Week 02

Things to Note ...

- Sample solutions to problem sets on the web on Tuesday

In This Lecture ...

- Abstract data objects and types (ADTs) (Slides, [M] 6.6-6.7, [S] 4.1-4.3)

Coming Up ...

- Dynamic data structures (Slides, [M] Ch. 10, [S] Ch.3)

Nerdy Things You Should Know

Consider the following scenario ...

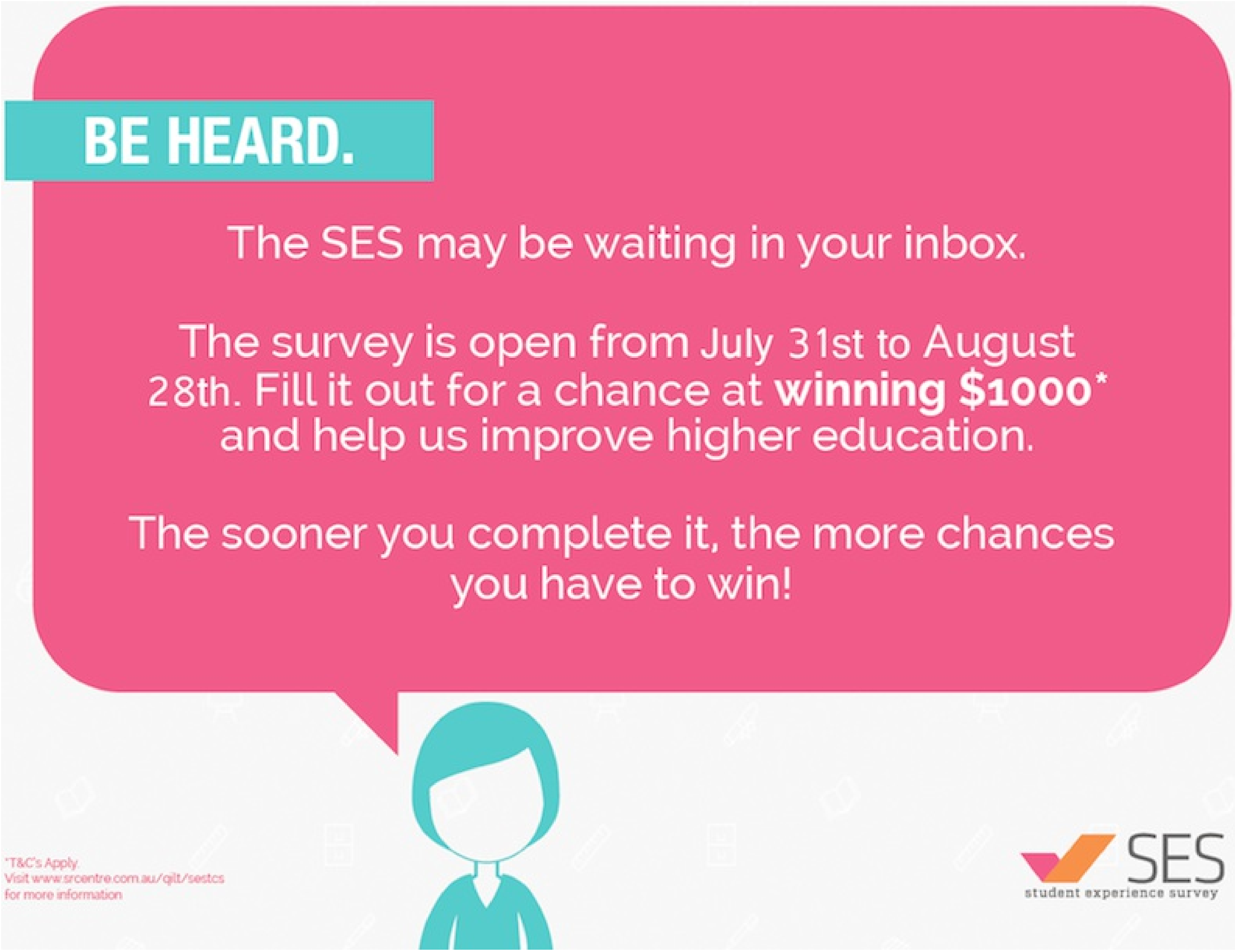
- you're sitting in a lab
- you're looking at some code like `'/^s?[0-9]{7}$/'`
- you want to ask a question about the code
- but you're not sure how to refer to the ^ char
- and you don't want to sound clueless

Fear not! This is ... **How to speak #@*%$! Ascii**

From
blog.codinghorror.com/ascii-pronunciation-rules-for-programmers/

Nerdy Things You Should Know (cont)

Symbol	Common Name	Silliest Name
&	ampersand	
*	star	
"	quote	
^	hat	
@	at sign	
!	exclamation	
#	hash	
%	precent sign	


BE HEARD.
The SES may be waiting in your inbox.
The survey is open from July 31st to August 28th. Fill it out for a chance at **winning $1000*** and help us improve higher education.
The sooner you complete it, the more chances you have to win!
*T&C's Apply
Visit www.srcentre.com.au/qilt/sestcs
for more information
SES
student experience survey

Abstract Data Objects and Types

Abstract Data Types

A data type is …

- a set of values (atomic or structured values) e.g. *integer stacks*
- a collection of operations on those values e.g. *push, pop, isEmpty?*

An abstract data type is …

- an approach to implementing data types
- separates interface from implementation
- users of the ADT see only the interface
- builders of the ADT provide an implementation

Abstract Data Types (cont)

ADT interface provides

- a user-view of the data structure
- function signatures (prototypes) for all operations
- semantics of operations (via documentation)
- ⇒ a "contract" between ADT and its clients

ADT implementation gives

- concrete definition of the data structures
- function implementations for all operations

Abstract Data Types (cont)

ADT interfaces are opaque

- clients *cannot* see the implementation via the interface

ADTs are important because …

- facilitate decomposition of complex programs
- make implementation changes invisible to clients
- improve readability and structuring of software

Abstract Data Types (cont)

Typical operations with ADTs

- create a value of the type
- modify one variable of the type
- combine two values of the type

