Resugaring: Lifting Evaluation Sequences through Syntactic Sugar

Justin Pombrio,
Shriram Krishnamurthi
Brown University

Syntactic Sugar

Syntactic Sugar

```
x + 2
```


```
x.__add__(2)
```

Syntactic Sugar

```
x + 2
```


```
x.__add__(2)
```

```
[x*x | x <- lst]
```


```
map (\x -> x*x) lst
```

Syntactic Sugar

```
x + 2
```


```
x.__add__(2)
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```
[x*x | x <- lst]
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```
map (\x -> x*x) lst
```

```
x or y
```


```
let t = x in
  if t then t else y
```

Surface language
(what you write)

Syntactic Sugar

```
x + 2
```


```
x.__add__(2)
```

```
[x*x | x <- lst]
```


```
map (\x -> x*x) lst
```

```
x or y
```


```
let t = x in
  if t then t else y
```

Syntactic Sugar

Surface language (what you write)

Core language (what runs)

```
x + 2
```

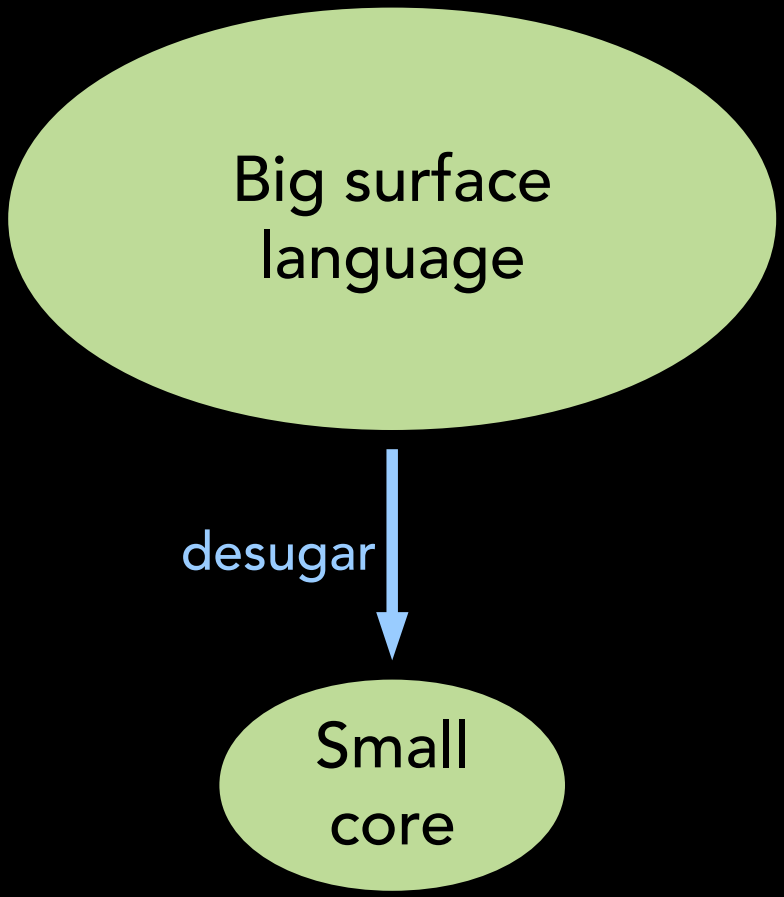

```
x.__add__(2)
```

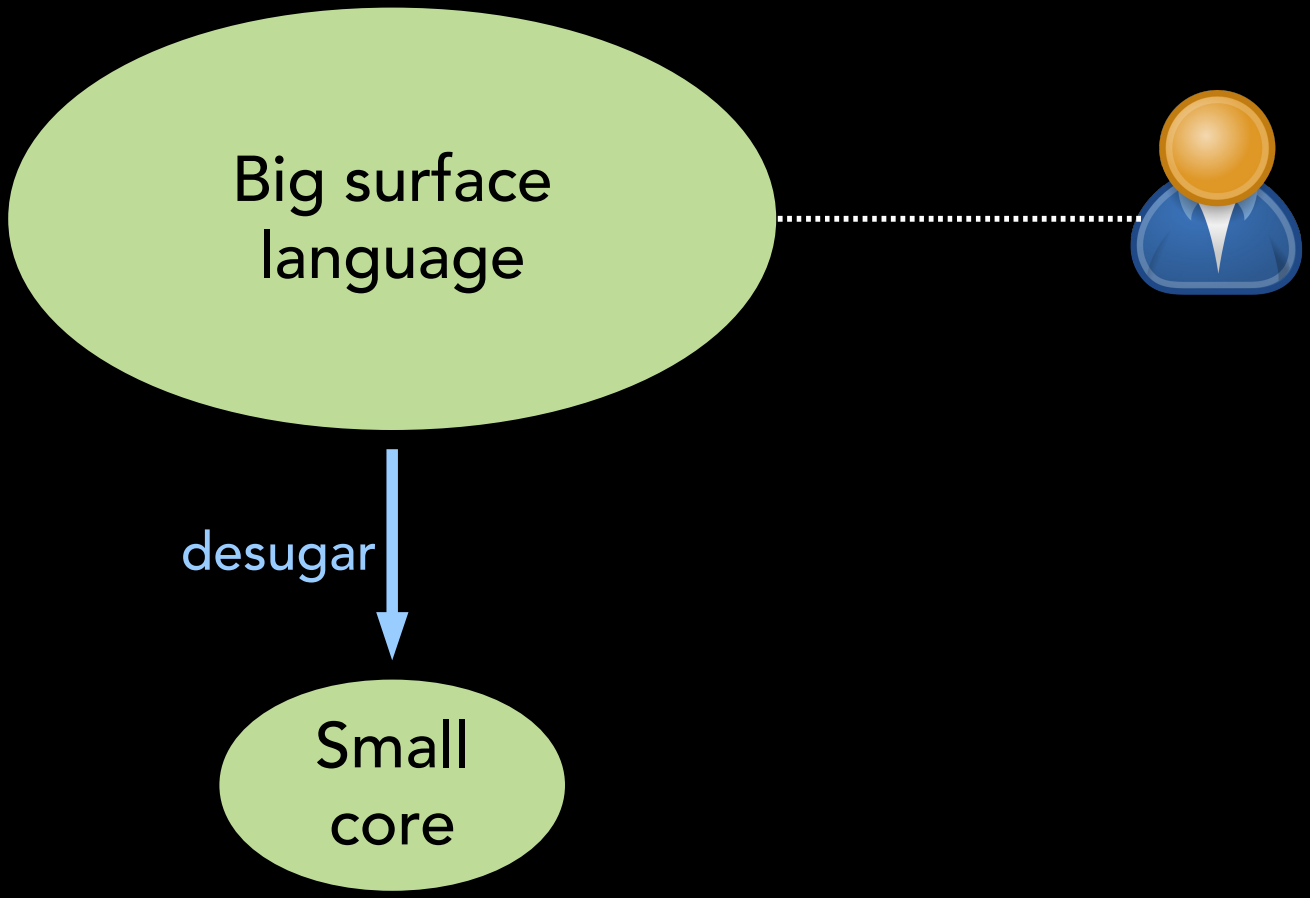
```
[x*x | x <- lst]
```

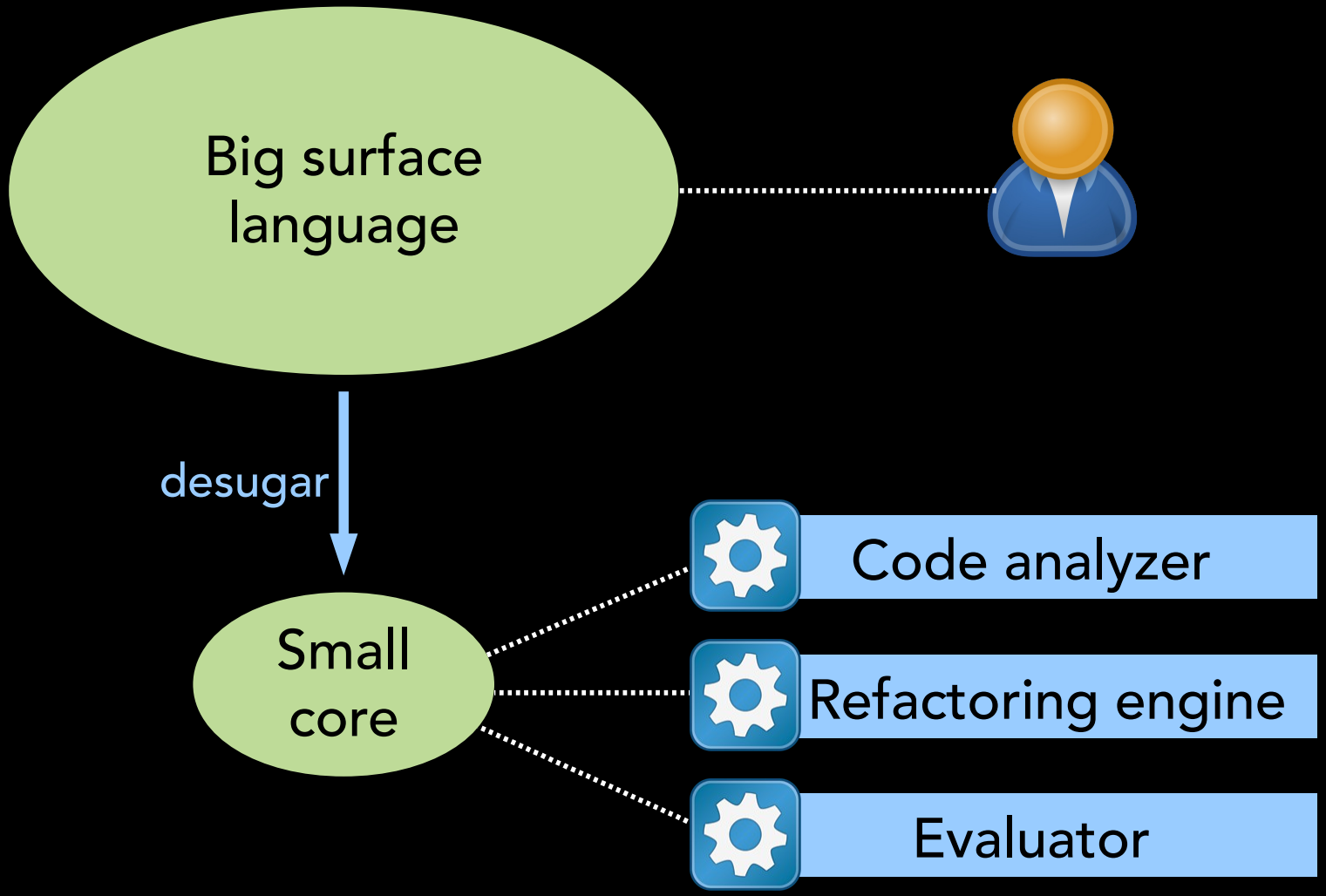

```
map (\x -> x*x) lst
```

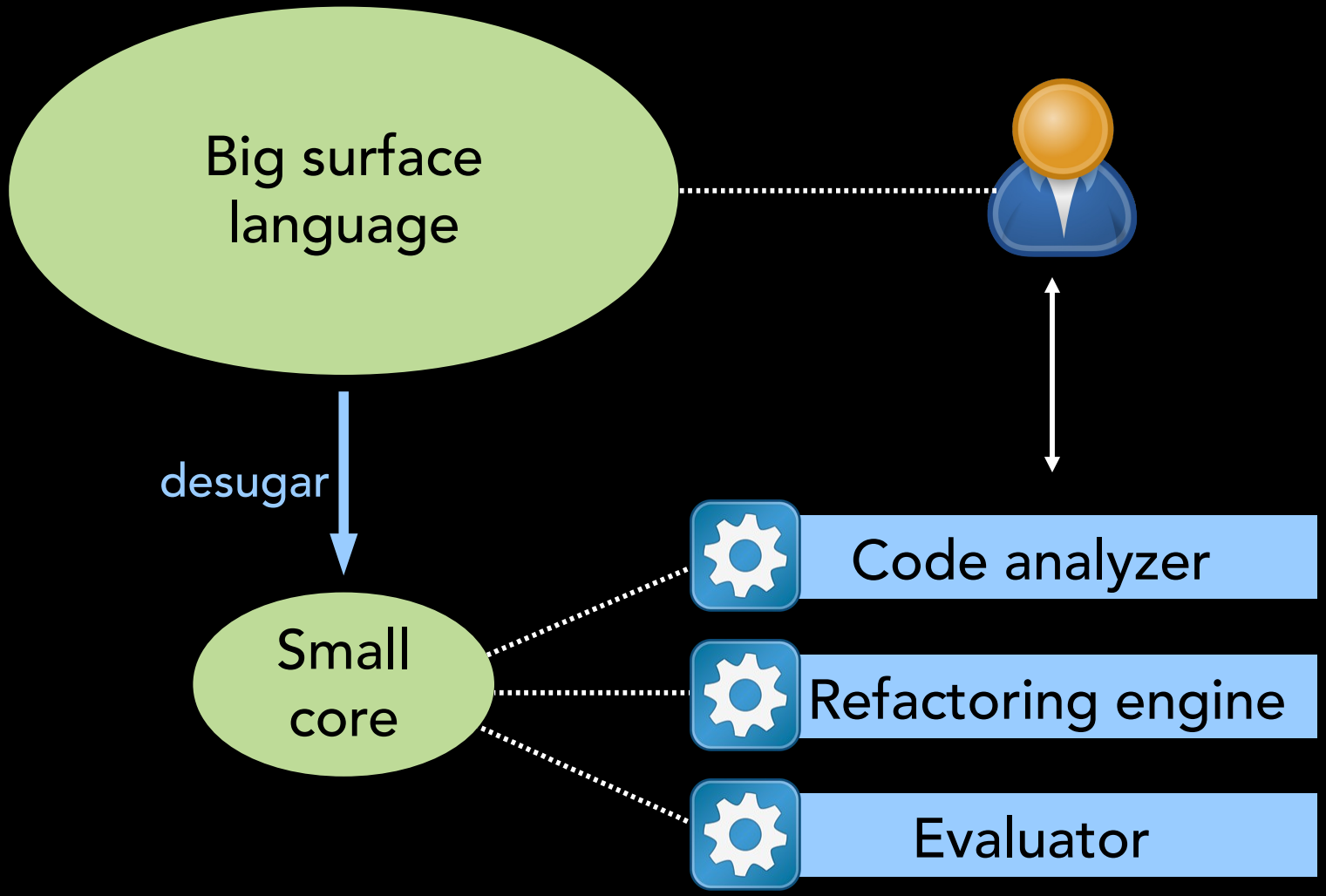
