

Chapter 29

Struct in struct

This section is another with no new rules – just useful tricks. Now that we have structs, and lists, and string indexes, we can combine them to make big data structures.

Usually these are pretty natural - maybe you have several people who can own several dogs each. With practice, that's easy to put into the computer and use.

Big data structures are also good practice writing double and triple loops.

29.1 Lists of structs

Making a list of Cow structs looks like this:

```
// review of Cow:
[System.Serializable]
public struct Cow { public string name; public int age; }

public List<Cow> Barn; // list of Cows
```

As we know, in the Inspector you have to type a non-zero number for the size of that list. Popping it open will show lots of Cow's, which you can also pop open.

More interesting is how to search around the Barn in code. The trick is the same as for things like `c1.spotColor` for the old cow's with colored spots. Go left-to-right, using the options for that type.

Here's code using Barn:

```
int n=Barn.Count; // # of cows, same as normal
n=Barn[0].age; // age of first cow
Barn[1].age=4; // make 2nd cow be 4 years old
Barn[1].name="Foursy";
```

Barn is a list, so we can use `Count`, or can pick out one item using `[]`.
`Barn[0]` is a `Cow`, so we can use dot-age or dot-name.

To compare, some errors:

```
Barn.age; // error - have to say which cow
Barn[0].Count; // error - cows don't have a count
```

We can also copy entire cows in and out of the barn. This is really the same boring stuff we did with lists of ints, or normal structs:

```
Cow cc; cc.name="Kow"; cc.age=5;
Barn[2] = cc; // simple var-assign, with a whole cow
Cow c3=Barn[3]; // c3 is a copy of that cow
Barn[4]=Barn[5]; // copy entire cows between list boxes
```

We can create the entire `Barn` list ourselves, adding each `Cow`. This makes six 1-year olds named `cowy`:

```
Barn = new List<Cow>(); // size 0
for(int i=0; i<6; i++) {
    Cow c; c.name="cowy"; c.age=1; // a normal cow
    Barn.Add(c); // <-standard Add
}
```

A list of classes works the same, except they also need to be `new'd`. This makes a list of six dog's (pretend `Dog` is a class):

```
List<Dog> Kennel= new List<Dog>(); // size 0
for(int i=0; i<6; i++) {
    Kennel.Add(new Dog());
}
```

That's a little sneaky. `new Dog()` creates a `Dog` and returns a pointer to it. Normally we assign that to a variable, but adding it to the list is just as good, since that's the final place for it.

We could use two steps instead, with a middeman variable:

```
Dog d=new Dog(); // 2-step version. d is a temp
Kennel.Add(d);
```

Here's an bugged version. See if you can spot the problem. Hint: how many Dog's are there?:

```
Kennel = new List<Dog>();
Dog d=new Dog(); // dog is a class, so each new creates one
for(int i=0; i<6; i++) {
    Kennel.Add(c); // <-standard Add
}
```

This creates 6 pointers, all aimed at the same Dog.

A neat Unity trick is making a list of `GameObjects`. This lets us drag many Cubes into the Inspector:

```
public List<GameObject> Blocks; // size in Inspector, drag in Cubes
```

We'd change them the usual way. `Blocks[0].transform.position=pos;` would move the first block. Or this would turn every other block red:

```
Color cc = new Color(1, 0, 0); // red
for(int i=0; i<Blocks.Count; i+=2) {
    Blocks[i].GetComponent<Renderer>().material.color=cc;
}
```

We can also fill that list ourself, by adding instantiated objects. They'll all be in the same spot, but we can move them later:

```
public GameObject ballPrefab; // drag in a Cube prefab
List<GameObject> Blocks;

void Start() {
    Blocks = new List<GameObject>(); // size 0, so far

    for(int i=0; i<10; i++) {
        GameObject gg=Instantiate(ballPrefab);
        Blocks.Add(gg);
    }
}
```

I like this because, sure, using gameObjects are a lot more complicated than Dogs, but making a list of them is the same.

We could also save a step with `Blocks.Add(Instantiate(ballPrefab));`.

