PROLOG 2025

ELTE, LOGIC DEPARTMENT

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Cut

Cut

Prolog works with backtracing which can lead to inefficiency, i.e. wasting time and memory on possibilities that lead nowhere.

We can control backtracking by the cut predicate: !/0

Cut is a goal that always succeeds, so  will always get through it.

```
p(X):- b(X), c(X), d(X), e(X).
```

vs

```
p(X):- b(X), c(X), !, d(X), e(X).
```

CUT

The cut only commits us to choices made since the parent goal was unified with the left-hand side of the clause containing the cut.

$\texttt{q:- p}_1\texttt{,..., p}_m\texttt{, !, r}_1\texttt{, ..., r}_n\texttt{.}$

when we reach the cut it commits us:

- to this particular clause of `q`
- to the choices made by $\texttt{p}_1\texttt{, ..., p}_m$
- NOT to choices made by $\texttt{r}_1\texttt{, ..., r}_n$

GREEN CUT

Let's consider the following `max/3` predicate:

```
max(X,Y,Y):- X =< Y.
max(X,Y,X):- X > Y.
```

Green cut

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```
?- max(2,3,3)
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max(X,Y,Y):- X =< Y.
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```
?- max(2,3,3)
yes

?- max(7,3,7)
```

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```

```
?- max(2,3,3)
yes

?- max(7,3,7)
yes
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max(X,Y,Y):- X =< Y.
max(X,Y,X):- X > Y.
```

```
?- max(2,3,3)
yes

?- max(7,3,7)
yes
```

```
?- max(2,3,2)
```

GREEN CUT

Let's consider the following `max/3` predicate:

```
max(X,Y,Y):- X =< Y.
max(X,Y,X):- X > Y.
```

```
?- max(2,3,3)
yes

?- max(7,3,7)
yes
```

```
?- max(2,3,2)
no

?- max(2,3,5)
```

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max(X,Y,Y):- X =< Y.
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```
?- max(2,3,3)
yes

?- max(7,3,7)
yes
```

```
?- max(2,3,2)
no

?- max(2,3,5)
no
```

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Let's consider the following `max/3` predicate:

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max(X,Y,Y) :- X =< Y.
max(X,Y,X) :- X > Y.
```

```
?- max(2,3,3)
yes

?- max(7,3,7)
yes
```

```
?- max(2,3,2)
no

?- max(2,3,5)
no
```

```
?- max(2,3,Y)
```

GREEN CUT

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```
max(X,Y,Y):- X =< Y.
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```

```
?- max(2,3,3)
yes

?- max(7,3,7)
yes
```

```
?- max(2,3,2)
no

?- max(2,3,5)
no
```

```
?- max(2,3,Y)
Y = 3

?- max(7,3,_)
```

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Let's consider the following `max/3` predicate:

```
max(X,Y,Y):- X =< Y.
max(X,Y,X):- X > Y.
```

`?- max(2,3,3)`
`yes`
 	
`?- max(7,3,7)`
`yes`
	`?- max(2,3,2)`
	`no`
	
	`?- max(2,3,5)`
	`no`
		`?- max(2,3,Y)`
		`Y = 3`
		
		`?- max(7,3,_)`
		`true`

GREEN CUT

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```
max(X,Y,Y):- X =< Y.
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?- max(2,3,3)
yes

?- max(7,3,7)
yes
```

```
?- max(2,3,2)
no

?- max(2,3,5)
no
```

```
?- max(2,3,Y)
Y = 3

?- max(7,3,_)
true
```

After `?- max(2,3,Y)` if asked for more solutions, polog will try to satisfy the second clause, which is completely useless – since we know the two clauses are exclusive (hence, it returns with `false`).

Green cut

We can fix this by adding a cut to the rule:

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X):- X > Y.
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Green cut

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max(X,Y,Y):- X =< Y, !.
max(X,Y,X):- X > Y.
```

Now

- If the `X =< Y` succeeds, the cut commits us to this choice, and the second clause of `max/3` is not considered.
- If the `X =< Y` fails, Prolog goes on to the second clause.

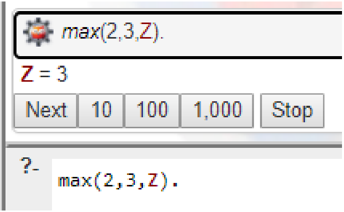
Without cut

