# Debugging [continued]

Admiral Grace Murray Hopper

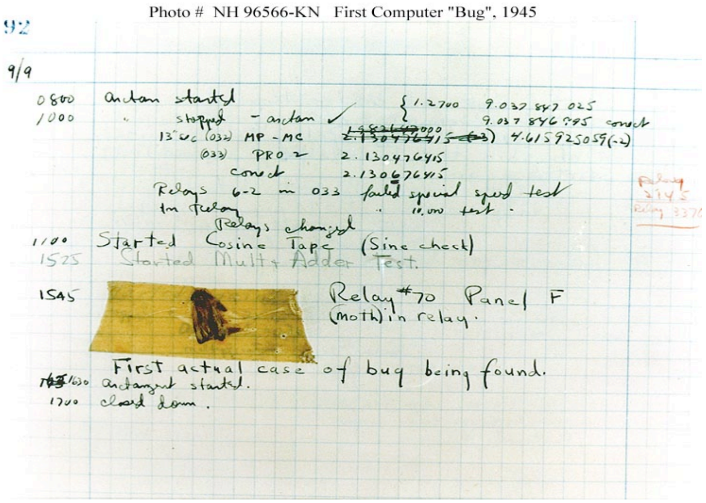


Photo # NH 96566-KN First Computer "Bug", 1945

92

9/9

0800 arctan started<br>
1000 " stopped - arctan ✓ {1.2700 9.037 847 025<br>
9.037 846 995 correct<br>
13" uc (032) MP - MC ~~1.982147000~~ ~~2.130476415~~ (~~-3~~) 4.615925059(-2)<br>
(033) PRO 2 2.130476415<br>
correct 2.130676415<br>
Relays 6-2 in 033 failed special speed test<br>
in relay " 10,000 test.<br>
Relays changed<br>
1100 Started Cosine Tape (Sine check)<br>
1525 Started Mult+ Adder Test.<br>
1545 Relay #70 Panel F<br>
(moth) in relay.<br>
First actual case of bug being found.<br>
1630 arctangent started.<br>
1700 closed down.

Relay 2145<br>
Relay 3370

http://www.history.navy.mil/photos/images/h96000/h96566kc.htm

# Debugging Your Program

## Debugging Your Program. [summary]

1. Edit the program (type in code).

2. Compile it.

   Compiler says: That's not a legal program.

   Back to step 1 to fix your syntax errors.

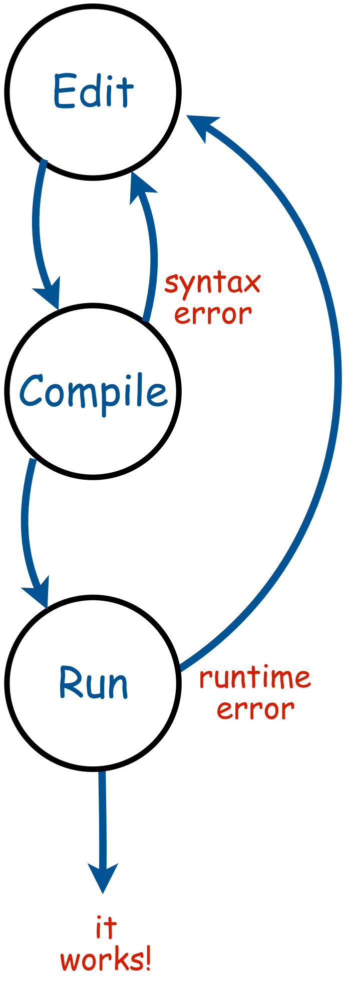
3. Run it.

   Result is bizarrely (or subtly) wrong.

   Back to step 1 to fix your runtime (semantic) errors.

4. Enjoy the satisfaction of a working program!

   [but stay tuned for more debugging]



# Debugging:  Where we left off

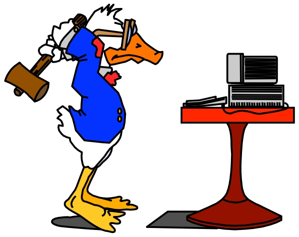
Success?  Found the last bugs (“corner cases”)?

- Need newline.
- Need to print largest factor.

```
public class Factors
{
   public static void main(String[] args)
   {
      long N = Long.parseLong(args[0])
      for (int i = 2; i < N; i++)
      {
         while (N % i == 0)
         {
            System.out.println(i + " ");
            N = N / i;
         }
         System.out.println("TRACE " + i + " " + N);
      }
   }
}
```

```
% javac Factors.java
% java Factors 5
TRACE 2 5
TRACE 3 5
TRACE 4 5
% java Factors 6
2
TRACE 2 3
```

AHA!
Print out N
after for loop
(if it is not 1)



# Debugging: Success?

## Success?

- Add code for corner case, remove trace, add comments.
- Try larger inputs

"Comment out" trace code (may need it later)

Corner case: print largest factor (and new line)

```
public class Factors
{
   public static void main(String[] args)
   {
      long N = Long.parseLong(args[0])
      for (int i = 2; i < N; i++)
      {  // Check whether i is a factor.
         while (N % i == 0)
         {  // If so, print and divide.
            // System.out.print(i + " ");
            N = N / i;
         }
      }
      if (N > 1) System.out.println(N);
      else       System.out.println();
   }
}
```

Time to document code (if not earlier).

???
%$%@$#!!
forgot to recompile

```
% java Factors 5
TRACE 2 5
TRACE 3 5
TRACE 4 5
% javac Factors.java
% java Factors 5
5
% java Factors 6
2 3
% java Factors 98
2 7 7
% java Factors 3757208
2 2 2 7 13 13 397
```

# Debugging: Performance Errors

Performance error. Correct program, but too slow.

- Are all iterations of inner loop necessary?
- Improve or change underlying algorithm.

```
public class Factors
{
   public static void main(String[] args)
   {
      long N = Long.parseLong(args[0])
      for (int i = 2; i < N; i++)
      {  // Check whether i is a factor.
         while (N % i == 0)
         {  // If so, print and divide.
            System.out.print(i + " ");
            N = N / i;
         }
      }
      if (N > 1) System.out.println(N);
      else       System.out.println();
   }
}
```

```
% java Factors 11111111
11 73 101 137
% java Factors 11111111111
21649 513239
% java Factors 11111111111111
11 239 4649 909091
% java Factors 11111111111111111
2071723
```

very long wait

# Debugging: Performance Errors

Performance error. Correct program, but too slow.

- Are all iterations of inner loop necessary?
- Improve or change underlying algorithm.

```
public class Factors
{
   public static void main(String[] args)
   {
      long N = Long.parseLong(args[0]);
      for (int i = 2; i < N/i; i++)
      {  // Check whether i is a factor.
         while (N % i == 0)
         {  // If so, print and divide.
            System.out.print(i + " ");
            N = N / i;
         }
      }
      if (N > 1) System.out.println(N);
      else       System.out.println();
   }
}
```

Fixes performance error: terminate when i*i > N since no larger factors left

```
% java Factors 11111111
11 73 101 137
% java Factors 11111111111
21649 513239
% java Factors 11111111111111
11 239 4649 909091
% java Factors 11111111111111111
2071723 5363222357
%
```

# Program Development: Analysis

Q. How large an integer can I factor?

```
% java Factors 3757208
2 2 2 7 13 13 397

% java Factors 9201111169755555703
9201111169755555703
```

after a few minutes of computing....

in largest factor →

| digits | (i <= N) | (i*i <= N) |
|---|---|---|
| 3 | instant | instant |
| 6 | 0.15 seconds | instant |
| 9 | 77 seconds | instant |
| 12 | 21 hours † | 0.16 seconds |
| 15 | 2.4 years † | 2.7 seconds |
| 18 | 2.4 millennia † | 92 seconds |

† estimated, using analytic number theory

Note. Can't break RSA this way (experts are still trying)

# Debugging Your Program

## Debugging Your Program. [summary]

1. Edit the program (type in code).

2. Compile it.

   Compiler says: That's not a legal program?

