We’ve used built-in types like `int` and `double` as well as the standard class `string` and the streams `cin` and `cout`.

- Each type supports certain operations and has a specific range of values
  - What are these for the types we’ve seen so far?

- We need more than these basic building blocks, why?

- We’ve used void functions to encapsulate concepts/statements with one name, avoid repeated code, help develop programs
  - Functions with parameters are useful
  - We need functions that return values to solve more problems than we’re currently able to solve
Types of control

- **Selection:** choose from among many options according to criteria the programmer codes (from which the user chooses)
  - If response is yes do this, else do that
  - If year is a leap year number of days is 366, else 365
  - If PIN is incorrect three times, keep banking card
  - If 10th caller, we have a winner

- **Repetition/iteration (next chapter), repeatedly execute statements until criteria met**
  - Print twelve months of a calendar
  - Allow three attempts at PIN entry
  - Make moves in game until game is over
Problem solving leads to programming

- Which is the better value, a 10 inch, $10.95 pizza or a 12 inch $15.95 pizza?
  - Details needed to solve the problem (no computer)?
  - What’s missing from programming repertoire?
  - Print two price/sq. in values, let user make conclusions
  - Program should determine best value after calculating

- We need selection (why?) and we’d like a function to return a value for comparison (what’s the function?)

```cpp
if ( PizzaValue(10,10.95) > PizzaValue(12,15.95) )
    cout << "10 inch pizza is better value" << endl;
```
First step, the assignment operator

- **Avoid repeated calculations**

```cpp
void SpherePizza(double radius, double price)
{
    double volume;
    volume = 4.0/3*radius*radius*radius*3.1416;
    double area;
    area = 4*radius*radius*3.1416;
    cout << " area = "   << area         << endl;
    cout << " volume = " << volume       << endl;
    cout << " $/cu.in "  << price/volume << endl;
}
```

- **Assign a value to a variable to give it a value**
  - We have used input stream to enter values for variables
  - Read the assignment operator as *gets*, “area gets ...”
    - Avoids confusion with equality operator we’ll see later
Calculating change (see `change.cpp`)

```cpp
int main()
{
    int amount;
    int quarters, dimes, nickels, pennies;
    cout << "make change in coins for what amount: ";
    cin >> amount;

    quarters = amount/25;
    amount = amount - quarters*25;
    dimes = amount/10;
    amount = amount - dimes*10;
    // more code here, see the full program
}
```

- **How does** `amount = amount - dimes*10` **execute?**
  - Evaluate expression on right hand side of operator =
  - Store value in variable named on left hand side
  - Problem if same variable used on both sides? Why?
    - Differences between reading and writing values
Problems with code in *change.cpp*?

```cpp
// previous code for entering value, doing quarters
dimes = amount/10;
amount = amount - dimes*10;
nickels = amount/5;
amount = amount - nickels*5;
pennies = amount;
cout << "# quarters =\t" << quarters << endl;
cout << "# dimes =\t" << dimes << endl;
cout << "# nickels =\t" << nickels << endl;
cout << "# pennies =\t" << pennies << endl;
```

- What about output statement if there are no quarters?
- What about repeated code?
  - Code maintenance is sometimes more important than code development. Repeated code can cause problems, why?
Control via selection, the if statement

```cpp
void Output(string coin, int amount)
{
    if (amount > 0)
    {
        cout << "# " << coin << " =\t" << amount << endl;
    }
}
int main()
{
    // code for assignment to quarters, dimes, etc
    Output("quarters",quarters);
    Output("dimes",dimes);
    Output("nickels",nickels);
    Output("pennies",pennies);
}
```

- User enters 23 cents, what’s printed? Why?
  - Selection statement determines if code executes; test or guard expression evaluates to true or false (Boolean)
Selection using if/else statement

```cpp
int main()
{
    string name;
    cout << "enter name: ";
    cin >> name;
    if (name == "Oogy")
    {
        cout << "that's a very nice name" << endl;
    } else
    {
        cout << name << " might be a nice name" << endl;
    }
    return 0;
}
```

- What if user enters “oogy” ? or “ Oogy”
- How many statements can be guarded by if or else?
- What other tests/guards can be used (we’ve seen < and ==)
More Operators: Relational

- The guard/test in an if statement must be a Boolean expression (named for George Boole)
  - Values are true and false
  - bool is a built-in type like int, double, but some older compilers don’t support it (very old)

```cpp
int degrees;
bool isHot = false;
cout << "enter temperature: ";
cin >> degrees;
if (degrees > 95) isHot = true; // or below
isHot = degrees > 95;
```

- Relational operators are used in expressions to compare values: <, <=, >, >=, ==, !=, used for many types
  - See Table 4.2 and A.4 for details, precedence, etc.
Details of Relational Operators

- Relational (comparison) operators work as expected with `int` and `double` values, what about `string` and `bool`?
  
