



<http://web.stanford.edu/class/cs106l/>

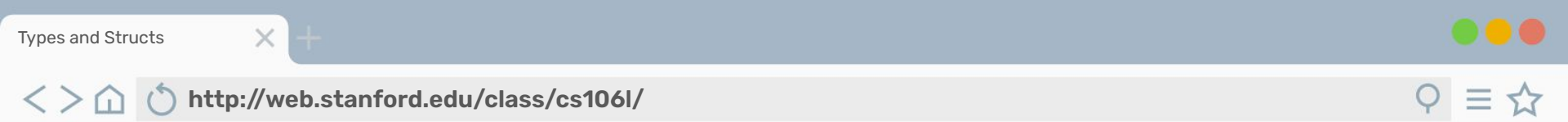


Types and Structs

The blessings (and curses) of a typed language and
how to use it properly!

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Spring 2024



Logistics Recap

As a reminder, all course materials can be found on our class website at cs106l.stanford.edu!

- If you missed the first lecture, definitely look over the slides because we covered the important logistics there.

We have an anonymous feedback form that is open all quarter! Feel free to communicate with us through that as well!

Logistics Recap

The mailing list issue has been fixed! Email us at:

cs106l-spr2324-staff@lists.stanford.edu



Agenda



01. C++ Basics

Comparing to other languages you might know

02. Types

Working with a statically typed language

03. Structs

...and pairs and structured binding





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01. C++ Basics

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C++: Basic Syntax + the STL

Basic syntax

- Semicolons at EOL
- Primitive types (ints, doubles etc)
- Basic grammar rules

The STL

- Tons of general functionality
- Built in classes like maps, sets, vectors
- Accessed through the namespace `std::`

C++: Basic Syntax + the STL

Basic syntax

- Semicolons at EOL
- Primitive types (ints, doubles etc)
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S,

This is some C++ code...

```
#include <iostream>

int main() {
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```


This is some C++ code...

```
#include <iostream>

int main() {
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```

To import additional
functionality, we use
`#include`



This is some C++ code...

```
#include <iostream>

int main() {
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```

All lines/statements
end in a semicolon.



This is some C++ code...

```
#include <iostream>

int main() {
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```

Function declarations need the type of the return, the name of the function, and any parameters (inside the parentheses).

This is some C++ code...

```
#include <iostream>
```

```
int main() {  
    std::cout << "Hello, world!" << std::endl;  
    return 0;  
}
```

The code of a function lives inside a block marked by curly brackets {}.

C++ Basic Syntax + the STL

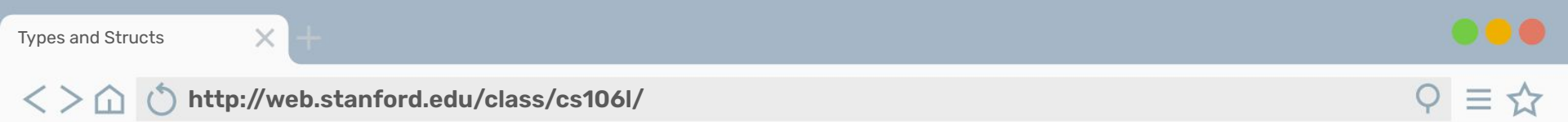
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The STL

- Tons of general functionality
- Built in classes like maps, sets, vectors
- Accessed through the namespace `std::`
- Extremely powerful and well-maintained

Namespaces

- MANY things are in the `std::` namespace
 - e.g. `std::cout`, `std::cin`, `std::lower_bound`
- CS 106B always uses the `using namespace std;` declaration, which automatically adds `std::` for you
- We won't (most of the time)
 - it's not good style!



STL Naming Conventions

STL = Standard Template Library

- It contains TONS of functionality (algorithms, containers, functions, iterators), some of which we will explore in this class.

std:: = the STL namespace

So to access elements from the **STL** use **std::** !

Questions?