   Back to step 1 to fix your syntax errors.

3. Run it.

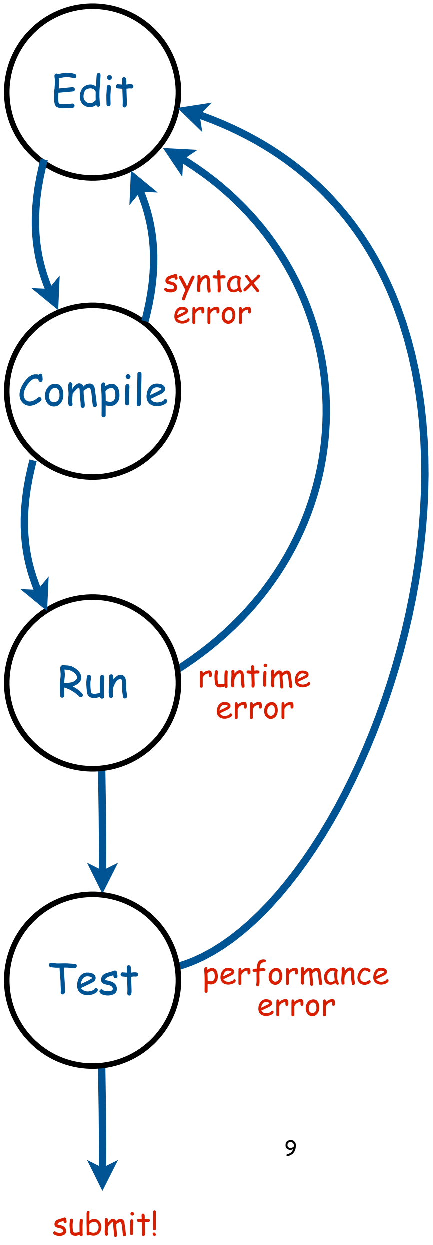
   Result is bizarrely (or subtly) wrong?

   Back to step 1 to fix your runtime (semantic) errors.

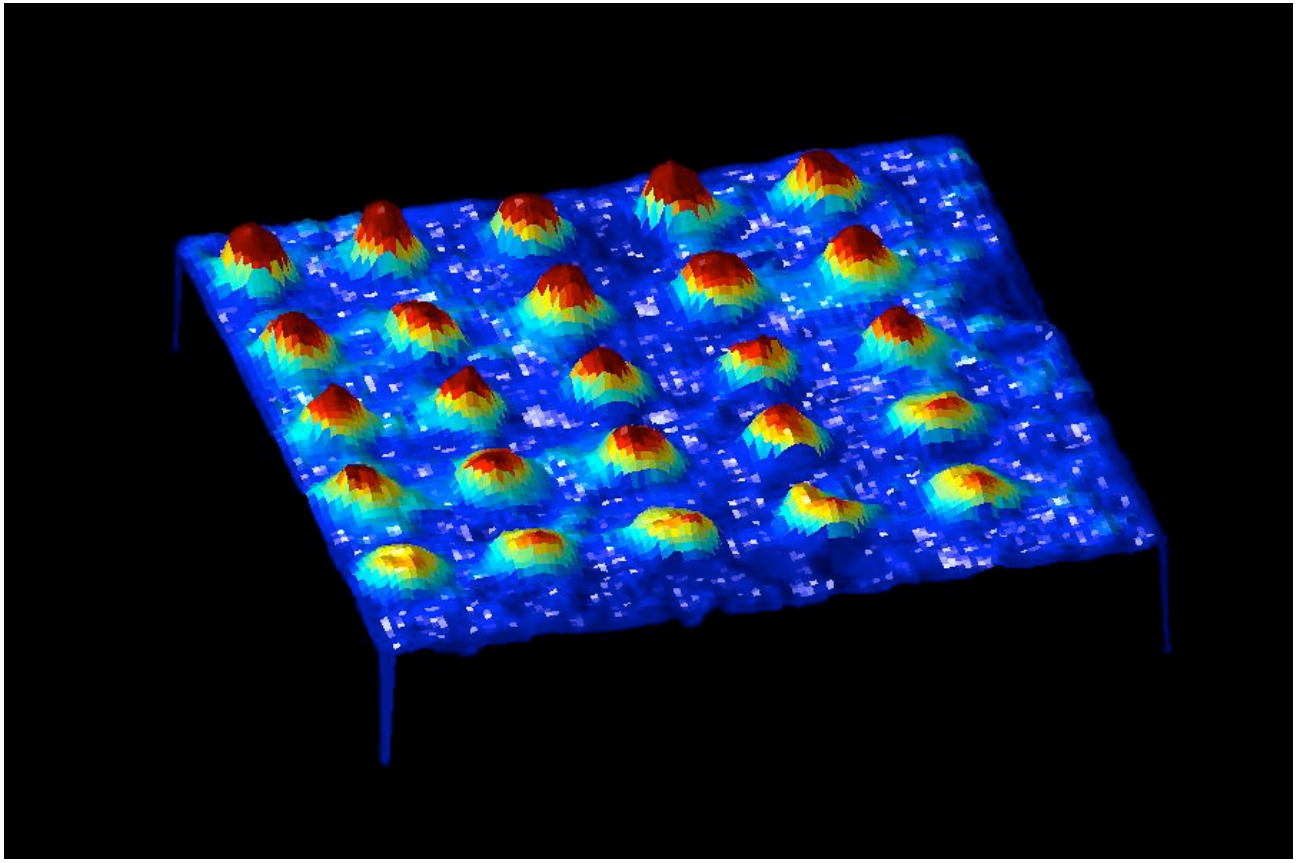
4. Test it.

   Too slow?