```
x or y
```


```
let t = x in
  if t then t else y
```


Big surface
language
desugar
Small
core


Big surface
language
desugar
Small
core


Big surface language
desugar
Small core
Code analyzer
Refactoring engine
Evaluator


Big surface language
desugar
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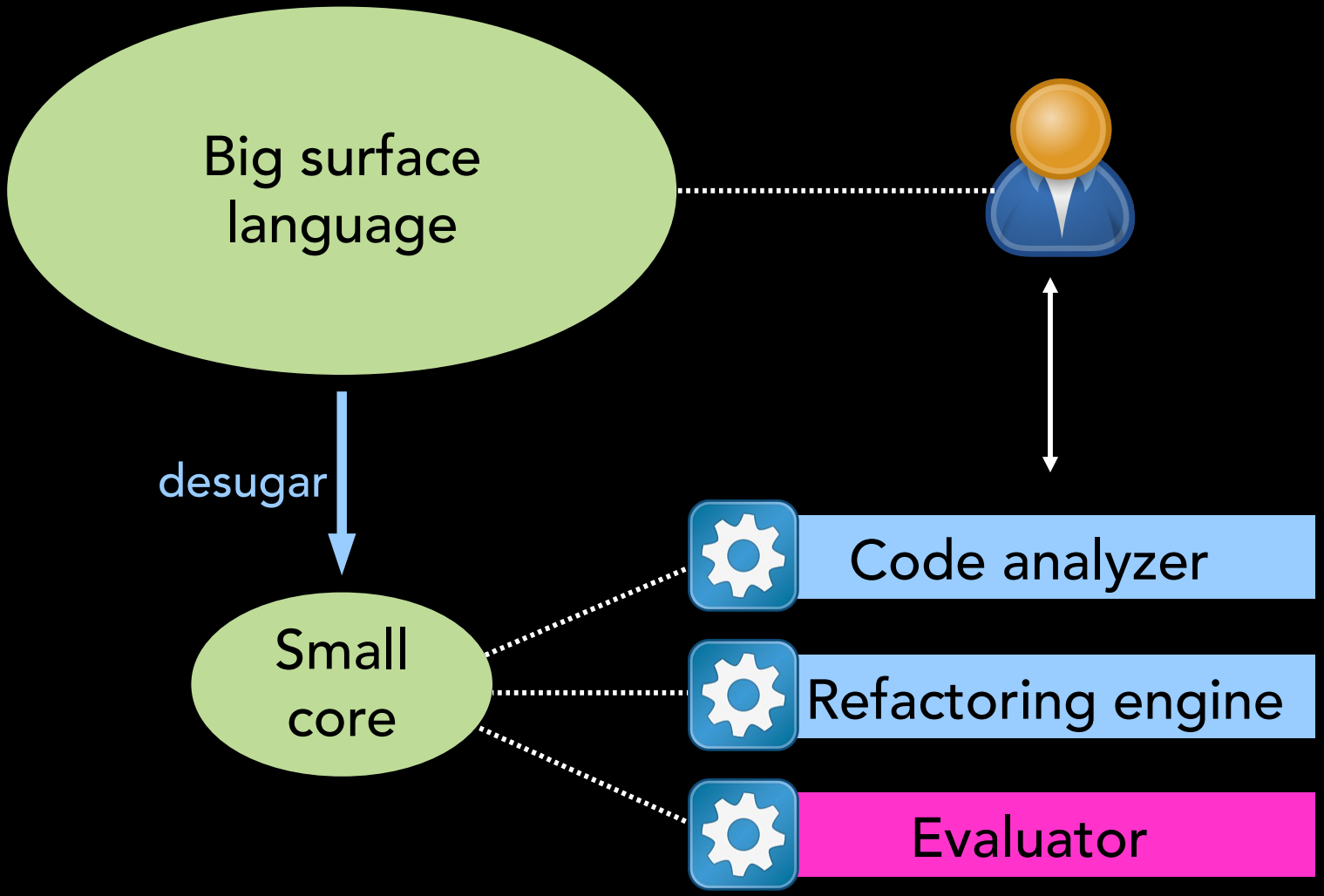

Big surface language
desugar
Small core
Code analyzer
Refactoring engine
Evaluator

Surface

```
not(true) or true
```

Core

Surface

```
not(true) or true
```

Core

```
let t = not(true) in
  if t then t else true
```

Surface

```
not(true) or true
```

desugar

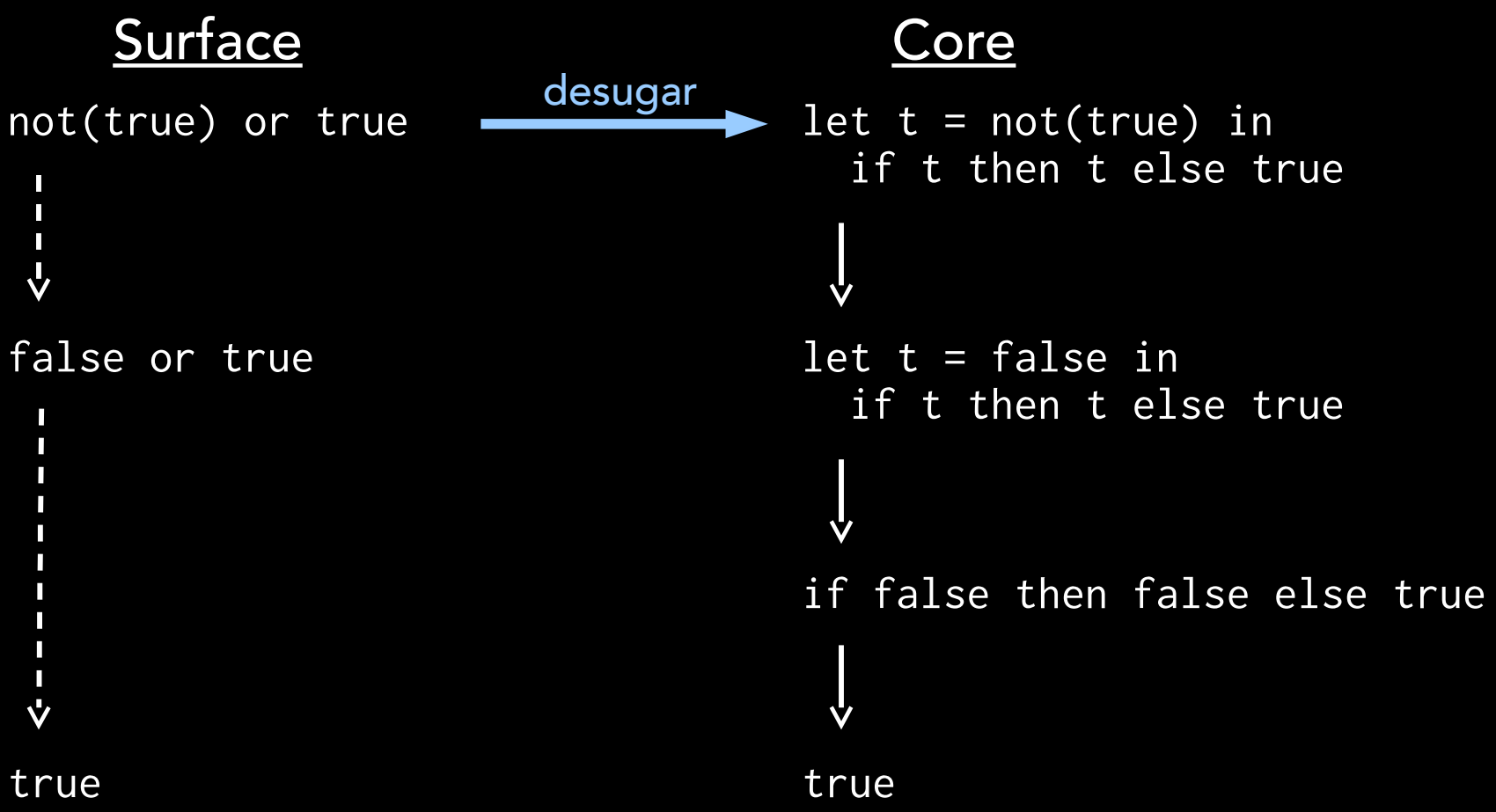
Core

```
let t = not(true) in
  if t then t else true
```

```
let t = false in
  if t then t else true
```

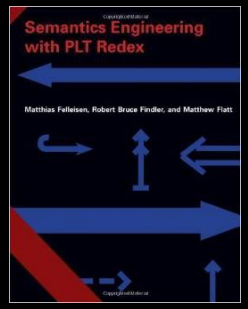
```
if false then false else true
```

```
true
```

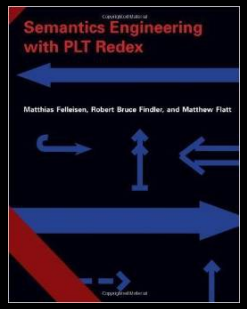

Surface
Core
desugar
not(true) or true
false or true
true
let t = not(true) in
if t then t else true
let t = false in
if t then t else true
if false then false else true
true

