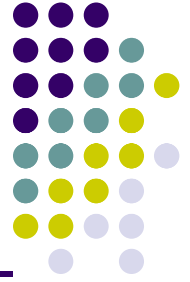
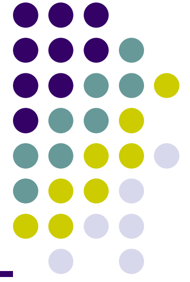


198:211
Computer Architecture

Week 4
Fall 2010

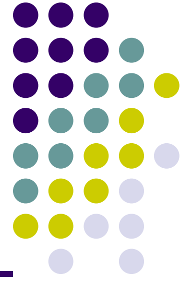
- Topics:
  - Memory Management
  - File I/O

Dynamic Allocation

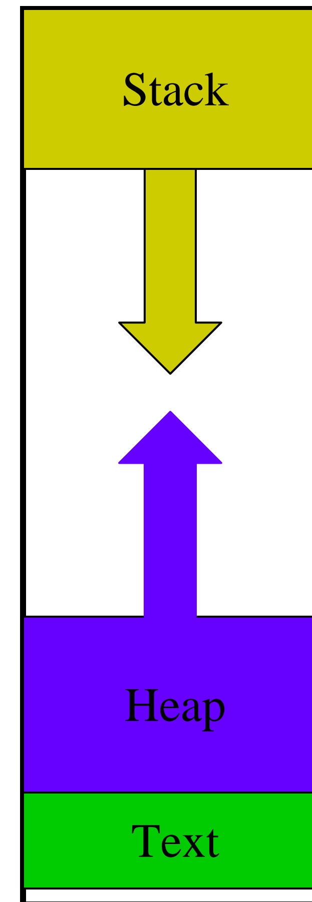


- When a variable is declared, memory is allocated for that variable
  - int i, j;
- What if we don't a priori how may instances of a variable are needed?
- E.g., a variable number of integers – as many as the user wants to enter.
  - We can't allocate an array of integers, because we don't know the maximum number of that might be required.
  - Even if we do know the maximum number,
it might be wasteful to allocate that much memory
because most of the time only a few integers may be needed.
- Solution:
Allocate storage for data dynamically, as needed.

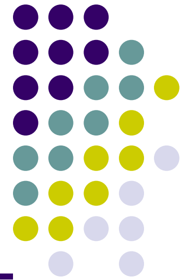
Memory partition



- Stack
  - Local variables on stack; grows and shrinks based on calls
    - dynamic
- Heap
  - Global variables, static constants
  - Dynamic (malloc)



Enter Dynamic Memory



Memory allocated from the stack has a limited life-time.

- What do we do if we want memory that exists outside the “life-time” of functions

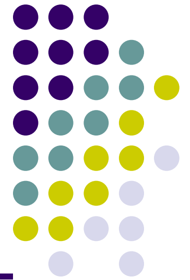
Two ways to “get memory”

- Declare a variable - gets placed on the stack
- Ask the run-time system for a “chunk” of memory

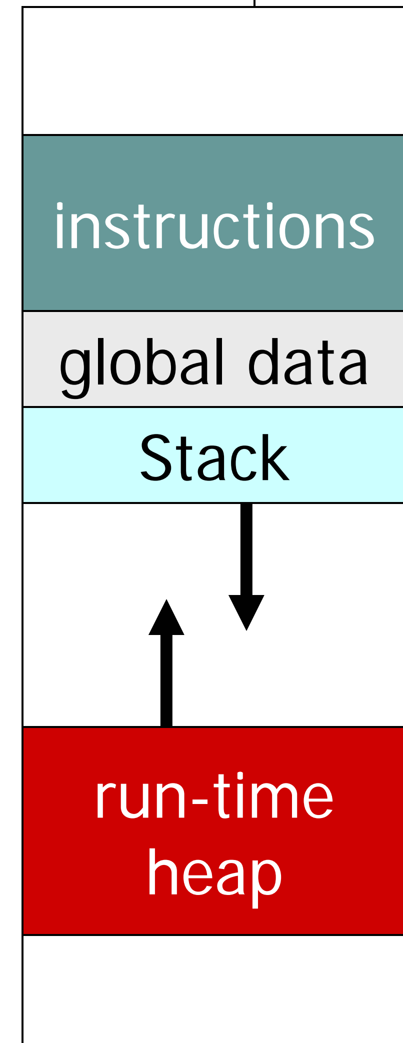
Requests for dynamic chunks of memory performed using a call to the underlying runtime system (a system call).

