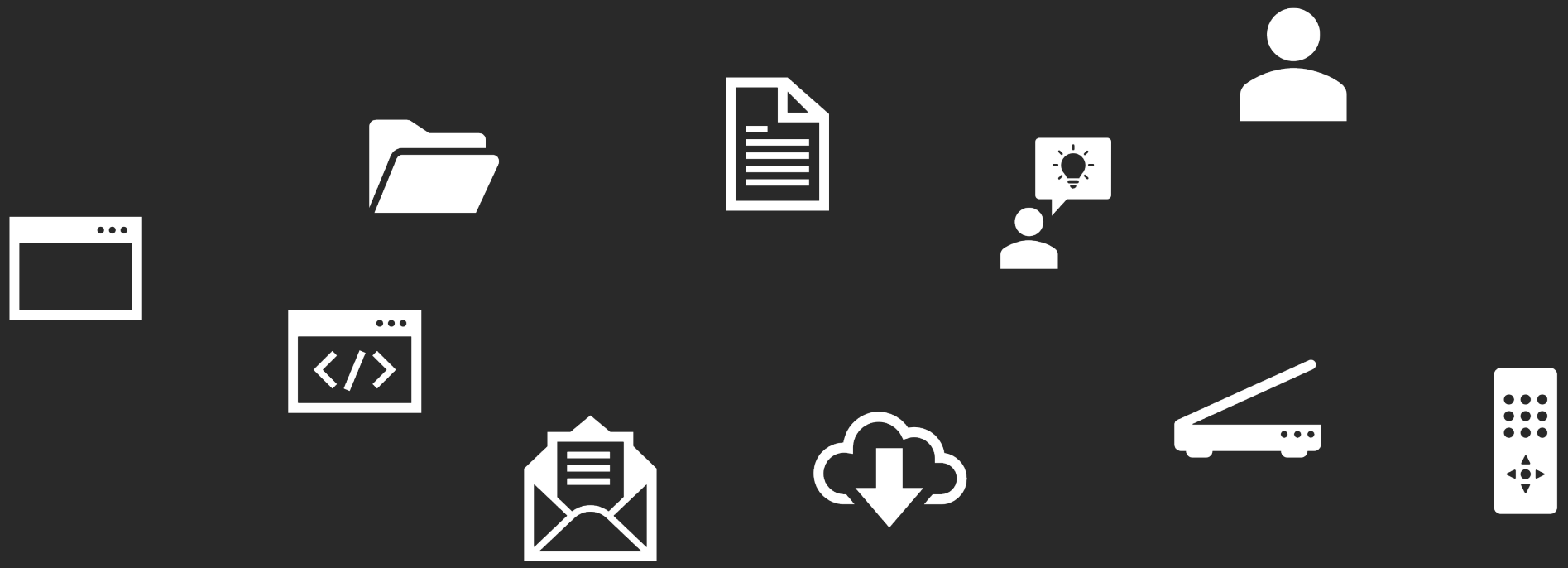
Streams

Game Plan

- overview
- stringstream
- state bits
- input/output streams
- manipulators

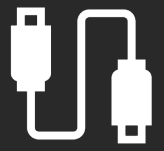
We often want our programs to interact with external devices.



Here are some common devices we will use.

console & keyboard

files



other programs (pipelines)

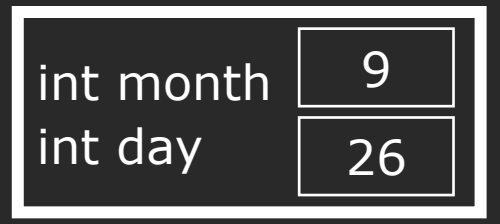
sockets (networking)

Take CS 110!

Take CS 144!

How would you print a Date object to the console?

console



A Date object in your program

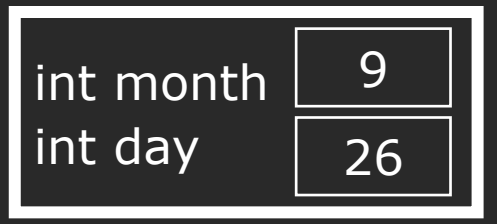
You'd first convert the object to a string.

console

"Sep. 26"

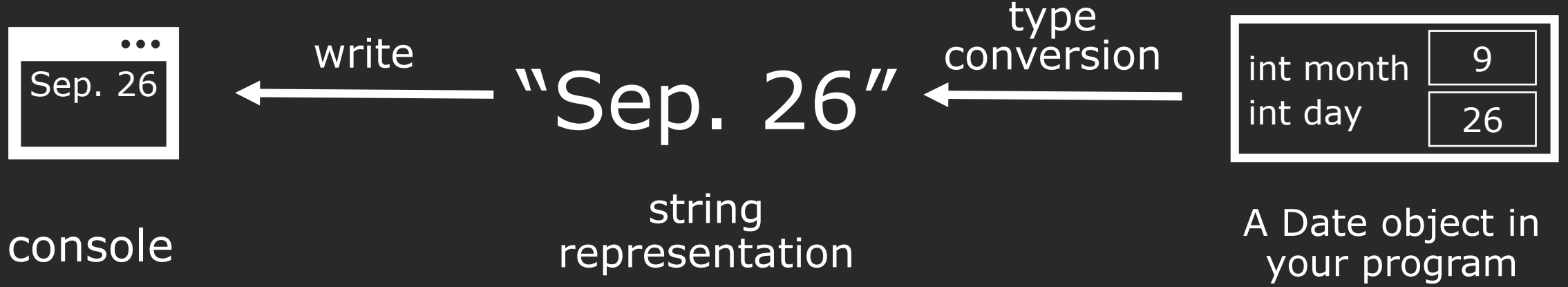
string representation

type conversion



A Date object in your program

Then write the string to the console.



