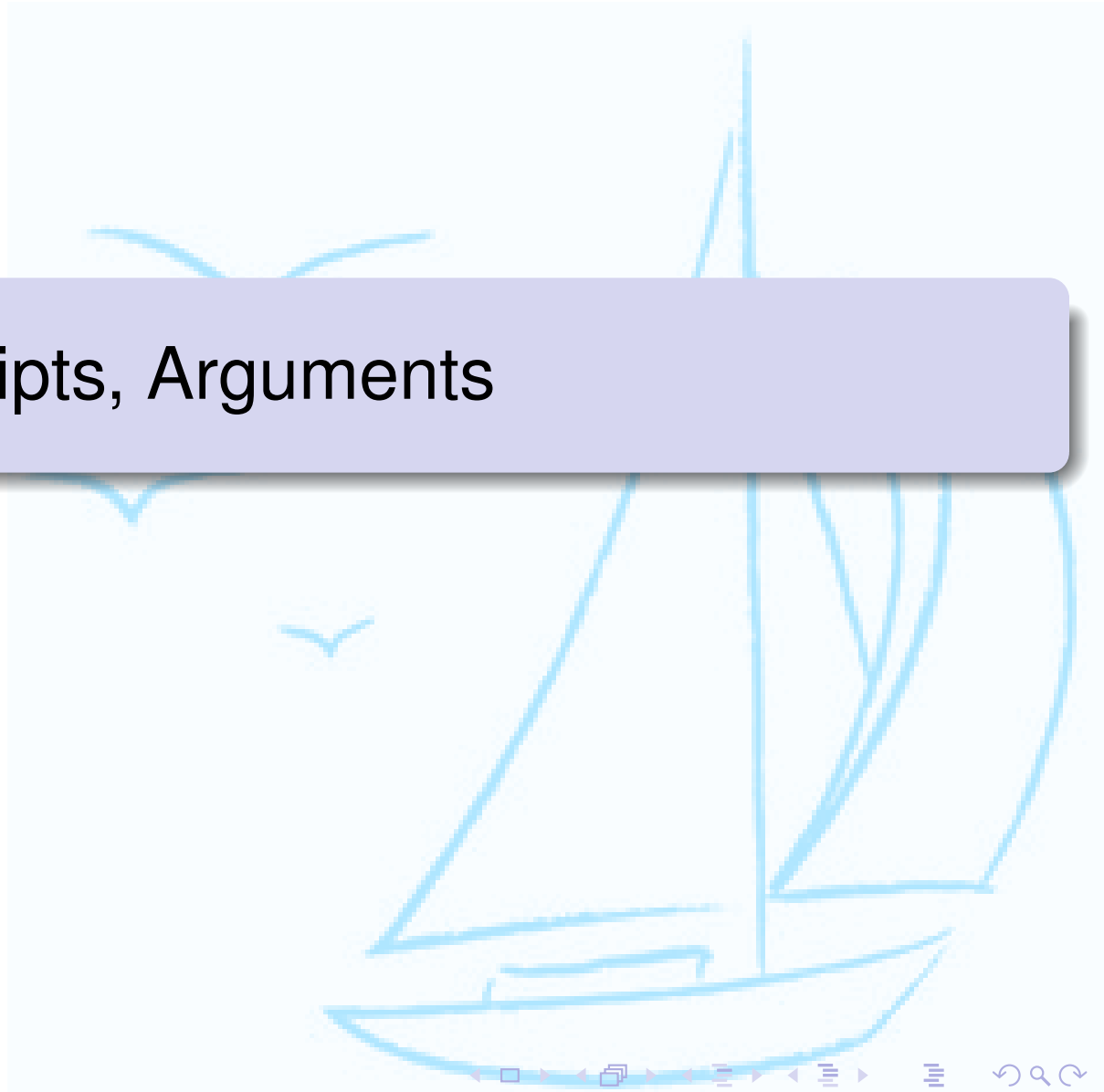
# select

`select` *name* `[in` *list*`]; do` *cmds* `; done`

- Much like the `for` loop
- Displays enumerated menu of *list*
- Puts user's choice in `name`

```
$ select resp in "This" "That" "Quit" ; do
>   echo "You chose $resp"
>   [ "$resp" == Quit ] && {echo 'bye!' ; break ; }
> done
1) This
2) That
3) Quit
#? 2
You chose That
#? 3
You chose Quit
bye!
$
```