Confection

core eval seq → surface eval seq




```
(Let
 M
 (Automaton
  init
  (init : ("c" -> more))
  (more
   :
   ("a" -> more)
   ("d" -> more)
   ("r" -> end))
  (end : "accept"))
 (apply M "cadr"))
```




```
(Let
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  (init : ("c" -> more))
  (more
   :
   ("a" -> more)
   ("d" -> more)
   ("r" -> end))
  (end : "accept"))
 (apply M "cadr"))
```
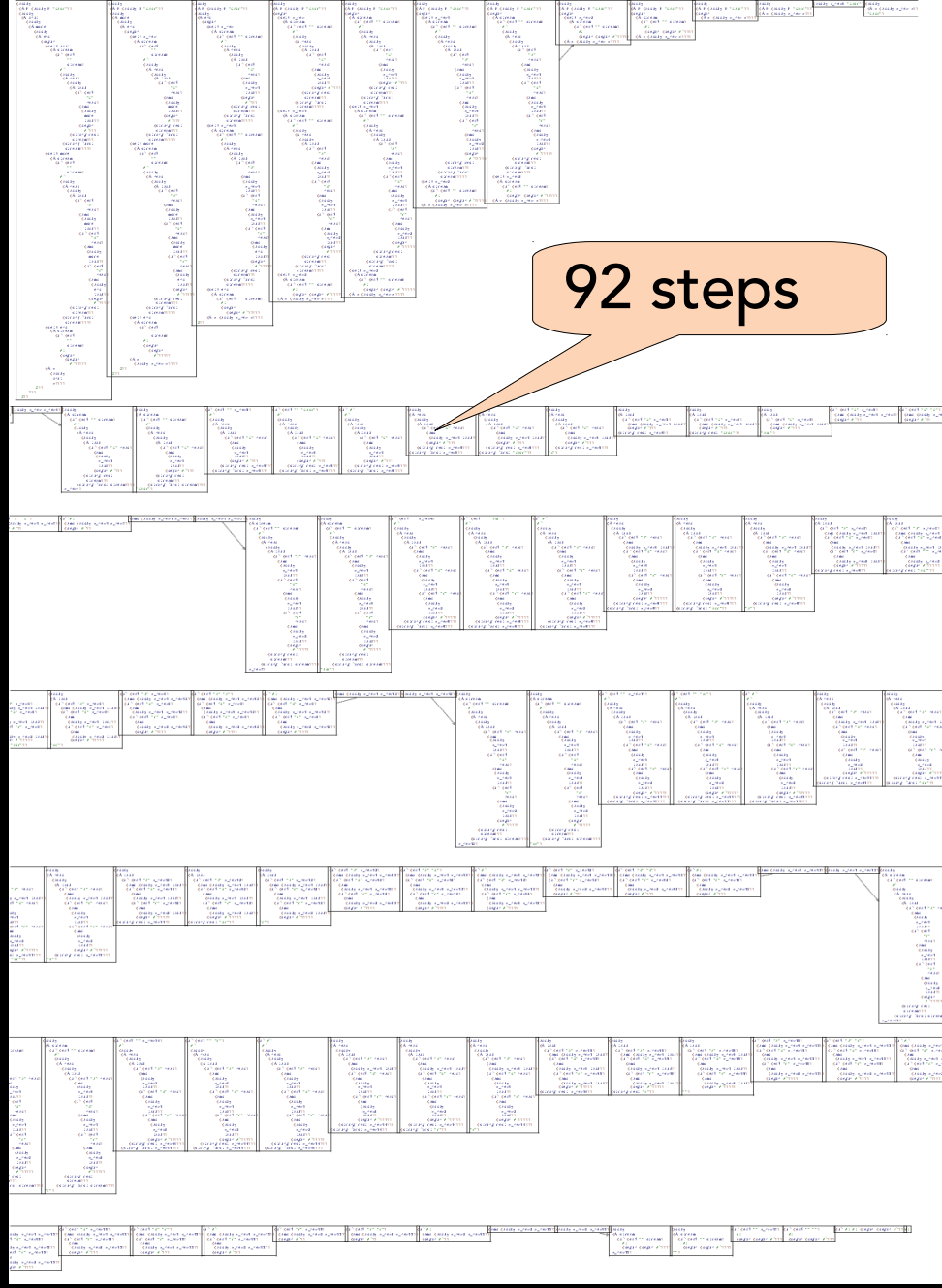
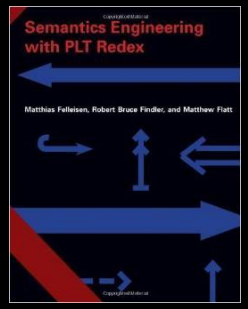






```
(Let
 M
 (Automaton
  init
  (init : ("c" -> more))
  (more
   :
   ("a" -> more)
   ("d" -> more)
   ("r" -> end))
  (end : "accept"))
 (apply M "cadr"))
```

7 steps

(apply M "cadr")

(apply init "cadr")

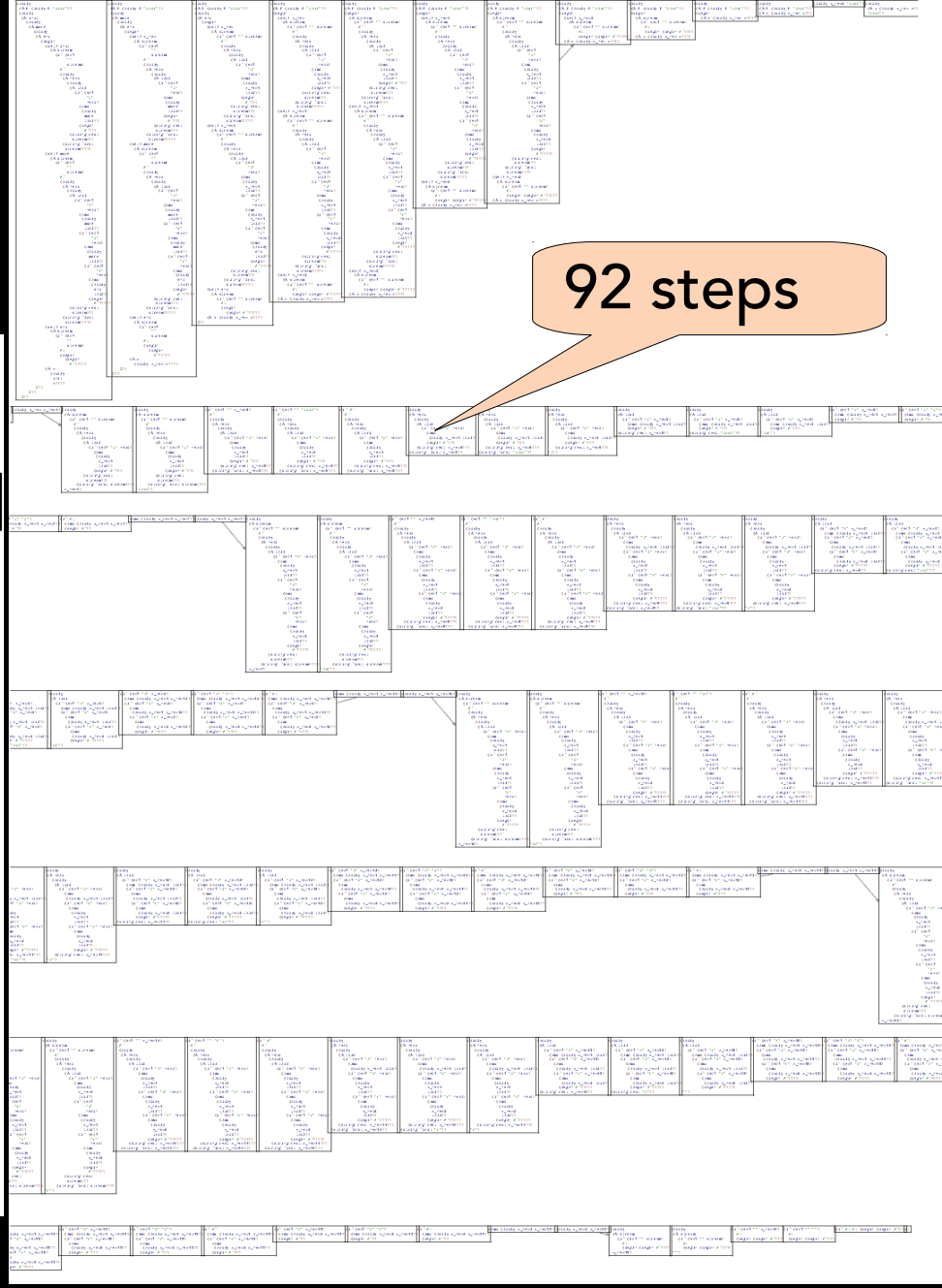
(apply more "adr")

(apply more "dr")

(apply more "r")

(apply end "")