How would you read a double from a file?

file

You would read the characters and convert it to a string first.

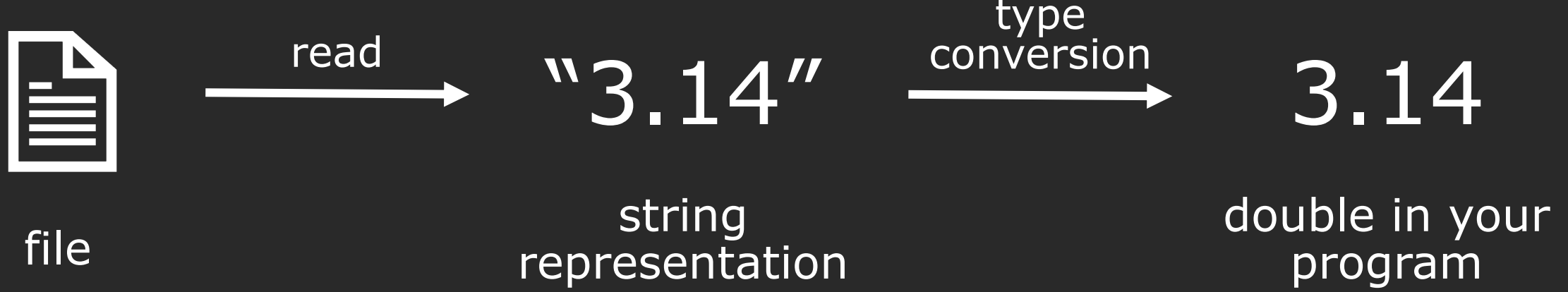
file

read

“3.14”

string
representation

Then, you would convert the string to the proper double as a variable.



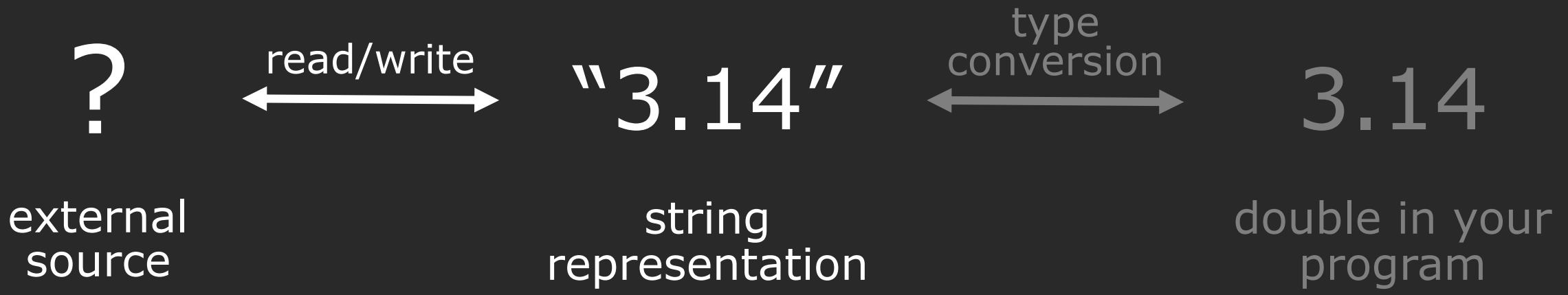
In general, there are two main challenges.