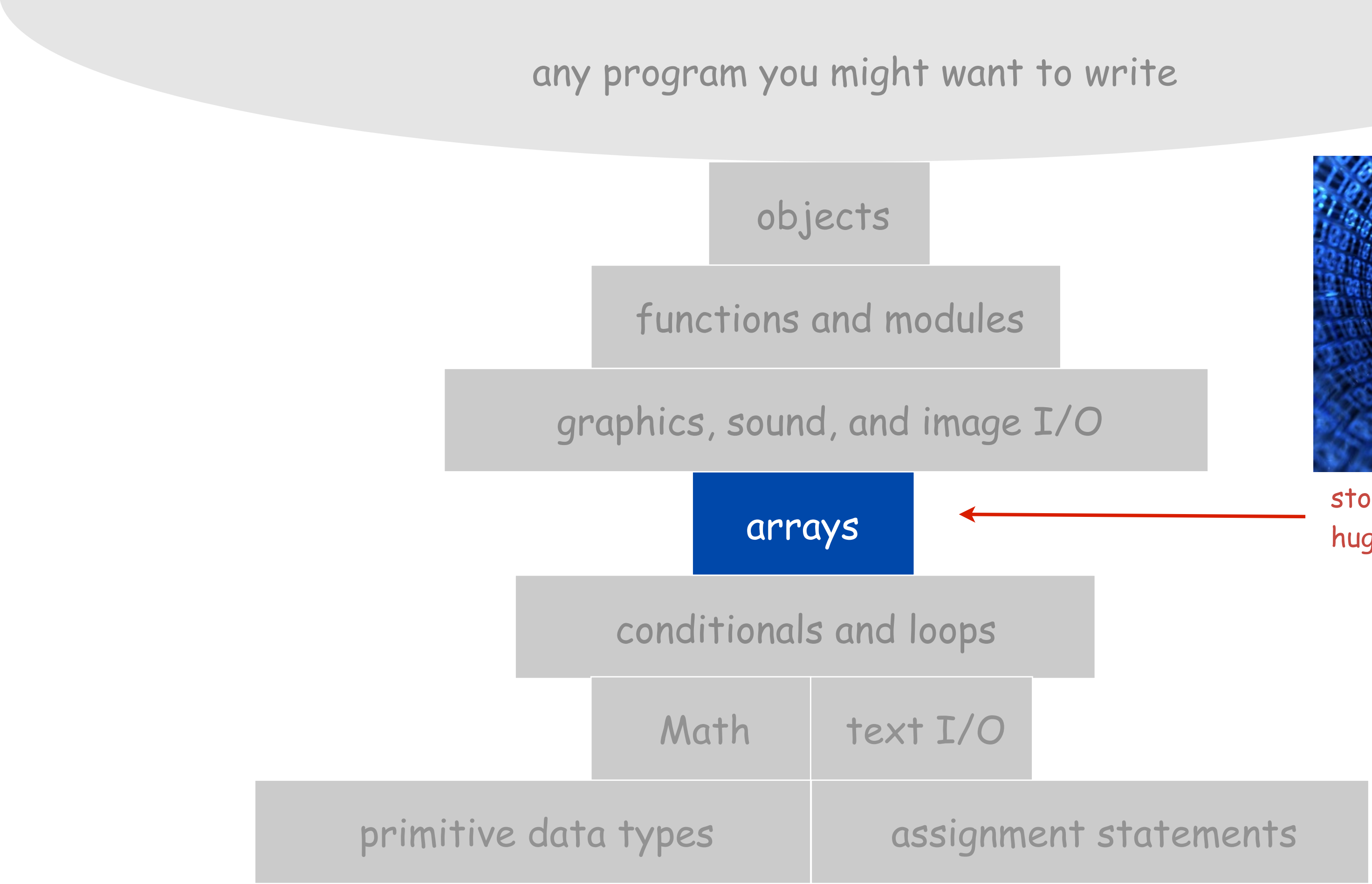
   Back to step 1 to try a different algorithm.



# 1.4 Arrays



# A Foundation for Programming



any program you might want to write

objects

functions and modules

graphics, sound, and image I/O

arrays

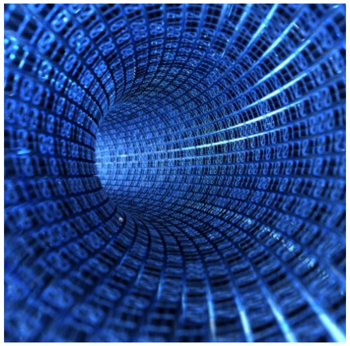
conditionals and loops

Math

text I/O

primitive data types

assignment statements



store and manipulate huge quantities of data

# Arrays

This lecture. Store and manipulate huge quantities of data.

Array. Indexed sequence of values of the same type.

Examples.

- 52 playing cards in a deck.
- 5 thousand undergrads at Princeton.
- 1 million characters in a book.
- 10 million audio samples in an MP3 file.
- 4 billion nucleotides in a DNA strand.
- 73 billion Google queries per year.
- 50 trillion cells in the human body.
- $6.02 \times 10^{23}$ particles in a mole.

| index | value |
|---|---|
| 0 | `wayne` |
| 1 | `doug` |
| 2 | `rs` |
| 3 | `maia` |
| 4 | `mona` |
| 5 | `cbienia` |
| 6 | `wkj` |
| 7 | `mkc` |

# Many Variables of the Same Type

Goal. 10 variables of the same type.

```
// Tedious and error-prone code.
double a0, a1, a2, a3, a4, a5, a6, a7, a8, a9;
a0 = 0.0;
a1 = 0.0;
a2 = 0.0;
a3 = 0.0;
a4 = 0.0;
a5 = 0.0;
a6 = 0.0;
a7 = 0.0;
a8 = 0.0;
a9 = 0.0;
...
a4 = 3.0;
...
a8 = 8.0;
...
double x = a4 + a8;
```

# Many Variables of the Same Type

Goal. 10 variables of the same type.

```
// Easy alternative.
double[] a = new double[10];
...
a[4] = 3.0;
...
a[8] = 8.0;
...
double x = a[4] + a[8];
```

declares, creates, and initializes
[stay tuned for details]

# Many Variables of the Same Type

Goal. 1 million variables of the same type.

```
// Scales to handle large arrays.
double[] a = new double[1000000];
...
a[234567] = 3.0;
...
a[876543] = 8.0;
...
double x = a[234567] + a[876543];
```

# Arrays in Java

Java has special language support for arrays.

- To make an array: declare, create, and initialize it.
- To access element `i` of array named `a`, use `a[i]`.
- Array indices start at `0`.

```
int N = 1000;
double[] a;                  // declare the array
a = new double[N];           // create the array
for (int i = 0; i < N; i++)  // initialize the array
   a[i] = 0.0;               // all to 0.0
```

# Arrays in Java

Java has special language support for arrays.

- To make an array: declare, create, and initialize it.
- To access element `i` of array named `a`, use `a[i]`.
- Array indices start at `0`.

```
int N = 1000;
double[] a;                      // declare the array
a = new double[N];               // create the array
for (int i = 0; i < N; i++)      // initialize the array
   a[i] = 0.0;                   // all to 0.0
```

Compact alternative: Declare, create, and initialize in one statement.