#t



Surface

```
not(true) or true
```

Core

Surface	Core

```
not(true) or true
```

```
false or true
```

```
true
```

Surface

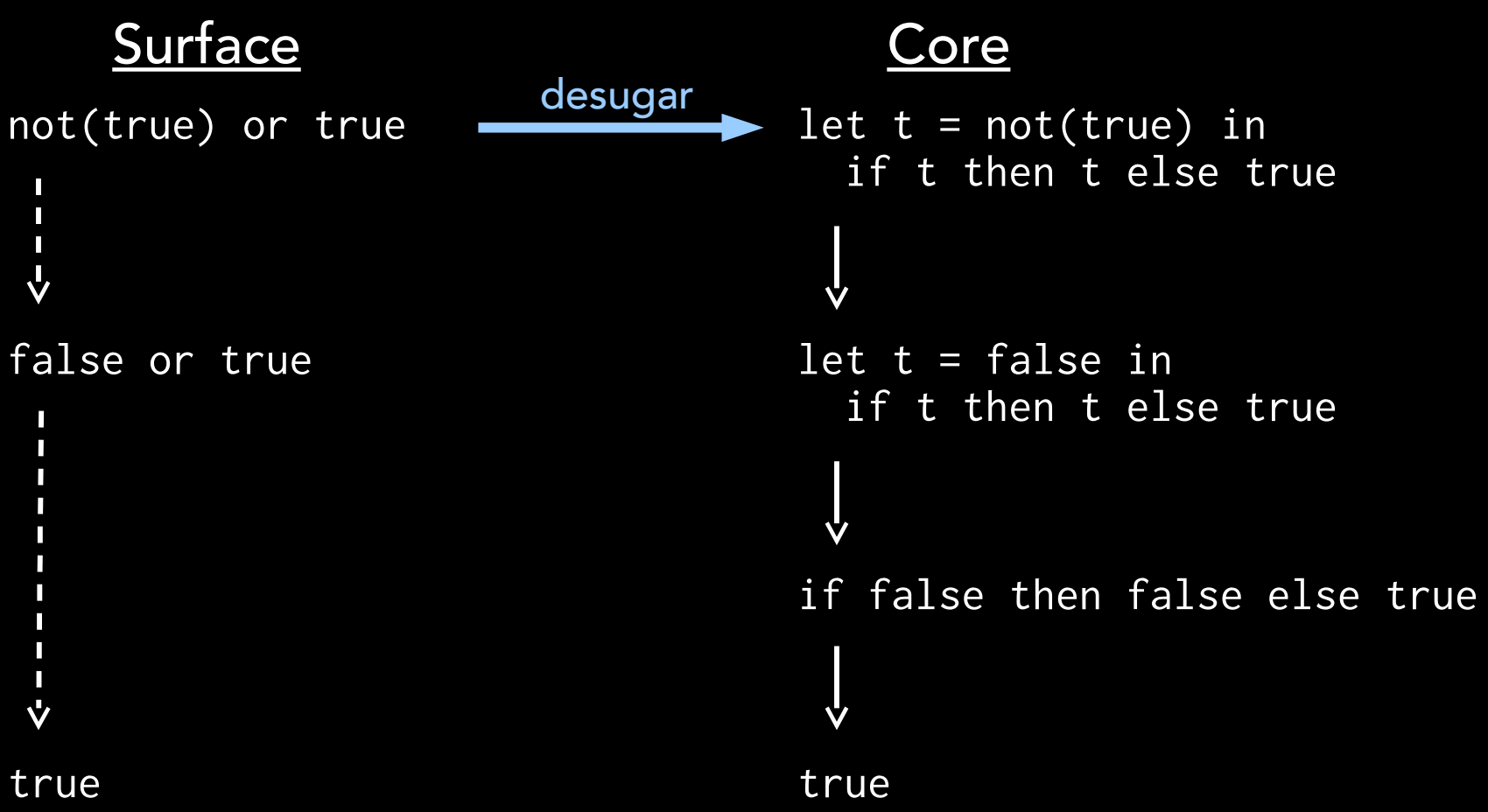
```
not(true) or true
```

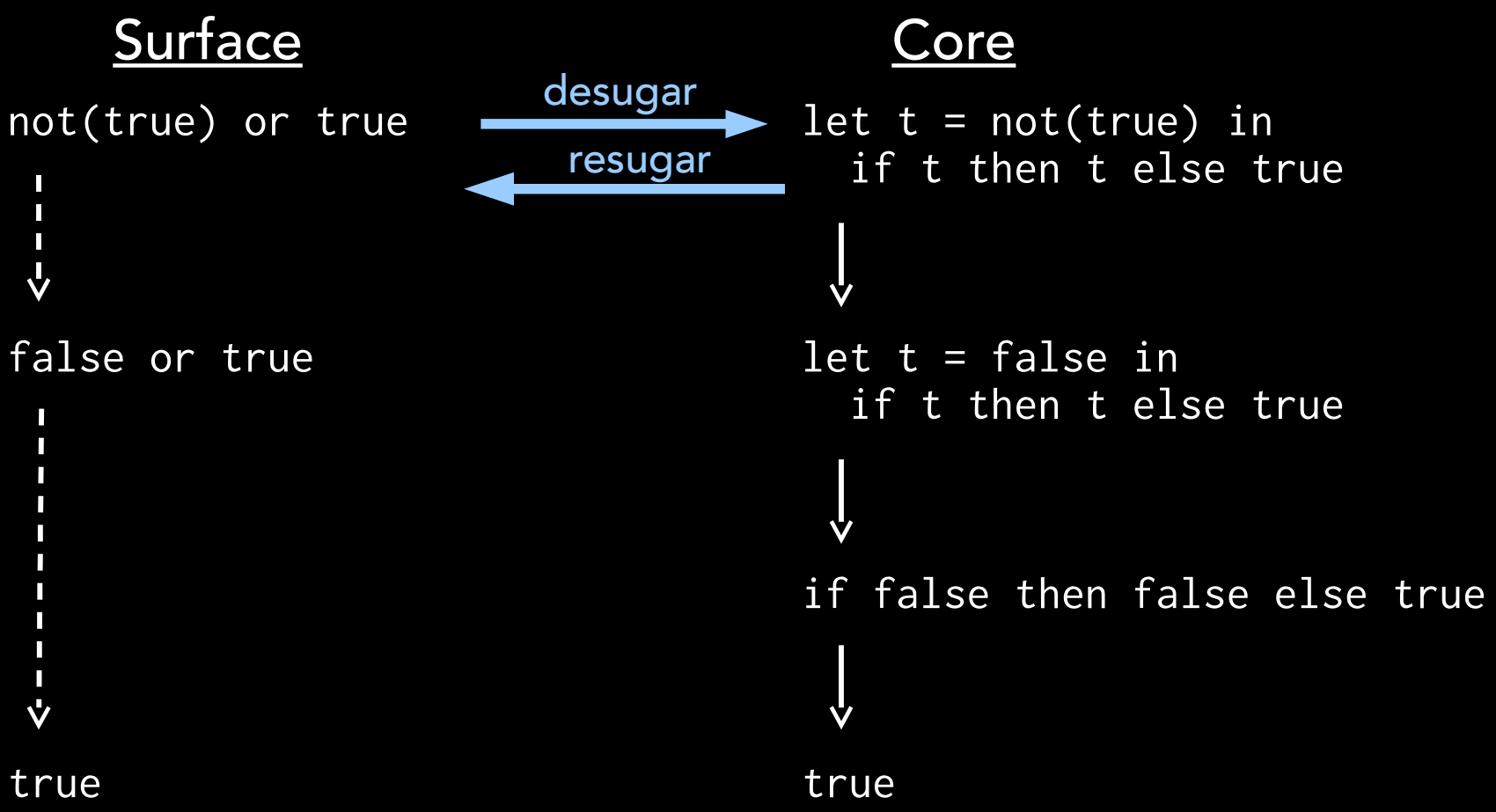
```
false or true
```

```
true
```

Core

```
let t = not(true) in
  if t then t else true
```


Surface
Core
desugar
not(true) or true
let t = not(true) in
if t then t else true
false or true
let t = false in
if t then t else true
if false then false else true
true
true


Surface
Core
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not(true) or true
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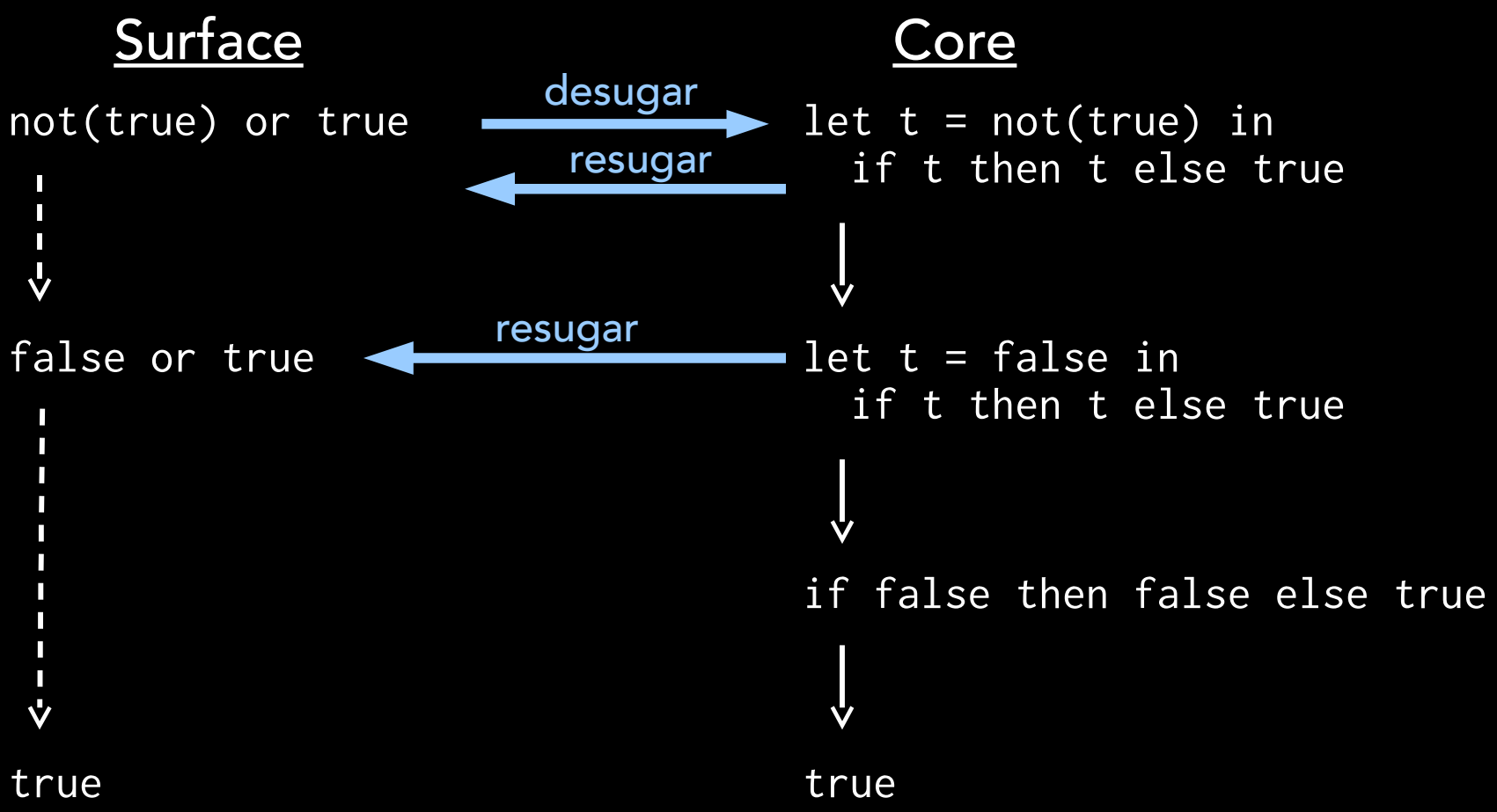
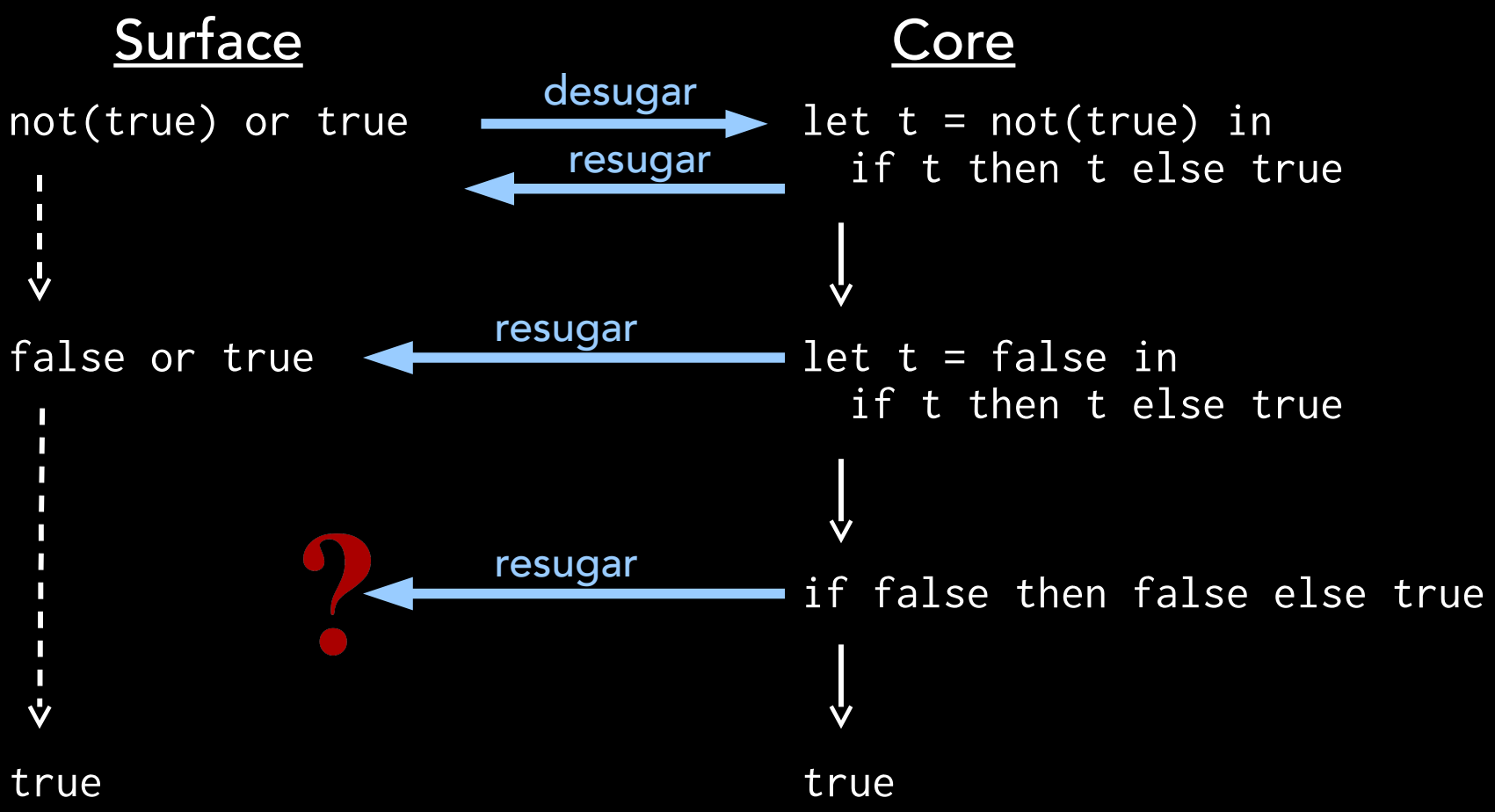
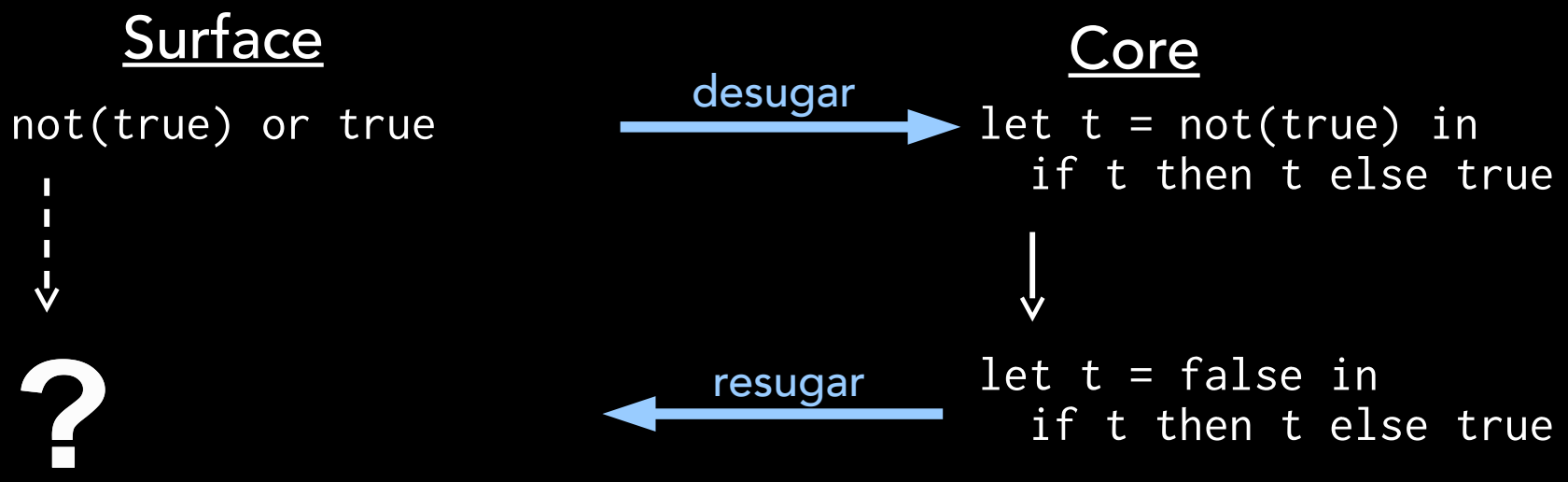
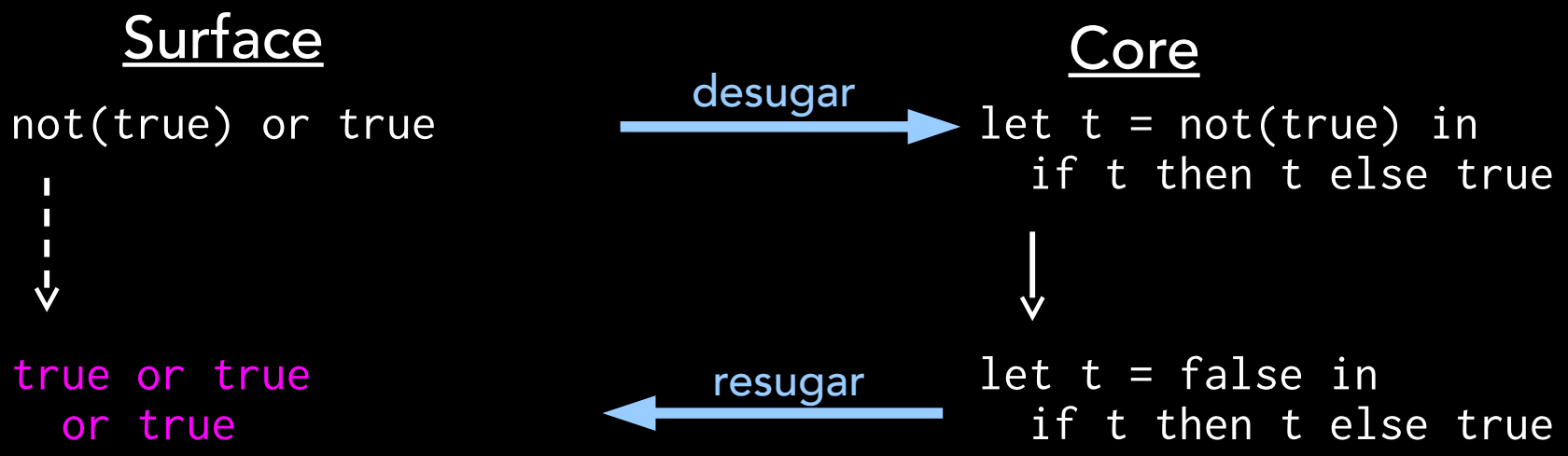
if t then t else true
false or true
let t = false in
if t then t else true
if false then false else true
true
true


