Administrivia

- Please make sure you have obtained a Unix account. If you have very recently (i.e., since today) signed up for concurrent enrollment please email us your name, email, and SID. After we have a chance to process it, you will be able to use WebAcct, as Lab #1 specifies.

- Lab #1 is due Wednesday (end of Wednesday at midnight). Usually, labs are due Friday midnight of the week they occur. It is especially important to set up your central repository.

- If you decide not to take this course after all, please tell CalCentral ASAP, so that we can adjust the waiting list accordingly.

- HW #0 now up; due next Friday at midnight. You get credit for any submission, but we suggest you give the problems a serious try.
Lecture #2: Let’s Write a Program: Prime Numbers

Problem: want java Primes \( U \) to print prime numbers through \( U \).
You type: java Primes 101
It types: 2 3 5 7 11 13 17 19 23 29
31 37 41 43 47 53 59 61 67 71
73 79 83 89 97 101

Definition: A prime number is an integer greater than 1 that has no divisors smaller than itself other than 1.
(Alternatively: \( p > 1 \) is prime iff \( \gcd(p, x) = 1 \) for all \( 0 < x < p \).)

Useful Facts:

- \( k \leq \sqrt{N} \) iff \( N/k \geq \sqrt{N} \), for \( N, k > 0 \).
- If \( k \) divides \( N \) then \( N/k \) divides \( N \).

So: Try all potential divisors up to and including the square root.
public class Primes {
    /** Print all primes up to ARG$[0]$ (interpreted as an integer), 10 to a line. */
    public static void main(String[] args) {
        printPrimes(Integer.parseInt(args[0]));
    }

    /** Print all primes up to and including LIMIT, 10 to a line. */
    private static void printPrimes(int limit) {
        /* { For every integer, x, between 2 and LIMIT, print it if isPrime(x), 10 to a line. } */
    }

    /** True iff X is prime */
    private static boolean isPrime(int x) {
        return /*( X is prime )*/;
    }
}
private static boolean isPrime(int x) {
    if (x <= 1)
        return false;
    else
        return !isDivisible(x, 2); // "!" means "not"
}

/** True iff X is divisible by any positive number >=K and < X, *
 * given K > 1. */
private static boolean isDivisible(int x, int k) {
    if (k >= x) // a "guard"
        return false;
    else if (x % k == 0) // "%" means "remainder"
        return true;
    else // if (k < x && x % k != 0)
        return isDivisible(x, k+1);
}
Thinking Recursively

Understand and check \texttt{isDivisible(13,2)} by \textit{tracing one level}.

/** True iff \texttt{X} is divisible by
 * some number $\geq K$ and $<$ \texttt{X},
 * given $K > 1$. */

private static boolean isDivisible...
  if (k $\geq$ x)
    return false;
  else if (x \% k == 0)
    return true;
  else
    return isDivisible(x, k+1);
}

Lesson: Comments aid understanding. Make them \textit{count}!

- Call assigns \texttt{x=13, k=2}
- Body has form \texttt{if (k $\geq$ x) S\textsubscript{1} else S\textsubscript{2}}.
- Since $2 < 13$, we evaluate the first else.
- Check if $13 \ mod \ 2 = 0$; it's not.
- Left with \texttt{isDivisible(13,3)}.
- Rather than tracing it, instead use the comment:
  - Since 13 is not divisible by any integer in the range 3..12 (and 3 $>$ 1), \texttt{isDivisible(13,3)} must be \texttt{false}, and we're done!
- Sounds like that last step begs the question. Why doesn't it?
Iteration

- isDivisible is tail recursive, and so creates an iterative process.
- Traditional “Algol family” production languages have special syntax for iteration. Four equivalent versions of isDivisible:

```plaintext
if (k >= x)
    return false;
else if (x % k == 0)
    return true;
else
    return isDivisible(x, k+1);
```

```plaintext
while (k < x) {  // !(k >= x)
    if (x % k == 0)
        return true;
    k = k+1;  // or k += 1, or (yuch) k++
}  
return false;
```

```plaintext
int k1 = k;
while (k1 < x) {
    if (x % k1 == 0)
        return true;
    k1 += 1;
}
return false;
```

```plaintext
for (int k1 = k; k1 < x; k1 += 1) {
    if (x % k1 == 0)
        return true;
}
return false;
```
Using Facts about Primes

• We haven’t used the Useful Facts from an earlier slide. Only have to check for divisors up to the square root.

• So, reimplement the iterative version of `isDivisible`:

```java
/** True iff X is divisible by some number >=K and < X, 
* given that K > 1, and that X is not divisible by 
* any number >1 and <K. */
private static boolean isDivisible(int x, int k) {
    int limit = (int) Math.round(Math.sqrt(x));
    for (int k1 = k; k1 <= limit; k1 += 1) {
        if (x % k1 == 0)
            return true;
    }
    return false;
}
```

• Why the additional (blue) condition in the comment?
Cautionary Aside: Floating Point

• In the last slide, we had

```java
int limit = (int) Math.round(Math.sqrt(x));
for (int k1 = k; k1 <= limit; k1 += 1) {
    ...
```

intending that this would check all values of k1 up to and including the square root of x.

• Since floating-point operations yield *approximations* to the corresponding mathematical operations, you might ask the following about `(int) Math.round(Math.sqrt(x))`:

  - Is it always at least ⌊√x⌋, where ⌊z⌋ is the largest integer ≤ z?  
    (If not, we might miss testing √x when x is a perfect square.)

• As it happens, the answer is “yes” for IEEE floating-point square roots.

• Just an example of the sort of detail that must be checked in edge cases.
Final Task: printPrimes (Simplified)

/** Print all primes up to and including LIMIT. */
private static void printPrimes(int limit) {

}
Simplified printPrimes Solution

/** Print all primes up to and including LIMIT. */
private static void printPrimes(int limit) {
    for (int p = 2; p <= limit; p += 1) {
        if (isPrime(p)) {
            System.out.print(p + " ");
        }
    }
    System.out.println();
}

/** Print all primes up to and including LIMIT, 10 to */

private static void printPrimes(int limit) {
    int np;
    np = 0;
    for (int p = 2; p <= limit; p += 1) {
        if (isPrime(p)) {
            System.out.print(p + " ");
            np += 1;
            if (np % 10 == 0)
                System.out.println();
        }
    }
    if (np % 10 != 0)
        System.out.println();
}