Chapter 19

Structs

This section is about making own own new variable types. It's not as exciting as it sounds, since all we can do is group together `int`s, `float`s and `string`s. But it's a nice trick, and it's the basis for classes and Object Oriented Programming.

For example, it takes three `float`s to make a color (red, green, blue.) A struct lets `Color` be an official type, which the computer knows is made of three `float`s.

Even better, the trick works for stuff we just make-up. Suppose we're writing a program about cows – each has a name, age and weight. It would be nice to build that into the program. Then we could declare `Cow c1;` and let the computer automatically make those variables for the parts.

The common name (and the one C# uses) for these is **struct**. There are some built-ins, and we can make our own. I think the best way to learn them is to make the `Cow` example, then a few more, then give the formal rules.

19.1 Cow struct example

Here's the top part of a program making a sample `struct` named `Cow`:

```
class TestA : MonoBehaviour {

  struct Cow {
    public string name;
    public int age;
    public float pounds;
  }
```

First, let's take a look at the overall form. The last five lines, `struct Cow { }`, count as one thing. The name `Cow` is in front. Then a big set of curly-braces mark what belongs to `Cow`. The inside looks like three variable declarations. They aren't, but it's the same rules.

Now onto what it does. This makes a new **type** named `Cow`, and says how to build it. It doesn't declare any variables, or really do anything. It's more like a recipe or a blueprint. It lets the computer know that if someone declares a `Cow` variable, it's legal, and says how to make one.

The names inside are called **fields**. It's the same use of the word as those web-based forms that say "required field." They describe the parts of a `Cow`.

Now we can declare some `Cows`:

```
int n; // old, boring declare just for reference

Cow c1;
Cow c2;
```

`Cow c1;` declares `c1` as a `Cow`. Just like you're probably thinking, the computer says "A Cow? How do you declare a Cow?" But then it looks near the top and sees `struct Cow`. That tells the computer it *can* declare a `Cow`, and the middle part tells it what the parts are – a string and int and a float.

`Cow c2;` declares another `Cow`. Nothing new there – I just want two `Cows` for later in the example.

Here's a picture of all 3 variables in the program:

```
n ___

c1               c2
-------------    ------------
| name:      |   | name:      |
| age:       |   | age:       |
| pounds:    |   | pounds:    |
-------------    ------------
```

Again, `n` is nothing special – it's just there for comparison. The interesting thing is that `c1` is one variable, with those three parts inside of it. Then `c2` is another variable, with the same three parts. Inside of `c1`, `name` is a string. There's another string. `name`, inside of `c2`.

Here's a program using `c1` and `c2` (I'm including everything here, so only `Start` is new):

```
class TestA : MonoBehaviour {

  struct Cow {
    public string name;
    public int age;
    public float pounds;
  }

  int n;
```

```
  Cow c1;
  Cow c2;

  void Start() {
    c1.name = "Bessy";
    c2.name = "Miss Cowy-cow";

    c1.age=6;
    c2.pounds=1200;

    print( c1.name + " is " + c1.age + " years old" );  // Bessy is 6 years old
  }
}
```

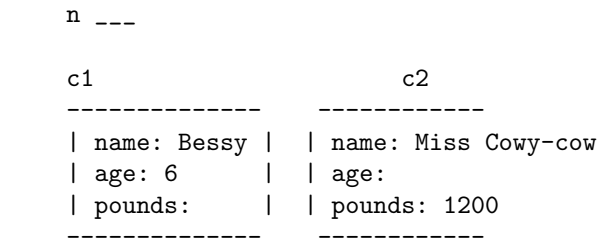
This is showing us the last thing we need – how to use the parts of a `struct`. `c1.name="Bessy";` shows the rule: put the variable name, then a dot, then the **field**. `c1.name` is the `name` slot in the first cow.

After you type `"c1.`" (c1, then a dot,) autocomplete will even show you the fields: `name`, `age` and `pounds`. It knows about them from the `struct Cow` we made at the top.

