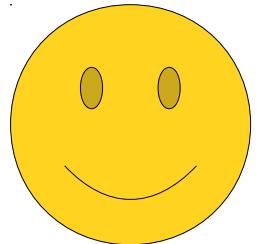
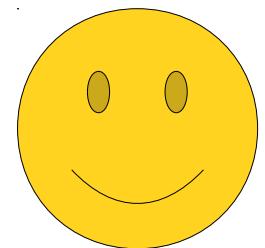


Guide to  $\in$  and  $\subseteq$

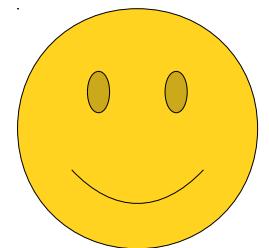


Hi everybody!

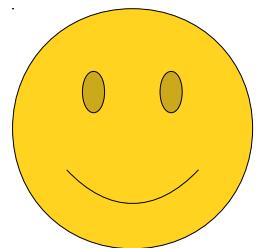
In our first lecture on sets and set theory, we introduced a bunch of new symbols and terminology.



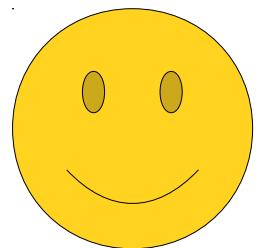
This guide focuses on two of those symbols:  $\in$  and  $\subseteq$ .



These symbols represent concepts that, while related, are different from one another and can take some practice to get used to.

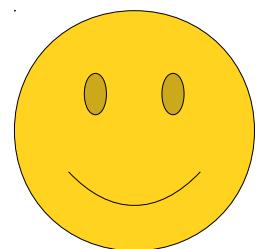


If you're still a bit confused,  
don't worry! Let's take some time  
to review them and see how they  
work and how they differ.



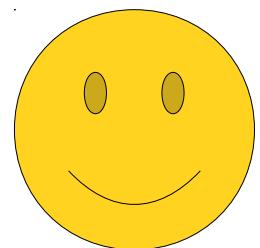
€

First, let's start off with this symbol.



€

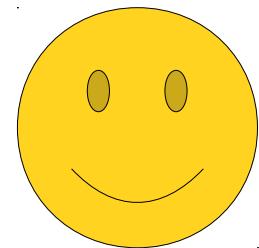
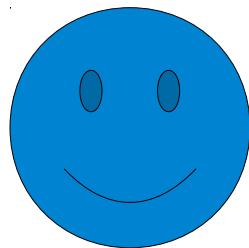
before we begin, do you remember what this symbol means? If not, pull up your notes or look back at the first set of lecture slides.



€

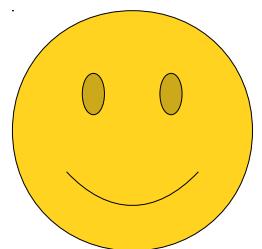
before we begin, do you remember what this symbol means? If not, pull up your notes or look back at the first set of lecture slides.

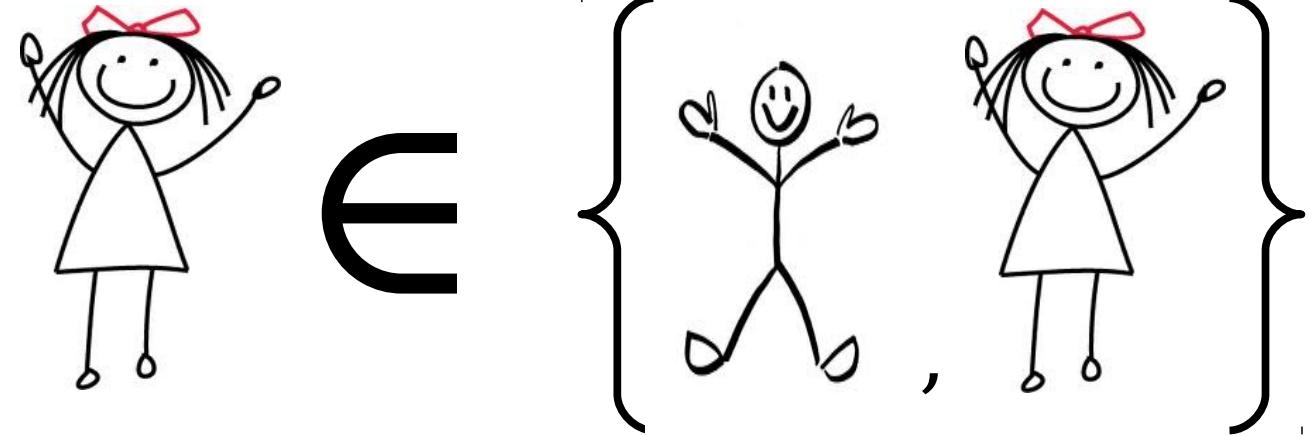
(If you haven't started taking notes in lecture, we really recommend it! It's extremely valuable.)



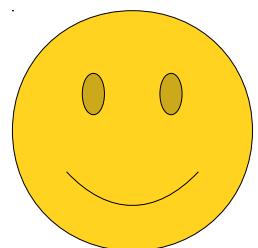
∈

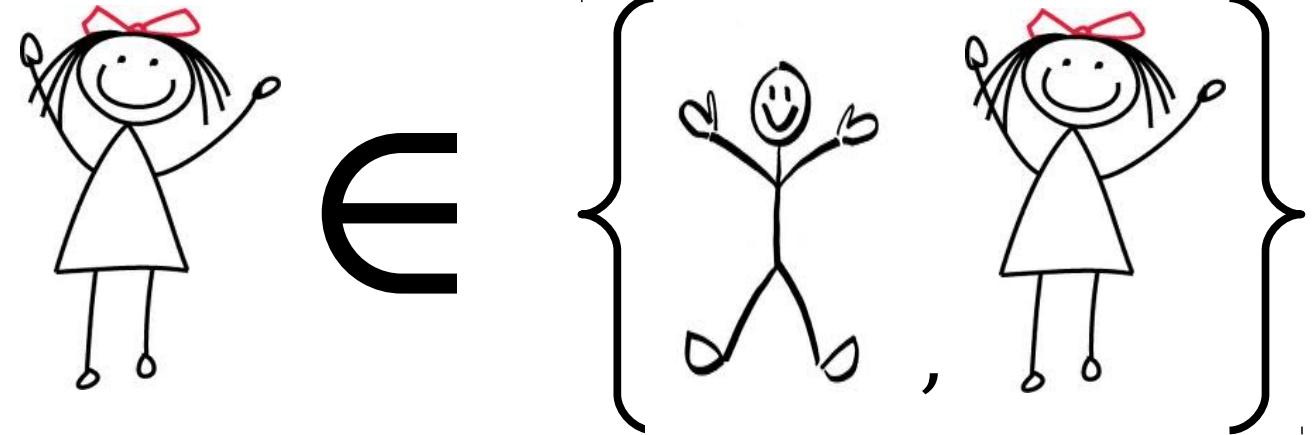
This symbol is the "element-of" symbol.



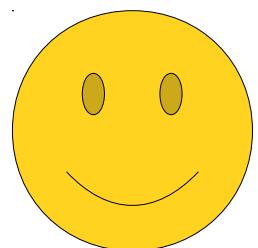


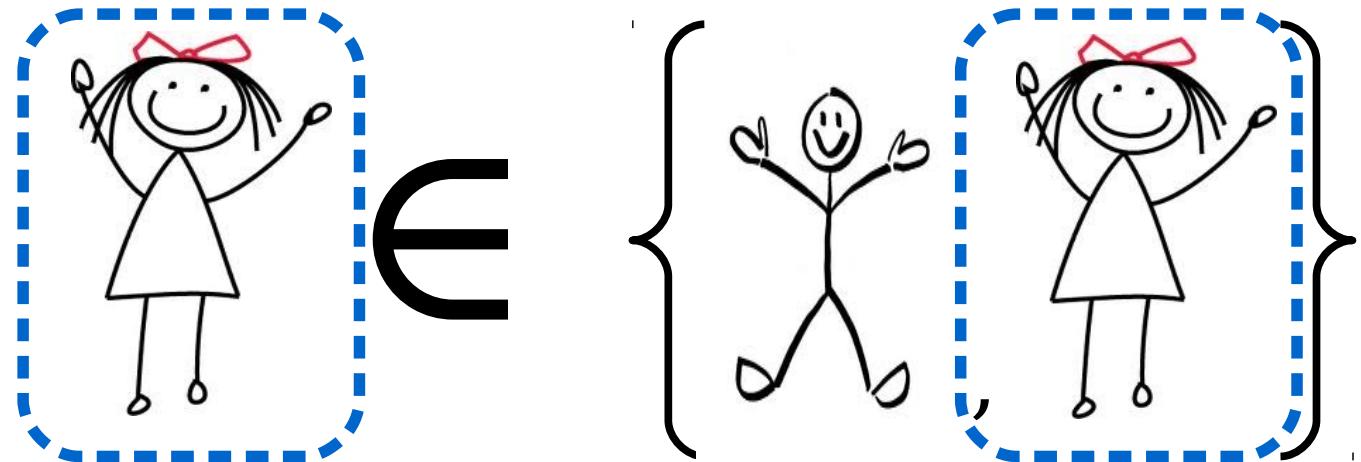
It's used to indicate that something is an **element** of a set.



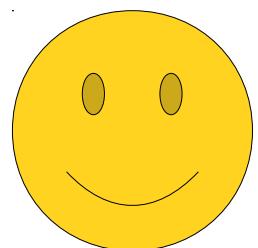


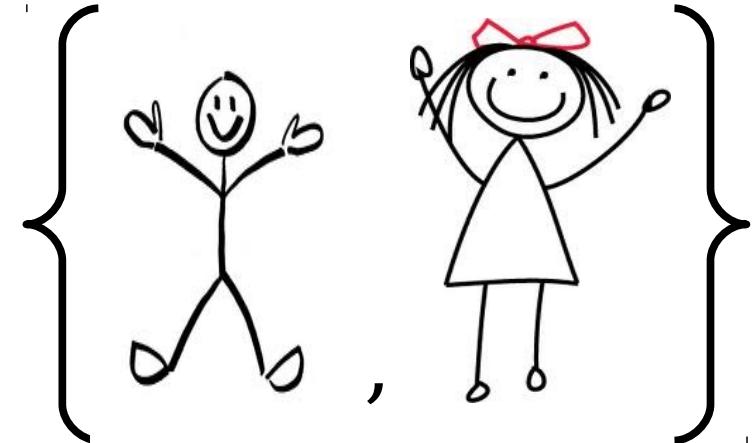
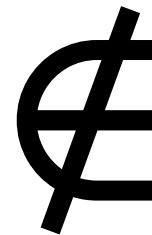
So, in this example, we're using the symbol to indicate that the girl belongs to the set containing the boy and the girl.



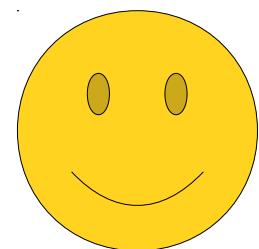


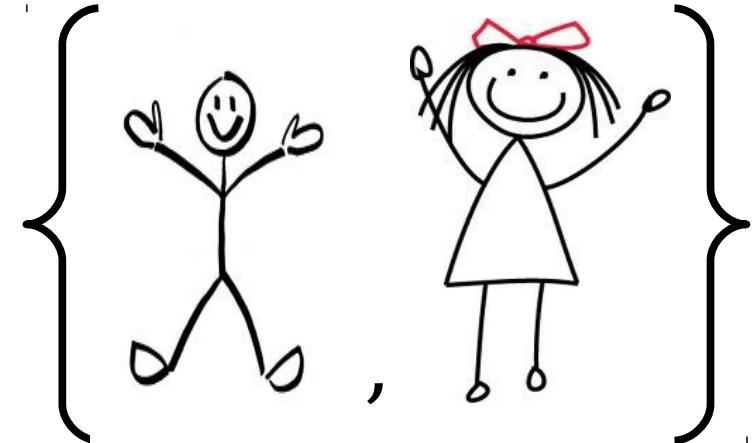
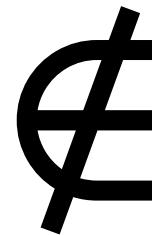
This statement is true because if you look inside the set on the right, you'll see the indicated person on the left.



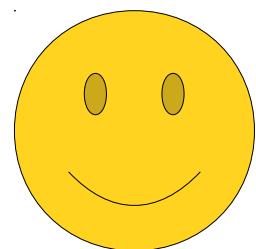


On the other hand, the dog on the left is not an element of the set on the right.

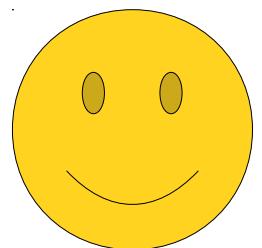




The reason why is that if we look inside the set on the right and take a look at what's inside of it, we won't find the dog anywhere.

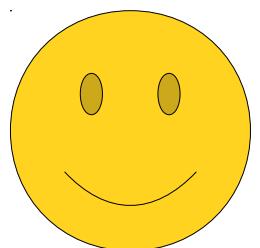


Often, when we're working with sets in mathematics, we tend to have sets with things like numbers in them.



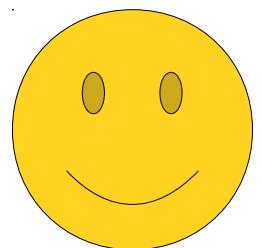
$$1 \in \{1, 2, 3, 4\}$$

So we'll typically see statements like this one, which is more mathematical in nature, even though the previous examples are perfectly correct uses of the  $\in$  and  $\notin$  symbols.



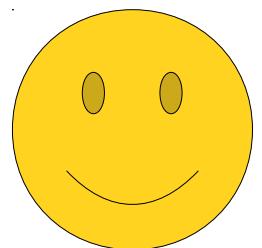
$\in$ 

When using the  $\in$  symbol, it's important to keep in mind that there's a "sidedness" to it.



$$x \in S$$

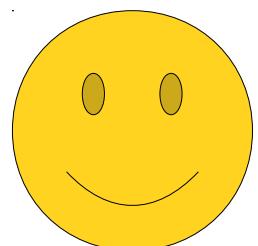
When we write something like  
this expression above...



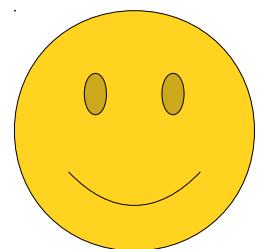
$$x \in S$$

This object is in this set

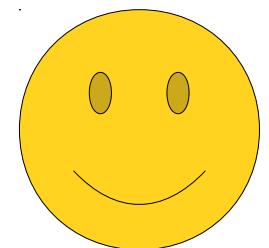
...the thing on the right will always be a set, and the thing on the left is the object we're saying belongs to the set.



So far, we've been thinking about  $\in$  symbolically - that is, by writing out symbols rather than drawing pictures.