external source

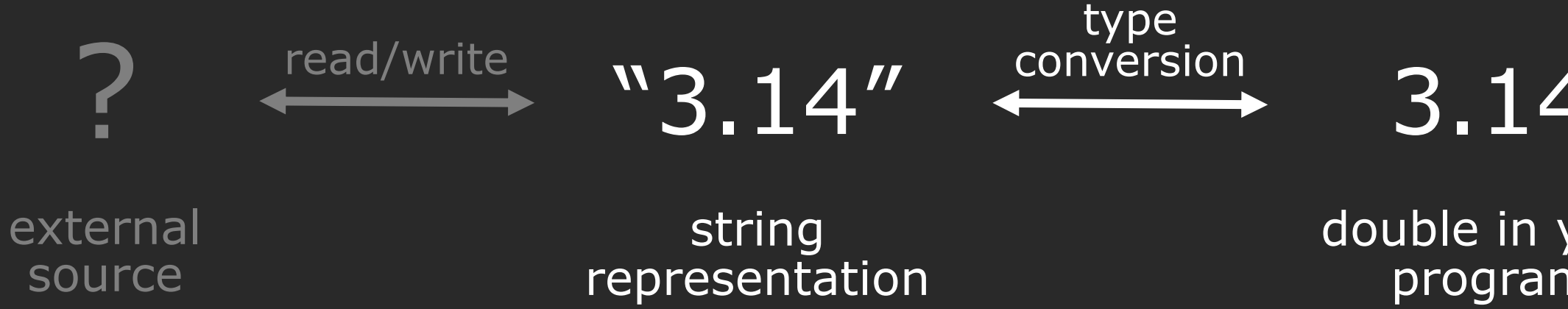
string representation

double in your program

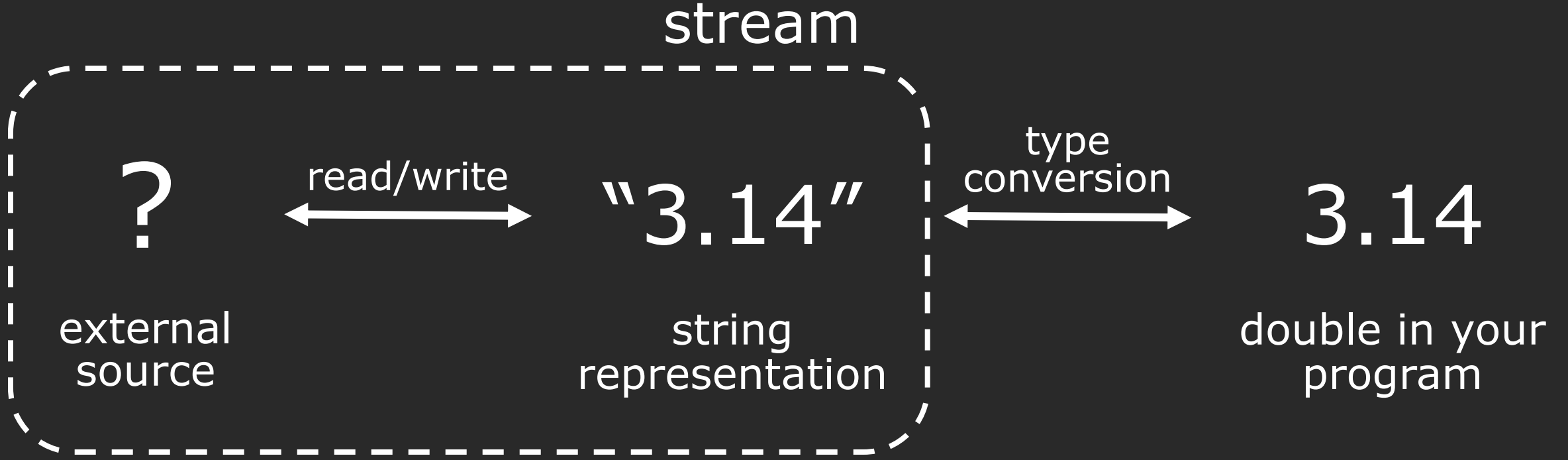
First: we need to retrieve/send data from the source in string form.



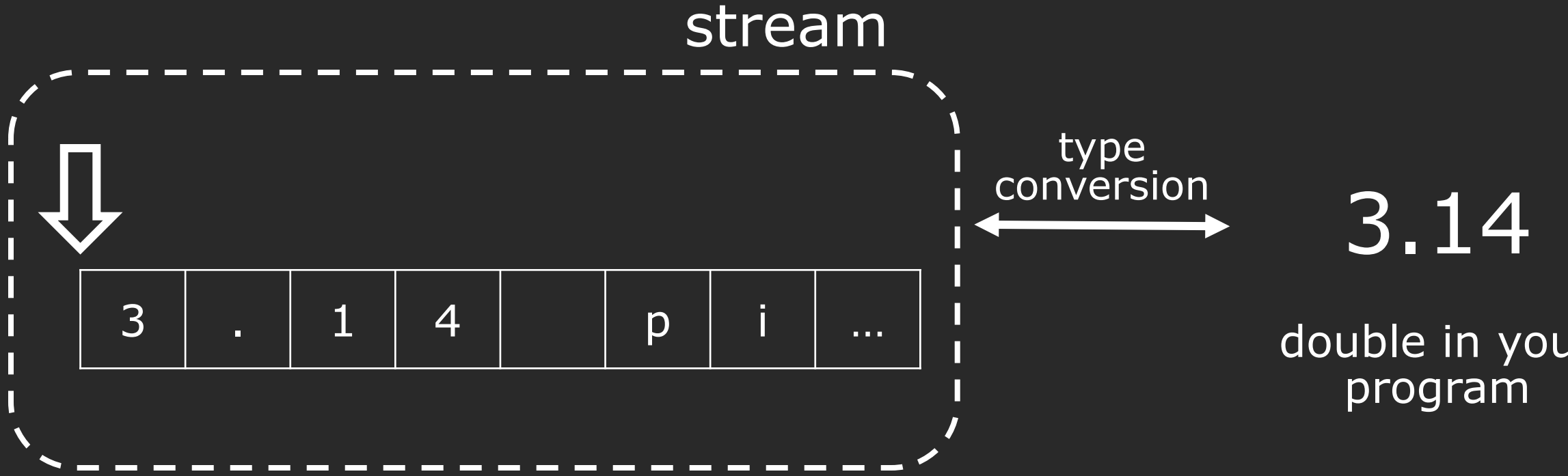
Second: we need to convert between data in our program and its string representation.



Streams provide a unified interface for interacting with external input.



You can imagine a stream to be a character buffer that automatically interacts with the external source.



Streams also convert variables to a string form that can be written in the buffer.