The first two lines are showing us that each `Cow` has it's own `name`. `c1.name` and `c2.name` are different. In other words, the picture is correct. The next two lines are using the `age` and `pounds` fields, just to show we can. `c2.pounds=1200;` goes to `c2`, then inside its `pounds` field, and sets that to 1200.

The `print` shows that the "varName-dot-field" rule is like a variable – you can assign to `c1.name` and also read from it.

After `Start` runs, here's the new picture:



The picture is really pretty boring. `Start` assigned four things, and the picture shows all four of them. The `pounds` in the lower-right is `c2.pounds`, the last assignment put 1200 in it, and there it is.

`c1.pounds` and `c2.age` are empty, since the code didn't put anything in them. If I tried to print them, I'd get the usual "has not been initialized" error.

L-values

In the assignment chapter, I made a big deal about how the thing on the left had to be a variable, all by itself. You could never have a formula – `x+1 = 7;` is an error. But here, the left side isn't quite a variable. `c1.age` says to find variable `c1`, and then look inside for the `age` part. It's like a little formula, so `c1.age=6;` looks like it breaks the rule.

The real rule for assignment statements is that the left side needs to count as a variable. It needs to be a box that can be changed. The technical name is **L-value**. It stands for "value that can be on the left-hand of an assignment statement." I know **L-value** sounds really fake, but put "lvalue" in a Search Engine – that's really what we call it.

Before this, only actual variables were **L-values**. Using a struct field is a new thing that also counts as a variable. In other words, in every way, `c1.age` works like an `int` variable. You can use `c1.age++;` or `c1.age *=2;` or `c1.name = "a" + c1.name + "b";`.

It takes a while to get used to seeing mini-formulas that count as variables, but they eventually feel natural. Later, we'll see other things like this – they aren't simple variables, but they count that way.

19.1.1 More examples

This is a traditional very basic **struct** example, with just two fields of the same type. It makes a FullName **struct** containing a first and last name. This mini-program creates it, declares some `FullName` variables and uses them a little:

```
// creates a new struct: "FullName":
struct FullName {
  public string first, last;
}
```

As with Cow, this doesn't create any variables. It defines `FullName` as a new struct type.

The fields are both the same type – two strings. You can re-use any types you need for the fields. This also uses the comma-declare shortcut. The same as always it's just a shortcut and isn't any different than declaring them on two lines. A trick in choosing field names is to remember that everyone knows they're part of a FullName. `first` and `last` are fine since we know it's fullname-first and fullname-last.

The start of the code using them:

```
void Start() {
  FullName mom1, mom2; // both are fullnames
```

```
  mom1.first = "Olga";
  mom1.last = "Pog";

  string m = mom1.first + " " + mom1.last;
  print( "Mother1's name: "+ m );  // Olga Pog
```

Structs can be declared using the comma shortcut. They can also be local or global, like `mom1` and `mom2` are local to Start here. You can use struct variables in pretty much all the ways and places you'd use ints or strings.

The two lines assigning to `mom1` are pretty typical. In our minds we're assigning "Olga Pog" as her name, and it takes two steps. It common to assign to every field, all together like this.

In the next line I wanted to show the fields act like strings in all ways: `mom.first + " " + mom.last` is just three strings added together.

I'll reuse some other old tricks for `mom2`:

```
  mom2.first= "blue" + "elf" + 451;
  mom2.last = mom1.last;
  mom2.last += "ie";

  print( "Mother 2 : "+ mom2.first + " " + mom2.last ); // blueelf451 Pogie
}
```

The second line, `mom2.last = mom1.last;` is just copying a string to a string, even if it took those funny dots to get to them. In the next line, the `+=` shortcut works as normal, tacking `ie` to the end.

Here's a short code snippet using a `Cow` and a `FullName` together. Nothing really special, just to show it can be done:

```
Cow a1;
a1.name = "Lou-Lou";
a1.age=7;

FullName p1;
// person has same name as the cow:
p1.first = a1.name; // no problem -- just string = string
p1.last = "Smith";
print( p1.first + " " + p1.last ); // Lou-Lou Smith

// a1.last = "Cowstein"; // ERROR no last in a Cow
// p1.age = 85; // ERROR no age in a FullName
```

`p1.first = a1.name;` is one of those things that can confuse you later. First off, it's simple: `p1.first` is a string, and so is `a1.name;`, so it's no different than `w1=w2;`.