Collections

Common ADTs …

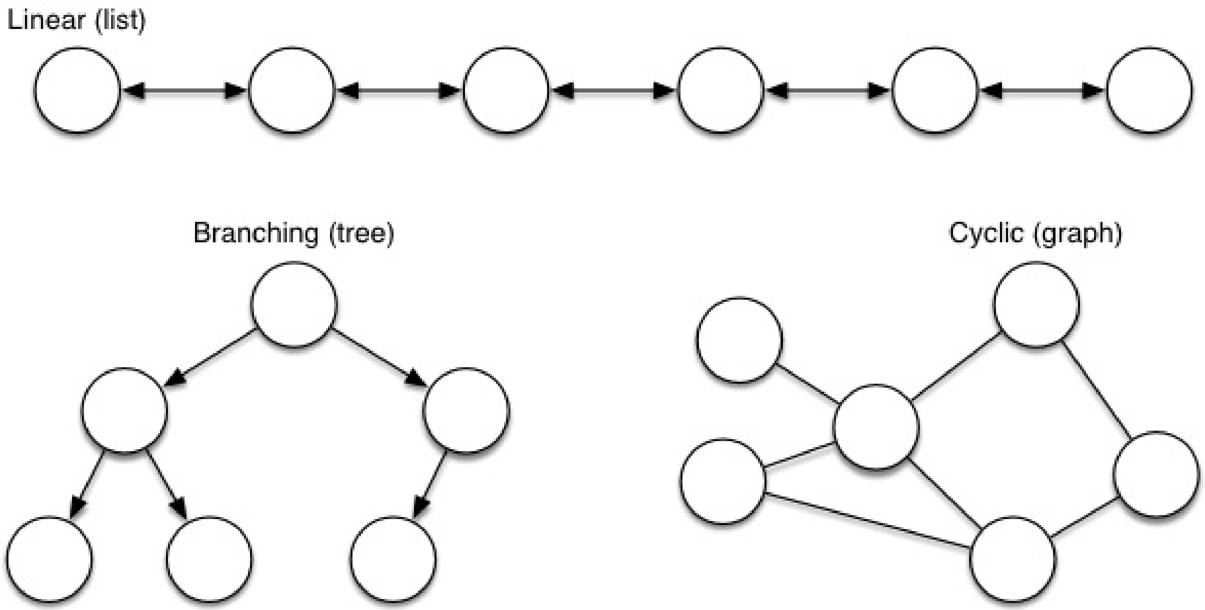
- consist of a collection of items
- where each item may be a simple type or an ADT
- and items often have a key (to identify them)

Collections may be categorised by …

- structure:
  linear (array, linked list), branching (tree), cyclic (graph)
- usage:
  matrix, stack, queue, set, search-tree, dictionary, map, …

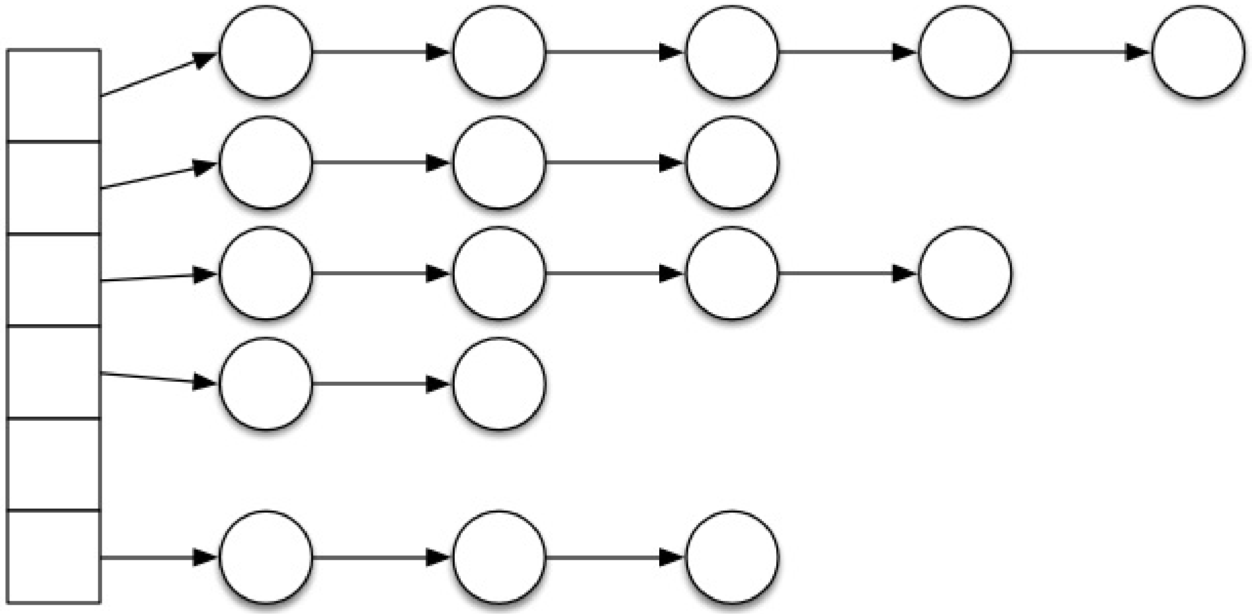
Collections (cont)

Collection structures:



Collections (cont)

Or even a hybrid structure like:



Collections (cont)

For a given collection type

- many different data representations are possible

For a given operation and data representation

- several different algorithms are possible
- efficiency of algorithms may vary widely

Generally,

- there is no overall "best" representation/implementation
- cost depends on the mix of operations
  (e.g. proportion of inserts, searches, deletions, …)

ADOs and ADTs

We want to distinguish …

- ADO = abstract data object
- ADT = abstract data type

Warning: Sedgewick's first few examples are ADOs, not ADTs.

Example: Abstract Stack Data Object

Stack, aka pushdown stack or LIFO data structure

Assume (for the time being) stacks of **`char`** values

Operations:

- create an empty stack
- insert (push) an item onto stack
- remove (pop) most recently pushed item
- check whether stack is empty

Example: Abstract Stack Data Object (cont)

Example of use:

Stack	Operation	Return value
?	create	-
-	push a	-
a	push b	-
a b	push c	-
a b c	pop	c
a b	isempty	false

Exercise #1: Stack vs Queue

Consider the previous example but with a queue instead of a stack.