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Fundamental Types

```
int val = 5; //32 bits (usually)
```

```
char ch = 'F'; //8 bits (usually)
```

```
float decimalVal1 = 5.0; //32 bits (usually)
```

```
double decimalVal2 = 5.0; //64 bits (usually)
```

```
bool bVal = true; //1 bit
```

Fundamental Types++

```
#include <string>
```

```
int val = 5; //32 bits (usually)
```

```
char ch = 'F'; //8 bits (usually)
```

```
float decimalVal1 = 5.0; //32 bits (usually)
```

```
double decimalVal2 = 5.0; //64 bits (usually)
```

```
bool bVal = true; //1 bit
```

```
std::string str = "Haven";
```

Fill in the blanks!

```
_____ a = "test";
```

```
_____ b = 3.2 * 5 - 1;
```

```
_____ c = 5 / 2;
```

```
_____ d(int foo) { return foo / 2; }
```

```
_____ e(double foo) { return foo / 2; }
```

```
_____ f(double foo) { return int(foo / 2); }
```

```
_____ g(double c) {
```

```
    std::cout << c << std::endl;
```

```
}
```

Fill in the blanks!

```
       std::string a = "test";
```

```
       b = 3.2 * 5 - 1;
```

```
       c = 5 / 2;
```

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       d(int foo) { return foo / 2; }
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       g(double c) {  
    std::cout << c << std::endl;  
}
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int c = 5 / 2;
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```

```
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```
_____ g(double c) {  
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}
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double b = 3.2 * 5 - 1;
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}
```




Fill in the blanks!

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double b = 3.2 * 5 - 1;
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int c = 5 / 2;
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int d(int foo) { return foo / 2; }
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_____ g(double c) {  
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Fill in the blanks!

```
std::string a = "test";  
double b = 3.2 * 5 - 1;  
int c = 5 / 2;
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int d(int foo) { return foo / 2; }  
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```

```
_____ g(double c) {  
    std::cout << c << std::endl;  
}
```

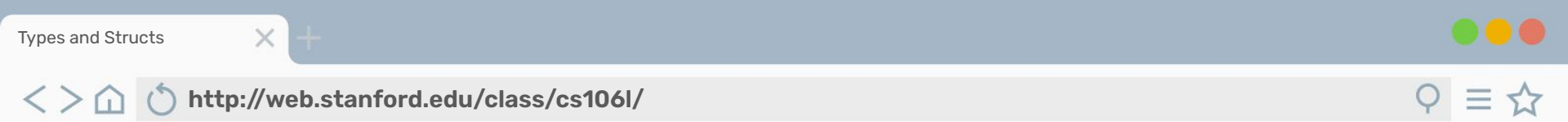


Fill in the blanks!

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double b = 3.2 * 5 - 1;  
int c = 5 / 2;
```

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int d(int foo) { return foo / 2; }  
double e(double foo) { return foo / 2; }  
int f(double foo) { return int(foo / 2); }
```

```
void g(double c) {  
    std::cout << c << std::endl;  
}
```



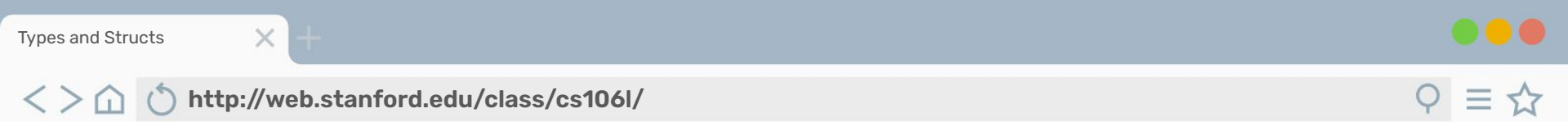
C++ is a statically typed language!

Statically typed: everything with a name (variables, functions, etc) is given a type **before runtime.**

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A language like Python is **dynamically typed:** everything with a name (variables, functions, etc) is given a type at runtime based on the thing's **current value**



C++ is a statically typed language!

Statically typed: everything with a name (variables, functions, etc) is given a type **before runtime.**

A language like Python is **dynamically typed:** everything with a name (variables, functions, etc) is given a type at runtime based on the thing's **current value**


What do we mean by runtime?



Compiled vs Interpreted

Spot the difference: When is source code translated?

Source Code: Original code, usually typed by a human into a computer (like C++ or Python)



Compiled vs Interpreted: When is source code translated?

Dynamically typed, interpreted

- Types are checked on the fly, during execution, line by line
- Example: Python

Statically typed, compiled

- Types before program runs during compilation
- Example: C++

Runtime: Period when program is executing commands (after compilation, if compiled)

Dynamic vs Static Typing

Python

```
a = 3
b = "test"

def func(c):
    # do something
```

C++

```
int a = 3;
string b = "test";

char func(string c) {
    // do something
}
```

Dynamic vs Static Typing

Python