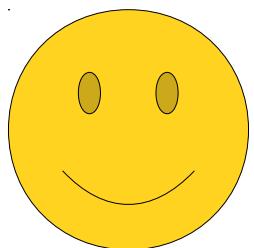


However, it's often helpful to think about the  $\in$  operator by drawing pictures.

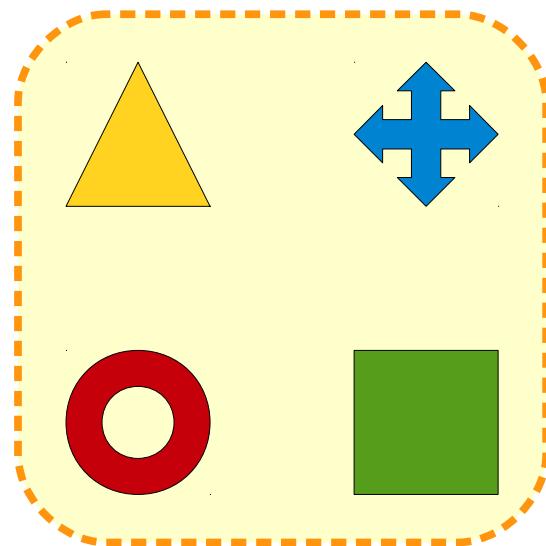


$$S = \{ \text{Yellow Triangle}, \text{Blue Double Arrow}, \text{Red Circle}, \text{Green Square} \}$$

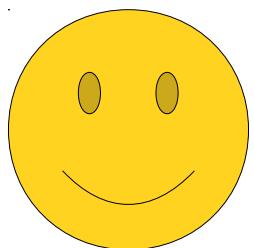
For example, let's imagine that we have this set  $S$ , which consists of shapes of different colors.



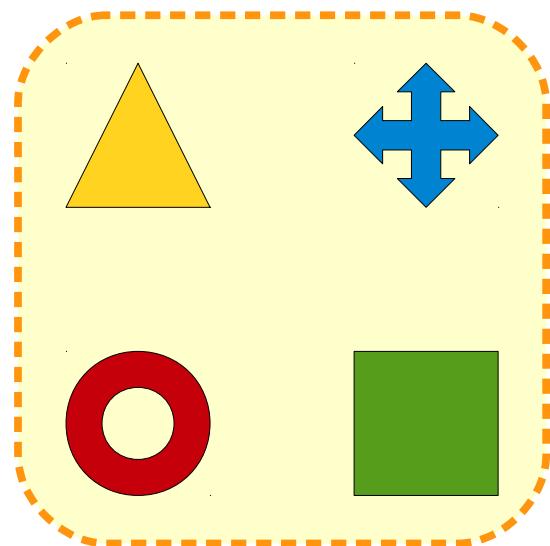
$$S = \{ \text{yellow triangle}, \text{blue double-headed arrow}, \text{red circle}, \text{green square} \}$$



We can draw  $S$  as a blob containing each of its elements.

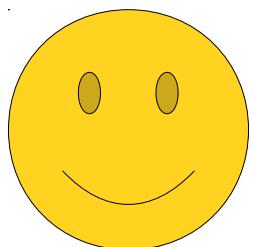


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

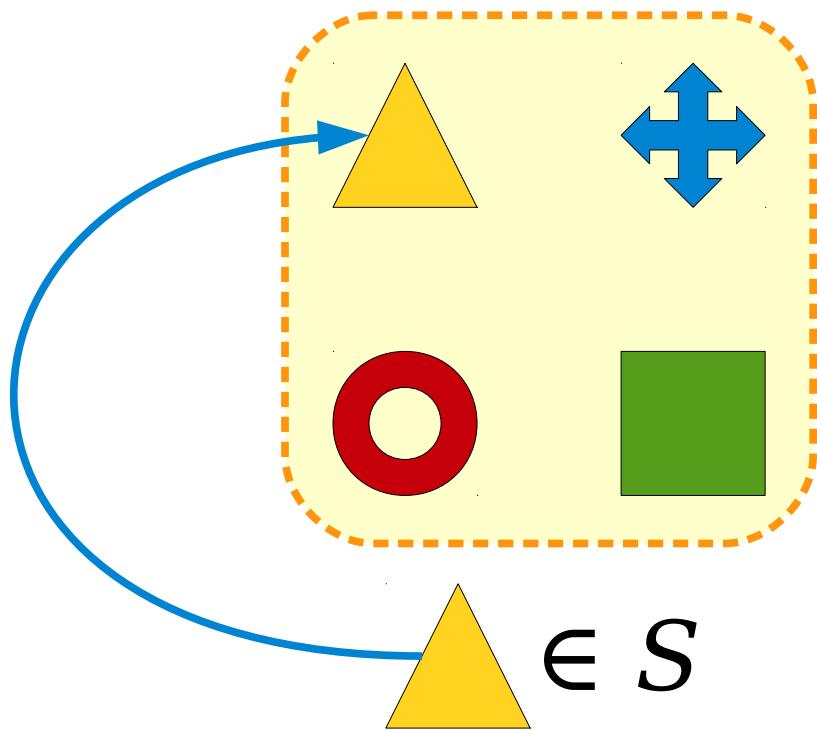


$$\text{Yellow Triangle} \in S$$

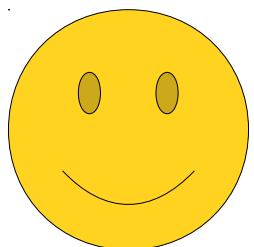
Now, if we write something like the statement above...



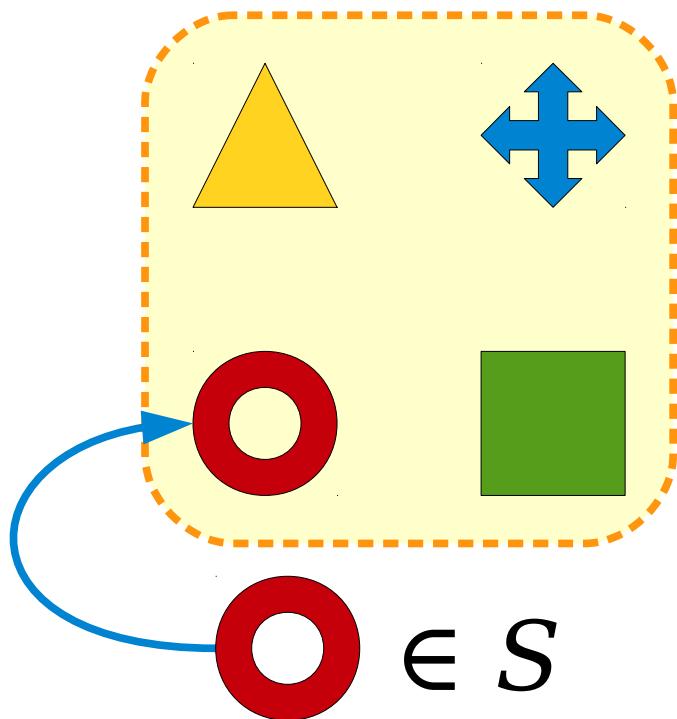
$$S = \{ \text{yellow triangle}, \text{blue double-headed arrow}, \text{red circle}, \text{green square} \}$$



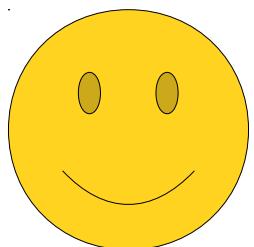
We can see that it's true because we can point at the yellow triangle inside of the blob for  $S$ .



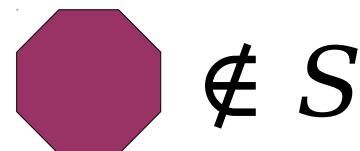
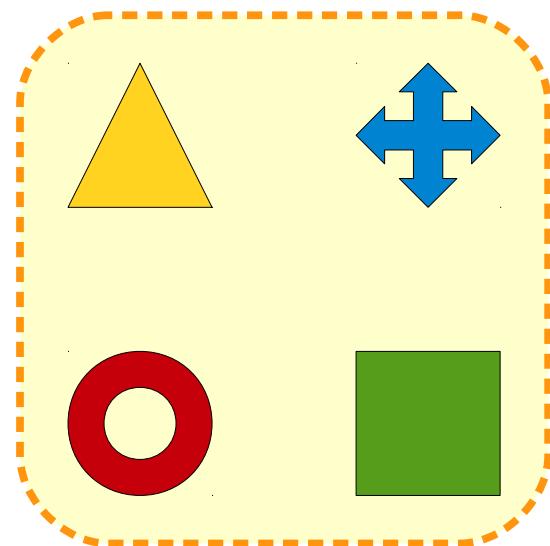
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



This other statement is also true because we can point out the element in question inside  $S$ .

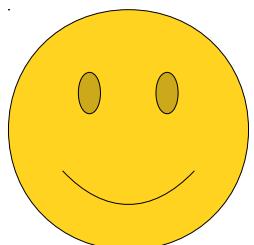


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

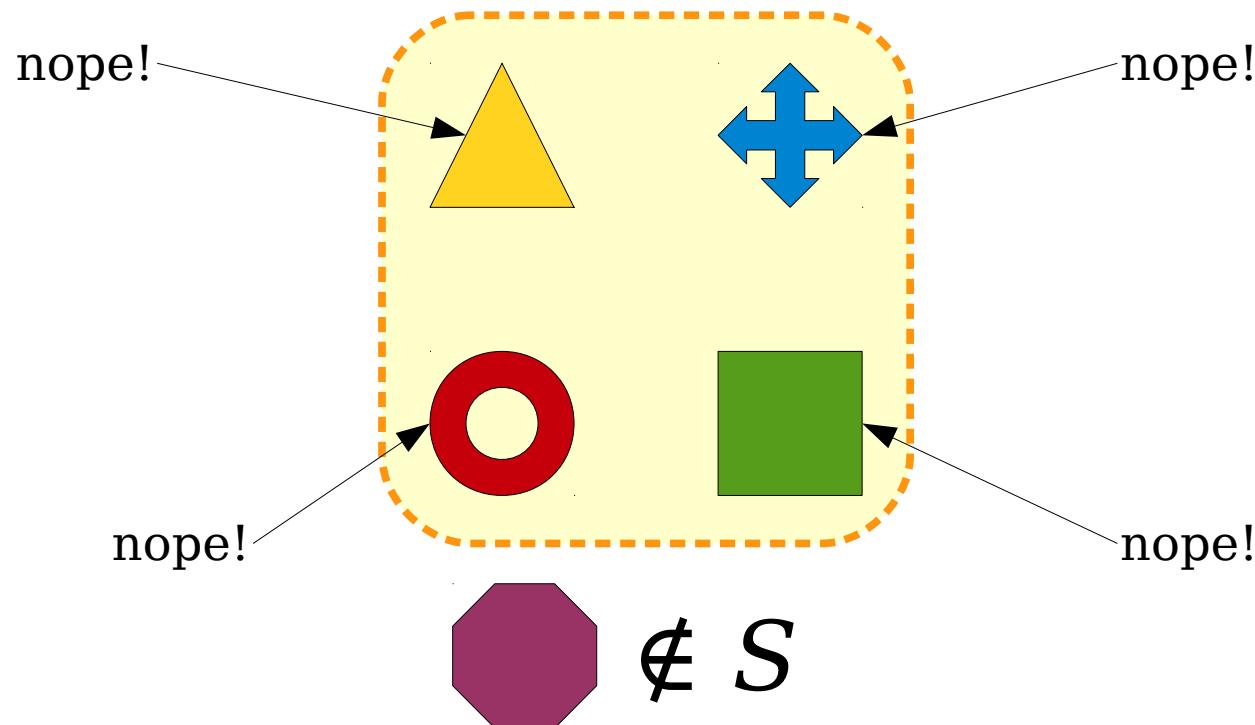


$\notin S$

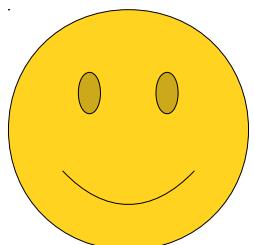
On the other hand we can see that the purple octagon isn't in the set...



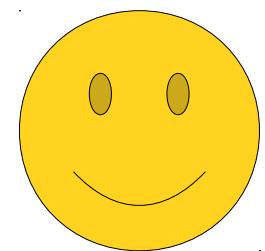
$$S = \{ \text{yellow triangle}, \text{blue double-headed arrow}, \text{red circle}, \text{green square} \}$$



...because we can look at all the elements in  $S$  and we won't see it there.



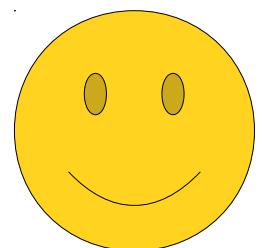
To recap things so far...



$$x \in S$$

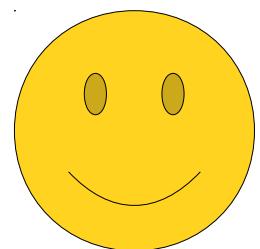
This object is in this set

We use the  $\in$  symbol to indicate that some object belongs to some set.



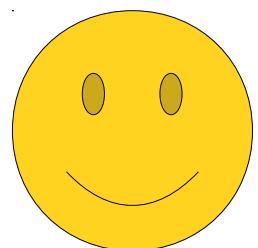
≤

With that said, let's switch to talking about this symbol for a while.



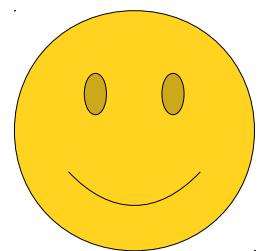
⊓

before we talk about it, look at your notes and see what this symbol means. If you don't remember, quickly jump back to the lecture slides to get the answer.



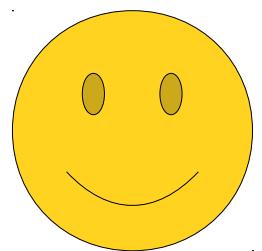
$\subseteq$ 

So this is the "subset-of" symbol



$$S \subseteq T$$

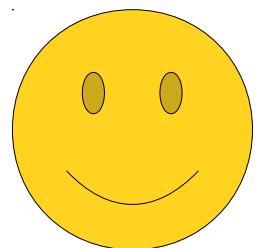
This expresses a relation that can hold between two sets.



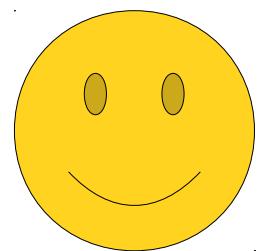
$$S \subseteq T$$

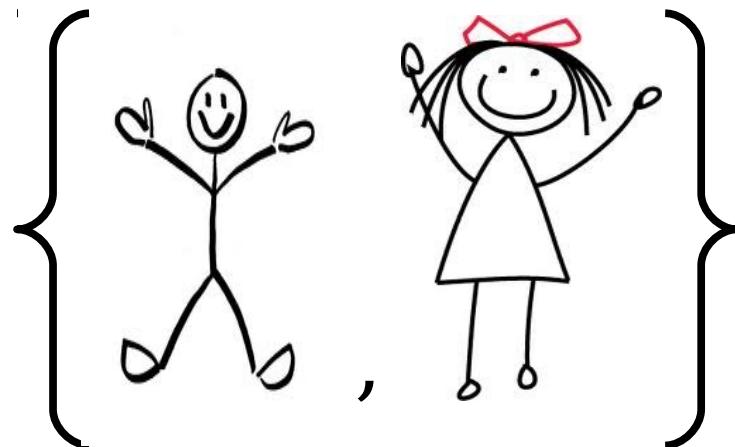
Every object in this set is in this set

Specifically, this statement means  
"every element of  $S$  is an element  
of  $T$ ."