The possibly confusing part, if you start thinking about it, is how we're copying from the inside a `Cow` into the inside of a `FullName`. It sort of looks like the types are different. The trick is, every step of the way doesn't have to match – only the end. You can copy a string field from a Cow into a string field of a FullName.

Here's the picture, after it runs:

```
a1                      p1
----------------     ------------
| name: Lou-Lou |   | first: Lou-Lou
| age: 7        |   | last: Smith
| pounds:       |   ------------
--------------
```

The two errors at the end are showing how each `struct` type has it's own personal fields – the ones listed in its `struct { }`, and nothing else. `Cow`s don't have last names, because we didn't write `public string last;` inside `Cow`.

This next example is about making a semi-useful `struct` to improve my old move-and-wrap code, and using some Unity-magic to see it.

To make something increase and wrap-around, I need 4 variables: the value, the speed, the maximum and the minimum (the last two are for the wrap-around part.) In my mind, those four variables make one variable-mover. So I'll make a `struct` for it:

```
struct Mover {
  public float val; // the main thing
  public float spd; // amount to change val, each update
  public float min, max; // the limits for val
}
```

I want to use them in a program that changes the red and green parts of my color. Each will use it's own `Mover` variable:

```
Mover red, green;
```

That creates the 4 `float`s I need for red, and the 4 for green. Here's a picture:

```
  red           green
 ---------     ---------
| val     |   | val     |
| spd     |   | spd     |
| min     |   | min     |
| max     |   | max     |
 ---------     ---------
```

We need to add some special Unity tricks to see them in the Inspector. Adding `public` in front of a global normally makes Unity show it, but `structs` need two extra things. You have to also write `public` before the struct definition, and `[System.Serializable]` on the line before. That second thing is a real C# thing, but it's pretty far-out and Unity is abusing it anyway, so I'll just say it's magic.

The final result looks like this:

```
[System.Serializable]
public struct Mover {
  public float val;
  public float spd;
  public float min, max;
}

public Mover red, green; // now they're visible in the inspector
```

The really cool part is, if you put just that in a script (before `Start`), on your Cube, the Inspector will show `red` and `green`. If you pop-open the little triangles, you can see that each one has `val`, `spd`, `min` and `max`. It knows about `struct Mover` and makes a picture for us!

Here's some code using them. It's the same color change code from way back, except using the struct:

```
void Update() {
  red.val += red.spd;
  if(red.val > red.max) red.val=red.min;

  green.val += green.spd;
  if(green.val > green.max) green.val=green.min;

  GetComponent<Renderer>().material.color = new Color( red.val, green.val, 0);
}
```

I like how a simple `struct` helps organize this. The program really just has 8 variables, and before we would have hand-declared all 8, like `float redMax;`. Using the `struct` automatically makes red and green have the same 4 subparts; and typing red-dot and using the pop-up is an easy way to write the program.

The variables start as all 0, so running this won't do anything good. Start could give them values, like `red.spd=0.02f;`. But it's easier entering values through the Inspector. Probably 0 and 1 for min and max. Or 0.5 to 1, and so on. A different speed for red and green will make a longer pattern. With a little work, they can cycle through a bunch of different shades before repeating.

19.2 Common errors

Seeing some common struct errors is a good excuse to talk about the rules, and explain more about how they work:

- `Cow.name = "steve";` is an error, because `Cow` isn't a variable. In the sample program, there are two cows: `c1` and `c2`, so there are only two `name`s – `c1.name` and `c2.name`. `Cow` is a **type**, so `Cow.name="Steve";` is like `int = 6;`. The thing in front of the dot has to be an actual declared variable.

- `age=6;` won't change the age of any cows, and is probably an error. There has to be a cow in front – `c1.age` or `c2.age`. Even if you have only one cow variable, `age=6;` won't assume you mean that cow.