Surface
Core
desugar
resugar
not(true) or true
let t = not(true) in
if t then t else true
resugar
false or true
let t = false in
if t then t else true
if false then false else true
true
true


Surface
Core
desugar
resugar
not(true) or true
let t = not(true) in
if t then t else true
resugar
false or true
let t = false in
if t then t else true
resugar
?
if false then false else true
true
true

THREE KEY PROPERTIES OF RESUGARING


Surface
Core
desugar
not(true) or true
let t = not(true) in
if t then t else true
?
resugar
let t = false in
if t then t else true


Surface
Core
desugar
not(true) or true
let t = not(true) in
if t then t else true
true or true
or true
resugar
let t = false in
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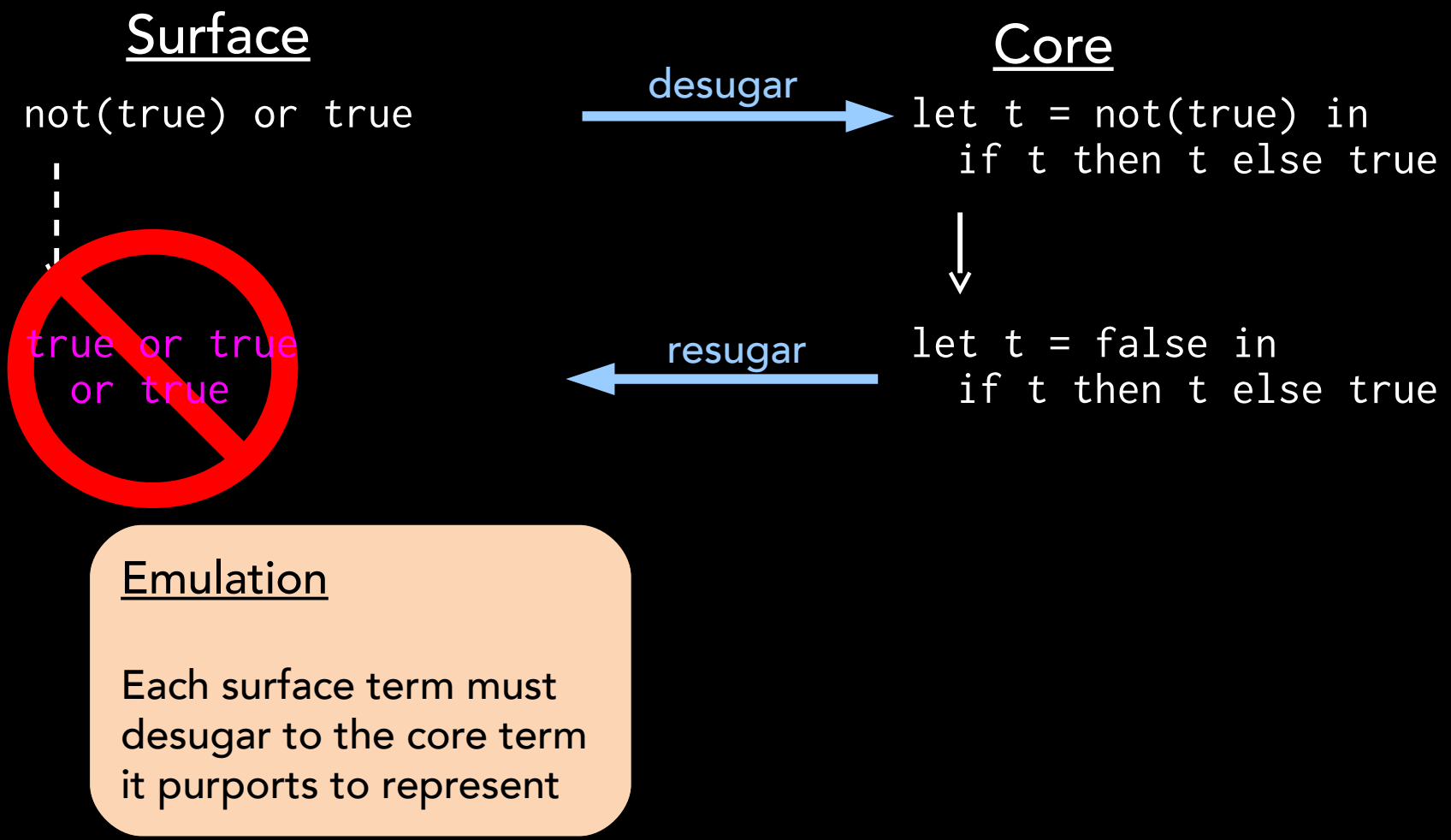
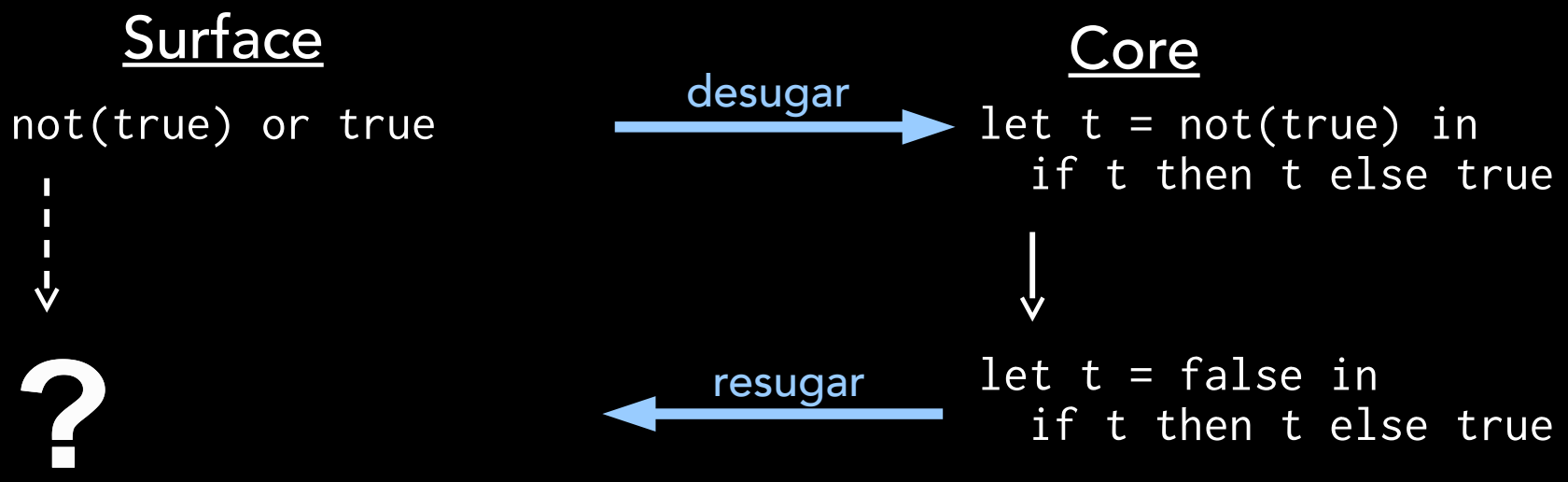
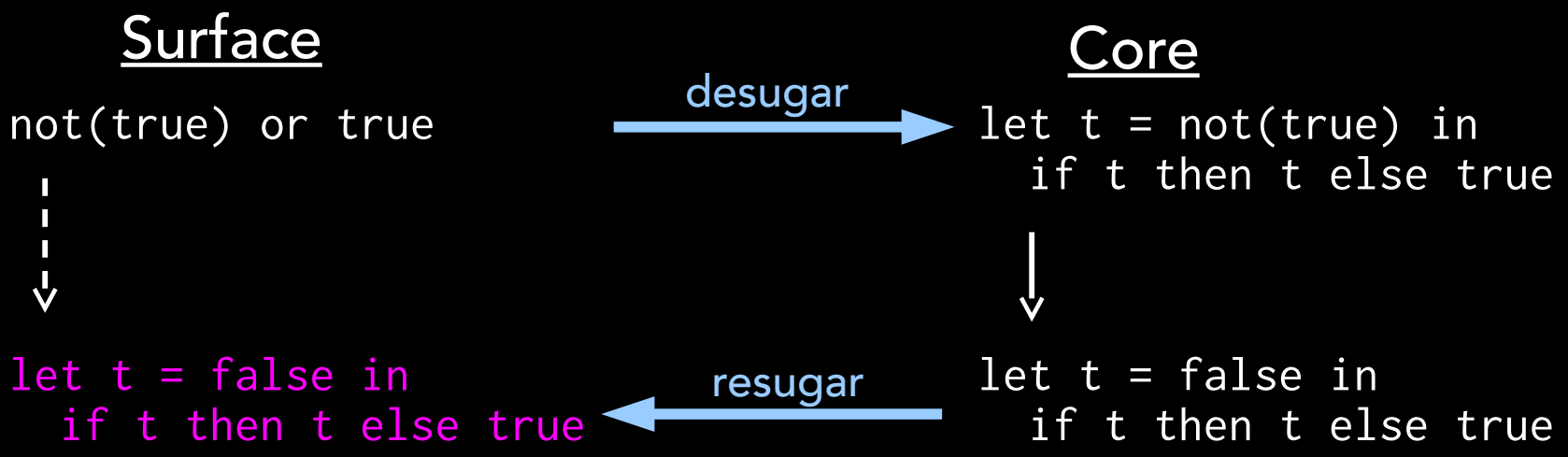
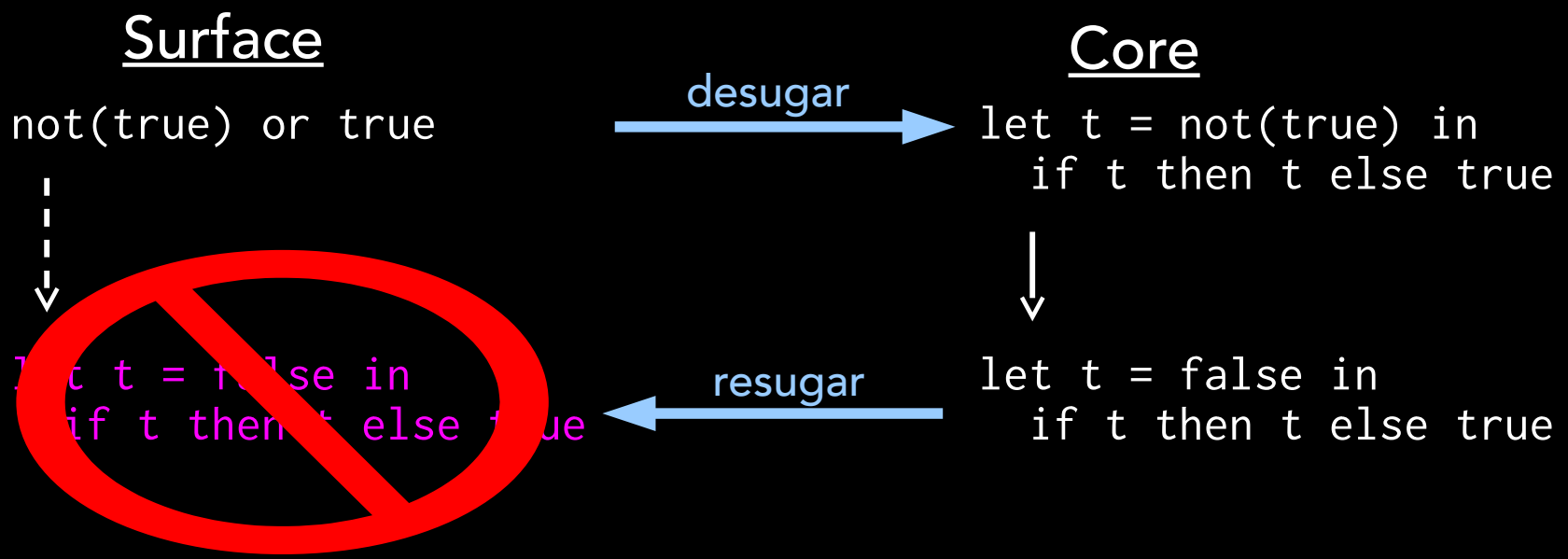


