Control, Functions, Classes

- **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 (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?)**

```
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**

```
void SpherePizza(double radius, double price)
{
   double volume;
   volume = 4.0/3*radius*radius*radius*3.1415;
   double area;
   area = 4*radius*radius*3.1415;
   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*)

```
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*?

```
// previous code for entering value, calculating #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

```
void Output(string coin, int amount)
{
    if (amount > 0)
    {   cout << "# " << coin << " =\t" << amount << endl;
    }
}
int main()
{
    // code for providing values to variables, now output
    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**
  - **`true/false` are boolean values**

Selection using `if/else` statement

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

- What if user enters "`ethan`" ? or " `Ethan`"
- 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**

```
int degrees;
bool isHot = false;
cout << "enter temperature: ";
cin >> degrees;
if (degrees > 95)
{  isHot = true;
}
// more code here
```

- **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 (suprisingly?) `"Ant" < "zebra"`
  - How do lengths of strings compare?
  - Why does uppercase 'A' come before lowercase 'z'?

- 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

```
cout << 23 + 4 < 16 - 2 << endl;
```

  - Causes following error using g++, fix using parentheses rather than deciphering:

```
invalid operands 'int' and 'ostream &
()(ostream &)' to binary 'operator <<'
```

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

```
if (3 + 4 - 7)
{ cout << "hi" << endl; }
else
{ cout << "goodbye" << endl; }
```

Logical operators

- **Boolean expressions can be combined using logical operators: AND, OR, NOT**
  - **C++ equivalents are &&, ||, and !, respectively**
    - **(standard requires *and*, *or*, *not*, most compilers don't)**

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

  - **What range of values generates 'A' message? Problems?**