- Command: malloc and free

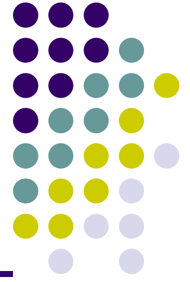
Dynamic Memory or heap



- Dynamic request for memory are honored from heap.
- Memory Management taken care of by the run-time system. Complicated…
- While functions are being called and returning, activations records are being added and removed from the heap.
  - This does NOT effect the heap.
  - Once allocated it will stay there until freed
- Question to ask: why do they grow from different directions?

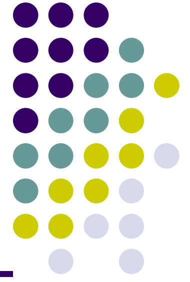


malloc



- The Standard C Library provides a function for allocating memory at run-time: malloc.
- ```
  void *malloc(int numBytes);
  ```
- It returns a generic pointer (`void*`) to a contiguous region of memory of the requested size (in bytes).
- The bytes are allocated from a region in memory called the heap.
  - The run-time system keeps track of chunks of memory from the heap that have been allocated.
  ```

Example 1

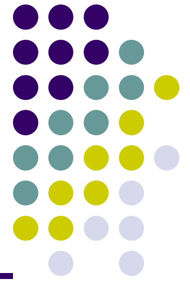


```
#include <stdio.h>
#include <malloc.h>

main(){
    int *base;
    int i,j;
    int cnt=0;
    int sum=0;
    printf("how many integers you have to store \n");
    scanf("%d",&cnt);
                        /* how many integers? */
     base = (int *)malloc(cnt * sizeof(int));

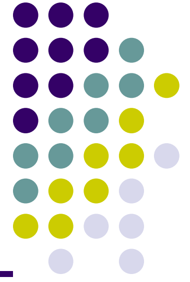
    if(!base)
        printf("unable to allocate size \n");
    else {
        for(j=0;j<cnt;j++)
           *(base+j)=5;
    }
}
```

Using malloc



- To use malloc, we need to know how many bytes to allocate. The `sizeof` operator is used to calculate the size of a particular type.
- ```
  planes = malloc(n * sizeof(Flight));
  ```
- We also need to change the type of the return value to the proper kind of pointer – this is called "casting."
- ```
  planes =
     (Flight *) malloc(n* sizeof(Flight));
  ```

Example 2



```
•int airbornePlanes;
Flight *planes;

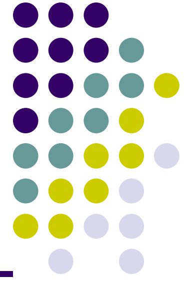
printf("How many planes are in the air?");
scanf("%d", &airbornePlanes);

planes =
  (Flight*) malloc(sizeof(Flight) *
              airbornePlanes);
if (planes == NULL) {
  fprintf(stderr, "Error in allocating the
data array.\n");
  ...
}
planes[0].altitude = ...
```

If allocation fails, malloc returns NULL.

Note: Can use array notation or pointer notation.

free

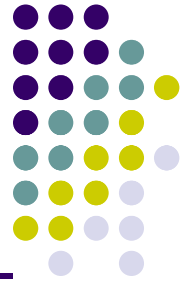


- Once the data is no longer needed, it should be released back into the heap for later use.

- This is done using the free function, passing it the same address that was returned by malloc.
- `void free(void*);`
- `free(base);  /* in example 1 */`

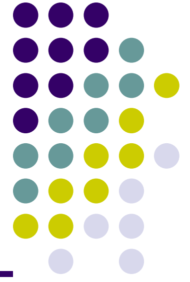
- If allocated data is not freed, the program might run out of
  heap memory and will be unable to continue.

Command Line Arguments



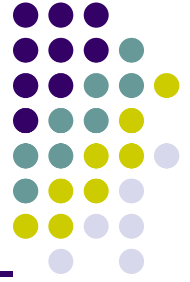
- You can use the command line to provide input to your programs.
- `int main( int argc, char * argv [] ){`
- …
- `}`
- `argc` - the number of arguments (including program name)
- `argv` - point to array of char arrays (strings)

Command Line (example)