# Scripts, Arguments



# Organised Evolution

## Do *not* write the whole thing at once!

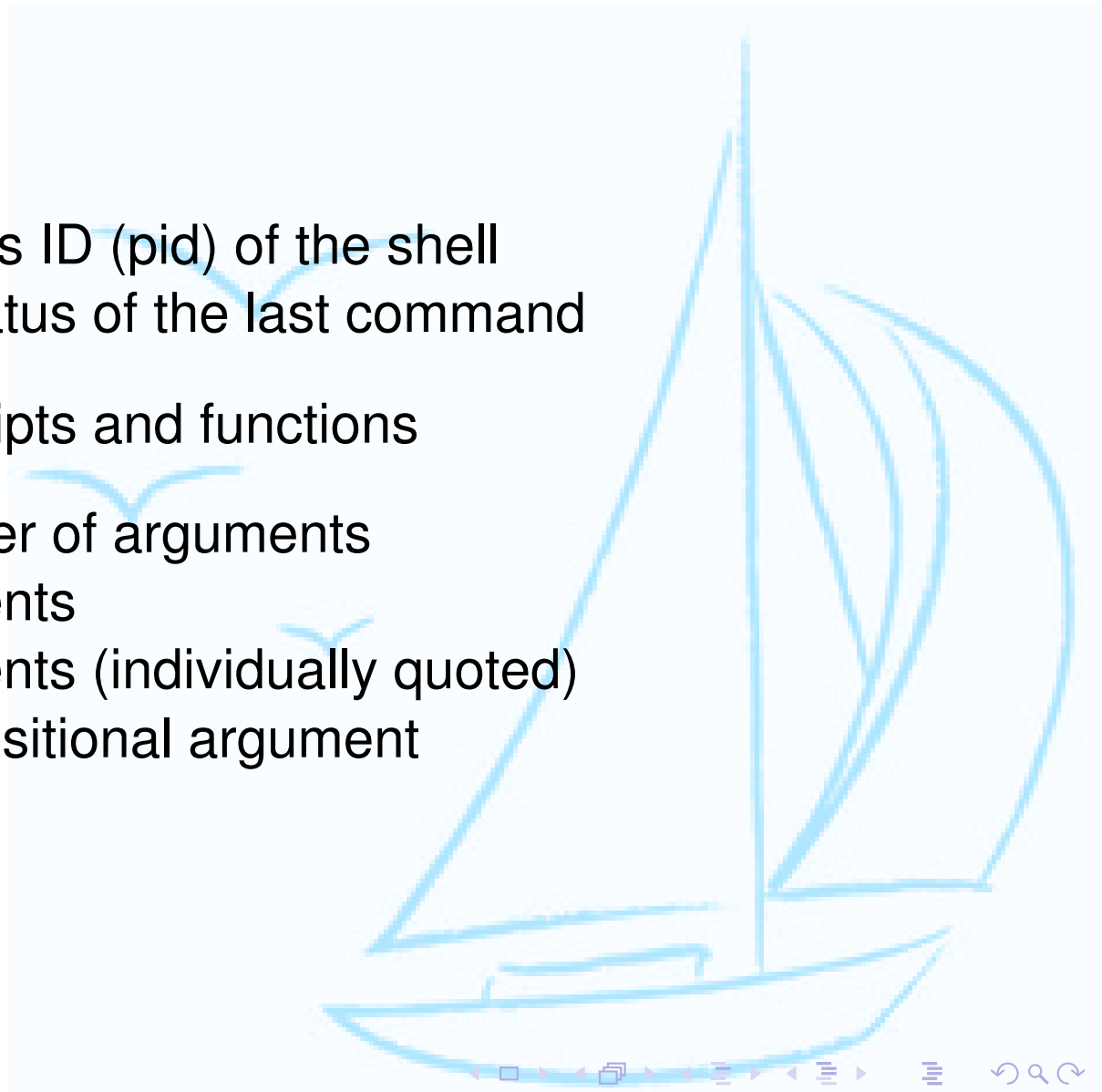
Guys, don't write the entire script, any program, then try to compile or run.