Emulation

Each surface term must desugar to the core term it purports to represent

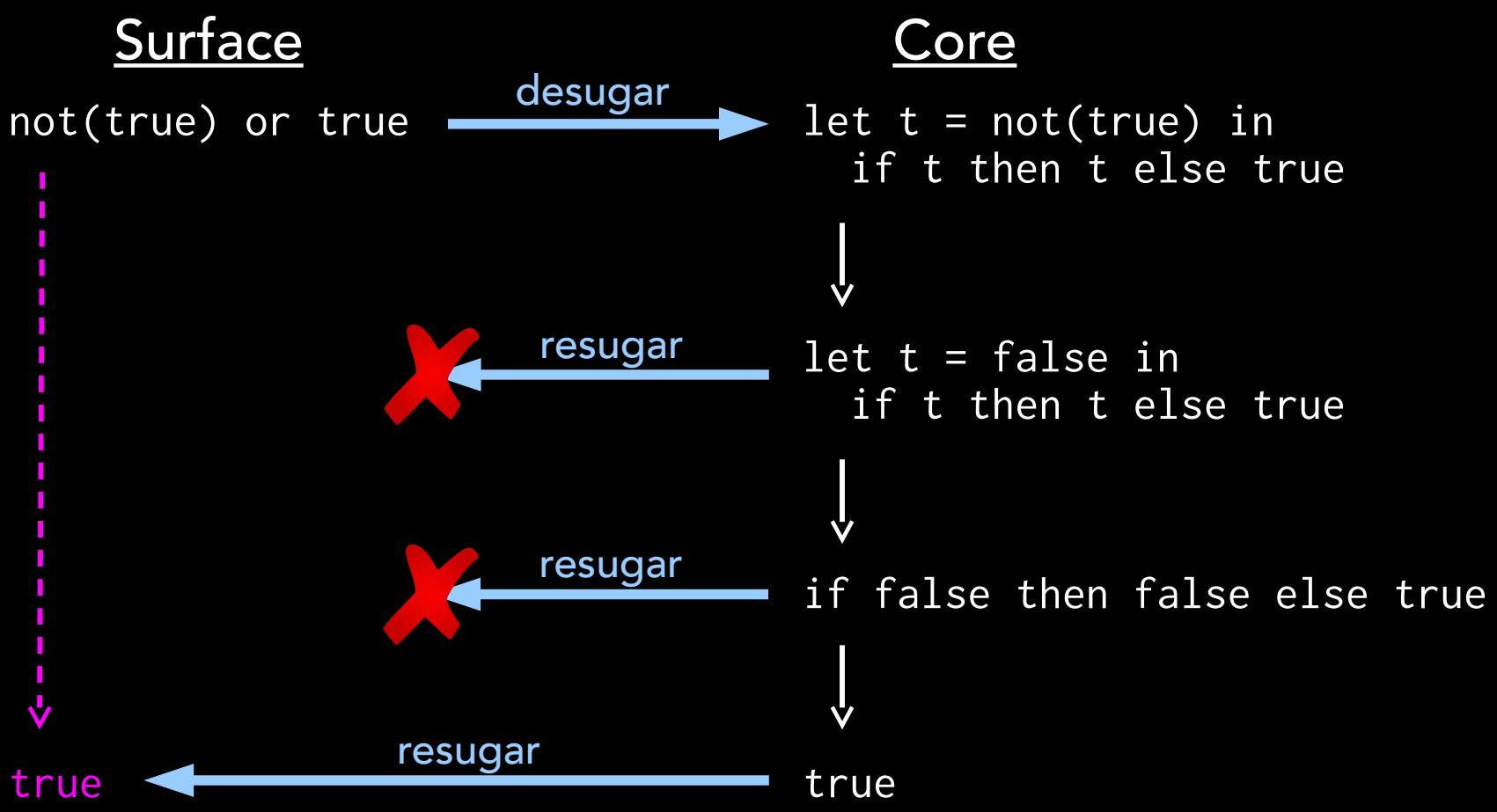

Surface
Core
desugar
not(true) or true
let t = not(true) in
if t then t else true
?
resugar
let t = false in
if t then t else true

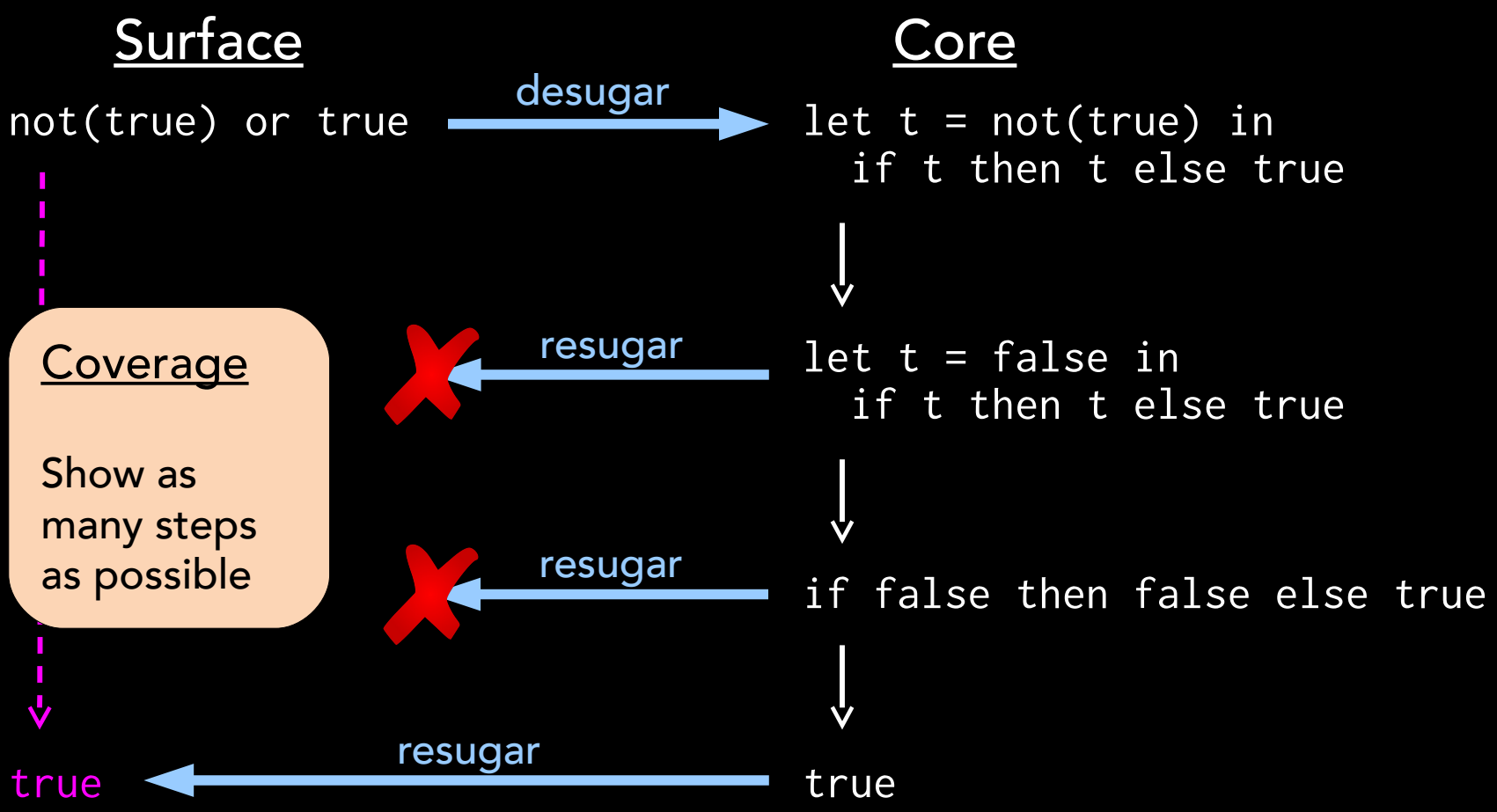

Surface
Core
desugar
not(true) or true
let t = not(true) in
if t then t else true
let t = false in
if t then t else true
resugar
let t = false in
if t then t else true



Abstraction

Show things in terms of a sugar precisely when the programmer used that sugar.


Surface
Core
not(true) or true
desugar
let t = not(true) in
if t then t else true
resugar
let t = false in
if t then t else true
resugar
if false then false else true
resugar
true
true

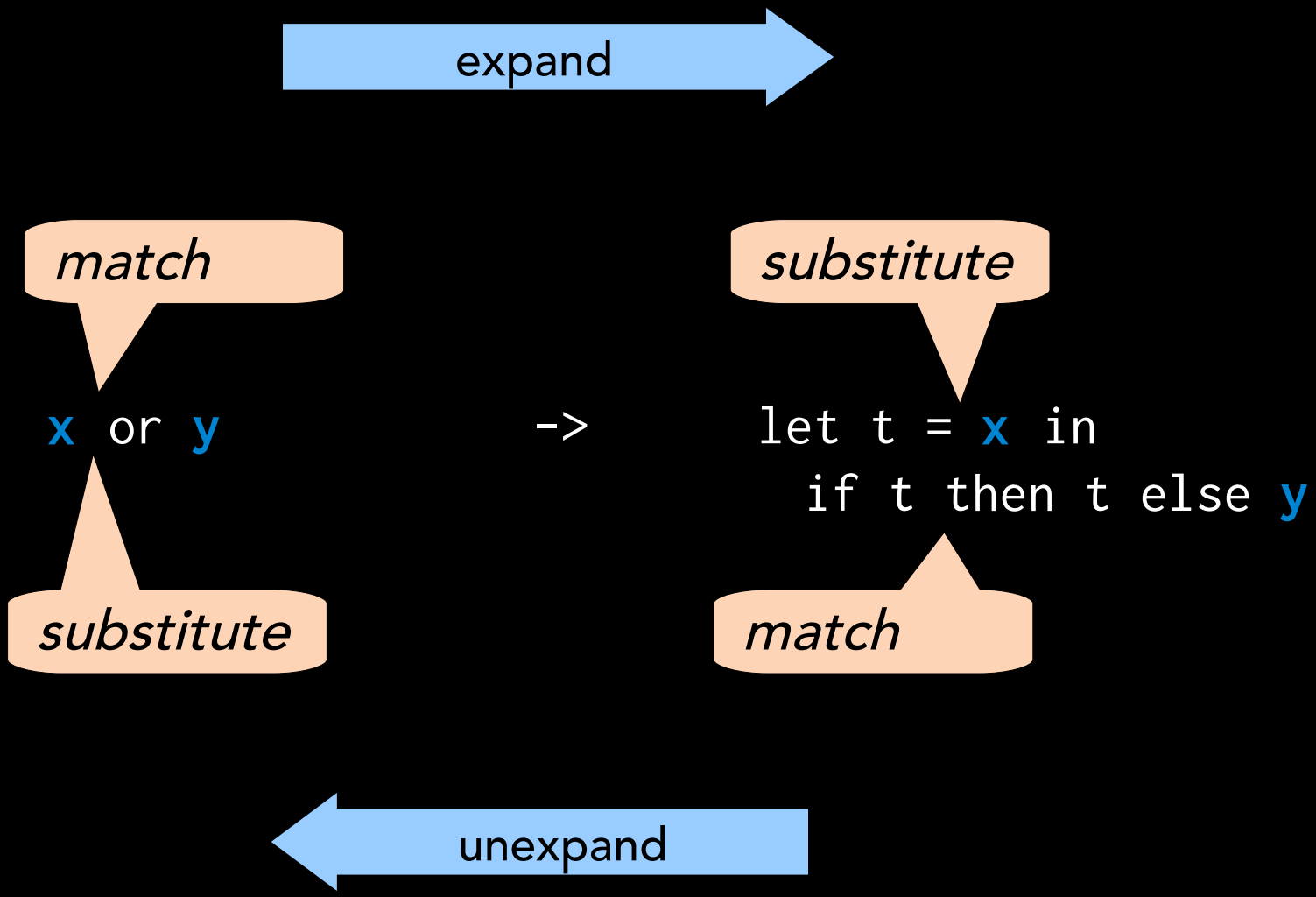

Surface
Core
not(true) or true
desugar
let t = not(true) in
if t then t else true
Coverage
Show as
many steps
as possible
resugar
let t = false in
if t then t else true
resugar
if false then false else true
resugar
true
true

```
x or y          ->      let t = x in
                          if t then t else y
```

match

substitute

```
x or y          ->      let t = x in
                          if t then t else y
```


expand
match
substitute
x or y
->
let t = x in
if t then t else y
substitute
match
unexpand

A Little Theory

$$\begin{aligned} \text{expand} &: \text{Surf Term} \to \text{Core Term} \\ \text{unexpand} &: \text{Core Term} \times \text{Surf Term} \to \text{Surf Term} \end{aligned}$$

A Little Theory

expand : Surf Term → Core Term

unexpand : Core Term × Surf Term → Surf Term

It's a lens!

