Program Representations

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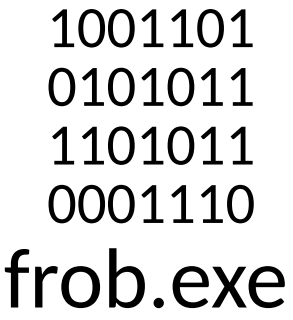

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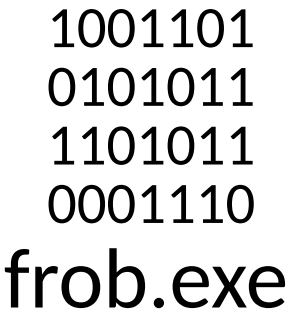

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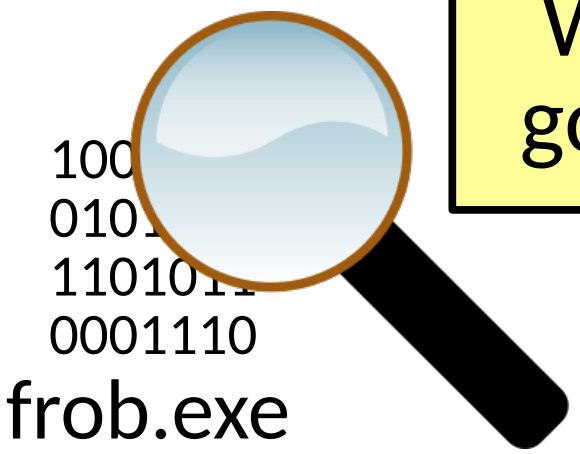

Why might binaries be good for security tasks?

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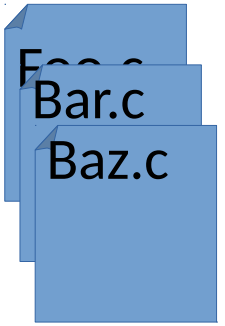

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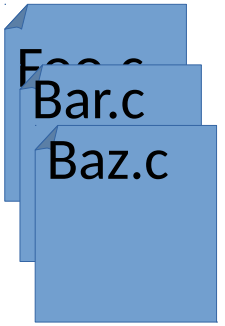

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- A *good* representation should make explicit the relationships you want to analyze

Program Representation

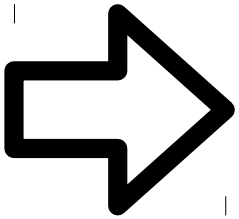
Core graph representations for analysis:

1) Abstract Syntax Trees
2) Control Flow Graphs
3) Program Dependence Graphs
4) Call Graphs
5) Points-to Graphs

1) Abstract Syntax Trees

- Lifts the source into a canonical tree form

```
for i in range(5,10):
    a[i] = i * 5
```



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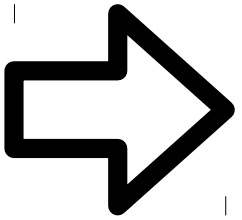