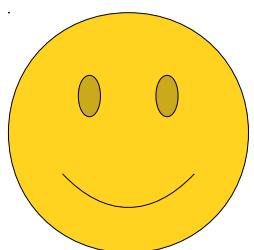


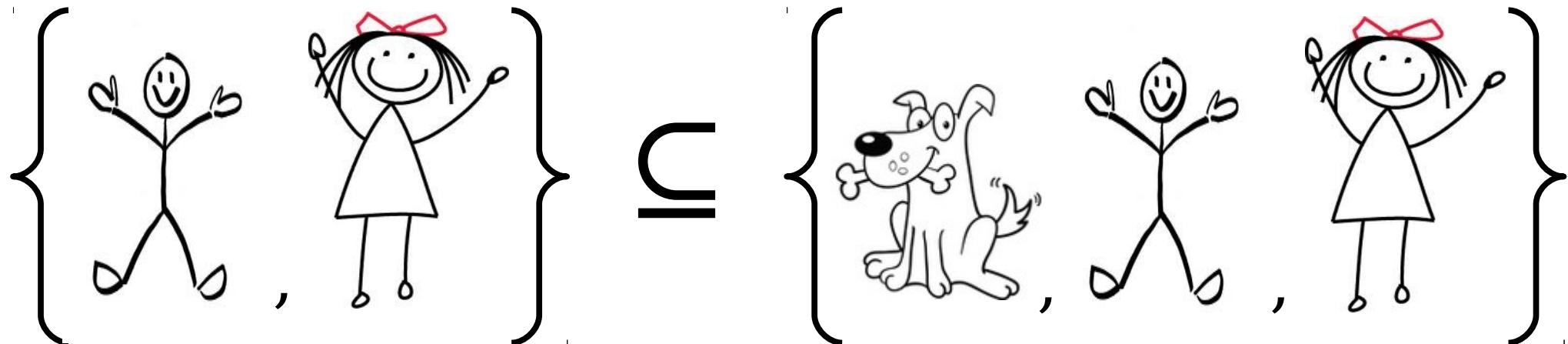
Let's do an example.



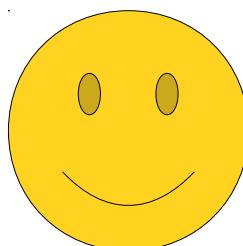


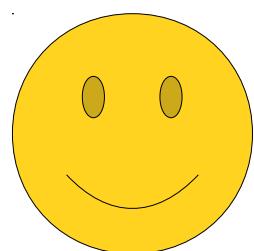
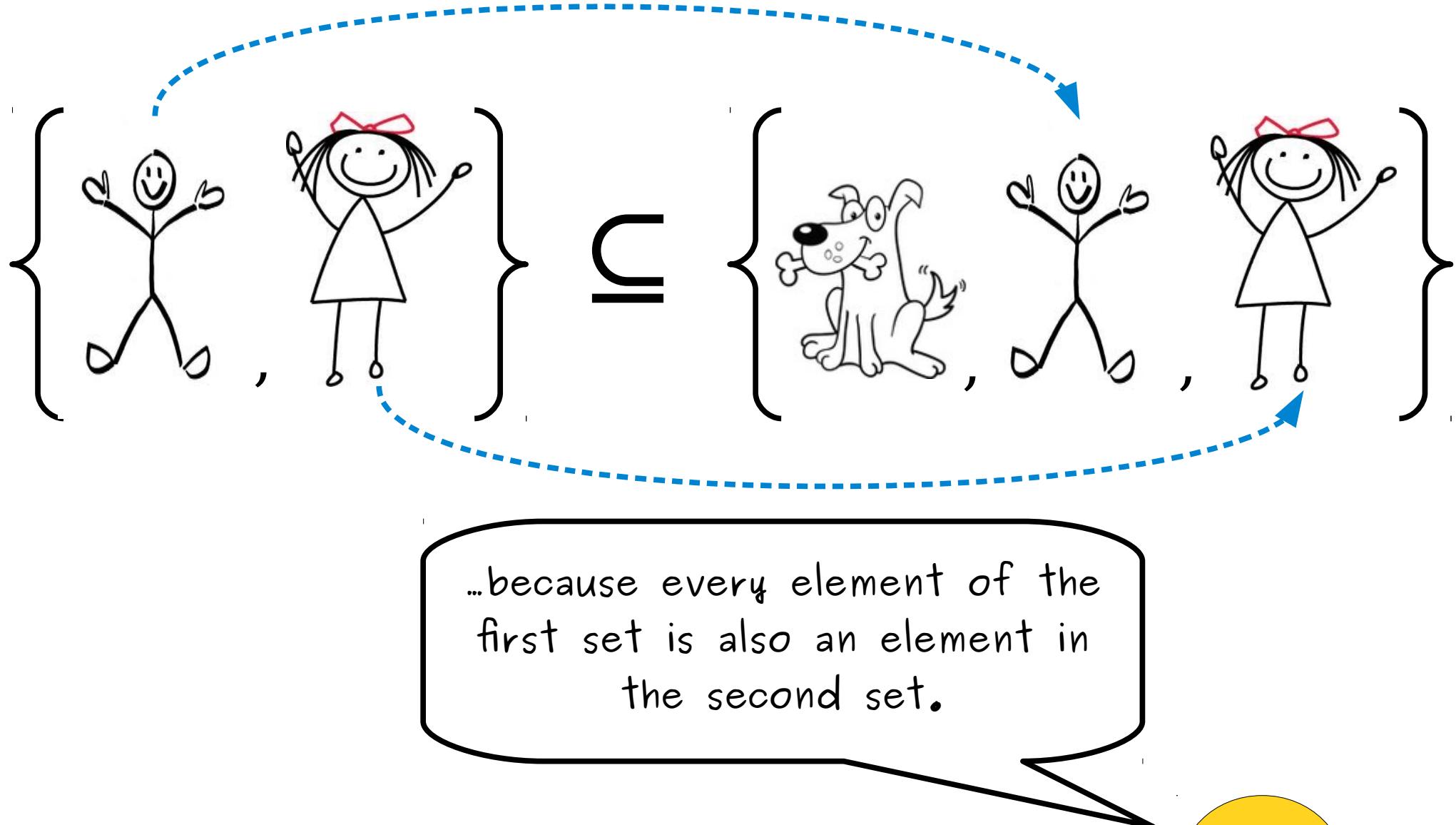
Here we have two different sets.



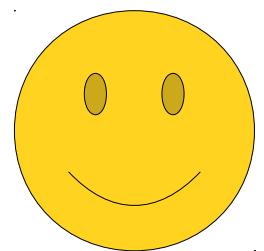


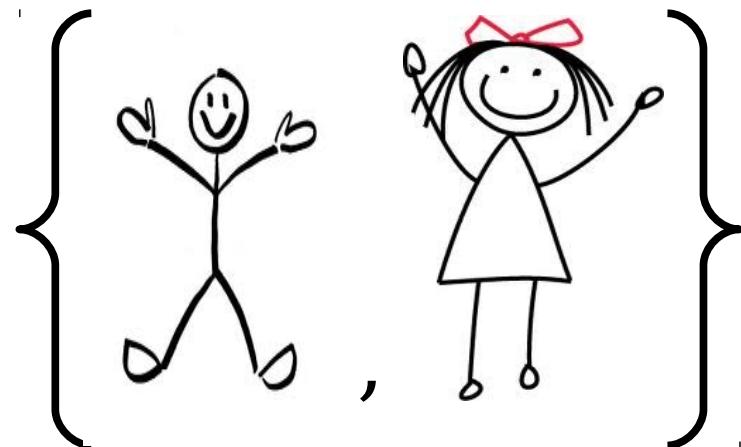
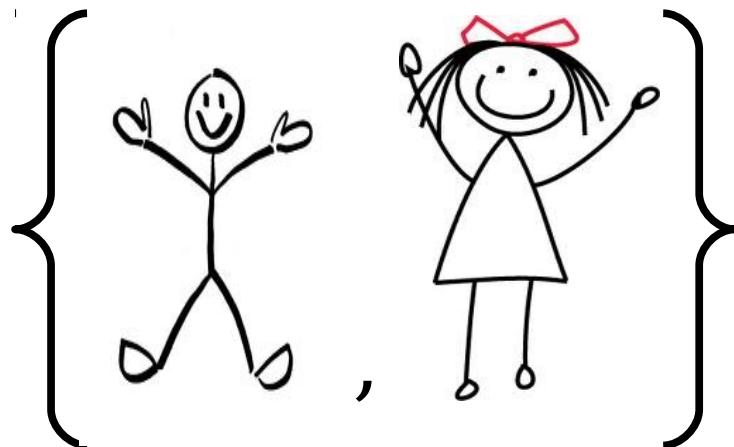
We can say that this first set  
is a subset of the second set...



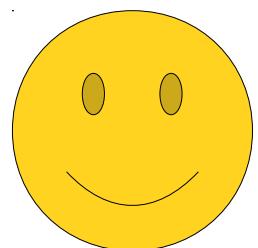


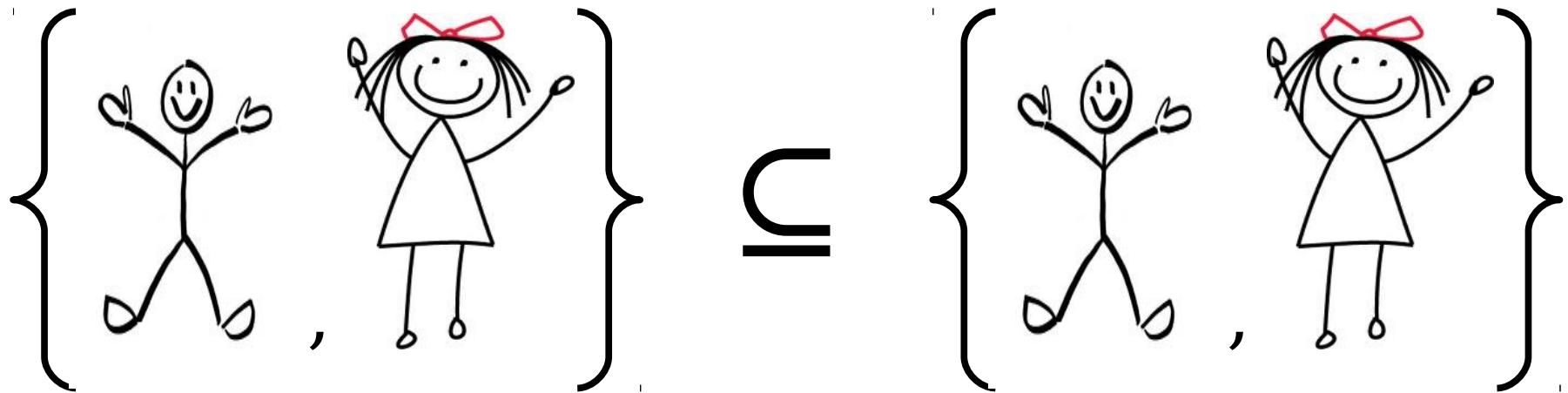
Here's another quick example.



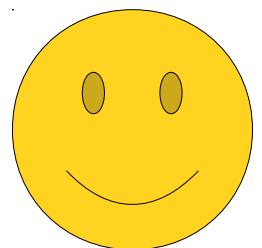


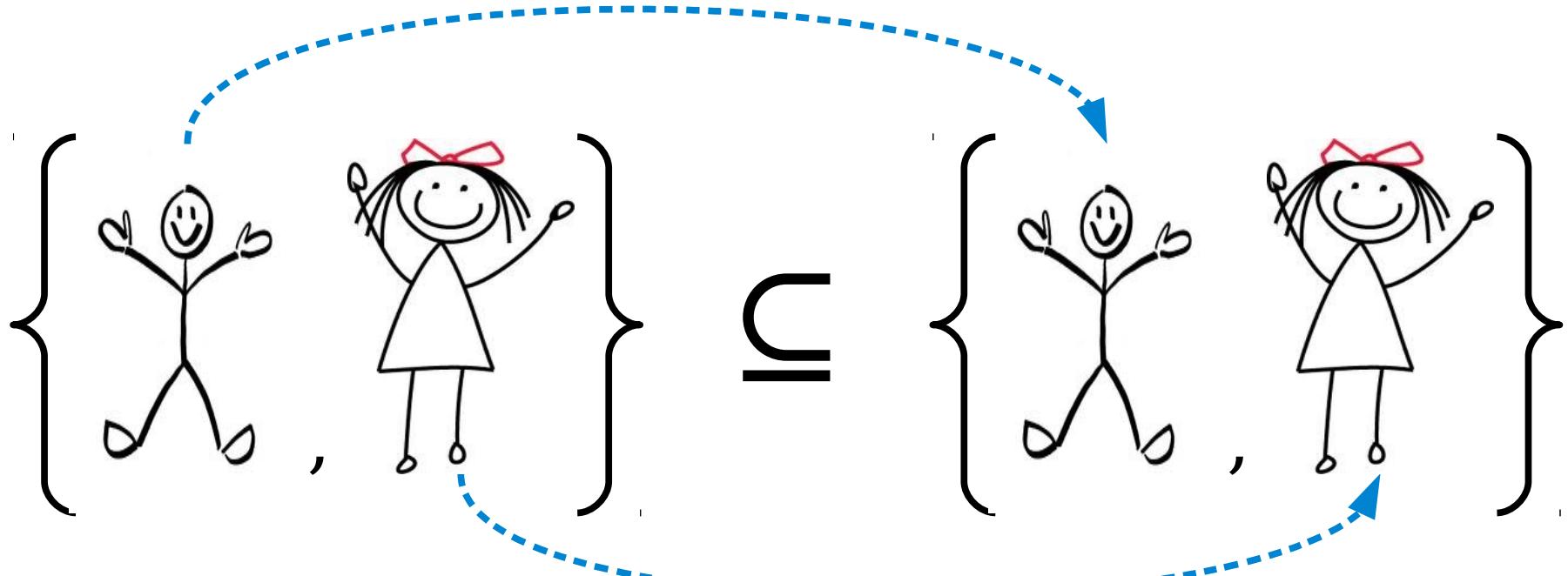
Here are two sets, which just happen to be the same set.



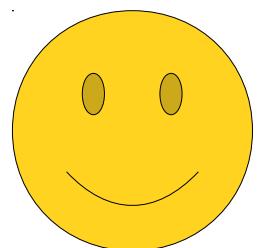


We say that the first set is a  
subset of the second set...

