Another object-oriented program

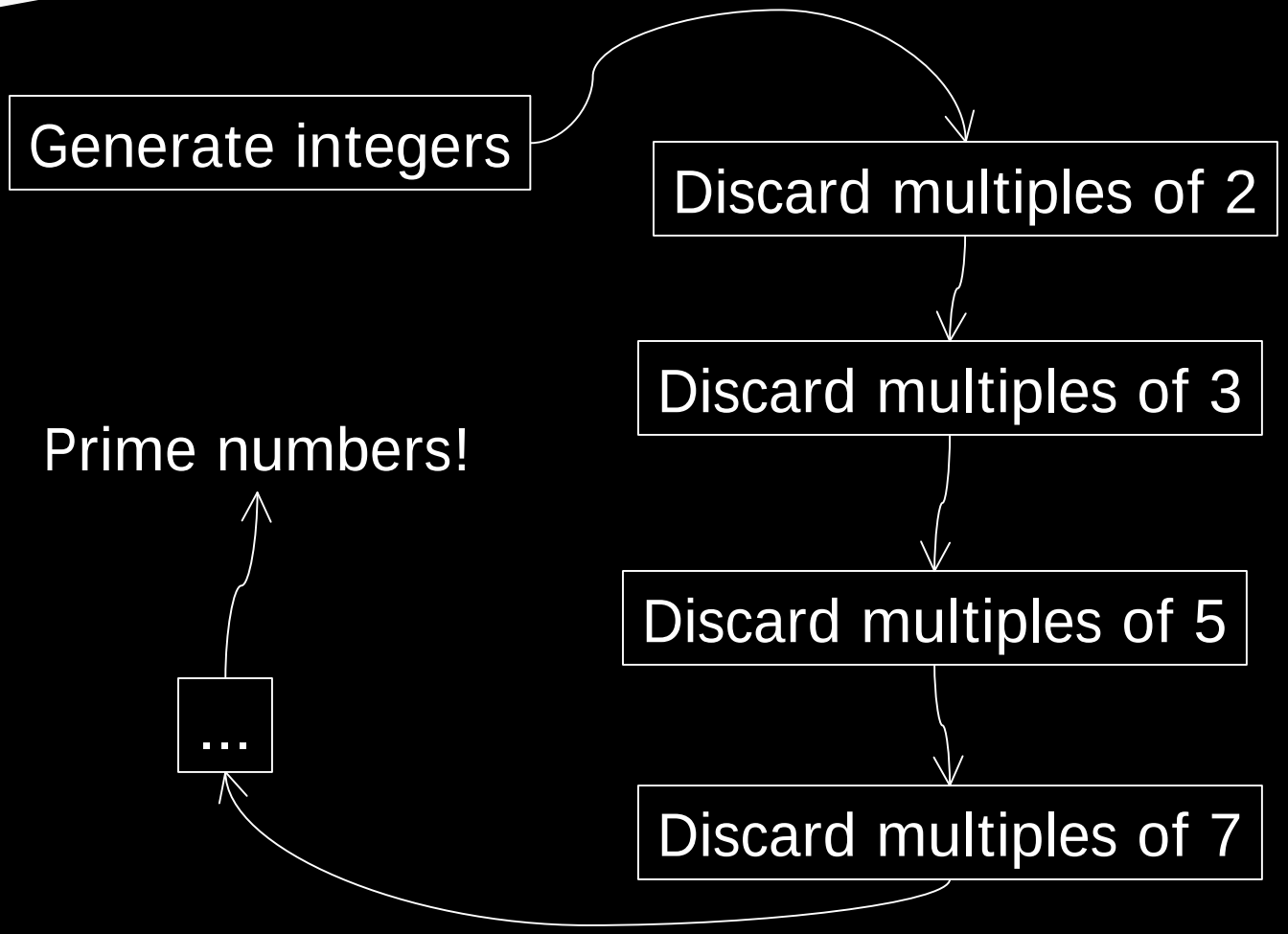
Prime numbers the hard way

(based on a program by Ravi Sethi in his book *Programming Languages—Concepts and Constructs*)

The object of this program

- Compute prime numbers, by
  - generating integers
  - discarding the ones that aren t prime
- Do so in an object-oriented style
  - a chain of objects, each of which discards multiples of a particular integer
  - the chain grows dynamically for each prime number computed

The data structure



What classes do we need?

- Classes that can act as a source of integers
  - `Counters` generate consecutive integers
  - `Filters` discard multiples of an integer
- A wrapper class to do the prime-number computation

We can already declare...

```
class Source { /* … */ };
class Counter: public Source
    { /* … */ };
class Filter: public Source
    { /* … */ };
class Sieve: public Source
    { /* … */ };
```

… but we can do better

- A `Filter` gets numbers from a `Source`
- So does a `Sieve`
- Therefore, we can define an auxiliary class to represent the idea of "a class that gets numbers from a `Source`"
- We will call that class `Conduit`

The revised hierarchy

```
class Source { /* … */ };
class Counter: public Source
    { /* … */ };
class Conduit: public Source
    { /* … */ }
class Filter: public Conduit
    { /* … */ };
class Sieve: public Conduit
    { /* … */ };
```

What is a Source?

- You poke at it and get a number back
- Other classes will be derived from it

```
class Source {
public:
    virtual int next() = 0;
    virtual ~Source() { }
    Source() { }
private:
    Source(const Source&);
    Source& operator=(const Source&);
};
```

Declaration of Counter

- Again, the declaration follows from the requirements

```
class Counter: public Source {
public:
    Counter(int);
    virtual int next();

private:
    int n;
};
```

Definition of Counter

```
Counter::Counter(int n0): n(n0) { }
int Counter::next()
{
    return n++;
}
```

We can already use our Counter class

```
int main()
{
    Counter c(1);
    int n;
    do {
        n = c.next();
        printf("%d\n", n);
    } while (n < 10);
    return 0;
}
```

What does a `Conduit` do?

