CS 360
Programming Languages
Streams Wrapup

Quick Review of Constructing Streams

- Usually two ways to construct a stream.
- Method 1: Use a function that takes a(n) argument(s) from which the next element of the stream can be constructed.

```
(define (integers-from n)
  (stream-cons n (integers-from (+ n 1))))
(define ints-from-2 (integers-from 2))
```

- When you use this technique, your code usually looks a lot like you have infinite recursion.
- Often the code is very clear (easy to see how it works).

Quick Review of Constructing Streams

- Usually two ways to construct a stream.
- Method 2: Construct the stream directly by defining it in terms of a modified version of another stream or itself.

```
(define ints-from-2-alt
  (stream-cons 2
    (stream-map (lambda (x) (+ x 1))
                ints-from-2-alt)))
```

- This technique is fine, but can be harder to figure out how it works.

Quick Review of Constructing Streams

- Usually two ways to construct a stream.
- Method 2: Construct the stream directly by defining it in terms of a modified version of another stream or itself.

```
(define ints-from-2-alt-alt
  (stream-cons 2
    (stream-map2 +
                 infinite-ones
                 ints-from-2-alt-alt)))
```

Fibonacci

- Method 1:

```
(define (make-fib-stream a b)
  (stream-cons a (make-fib-stream b (+ a b))))

(define fibs1 (make-fib-stream 0 1))
```

Fibonacci

- Method 2:

```
(define fibs
  (stream-cons 0
    (stream-cons 1
      (stream-map2 + (stream-cdr fibs) fibs))))
```

Sieve of Eratosthenes

- Start with an infinite stream of integers, starting from 2.
- Remove all the integers divisible by 2.
- Remove all the integers divisible by 3.
- Remove all the integers divisible by 5…etc

Sieve of Eratosthenes

```
(define (not-divisible-by s div)
  (stream-filter
     (lambda (x) (> (remainder x div) 0)) s))

(define (sieve s)
  (stream-cons
   (stream-car s)
   (sieve (not-divisible-by s (stream-car s)))))

(define primes (sieve ints-from-2))
```

Stream wrapup

- Streams are an implementation of the **Iterator** abstraction.
- An Iterator is something that lets the programmer traverse data in a ordered, linear fashion.
- You've seen C++ iterators that let you iterate over vectors.
  – There are also C++ iterators that let you iterate over sets, the entries in maps, and lots of other data structures.

Stream wrapup

- Racket's streams obey the same semantics as C++ iterators.

	Racket Stream	**C++ iterators**
Get the current element	**stream-car**	***it**
Advance to the next element	**stream-cdr**	**it++**

- You can easily create infinite iterators in C++, just like you can create infinite streams in Racket.
- The concept of an iterator doesn't distinguish between **iterating over a pre-existing data structure** and **iterating over something that's being generated on the fly**.

Stream wrapup

- What to take away from all this:
- Most modern languages have one or more data types that encapsulate this iteration concept.
  - Iterators: C++, Java
  - Streams: Racket, Scheme, and most functional languages
  - Generators: Python
  - Functions: Almost any language
- Can "fake" an iterator with a functions:

```
int nextInt()
{
  static int i = 0;
  i++;
  return i;
}
```

```
int nextInt(int old)
{
  return old + 1;
}
```