```
• int main(int argc, char * argv []){
•     int i;
•     printf("%d arguments\n", argc);
•     for(i=0; i<argc; i++)
•          printf("\t%d: %s\n", i, argv[i]);
•     return 0;
• }
```

File I/O

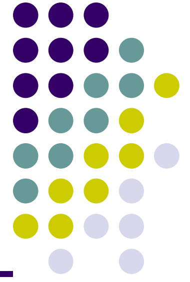


- For our purposes, a file is a sequence of ASCII characters stored on some device.
  - Allows us to process large amounts of data without having to type it in each time or read it all on the screen as it scrolls by.
- Each file is associated with a stream.
  - May be input stream or output stream (or both!).
- The type of a stream is a "file pointer", declared as:

```
FILE *infile;
```

- The `FILE` type is defined in <stdio.h>.

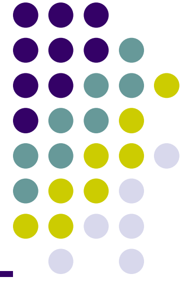
example



- #include<stdio.h>

```
void main(){
    FILE *fp;
    fp = fopen(“PA1.ANS",“w");
    fprintf(fp,"%s %d\n",“OBAMA",44);
    fclose(fp) ;
}
```

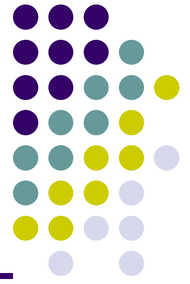
fopen



- The fopen **(pronounced "eff-open")** function associates a physical file with a stream.
- `FILE *fopen(char* name, char* mode);`

- First argument: `name`
  - The name of the physical file, or how to locate it on the storage device. This may be dependent on the underlying operating system.
- Second argument: `mode`
  - How the file will be used:
    `"r"` -- read from the file
    `"w"` -- write, starting at the beginning of the file
    `"a"` -- write, starting at the end of the file (append)

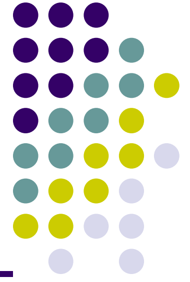
fprintf and fscanf



- Once a file is opened, it can be read or written using `fscanf()` and `fprintf()`, respectively.

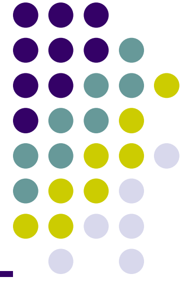
- These are just like `scanf()` and `printf()`, except an additional argument specifies a file pointer.
- FILE * fpout; fpin;
- fpout = fopen(“PA1.out”, “w”);
- `fprintf(fpout, "The answer is %d\n", x);`
- fpin = fopen(“PA1.in”, “r”);
-
```
fscanf(fpin, "%s %d/%d/%d %lf\n",
     name, &bMonth, &bDay, &bYear, &gpa);
```

A String is an Array of Characters



- Allocate space for a string just like any other array:
- ```
  char outputString[16];
  ```
- Space for string must contain room for terminating zero (i.e. '\0')
- Special syntax for initializing a string:
- ```
  char outputString[16] = "Result = ";
  ```
- …which is the same as:
- ```
  outputString[0] = 'R';
  outputString[1] = 'e';
  outputString[2] = 's';
  ...
  ```
  ```

I/O with Strings

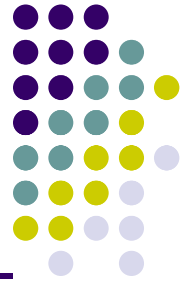


- printf and scanf use "%s" format character for string

- printf -- print characters up to terminating zero
- `printf("%s", outputString);`
- scanf -- read characters until whitespace,
  store result in string, and terminate with zero
- `scanf("%s", inputString);`

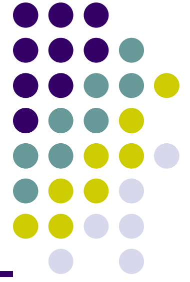
```
char outputString[16] = "Result =";
printf("Length: %d\n", strlen(outputString));
printf("Length: %d\n", sizeof(outputString));
```

Useful functions for Strings



- Useful string related functions in `string.h`
- `char * strcpy(ct, cs)` Copy string `cs` to `ct`
  - `char * ct, cs`
- `int strcmp(str1, str2)` Compare string str1 to str2
  - `char * str1, str2`
  - A zero value indicates that both strings are equal. A value greater than zero indicates that the first character that does not match has a greater value in *str1* than in *str2*; And a value less than zero indicates the opposite.
- `size_t strlen(ls)` Returns length of ls
  - `char * ls`