Which element would have been taken out ("dequeued") first?

a

Stack as ADO

Interface (a file named **`Stack.h`**)

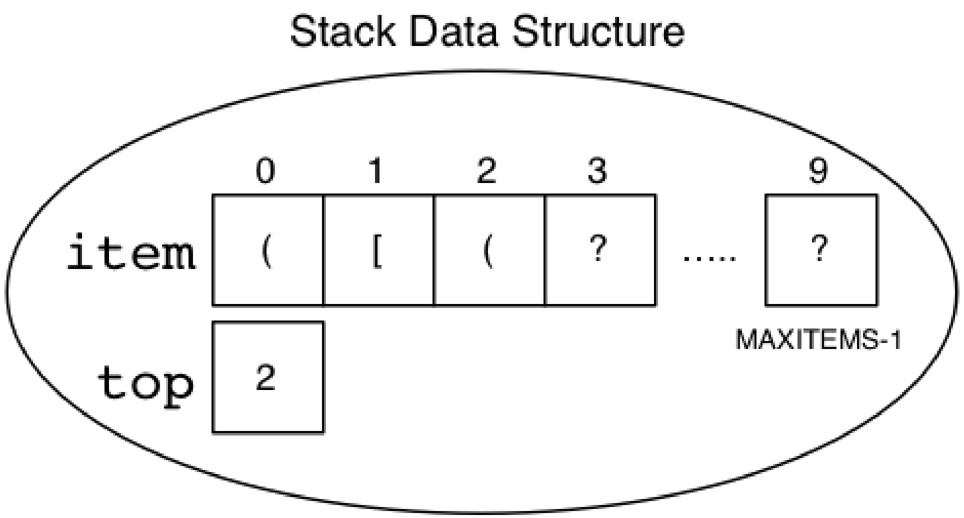
```
// Stack ADO header file

void StackInit();          // set up empty stack
int  StackIsEmpty();       // check whether stack is empty
void StackPush(char);      // insert char on top of stack
char StackPop();           // remove char from top of stack
```

Note:

- no explicit reference to Stack object
- this makes it an Abstract Data Object (ADO)

Stack as ADO (cont)

Implementation may use the following data structure:



Stack as ADO (cont)

Sidetrack: Character I/O Functions in C (requires **<stdio.h>**)

```
int getchar(void);
```

- returns character read from standard input as an **`int`**, or returns **`EOF`** on end of file

```
int putchar(int ch);
```

- writes the character **`ch`** to standard output
- returns the character written, or **`EOF`** on error

Both functions do automatic type conversion

- **`putchar('A')`** has the same effect as **`putchar((int)'A')`** (explicit type conversion)

Stack as ADO (cont)

Implementation (in a file named **`Stack.c`**):

```
#include "Stack.h"
#include <assert.h>

#define MAXITEMS 10
static struct {
   char item[MAXITEMS];
   int  top;
} stackObject;  // defines the Data Object

// set up empty stack
void StackInit() {
   stackObject.top = -1;
}

// check whether stack is empty
int StackIsEmpty() {
   return (stackObject.top < 0);
}
```

```
// insert char on top of stack
void StackPush(char ch) {
   assert(stackObject.top < MAXITEMS-1);
   stackObject.top++;
   int i = stackObject.top;
   stackObject.item[i] = ch;
}

// remove char from top of stack
char StackPop() {
   assert(stackObject.top > -1);
   int i = stackObject.top;
   char ch = stackObject.item[i];
   stackObject.top--;
   return ch;
}
```

`assert(`*`test`*`)` terminates program with error message if *test* fails.

Exercise #2: Bracket Matching

Bracket matching … check whether all opening brackets such as '(', '[', '{' have matching closing brackets ')', ']', '}'

Which of the following expressions are balanced?

1. **`(a+b) * c`**
2. **`a[i]+b[j]*c[k])`**
3. **`(a[i]+b[j])*c[k]`**
4. **`a(a+b]*c`**
5. **`void f(char a[], int n) {int i; for(i=0;i<n;i++) { a[i] = (a[i]*a[i])*(i+1); }}`**
6. **`a(a+b * c`**

1. balanced
2. not balanced (case 1: an opening bracket is missing)
3. balanced
4. not balanced (case 2: closing bracket doesn't match opening bracket)
5. balanced
6. not balanced (case 3: missing closing bracket)

Stack as ADO (cont)

Bracket matching algorithm, to be implemented as a *client* for Stack ADO:

```
#include "Stack.h"

bracketMatching(s):
|  Input  stream s of characters
|  Output TRUE if parentheses in s balanced, FALSE otherwise
|
|  for each ch in s do
|  |  if ch = open bracket then
|  |     push ch onto stack
|  |  else if ch = closing bracket then
|  |  |  if stack is empty then
|  |  |     return FALSE                           // opening bracket missing (case 1)
|  |  |  else
|  |  |     pop top of stack
|  |  |     if brackets do not match then
|  |  |        return FALSE                        // wrong closing bracket (case 2)
|  |  |     end if
|  |  |  end if
|  |  end if
|  end for
|  if stack is not empty then return FALSE  // some brackets unmatched (case 3)
|                        else return TRUE
```

Stack as ADO (cont)

Execution trace of client on sample input:

([{ }])

Next char	Stack	Check
-	empty	-
(	(	-
[	([	-
{	([{	-
}	([	{ vs } ✓
]	(	[vs] ✓
)	empty	(vs) ✓
eof	empty	-

Exercise #3: Bracket Matching Algorithm

Trace the algorithm on the input

```
void f(char a[], int n) {
    int i;
    for(i=0;i<n;i++) { a[i] = a[i]*a[i])*(i+1); }
}
```

Next bracket	Stack	Check
start	empty	-
(	(	-
[	([	-
]	(	✓
)	empty	✓
{	{	-
(	{ (	-
)	{	✓
{	{ {	-
[	{ { [	-
]	{ {	✓
[	{ { [	-
]	{ {	✓
[	{ { [	-
]	{ {	✓
)	{	FALSE