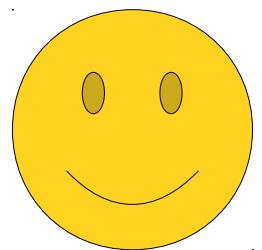


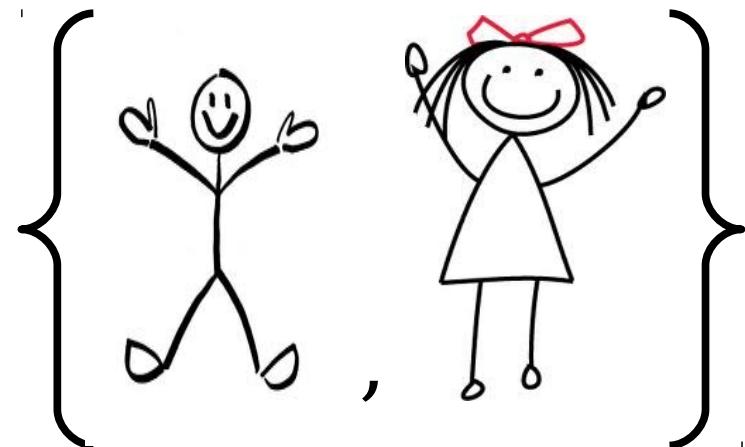
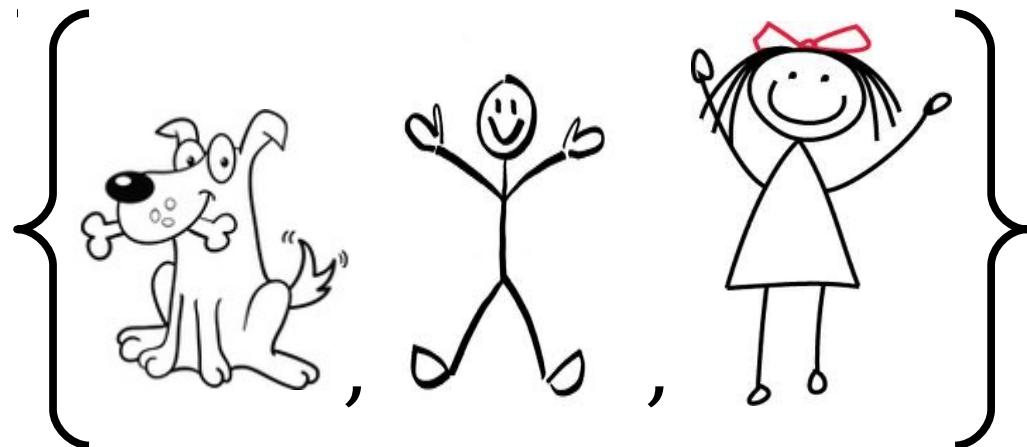


...because every element of the first set is also an element of the second set.

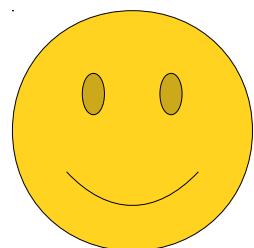


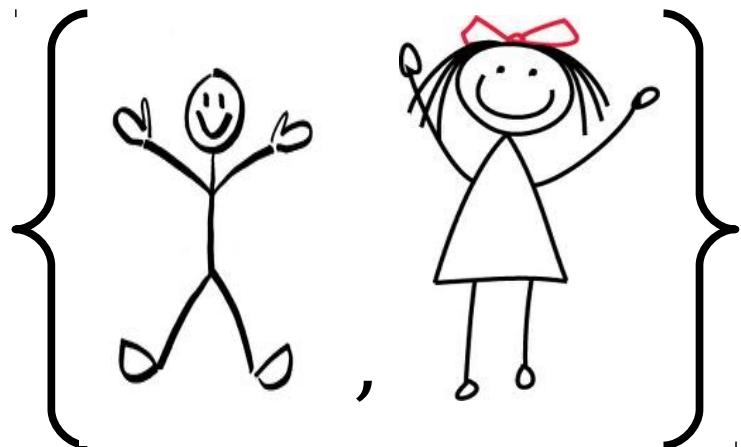
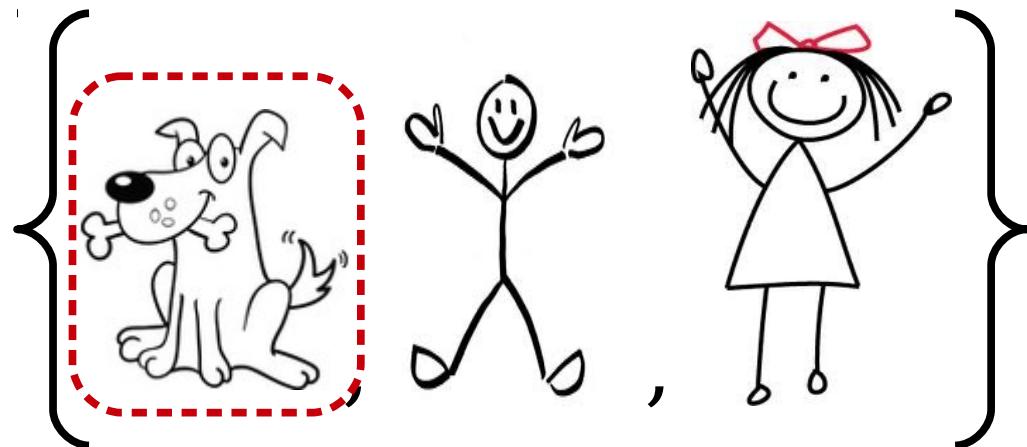
Let's do one more example before we move on.



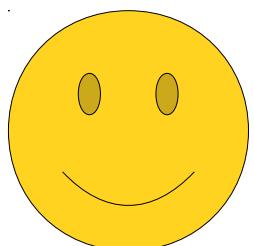


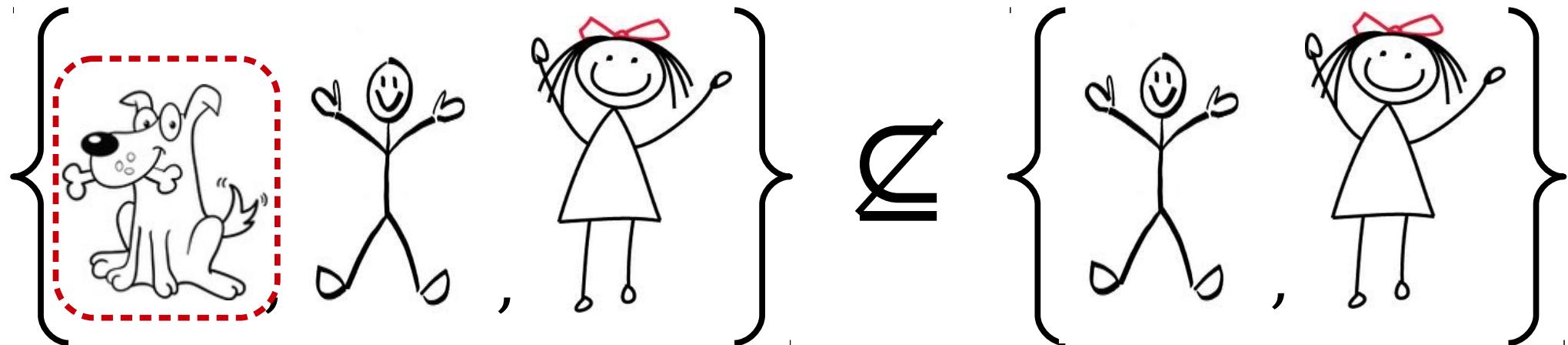
Here are two sets that we talked about earlier, but presented in the reverse order.



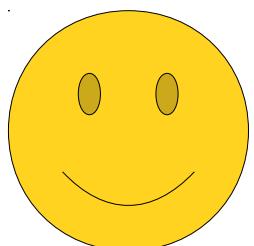


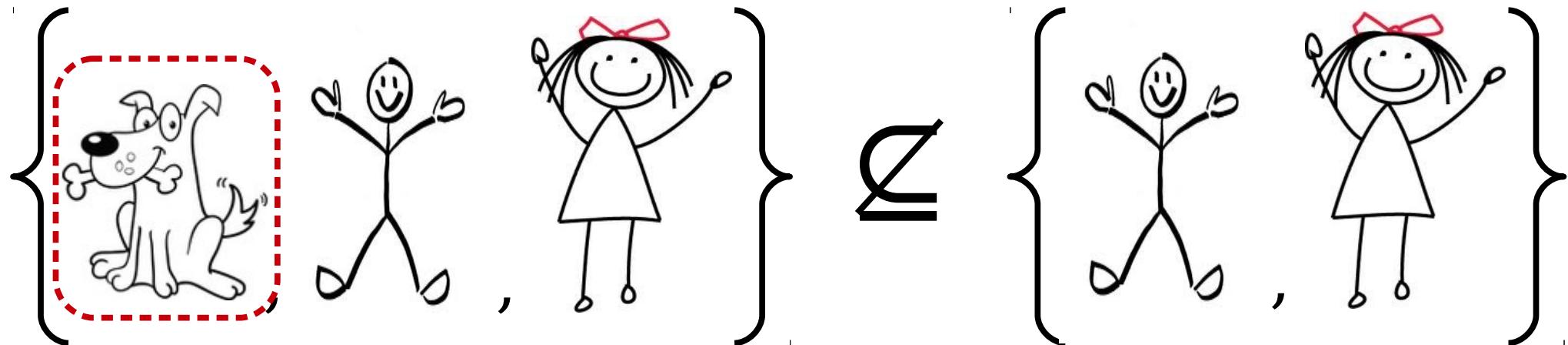
Notice how this first set contains an element that isn't present in the second set.



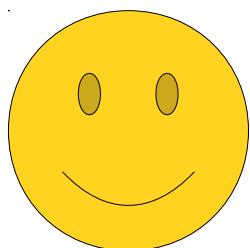


As a result, this first set is  
not a subset of the second  
set.

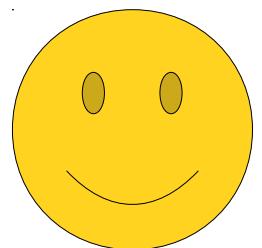




We denote this by using this special "not a subset" symbol. It's basically the subset symbol with a slash through it.

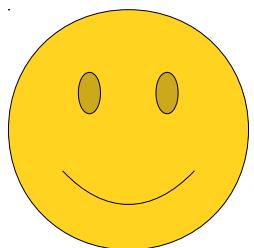


Earlier, we saw a visual intuition  
for what the  $\in$  symbol meant.  
Let's take a few minutes to  
get a visual intuition for  $\subseteq$ .

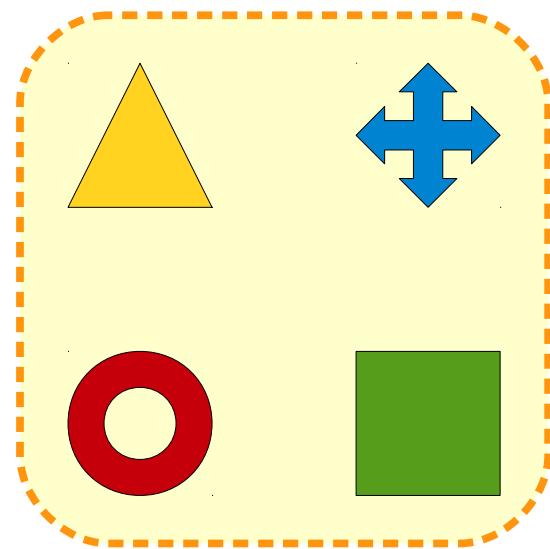


$$S = \{ \text{yellow triangle}, \text{blue double-headed arrow}, \text{red circle}, \text{green square} \}$$

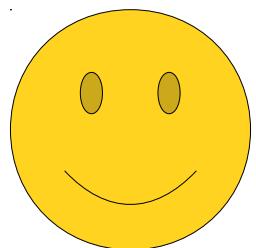
As before, let's look at this set  $S$ , which consists of a bunch of colorful shapes.



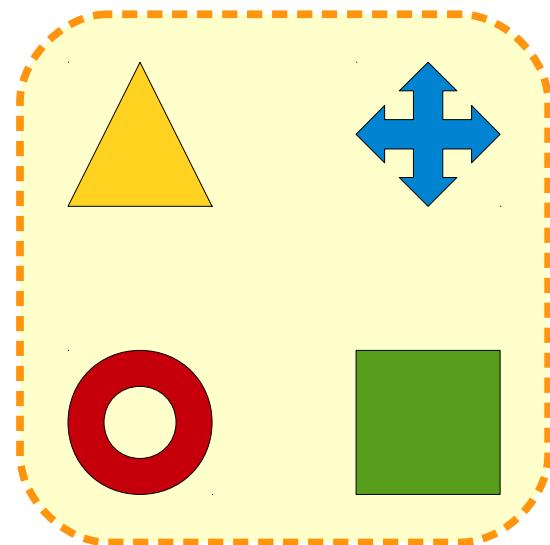
$$S = \{ \text{yellow triangle}, \text{blue double-headed arrow}, \text{red circle}, \text{green square} \}$$



Also as before, we'll draw  $S$  as a blob containing each of its elements.

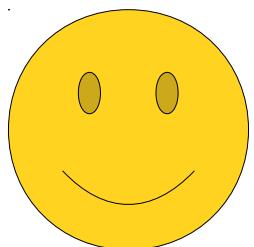


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

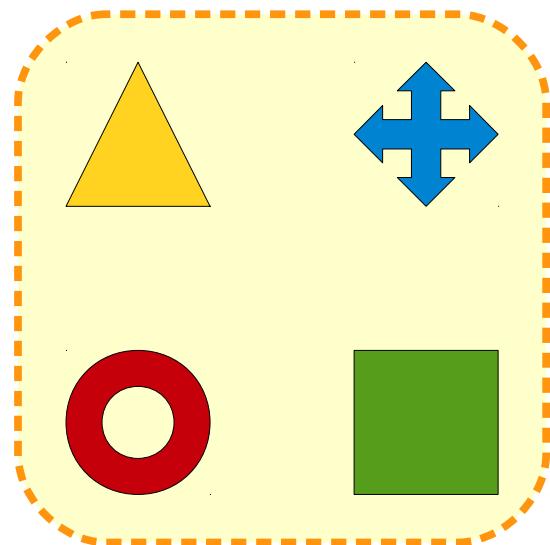


$$\{ \text{Yellow Triangle}, \text{Green Square} \} \subseteq S$$

So imagine that we're given the above statement and asked to determine whether it's true.