Break it into smaller, logical pieces, and build upwards:

- Get the loop/input correct, e.g., selecting only files of interest
- Separately, get the processing for a single file correct
- Now, put those pieces together

Interactive interpreters help you, here, because you can test a line or a loop interactively as you're writing your script.

# More Bash Parameters



These should be familiar:

| | |
|---|---|
| `$$` | The process ID (pid) of the shell |
| `$?` | The exit status of the last command |

These are handy inside scripts and functions

| | |
|---|---|
| `$#` | The number of arguments |
| `$*` | All arguments |
| `$@` | All arguments (individually quoted) |
| `${`$n$`}` | The $n^{th}$ positional argument |

# Arguments to Scripts

- If the script has a proper sha-bang, and the execution bit is set, the script may be invoked directly
- Arguments may be supplied, as with any other commad

```
myScript arg1 arg2 ...
```

- Or, `bash` may be invoked explicitly, and given a script as input
- Arguments to the script would follow the script

```
bash myScript arg1 arg2 ...
```

# Arguments to Scripts

- Bash, in turn, can take options
- There are two helpful ones for writing and debugging scripts
  - `-n` Dry run. File is parsed, but commands aren't executed. Check syntax
  - `-x` Echo on. Commands are echoed to `stderr` as they're executed (after parameter, file, etc. expansion has happened)

```
$ bash -x ./hello
+ echo 'Hello World'
Hello World
+ echo 'My name is kschmidt'
My name is kschmidt
```

# Arguments in Scripts

- Arguments are positional
- `$0` is the name of the command (how it was invoked)
- In Bourne, `$1` – `$9`
  - Can't access `$10`, it'd be `$1` followed by 0
- In Bash, we can wrap parameters in curly braces, so, `${1}`, `${12}`, etc.

(See `Labs/Bash/args.bash`)

```
echo "Here is how the script was invoked:  $0"
echo "Here are the arguments:  $*"
echo "This is the number of arguments:  $#"
echo "We'll show each arg:"
for a in "$@" ; do echo "$a" ; done
```

# Processing Args – `shift`

**`shift [`*`cnt`*`]`**

- Shifts args to the left *cnt* (default 1) positions
- $1 is gone, $2 → $1, etc.

```
i=0
while [ ! -z "$1" ] ; do
   (( i+=1 ))   # just here to enumerate output
   echo -e "$i\t$1"
   shift   # old $1 is gone
done
```

# Processing Args – `getopts`

`getopts` *`optstring name`*

- Bash built-in
- Just handles short (single character) options[1]
- Returns SUCCESS when it finds an option
- *`optstring`* is the list of options
  - Options that take an arg are followed by a colon (`:`)
- *`name`* holds the current option
- Index of current arg stored in `$OPTIND`
- If option takes an arg, it is stored in `$OPTARG`

[1] See `getopt` utility

# getopts – e.g.

```
while getopts "ab:cC" opt; do
  case $opt in
    a  ) echo "option a, at index $OPTIND";;
    b  ) echo "option b with arg = $OPTARG, at index $OPTIND";;
    c | C ) echo "option $opt, at index $OPTIND";;
    ? ) echo "usage: $0 [-a] [b arg] [-c] args..." ; exit 1;;
  esac
done

echo "\$OPTIND = $OPTIND"
shift $(($OPTIND -1))  # shift off the options

echo -e "\nHere are the remaining arguments:"
for i in "$@" ; do
  echo -e "\t$i"
done
```

# Functions

# Bash Functions

`function` *`name`* `{`*`body`*`}` [1]