29.2 Structs with Lists in them

Structs with lists inside them also aren't special, but look interesting. As usual, the list needs to be new'd. Here's a Goat struct which has a list of everything the goat eats:

```
struct Goat {
    public string name;
    public int age;
    public List<string> eats; // currently null
}
```

Some sample code playing around with Goat `g;`, showing how to use `eats`. This goat will eat tin cans and old shoes:

```

g.name = "Billy";
g.eats.Add("cans"); // error - null reference exception. eats not created yet
g.eats = new List<string>();
g.eats.Add("tin cans");
g.eats.Add("old shoes");
int n=g.eats.Count; // 2. g eats two things

```

Then some errors:

```

g.Add("grapes"); // error. g is not a list
g[0]="raisins"; // same error. g is not a list
int n=g.Count; // ditto

```

We could also create an eat-list first, then assign it all at once:

```

List<string> BillyFood = new List<string>();
BillyFood.Add("crates"); BillyFood.Add("barrels");
Goat g2;
g2.eats = BillyFood; // g2 now eats crates and barrels

```

Classes with lists in them don't give any free new's. if Goat was a class, you still need both:

```

Goat g = new Goat(); // new for class
g.eats=new List<string>(); // still need to new the eats list

```

29.3 Lists of strings tricks

A string can use indexes and has a length. So an list of strings is sort of like a 2-dimensional list. A warm-up review:

```

public List<string> W; // ["cow","banana","anteater", aardvark"]

int n=W.Count; // 4 words in the list
n=W[0].Length; // 3 letters in cow

```

Now the new-looking part, using two []'s in a row:

```

char ch=W[0][2]; // w (3rd letter of cow)
ch=W[2][0]; // a (1st letter of aardvark)

```

The cool thing is it's not a new rule. W[0] is "cow", which is a string. So of course adding [2] after grabs the 'w' character.

Now we can write this cool nested loop to count the total number of a's in every word in the list:

```

int aCount=0;
for(int i=0; i<W.Count; i++) { // each word
    for(int j=0; j<W[i].Length; j++) { // each letter in word
        if( W[i][j]=='a' ) aCount++;
    }
}

```

As usual, it's easy to mix up the i's and j's and get wrong counts and out-of-range crashes.

A cute trick with arrays of strings is to use them to make a map. This usually isn't the best way, but it's fun and a nice example.

If we want a 3x4 map, we can make a list with 3 length 4 strings. We'll say o is an open space, and X has a block in it:

```

List<string> M=new List<string>();
M.Add("xoox");
M.Add("xxxo");
M.Add("xooo");

```

Then we can use a nested loop to make that picture out of Cubes where the X's are. This is just a copy of the nested grid loop from last chapter, except we check the map before deciding to make a block:

```

for(int i=0; i<M.Count; i++) { // 3 rows
    for(int j=0; j<M[i].Count; j++) { // each x or o
        if( M[i][j]=='x' )
            newBlockAt(i,j); // from previous chapter
    }
}

```

I think that feels like a real 2D thing, even though it's technically just one list.

For one more 2D-ness, we can count how many walls are next to (x,y). We take a step in each of the 4 directions:

```

int nearWalls=0;
if(M[y][x-1]=='x') nearWalls++; // left
if(M[y][x+1]=='x') nearWalls++; // right
if(M[y+1][x]=='x') nearWalls++; // down (b/c of the picture)
if(M[y-1][x]=='x') nearWalls++; // up

```

It crashes if we're on an edge (if's would fix it.) But I think it still gives a nice grid-y feeling.

29.4 2D lists

A real 2D list is just a list of lists. The cool thing is there are no new rules - we can make them out of what we have now.

For example, `List<List<string>>` is a list of lists of words. The inside part is `List<string>`, a normal list of strings. Then `List< ... >` goes around it. So it's a list, containing lists of strings (if you can figure out the TV show about a serial killer who kills serial killers, you can figure out this.)

To get started, suppose we have some lists of words for a Mad Lib:

```
public List<string> Subjects; // ["Bob", "The cat", "My face"];
public List<string> Verbs; // ["runs", "sits", "cries", "inspects", "tolerates"];
public List<string> Adjectives; // ["cowardly", "heavy duty"];
public List<string> DirectObjects;
    // ["clouds", "fish", "tears", "truth", "gold", "needles"];
```

We want to use this to randomly make things like “The cat inspects heavy duty truth”.

We could do this now, but to make it a little nicer, we'll put those four lists into a big list:

```
List<List<string>> AllParts=new List<List<string>>(); // a list of lists
AllParts.Add(Subjects);
AllParts.Add(Verbs);
AllParts.Add(Adjectives);
AllParts.Add(DirectObjects);
```

Now `AllParts` has four string lists in it. `AllParts[1]` is the verb list, and `AllParts[1][0]` is the first verb, "runs".