<< output

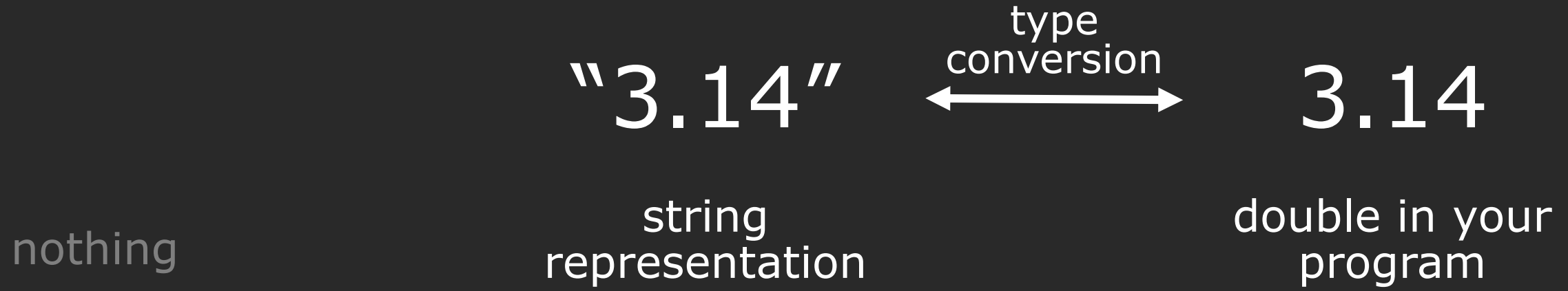
>> input

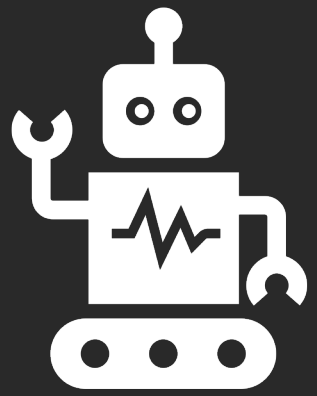
3.14

double in your program

stringstream

A stringstream is not connected to any external source.





Example

creating, extracting, and inserting
from a stringstream

stringstream constructors

```
istringstream iss(“Initial”);

ostringstream oss(“Initial”);
```

Constructors with initial text in the buffer.

Can optionally provide “modes” such as ate (start at end) or bin (read as binary).

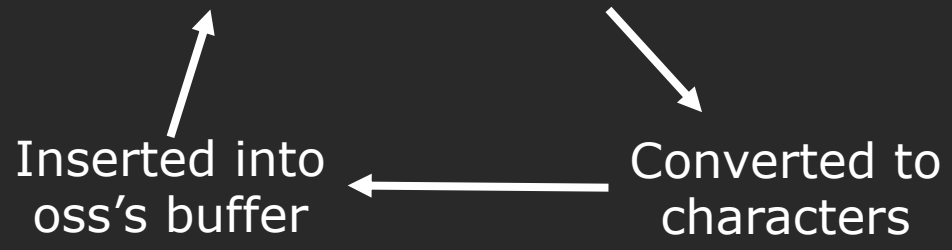
```
istringstream iss(“Initial“, stringstream::bin);
ostringstream oss(“Initial“, stringstream::ate);
```

stringstream constructors

```
// “16.9 Ounces”, pos at front
istringstream iss(“16.9 Ounces”);

// “16.9 Ounces”, pos at front
ostringstream oss(“16.9 Ounces”);

// “16.9 Ounces”, pos at back
ostringstream oss(“16.9 Ounces”, stringstream::ate);
```

stringstream formatted i/o

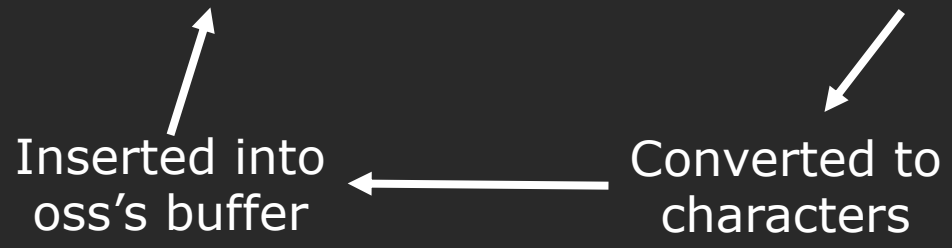
```
oss << var1 << var2;
```




```
iss >> var1 >> var2;
```

stringstream formatted i/o

```
oss << var1 << var2;
```




```
iss >> var1 >> var2;
```