*`name`*`() {`*`body`*`}`

- Executed in the same environment
- Arguments to function are handled the same as arguments to a script[2]
- Can be called recursively (see `$FUNCNEST`)
- Built-in `return` *rv* can be used in a function, to return execution (and optional status *rv*) to caller
  - Otherwise, status of last command is used
- Export to make available to subshells:

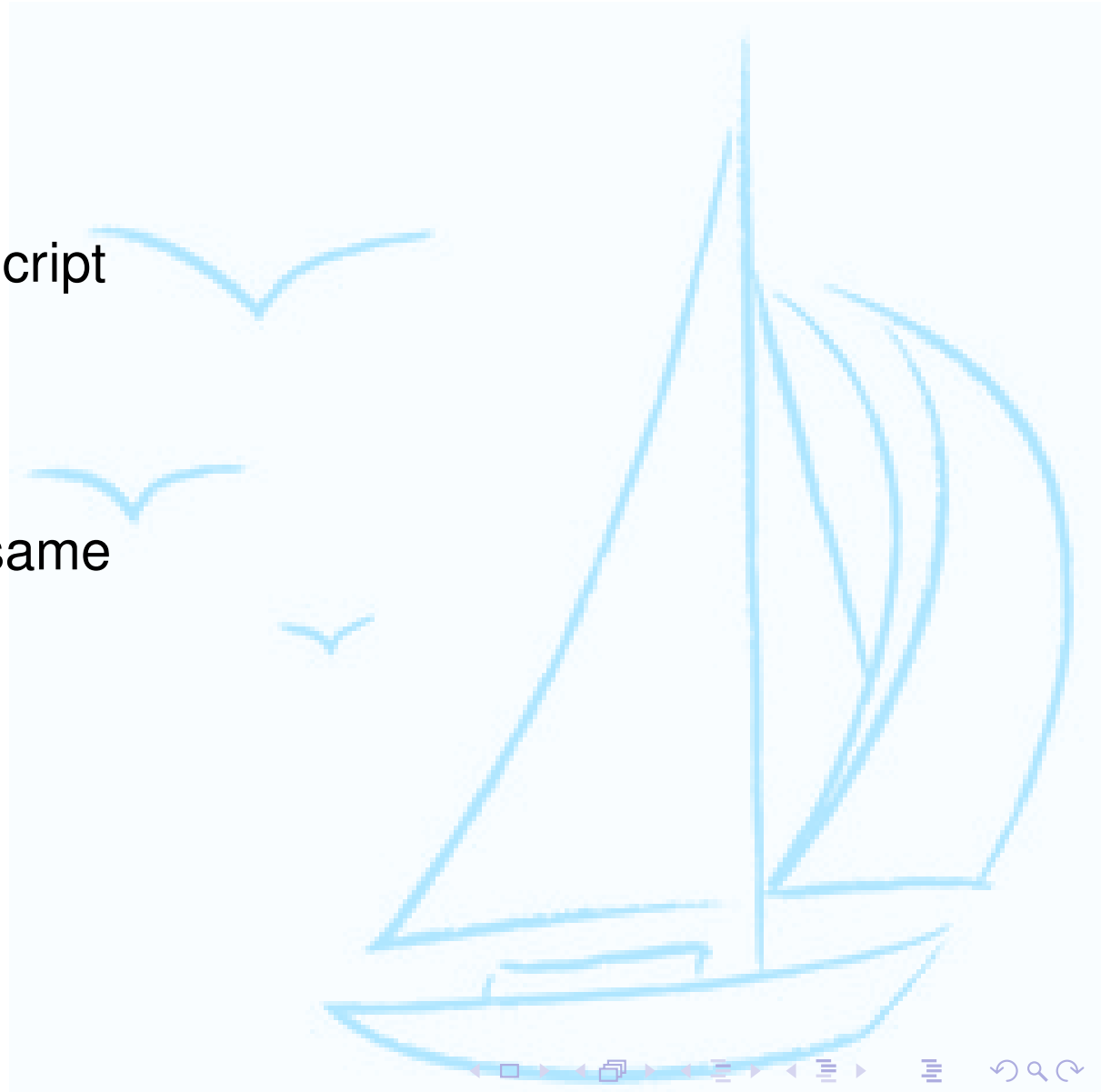
`export -f` *`funcname`*

[1] In fact, the curly braces and body can be any compound command

[2] Except that `$0` is unchanged. See `$FUNCNAME`

# Functions – Parameters

- Accessed just as in a script
- `$1`, `$2`, ...
  - `$0` is the caller's `$0`
  - See `$FUNCNAME`
- `$#`, `$*`, `$@` behave the same
- `shift` works the same