A picture would look like:

```
AllParts
[0] -> Bob, The cat, My face
[1] -> runs, sits, cries, inspects, tolerates
[2] -> cowardly, heavy duty
[3] -> clouds, fish, tears, truth, gold, needles
```

This isn't exactly what we think of as 2D - it has rows but not really columns - but it has some definite 2D-ness, and the math is the same.

Playing with it some, we can do things like this:

```
AllParts[2].Add("slow"); // add a new adjective
AllParts[0][1]="The dog"; // replace cat with dog
AllParts.Count; // 4. Four lists of words
AllParts[3].Count; // 6. clouds, fish ... is 6 things
AllParts.Add(new List<string>()); // add 5th sentence part
AllParts[4].Add("?"); AllParts[4].Add("!!!"); // possible sentence enders
```

We can make a random sentence using a loop to pick from each part:

```
string madLib="";
for(int i=0;i<AllParts.Count;i++) {
    if(i!=0) madLib+=" "; // space in front of every word except the first
    int randPos=Random.Range(0, AllParts[i].Count);
    madLib+=AllParts[i][randPos];
}
```

Notice how the last line uses the usual `[] []`. Down the side to the sentence slot we're on now, then across to the random word for that slot.

There's one final super-cool thing a list of lists lets us do. Each of the inside lists counts as a normal list, and we can do normal list things with it. For example, we could write a function to pick a random word from a normal list:

```
string getRandWord(List<string> W) { return W[Random.Range(0, W.Count)]; }
```

This is a totally normal list function, that knows nothing about lists of lists and won't work with them. But we can still use it in our 2D list sentence maker:

```
for(int i=0;i<AllParts.Count;i++) {
    ...
    madLibs+=getRandWord(AllParts[i]); // <- calling normal list function
}
```

This works since `AllParts[i]` counts as an ordinary list of strings. `getRandWord` is happy to take it as an input and pick out a random work from that one list.

A 2D integer list of lists feels more griddy, but it's made mostly the same way. This makes a 4x4 grid:

```
List<List<int>> G=new List<List<int>>(); // 2D list
for(int i=0;i<4;i++) G.Add( new List<int>() );
// now we have 4 empty lists. Grow them all by four 0's:
for(int i=0;i<G.Count;i++) // each column
    for(int j=0;j<4;j++) G[i].Add(0); // add four 0's, up this column
```

Probably the most confusing line is `G.Add(new List<int>());`. The inside of it creates a fresh int-list. Normally we assign that to a variable, but we're allowed to skip the middle-man and jam it straight into the list.

We can think of this as a real grid:

```
[3] 0 0 0 0
[2] 0 0 0 0
[1] 0 0 0 0
[0] 0 0 0 0
G-> [0] [1] [2] [3]
```

I put `G` across the bottom, with the lists going up, so we could use `G[x][y]` in the more normal way. For example, `G[3][0]` is the lower right.

These next two single loops put 7's up the right side, and 8's across the middle (the last 8 overwrites a 7). Notice which slots have the variables:

```
for(int y=0;y<3;y++) G[3][y]=7; // up last column
for(int x=0;x<3;x++) G[x][1]=8; // across 2nd row

// result:
[3] 0 0 0 7
[2] 0 0 0 7
[1] 8 8 8 8
[0] 0 0 0 7
G-> [0] [1] [2] [3]
```

This is a case where we can visualize it any way we want. But if we draw it on the screen, we'll need to make the x,y math match our picture.

We can even use a normal `List<int>` function on each column, since each column is a list (but not on a row.) This sets everything in an ordinary list to a value:

```
void setVal(List<int> A, int val) {
    for(int i=0;i<A.Count;i++) A[i]=val;
}
```

Now `setVal(G[3],9)`; replaces those 7's with 9's. But it only works on columns, since only those are Lists.

29.5 Larger structures

We can use these rules to make structs with lists of structs, and larger. It's not that complicated, since you make them based on the data you already have.

For example, making a list of goats (which have lists of what they eat):

```
// repeat of Goat class:
class Goat {
    public string name;
    public List<string> eats;
}

// make goat list:
List<Goat> GG=new List<Goat>();
for(int i=0; i<8; i++) { // make 8 empty goats
    Goat g=new Goat();
```



```

    g[i].name = "goat #"+(i+1);
    g[i].eats = new List<string>();
    G[i].eats.Add("goat chow");
    GG.Add(g);
}

```

Notice we have to new the goat-list, new each goat in the list and new each eats list for each goat.