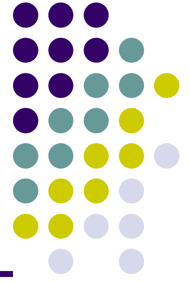
Standard C Library



- I/O commands are not included as part of the C language.
- Instead, they are part of the Standard C Library.
  - A collection of functions and macros that must be implemented by any ANSI standard implementation.
  - Automatically linked with every executable.
  - Implementation depends on processor, operating system, etc., but interface is standard.

- Since they are not part of the language, compiler must be told about function interfaces. Standard header files are provided, which contain declarations of functions, variables, etc.

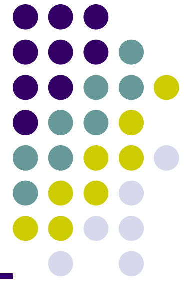
Basic I/O Functions



- The standard I/O functions are declared in the <stdio.h> header file.

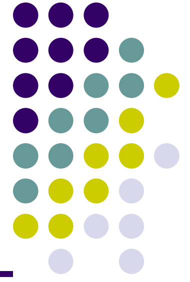
Function	*Description*
`putchar`	Displays an ASCII character to the screen.
`getchar`	Reads an ASCII character from the keyboard.
`printf`	Displays a formatted string,
`scanf`	Reads a formatted string.
`fopen`	Open/create a file for I/O.
`fprintf`	Writes a formatted string to a file.
`fscanf`	Reads a formatted string from a file.

Text Streams



- All character-based I/O in C is performed on text streams.
- A stream is a sequence of ASCII characters, such as:
  - the sequence of ASCII characters printed to the monitor by a single program
  - the sequence of ASCII characters entered by the user during a single program
  - the sequence of ASCII characters in a single file
- Characters are processed in the order in which they were added to the stream.
  - E.g., a program sees input characters in the same order as the user typed them.
- Standard input stream (keyboard) is called stdin.
- Standard output stream (monitor) is called stdout.
- Standard error output stream (monitor) is called stderr.

Character I/O



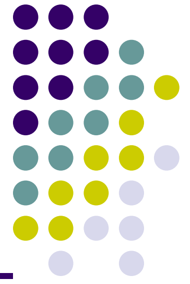
- `putchar(c)` Adds one ASCII character (c) to stdout.
- `getchar()` Reads one ASCII character from stdin.

- These functions deal with "raw" ASCII characters; no type conversion is performed.

```
char c = 'h';
 ...
putchar(c);
putchar('h');
putchar(104);
```

Each of these calls prints 'h' to the screen.

Buffered I/O

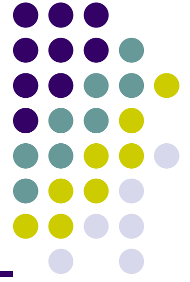


- In many systems, characters are buffered in memory during an I/O operation.
  - Conceptually, each I/O stream has its own buffer.

- Keyboard input stream
  - Characters are added to the buffer only when the newline character (i.e., the "Enter" key) is pressed.
  - This allows user to correct input before confirming with Enter.

- Output stream
  - Characters are not flushed to the output device until the newline character is added.

Input Buffering



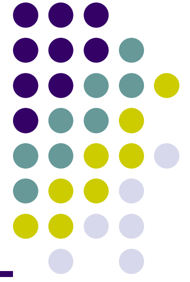
-

```
printf("Input character 1:\n");
inChar1 = getchar();

printf("Input character 2:\n");
inChar2 = getchar();
```

- After seeing the first prompt and typing a single character, nothing happens.
- Expect to see the second prompt, but character not added to stdin until Enter is pressed.
- When Enter is pressed, newline is added to stream and is consumed by second getchar(), so `inChar2` is set to `'\n'`.

Output Buffering



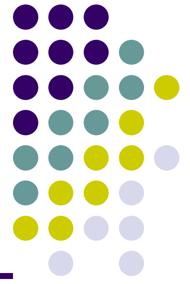
-

```
putchar('a');
/* generate some delay */
for (i=0; i<DELAY; i++) sum += i;

putchar('b');
putchar('\n');
```

- User doesn't see any character output until after the delay.
- `'a'` is added to the stream before the delay, but the stream is not flushed (displayed) until `'\n'` is added.