```
val = 5  
bVal = true  
str = "hi"
```

val



bVal



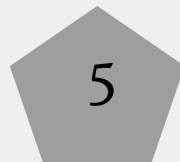
str



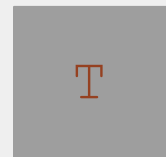
C++

```
int val = 5;  
bool bVal = true;  
string str = "hi";
```

val



bVal



str



Dynamic vs Static Typing

Python

```
val = 5
bVal = true
str = "hi"
val = "hi"
str = 100
```

val

bVal

str



C++

```
int val = 5;
bool bVal = true;
string str = "hi";
```

val

bVal

str



Dynamic vs Static Typing

Python

```
val = 5
bVal = true
str = "hi"
val = "hi"
str = 100
```

val

bVal

str

"hi"

T

100

C++

```
int val = 5;
bool bVal = true;
string str = "hi";
val = "hi";
str = 100;
```

val

bVal

str

"hi"

T

100

ERROR!

Dynamic vs Static Typing

Python

```
def div_3(x):  
    return x / 3  
div_3("hello")
```

C++

```
int div_3(int x) {  
    return x / 3;  
}  
div_3("hello")
```

Dynamic typing can
cause some
unexpected results!

Dynamic vs Static Typing

Dynamic typing can cause some unexpected results!

Python

```
def div_3(x):  
    return x / 3  
div_3("hello")
```

//CRASH during runtime, can't divide a string

C++

```
int div_3(int x) {  
    return x / 3;  
}  
div_3("hello")
```

//Compile error: this code will never run

Dynamic vs Static Typing

Python

```
def mul_3(x):  
    return x * 3  
mul_3("10")
```

C++

```
int mul_3(int x) {  
    return x * 3;  
}  
mul_3("10");
```

Dynamic vs Static Typing

Python

```
def mul_3(x):  
    return x * 3  
mul_3("10")
```

//returns "101010"

C++

```
int mul_3(int x) {  
    return x * 3;  
}  
mul_3("10");
```

//Compile error: "10" is a string!
This code won't run

Dynamic vs Static Typing

Python

```
def add_3(x):  
    return x + 3  
add_3("10")
```

//returns "103"

C++

```
int add_3(int x) {  
    return x + 3;  
}
```

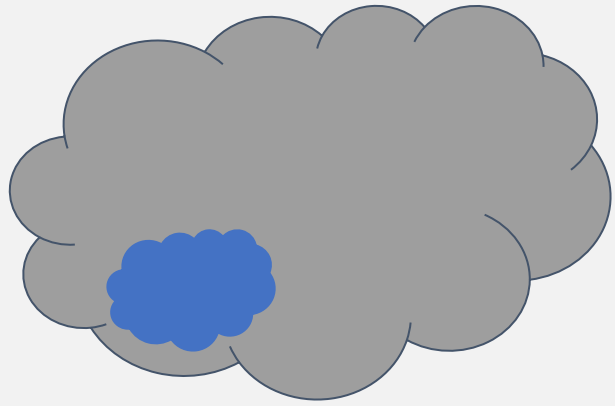
```
add_3("10");  
//Compile error: "10" is a string!  
This code won't run
```

Python

Static typing makes your functions more readable!

```
def div_3(x)
```

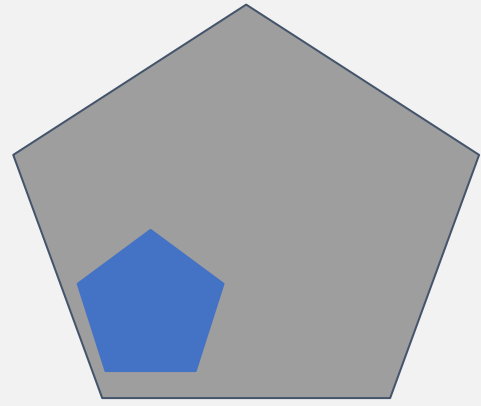
div_3: __ -> ??



C++

```
int div_3(int x)
```

div_3: int -> int



C++ to Python, probably



Fill in the blanks (again)!

```
int add(int a, int b);  
    int, int -> int  
string echo(string phrase);  
_____  
string helloworld();  
_____  
double divide(int a, int b);  
_____
```



Fill in the blanks (again)!

```
int add(int a, int b);  
    int, int -> int  
string echo(string phrase);  
    string -> string  
string helloworld();  
_____  
double divide(int a, int b);  
_____
```



Fill in the blanks (again)!