A partial picture:

```

GG 0 -> | name: goat#1
        | eats --> ["goat chow"]

    1 -> | name: goat#2
        | eats --> ["goat chow"]

    2 -> | name: goat#2
        | eats --> ["goat chow"]

```

A few sample lines that do and don't work:

```

int n = GG.Count; // 8 goats
n = GG[0].Count; // ERROR -- goats don't have a length
n = GG[0].eats.Count; // 1 food
string s=GG[0].eats[0]; // "goat chow"
n = GG[0].eats[0].Length; // 9 letters in "goat chow"
GG[2].eats.Add("shoes"); // legal. also eat shoes
GG[2].Add("cake"); // ERROR - goats aren't lists

```

We can run some interesting loops through this. This nested loop counts how many goats like a certain food:

```

int howManyLikeThis(List<Goat> G, string food) {
    int foodCount=0;
    for(int i=0; i<GG.Count; i++) { // check each goat
        // check all foods this goat eats:
        for(int j=0; j<G[i].eats.Count; j++) {
            if(GG[i].eats[j] == food) {
                foodCount++;
                break; // don't double-count this goat; quit eats loop
            }
        }
    }
    return count;
}

```

It checks the obvious way: scan every goat, look through what that goat eats, count it and skip to the next if you get a food match.

Here's a triple loop to count the total Z's in all food items (if five liked "pizza", one of them twice, that would count as 12):

```
int zCount=0;
for(int i=0; i<GG.Count; i++) { // each goat
    // each food:
    for(int j=0; j<GG[i].eats.Count; j++) {
        // each letter:
        for(int k=0; k<GG[i].eats[j].Length; k++) {
            if(GG[i].eats[j][k]=='z') zCount++;
        }
    }
}
```

`GG[i].eats[j][k]` has four total look-ups, but it's fine since we really need that many: which goat, what it eats, which food, which letter.

29.6 Giant game board example

Previously we used a nested loop to create a 2D grid of Cubes. But we couldn't save pointers to them, which meant we couldn't find and change them later. Now we can, which means we can almost make a game.

Our game will eventually allow you to toggle spaces (selected or un-selected) letting you make crude pixel shapes. First a simple class to hold data for each space:

```
class BoardSquare {
    public GameObject cube; // pointer to Cube at this space
    public bool selected; // selected squares change color
}
```

Then we'll make a simple 2D list, to hold them, for when we make the cubes, later:

```
// 2D grid of boardSquares:
List<List<BoardSquare>> Board; // want 8 wide, 6 high grid

void Start() {
    Board = new List<List<BoardSquare>>(); // main 2D list
    for(int i=0; i<8; i++) {
        Board.Add(new List<BoardSquare>()); // add empty column
        // grow column to 6 high:
        for(int j=0; j<6; j++) Board[i].Add(new BoardSquare());
    }
}
```

Now `Board.Count` is 8 (going across the bottom.) `Board[0].Count` is 6 (going up.) `Board[7][5].selected=true`; selects the upper-right corner.

Making the blocks and hooking them up is nothing special. We'll use `Board[x][y].cube=gg`; as we create each real `Cube`, then math to get the proper arrangement:

```
public GameObject cubePrefab; // drag in

// the rest of Start:
for(int x=0; x<8; x++) {
    for(int y=0; y<6; y++) {
        Vector3 pos; pos.z=0;
        pos.x=-4.0f+x*1.2f; // x goes across, from left
        pos.y=-3.0f+y*1.2f; // y goes up, from bottom
        Board[i][j].cube = Instantiate(cubePrefab, pos); // create and place shortcut
        Board[i][j].selected=false;
    }
}
```

The game is to move around and toggle the current square on/off. All we can do is make a terrible 6x8 1-color picture, but that's still pretty cool. Update looks nice with one function to move, and another to select items:

```
int row=0, col=0; // where we are on the board now
void Update() {
    moveCheck();
    selectCheck();
}
```

`moveCheck` will change `row` and `col` between 0-5 and 0-7 with the arrow keys. `selectCheck` will select on/off with the space key:

```
void selectCheck() {
    if(Input.GetKeyDown(KeyCode.Space)) {
        BoardSquare bs=Board[col][row]; // <- using row/col to look up current space
        bs.selected = !bs.selected; // common way to flip T/F
        // now set to correct on/off color:
        Color cc=Color.blue;
        if(bs.selected) cc=Color.red;
        bs.cube.GetComponent<Renderer>().material.color = cc;
    }
}
```

The best part of this is the top line with `bs=Board[col][row]`. It picks out the current spot, based on `row` and `col`, exactly how we want in a 2D grid. A fun bug would be flipping `row` and `col` in some places – a different square would

sometimes change.