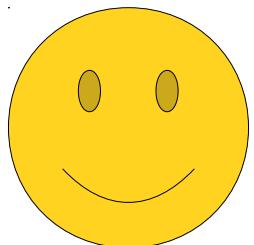


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

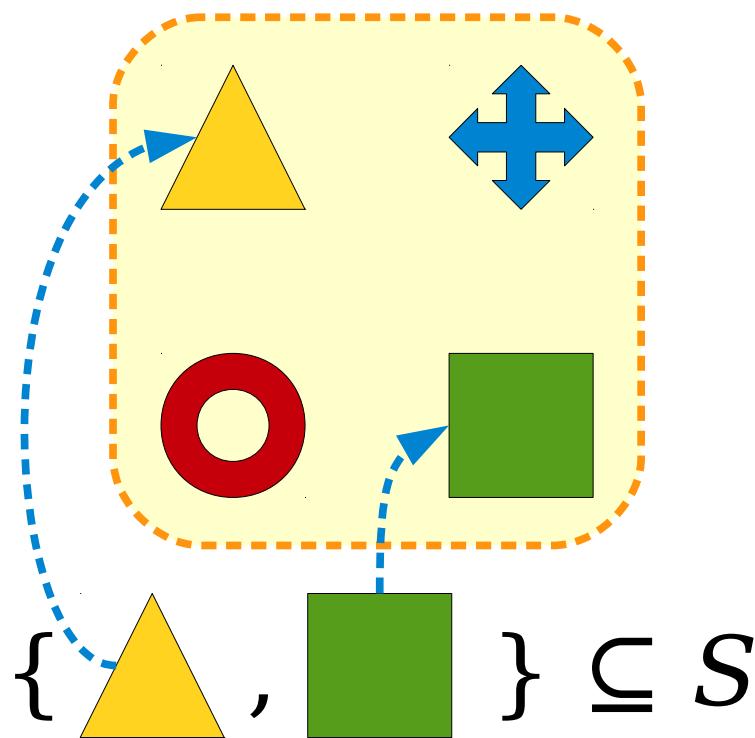


$$\{ \text{Yellow Triangle}, \text{Green Square} \} \subseteq S$$

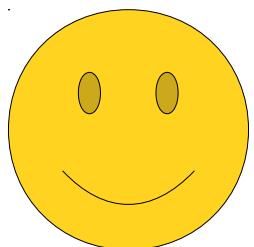
This is equivalent to asking whether every element in the set on the left happens to be in the set  $S$ .



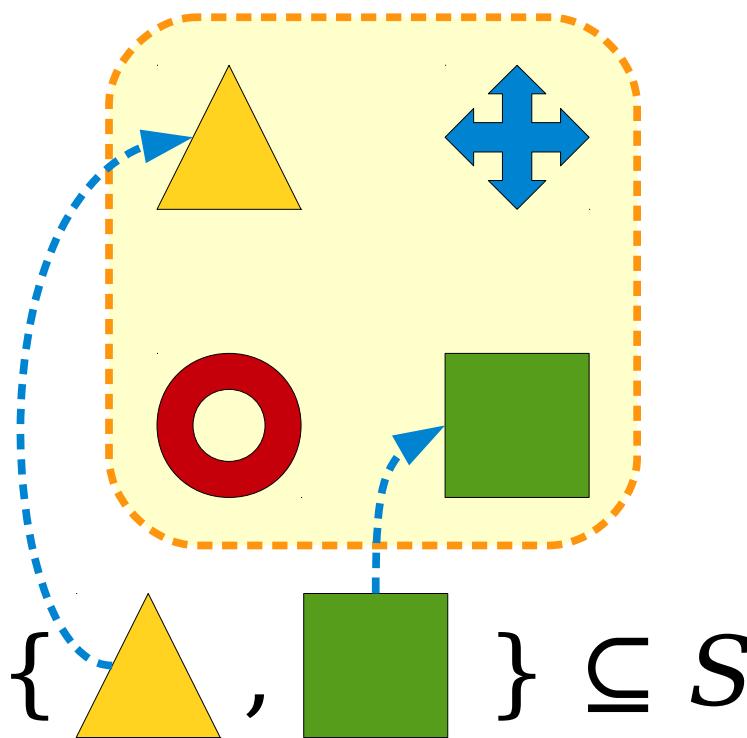
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



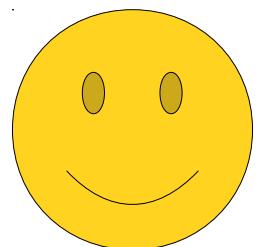
In this case, we can see that this is indeed the case. Notice that both objects are in  $S$ .



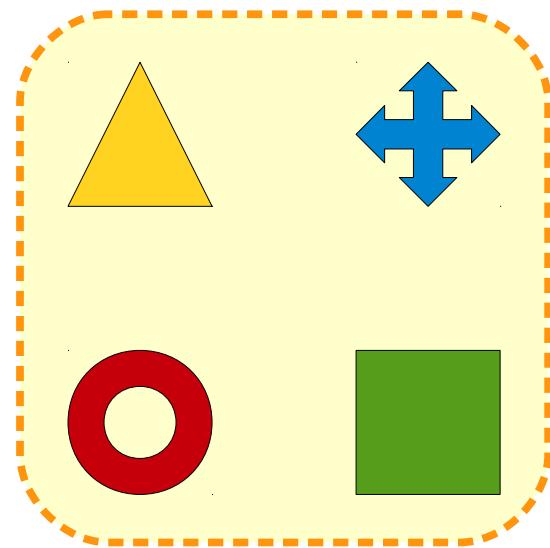
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



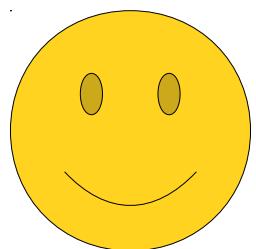
Therefore, the above statement is true.



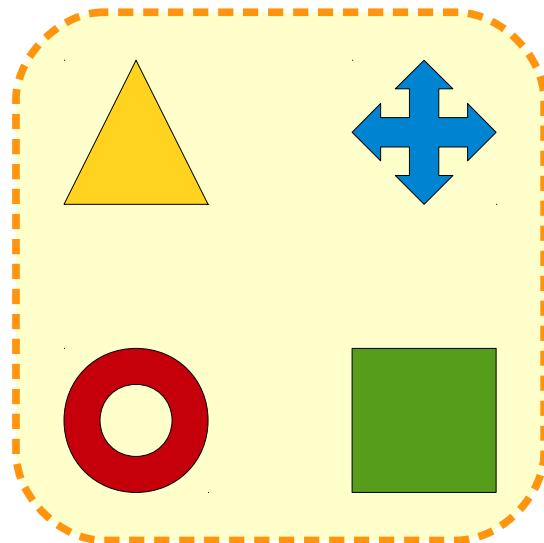
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



So let's try out a new statement.

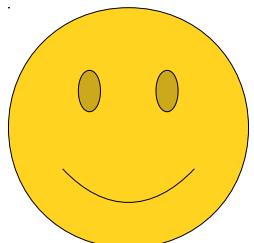


$$S = \{ \text{Yellow Triangle}, \text{Blue Double Arrow}, \text{Red Circle}, \text{Green Square} \}$$

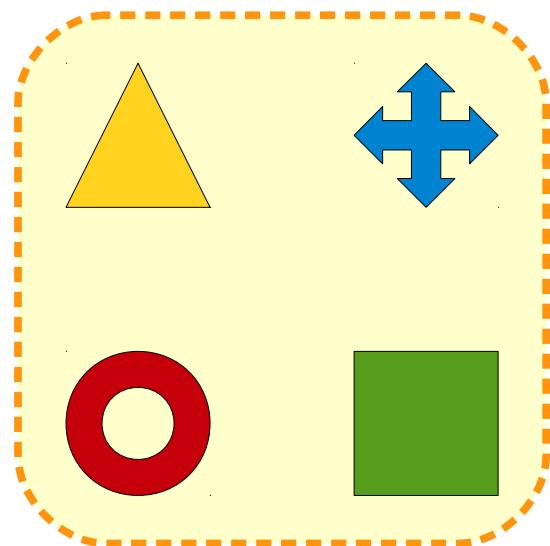


$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

Here's a statement that we're not sure about, which is why we have a question mark above the  $\subseteq$  symbol.

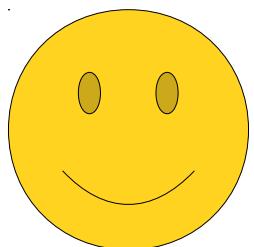


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

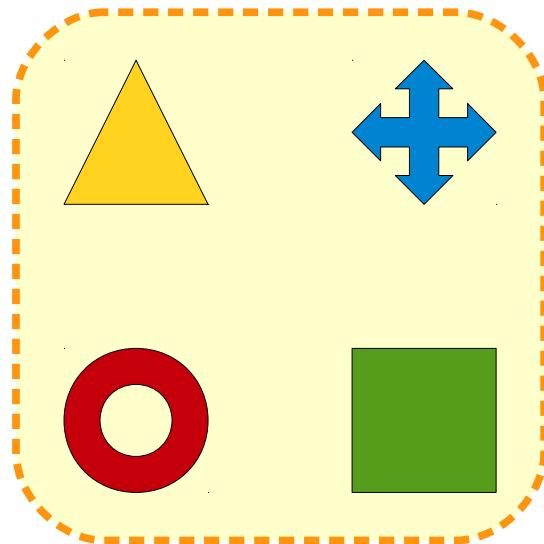


$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

So... is this statement true or false?

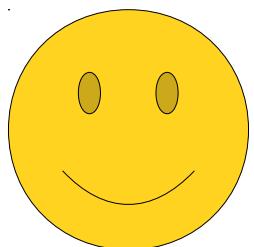


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

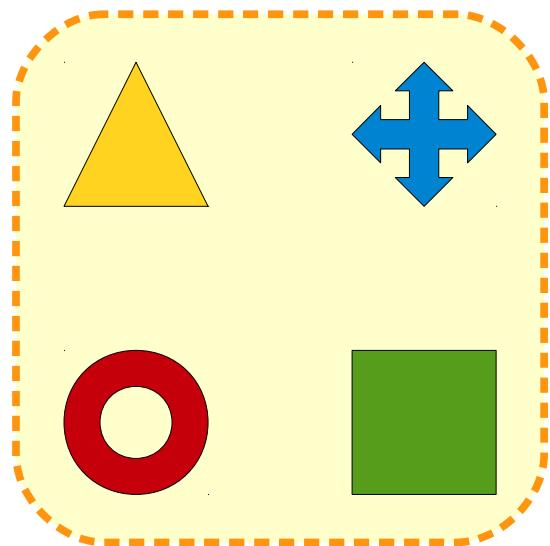


$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

Before you move on, make a guess!  
There's no risk involved - you're still learning!

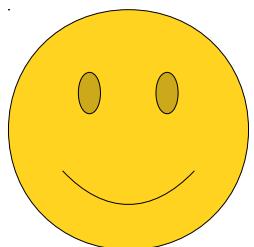


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

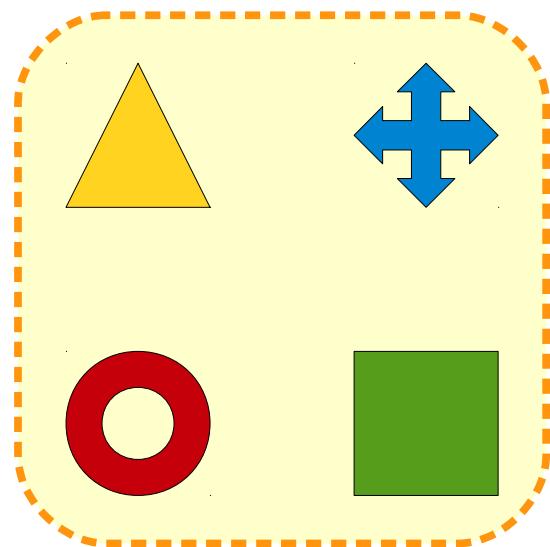


$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

So you have a guess about whether this statement is true or false? Like, really? Because if you haven't guessed yet, you totally should do that before moving on.

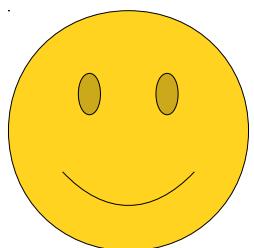


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

Okay, so let's see whether this is true or false.



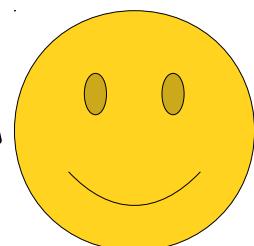
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

$$S \subseteq T$$

Every object in this set is in this set

$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

Earlier, we said that the  $\subseteq$  relation means that every object in the set on the left-hand side is an element of the set on the right-hand side.



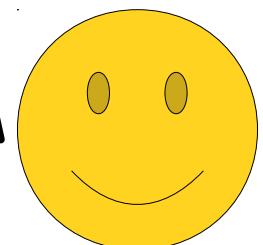
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

$$S \subseteq T$$

Every object in this set is in this set

$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

An important detail here is that the thing on the left-hand side of the  $\subseteq$  relation has to be a set for the relation to even make sense.



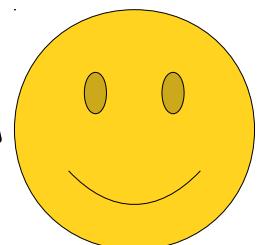
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

$$S \subseteq T$$

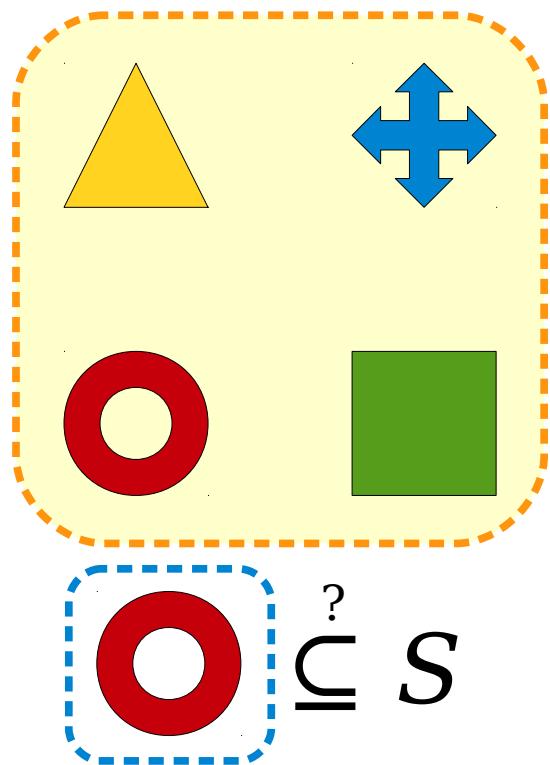
Every object in this set is in this set

$$\text{Red Circle} \stackrel{?}{\subseteq} S$$

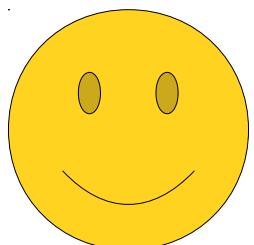
Otherwise, it would be like asking whether giraffe < 137 - it's a meaningless statement because you can't compare giraffes to numbers using less-than.