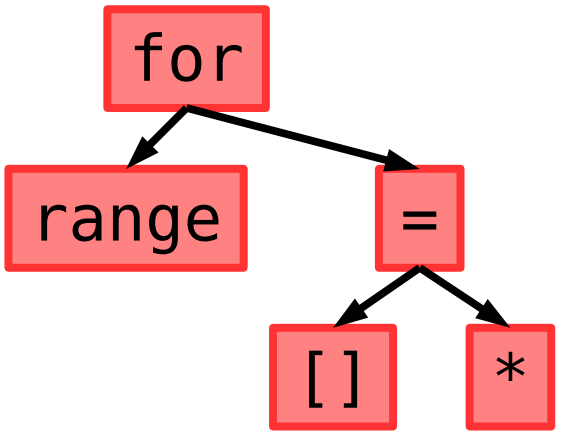

1) Abstract Syntax Trees

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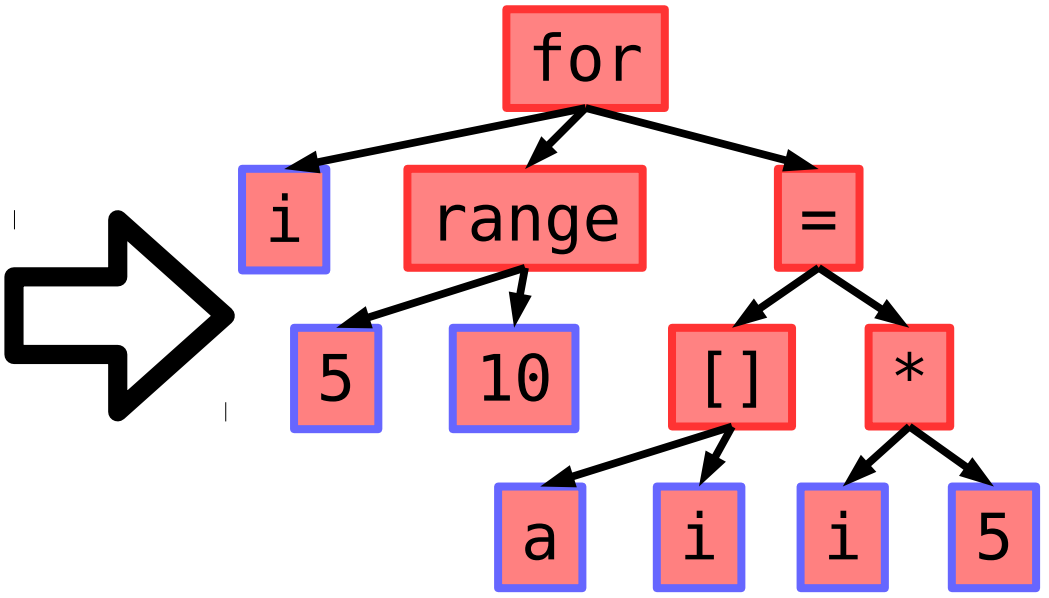

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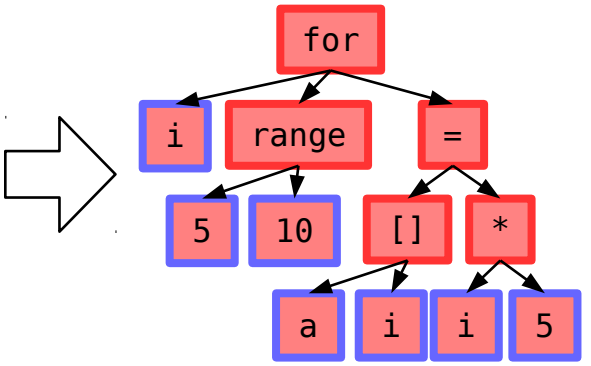

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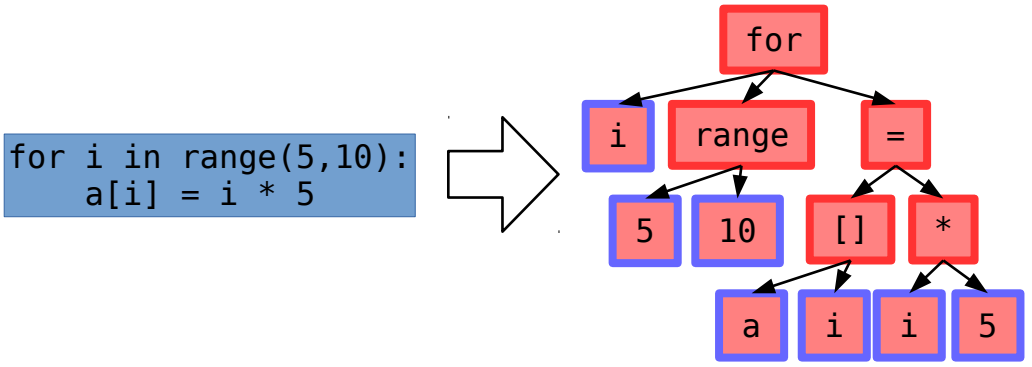

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But the same program
may still be spelled many ways.

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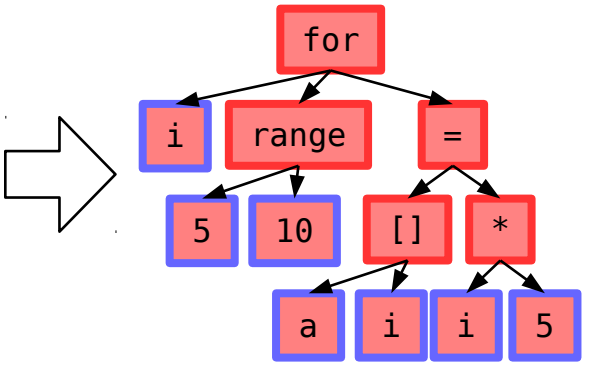