A Little Theory

expand : Surf Term → Core Term

unexpand : Core Term × Surf Term → Surf Term

It's a lens!

unexpand (expand T) T = T — *GetPut*

expand (unexpand T′ T) = T′ — *PutGet*

A Little Theory

expand : Surf Term → Core Term

unexpand : Core Term × Surf Term → Surf Term

It's a lens!

unexpand (expand T) T = T — *GetPut*

expand (unexpand T′ T) = T′ — *PutGet*

Well-formedness criteria on rules ensure these laws.

Key Properties

- [ ] Emulation
- [ ] Abstraction
- [ ] Coverage

Key Properties

- [x] Emulation (Lens Laws)
- [ ] Abstraction
- [ ] Coverage

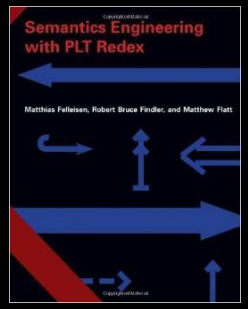
Key Properties

- [x] Emulation (Lens Laws)
- [x] Abstraction (Tagging – see paper)
- [ ] Coverage

Key Properties

- [x] Emulation (Lens Laws)
- [x] Abstraction (Tagging – see paper)
- [x] Coverage (Empirical)

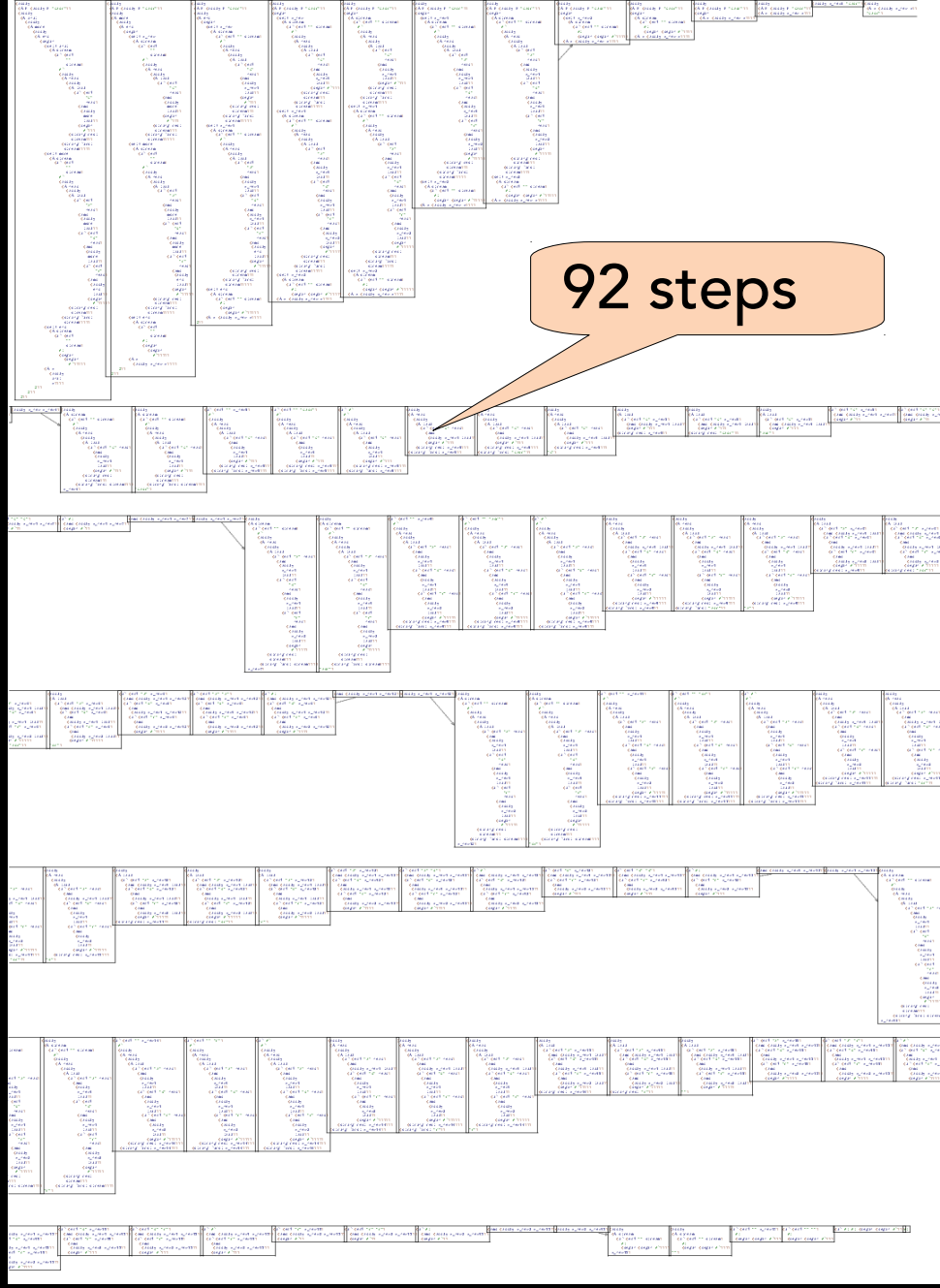
A WORKING SYSTEM




```
(Let
 M
 (Automaton
  init
  (init : ("c" -> more))
  (more
   :
   ("a" -> more)
   ("d" -> more)
   ("r" -> end))
  (end : "accept"))
 (apply M "cadr"))
```

```
(apply M "cadr")
(apply init "cadr")
(apply more "adr")
(apply more "dr")
(apply more "r")
(apply end "")
#t
```

7 steps



Surface

```
(or (and #t #f) #f)
```

Core

Surface

```
(or (and #t #f) #f)
```

desugar

Core

```
((lambda (t) (begin
   (if t t ((lambda () #f)))))
 (if #t ((lambda () #f)) #f))
```

Surface

```
(or (and #t #f) #f)
```

desugar

Core

```
((lambda (t) (begin
   (if t t ((lambda () #f)))))
 (if #t ((lambda () #f)) #f))
```

⇓

```
((lambda (t) (begin
   (if t t ((lambda () #f)))))
 ((lambda () #f)))
```

⇓

```
((lambda (t) (begin
   (if t t ((lambda () #f))))) #f)
```

⇓

```
(if #f t ((lambda () #f)))
```

⇓

```
((lambda () #f))
```

⇓

```
#f
```

Surface

```
(or (and #t #f) #f)
 ⇣
(or #f #f)
 ⇣
(or #f)
 ⇣
#f
```

desugar →

Core

```
((lambda (t) (begin
   (if t t ((lambda () #f)))))
 (if #t ((lambda () #f)) #f))
 ⇣
((lambda (t) (begin
   (if t t ((lambda () #f)))))
 ((lambda () #f)))
 ⇣
((lambda (t) (begin
   (if t t ((lambda () #f))))) #f)
 ⇣
(if #f t ((lambda () #f)))
 ⇣
((lambda () #f))
 ⇣
#f
```

Surface

Core

```
my-list = [2]
cases(List) my-list:
  | empty() => print("empty")
  | link(something, _) =>
    print("not empty")
end
```

Surface

```
my-list = [2]
cases(List) my-list:
  | empty() => print("empty")
  | link(something, _) =>
    print("not empty")
end
```

desugar

Core

```
my-list = list.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({
    "empty" : fun(): print("empty") end,
    "link" : fun(something, _):
      print("not empty") end
  },
  fun(): raise("cases: no cases matched") end)
end
```

Surface

```
my-list = [2]
cases(List) my-list:
  | empty() => print("empty")
  | link(something, _) =>
    print("not empty")
end
```

desugar

Core

```
my-list = list.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({
    "empty" : fun(): print("empty") end,
    "link" : fun(something, _):
      print("not empty") end
  },
  fun(): raise("cases: no cases matched") end)
end
```

```
my-list = obj.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = obj.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, obj.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, obj.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, [])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty")
end, "link" : fun(something, _):   print("not empty") end},
fun():   raise("cases: no cases matched") end)
end
```

```
my-list = [2]
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty")
end, "link" : fun(something, _):   print("not empty") end},
fun():   raise("cases: no cases matched") end)
end
```

```
tempMODRIOUJ :: List = [2]
tempMODRIOUJ.["_match"]({"empty" : fun(): print("empty")
end, "link" : fun(something, _): print("not empty") end},
fun(): raise("cases: no cases matched") end)
```

```
[2].["_match"]({"empty" : fun(): print("empty") end,
"link" : fun(something, _): print("not empty") end}, fun():
raise("cases: no cases matched") end)
```

```
[2].["_match"]({"empty" : fun(): print("empty") end,
"link" : fun(something, _): print("not empty") end}, fun():
raise("cases: no cases matched") end)
```

```
<func>({"empty" : fun(): end, "link" : fun(something, _):
print("not empty") end}, fun(): raise("cases: no cases
matched") end)
```

```
<func>({"empty" : fun(): end, "link" : fun(): end}, fun():
raise("cases: no cases matched") end)
```

```
<func>(obj, fun(): raise("cases: no cases matched") end)
```

```
<func>(obj, fun(): end)
```

```
<func>("not empty")
```

```
"not empty"
```

Surface

```
my-list = [2]
cases(List) my-list:
  | empty() => print("empty")
  | link(something, _) =>
    print("not empty")
end
```

↓

```
my-list = [2]
cases(List) my-list:
  | empty() => print("empty")
  | link(something, _) =>
    print("not empty")
end
```

↓

```
cases(List) [2]:
  | empty() => print("empty")
  | link(something, _) =>
    print("not empty")
end
```

↓

```
<func>("not empty")
```

↓

```
"not empty"
```

desugar

Core

```
my-list = list.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({
    "empty" : fun(): print("empty") end,
    "link" : fun(something, _):
      print("not empty") end
  },
  fun(): raise("cases: no cases matched") end)
end
```

```
my-list = obj.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = obj.["link"](2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, list.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, obj.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, obj.["empty"])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty") end,
"link" : fun(something, _):   print("not empty") end}, fun():
raise("cases: no cases matched") end)
end
```

```
my-list = <func>(2, [])
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty")
end, "link" : fun(something, _):   print("not empty") end},
fun():   raise("cases: no cases matched") end)
end
```

```
my-list = [2]
block:
  tempMODRIOUJ :: List = my-list
  tempMODRIOUJ.["_match"]({"empty" : fun():   print("empty")
end, "link" : fun(something, _):   print("not empty") end},
fun():   raise("cases: no cases matched") end)
end
```

```
tempMODRIOUJ :: List = [2]
tempMODRIOUJ.["_match"]({"empty" : fun(): print("empty")
end, "link" : fun(something, _): print("not empty") end},
fun(): raise("cases: no cases matched") end)
```

```
[2].["_match"]({"empty" : fun(): print("empty") end,
"link" : fun(something, _): print("not empty") end}, fun():
raise("cases: no cases matched") end)
```

```
[2].["_match"]({"empty" : fun(): print("empty") end,
"link" : fun(something, _): print("not empty") end}, fun():
raise("cases: no cases matched") end)
```

```
<func>({"empty" : fun(): end, "link" : fun(something, _):
print("not empty") end}, fun(): raise("cases: no cases
matched") end)
```

```
<func>({"empty" : fun(): end, "link" : fun(): end}, fun():
raise("cases: no cases matched") end)
```