- Default: all entries automatically set to 0.

```
int N = 1000;
double[] a = new double[N];
```

- Alternative: entries initialized to given literal values.

```
double[] x = { 0.3, 0.6, 0.1 };
```

# Sample Array Code: Vector Dot Product

Dot product. Given two vectors `x[]` and `y[]` of length `N`, their dot product is the sum of the products of their corresponding components.

```
double[] x = { 0.3, 0.6, 0.1 };
double[] y = { 0.5, 0.1, 0.4 };

double sum = 0.0;
for (int i = 0; i < N; i++)
   sum += x[i]*y[i];
```

| i | x[i] | y[i] | x[i]*y[i] | sum |
|---|---|---|---|---|
| | | | | 0 |
| 0 | .30 | .50 | .15 | .15 |
| 1 | .60 | .10 | .06 | .21 |
| 2 | .10 | .40 | .04 | .25 |
| | | | | .25 |

# Array Processing Examples

```
double[] a = new double[N];
for (int i = 0; i < N; i++)
   a[i] = Math.random();
```

create an array with N random values

```
double[] b = new double[N];
for (int i = 0; i < N; i++)
   b[i] = a[i];
```

copy to another array

```
for (int i = 0; i < N; i++)
   System.out.println(a[i]);
```

print the array values, one per line

```
double sum = 0.0;
for (int i = 0; i < N; i++)
   sum += a[i];
double average = sum / N;
```

compute the average of the array values

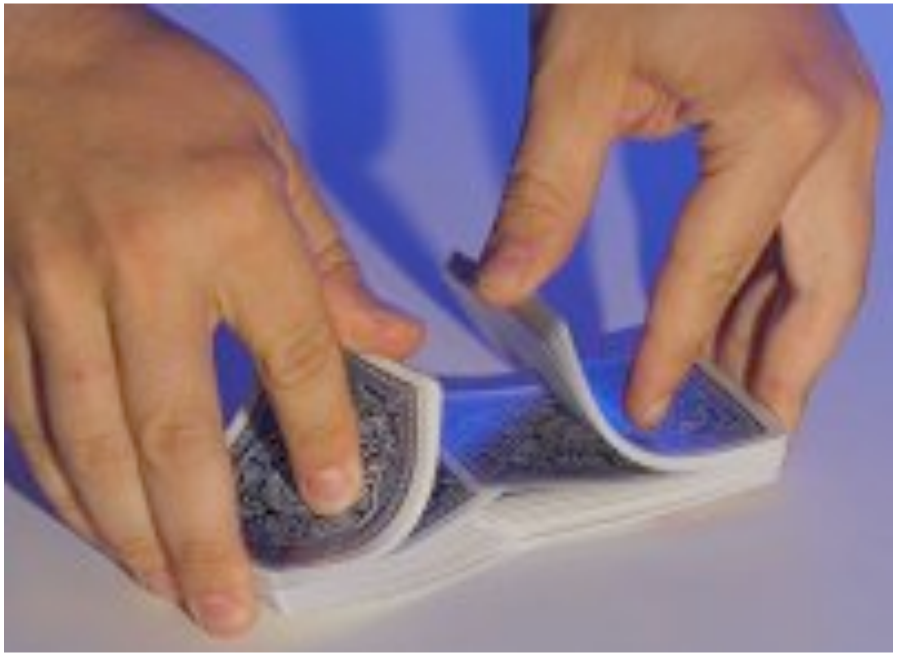
```
double max = Double.NEGATIVE_INFINITY;
for (int i = 0; i < N; i++)
   if (a[i] > max) max = a[i];
```

find the maximum of the array values

```
for (int i = 0; i < N/2; i++)
{
   double temp = b[i];
   b[i] = b[N-1-i];
   b[N-i-1] = temp;
}
```

reverse the elements within the array

# Shuffling a Deck



# Setting Array Values at Compile Time

Ex. Print a random card.

```
String[] rank =
{
   "2", "3", "4", "5", "6", "7", "8", "9",
   "10", "Jack", "Queen", "King", "Ace"
};


String[] suit =
{
   "Clubs", "Diamonds", "Hearts", "Spades"
};

int i = (int) (Math.random() * 13);  // between 0 and 12
int j = (int) (Math.random() * 4);   // between 0 and 3

System.out.println(rank[i] + " of " + suit[j]);
```

# TEQ on Arrays 1

The following code sets array values to the 52 card values and prints them.

In which order are they printed?

```
String[] rank = { "2", "3" ..., "King", "Ace" };
String[] suit =
  { "clubs", "diamonds", "hearts", "spades" };

String[] deck = new String[52];
for (int i = 0; i < 13; i++)
   for (int j = 0; j < 4; j++)
      deck[4*i + j] = rank[i] + " of " + suit[j];

for (int i = 0; i < 52; i++)
   System.out.println(deck[i]);
```

typical array processing code changes values at runtime

A.

```
2 of clubs
2 of diamonds
2 of hearts
2 of spades
3 of clubs
...
```

B.

```
2 of clubs
3 of clubs
4 of clubs
5 of clubs
6 of clubs
...
```

# Shuffling

Goal. Given an array, rearrange its elements in random order.

Shuffling algorithm.

- In iteration `i`, pick random card from `deck[i]` through `deck[N-1]`, with each card equally likely.
- Exchange it with `deck[i]`.

```
int N = deck.length;
for (int i = 0; i < N; i++)
{
   int r = i + (int) (Math.random() * (N-i));
   String t = deck[r];
   deck[r] = deck[i];
   deck[i] = t;
}
```

swap idiom

between i and N-1

# Shuffling a Deck of Cards

```
public class Deck
{
   public static void main(String[] args)
   {
      String[] suit = { "Clubs", "Diamonds", "Hearts", "Spades" };
      String[] rank = { "2", "3", "4", "5", "6", "7", "8", "9",
                        "10", "Jack", "Queen", "King", "Ace"    };
      int SUITS = suit.length;
      int RANKS = rank.length;
      int N = SUITS * RANKS;
```

← avoid "hardwired" constants like 52, 4, and 13.

```
      String[] deck = new String[N];
      for (int i = 0; i < RANKS; i++)
         for (int j = 0; j < SUITS; j++)
            deck[SUITS*i + j] = rank[i] + " of " + suit[j];
```

build the deck

```
      for (int i = 0; i < N; i++)
      {
         int r = i + (int) (Math.random() * (N-i));
         String t = deck[r];
         deck[r] = deck[i];
         deck[i] = t;
      }
```

shuffle

```
      for (int i = 0; i < N; i++)
         System.out.println(deck[i]);
   }
}
```

print shuffled deck

# Shuffling a Deck of Cards

```
% java Deck
5 of Clubs
Jack of Hearts
9 of Spades
10 of Spades
9 of Clubs
7 of Spades
6 of Diamonds
7 of Hearts
7 of Clubs
4 of Spades
Queen of Diamonds
10 of Hearts
5 of Diamonds
Jack of Clubs
Ace of Hearts
...
5 of Spades
```

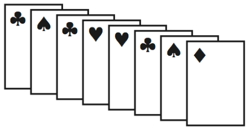
```
% java Deck
10 of Diamonds
King of Spades
2 of Spades
3 of Clubs
4 of Spades
Queen of Clubs
2 of Hearts
7 of Diamonds
6 of Spades
Queen of Spades
3 of Spades
Jack of Diamonds
6 of Diamonds
8 of Spades
9 of Diamonds
...
10 of Spades
```

# Coupon Collector

# Coupon Collector Problem

Coupon collector problem. Given `N` different card types, how many do you have to collect before you have (at least) one of each type?

assuming each possibility is equally likely for each card that you collect



Simulation algorithm. Repeatedly choose an integer **`i`** between `0` and **`N-1`**. Stop when we have at least one card of every type.