stringstream formatted i/o

```
oss << var1 << var2;
```

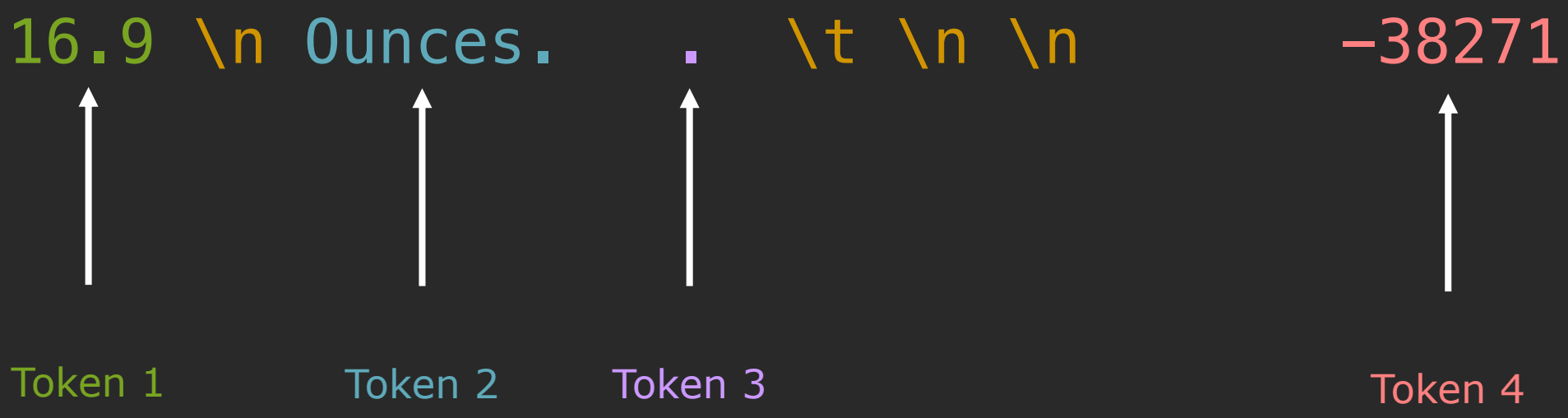
```
iss >> var1 >> var2;
```

stringstream formatted i/o

```
oss << var1 << var2;
```

```
iss >> var1 >> var2;
```

What is a whitespace separated token?




```
iss >> token1 >> token2 >> token3 >> token4;
```

Types matter! Stream stops reading at any whitespace or any invalid character for the type.

```
16.9 \n Ounces.   .  \t \n \n       -38271
```

Token 1 Token 2 Token 3 Token 4

```
int token1, string token2, char token3, bool token4

iss >> token1 >> token2 >> token3 >> token4;
```

stringstream formatted i/o

```
// buffer contains ”Ito En Green Tea “, pos at end
ostringstream oss("Ito En Green Tea “, stringstream::ate);

// str function returns characters in buffer as a string
cout << oss.str() << endl;

// Converts 16.9 to string and insert into buffer
oss << 16.9 << “ Ounce ”;

// prints ”Ito En Green Tea 16.9 Ounce “
cout << oss.str() << endl;
```

stringstream formatted i/o

```
// buffer contains ”Ito En Green Tea “, pos at front
istringstream iss(“16.9 Ounces”);

double amount, string unit;

// reads next whitespace-separated token ”16.9”
// converts to correct type (double) and placed into ‘amount’
// same for unit, except no conversion needed
iss >> amount >> unit;

// amount is now 8.45
amount /= 2;
```

Questions to Ponder

- What exactly does >> do?
- Why can you chain << and >>?
- Is there a stringstream that can you can both insert and extract?

Key Takeaways

- >> extracts the next variable of a certain type, up to the next whitespace.
- The >> and << operators return a reference to the stream itself, so in each instance the stream is the left-hand operand.
- Yes, it’s called a stringstream. Reading and writing simultaneously can often lead to subtle bugs, be careful!

stringstream positioning functions

get position	`oss.tellp();`	`iss.tellg();`
set position	`oss.seekp(pos);`	`iss.seekg(pos);`
create offset		`streamoff(n)`

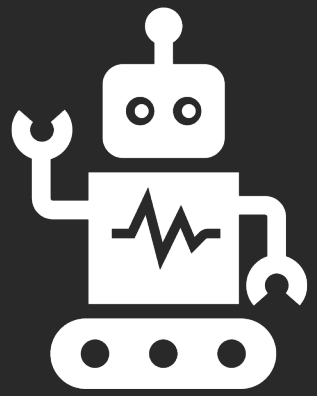
These methods let you manually set the position.
Most useful is the offset which can be added to positions.

Note: the types are a little funky. Read the documentation!

Learn more about stringbuf!

For more fine-tuned control, you can access and modify the underlying buffer.

Requires knowledge of pointers and C-arrays. Learn more about them after taking CS 107!



Example

implementing stringToInteger (first attempt)

First attempt: no error-checking.

```
int stringToInteger(const string& str) {
    istringstream iss(str);

    int result;
    iss >> result; // problem: what if this fails?

    return result;
}
```

state bits

Four bits indicate the state of the stream.

Good bit: ready for read/write.

Fail bit: previous operation failed, all future operations frozen.

EOF bit: previous operation reached the end of buffer content.

Bad bit: external error, likely irrecoverable.

Common reasons why that bit is on.

G — Nothing unusual, on when other bits are off.

F — Type mismatch, file can’t be opened, seekg failed.

E — Reached the end of the buffer.

B — Could not move characters to buffer from external source. (e.g. the file you are reading from suddenly is deleted)

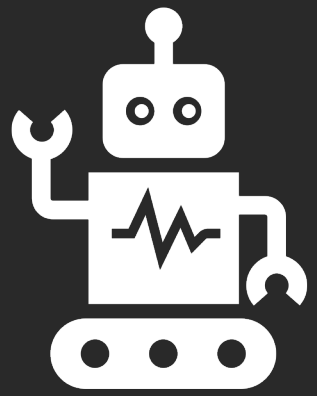
Important things about state bits.