  ```
  23 < 45       49.0 >= 7*7       "apple" < "berry"
  ```

- Strings are compared lexicographically (alphabetically) so that "ant" < "zebra" but (surprisingly?) "Ant" < "zebra"
  - How do lengths of strings compare?
  - Why does uppercase ‘A’ come before lowercase ‘z’?
  - (Actually “Ant” < “zebra” doesn’t work, need string)

- Boolean values have numeric equivalents, 1 is true, 0 is false
  ```
  cout << (23 < 45) << endl;
  cout << ("guava" == "Guava") << endl;
  ```
Relational Operators: details, details,…

- Use parentheses liberally, or hard-to-find problems occur
  
  \[
  \text{cout} \ll 23 + 4 < 16 - 2 \ll \text{endl};
  \]
  
  Causes following error using g++, fix using parentheses rather than deciphering:
  
  \[
  \text{invalid operands `int' and `ostream & (ostream &)' to binary `operator <<'}
  \]

- What about true/false and numeric one/zero equivalent?

  \[
  \begin{align*}
  \text{if } (3 + 4 - 7) \\
  \{ \text{cout} \ll \text{"hi"} \ll \text{endl}; \} \\
  \text{else} \\
  \{ \text{cout} \ll \text{"goodbye"} \ll \text{endl}; \}
  \end{align*}
  \]
Logical operators

- **Boolean expressions** can be combined using logical operators: **AND, OR, NOT**
  - C++ equivalents are `&&`, `||`, and `!`, respectively

```cpp
if (90 <= grade)
    {   if (grade < 95)
        {   cout << "that’s an A" << endl;
        }
    }

What range of values generates ‘A’ message? Problems?

```cpp
if (90 <= grade && grade < 95)
    {   cout << "that’s an A" << endl;
    }
```
Short-circuit Evaluation

- Subexpressions in Boolean expressions are not evaluated if the entire expression’s value is already known:

  ```
  if (count != 0 && scores/count < 60)
  {   cout << "low average warning" << endl;
  }
  ```

  Potential problems if there are no grades to average? What happens in this case?

  Alternatives in absence of short-circuit evaluation:

  ```
  if (count != 0)
  {
   if (scores/count < 60)
   {   cout << "low average warning" << endl;
   }
  }
  ```

  Examples when OR short-circuits?
Donald Knuth (b. 1938)

- **Scholar, practitioner, artisan**
  - Has written three of seven+ volumes of *The Art of Computer Programming*
  - Began effort in 1962 to survey entire field, still going

- **Strives to write beautiful programs**
  - Developed TeX to help typeset his books, widely used scientific document processing program

- **Many, many publications**
  - First was in Mad Magazine
  - *On the Complexity of Songs*
  - *Surreal Numbers*
It’s all relative and it depends

I make the best bread in the city

I make the best bread in the world

I make the best bread in the universe

I make the best bread on the block
Functions that return values

- Functions we’ve written so far allow us to decompose a program into conceptual chunks: void functions
  - Each function call is a statement, not used in an expression
    
    ```
    DoThis();
    DoThat();
    Sing("cow", "moo");
    WriteHTMLHeader();
    ```

- Perhaps more useful are functions that return values:
  
  ```
  double hypotenuse = sqrt(a*a + b*b);
  int days = DaysIn("September");
  string userID = GetCurrentUser();
  ```
Functions that return values

- Function prototype indicates return type
  - Nearly any type can be returned, all types we’ll use can be
  - A function call evaluates to the return type, the call must be part of an expression, not a stand-alone statement
    - Yes: `double hypotenuse = sqrt(a*a + b*b);`
    - No: `sqrt(a*a + b*b);`
    - ??: `cout << sqrt(100) << endl;`
    - ??: `double adjacent = cos(angle)*hypotenuse;`
    - ??: `if ( sqrt(x*x + y*y) > min) {...}`
    - ??: `cos(3.1415) == -1;`

- The math functions are accessible using `#include<cmath>`, on older systems this is `<math.h>`
Anatomy of a function

- **Function to calculate volume of a sphere**

  ```c
  double SphereVol(double radius)
  {
    return 4.0*radius*radius*radius*acos(-1)/3;
  }
  ```

  - Function prototype shows return type, `void` functions do not return a value
  - The `return` statement alters the flow of control so that the function immediately exits (and returns a value)
  - A function can have more than one return statement, but only one is executed when the function is called (see next example)
Functions can return strings