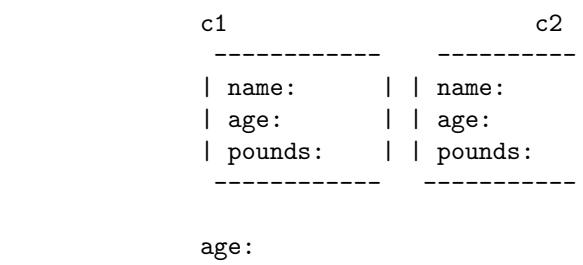
- `c1 = "Elly";` is an error. Struct variables always have to use a dot and say which field you want (there are a few exceptions.) Even though `name` is the only place it could go, you still have to write `c1.name="Elly";` The computer will never "guess" a **field** for you.
  Also, as a double-check, the types don't even match: `c1` is a `cow` and `"Elly"` is a string.

- `FullName p; p="Mark";` is an error. I thought that since both parts of a `FullName` are strings, maybe the computer would change them both to "Mark". But it still won't guess fields for me. I have use `p.first = "Mark";`. Or I could use the old same-assign shortcut: `p.first=p.last="Mark";`.

- `print(c1);` isn't a red-dot error, but won't work. You have to print out each part yourself: `print(c1.name+", "+c1.age+ ...)`.
  Most commands with **struct**s are that way. For example, you can't use `f1+f2` on two `FullName`s. You have to add `f1.first+f2.first` yourself.

- `int age;` is *not* an error! The field names only live inside that struct. If you declare variable `age` like that, and use `age=7;` the computer knows you're talking about the regular `age` variable. If you use `c1.age=7;`, it's definitely the `age` field of `c1`.

  Here's a picture of `cow c1, c2; float age;`:



  The three ages are `c1.age`, `c2.age` and `age`. The regular `age` could even be a float or a string. That `age` and the Cows' `age`'s are totally unrelated.

19.3 rules

We've seen most of the rules in examples, but it's still nice to have them all in one place. For most, just skim them to be sure you've gotten them right. But there should be a few new things in here:

- A new **struct** type is defined using `struct` *identifier* { *list-of-fields* }. It goes in the global area. `struct` is short for *structure*, as in a small building.
- The name of a struct is any legal identifier: `a`, `d_2`, `bunchOfRocks` .... We try to use style rules so you don't confuse struct names with variable names. One rule is to capitalize the first letter. Another is to add underscore-t (for example `cow_t`).
- Each field looks like a variable declaration with the word `public` in front: any type, a space, and an identifier. Ex: `public float f;`. They aren't really variable declarations, but it seemed right to borrow the syntax.
  If you forget the word `public`, it isn't a "red dot" error, but it means you can't use that variable (this is a somewhat silly, tricky rule. If you make a struct, but you get errors when you try to use a part, check you put `public` in front of that field).
- Can use the multi-declare shortcut for fields: `struct FullName { public string first, last;}`
- Fields can be different types, the same type, or any combination. There's nothing special about a struct where all fields happen to be the same type, or all different.
- It's legal to have only one field, or even zero. That's usually pointless, but sometimes people have a reason to do it. Ex:
  `struct Number { public int val; }`. If you do that, you still have to use the fields: `Number x; x.val=5;`
- The order you create fields doesn't matter. In other words, the definition of `Cow` could have `age` first, and it would work the same. Since you look them up using words, the computer finds the correct `field` no matter where it is.
- The field names can be reused outside of that `struct`. Here's a legal example where `Book` uses `title` as a field name, and so does `Song`, and we also declare it as a global:

```
struct Book { public string title;  public int pages; }
string Song { public string artist, title;  public float length; }
int title;
```

The three `titles` have nothing in common with each other. It's just a coincidence they have the same name.

- There isn't any short-cut for using field names by themselves. Even if you only have 1 `Cow` variable, `age=6;` won't work on it. You always have to have variable-dot-fieldName.

- Structs have a special `=` shortcut to copy one entire struct to another. For two cows, `c1=c2;` means to use `=` on each part. It's a shortcut for `c1.name=c2.name; c1.age=c2.age; c1.pounds=c2.pounds;`.