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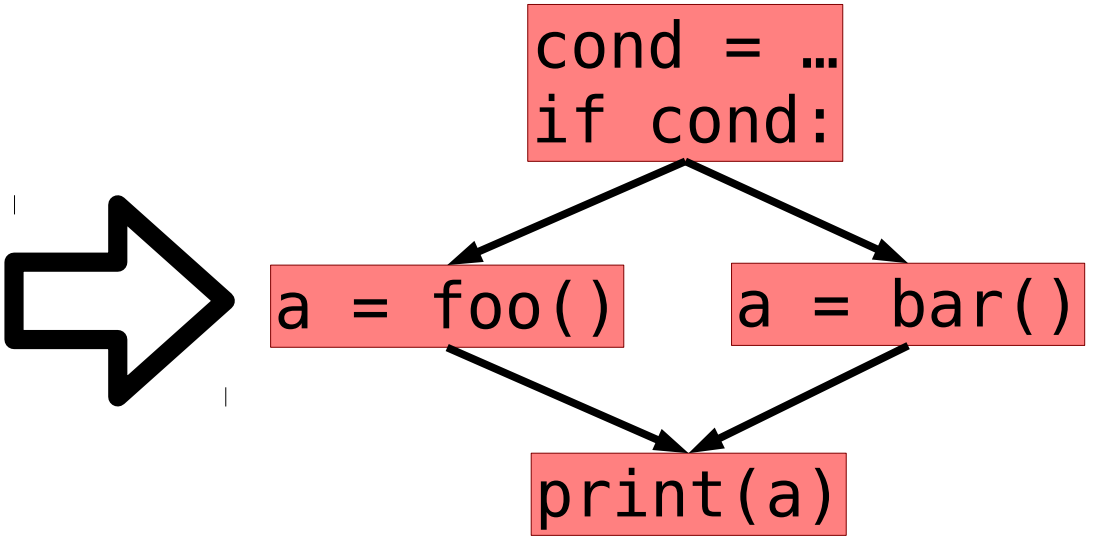

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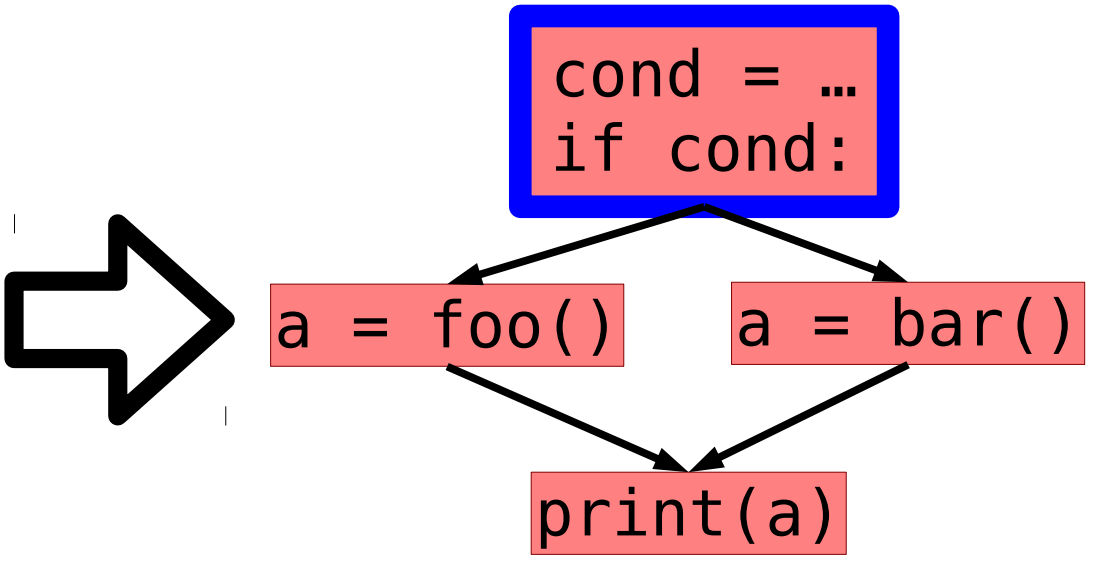