```cpp
string WeekDay(int day)
{
    if (0 == day)
    {
        return "Sunday";
    }
    else if (1 == day)
    {
        return "Monday";
    }
    else if (2 == day)
    {
        return "Tuesday";
    }
    else if (3 == day)
    {
        return "Wednesday";
    }
    ...
}
```

- **Shorter (code) alternatives?**
  - Is shorter better?

- **What function call looks like?**

```cpp
string dayName;
int dayNum;
cout << "enter day (0-6): ";
cin >> dayNum;
dayName = WeekDay(dayNum);
```

- **Which is/are ok? Why?**

```cpp
cout << WeekDay(5) << endl;
int j = WeekDay(0);
cout << WeekDay(2.1) << endl;
string s = WeekDay(22);
WeekDay(3);
```
Another version of WeekDay

```java
string WeekDay(int day)
// precondition: 0<= day <= 6
// postcondition: return "Sunday" for 0,
//                "Monday" for 1, ... "Saturday" for 6
{
    if (0 == day) return "Sunday";
    else if (1 == day) return "Monday";
    else if (2 == day) return "Tuesday";
    else if (3 == day) return "Wednesday";
    else if (4 == day) return "Thursday";
    else if (5 == day) return "Friday";
    else if (6 == day) return "Saturday";
}
```

- Every occurrence of else can be removed, why?
- Why aren’t the braces `{ ... }` used in this version?
Function documentation

• **Functions usually have a precondition**
  - What properties (e.g., of parameters) must be true for function to work as intended?
  - If there are no parameters, sometimes no precondition
  - Some functions work for every parameter value

    ```
    double sqrt(double val);
    // precondition:
    ```

    ```
    string LoginID(string name)
    // precondition:
    ```

• **Functions always have a postcondition**
  - If precondition is satisfied what does the function do, what does the function return?
Free functions and member functions

- The functions in `<cmath>` are free functions, they aren’t part of a class
  - C++ is a hybrid language, some functions belong to a class, others do not
  - Java is a pure object-oriented language, every function belongs to a class

- We’ve used string objects in programs, string is a class
  - String variables are objects, they’re instances of the class

- A class is a collection having members that have common attributes (from American Heritage Dictionary)
  - strings share many properties, but have different values
  - My little red corvette, her 1958 corvette, his 1977 corvette
string member functions

- The function `length()` returns the number of characters

```c++
string s = "hello";
int len = s.length();  // value of len is 5
s = "";
    // what is value of len here?
len = s.length();  // value of len here?
```

- Member functions are *applied* to objects using *dot* notation
  - Cannot use `length()` without an object to apply it to
  - Not valid  `int x = length(s);`
  - Valid?  `double y = sqrt(s.length());`
Finding substrings

- A substring is part of a string, substrings can be extracted from a string using member function `substr(...)`

```cpp
string s = "theater";
int len = s.length(); // value of len is ??
string t = s.substr(0,3); // t is "the", s is ??
t = s.substr(1,4); // t is now ???
s = s.substr(3,3); // s is ?? t is ??
```

- Function prototype for `substr`

```cpp
string substr(int pos, int len);
// pre: 0 <= pos < s.length()
// post: returns substring of len characters
// beginning at position pos
// ok if len too big, NOT ok if pos too big
```
Find pieces of symbolic IP addresses

- cs.duke.edu    mahimahi.cs.duke.edu    duke.edu
- Pieces are separated by a period or dot
- Assume at most four pieces, first is the 0-th piece
- Prototype for function is:

```cpp
string NthIP(string IP, int n);
// pre: 0 <= n < 4
// post: return n-th piece of IP, return "" if there is no n-th piece
```

- What are the values of each variable below?

```cpp
string first = NthIP("cs.duke.edu",0);
string last = NthIP("cs.duke.edu",2);
string xxyy = NthIP("cs.duke.edu",100); // 3?
```
We need **find** to write NthIP

- **String** member function **find** looks for an occurrence of one string in another, returns position of start of first occurrence
  - If no occurrence, then **string::npos** is returned

```cpp
string s = "I am the eggman";
int k = s.find("I"); // k is 0
k = s.find("he"); // k is 6
k = s.find("egg"); // what is k?
k = s.find("a"); // what is k?
k = s.find("walrus"); // what is k?
s = "duke.edu";
k = s.find(". "); // what is k?
if (k != string::npos)
{  s = s.substr(k+1,s.length()); // what is s?  }
```
How to get started writing NthIP?