  There's a new error here as well: every part must have been assigned. `FullName f1, f2; f1.first="A"; f2=f1;` is an error. You have to at least write `f1.last="";` before you can copy it.

- Different structs always count as different, even if they have the exact same fields. For example, if you made `struct Sheep` with the exact same contents as `struct Cow`, and had `Cow c1; Sheep s1;`, then `s1=c1;` would be an error.

  This is on purpose. If you made one `struct` for sheep and another for cow, it's because you want the computer to tell you when you mix them up.

  Of course, `c1.name = s1.name;` is always legal – it's just a string to a string.

19.3.1 namespace vs. struct dots

We already know C# uses the dot for namespaces. In that chapter I warned you we were going to double-use the dot for something else. This is the second use. An example of both uses:

```
float n = Mathf.PI; // namespace
int a = c1.age; // inside struct
```

They both look inside the thing before the dot, but besides that, they're very different. `Mathf` isn't a variable, and there's one `Mathf.PI`. It's really a built-in global.

On the other hand, there's one `age` for each `Cow` we declare; and `Cow.age` is an error.

There really should have been a different symbol for each, and it is confusing at first, but you get used to it. When you see `Jark.groat` you just have to check whether `Jark` is a namespace, in which case `groat` is a global there; or whether `Jark` is a declared variable, in which case `groat` is a field.

Examples:

```
Cow c1; c1.age=Random.Range(0,8);
     field^          ^namespace
int n = Mathf.Max(c1.age, c2.age);
    namespace^      ^field  ^field
```

19.4 Builtin structs: Color, Vector3

We know Unity3D's position and size are a combined x,y&z. Now that we've seen structs, it should be obvious that's how Unity is doing that. `Vector3` is just three floats, named x, y and z. It's already in the computer, so you can't redefine it, but here's what it looks like:

```
struct Vector3 {
  public float x, y, z;
}
```

The name is from math: vector is a math term for list of numbers, and the 3 at the end is a reminder it has 3 parts.

The old position line, `transform.position = new Vector3(x,0,0);`, was using a shortcut. `new Vector3(x,0,0)` is a way to create an instant struct. Creating a normal Vector3 variable can be nicer. Here's the old and the new way:

```
void Start() {
  transform.position = new Vector3(0,0,0); // old way

  // new way:
  Vector3 upperLeft;
  upperLeft.x=-6.5f; // just pick some numbers for x,y,z
  upperLeft.z=4.0f;
  upperLeft.y=0;

  transform.position = upperLeft;
}
```

The last line is assigning a struct to a struct – it copies the x,y,z from `upperLeft` into position (the old line also did that, but I didn't make a big deal about it.)

We'll see how this improves movement code, later.

For fun, write `public Vector3 p;` as a global variable in any script and look in the Inspector. You should see the x, y and z fields going across. It lists them that way instead of with the triangle-toggle, since it's built-in – they tried to make it look nicer.

Scale, a Cube's size, is also a `Vector3`. That might seem odd, since Vector3 is for position, but it makes perfect sense. After all, we use floats for anything that wants a decimal – position, how red to be, how much a cow weighs. Anytime we want an x,y,z together, we should use a Vector3.

This make us be wide and skinny (I'm leaving out the old way):

```
void Start() {
  Vector3 sz;
  sz.x=3; // wide
  sz.y=sz.z=0.4f; // standard double-assign trick
  transform.localScale = sz;
}
```

For extra fun, this uses the same Vector3 to set position, then size:

```
void Start() {
  Vector3 v; v.x=6; v.y=-2; v.z=0; // just some position
  transform.position = v;

  v.x=0.4f; v.y=2; v.z=1; // redo v to use as scale
  transform.localScale = v;
}
```

19.4.1 Color

We've been setting colors using r, g and b – another struct. It looks like this (Unity already has it defined):

```
struct Color {
  public float r, g, b, a;
}
```

The very short field names are fine, since they're inside of a color – `r` clearly stands for red. The last one, `a`, is "alpha" for transparency. It won't do anything (setting up the ability to be transparent takes a few steps).