Compilation and Makefiles

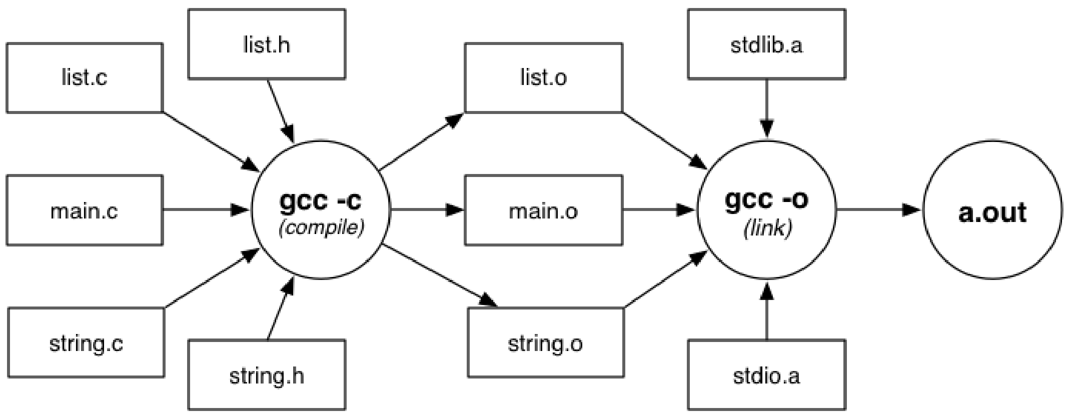
Compilers

Compilers are programs that

- convert program source code to executable form
- "executable" might be machine code or bytecode

The Gnu C compiler (**`gcc`**)

- applies source-to-source transformation (pre-processor)
- compiles *source code* to produce *object files*
- links object files and *libraries* to produce *executables*



Compilers (cont)

Compilation/linking with **`gcc`**

```
gcc -c Stack.c
produces Stack.o, from Stack.c and Stack.h
gcc -c bracket.c
produces bracket.o, from bracket.c and Stack.h
gcc -o rbt bracket.o Stack.o
links bracket.o, Stack.o and libraries
producing executable program called rbt
```

Note that **`stdio,assert`** included implicitly.

`gcc` is a multi-purpose tool

- compiles (**`-c`**), links, makes executables (**`-o`**)

Make/Makefiles

Compilation process is complex for large systems.

How much to compile?

- ideally, what's changed since last compile
- practically, recompile everything, to be sure

The **`make`** command assists by allowing

- programmers to document dependencies in code
- minimal re-compilation, based on dependencies

Make/Makefiles (cont)

Example multi-module program …

main.c

```
#include <stdio.h>
#include "world.h"
#include "graphics.h"

int main(void)
{
    ...
    drawPlayer(p);

    spin(...);
}
```

world.h

```
typedef ... Ob;
typedef ... Pl;

extern addObject(Ob);
extern remObject(Ob);
extern movePlayer(Pl);
```

world.c

```
#include <stdlib.h>

addObject(...)
{ ... }

remObject(...)
{ ... }

movePlayer(...)
{ ... }
```

graphics.h

```
extern drawObject(Ob);
extern drawPlayer(Pl);
extern spin(...);
```

graphics.c

```
#include <stdio.h>
#include "world.h"

drawObject(Ob o);
{ ... }

drawPlayer(Pl p)
{ ... }

spin(...)
{ ... }
```

Make/Makefiles (cont)

`make` is driven by dependencies given in a **`Makefile`**

A dependency specifies

```
target : source1 source2 …
        commands to build target from sources
```

e.g.

```
game : main.o graphics.o world.o
 gcc -o game main.o graphics.o world.o
```

Rule: *target* is rebuilt if older than any $source_i$

Make/Makefiles (cont)

A **`Makefile`** for the example program:

```
game : main.o graphics.o world.o
	gcc -o game main.o graphics.o world.o

main.o : main.c graphics.h world.h
	gcc -Wall -Werror -c main.c

graphics.o : graphics.c world.h
	gcc -Wall -Werror -c graphics.c

world.o : world.c
	gcc -Wall -Werror -c world.c
```

Things to note:

- A target (**`game`**, **`main.o`**, …) is on a newline
  - followed by a **`:`**
  - then followed by the files that the target is dependent on
- The action (**`gcc …`**) is always on a newline
  - and must be indented with a TAB

Make/Makefiles (cont)

If **`make`** arguments are targets, build just those targets:

```
prompt$ make world.o
gcc -Wall -Werror -c world.c
```

If no args, build first target in the **`Makefile`**.

```
prompt$ make
gcc -Wall -Werror -c main.c
gcc -Wall -Werror -c graphics.c
gcc -Wall -Werror -c world.c
gcc -o game main.o graphics.o world.o
```

Exercise #4: Makefile

Write a **`Makefile`** for the bracket matching program.

From ADOs to ADTs

Abstract Data Objects

- **`Stack.c`** provides a single abstract object **`stackObject`**

Abstract Data Types

- allow clients to create and manipulate arbitrarily many data objects of an abstract type
- … without revealing the implementation to a client

In C, ADTs are implemented using pointers and dynamic memory allocation

Pointers

Sidetrack: Numeral Systems

Numeral system … system for representing numbers using digits or other symbols.