```
max(X,Y,Y):- X =< Y.
max(X,Y,X):- X > Y.
```

With cut

WITHOUT CUT

```
max(X,Y,Y):- X =< Y.
max(X,Y,X):- X > Y.
```



WITH CUT

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max(X,Y,X):- X > Y.
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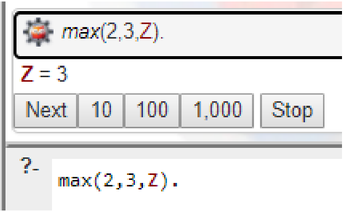

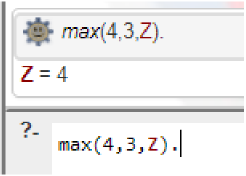

With cut

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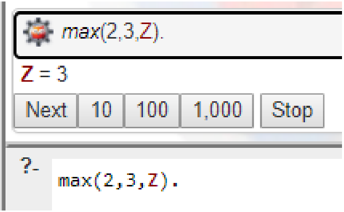

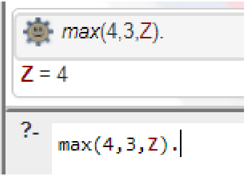

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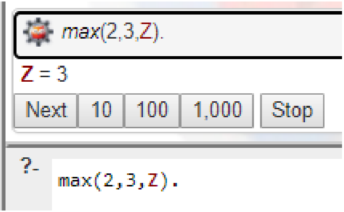

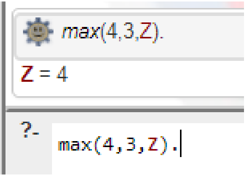

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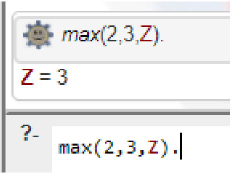

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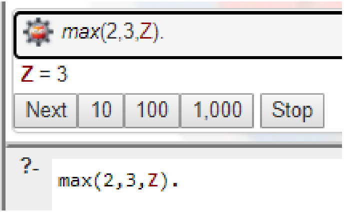

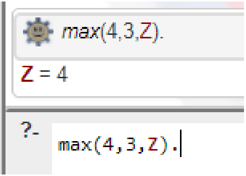

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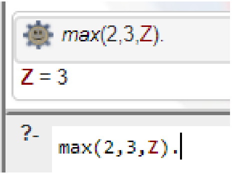

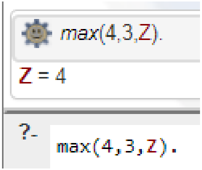

Green cut, red cut

Green cut: cuts that do not change the meaning of a predicate.
E.g. `max/3` – the new code gives exactly the same answers as the old version, but it is more efficient.

Green cut, red cut

GREEN CUT: cuts that do not change the meaning of a predicate.
E.g. `max/3` – the new code gives exactly the same answers as the old version, but it is more efficient.

To see how red cuts work, let's modify our `max/3`:

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X):- X > Y.
```

The second clause is basically redundant. Let's remove it!

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

Now what?

Red cut

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

Red cut

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
```

RED CUT

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
X = 3
```

RED CUT

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
X = 3
```

```
?- max(4,3,X)
```

RED CUT

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
X = 3
```

```
?- max(4,3,X)
X = 4
```

Red cut

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
X = 3
```

```
?- max(4,3,X)
X = 4
```

```
?- max(2,3,2)
```

Red cut

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
X = 3
```

```
?- max(4,3,X)
X = 4
```

```
?- max(2,3,2)
true
```

Red cut

```
max(X,Y,Y) :- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,X)
X = 3
```

```
?- max(4,3,X)
X = 4
```

```
?- max(2,3,2)
true
```

Now  will be able to answer alternative questions/queries, but not yes-no ones.

Because of the form of the query, it will go directly to the second clause, and only check `max(X,Y,X).`, which is obviously true – syntactically.

Red cut

```
max(X,Y,Y):- X =< Y, !.
max(X,Y,X).
```

```
?- max(2,3,2)
true
```

...however, we can patch it with a unification after the cut:

```
max(X,Y,Z):- X =< Y, !, Y=Z.
max(X,Y,X).
```

Red cut

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```

Mind the `Z` in the head of the rule! This `(X,Y,Z)` tempts  to try to substitute in the first clause, since `(X,Y,Z)` under appropriate circumstances can unify with `(X,Y,X)`!

Red cut

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After `X =< Y` (2 =< 3) succeeds, we ask if 3=2, which will be false.

RED CUT

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Because of the `!` cannot go back and try another setup for substitution (`max(X,Y,X)`), it will be stuck with what was given before the `!`.