# Functions – e.g.

```
function hello
{
  echo "hello $1"
  if [[ -n "$2" && "$2" -gt 1 ]] ; then
    hello $1 $(($2-1))
  fi
}
```

- Called as a script would be:

```
$ hello Vera 3
hello Vera
hello Vera
hello Vera
```

# Local Variables in Functions

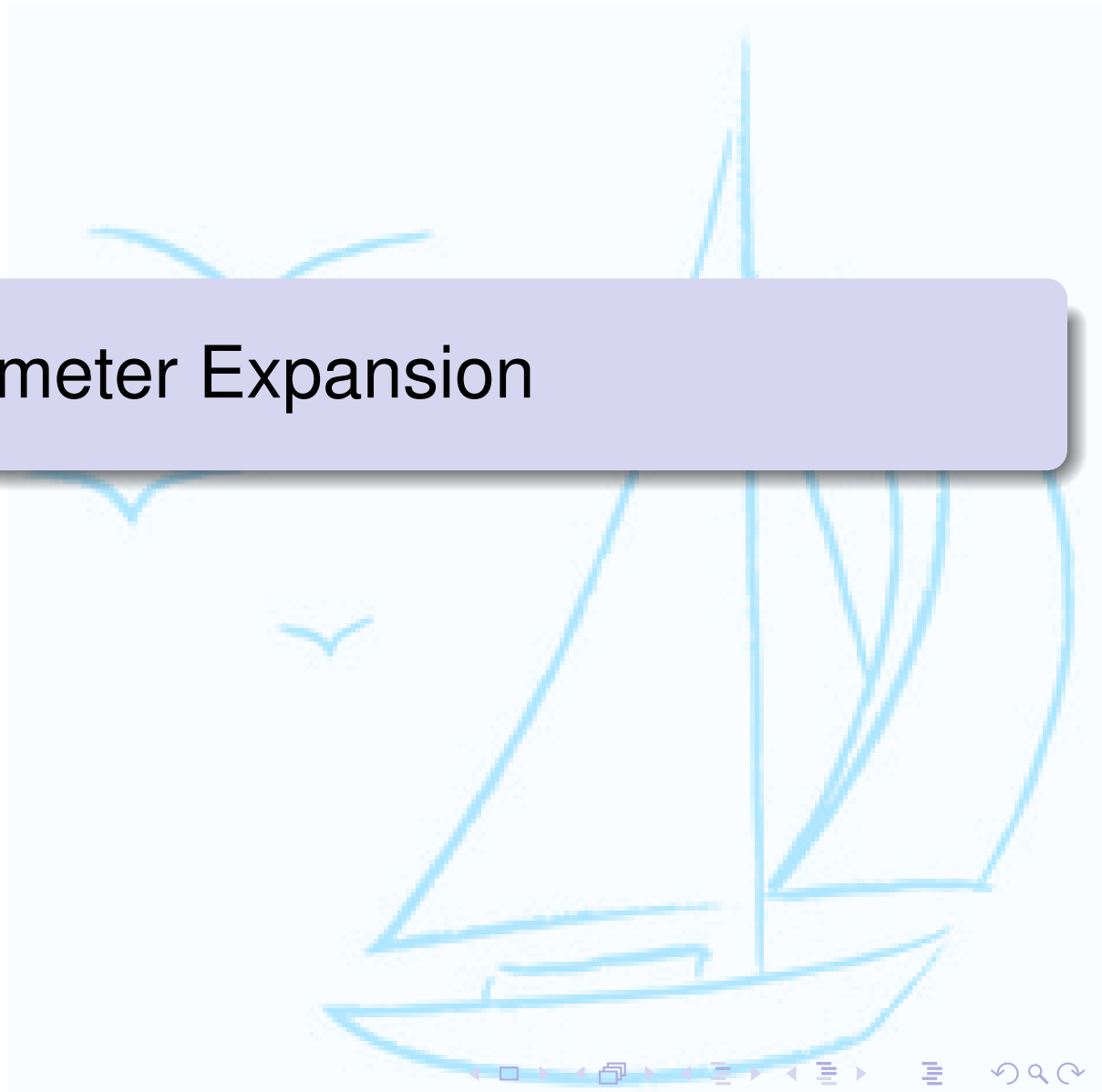
`local {var}`

- Defines variable(s) local to function
- Won't step on caller's environment

```
function hello {
  local USER='Elmer Fudd'
  FOO='Hunting Wabbit'
  echo "Hello, $USER, you are $FOO"
}
```

```
$ FOO='Baking Cookies'
$ echo $USER
kschmidt
$ hello
Hello, Elmer Fudd, you are Hunting Wabbit
$ echo $FOO
Hunting Wabbit
$ echo $USER
kschmidt
```

# Parameter Expansion



# Unset or Null Parameters

Expansions for unset (or null) parameters:

| | |
|---|---|
| `${`*param*`:-`*word*`}` | Use *word* if *param* is not set or is null |
| `${`*param*`:=`*word*`}` | Use *word* if *param* is not set or is null, set it to *word* |
| `${`*param*`:?`*word*`}` | If *param* is not set or is null, print *word* to `stderr`, exit shell (if not interactive) |
| `${`*param*`:+`*word*`}` | If *param* is *set*, use *word* , otherwise use null |

# E.g. – Null Parameters

```
$ unset foo
$ echo ${foo:-"Hello!"}
Hello!
$ echo $foo

$ echo ${foo:?"Houston, we have a problem"}
bash: foo: Houston, we have a problem
$ echo ${foo:+"We here?"}

$ echo ${foo:='I am de Fault'}
I am de Fault
$ echo $foo
I am de Fault
$ echo ${foo:?"Houston, we have a problem"}
I am de Fault
$ echo ${foo:+"We here?"}