Q. How to check if we've seen a card of type `i`?

A. Maintain a boolean array so that **`found[i]`** is **`true`** if we've already collected a card of type **`i`**.

# Coupon Collector: Java Implementation

```
public class CouponCollector
{
   public static void main(String[] args)
   {
      int N = Integer.parseInt(args[0]);
      int cardcnt = 0;   // number of cards collected
      int valcnt = 0;    // number of distinct cards

      // Do simulation.
      boolean[] found = new boolean[N];
      while (valcnt < N)
      {
         int val = (int) (Math.random() * N);
         cardcnt++;
         if (!found[val])
         {
            valcnt++;
            found[val] = true;
         }
      }

      // all N distinct cards found
      System.out.println(cardcnt);
   }
}
```

type of next card
(between 0 and N-1)

# Coupon Collector: Debugging

Debugging. Add code to print contents of all variables.

| val | found | | | | | | valcnt | cardcnt |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | | |
| | F | F | F | F | F | F | 0 | 0 |
| 2 | F | F | T | F | F | F | 1 | 1 |
| 0 | T | F | T | F | F | F | 2 | 2 |
| 4 | T | F | T | F | T | F | 3 | 3 |
| 0 | T | F | T | F | T | F | 3 | 4 |
| 1 | T | T | T | F | T | F | 4 | 5 |
| 2 | T | T | T | F | T | F | 4 | 6 |
| 5 | T | T | T | F | T | T | 5 | 7 |
| 0 | T | T | T | F | T | T | 5 | 8 |
| 1 | T | T | T | F | T | T | 5 | 9 |
| 3 | T | T | T | T | T | T | 6 | 10 |

Challenge. Debugging with arrays requires tracing many variables.

# Coupon Collector: Mathematical Context

Coupon collector problem. Given N different possible cards, how many do you have to collect before you have (at least) one of each type?

Fact. About $N (1 + 1/2 + 1/3 + \ldots + 1/N) \sim N \ln N$

see ORF 245 or COS 341

Ex. $N = 30$ baseball teams. Expect to wait $\approx$ 120 years before all teams win a World Series.

under idealized assumptions

# Coupon Collector: Scientific Context

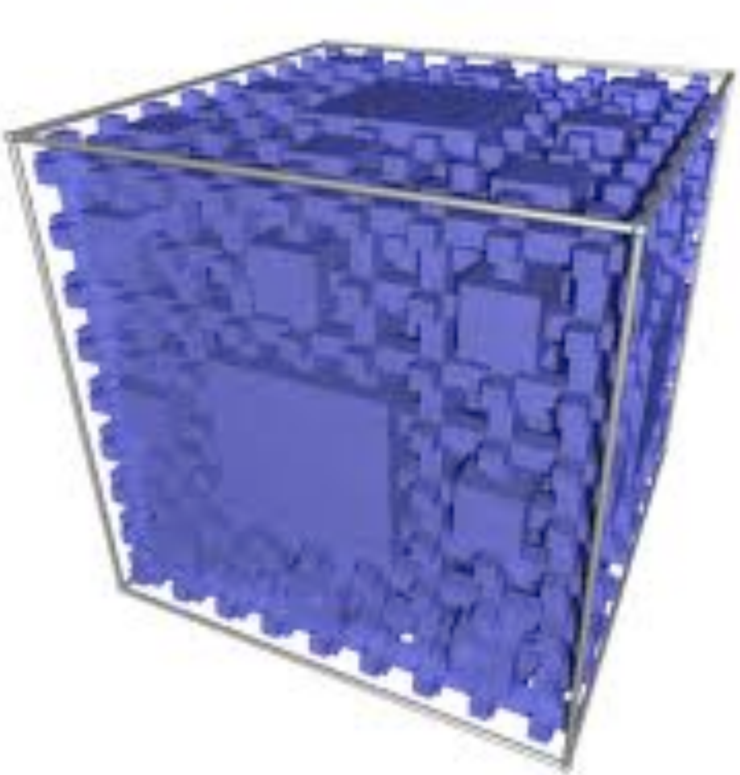
Q. Given a sequence from nature, does it have same characteristics as a random sequence?

A. No easy answer - many tests have been developed.

Coupon collector test. Compare number of elements that need to be examined before all values are found against the corresponding answer for a random sequence.

TOUR OF ACCOUNTING
OVER HERE WE HAVE OUR RANDOM NUMBER GENERATOR.
NINE NINE NINE NINE NINE NINE
ARE YOU SURE THAT'S RANDOM?
THAT'S THE PROBLEM WITH RANDOMNESS: YOU CAN NEVER BE SURE.
10/25/01 © 2001 United Feature Syndicate, Inc.

# Multidimensional Arrays



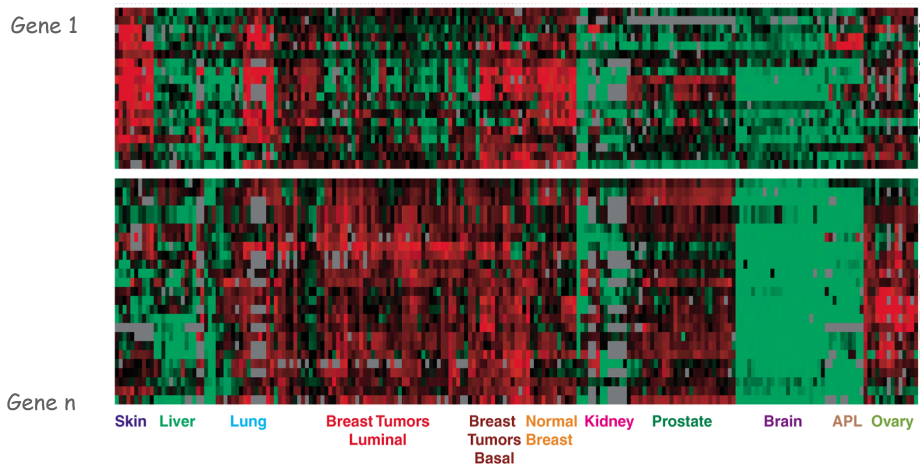
# Two Dimensional Arrays

Two dimensional arrays.

- Table of data for each experiment and outcome.
- Table of grades for each student and assignments.
- Table of grayscale values for each pixel in a 2D image.

Mathematical abstraction. Matrix.

Java abstraction. 2D array.



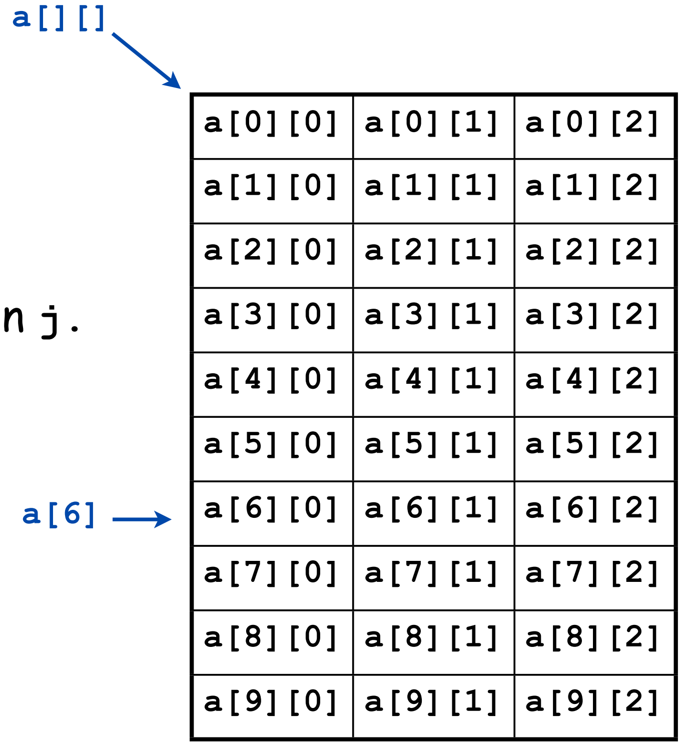
Reference: Botstein & Brown group

🟥 gene expressed
🟩 gene not expressed

# Two Dimensional Arrays in Java

Declare, create, initialize. Like 1D, but add another pair of brackets.

```
int M = 10;
int N = 3;
double[][] a = new double[M][N];
```



a[][]

a[6]

|  |  |  |
|---|---|---|
| a[0][0] | a[0][1] | a[0][2] |
| a[1][0] | a[1][1] | a[1][2] |
| a[2][0] | a[2][1] | a[2][2] |
| a[3][0] | a[3][1] | a[3][2] |
| a[4][0] | a[4][1] | a[4][2] |
| a[5][0] | a[5][1] | a[5][2] |
| a[6][0] | a[6][1] | a[6][2] |
| a[7][0] | a[7][1] | a[7][2] |
| a[8][0] | a[8][1] | a[8][2] |
| a[9][0] | a[9][1] | a[9][2] |

*A 10-by-3 array*

Array access.