- Most cultures have developed a decimal system (based on 10)
- For computers it is convenient to use a binary (base 2) or a hexadecimal (base 16) system

Sidetrack: Numeral Systems (cont)

Decimal representation

- The base is 10; digits 0 - 9
- Example: decimal number 4705 can be interpreted as

$$4 \cdot 10^3 + 7 \cdot 10^2 + 0 \cdot 10^1 + 5 \cdot 10^0$$

- Place values:

…	1000	100	10	1
…	10^3	10^2	10^1	10^0

- Write number as 4705_{10}
    - Note use of subscript to denote base

Sidetrack: Numeral Systems (cont)

Binary representation

- The base is 2; digits 0 and 1
- Example: binary number 1011 can be interpreted as

$$1 \cdot 2^3 + 0 \cdot 2^2 + 1 \cdot 2^1 + 1 \cdot 2^0$$

- Place values:

…	8	4	2	1
…	2^3	2^2	2^1	2^0

- Write number as 1011_2 $(= 11_{10})$

Sidetrack: Numeral Systems (cont)

Hexadecimal representation

- The base is 16; digits 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F
- Example: hexadecimal number 3AF1 can be interpreted as

$$3\cdot 16^3 + 10\cdot 16^2 + 15\cdot 16^1 + 1\cdot 16^0$$

- Place values:

…	4096	256	16	1
…	16^3	16^2	16^1	16^0

- Write number as $3AF1_{16}$ (= 15089_{10})

Exercise #5: Conversion Between Different Numeral Systems

1. Convert $\mathbf{101011}_2$ to base 10
2. Convert $\mathbf{74}_{10}$ to base 2
3. Convert $\mathbf{2D}_{16}$ to base 10
4. Convert $\mathbf{273}_{10}$ to base 16

1. 43_{10}
2. 1001010_2
3. 45_{10}
4. 111_{16}

Sidetrack: Numeral Systems (cont)

Conversion between binary and hexadecimal

0	1	2	3	4	5	6	7
0000	0001	0010	0011	0100	0101	0110	0111
8	9	A	B	C	D	E	F
1000	1001	1010	1011	1100	1101	1110	1111

- Binary to hexadecimal
  - Collect bits into groups of four starting from right to left
  - "pad" out left-hand side with 0's if necessary
  - Convert each group of four bits into its equivalent hexadecimal representation (given in table above)
- Hexadecimal to binary
  - Reverse the previous process
  - Convert each hex digit into equivalent 4-bit binary representation

Exercise #6: Conversion Between Binary and Hexadecimal

1. Convert **1011111000101001**$_2$ to base 16
   - Hint: **1011111000101001**
2. Convert **10111101011100**$_2$ to base 16
   - Hint: **10111101011100**
3. Convert **12D**$_{16}$ to base 2

1. $\mathbf{BE29}_{16}$
2. $\mathbf{2F5C}_{16}$
3. $\mathbf{100101101}_2$

Memory

Computer memory … large array of consecutive data cells or bytes

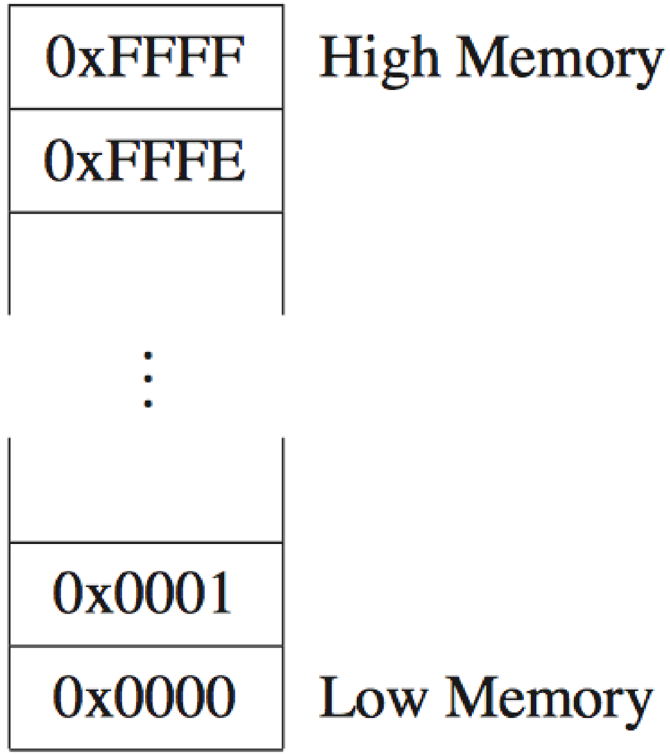
- **`char`** … 1 byte **`int,float`** … 4 bytes
  `double` … 8 bytes

When a variable is declared, the operating system finds a place in memory to store the appropriate number of bytes.

If we declare a variable called **`k`** …

- the place where **`k`** is stored is denoted by **`&k`**
- also called the address of k

It is convenient to print memory addresses in Hexadecimal notation



Memory (cont)

Example:

```
int k;
int m;

printf("address of k is %p\n", &k);
printf("address of m is %p\n", &m);
```

```
address of k is BFFFFB80
address of m is BFFFFB84
```

This means that

- **`k`** occupies the four bytes from **`BFFFFB80`** to **`BFFFFB83`**
- **`m`** occupies the four bytes from **`BFFFFB84`** to **`BFFFFB87`**

Note the use of **`%p`** as placeholder for an address ("pointer" value)

Memory (cont)

When an array is declared, the elements of the array are guaranteed to be stored in consecutive memory locations:

```
int array[5];

for (i = 0; i < 5; i++) {
   printf("address of array[%d] is %p\n", i, &array[i]);
}
```

```
address of array[0] is BFFFFB60
address of array[1] is BFFFFB64
address of array[2] is BFFFFB68
address of array[3] is BFFFFB6C
address of array[4] is BFFFFB70
```

Application: Input Using `scanf()`

Standard I/O function **`scanf()`** requires the address of a variable as argument

- **`scanf()`** uses a format string like **`printf()`**
- use **`%d`** to read an integer value

```
#include <stdio.h>
…
int answer;
printf("Enter your answer: ");
scanf("%d", &answer);
```

- use **`%f`** to read a floating point value (**`%lf`** for **`double`**)

```
float e;
printf("Enter e: ");
scanf("%f", &e);
```

- **`scanf()`** returns a value — the number of items read
  - use this value to determine if **`scanf()`** successfully read a number
    - **`scanf()`** could fail e.g. if the user enters letters

Exercise #7: Using `scanf`

Write a program that

- asks the user for a number
- checks that it is positive
- applies Collatz's process (Exercise 4, Problem Set 1) to the number

Pointers

A pointer …

- is a special type of variable
- storing the address (memory location) of another variable

A pointer occupies space in memory, just like any other variable of a certain type