```
int add(int a, int b);  
    int, int -> int  
string echo(string phrase);  
    string -> string  
string helloworld();  
    void -> string  
double divide(int a, int b);
```



Fill in the blanks (again)!

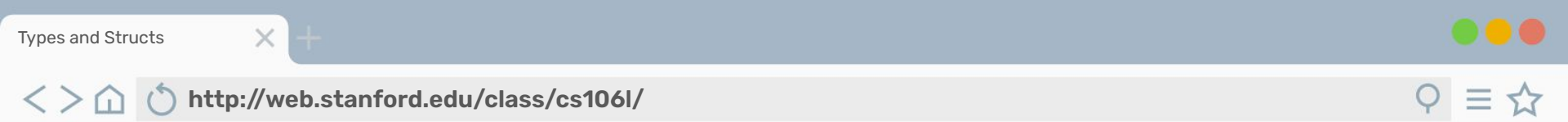
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int add(int a, int b);  
    int, int -> int  
string echo(string phrase);  
    string -> string  
string helloworld();  
    void -> string  
double divide(int a, int b);  
    int, int -> double
```



Questions?

Aside: Function overloading

In C++, you cannot define multiple identical functions.



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In C++, you cannot define multiple identical functions.

But what if we want two versions of a function for two different types?

- Example: int division vs double division



Aside: Function overloading

In C++, you cannot define multiple identical functions.

But what if we want two versions of a function for two different types?

- Example: int division vs double division

We can **overload** a function to have multiple versions!

Aside: Function overloading

```
int half(int x) {  
    std::cout << "1" << endl;    // (1)  
    return x / 2;  
}  
  
double half(double x) {  
    cout << "2" << endl;    // (2)  
    return x / 2;  
}  
  
half(3)                // uses version (1), returns 1  
half(3.0)              // uses version (2), returns 1.5
```

To overload a function, declare multiple functions with the same name but differently typed parameters or a different number of parameters!

Aside: Function overloading

C++ allows specifying default parameter values!



```
int half(int x, int divisor = 2) { // (1)
    return x / divisor;
}

double half(double x) { // (2)
    return x / 2;
}

half(4) // uses version ??, returns ??
half(3, 3) // uses version ??, returns ??

half(3.0) // uses version ??, returns ??
```

Aside: Function overloading

```
int half(int x, int divisor = 2) { // (1)
    return x / divisor;
}

double half(double x) { // (2)
    return x / 2;
}

half(4) // uses version (1), returns 2
half(3, 3) // uses version (1), returns 1

half(3.0) // uses version (2), returns 1.5
```

Questions?



Agenda



01. C++ Basics

Comparing to other languages you might know

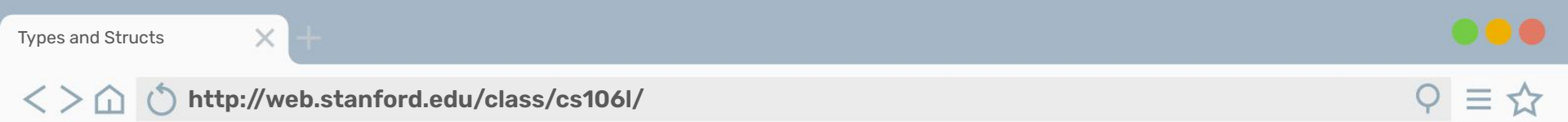
02. Types

Working with a statically typed language

03. Structs

...and pairs and structured binding

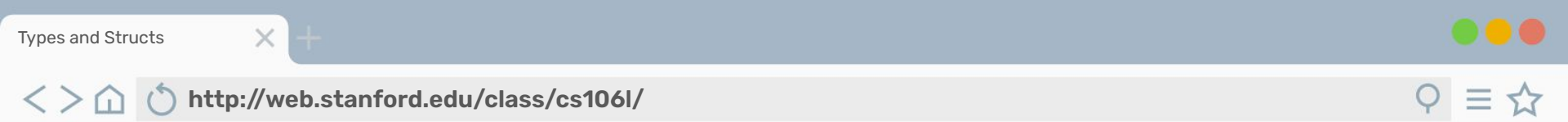




The problem with types so far

Strongly and statically typed languages are great, but there are a few downsides:

- it can be a pain to know what the type of a variable is
- any given function can only have exactly one return type
- C++ primitives (and even the types in the STL) can be limited