Movement is the arrow keys. All you need to know is we can have them move row from 0 to 7 and col between 0 and 5, letting us walk around the board.

This code is long-ish, a little repetitive, but has some interesting parts. It shows we're "on" a Cube by making it a little smaller:

```
void moveCheck() {
    int oldRow=row, oldCol=col; // save old row/column

    if(Input.GetKeyDown(KeyCode.RightArrow)) {
        col++; if(col>=8) col=0; } // wrap-around
    if(Input.GetKeyDown(KeyCode.LeftArrow)) {
        col--; if(col<0) col=7; }
    if(Input.GetKeyDown(KeyCode.UpArrow)) {
        row++; if(row>=6) row=0; }
    if(Input.GetKeyDown(KeyCode.DownArrow)) {
        row--; if(row<0) row=5; }

    // if anything changed, show new spot:
    if(oldRow!=row || oldCol!=col) {
        // Reset old square to normal size:
        Board[oldCol][oldRow].cube.transform.localScale = new Vector3(1,1,1);
        // Make new square smaller:
        Board[col][row].cube.transform.localScale = new Vector3(0.8f,0.8f,0.8f);
    }
}
```

Moving with the arrows is nothing special. But I like how it shows a simple idea can sometimes take lots of boring lines of code.

The last two lines are using the `Board[col][row]` look-up again, to get one square.

This type of set-up is common, where you have a 2D grid with a class as each item. The class usually stores all sorts of stats about that one space, plus a link to the created square.

29.7 List of indexes

This is an old trick, not very common anymore, but it's a fun exercise. Suppose you want to make a list of *some* of the things in a list. If you wanted items 1,4 and 6. You'd make a list `[1,4,6]`, which is an array of indexes. Here it is in code:

```
public List<string> Ani; // ["ant","bear","cow","deer","eel","ferret","goat","hawk"]
public List<int> InZoo; // [1,4,6] // stands for bear,eel,goat
```

```

void Start() {
    // print animal names in the zoo:
    for(int i=0;i<InZoo.Count;i++)
        print( Ani[InZoo[i]]); // bear eel goat
}

```

We've never seen anything like `Ani[InZoo[i]]` before. It's a nested look-up, doing the thing above. `InZoo[i]` goes through 1, 4, 6. So `Ani[InZoo[i]]` goes through items 1, 4 and 6: bear, eel, goat.

Here's a longer version of the same trick. Suppose we want to print the animals in a random order. A cheap way is to shuffle a list with 0-7, then read the animals in that order:

```

List<int> RandIndexes=new List<int>();
for(int i=0; i<Ani.Count; i++) RandIndexes.Add(i); // 0-7
shuffle(RandIndexes); // old function. ex: 2,6,0,1,5,7,4,3

for(int i=0;i<RandIndexes;i++)
    print(Ani[RandIndexes[i]]);

```

The last line is the same nested look-up as before.

This is really a version of pointer thinking. We can't have pointers to strings, but we can use the indexes like pointers. It's not common, but it's a nice way to practice.

29.8 Internal list pointers

If we have a list of objects, we can pick out some of them with another list of pointers. For example `AllDogs` is a list of every dog. `SledTeam` won't have any new dogs – it will only point to things in `AllDogs`:

```

public List<Dog> AllDogs; // created and filled in Inspector
List<Dog> SledTeam; // will point to some things in AllDogs

void Start() {
    SledTeam=new List<Dog>();
    for(int i=0;i<4;i++) SledTeam.Add(null); // 4 empty Dogs pointers

    // start with first 4 dogs, but can change:
    for(int i=0;i<4;i++) SledTeam[i]=AllDogs[i];
}

```

You can't tell by the definition. but in our minds, and by how we filled it, `SledTeam` is merely picking 4 dogs out of the main list.

This would print the names of all dogs on our team:

```

for(int i=0;i<SledTeam.Count;i++) {
    if(SledTeam[i]==null) print("(missing)");
    else print(SledTeam[i].name);
}

```

In a list of pointers, checking `SledTeam[i]==null`; makes perfect sense. It's saying we haven't picked that dog yet. In our minds `SledDog[i].name` is reaching over into `AllDogs` and printing that dog's name, but, again, we can't easily tell that from the loop.