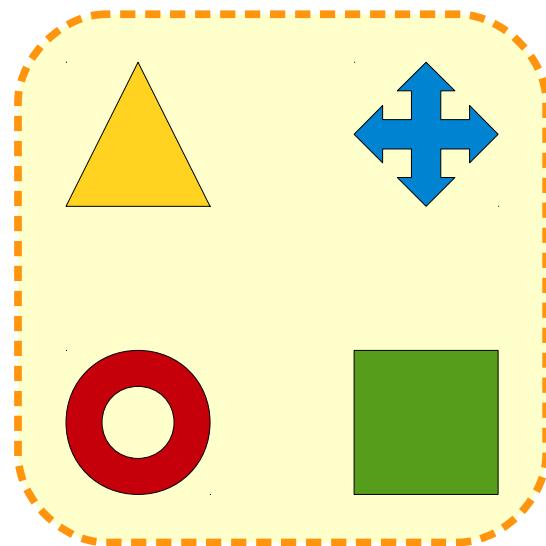
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



In this particular case, the object on the left-hand side of the subset symbol isn't a set...

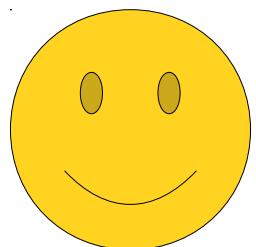


$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$

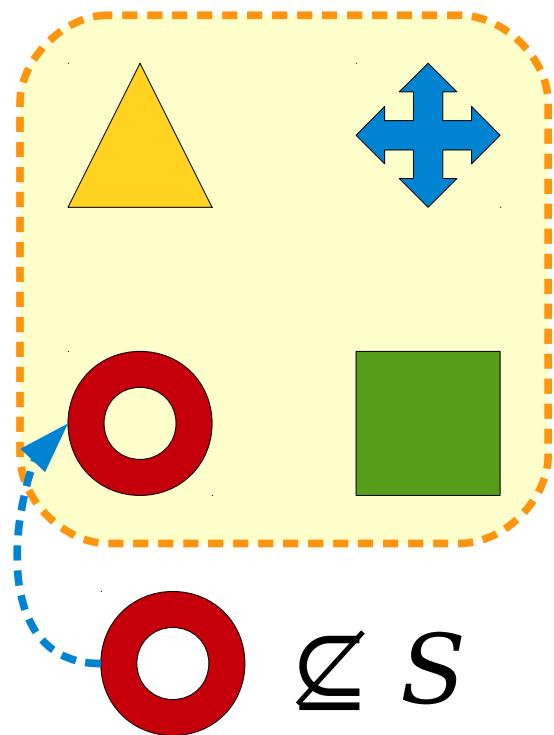


$$\text{Red Circle} \not\in S$$

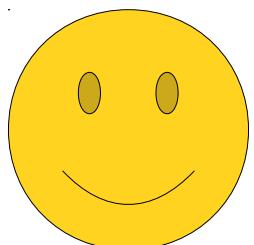
... so the initial statement was false.



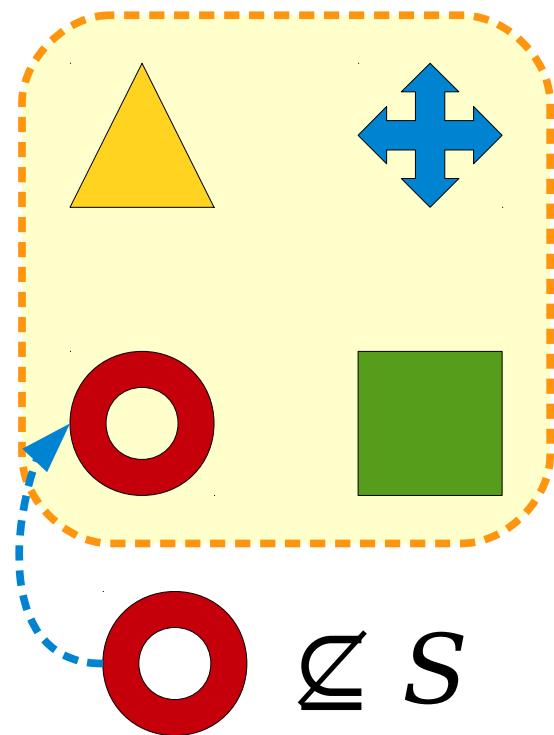
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



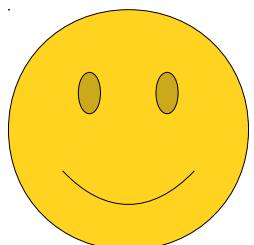
This might seem a bit counterintuitive at first because the red circle is in the set  $S$ .



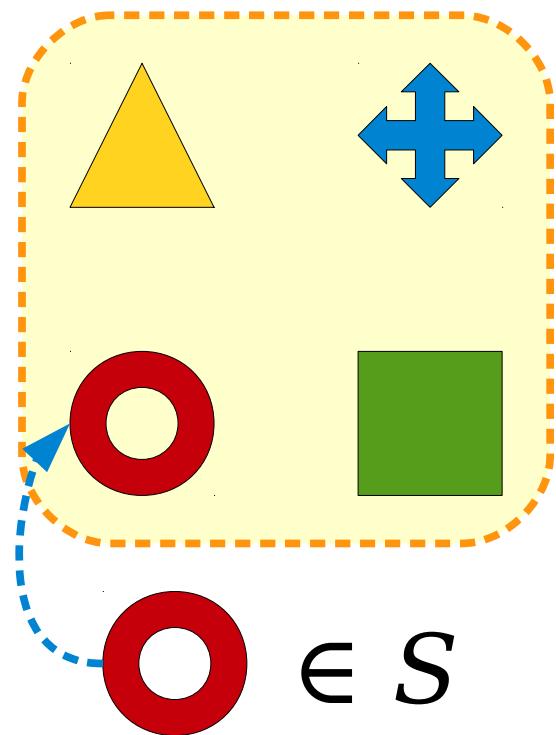
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



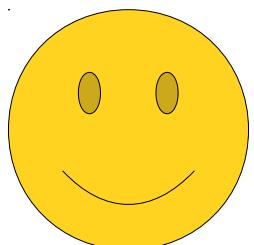
But we have a different way of expressing that idea!



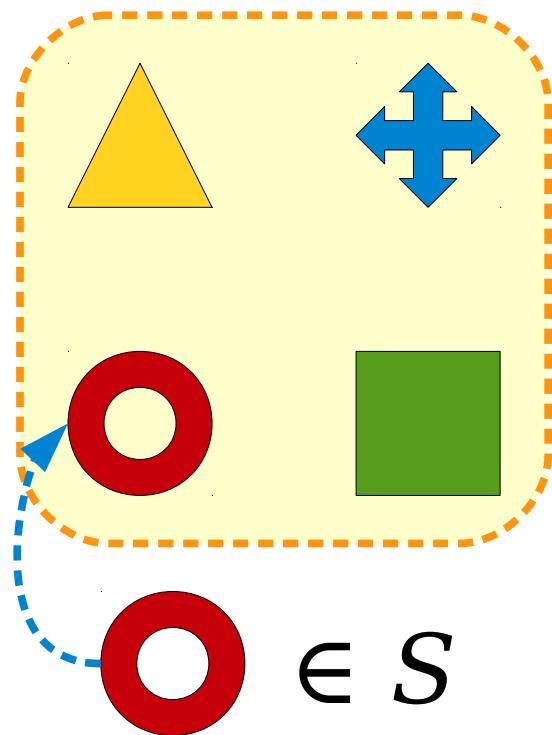
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



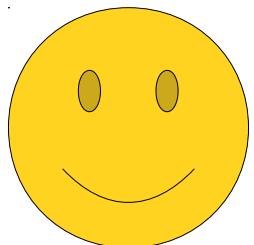
We can always say that the red circle is an element of the set  $S$ , even if it's not a subset of the set  $S$ .



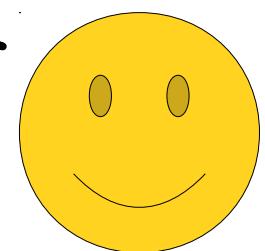
$$S = \{ \text{Yellow Triangle}, \text{Blue Double-headed Arrow}, \text{Red Circle}, \text{Green Square} \}$$



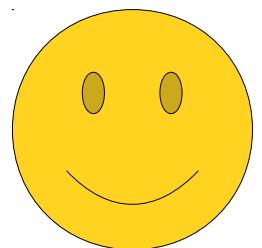
So remember that  $\in$  and  $\subseteq$  aren't the same thing. You can be an element of a set without being a subset and vice-versa.



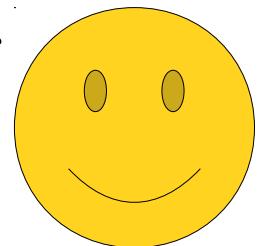
So now we've seen a little bit about  
the  $\in$  and  $\subseteq$  relations.



We've seen that you use  $\in$  to ask whether objects belong to sets and  $\subseteq$  to ask whether one set is a subset of another.

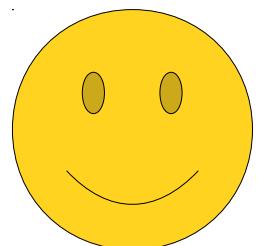


Things get a little bit more interesting when we start talking about sets that contain other sets.



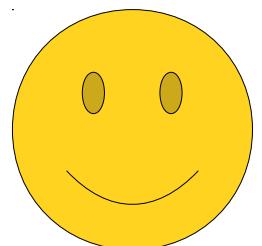
$$\{ 1, \{2, 3\}, 4 \}$$

For example, take a look at this set.



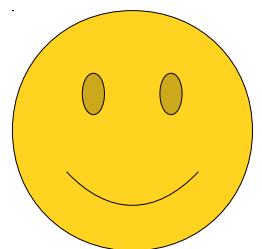
$$\{ 1, \{2, 3\}, 4 \}$$

This set has three elements...



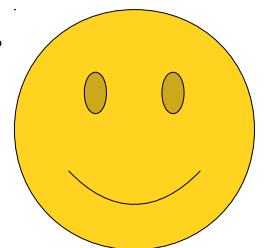
{ 1, {2, 3}, 4 }

... the number one, ...



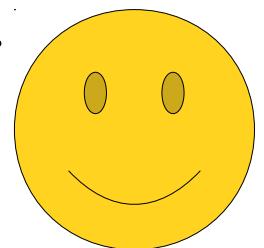
$$\{ 1, \{2, 3\}, 4 \}$$

... the set  $\{2, 3\}$ , which contains the numbers two and three, ...



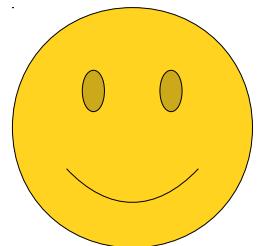
{ 1, {2, 3}, 4 }

... and the number four.



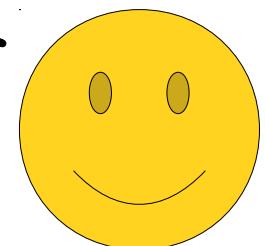
$$\{ 1, \{2, 3\}, 4 \}$$

Restated using our new notation...



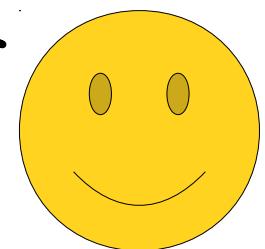
$$1 \in \{ 1, \{2, 3\}, 4 \}$$

...we can say that 1 is an element of the set, ...



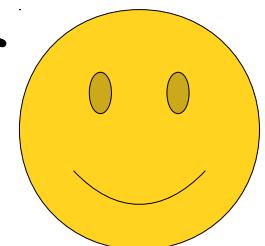
$$\{2, 3\} \in \{ 1, \{2, 3\}, 4 \}$$

... that the set  $\{2, 3\}$  is an element of  
the set, ...



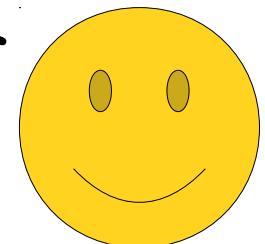
$$4 \in \{ 1, \{2, 3\}, 4 \}$$

... and that the number 4 is an element of the set.



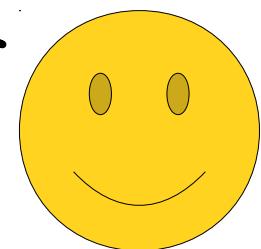
$$2 \notin \{ 1, \{2, 3\}, 4 \}$$

However, it isn't true that 2 is an element of this set.



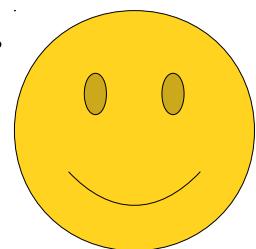
$$2 \notin \{ 1, \{2, 3\}, 4 \}$$

So why is that?



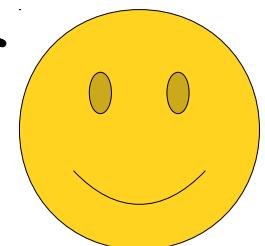
$$2 \notin \{ 1, \{2, 3\}, 4 \}$$

Remember, the set on the right has three different elements: the number 1, the set  $\{2, 3\}$ , and the number 4.



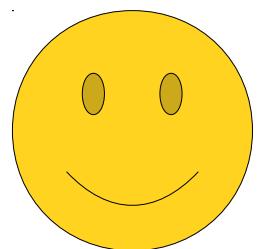
$$2 \notin \{ 1, \{2, 3\}, 4 \}$$

None of the terms highlighted in blue is exactly equal to the number two.



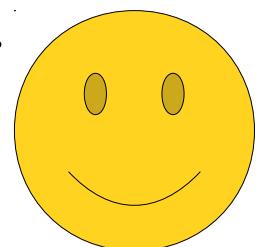
$$2 \notin \{ 1, \{2, 3\}, 4 \}$$

In other words, you can't point at something in the set and say "that thing right there is the number two."



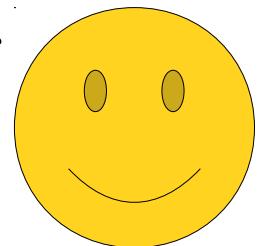
$$2 \notin \{ 1, \{2, 3\}, 4 \}$$

While it's true that the set  $\{2, 3\}$  contains the number 2, that doesn't mean that the set as a whole contains 2.



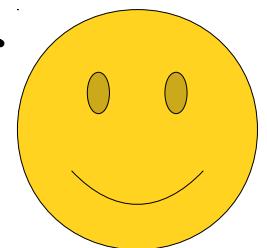
```
{ 1, {2, 3}, 4 }
```

Let's look at another statement.



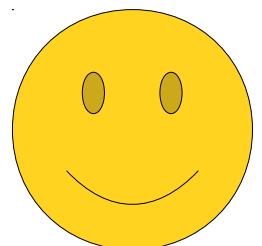
$$\{4\} \in \{ 1, \{2, 3\}, 4 \}$$

Is this statement true or false?



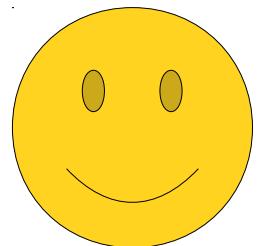
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

Before moving on, take a guess and try to give a justification for it.