```
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;
}
```

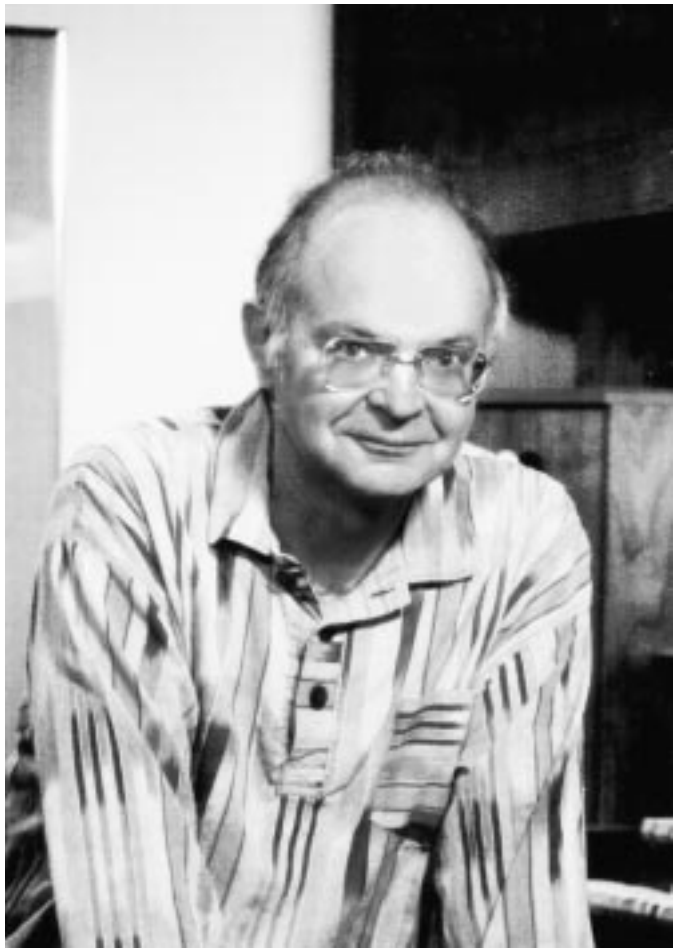
  - **Potential problems if there are no grades to average? What happens in this case?**
  - **Alternatives in absence of short-circuit evaluation:**

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

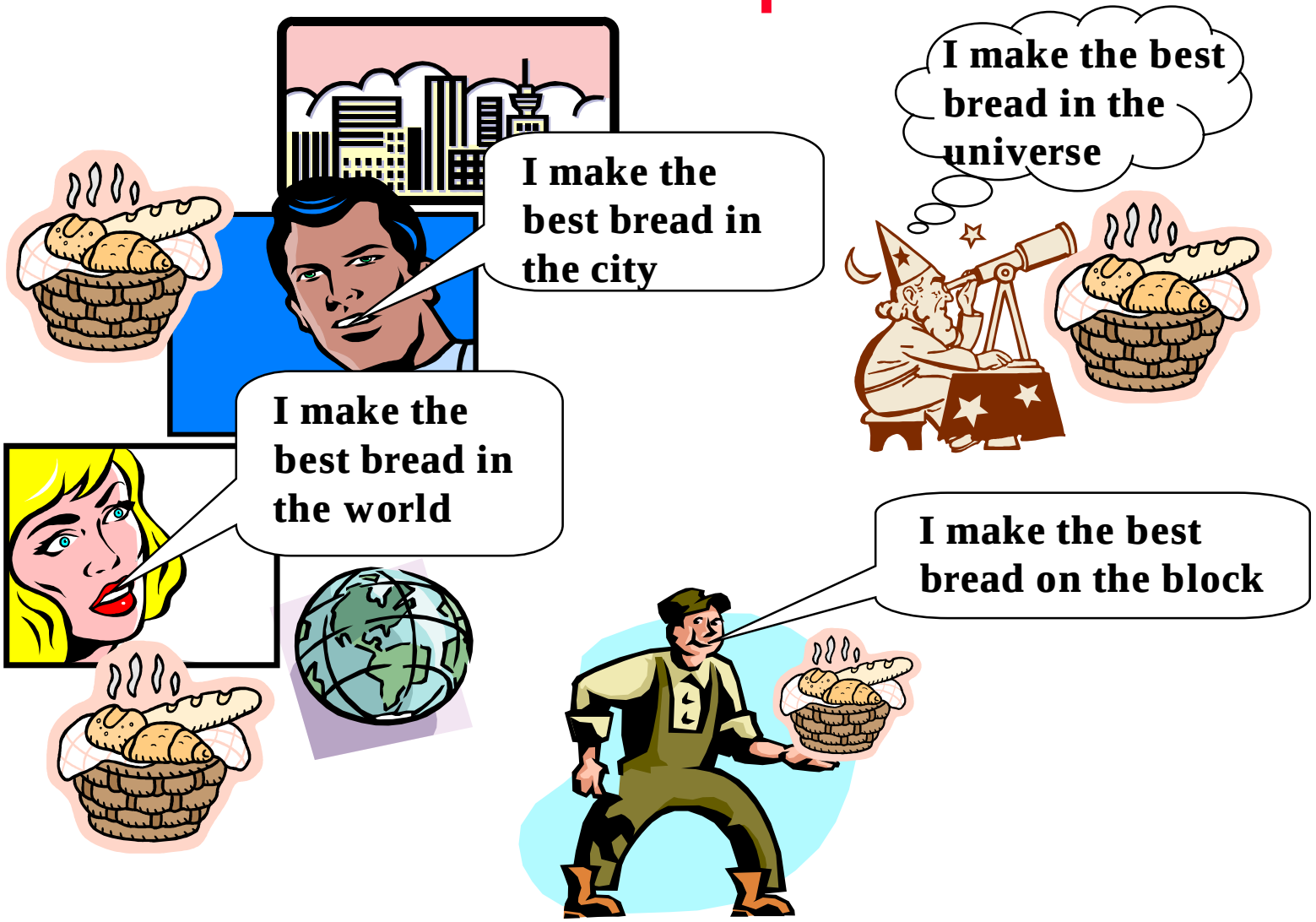
  - **Examples when OR short-circuits?**

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



Richard Stallman (born 1953)

- **Described by some as "world's best programmer"**
  - **Wrote/developed GNU software tools, particularly g++**
  - **Believes all software should be free, but like "free speech", not "free beer"**
  - **Won MacArthur award for his efforts and contributions**
  - **League for Programming Freedom**
- **Gnu/Linux is a free operating system and computing environment**
  - **Heavy industry/web use**
  - **Wintel killer??**

- **Local tie-in: Red Hat Linux,**
  - headquarted in Durham, NC
  - IPO in 1999 at $14
  - One month later at $110+
  - Markets "free" product

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**

```
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

```
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 does function call look like?

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

- Which is/are ok? Why?

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

Another version of WeekDay

```
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**

```
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(...)`

```
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

```
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` `goby.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:

```
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?

```
string first = NthIP("cs.duke.edu",0);
string last = NthIP("cs.duke.edu",3);
string xxyy = NthIP("cs.duke.edu",100);
```

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

```
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?

```
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?
```

```
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**

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

Once more again, into the leap

```
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 …

```
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 && b)          (!a) || (!b)
!(a || b)          (!a) && (!b)
```

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

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

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

```
if (                                ) // not ok
```