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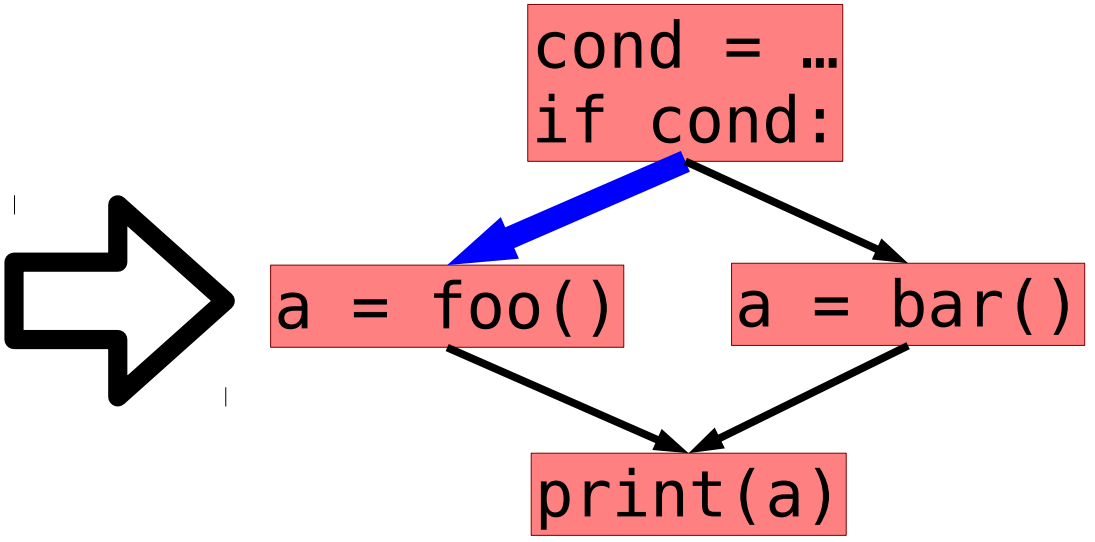

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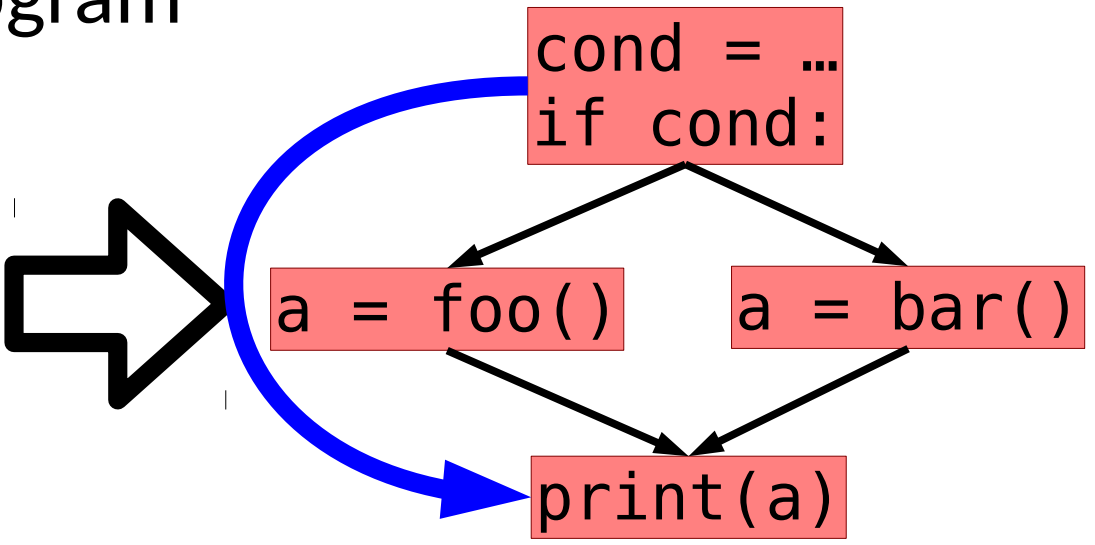

2) Control Flow Graphs (CFGs)

- Language specific features are often abstracted away

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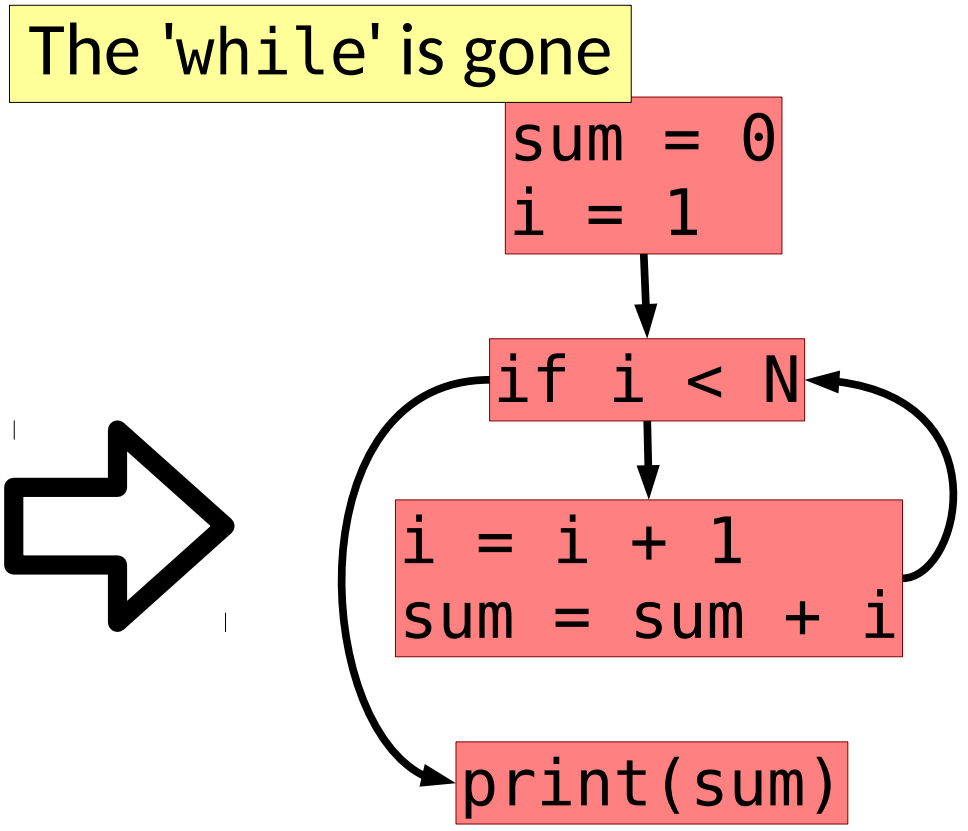