G and B are not opposites! (e.g. type mismatch)

G and F are not opposites! (e.g. end of file)

F and E are normally the ones you will be checking.

Conclusion: You should rarely be using G.



Example

print the stream bits in our function

implementing stringToInteger (second attempt)

Second attempt: incomplete error-checking.

```
int stringToInteger(const string& str) {
    istringstream iss(str);

    int result;
    iss >> result;
    if (iss.fail()) throw domain_error(…);

    return result;
}
```

Check if the operation failed (due to type mismatch).

Third attempt: complete error-checking.

```
int stringToInteger(const string& str) {
    istringstream iss(str);

    int result;
    iss >> result;
    if (iss.fail()) throw domain_error(…);

    char remain;
    iss >> remain;
    if (!iss.fail()) throw domain_error(…);
    return result;
}
```

Why do we need ‘remain’? Ensure no characters after the integer.

These are equivalent!

```
iss >> remain;
if (iss.fail()) { // report error }
```

```
if (!(iss >> remain)) { // report error }
```

Reason: >> returns iss itself, which can act like a boolean for iss.fail().

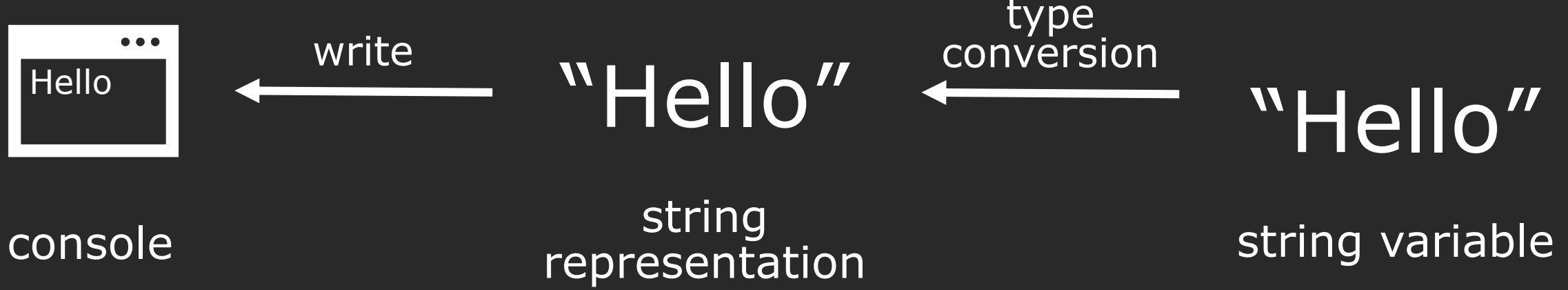
Third attempt: complete error-checking.

```
int stringToInteger(const string& str) {
     istringstream iss(str);

     int result; char remain;
     if (!(iss >> result) || iss >> remain)
          throw domain_error(…);

     return result;
}
```

Notice the short circuiting!

cout and cin

Key difference: there is an external source.



Data is sent between the external source and the buffer.

keyboard

read

"42"

string representation

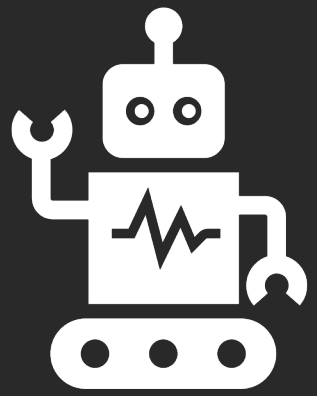
type conversion

42

int in your program

There are four standard iostreams.

`cin`	Standard input stream
`cout`	Standard output stream (buffered)
`cerr`	Standard error stream (unbuffered)
`clog`	Standard error stream (buffered)



Example

output streams, buffering, and flushing

Buffered stream: characters are stored in an intermediate buffer before being moved to the external source.

To push the characters to the external source, the stream must be “flushed”

```
cout << “CS”;
cout << 106;
cout << flush;
cout << ‘L’;
cout << endl;
```

“CS106” only shows up at this point.

To push the characters to the external source, the stream must be “flushed”

```
cout << “CS”;
cout << 106;
cout << flush;
cout << ‘L’;
cout << endl;
```