Use `a[i][j]` to access entry in row `i` and column `j`.

Indices start at `0`.

Initialize.

This code is implicit (sets all entries to 0).

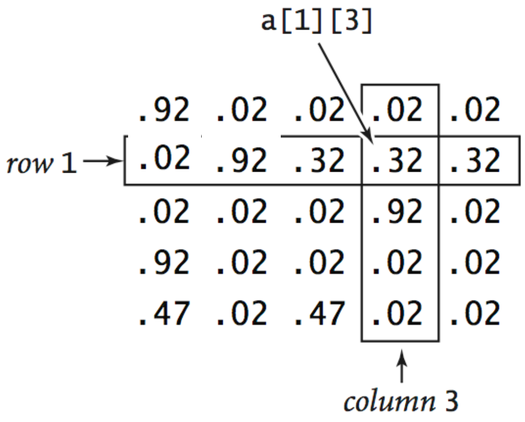
```
for (int i = 0; i < M; i++)
   for (int j = 0; j < N; j++)
      a[i][j] = 0.0;
```

Warning. This implicit code might slow down your program for big arrays.

# Setting 2D Array Values at Compile Time

Initialize 2D array by listing values.

```
double[][] p =
{
   { .02, .92, .02, .02, .02 },
   { .02, .02, .32, .32, .32 },
   { .02, .02, .02, .92, .02 },
   { .92, .02, .02, .02, .02 },
   { .47, .02, .47, .02, .02 },
};
```

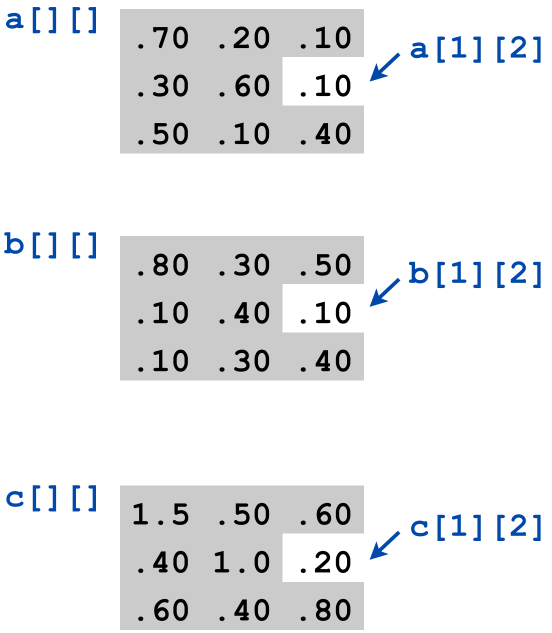


| | | | | |
|---|---|---|---|---|
| .92 | .02 | .02 | .02 | .02 |
| .02 | .92 | .32 | .32 | .32 |
| .02 | .02 | .02 | .92 | .02 |
| .92 | .02 | .02 | .02 | .02 |
| .47 | .02 | .47 | .02 | .02 |

# Matrix Addition

Matrix addition. Given two N-by-N matrices `a` and `b`, define `c` to be the N-by-N matrix where `c[i][j]` is the sum `a[i][j] + b[i][j]`.

```
double[][] c = new double[N][N];
for (int i = 0; i < N; i++)
   for (int j = 0; j < N; j++)
      c[i][j] = a[i][j] + b[i][j];
```



a[][]

|  |  |  |
|---|---|---|
| .70 | .20 | .10 |
| .30 | .60 | .10 |
| .50 | .10 | .40 |

a[1][2]

b[][]

|  |  |  |
|---|---|---|
| .80 | .30 | .50 |
| .10 | .40 | .10 |
| .10 | .30 | .40 |

b[1][2]

c[][]

|  |  |  |
|---|---|---|
| 1.5 | .50 | .60 |
| .40 | 1.0 | .20 |
| .60 | .40 | .80 |

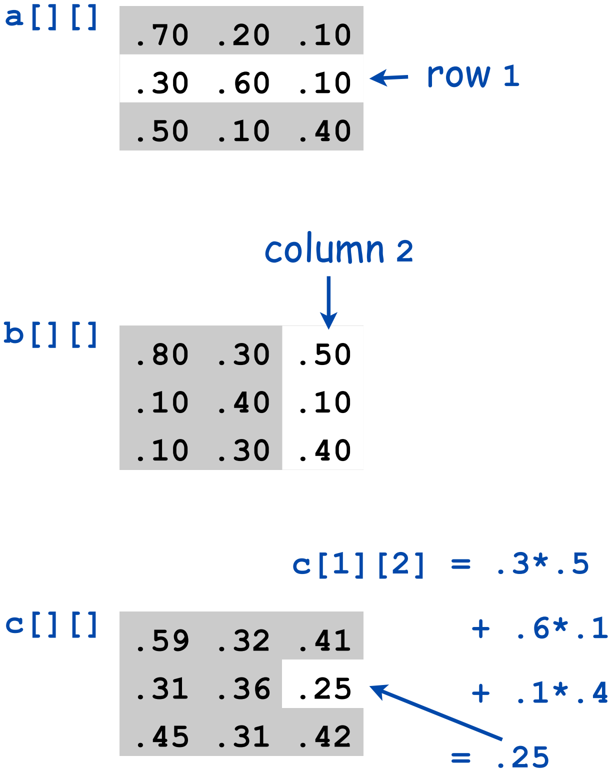
c[1][2]

# Matrix Multiplication

Matrix multiplication. Given two N-by-N matrices a and b, define c to be the N-by-N matrix where **c[i][j]** is the dot product of the **i**th row of **a** and the **j**th row of **b**.

all values initialized to 0

```
double[][] c = new double[N][N];
for (int i = 0; i < N; i++)
   for (int j = 0; j < N; j++)
      for (int k = 0; k < N; k++)
         c[i][j] += a[i][k] * b[k][j];
```



$$\texttt{a[][]} \quad \begin{array}{ccc} .70 & .20 & .10 \\ .30 & .60 & .10 \\ .50 & .10 & .40 \end{array} \leftarrow \text{row 1 (second row)}$$

row 1

column 2

$$\texttt{b[][]} \quad \begin{array}{ccc} .80 & .30 & .50 \\ .10 & .40 & .10 \\ .10 & .30 & .40 \end{array}$$

$$\texttt{c[][]} \quad \begin{array}{ccc} .59 & .32 & .41 \\ .31 & .36 & .25 \\ .45 & .31 & .42 \end{array}$$

```
c[1][2] = .3*.5
        + .6*.1
        + .1*.4
        = .25
```