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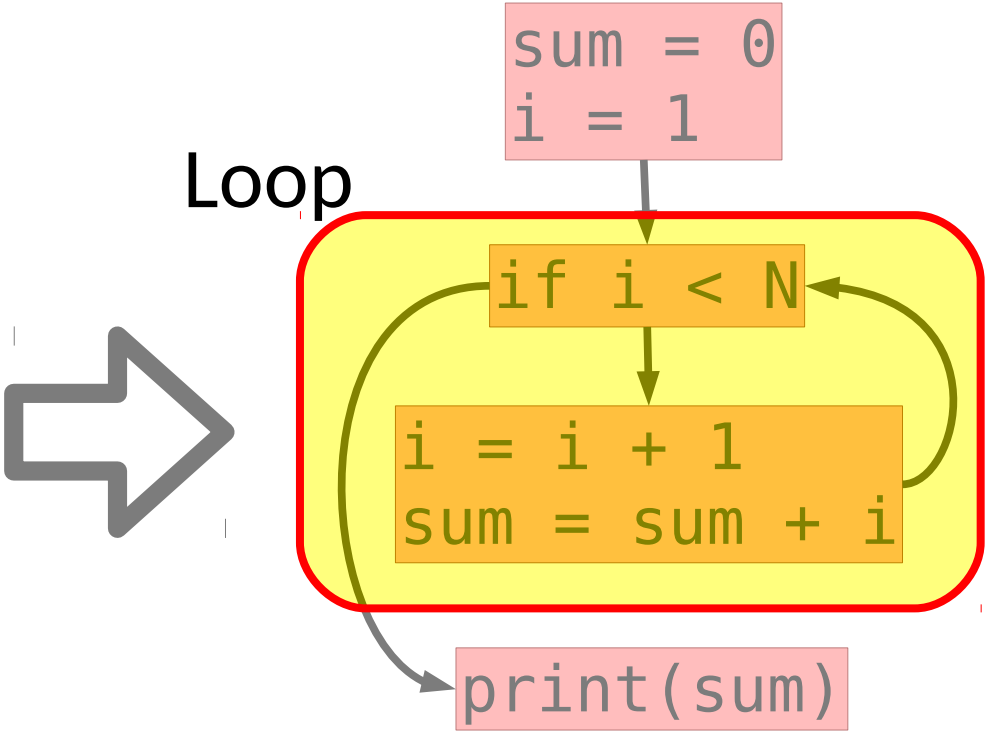