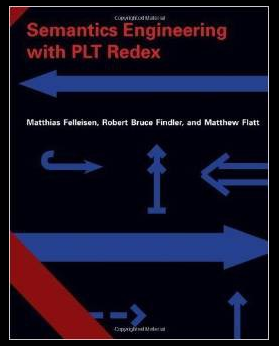
```
<func>(obj, fun(): raise("cases: no cases matched") end)
```

```
<func>(obj, fun(): end)
```

```
<func>("not empty")
```

```
"not empty"
```

1. Redex semantics engineering tool



2. Racket (racket.org)

3. Pyret (pyret.org)

Resugaring

Fork us on GitHub
tinyurl.com/resugar

The *Confection* tool

- Declarative sugar specification
- Language agnostic
- Guarantees Emulation and Abstraction

Current/future work

- Hygiene!
- Better error messages through resugaring

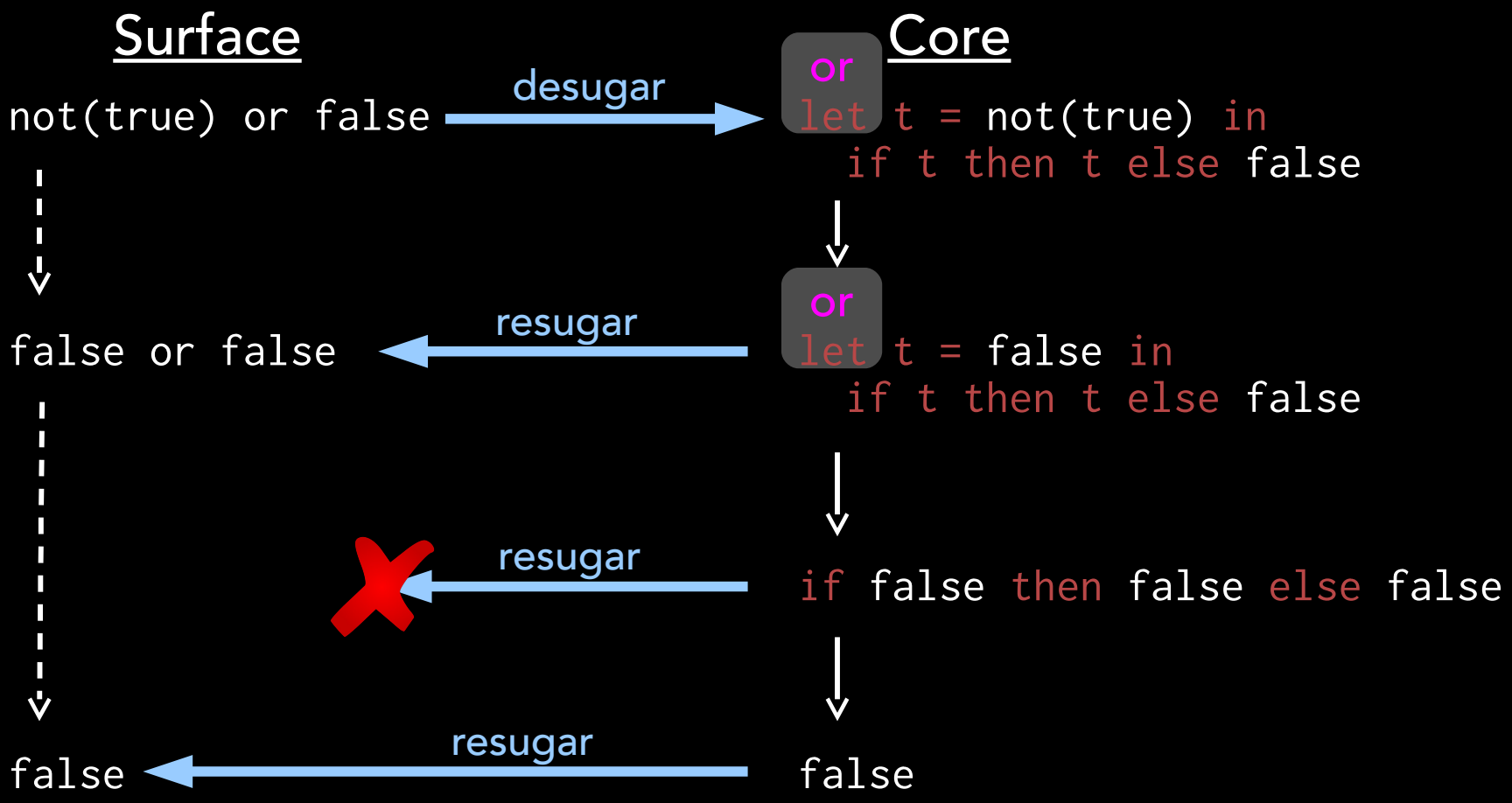
BACKUP SLIDES

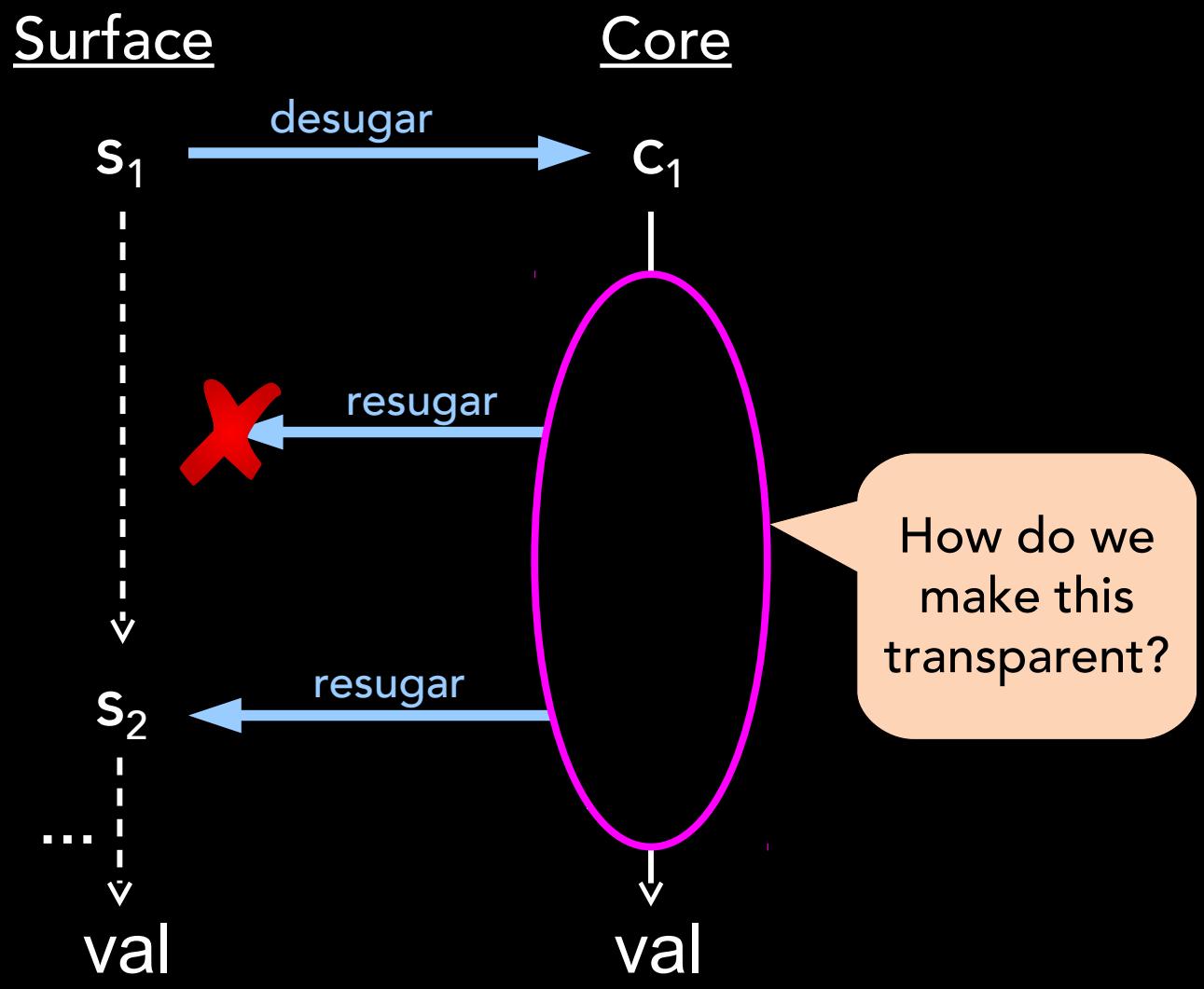
How should this resugar?

```
let t = not(true) in
  if t then t else true
```

Looks like the desugaring of an ‘or’.

But maybe the user wrote it?


Surface
Core
not(true) or false
desugar
or
let t = not(true) in
if t then t else false
false or false
resugar
or
let t = false in
if t then t else false
resugar
if false then false else false
false
resugar
false


Surface
Core
desugar
s_1
c_1
resugar
How do we make this transparent?
resugar
s_2
...
val
val

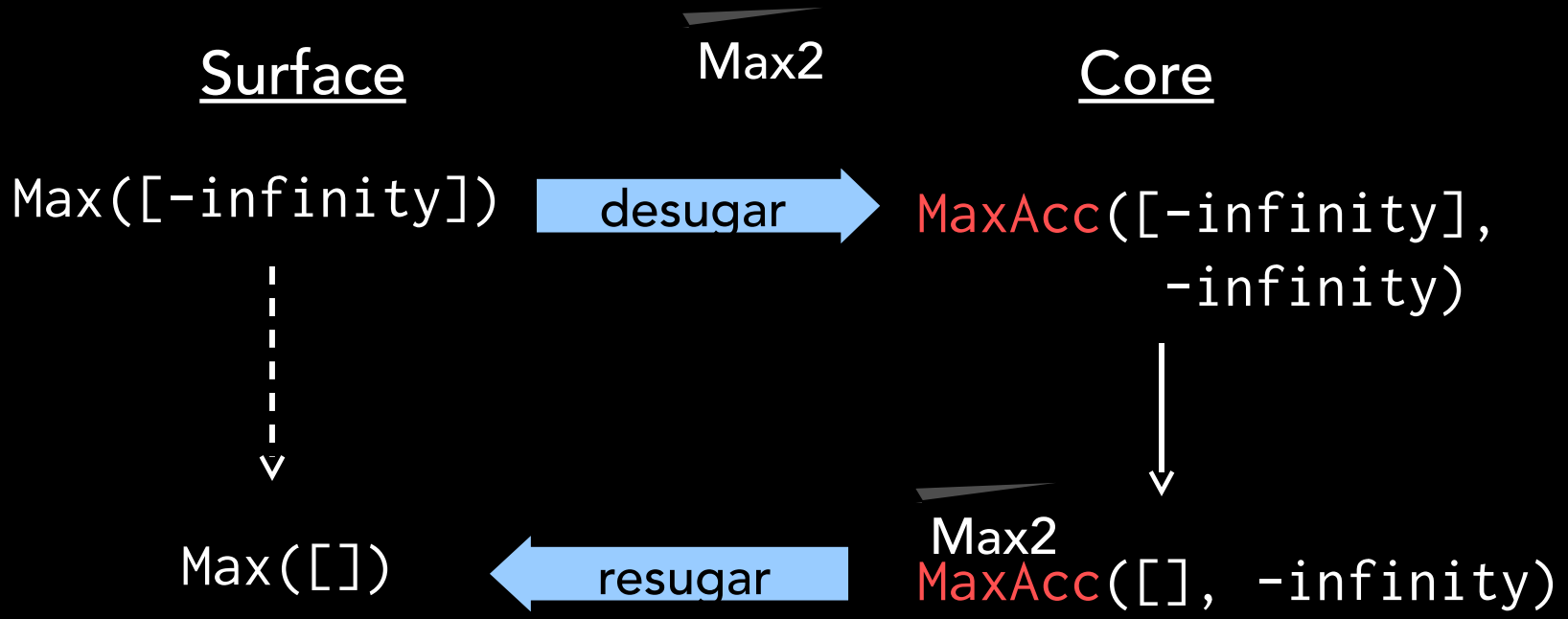
Reconstruct the (core) program as source at each evaluation step (along with its tags).

Either instrument the compiler
or do a pre-compilation step

CPS/ANF makes this easier;
or just statefully keep track of the stack

```
Max([]) -> Raise("empty list");

Max(xs) -> MaxAcc(xs, -infinity);
```



Related Work

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- J. Clements, M. Flatt, and M. Felleisen. Modeling an algebraic stepper. In European Symposium on Programming Languages and Systems, 2001.
- R. Perera, U. A. Acar, J. Cheney, and P. B. Levy. Functional programs that explain their work. In International Conference on Functional Programming, 2012
- A. V. Deursen, P. Klint, and F. Tip. Origin tracking. Journal of Symbolic Computation, 15(5–6), 1993.