```cpp
string NthIP(string s, int n)
// pre: 0<= n < 4
// post: return n-th piece of IP s, return ""
//       if there is no n-th piece
{
    int len = s.length();
    int pos = s.find(".");
    if (pos == string::npos) return "";
    if (1 == n) { // s must have dot, why?
        return s.substr(0,pos);
    }
    s = s.substr(pos, len); // what’s value of s?
}
```

```cpp
string s = NthIP("duke.edu",1); // trace the call
```
When is a year a leap year?

- **Every year divisible by four is a leap year**
  - Except years divisible by 100 are not
    - Except years divisible by 400 are

- **Alternatively:**
  - Every year divisible by 400 is a leap year
  - Otherwise, years divisible by 100 are not leap years
  - Otherwise, years divisible by 4 are leap years
  - Otherwise, not a leap year

```cpp
bool IsLeap(int year);
// post: return true iff year is a leap year
```
bool IsLeap(int year)
// post: return true iff year is a leap year
{
    if (year % 400 == 0)
    {
        return true;
    }
}

int main()
{
    if (IsLeap(2000)) cout << "millennium leap" << endl;
    else cout << "Y2K bug found" << endl;
    return 0;
}
There’s more than one way to …

```cpp
bool IsLeap(int year)
    // post: return true iff year is a leap year

    {
        return (year % 400 == 0) ||
                (year % 4 == 0 && year % 100 != 0);
    }
```

- **How does this work?**
  - Why isn’t an if/else necessary?
  - What’s the value of an expression formed from Boolean operators?
  - Is this version more efficient?
  - Are these two versions different? From what perspective?
Preview: the class Date

- In addition to int, double, and string, there are several standard C++ classes and several classes standard to A Computer Science Tapestry
  - Most C++ classes designed to be “industrial strength”
    - This often means efficiency at the expense of safety
    - Easy to hang yourself, shoot yourself in the foot, ...
  - Tapestry classes designed for novice programmers
    - Sacrifice some efficiency, but often not noticeable
    - Make it run, make it run, make it fast:
      - it’s better to write correct code than to write fast code

- The class Date is accessible using #include"date.h", the class represents calendar dates, e.g., June 14, 1999
What can you do with a Date?

```
#include <iostream>
using namespace std;
#include "date.h"

int main()
{
    int month, year;
    cout << "enter month (1-12) and year ";
    cin >> month >> year;

    Date d(month, 1, year);
    cout << "that day is " << d << ", it is a "
         << d.DayName() << endl;
    cout << "the month has " << d.DaysIn()
         << " days in it " << endl;

    return 0;
}
```
Date member functions

- **Date d(9,15,1999);**
  - *Construct* a `Date` object given month, day, year
  - Problems in other countries?
  - Other useful ways to construct a `Date`?

- **d.DayName()**
  - Returns “Saturday”, “Sunday”, and so on

- **d.DaysIn()**
  - Returns the number of days in the month

- Other functions you think might be useful?
DeMorgan’s Law: Boolean operators

- **Writing complex Boolean expressions can be tricky**
  - Prompt user for a number, print a message if the value entered is anything other than 7 or 11 (e.g., 2, 3, 22, ...)
  
  - Prompt user for “rock”, “paper”, “scissors”, print message if anything else is entered
DeMorgan continued

- **Logical equivalents**

  \[(a \land b) \iff (\neg a) \lor (\neg b)\]
  \[(a \lor b) \iff (\neg a) \land (\neg b)\]

- **If 7 and 11 are legal values, what are the illegal values?**

  ```java
  if (value == 7 || value == 11) // ok here
  ```

  ➢ **How to write a statement for illegal values:**

  ```java
  if ( ) // not ok
  ```
Think about it

Puzzle: More light bulbs
- You have three light bulbs in the attic labeled 1, 2, and 3.
- Each one of light switches (A, B, C) downstairs controls exactly one of the bulbs
- You would like to find out which switch controls which light (e.g. A-2, B-3, C-1)
- You can clearly figure it out by going to the attic three times. How?
- If you’re clever, you can figure it out by going to the attic two times?
- Can you figure it out by going to the attic only once? How?

Game: Take numbers from both ends
- The game begins with a line of numbers e.g. [ 10 5 7 88 1 -5 ].
- There are an even number of numbers
- Players take turns removing numbers from the ends and keeping a personal running total of the amount collected so far
- The player with the largest sum at the end wins.
- What is a winning strategy? Should you go first or second?