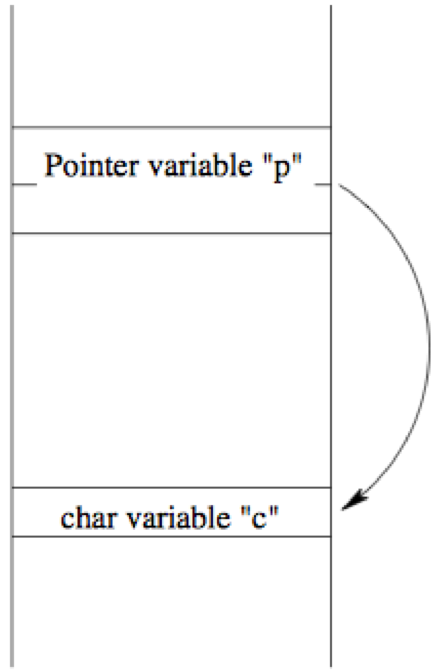
The number of memory cells needed for a pointer depends on the computer's architecture:

- Old computer, or hand-held device with only 64KB of addressable memory:
  - 2 memory cells (i.e. 16 bits) to hold any address from **`0x0000`** to **`0xFFFF`** (= 65535)
- Desktop machine with 4GB of addressable memory
  - 4 memory cells (i.e. 32 bits) to hold any address from **`0x00000000`** to **`0xFFFFFFFF`** (= 4294967295)
- Modern 64-bit computer
  - 8 memory cells (can address 2^{64} bytes, but in practice the amount of memory is limited by the CPU)

Pointers (cont)

Suppose we have a pointer **p** that "points to" a **char** variable **c**.

Assuming that the pointer **p** requires 2 bytes to store the address of **c**, here is what the memory map might look like:



Pointers (cont)

Now that we have assigned to p the address of variable **`c`** …

- need to be able to reference the data in that memory location

Operator `*` is used to access the object the pointer points to

- e.g. to change the value of **`c`** using the pointer **`p`**:

```
*p = 'T';   // sets the value of c to 'T'
```

The `*` operator is sometimes described as "dereferencing" the pointer, to access the underlying variable

Pointers (cont)

Things to note:

- all pointers constrained to point to a particular type of object

```
// a potential pointer to any object of type char
char *s;

// a potential pointer to any object of type int
int *p;
```

- if pointer **`p`** is pointing to an integer variable **`x`**
  ⇒ **`*p`** can occur in any context that **`x`** could

Examples of Pointers

```
int *p; int *q; // this is how pointers are declared
int a[5];
int x = 10, y;

 p = &x;        // p now points to x
*p = 20;        // whatever p points to is now equal to 20
 y = *p;        // y is now equal to whatever p points to
 p = &a[2];     // p points to an element of array a[]
 q = p;         // q and p now point to the same thing
```

Exercise #8: Pointers

What is the output of the following program?

```
#include <stdio.h>

int main(void) {
    int *ptr1, *ptr2;
    int i = 10, j = 20;

    ptr1 = &i;
    ptr2 = &j;

    *ptr1 = *ptr1 + *ptr2;
    ptr2 = ptr1;
    *ptr2 = 2 * (*ptr2);
    printf("Val = %d\n", *ptr1 + *ptr2);
    return 0;
}
```

Val = 120

Examples of Pointers (cont)

Can we write a function to "swap" two variables?

The wrong way:

```
void swap(int a, int b) {
   int temp = a;                         // only local "copies" of a and b will swap
   a = b;
   b = temp;
}

int main(void) {
   int a = 5, b = 7;
   swap(a, b);
   printf("a = %d, b = %d\n", a, b); // a and b still have their original values
   return 0;
}
```

Examples of Pointers (cont)

In C, parameters are "call-by-value"

- changes made to the value of a parameter do not affect the original
- function **`swap()`** tries to swap the values of **`a`** and **`b`**, but fails because it only swaps the copies, not the "real" variables in **`main()`**

We can achieve "simulated call-by-reference" by passing pointers as parameters

- this allows the function to change the "actual" value of the variables

Examples of Pointers (cont)

Can we write a function to "swap" two variables?

The right way:

```
void swap(int *p, int *q) {
   int temp = *p;                    // change the actual values of a and b
   *p = *q;
   *q = temp;
}

int main(void) {
   int a = 5, b = 7;
   swap(&a, &b);
   printf("a = %d, b = %d\n", a, b);  // a and b now successfully swapped
   return 0;
}
```

Pointers and Arrays

An alternative approach to iteration through an array:

- determine the address of the first element in the array
- determine the address of the last element in the array
- set a pointer variable to refer to the first element
- use pointer arithmetic to move from element to element
- terminate loop when address exceeds that of last element

Example:

```
int a[6];
int *p = &a[0];
while (p <= &a[5]) {
    printf("%2d ", *p);
    p++;
}
```

Pointers and Arrays (cont)

Pointer-based scan written in more typical style

address of first element

address of last element + 1

```
int *p;
int a[6];
for (p = &a[0]; p < &a[6]; p++)
     printf("%2d ", *p);
```

pointer arithmetic

(move to next element)

access current element

Note: because of pointer/array connection `a[i] == *(a+i)`

Sidetrack: Pointer Arithmetic

A pointer variable holds a value which is an address.

C knows what type of object is being pointed to

- it knows the **`sizeof`** that object
- it can compute where the next/previous object is located

Example:

```
int a[6];     // address 0x1000
int *p;
p = &a[0];    // p contains 0x1000
p = p + 1;    // p now contains 0x1004
```

Sidetrack: Pointer Arithmetic (cont)

For a pointer declared as **`T *p;`** (where **`T`** is a type)

- if the pointer initially contains address **`A`**
  - executing **`p = p + k;`** (where **`k`** is a constant)
    - changes the value in **`p`** to **`A + k*sizeof(T)`**

The value of **`k`** can be positive or negative.