- It takes input from a `Source`
- It delivers output on demand through the `next` function
- It lets you find its `Source`
- It gives you a way to change the `Source` to be somewhere else
- It manages memory

Memory management

- As in the last lecture, we will assume that if you give away a pointer to an object, you also delegate responsibility for deleting that object
- Class `Sieve` will hide memory details from users
- So it is sufficient for a `Conduit` to delete its `Source` when destroyed

Declaration of Conduit

```
Class Conduit: public Source {
public:
    Conduit(Source*);
    virtual ~Conduit();
protected:
    Source* source();
    void splice(Source*);
private:
    Source* src;
};
```

Definition of Conduit

```
Conduit::Conduit(Source* s):
    src(s) { }
Conduit::~Conduit() { delete src; }
Source* source() { return src; }
void Conduit::splice(Source* s)
{
    src = s;
}
```

Class `Filter`

- A `Filter` accepts numbers from a `Source` and screens out multiples of a given integer
- Fundamental operations:
  - Construct a `Filter` from a given integer and `Source`
  - Fetch an integer

Filter declaration

```
class Filter: public Conduit {
public:
    Filter(int, Source*);
    virtual int next();
private:
    int factor;
};
```

How does a `Filter` work?

- Obviously, it must remember its source (`Conduit` does that) and what to filter
- The `next` function does the actual screening

Definition of Filter

```
Filter::Filter(int f, Source* s):
    Conduit(s), factor(f) { }
int Filter::next()
{
    int n;
    do n = source()->next();
    while (n % factor == 0);
    return n;
}
```

What should a `Sieve` do?

- Actual prime number computation
  - Start a `Counter` at 2
  - Each time we get back a number, create a new `Filter` to screen out multiples of that number
- Clean interface to the rest of the world
  - Conceal the other classes
  - Memory management

Using a Sieve

```
int main()
{
    Sieve s;
    int n;
    do {
        n = s.next();
        printf("%d\n", n);
    } while (n < 100);
    return 0;
}
```

Declaring class Sieve

```
class Sieve: public Conduit {
public:
    Sieve();
    virtual int next();
};
```

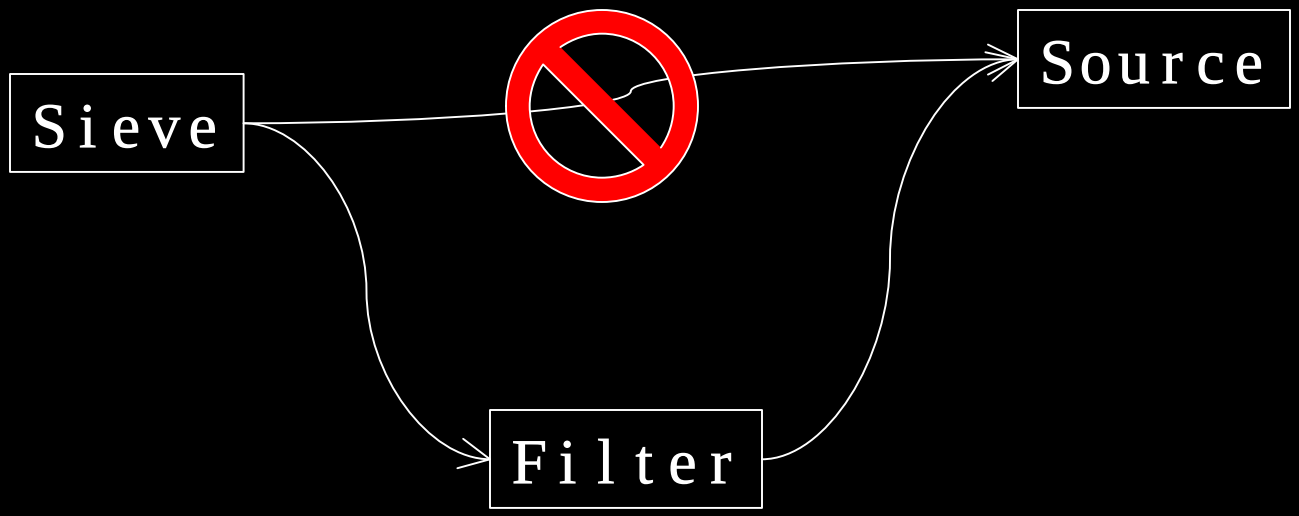
Defining class `Sieve`

- The constructor is easy:

```
Sieve::Sieve():
    Conduit(new Counter(2)) { }
```

- But what about the `next` function?
  - It calls `source()->next()`, which yields the next prime
  - Then it has to splice in a new `Filter`

The data structure



Definition of `Sieve::next`

```
int Sieve::next()
{
    int n = source()->next();
    splice(new Filter(n, source()));
    return n;
}
```

Observations

- A `Sieve` turns out to act like a `Conduit`, so it simplifies the code to use `Conduit` as a base class
- Class `Sieve` does not need an explicit destructor, because class `Conduit` takes care of it
- Class `Sieve` is the only one intended for end-user consumption

More observations

- Not an optimal algorithm
- Recursive `deletes` could be improved
- Nevertheless, the idea of growing a data structure to represent an increasingly complicated computation is an important one
- In effect, we've built an interpreter for a tiny, special-purpose language

Understanding object-oriented programs

- Following the whole program at once can be tricky
- One useful strategy
  - Understand the whole program approximately
  - Understand each piece and its immediate context
  - Walk through it for some test cases