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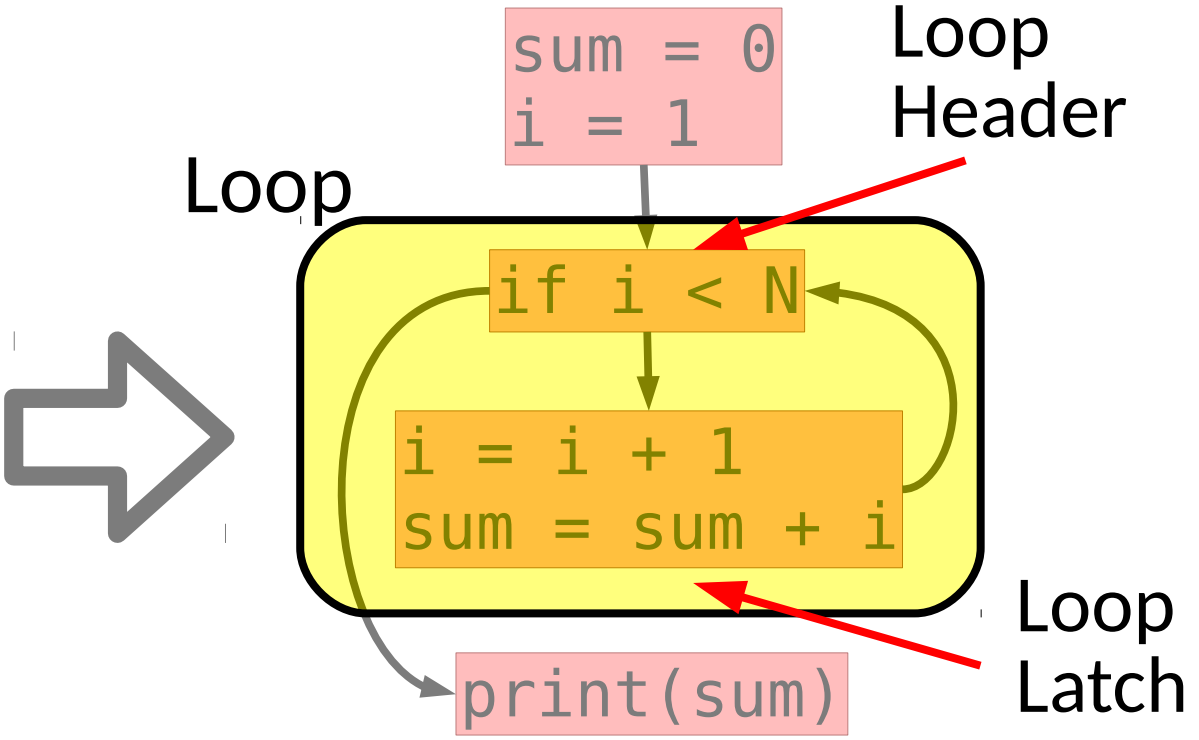

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Why is the 'if' in a separate block?

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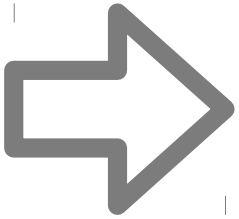

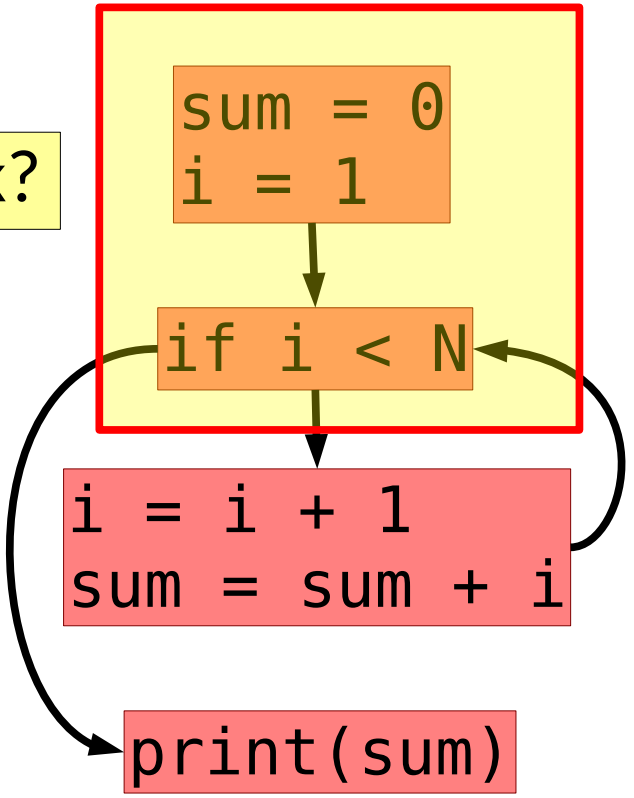

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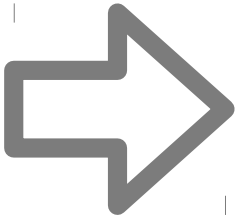