It turns out Unity has a `Vector4`, which is also four floats. Vector4 and Color are identical structs. But's that legal, and fine, like Cow and Sheep. We prefer using a struct named `Color` for colors, with floats named r, g and b.

If you declare `public Color c1;` as a global, the Inspector will make a fancy color-picker. That's just great, and why we use fancy editors. But it's merely a very nice way to set the 4 floats in a color stuct.

The code below will turn us orange, using a Color variable. Even though alpha is ignored, we have to set it to something – the rule where you can't assign a struct unless every field is set:

```
void Start() {
  Color cc;
  cc.r=0.9f;
  cc.g=0.6f;
  cc.b=0.1f;
  cc.a=1; // ignored, but must be set to something

  // same old line, but assigning our Color variable:
  GetComponent<Renderer>().material.color = cc;
}
```

19.5 Constructors, struct literals

We've seen how you can create an instant red using `Color(1,0,0);` or an instant xyz position with `Vector3(-7,0,0)`. The basic rule for an instant struct is to put the name with parens around the values, for example (this is almost legal): `Cow("Amy",12,1600)`.

The cow in front should make sense. (0,1,1) could be a color, or a Vector3, or a hundred other structs we wrote which happen to have three numbers. We have to say which one it is.

The technical term for the command is Constructor – it constructs a color from those values. Cute, right? Technically `new Vector3(1,2,0)` constructs a struct literal. Remember *literal* is the term for a constant value of a type.

`C#` requires the word `new` in front. We've already seen this in `transform.position = new Vector3(x,0,0);`. Eventually our Cow will be `new Cow("Amy",12,1600);`

We can use constructors to assign to struct variables. Here we set up a Vector3 and a Color using the shortcut:

```
Vector3 pos = new Vector3(5,0,0); // assigns all 3 at once
Color winCol = new Color(0.5f, 0.2f, 0);

winCol = new Color(0,0,0); // can change later with same shortcut
winCol.g=1; // can assign fields like normal
```

Another rule, and this is common in many languages: empty parens gets you all 0's or empty strings. For example `new Vector3()` is the same as `new Vector3(0,0,0)`, and `new Cow()` is a shortcut for initializing the name to `""` and age and weight to 0's.

`new Color();` gets you four 0's, which is a useless see-through black. But at least it follows the constructor rules.

Another rule, also common, is you have to write the useful constructors yourself. This means none of the structs we write will have any until we learn

to write them. We can use `Cow c = new Cow();` to blank it out, but we'll have to make real cows the long way until we write a Cow constructor.

But this rule also means you can write all kinds. If you type "`new Vector3(`" the drop-down shows three versions. Besides all three or none, you can enter just x and y, leaving z at 0:

```
transform.position = new Vector3(x,y); // sets z to 0
```

For color, they added a different shortcut. If you leave off the final transparency, it sets it to you 1 (1 means solid, not transparent at all). I've been using it the entire time:

```
Color c = new Color(1,0,0,1); // solid red (final 1=not see-through)
c=new Color(1,0,0); // short-cut (sets alpha to 1)
```

There's no shorter shortcut, since why would anyone want to enter just red and blue?

Then, remember, constructors are only shortcuts – we can always declare a variable and hand-set each field.

19.6 Nested structs

The fields in a `struct` can be any type, even another `struct`. We usually call that a nested struct, like those Russian dolls nested inside of each other. It's a useful thing to be able to do. There aren't any special rules for this – structs inside structs work the normal way – but they can look funny. This is just a lot of examples.

I want to change the `Cow` struct so each Cow also has two `Color`'s. So that's a struct in a struct. To simplify, I'm getting rid of age and weight:

```
struct Cow {
  public string name;
  public Color mainCol;
  public Color spotCol;
}
```

Here's some code using it. I set each color a different way. For `mainCol` I copy an entire `Color` variable into it. For `spotCol` I copy in r,g,b,a one at a time:

```
Cow c1;
c1.name = "Bessy"; // same as before

Color blk; blk.r=0; blk.g=0; blk.b=0; blk.a=1;
c1.mainCol = blk; // copy a Color to a Color

c1.spotCol.r=0.4f;
```

```
c1.spotCol.g=0.3f;
c1.spotCol.b=0.1f;
c1.spotCol.a=1;
```

The last part with `c1.spotCol.r=0.4f;` is the most interesting. Using more than one dot isn't a new rule – it's just the way the usual struct rule works out. The trick is to read left-to-right. `c1` is a Cow. It has mainCol or spotCol. `c1.spotCol` is a Color, it has r, g, or b.