Example:

```
int a[6];      (addr 0x1000)        char s[10];    (addr 0x2000)
int *p;        (p == ?)             char *q;       (q == ?)
p = &a[0];     (p == 0x1000)        q = &s[0];     (q == 0x2000)
p = p + 2;     (p == 0x1008)        q++;           (q == 0x2001)
```

Arrays of Strings

One common type of pointer/array combination are the command line arguments

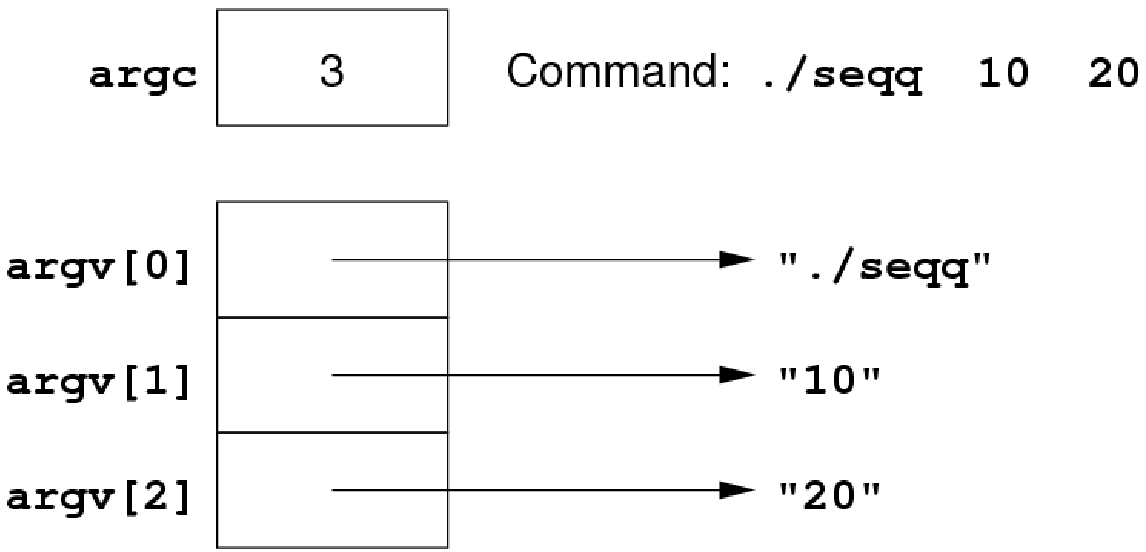
- These are 0 or more strings specified when program is run
- If you run this command in a terminal:

```
prompt$ ./seqq 10 20
```

then **`seqq`** will be given 2 command-line arguments: **`"10", "20"`**

Arrays of Strings (cont)

```
prompt$ ./seqq 10 20
```



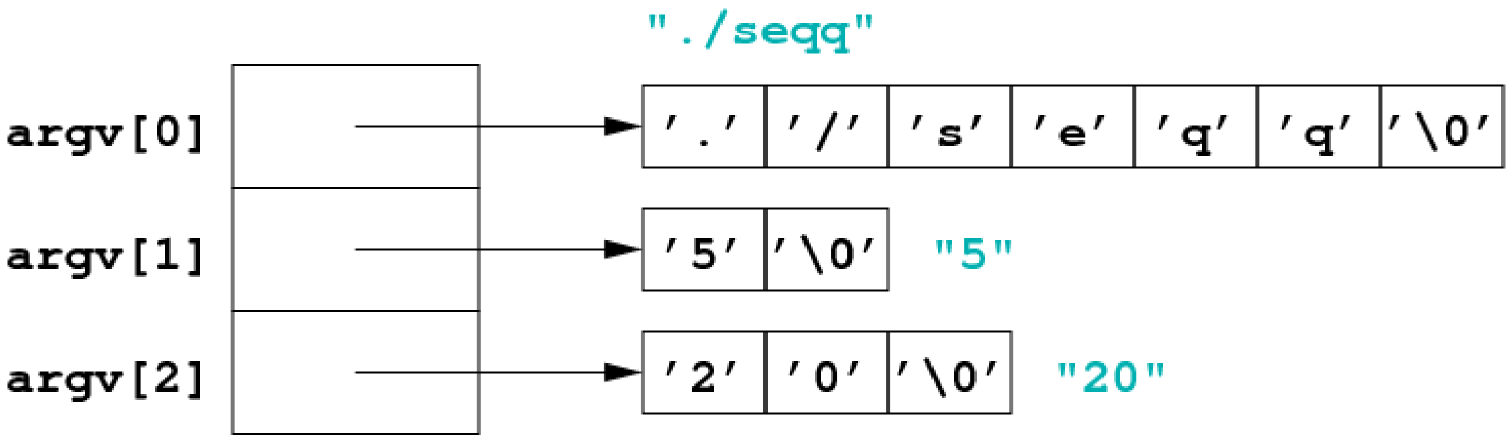
Each element of **`argv[]`** is

- a pointer to the start of a character array (**`char *`**)
  - containing a **`\0`**-terminated string

Arrays of Strings (cont)

More detail on how **`argv`** is represented:

```
prompt$ ./seqq 5 20
```



Arrays of Strings (cont)

main() needs different prototype if you want to access command-line arguments:

```
int main(int argc, char *argv[]) { ...
```

- **argc** … stores the number of command-line arguments + 1
  - **argc == 1** if no command-line arguments
- **argv[]** … stores program name + command-line arguments
  - **argv[0]** always contains the program name
  - **argv[1],argv[2],…** are the command-line arguments if supplied

<stdlib.h> defines useful functions to convert strings:

- **atoi(char *s)** converts string to int
- **atof(char *s)** converts string to double (can also be assigned to **float** variable)

Exercise #9: Command Line Arguments

Write a program that

- checks for a single command line argument
    - if not, outputs a usage message and exits with failure
- converts this argument to a number and checks that it is positive
- applies Collatz's process (Exercise 4, Problem Set 1) to the number

```
#include <stdio.h>
#include <stdlib.h>

void collatz(int n) {
   printf("%d\n", n);
   while (n != 1) {
      if (n % 2 == 0)
  n = n / 2;
      else
  n = 3*n + 1;
      printf("%d\n", n);
   }
}

int main(int argc, char *argv[]) {
   if (argc != 2) {
      printf("Usage: %s [number]\n", argv[0]);
      return 1;
   }
   int n = atoi(argv[1]);
   if (n > 0)
      collatz(n);
   return 0;
}
```