There's another version of this trick where a class has pointers to itself inside of it. For example, all of our Rabbits can have another Rabbit best friend:

```

[System.Serializable]
public class Rabbit {
    public string name;
    public int age;
    public Rabbit bestFriend; // <- yikes
}

public List<Rabbit> AllRabbits; // set up in Inspector

```

The trick to reading this is knowing `bestFriend` isn't an actual rabbit. It will only point to some other rabbit in `AllRabbits`. Put another way, we'll never use `new` with it.

For example, this code makes every pair of rabbits be mutual best friends:

```

for(int i=1;i<AllRabbits.Count;i+=2) { // 1,3,5,7 ...
    Rabbit r1=AllRabbits[i-1], r2=AllRabbits[i];
    r1.bestFriend=r2;
    r2.bestFriend=r1;
}

```

Or we could randomly assign best friends, with some anti-social rabbits whose best friends are null:

```

for(int i=0;i<AllRabbits.Count;i++) {
    Rabbit fr=null; // no best friend, so far
    if(Random.Range(1,6+1)!=1) { // 1 in 6 for no friend
        int friendNum=Random.Range(0,AllRabbits.Count);
        if(friendNum!=i) fr=AllRabbits[friendNum];
        // can't be friends with yourself
    }
    AllRabbits[i].bestFriend=fr;
    // note: assigning null is legal, and fine
}

```

This would count how many rabbits have a best friend named Thumper:

```

int count=0;
for(int i=0;i<AllRabbits.Count;i++) {
    Rabbit bf=AllRabbits[i].bestFriend;
    if(bf!=null) { // we may not have a best friend
        if(bf.name=="Thumper") count++;
    }
}

```

That one is pretty straight-forward. We didn't even need to know `bestFriend` was a link to a rabbit in the same list as we're in. For this next one we do.

To find the most popular rabbit, we'll check every rabbit, counting how many other rabbits like it with a nested loop:

```

int bestIndex=-1; // most popular rabbit, so far (Price is Right strategy)
int bestVotes=-999; // votes for that rabbit
for(int i=0; i<AllRabbits.Count; i++) {
    Rabbit currentBunny=AllRabbits[i]; // shortcut to this bunny
    int votes=0; // how many other bunnies like this one:
    for(int j=0;j<AllRabbits.Count;j++) {
        if(AllRabbits[j].bestFriend==currentBunny) votes++;
    }
    if(votes>bestVotes) { bestIndex=i; bestVotes=votes; }
}
print("Everyone loves "+AllRabbits[bestIndex]);

```

It's a nested loop because each rabbit knows who it likes, but not who likes it. We have to search through all rabbits to count how popular any one rabbit is.

This next one shows a funny issue. Suppose `rr` has a pointer to its best friend, who is named Jup-jup and is in `AllRabbits[9]`. We can follow `rr.bestFriend.name` to find Jup-jup, but how do we find out Jup-jup is in slot 9? We can't, not directly. We've have to loop through `AllRabbits` using `if(AllRabbits[i]==rr.bestFriend)`.

An example where we need this, suppose I want to find the most popular rabbit by adding all the votes, using int list `Votes` to record them:

```

// makes list of votes for each rabbit, starting at 0:
List<int> Votes=new List<int>();
for(int i=0;i<AllRabbits.Count;i++) Votes.Add(0);

// count all votes:
for(int i=0; i<AllRabbits.Count; i++) {
    Rabbit voteFor=AllRabbits[i].bestFriend;
    if(voteFor==null) continue; // has no best friend
    int voteForIndex=voteFor.posInAllRabbits; // <-this doesn't exist
    Votes[voteForIndex]++;
}

```

To solve this, for classes meant to be in a list we often add an extra `index` field:

```
public class Rabbit {
    public string name;
    public int age;
    public Rabbit bestFriend;
    public int index; // <- new
}
...
for(int i=0; i<AllRabbits.Count; i++)
    AllRabbits[i].index=i;
```

Now we can use the nicer vote count. Or, suppose we have some function like `Rabbit rr=GetSomeRabbit(AllRabbits);`. If we need to, we can check `rr.index` to see where it came from.

Or, another way to solve this, `bestFriend` could be an integer index instead of a Rabbit pointer. Rabbit `r`'s best friend would now use a double-index look-up: `AllRabbits[AllRabbits[r].bestFriend]`. Ug.