The problem with types so far

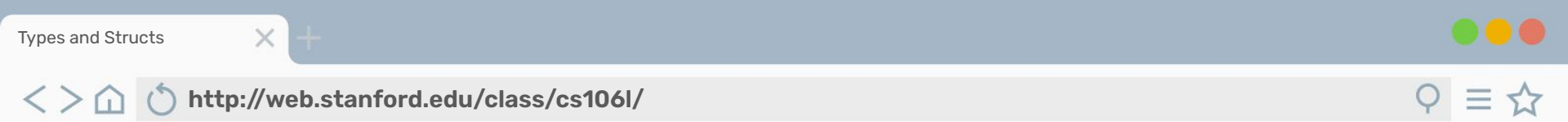
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Aside: the `auto` keyword

`auto`: a keyword used in lieu of type when declaring a variable that tells the compiler to **deduce the type**.



Aside: the auto keyword

auto: a keyword used in lieu of type when declaring a variable that tells the compiler to **deduce the type**.

- This is NOT the same as not having a type!
- The compiler is able to determine the type itself without being explicitly told.

Aside: the auto keyword

I hope it's an int...

auto: a keyword used in lieu of type when declaring a variable that tells the compiler to **deduce the type**.

- This is NOT the same as not having a type!
- The compiler is able to determine the type itself without being explicitly told.



Using auto

```
// What types are these?  
auto a = 3;  
auto b = 4.3;  
auto c = 'X';  
auto d = "Hello";
```

Using auto

```
// What types are these?  
auto a = 3; // int  
auto b = 4.3; // double  
auto c = 'X'; // char  
auto d = "Hello"; // char* (a C string)
```

Questions?



The problem with types so far

Strongly and statically typed languages are great, but there are a few downsides:

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The problem with types so far

Strongly and statically typed languages are great, but there are a few downsides:

- it can be a pain to know what the type of a variable is
- any given function can only have exactly one return type
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Let's address these with structs!

What is a struct?

A **struct** is a a group of **named variables**, each with their own type, that allows programmers to **bundle different types** together!

Structs in code

```
struct Student {  
    string name; // these are called fields  
    string state; // separate these by semicolons  
    int age;  
};
```

```
Student s;  
s.name = "Haven";  
s.state = "AR";  
s.age = 22; // use . to access fields
```



Structs can pass around grouped information...

```
Student s;  
s.name = "Haven";  
s.state = "AR";  
s.age = 22; // use . to access fields
```

```
void printStudentInfo(Student s) {  
    cout << s.name << " from " << s.state;  
    cout << " (" << s.age ")" << endl;  
}
```

...or return grouped information!

```
Student randomStudentFrom(std::string state) {  
    Student s;  
    s.name = "Haven"; //random = always Haven  
    s.state = state;  
    s.age = std::randint(0, 100);  
    return s;  
}
```

```
Student foundStudent = randomStudentFrom("AR");  
cout << foundStudent.name << endl; // Haven
```

...or return grouped information!

```
Student randomStudentFrom(std::string state) {  
    Student s;  
    s.name = "Haven"; //random = always Haven  
    s.state = state;  
    s.age = std::randint(0, 100);  
    return s;  
}
```

This syntax is a little clunky to initialize!

```
Student foundStudent = randomStudentFrom("AR");  
cout << foundStudent.name << endl; // Haven
```



Let's abbreviate!

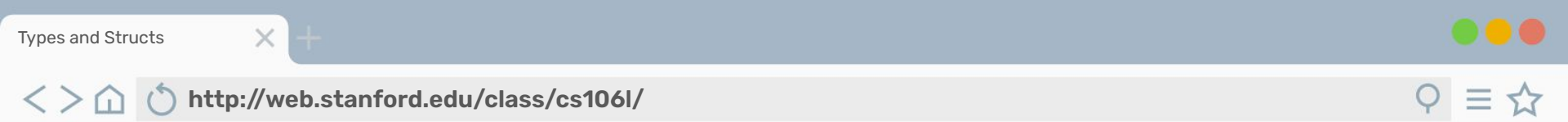
```
Student s;  
s.name = "Haven";  
s.state = "AR";  
s.age = 22;
```

//is the same as ...

```
Student s = {"Haven", "AR", 22};
```


The STL has its own structs!

`std::pair`: An STL built-in struct with **two fields** of **any type**



The STL has its own structs!