As usual, once you get to a box, it counts as a variable of that type. `c1.mainCol.g` is a regular float. You can do float things with it, like `c1.mainCol.g+=0.2f;`.

`c1.r` is an error (plus it makes no sense.) We have to use `c1.mainCol` or `c1.spotCol`, then we can add the dot-r. It's really the old can't-jump-over-a-field error.

Here's another example, putting one of my own **struct**s inside another. A `Plumber` has a FullName and an hourly rate:

```
struct FullName { public string first, last; } // no change

struct Plumber {
  public FullName name;
  public float hourlyRate;
}

FullName customer; // for comparison
Plumber p1;
```

The first thing is that this doesn't hurt or change `FullName`. We can still use it like normal, to declare `FullName customer;`. In other words, now that `FullName` is a type, anyone can use it, including Plumber.

Here's a picture of `p1`:

```
p1
------------------
|       ----------
| name | first:
|      | last:
|       ----------
| hourlyRate:
-------------------
```

`p1` has two parts. That's what the definition of `Plumber` says. The first part, `name`, also has two parts: `p1.name.first` and `p1.name.last`.

Here's some code using `customer` and `p1`:

```
// this is just a regular FullName, to show it works the same:
```

```
customer.first = "Lom";
customer.last = "Lomson";

p1.hourlyRate = 24.50f; // nothing special here

p1.name.first = "Larch";
p1.name.last = "Larchenson";

// redo the name:
p1.name = customer; // plumber's name is now Lom Lomson
```

Same as before, `p1.first` would be an error. You can't skip past `name`.

There's no limit to putting structs in structs in structs. You just use as many dots as you need.

19.7 Structs as function inputs

Since a struct is a type, it can be used as a parameter. Here's an example of a function which turns a FullName into a nice string:

```
string commaName(FullName f) {
  string w=f.last + ", " + f.first; // last, first
  return w;
}
```

`commaName(customer);` would give us `"Larchenson, Larch"`. Since structs can't print themselves, functions turning them into nice-looking strings are common.

This one turns a plumber into a string. It's interesting since a plumber contains a FullName, so we can re-use `commaName` for the plumber's name:

```
string PlumberDesc(Plumber p) {
  string nm= commaName( p.name ); // re-using. p.name is a FullName
  return nm+"; Hourly rate: $" + p.hourlyRate;
  // ex: Clark, Stan; Hourly rate: $37
}
```

If plumber names were printed in a different way we'd write it out. Say we only wanted "Clark, $37/hr:

```
string PlumberShortDesc(Plumber p) {
  return p.name.last + ", $" + p.hourlyRate + "/hr";
}
```

Built-in structs can be inputs. This is a somewhat silly function that tells us how bright a color is (it averages red, green and blue):

```
float getBrightness(Color c) {
  float sum=c.r+c.g+c.b;
  return sum/3.0f; // range is 0-1
}
```

Suppose we had some funny loop that cycled `c1` through a lot of colors. `if(brightness(c1)<0.1f)` could be used to test when it's too dark.

Passing structs to functions is another of the main reasons we make them. It's a lot clearer and shorter for a function heading to say it takes a `Cow` than to say it takes a string, int and float.

19.8 Structs as return values

Functions can also return `struct`s. There's no special rule for it – these are just examples:

This one returns a random `Color`. I like it because it follows my standard pattern: declare variable for the answer, fill it, return it:

```
Color randCol() {
  Color ans;
  ans.r = Random.Range(0.0f, 1.0f);
  ans.g = Random.Range(0.0f, 1.0f);
  ans.b = Random.Range(0.0f, 1.0f);
  ans.a=1;
  return ans;
}
```

We can use it with `Color c1 = randCol();`. Just so you know, this method tends to get a lot of ugly browns and greys.