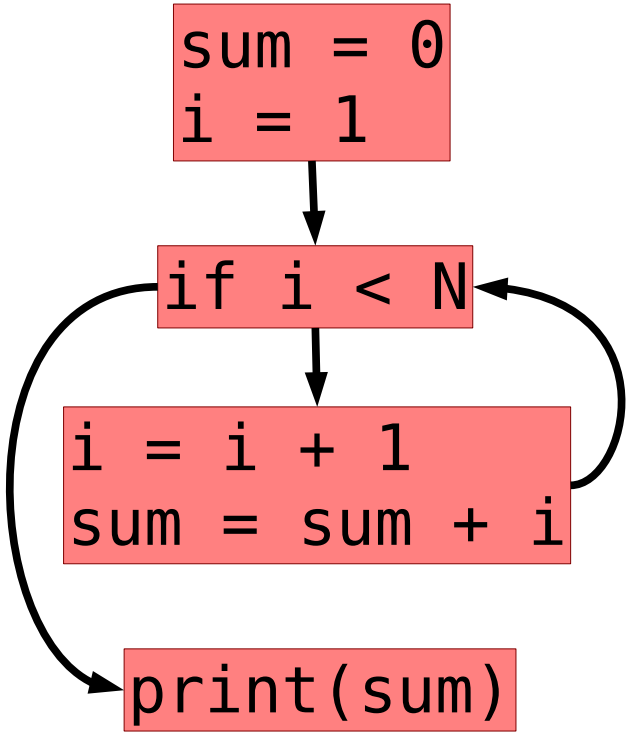

What would the CFG of the equivalent '`for`' look like?

3)Program Dependence Graph (PDG)

- A ***Program Dependence Graph*** captures how instructions can influence each other