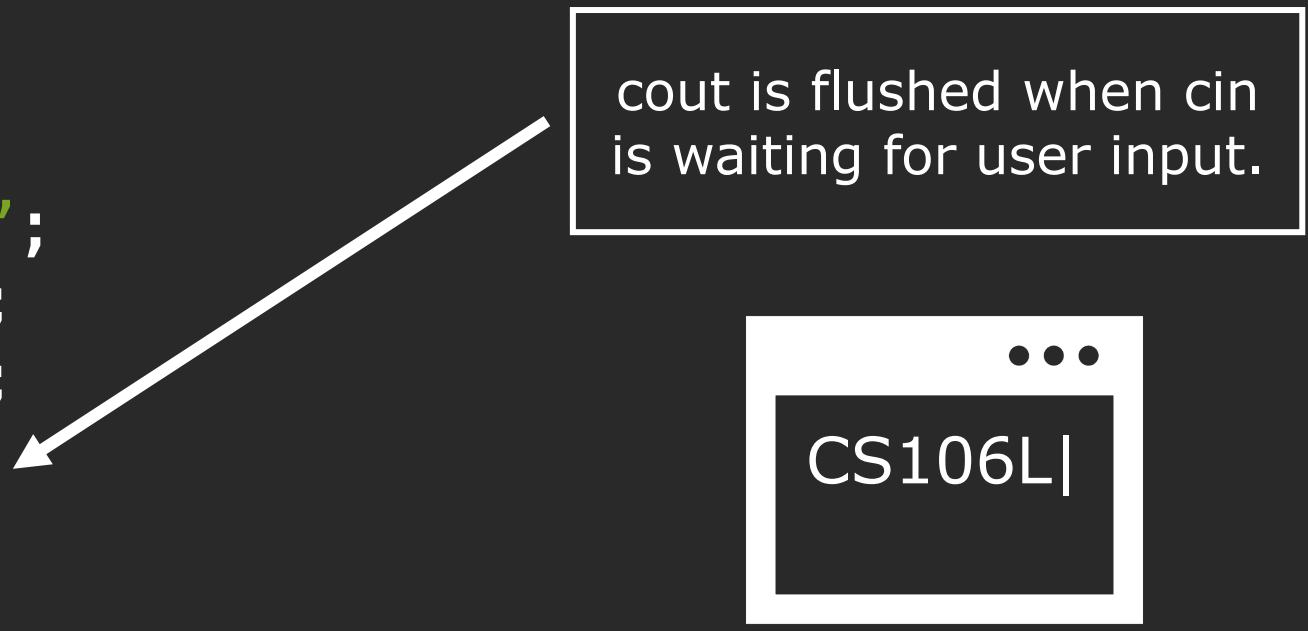
To flush or not to flush?

```
// Option 1: flush every int
for (int i = 0; i < 100000; ++i) {
  cout << i << endl;
}


// Option 2: flush oonly at the end
for (int i = 0; i < 100000; ++i) {
  cout << i << '\n';
}
cout << flush;
```

What's the pros/cons of each option?

Other streams using the console may also flush cout.

```
int num;

cout << “CS”;
cout << 106;
cout << ‘L’;
cin >> num;
```



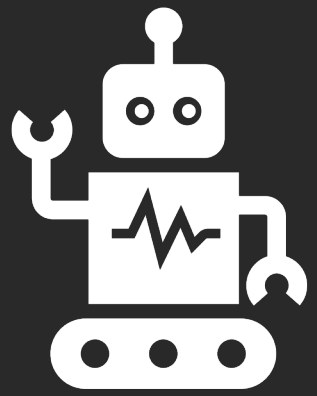
Streams also convert variables to a string form that can be written in the buffer.

<< output

>> input

3.14

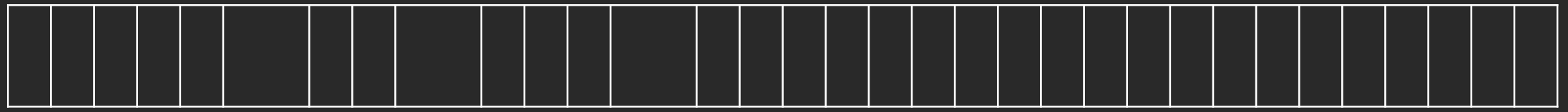
double in your program



Example

input streams, buffering, and waiting for user input.

cin



G F E B

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

???

response
(string)

???

age
(int)

???

The lecture code included cout statements.


```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

???

response
(string)

???

age
(int)

???

Since there is nothing in the buffer, cin waits for the user to type something in.

cin

A	v	e	r	y	\n																										

G F E B

Avery

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

???

response
(string)

???

age
(int)

???

After typing in my name and pressing enter, cin transfers what I typed into the buffer.

Avery

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

Then we read from the buffer into the variable name, just like a stringstream.

Avery
|

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

cin skips whitespace, sees no more input, and prompts the user again.

Avery
20

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

Everything I type is transferred to the buffer.


```
Avery
20
```

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name (string) — "Avery"

age (int) — 20

response (string) — ???

We read directly into an int, stopping at a whitespace.

Avery
20

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

20

We read directly into an int, stopping at a whitespace.


```
Avery
20
```

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name (string) — "Avery"

age (int) — 20

response (string) — ???

We now print the variables (don't forget cout is buffered!)

Avery
20
Avery20

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

age
(int)

20

response
(string)

???

But attempting reading again will flush cout.


```
Avery
20
Avery20|
```

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

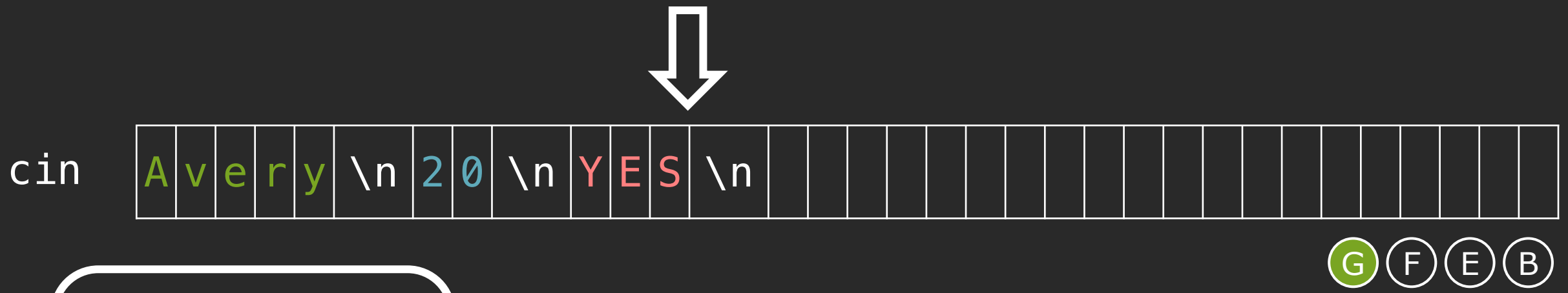
response
(string)

???

age
(int)

20

We prompt the user again.