RED CUT

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After `X =< Y` (2 =< 3) succeeds, we ask if 3=2, which will be false.

Because of the `!`  cannot go back and try another setup for substitution (`max(X,Y,X)`), it will be stuck with what was given before the `!`.

However, if we ask `max(4,3,X)`, it will be able to go to the second clause after failing with the first, since if fails already before the `!`, at `X =< Y`.

RED CUT

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RED CUT: a cut that changes the meaning of the predicate. If we remove it, we do not get an equivalent program. Using red cut the resulting program

- will not be fully declarative (we interfere with the control flow)
- can be harder to read
- might be prone to subtle programming mistakes

Negation as Failure

Combining `!, fail.` we can express negation:

NEGATION AS FAILURE

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burger(X):- bigMac(X).
burger(X):- bigKahunaBurger(X).
burger(X):- whopper(X).
```

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bigMac(a).
bigKahunaBurger(b).
bigMac(c).
whopper(d).
```

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bigMac(a).
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bigMac(c).
whopper(d).

enjoys(vincent,X):- bigKahunaBurger(X),!, fail.
enjoys(vincent,X):- burger(X).
```

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enjoys(vincent,X):- bigKahunaBurger(X),!, fail.
enjoys(vincent,X):- burger(X).

?- enjoys(vincent,a).
```

Negation as Failure

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bigKahunaBurger(b).
bigMac(c).
whopper(d).

enjoys(vincent,X):- bigKahunaBurger(X),!, fail.
enjoys(vincent,X):- burger(X).

?- enjoys(vincent,a).
true
```

Negation as Failure

Combining `!, fail.` we can express negation:

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bigMac(a).
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bigMac(c).
whopper(d).

enjoys(vincent,X):- bigKahunaBurger(X),!, fail.
enjoys(vincent,X):- burger(X).

?- enjoys(vincent,a).
true
```

`a` gets substituted in `bugKahunaBurger(X)` where it will fail and go for the second clause. Among `burger`s `bigMac` is the first, so it succeeds, the query will be true.

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burger(X):- whopper(X).

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bigMac(c).
whopper(d).

enjoys(vincent,X):- bigKahunaBurger(X),!, fail.
enjoys(vincent,X):- burger(X).

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```

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enjoys(vincent,X):- burger(X).

?- enjoys(vincent,b).
false
```

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bigKahunaBurger(b).
bigMac(c).
whopper(d).

enjoys(vincent,X):- bigKahunaBurger(X),!, fail.
enjoys(vincent,X):- burger(X).

?- enjoys(vincent,b).
false
```

Prolog tries to substitute `b` in `bigKahunaBurger(X)` in the first clause. It will succeed, since `bigKahunaBurger(b).`, so it goes on, through `!` all the way to `fail`. Because of the `!`  cannot go back and look for other possible substitutions for `b`...

Negation as Failure

The cut-fail combination offers us some form of negation.

It is called negation as failure, and defined as follows:

```
neg(Goal):- Goal, !, fail.
neg(Goal).
```

If Goal succeeds, make the clause fail, otherwise let it go on.

Since negation as failure is frequently used in , there is a built-in predicate for it: `\+`

Negation as Failure

3 equivalent expressions of the fact that `vincent enjoys` all sorts of `burger`s except for `bigKahunaBurger`:

```
enjoys(vincent,X):- bigKahunaBurger(X), !, fail.
enjoys(vincent,X):- burger(X).

enjoys(vincent,X):- burger(X), neg(bigKahunaBurger(X)).

enjoys(vincent,X):- burger(X), \+bigKahunaBurger(X).
```

Negation as failure is not a logical negation.

After the `!` we cannot go back, the program will fail.

This is why we need to have `burger(X)` before `\+`. We need to allow 🦉 to freely select, substitute from our set of `burger`s first.

A trick with `fail`

A TRICK WITH `FAIL`

Let's say we want not only to give us a suggestion about what `burger`s `vincent` would like, but we want to be able to have a full list of these `burger`s!

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enjoys(vincent,X):- burger(X), \+bigKahunaBurger(X).

whattobuyto(Y):- enjoys(Y,X), write(X), nl, fail; true.
```

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enjoys(vincent,X):- burger(X), \+bigKahunaBurger(X).

whattobuyto(Y):- enjoys(Y,X), write(X), nl, fail; true.
```

Until there are `burger`s that have never been tested, `fail` will make going back to `burger`s – since backtracks locally. At the point where all the `burger`s inthe KB have been checked, will go back to the main rule (`whattobuyto`) to see if there are any other ways to save the day,