`std::pair`: An STL built-in struct with **two fields** of **any type**

- `std::pair` is a template: You specify the types of the fields inside `<>` for each pair object you make
- The fields in `std::pairs` are named `first` and `second`.

The STL has its own structs!

`std::pair`: An STL built-in struct with **two fields** of **any type**

- `std::pair` is a template: You specify the types of the fields inside `<>` for each pair object you make
- The fields in `std::pairs` are named **first** and **second**.

```
std::pair<int, string> numSuffix = {1, "st"};
cout << numSuffix.first << numSuffix.second; //prints 1st
```

The STL has its own structs!

`std::pair`: An STL built-in struct with **two fields** of **any type**

- `std::pair` is a template: You specify the types of the fields inside `<>` for each pair object you make
- The fields in `std::pairs` are named `first` and `second`.

```
struct Pair {  
    fill_in_type first;  
    fill_in_type second;  
};
```

Basically the struct looks like this!



Use `std::pair` to return success and result

```
std::pair<bool, Student> lookupStudent(string name) {  
    Student blank;  
  
    if (notFound(name)) return std::make_pair(false, blank);  
  
    Student result = getStudentWithName(name);  
  
    return std::make_pair(true, result);  
}  
  
std::pair<bool, Student> output = lookupStudent("Julie");
```

Use `std::pair` to return success and result

```
std::pair<bool, Student> lookupStudent(string name) {  
    Student blank;  
  
    if (notFound(name)) return std::make_pair(false, blank);  
  
    Student result = getStudentWithName(name);  
    return std::make_pair(true, result);  
}
```

We can use `std::make_pair` to avoid specifying the type!

```
std::pair<bool, Student> output = lookupStudent("Julie");
```

Use `std::pair` to return success and result

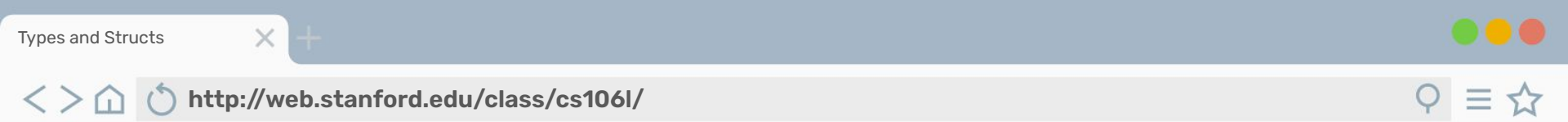
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    Student blank;  
  
    if (notFound(name)) return std::make_pair(false, blank);  
  
    Student result = getStudentWithName(name);  
  
    return std::make_pair(true, result);  
}  
  
auto output = lookupStudent("Julie");
```

**auto makes this
neater!**

Questions?

Code Demo!

[quadratic.cpp](#)



In case you forgot...

You can write a general quadratic equation in the format of:

$$ax^2 + bx + c = 0$$

Which can then be solved for x as:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

In case you forgot...

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Known as the radical!

In case you forgot...

You can write a general quadratic equation in the format of:

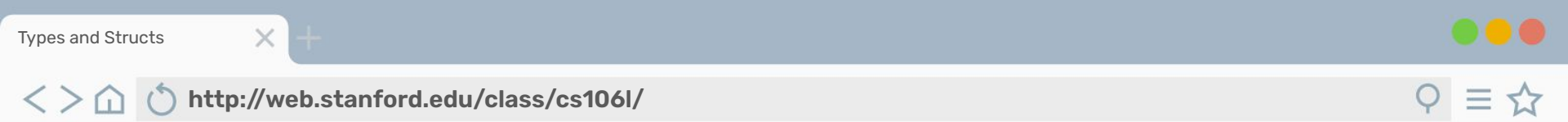
$$ax^2 + bx + c = 0$$

Which can then be solved for x as:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Known as the radical!

If the radical < 0, there are no real roots.



Recap:

- Everything with a name in your program has a **type**
- **Static type system** prevent errors before your code runs!
- **Structs** are a way to bundle a bunch of variables of many types
- **std::pair** is a type of struct that had been defined for you and is in the STL
- So you access it through the **std:: namespace** (std::pair)
- **auto** is a keyword that tells the compiler to deduce the type of a variable, it should be used when the type is obvious or very cumbersome to write out



 <http://web.stanford.edu/class/cs106l/>



Thanks!

Next up: Initialization and
References!