This one does a table look-up (pretend we have Colors 0, 1 and 2, and use an `int` to say which one to use):

```
Color numToCol(int colNum) {
  Color ans;
  if(colNum==0) ans=new Color(1,0,0); // red
  else if(colNum==1) ans=new Color(0,1,0); // green
  else if(colNum==2) ans=new Color(0.5f, 0.5f, 1); // light blue
  else ans=new Color(1, 0, 1); // error purple
  return ans;
}
```

It's just a standard table-making cascading `if`, with a none-of-the-above in the final `else` (purple.) I used the constructor short-cuts to make the colors, but didn't have to (I could have used curly-braces and set rgb by hand.)

A sample use is `GetComponent<Renderer>().material.color=numToCol(1);`.

A lot of programs use 0-255 for color values. For example, (255,128,0) is orange. This function makes a usable Color from 0-255 values. For example, `Color c = colFrom255(255,128,0);` will give us (1,0.5,0), which is the orange value in Unity:

```
// lets us make a Color using 0-255 numbers:
Color colFrom255(int r, int g, int b) {
  Color ans; ans.a=1;
  ans.r = r/255.0f;
  ans.g = g/255.0f;
  ans.b = b/255.0f;
  return ans;
}
```

We could use `GetComponent<Renderer>().material.color = colFrom255(210,0,255);` to turn ourself blueish-purple.

The next, slightly fakey, function returns a `Vector3`. It takes a `y` coordinate and returns a point on the left edge of the screen (it just fills in -7 for `x` and 0 for `z`):

```
Vector3 leftPos(float y) {
  Vector3 ans;
  ans.z=0;  ans.y=y;
  ans.x = -7; // left edge
  return ans;
}
```

We might use it like `transform.position = leftPos(-3);`, to put us on the left near the bottom.

It also shows the "field names only matter in the struct" rule. Input `y` is a regular float. `ans.y = y;` is fine. It copies the input `y` into the `y` field.

Finally, we can do both – use a struct for input and output. This one brightens (or darkens) the input Color. It uses the "modify the input" trick, to save declaring an extra variable:

```
Color brighterCol(Color c, float amt) {
  c.r+=amt; if(c.r>1) c.r=1;
  c.g+=amt; if(c.g>1) c.g=1;
  c.b+=amt; if(c.b>1) c.b=1;
  return c;
}
```

It's also an example of a function that seems like it might change you, but doesn't:

```
brighterCol(c1, 0.1f); // does nothing
Color c2 = brighterCol(c1, 0.1f); // c1 unchanged, c2 is a brighter c1
c1=brighterCol(c1, 0.1f); // makes c1 10% brighter
```

19.9 Uninitialized structs

Structs don't automatically initialize any of their fields. As usual, `cow c2; n=c2.age;` is an uninitialized variable error. That seems about right.

But since they have parts, structs have an extra bonus rule: when you use a whole struct, every part needs to have a value. In other words, `c2=c1` or `doCowStuff(c1)` are errors unless every part is filled in.

The idea is, what if `c1` only has the name filled in? `c2=c1;` technically makes `c2` into an exact copy, with only its named filled in. But it seems weird that a variable can have empty parts after an `=`. So they made it illegal.

For example, this function only reads the age. But you need to fill in the whole cow to run it:

```
float normalCowWt(Cow c) {
  return 20.0f + 40.5f*c.age;
}

Cow c1; c1.age=8;
int n = normalCowWt(c1); // error. Passing uninitialized c1
```

This rule is a cool example of how computer languages always have rough spots and have to choose. C# is trying to be safer, so make some things errors that aren't actually a problem.

It also leads to a fun style rule. C# users are in the habit of always using the empty constructor: `Cow c = new Cow();`. It's a simple way to make sure everything is filled in. You don't need to. If you were going to fill every part anyway it's a complete waste. But it doesn't hurt and feels like a "better safe than sorry" thing.