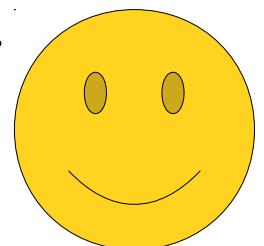
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

So you've made your guess? Like, really?  
Because if you haven't, you totally should!



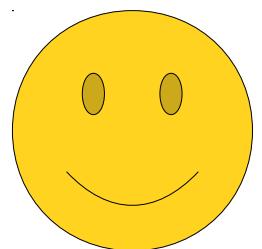
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

Okay, now that you've got your guess,  
let's see what the answer is.



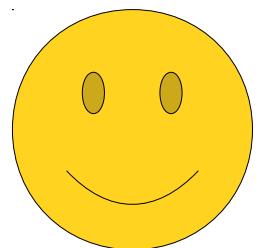
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

The question is whether  $\{4\}$ , the set containing the number 4, is an element of the set on the right-hand side.



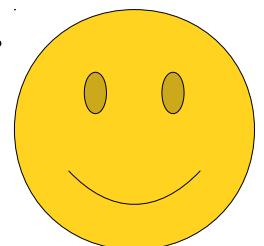
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

To answer this question, we can just go one element at a time through the set and see if any of them are  $\{4\}$ .



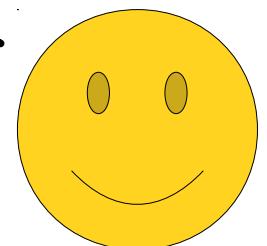
$$\{4\} \stackrel{?}{\in} \{ \textcolor{red}{1}, \{2, 3\}, 4 \}$$

Well, this element isn't equal to  $\{4\}$ ,  
so that doesn't help us.



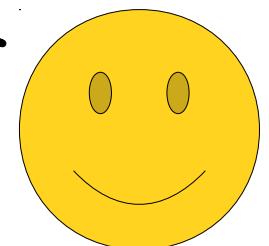
$$\{4\} \in \{ 1, \{2, 3\}, 4 \}$$

This one isn't equal to  $\{4\}$  either.



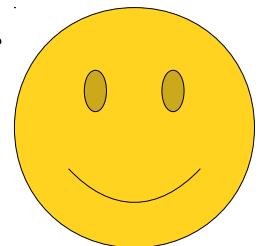
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

So what about this one?



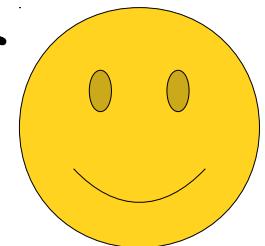
$$\{4\} \in \{ 1, \{2, 3\}, 4 \}$$

It's a 4, which looks pretty similar to  $\{4\}$ .



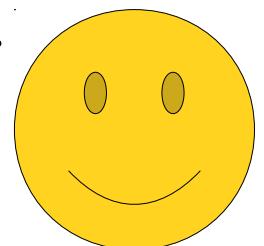
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

But remember - the number 4 is not the same as the set containing the number 4!



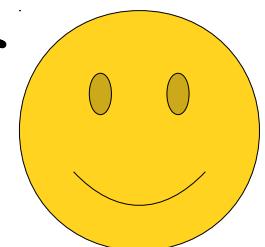
$$\{4\} \in \{ 1, \{2, 3\}, 4 \}$$

Generally speaking, no object is ever equal to the set that contains it.



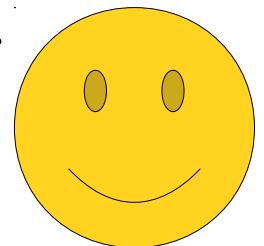
$$\{4\} \in \{ 1, \{2, 3\}, 4 \}$$

So that means that even though this 4 looks a lot like the set  $\{4\}$ ...



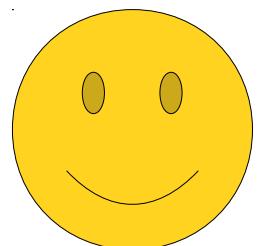
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, \textcolor{red}{4} \}$$

... this element isn't equal to  $\{4\}$  either.



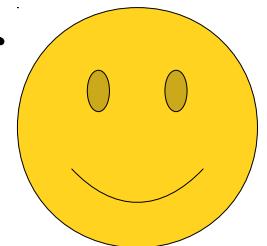
$$\{4\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

So we've gone through all the elements of the set, trying to see if any of them are equal to  $\{4\}$ , and it looks like none of them are.



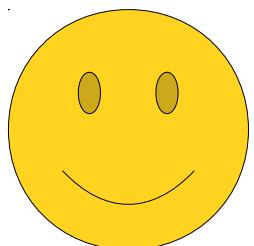
$$\{4\} \notin \{ 1, \{2, 3\}, 4 \}$$

That means that  $\{4\}$  is not an element of the set.



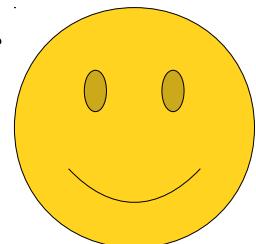
$$\{4\} \notin \{ 1, \{2, 3\}, 4 \}$$

If you thought that  $\{4\}$  was an element of the set, don't worry! It's a reasonable thought. It just happens to not work given how we've chosen to define sets and the  $\in$  symbol.



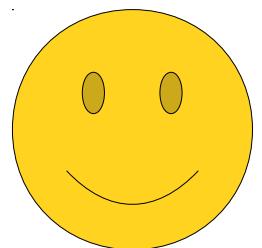
$$\{4\} \notin \{ 1, \{2, 3\}, 4 \}$$

Going forward, remember that  $x$  and  $\{x\}$  are different things –  $x$  is an individual object, while  $\{x\}$  is a set containing the object  $x$ .



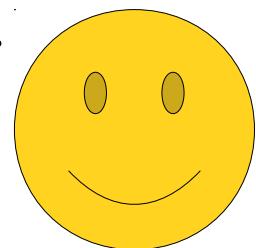
$$\{ 1, \{2, 3\}, 4 \}$$

With that idea in mind, let's move forward to looking back at the subset relation.



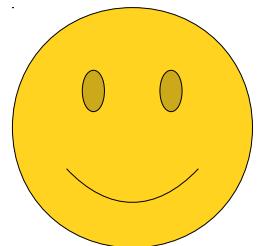
$$\{1\} \overset{?}{\subseteq} \{ 1, \{2, 3\}, 4 \}$$

Take a look at this statement. Do you think it's true or false?



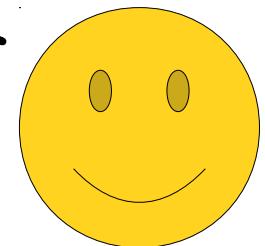
$$\{1\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

As before, take a minute to come up with a guess before moving on. You'll be happier if you do.



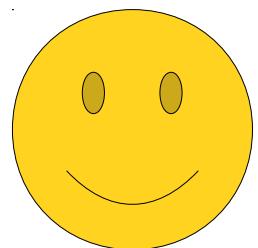
$$\{1\} \overset{?}{\subseteq} \{ 1, \{2, 3\}, 4 \}$$

So you've got your guess? Great!



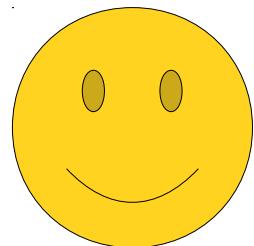
$$\{1\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

To determine whether  $\{1\}$  is a subset of  $\{1, \{2, 3\}, 4\}$ , we need to ask whether every element of  $\{1\}$  is also an element of  $\{1, \{2, 3\}, 4\}$



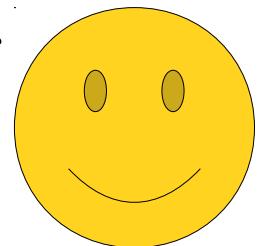
$$\{ \textcolor{blue}{1} \} \subseteq \{ \text{ } \overset{?}{1}, \{2, 3\}, 4 \text{ } \}$$

The set  $\{1\}$  only has one element (the number 1), so we just need to see whether the number 1 is contained in the set on the right.



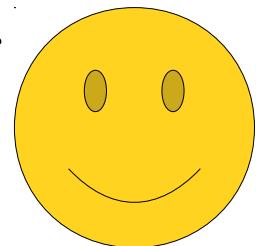
$$\{ \textcolor{blue}{1} \} \subseteq \{ \textcolor{blue}{1}, \{2, 3\}, 4 \}$$

And, indeed, it is!



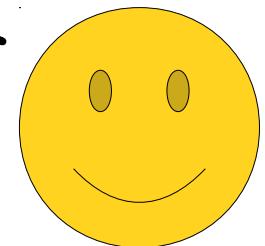
$$\{1\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

So that means that the set  $\{1\}$  is indeed a subset of the set on the right.



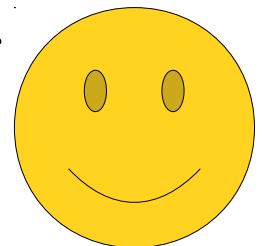
$$\{1\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

To mix things up a bit, let's ask a different question.



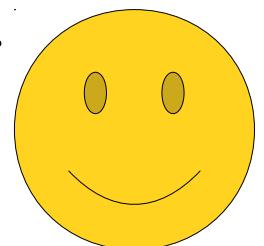
$$\{1\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

Is this new statement true? As before, take a minute to think it over.



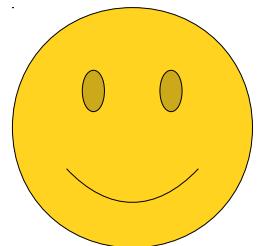
$$\{1\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

Got a guess? Great! Let's move on.



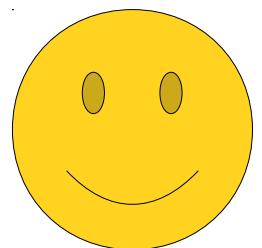
$$\{1\} \stackrel{?}{\in} \{1, \{2, 3\}, 4\}$$

We're asking whether the set  $\{1\}$  is an element of the set  $\{1, \{2, 3\}, 4\}$ .



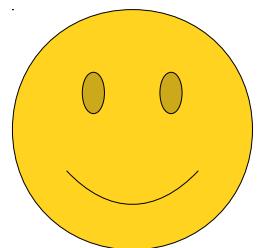
$$\{1\} \stackrel{?}{\in} \{1, \{2, 3\}, 4\}$$

That means that we need to see if anything in the set  $\{1, \{2, 3\}, 4\}$  is equal to the set  $\{1\}$ .



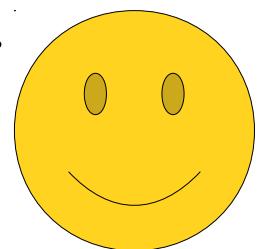
$$\{1\} \in \{ \textcolor{red}{1}, \{2, 3\}, 4 \}$$

Using our reasoning from before, we know that 1 and  $\{1\}$  aren't the same thing, so this element isn't the set  $\{1\}$ .



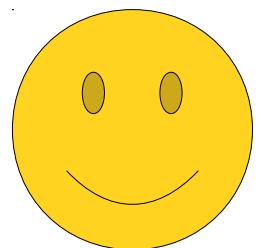
$$\{1\} \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

And hopefully it's not too much of a stretch to see that these elements aren't equal to  $\{1\}$ .



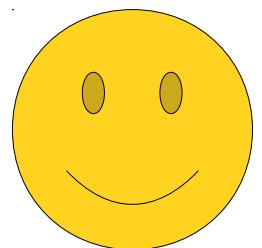
$$\{1\} \notin \{1, \{2, 3\}, 4\}$$

So overall we see that nothing in the set on the right is equal to  $\{1\}$ , so  $\{1\}$  is not an element of  $\{1, \{2, 3\}, 4\}$ .



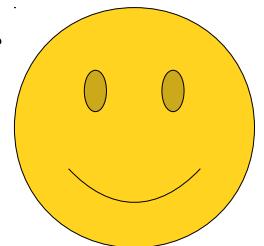
$$\{ 1, \{2, 3\}, 4 \}$$

We've gotten a lot of mileage out of  
this one single set, and we're not  
done yet!



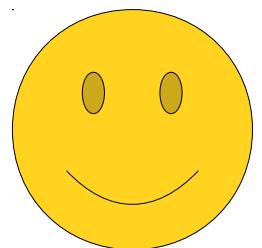
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

Here's another one to ponder.



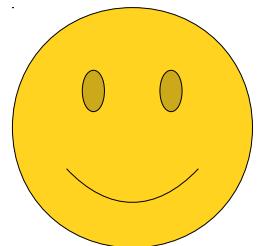
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

You know the drill - think it over,  
take a guess, and let's move on!



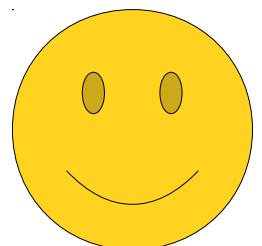
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

Got a guess? Great! Let's proceed.



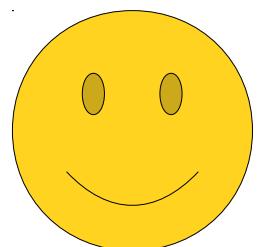
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

We're asking whether  $\{2, 3\}$  is a subset of  $\{1, \{2, 3\}, 4\}$ .



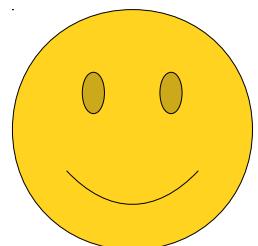
$$\{2, 3\} \stackrel{?}{\subseteq} \{ 1, \{2, 3\}, 4 \}$$

To answer that question, we have to see whether every element of  $\{2, 3\}$  is an element of  $\{1, \{2, 3\}, 4\}$ .



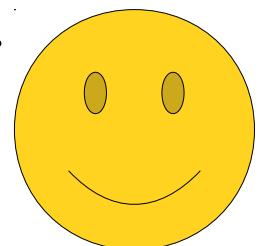
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

Let's begin with this element of  $\{2, 3\}$   
and ask - is 2 an element of  $\{1, \{2, 3\}, 4\}$ ?



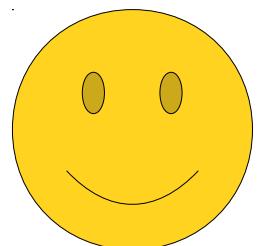
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

But wait! We already know the answer to this question. We did this earlier.



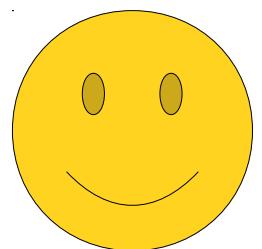
$$\{2, 3\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

We know that 2 is not an element of  
 $\{1, \{2, 3\}, 4\}$ .