Formatted I/O

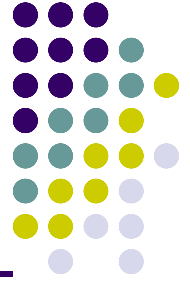


- printf and scanf allow conversion between ASCII representations and internal data types.

- Format string contains text to be read/written, and formatting characters that describe how data is to be read/written.

- `%d` signed decimal integer
  `%f` signed decimal floating-point number
  `%x` unsigned hexadecimal number
  `%c` ASCII character
  `%s` ASCII string

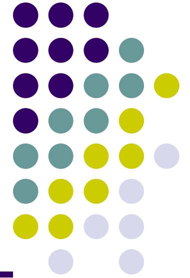
Special Character Literals



- Certain characters cannot be easily represented by a single keystroke, because they
  - correspond to whitespace (newline, tab, backspace, ...)
  - are used as delimiters for other literals (quote, double quote, ...)
- These are represented by the following sequences:

`\n`	newline
`\t`	tab
`\b`	backspace
`\\`	backslash
`\'`	single quote
`\"`	double quote
`\0`*nnn*	ASCII code *nnn* (in octal)
`\x`*nnn*	ASCII code *nnn* (in hex)

printf

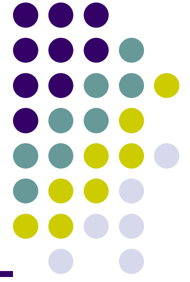


- Prints its first argument (format string) to `stdout` with all formatting characters replaced by the ASCII representation of the corresponding data argument.

```
int a = 100;
int b = 65;
char c = 'z';
char banner[10] = "Hola!";
double pi = 3.14159;

printf("The variable 'a' decimal: %d\n", a);
printf("The variable 'a' hex: %x\n", a);
printf("'a' plus 'b' as character: %c\n", a+b);
printf("A char %c.\t A string %s\n A float %f\n",
       c, banner, pi);
```

scanf

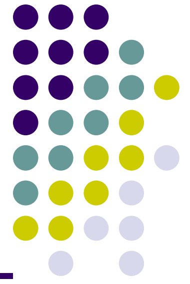


- Reads ASCII characters from `stdin`, matching characters to its first argument (format string), converting character sequences according to any formatting characters, and storing the converted values to the addresses specified by its data pointer arguments.

- ```
  char name[100];
  int bMonth, bDay, bYear;
  double gpa;

  scanf("%s %d/%d/%d %lf",
        name, &bMonth, &bDay, &bYear, &gpa);
  ```
  ```

scanf Conversion

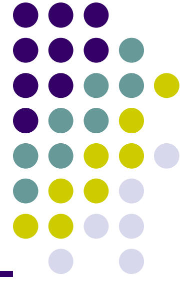


- For each data conversion, scanf will skip whitespace characters and then read ASCII characters until it encounters the first character that should NOT be included in the converted value.

- `%d` Reads until first non-digit.
- `%x` Reads until first non-digit (in hex).
- `%s` Reads until first whitespace character.

- Literals in format string must match literals in the input stream.
- Data arguments must be pointers, because scanf stores the converted value to that memory address.

scanf Return Value



- The scanf function returns an integer, which indicates the number of successful conversions performed.
  - This lets the program check whether the input stream was in the proper format.
- Example:

```
int rv = scanf("%s %d/%d/%d %lf",
                &name, &bMonth, &bDay, &bYear,
&gpa);
```

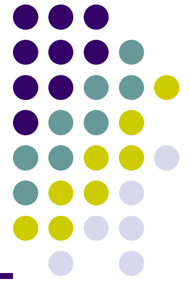
- *Input Stream* *Return Value*

```
Mudd 02/16/69 3.02        5
```

- `Muss 02 16 69 3.02        2`

Doesn't match literal '/', so scanf quits after second conversion.

Bad scanf Arguments



- Two problems with scanf data arguments
- 1. Not a pointer

```
int n = 0;
scanf("%d", n);
```

- Will use the value of the argument as an address.
- 2. Missing data argument

```
scanf("%d");
```

- Will get address from stack, where it expects to find first data argument.

- If you're lucky, program will crash because of trying to modify a restricted memory location (e.g., location 0). Otherwise, your program will just modify an arbitrary memory location, which can cause very unpredictable behavior.