Stream wrapup

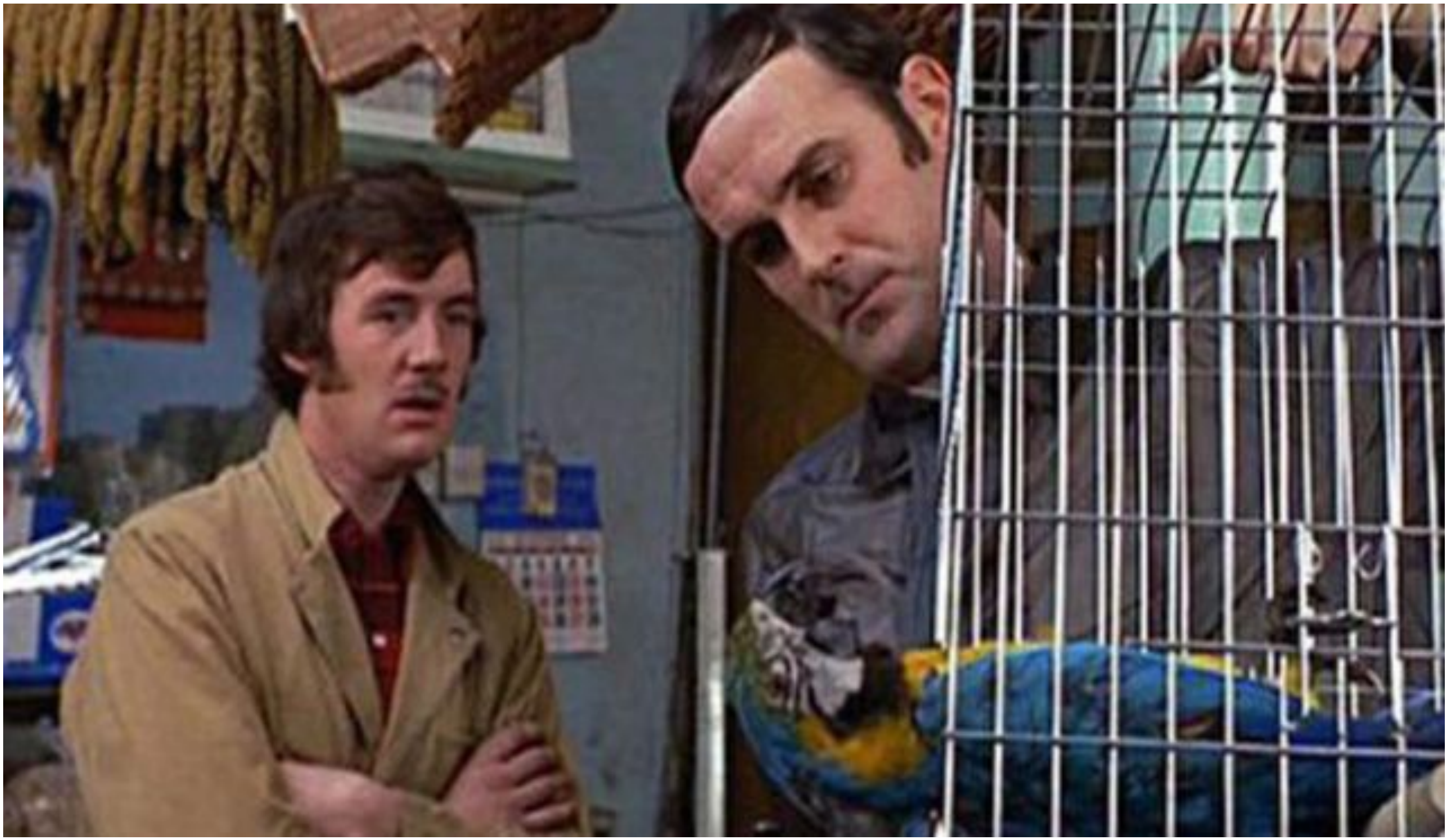
-

```
for x in range(0, 100**100):
  print(x)
```

  - This code would never run if Python actually computed a list containing 100^{100} integers before starting to print them.
  - Instead, **`range`** returns an iterator over the numbers that doesn't generate the next integer until it's needed.

- Python actually has the advantage here over Racket, because Racket could never generate a stream of 100^{100} integers.
- Why not?

And Now For Something Completely Different (But Kind of Related)



Fibonacci

```
(define (make-fib-stream a b)
  (stream-cons a (make-fib-stream b (+ a b))))
(define fibs1 (make-fib-stream 0 1))
```

- More efficient (but less clear?) than

```
(define (fib n)
  (cond ((= n 0) 0)
        ((= n 1) 1)
        (#t (+ (fib (- n 1)) (fib (- n 2))))))
```

- How to get the best of both worlds?

Memoization

- If a function has no side effects and doesn't read mutable memory, no point in computing it twice for the same arguments
  - Can keep a *cache* of previous results
  - Net win if (1) maintaining cache is cheaper than recomputing and (2) cached results are reused

- Similar to how we implemented promises, but the function takes arguments so there are multiple "previous results"

- For recursive functions, this *memoization* can lead to *exponentially* faster programs
  - Related to algorithmic technique of dynamic programming

```scheme
(define fast-fib
 (let ((cache '()))
  (define (lookup-in-cache cache n)
   (cond ((null? cache) #f)
         ((= (caar cache) n) (cadar cache))
         (#t (lookup-in-cache (cdr cache) n))))

 (lambda (n)
  (if (or (= n 0) (= n 1)) n
      (let ((check-cache (lookup-in-cache cache n)))
       (cond ((not check-cache)
              (let ((answer (+ (fast-fib (- n 1))
                               (fast-fib (- n 2)))))
               (set! cache (cons (list n answer) cache))
                    answer))
             (#t check-cache)))))))
```

Memoization in other languages

- Code for memoization is often easier with an explicit hashtable data structure:

```
int fib(int n) {
  static map<int, int> cache;
  if (n < 2) return n;
  if (cache.count(n) == 0) {
    int ans = fib(n-1) + fib(n-2);
    cache[n] = ans;
    return ans;
  } else return cache[n];
}
```

Memoization wrapup

- Memoization is related to streams in that streams also remember their previously-computed values.
  - Remember how promises save their results and return them instead of re-computing?
- But memoization is more flexible because it works with any function.

- Memoization is a classic example of the time-space trade-off in CS:
  - With memoization, we use more space, but use less time.