# TEQ on Arrays 2

How many multiplications to multiply two N-by-N matrices?

```
double[][] c = new double[N][N];
for (int i = 0; i < N; i++)
   for (int j = 0; j < N; j++)
      for (int k = 0; k < N; k++)
         c[i][j] += a[i][k] * b[k][j];
```

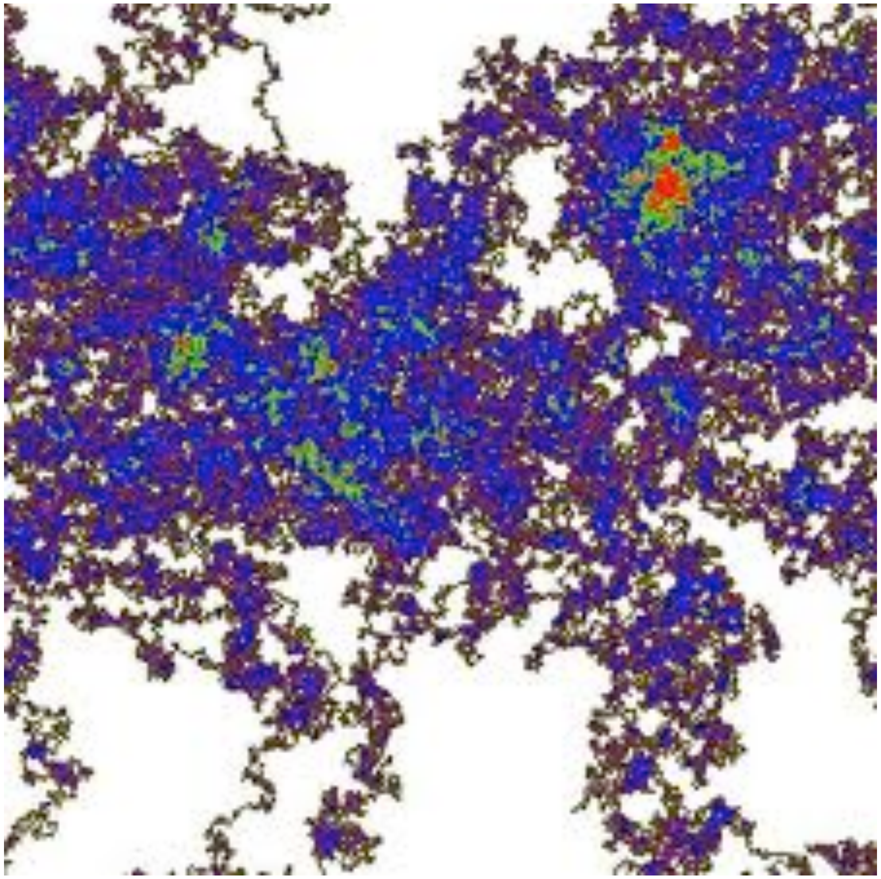
A. N

B. $N^2$

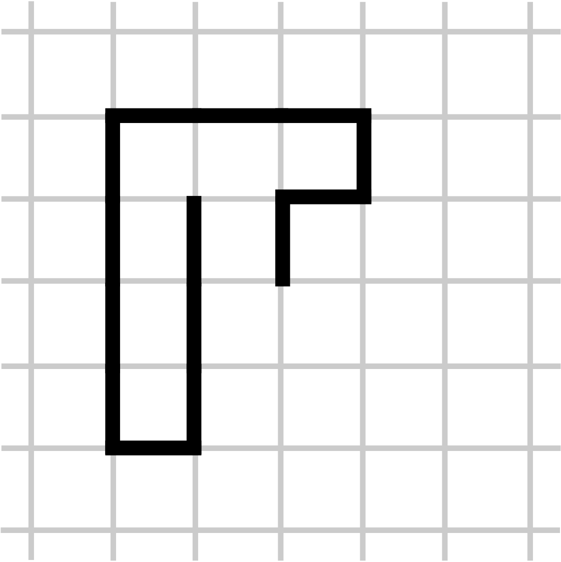
C. $N^3$

D. $N^4$

# Application: 2D Random Walks



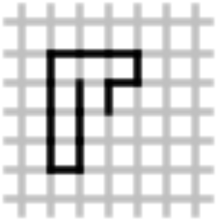
# Application: Self-Avoiding Walks



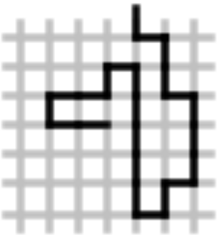
# Self-Avoiding Walk

Model.

- N-by-N lattice.
- Start in the middle.
- Randomly move to a neighboring intersection, avoiding all previous intersections.
- Two possible outcomes: escape and dead end



dead end



escape

Applications. Polymers, statistical mechanics, etc.