Arrays of Strings (cont)

`argv` can also be viewed as double pointer (a pointer to a pointer)

⇒ Alternative prototype for **`main()`**:

```
int main(int argc, char **argv) { ...
```

Can still use **`argv[0]`**, **`argv[1]`**, …

Pointers and Structures

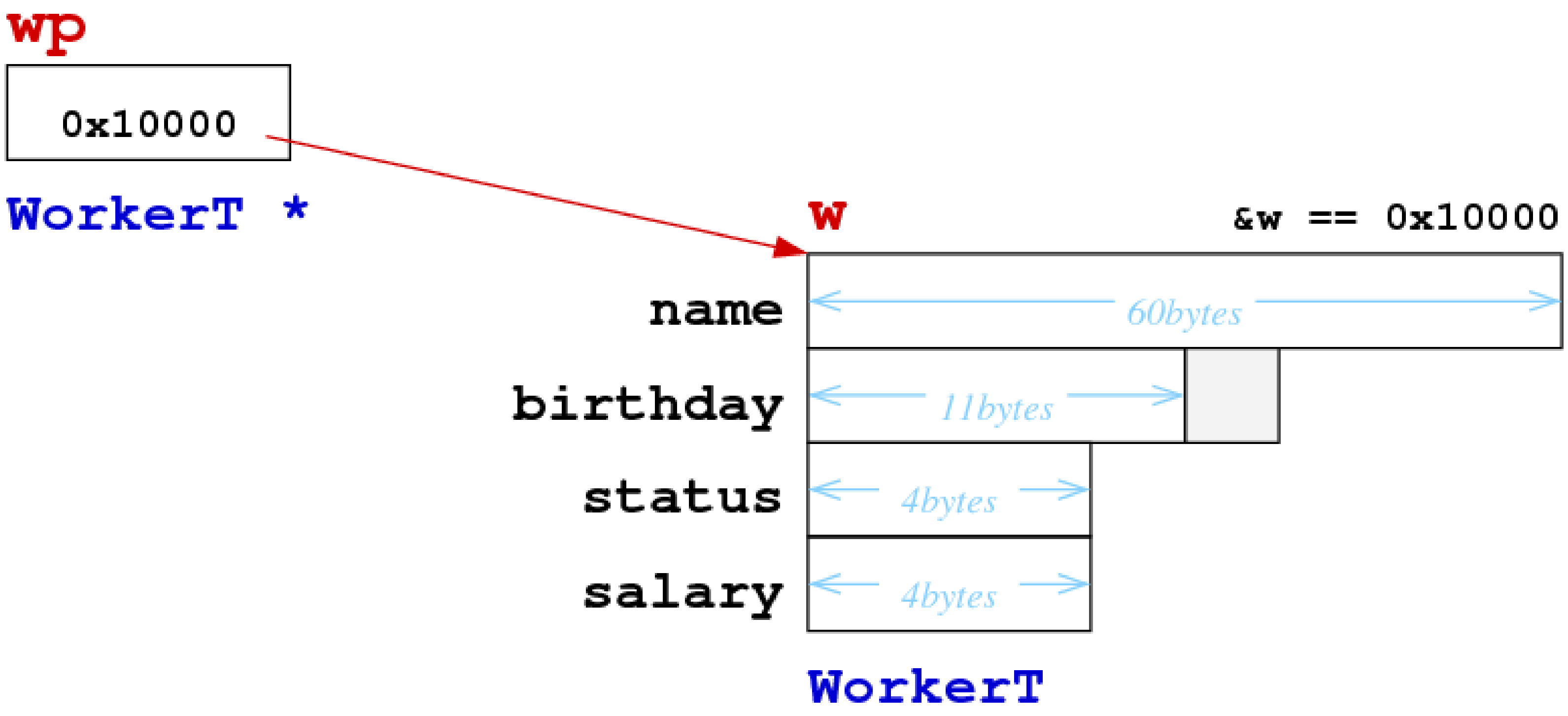
Like any object, we can get the address of a **`struct`** via **`&`**.

```
typedef char Date[11];  // e.g. "03-08-2017"
typedef struct {
    char  name[60];
    Date  birthday;
    int   status;        // e.g. 1 (≡ full time)
    float salary;
} WorkerT;

WorkerT w;  WorkerT *wp;
wp = &w;
// a problem …
*wp.salary = 125000.00;
// does not have the same effect as
w.salary = 125000.00;
// because it is interpreted as
*(wp.salary) = 125000.00;

// to achieve the correct effect, we need
(*wp).salary = 125000.00;
// a simpler alternative is normally used in C
wp->salary = 125000.00;
```

Learn this well; we will frequently use it in this course.

Pointers and Structures (cont)

Diagram of scenario from program above:



Pointers and Structures (cont)

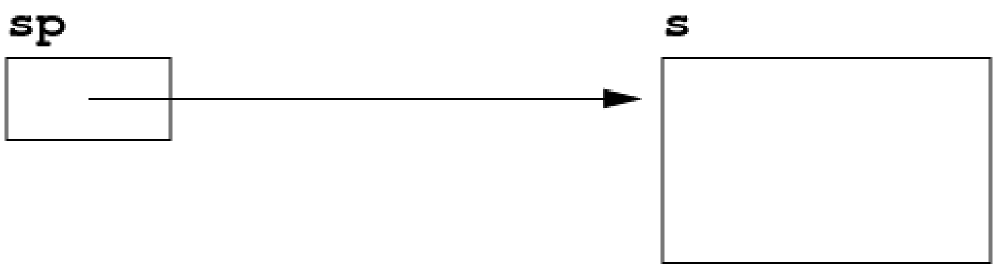
General principle …

If we have:

```
SomeStructType  s,   *sp = &s;
```

then the following are all equivalent:

```
s.SomeElem    sp->SomeElem    (*sp).SomeElem
```



Summary

- Introduction to ADOs and ADTs
- Compilation and `Makefile`s
- Numeral systems
- Pointers

- Suggested reading:
  - introduction to ADTs … Sedgewick, Ch.4.1-4.3
  - pointers … Moffat, Ch.6.6-6.7