```
Avery
20
Avery20YES
```

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

"YES"

age
(int)

20

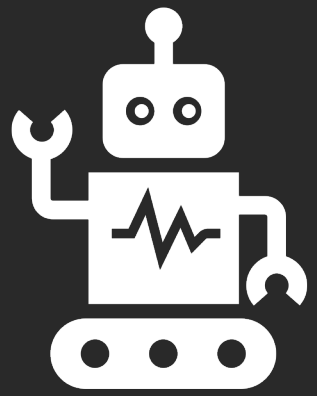
We type something, it's transferred to the buffer, and read into the variable.

Key Takeways

- When does the program prompt the user for input?
- Why does the cout operation not immediately print the output onto the console? When is the output printed?
- Does the position pointer skip whitespace before the token or after the token with each >> operation? (this is important!)
- Does the position pointer always read up to a whitespace? If not, come up with a counterexample.

Key Takeways

- The program hangs and waits for user input when the position reaches EOF, past the last token in the buffer.
- All input operations will flush cout.
- The position pointer does the following:
  - consume all whitespaces (spaces, newlines, etc.)
  - reads as many characters until:
    - a whitespace is reached, or…
    - for primitives, the maximum number of bytes necessary to form a valid variable.
    - example: if we extract an int from “86.2”, we’ll get 86, with pos at the decimal point.



Example

when input streams go wrong


```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

???

response
(string)

???

age
(int)

???

Let’s try something innocuous.
I type in my full name.

G F E B

Avery Wang

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name (string): ???

response (string): ???

age (int): ???

After typing in my name and pressing enter, cin transfers what I typed into the buffer.

Avery Wang

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

Remember cin reads up to a whitespace.

Avery Wang

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

cin now tries to read an int. It skips past the initial whitespace.

G F E B

Avery Wang

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

It tries to read in an int,
but fails.

cin

G F E B

Avery Wang

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name (string): "Avery"

response (string): ???

age (int): ???

The fail bit is turned on.


```
Avery Wang
Avery-2736262
```

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

cout now prints the name and age (which is uninitialized!)


```
Avery Wang
Avery-2736262
```

```
cin >> name;
cin >> age;
cout << name << age;
cin >> response;
```

name
(string)

"Avery"

response
(string)

???

age
(int)

???

Worst, since the fail bit is on, all future cin operations fail.

3 reason why >> with cin is a nightmare.

1. cin reads the entire line into the buffer but extracts whitespace-separated tokens.

2. Trash in the buffer will make cin not prompt the user for input at the right time.

3. When cin fails, all future cin operations fail too.

manipulators

BTW these exist, they’re easy to use, just look them up.

There are some keywords that will change the behavior of the stream when inserted.

`endl`	insert newline and flush stream
`ws`	skips all whitespace until it finds another char
`boolalpha`	prints “true” and “false for bools.
`hex`	prints numbers in hexadecimal
`setpercision`	adjusts the precision of printed numbers

We can use manipulators to pad the output.

```
cout << "[" << setw(10) << "Ito" << "]";
```

Output: [Ito]

```
cout << "[" << left << setw(10) << "Ito" << "]";
```

Output: [Ito]

```
cout << "[" << left << setfill('-') << setw(10) << "Ito" << "]";
```

Output: [Ito-------]

Your challenge for Tuesday

```
// Given a string that has whitespace separated tokens
// return a vector containing those tokens

input string: “I 3 \n MM 6”
output vector: {“I”, “3”, “MM”, “6”}

vector<string> stringSplit(const string& str) {
     vector<string> tokens;
     // use tokens.push_back(token);
     return tokens;
}
```

Your challenge for Tuesday

```
// Given a start time and a duration,
// calculate the end time.
// Assume correct formatting of string.

input string: “1:30 PM \n 1 hour 20 minute”
console string: “2:50 PM”

void printEndTime(const string& input) {
     // you fill this out!
}
```

How do you avoid this bug?

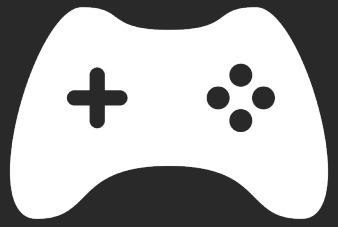
```
int hour = 3;
int minute = 0;

cout << hour << ":" << minute << "\n";
// prints 3:0 instead of 3:00
```

Your challenge for Tuesday

Play around with streams and try printing out the state bits.

See if you can use the state bits to help you control the streams.

On Friday's 106B lecture, you'll learn about file streams. Test the state bits on those too!



Next time

Stream error-handling: implementing simpio
and other Stanford i/o libraries