Q. What fraction of time will you escape in an 5-by-5 lattice?

Q. In an N-by-N lattice?

Q. In an N-by-N-by-N lattice?

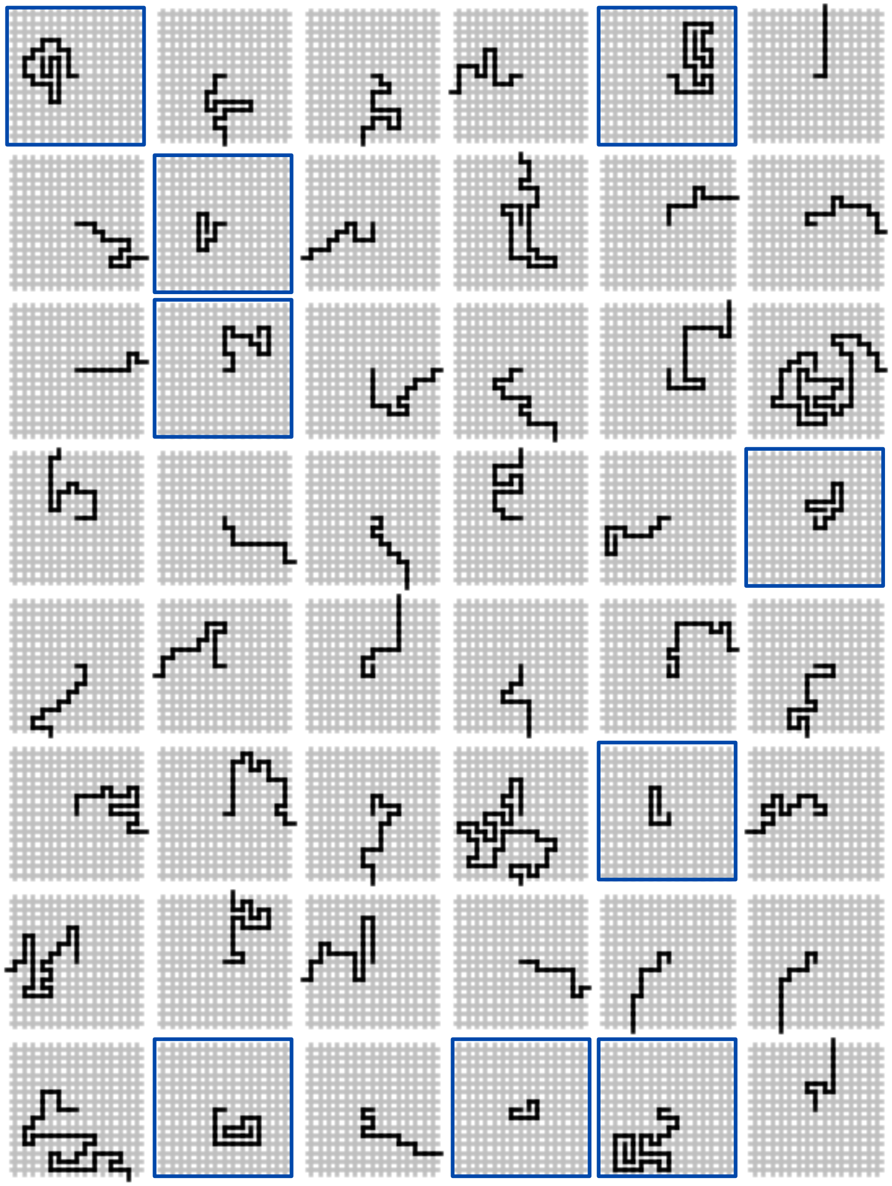
# Self-Avoiding Walk:  Implementation

```
public class SelfAvoidingWalk
{
   public static void main(String[] args)
   {
      int N = Integer.parseInt(args[0]);    // lattice size
      int T = Integer.parseInt(args[1]);    // number of trials
      int deadEnds = 0;                     // trials ending at dead end

      for (int t = 0; t < T; t++)
      {
         boolean[][] a = new boolean[N][N];  // intersections visited
         int x = N/2, y = N/2;               // current position

         while (x > 0 && x < N-1 && y > 0 && y < N-1)
         {

            if (a[x-1][y] && a[x+1][y] && a[x][y-1] && a[x][y+1])
            {  deadEnds++;  break; }

            a[x][y] = true;                 // mark as visited

            double r = Math.random();
            if      (r < 0.25) { if (!a[x+1][y]) x++; }
            else if (r < 0.50) { if (!a[x-1][y]) x--; }
            else if (r < 0.75) { if (!a[x][y+1]) y++; }
            else if (r < 1.00) { if (!a[x][y-1]) y--; }
         }
      }
      System.out.println(100*deadEnds/T + "% dead ends");
   }
}
```

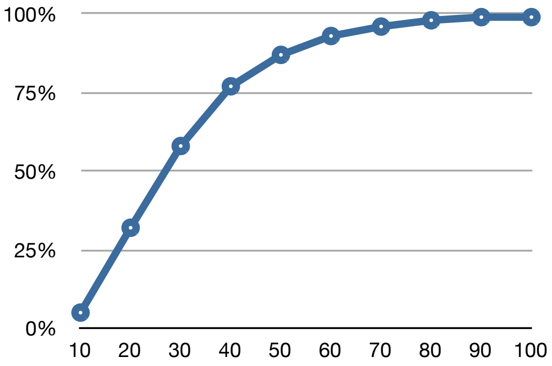
dead end

take a random step to a new intersection

# Self-Avoiding Walks



```
% java SelfAvoidingWalk 10 100000
5% dead ends
% java SelfAvoidingWalk 20 100000
32% dead ends
% java SelfAvoidingWalk 30 100000
58% dead ends
% java SelfAvoidingWalk 40 100000
77% dead ends
% java SelfAvoidingWalk 50 100000
87% dead ends
% java SelfAvoidingWalk 60 100000
93% dead ends
% java SelfAvoidingWalk 70 100000
96% dead ends
% java SelfAvoidingWalk 80 100000
98% dead ends
% java SelfAvoidingWalk 90 100000
99% dead ends
% java SelfAvoidingWalk 100 100000
99% dead ends
```

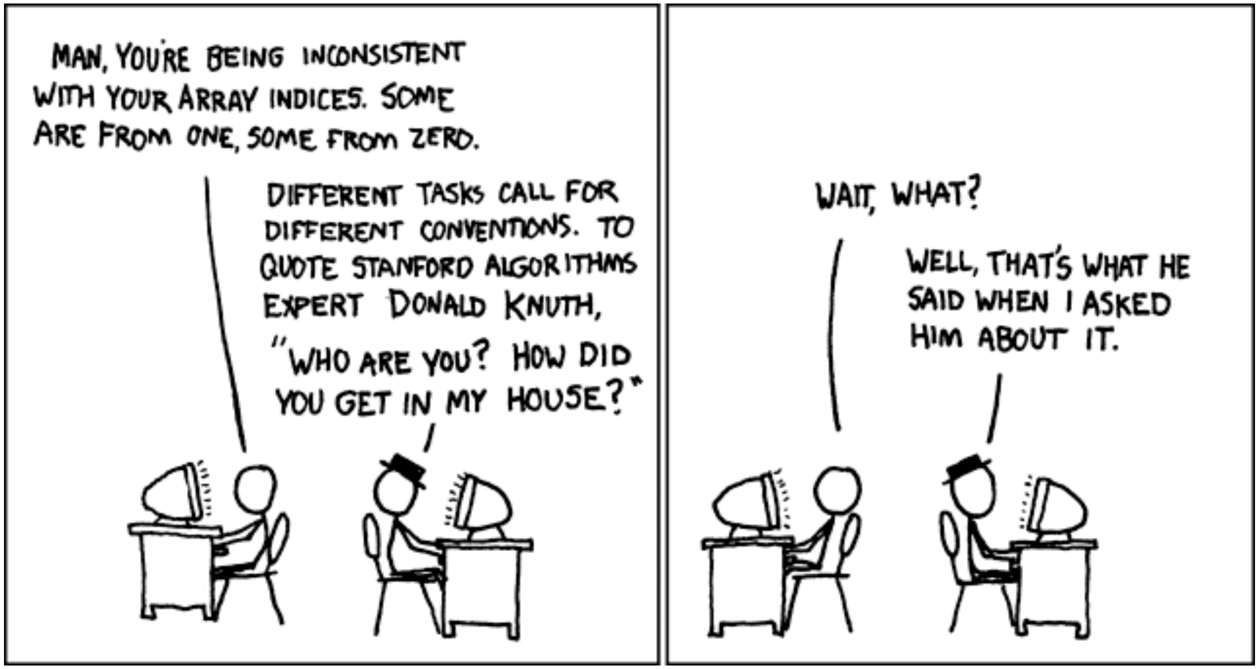


# Summary

Arrays.

- Organized way to store huge quantities of data.
- Almost as easy to use as primitive types.
- Can directly access an element given its index.

Ahead. Reading in large quantities of data from a file into an array.


MAN, YOU'RE BEING INCONSISTENT WITH YOUR ARRAY INDICES. SOME ARE FROM ONE, SOME FROM ZERO.
DIFFERENT TASKS CALL FOR DIFFERENT CONVENTIONS. TO QUOTE STANFORD ALGORITHMS EXPERT DONALD KNUTH, "WHO ARE YOU? HOW DID YOU GET IN MY HOUSE?"
WAIT, WHAT?
WELL, THAT'S WHAT HE SAID WHEN I ASKED HIM ABOUT IT.

http://imgs.xkcd.com/comics/donald_knuth.png