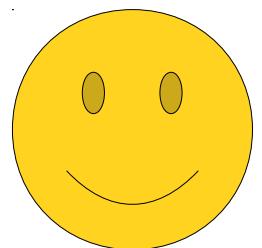
$$\{2, 3\} \not\subset \{1, \{2, 3\}, 4\}$$

That means that the set  $\{2, 3\}$  isn't a subset of  $\{1, \{2, 3\}, 4\}$ , because the set  $\{1, \{2, 3\}, 4\}$  doesn't contain 2.



$$\{2, 3\} \in \{ 1, \{2, 3\}, 4 \}$$

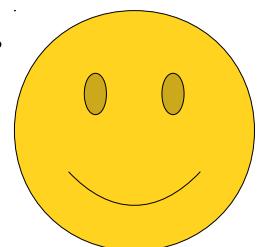
However, we could say that  $\{2, 3\}$  is an element of  $\{1, \{2, 3\}, 4\}$ ...



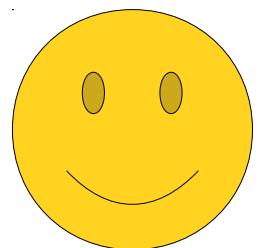
$$\{2, 3\} \in \{ 1, \{2, 3\}, 4 \}$$

...because  $\{2, 3\}$  is right here.

Remember,  $\in$  and  $\subseteq$  ask different  
questions!

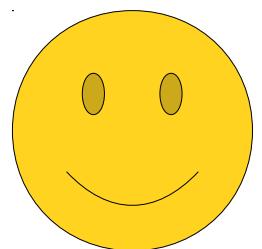


To conclude our little tour of  $\in$  and  $\subseteq$ , let's talk about our friend the empty set.



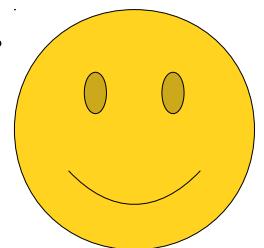


The empty set - which we denote using the symbol shown above - is a set that contains no elements.





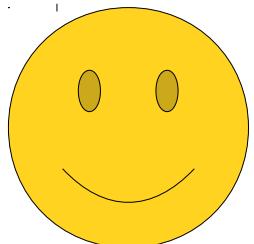
The empty set has a few nice properties  
that are worth keeping in mind.



$$x \notin \emptyset$$

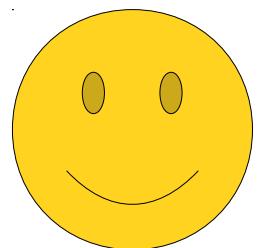
First, since the empty set has no elements, if you take any object  $x$ , you'll know it's not an element of the empty set.

In fact, that's how the empty set is sometimes defined!



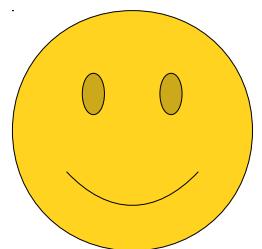
$$\emptyset \subseteq S$$

Second, as mentioned in class, we mentioned that the empty set is a subset of any set  $S$ . This is a consequence of vacuous truth.



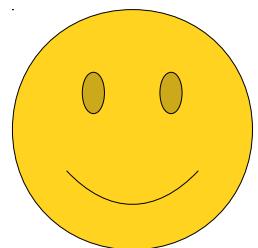


Although the empty set is probably most famous because of these two properties, it's just a set like any other and it obeys all the regular rules of the  $\in$  and  $\subseteq$  relations.



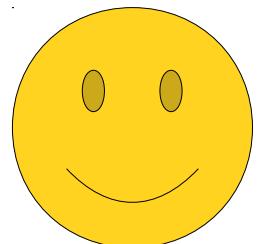


It's also somewhat famous because it's a great edge case and can be a bit weird when you first encounter it.



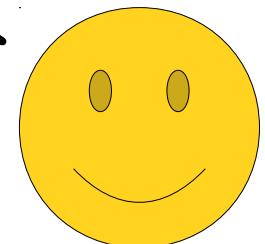


To help give you a little bit of practice,  
let's look at some examples.



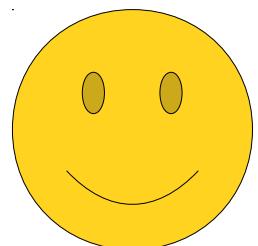
$$\emptyset \in \{ 1, \{2, 3\}, 4 \}$$

First, take a look at this statement. Is this statement true or false?



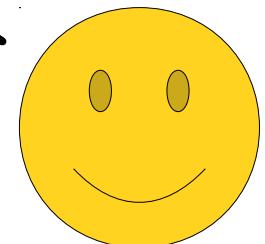
$$\emptyset \in \{ 1, \{2, 3\}, 4 \}$$

Don't move on until you've got a guess...  
this is a really good problem to work  
through!



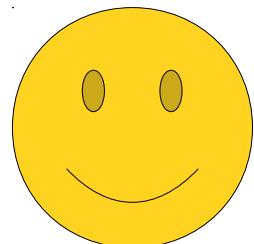
$$\emptyset \in \{ 1, \{2, 3\}, 4 \}$$

Okay, you've got your guess? Great!  
Let's take a look a this.



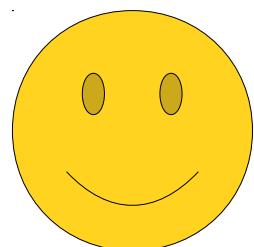
$$\emptyset \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

We're asking whether  $\emptyset$  is an element of  $\{1, \{2, 3\}, 4\}$ .



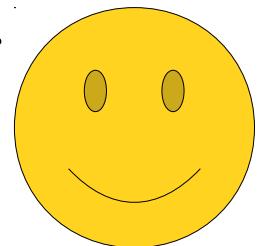
$$\emptyset \stackrel{?}{\in} \{ 1, \{2, 3\}, 4 \}$$

That means we need to see whether any of the elements of  $\{1, \{2, 3\}, 4\}$  happen to be equal to  $\emptyset$ .



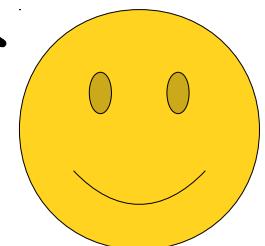
$$\emptyset \in \{ \textcolor{red}{1}, \{2, 3\}, 4 \}$$

Well, this element of the set isn't  $\emptyset$ ...



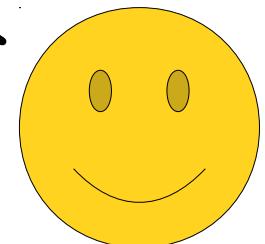
$$\emptyset \in \{ 1, \{2, 3\}, 4 \}$$

... nor is this one ...



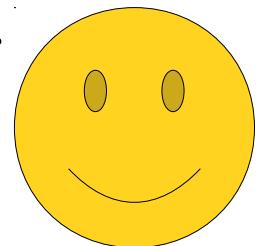
$$\emptyset \in \{ 1, \{2, 3\}, \textcolor{red}{4} \}$$

... and neither is this one.



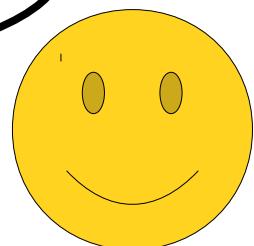
$$\emptyset \notin \{ 1, \{2, 3\}, 4 \}$$

Since none of the elements of this set are equal to  $\emptyset$ , we say that  $\emptyset$  isn't an element of  $\{1, \{2, 3\}, 4\}$ .

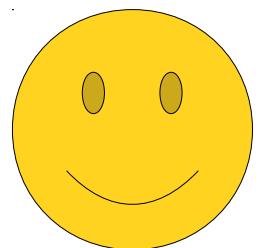


$$\emptyset \subseteq \{ 1, \{2, 3\}, 4 \}$$

Now, we could correctly say that the empty set is a subset of  $\{1, \{2, 3\}, 4\}$ , because it's a subset of every set. But, as you've seen before,  $\in$  and  $\subseteq$  represent different concepts, so that doesn't mean that  $\emptyset$  would be an element of this set.

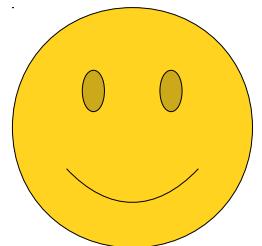


That previous exercise hopefully gets you thinking about  $\in$  and  $\subseteq$  as applied to the empty set.



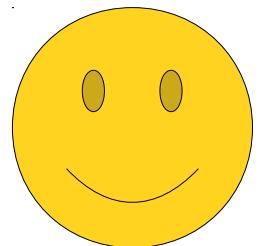
$$\emptyset \in \{ \emptyset, 137 \}^?$$

Let's take a look at the above statement.  
What exactly is going on here?



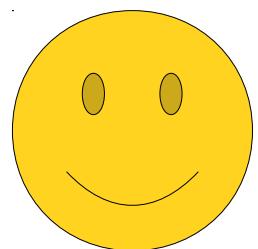
$$\emptyset \in \{ \emptyset, 137 \}$$

This set on the left is a set that contains two elements.



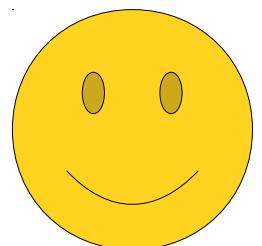
$$\emptyset \in \{ \emptyset, 137 \}$$

The first element is the empty set. You've seen examples of sets containing other sets before, and in this case this set just happens to contain  $\emptyset$ .



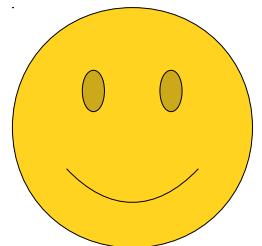
$$\emptyset \stackrel{?}{\in} \{ \emptyset, \textcolor{blue}{137} \}$$

The second element is 137, which is a nice and pretty number.



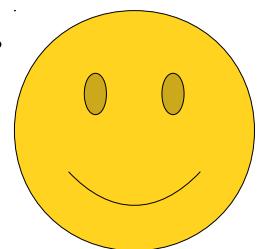
$$\emptyset \in \{ \emptyset, 137 \}^?$$

So is this statement true?



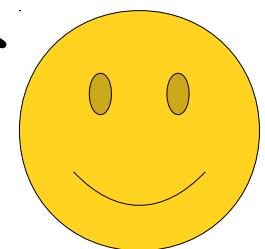
$$\emptyset \in \{ \emptyset, 137 \}^?$$

The answer is... well, first, make a quick guess!



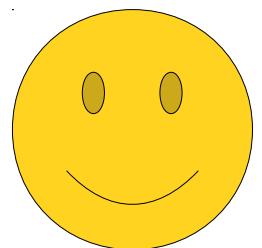
$$\emptyset \in \{ \emptyset, 137 \}$$

The answer is yes...



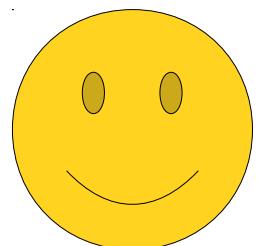
$$\emptyset \in \{ \emptyset, 137 \}$$

... because the empty set is right here inside our set on the right.

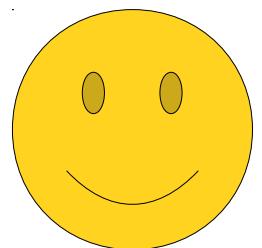


$$\emptyset \in \{ \emptyset, 137 \}$$

So this is an example of a set that contains the empty set. This is totally normal - it happens all the time.

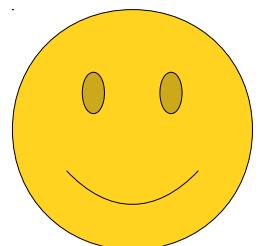


I've been talking for a while now, so  
let's do one final exercise and then  
call it a day.



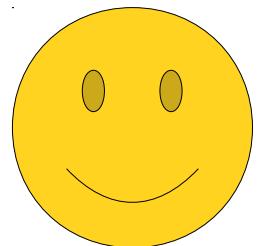
$$\{\emptyset, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

Take a minute to think about whether this statement is true or false.



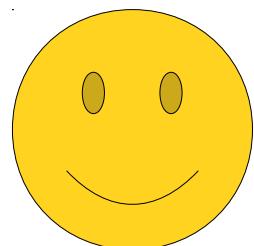
$$\{\emptyset, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

Got a guess? Great! Let's take a look at what the answer is.



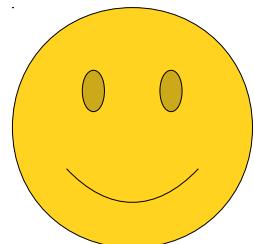
$$\{\emptyset, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

This is the set containing two elements,  
the empty set  $\emptyset$  and the number 4.



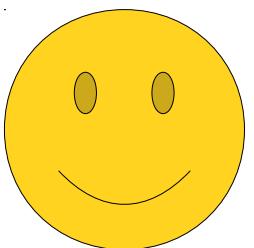
$$\{\emptyset, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

We're asking whether this set is a subset of the set  $\{1, \{2, 3\}, 4\}$ .



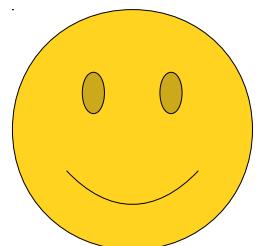
$$\{\emptyset, 4\} \subseteq \{ ? \ 1, \{2, 3\}, 4 \}$$

As you've seen before, this means that we need to check whether every element of the set on the left happens to be an element of the set on the right.



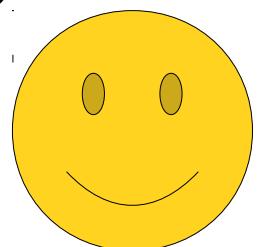
$$\{\emptyset, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

So let's start by asking whether the empty set is an element of  $\{1, \{2, 3\}, 4\}$ .



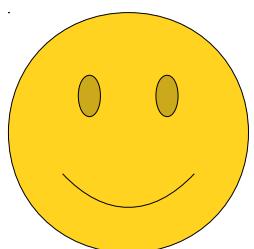
$$\{\emptyset, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

Something to notice here is that even though the “top-level” question asks about the  $\subseteq$  relation, right now we’re asking whether this particular thing (the empty set) is an element of another set, and that involves the  $\in$  relation.



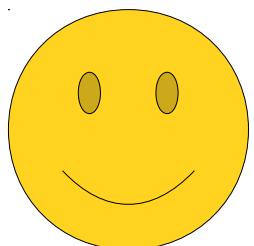
$$\{\cancel{\emptyset}, 4\} \subseteq \{ 1, \{2, 3\}, 4 \}$$

And, as we saw before, we know that the empty set is not an element of  $\{1, \{2, 3\}, 4\}$ , because none of the elements of that set are equal to  $\emptyset$ .



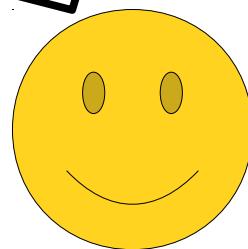
$$\{\emptyset, 4\} \not\subseteq \{1, \{2, 3\}, 4\}$$

As a result, we can say that the set on the left is not a subset of the set on the right, even though the above statement involves  $\emptyset$  and the  $\subseteq$  relation.



Hope this helps!

Please feel free to ask  
questions if you have them.



Did you find this useful? If so, let us know! We can go and make more guides like these.