We here?
```

# Removing Patterns

Remove leading or trailing Patterns (globs)

| | |
|---|---|
| ${*param*#*pattern*} | Remove shortest leading *pattern* |
| ${*param*##*pattern*} | Remove longest leading *pattern* |
| ${*param*%*pattern*} | Remove shortest trailing *pattern* |
| ${*param*%%*pattern*} | Remove longest trailing *pattern* |

```
$ f=a^b^c
$ echo ${f#*^}
b^c
$ echo ${f##*^}
c
$ echo ${f%%^*}
a
$ echo ${f%^*}
a^b
```

# Parameters – Pattern Substitution

`${param/pattern/string}`

- Substitutes *string* for longest matching *pattern*
  - Again, *pattern* is a glob, not a regular expression
- If *pattern* starts with `/`, it substitutes all occurrences

```
$ f="The cat sat on the hat"
$ echo ${f/[hcs]at/XXX}
The XXX sat on the hat
$ echo ${f//[hcs]at/XXX}
The XXX XXX on the XXX
```

# Parameters – Substrings

`${param:offset}`
`${param:offset:length}`

- Extract substring starting at index offset
- Extract length (all remaining) characters

```
$ n='Kurt Schmidt'
$ echo ${n:3}
t Schmidt
$ echo ${n:5:3}
Sch
```

# Parameters – Change Case

`${param<OP>pattern}`

- Change case of characters matched by *pattern*
- *pattern* should not attempt to match a larger string
- If *pattern* is missing, treated as a `?`
- `^ ^^` – Convert first (each) matched character to upper
- `, ,,` – Convert first (each) matched character to lower

```
$ f=SHOUT
$ echo ${f,}
sHOUT
$ echo ${f,,}
shout
$ echo ${f,[SOT]}
sHOUT
$ echo ${f,,[SOT]}
sHoUt
$ f=quiet
$ echo ${f^^}
QUIET
```