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```
password = input()
...
log(message)
```

e.g. Can my password influence this `log` statement?

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  - Nodes are instructions
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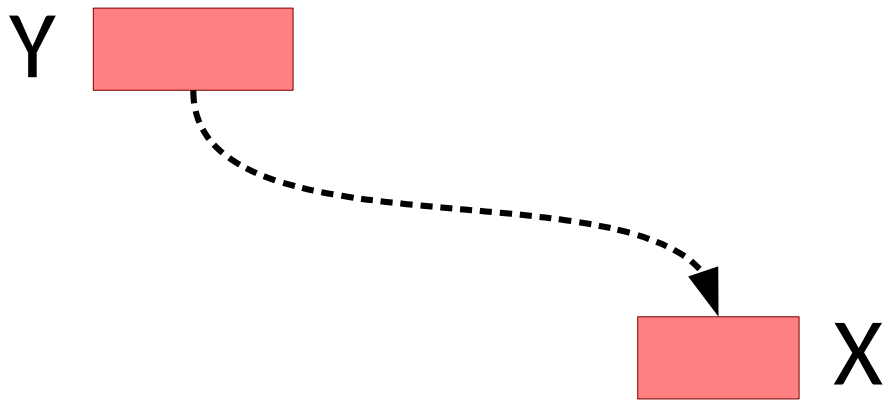
  - ***Control dependence*** – influence through decisions

Data Dependence

X data depends on Y if

- There exists a path from Y to X in the CFG



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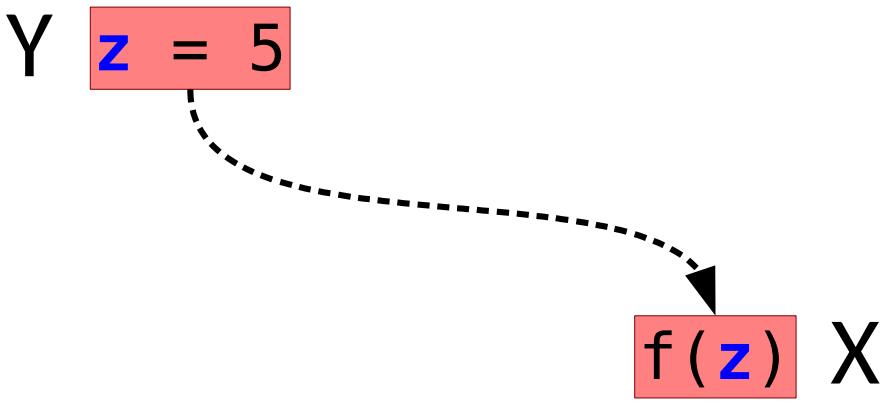

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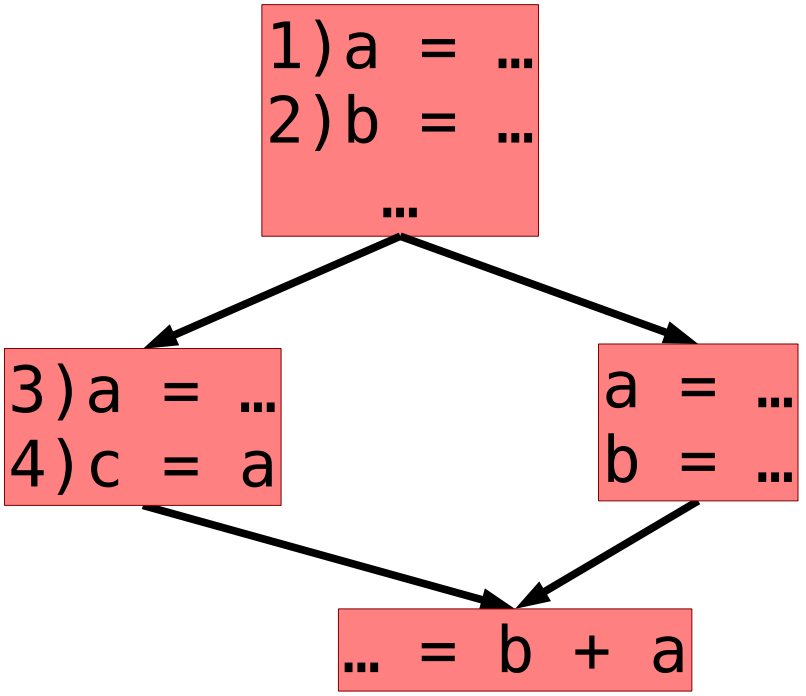

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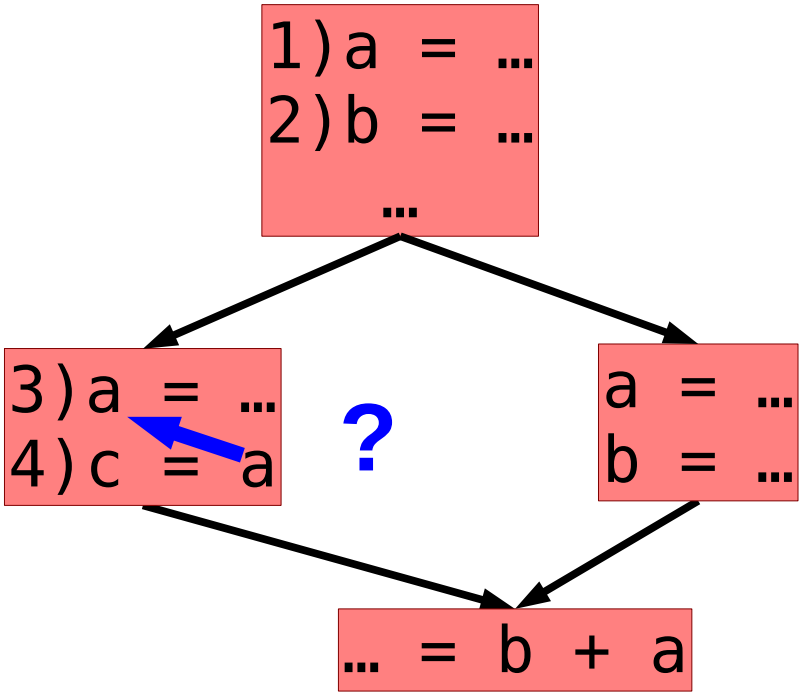

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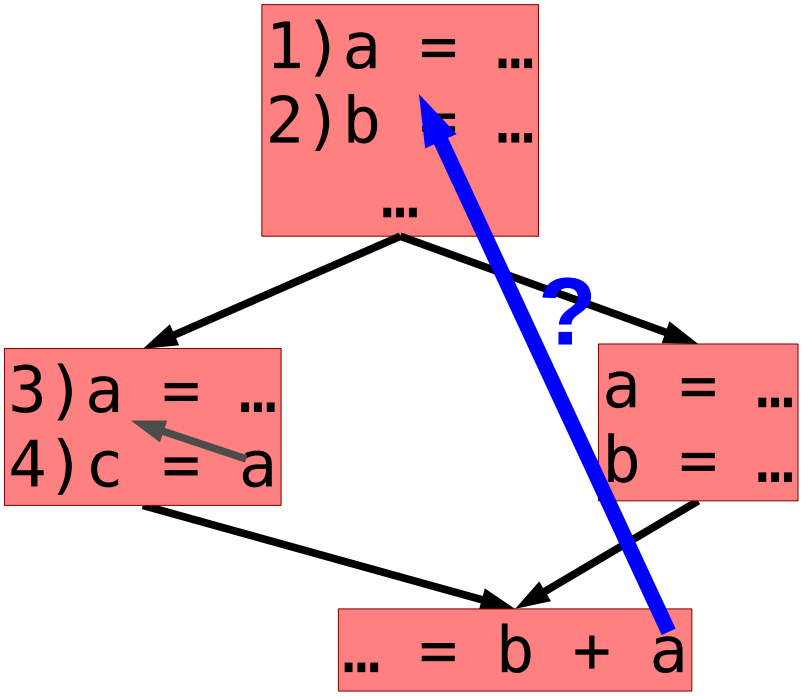

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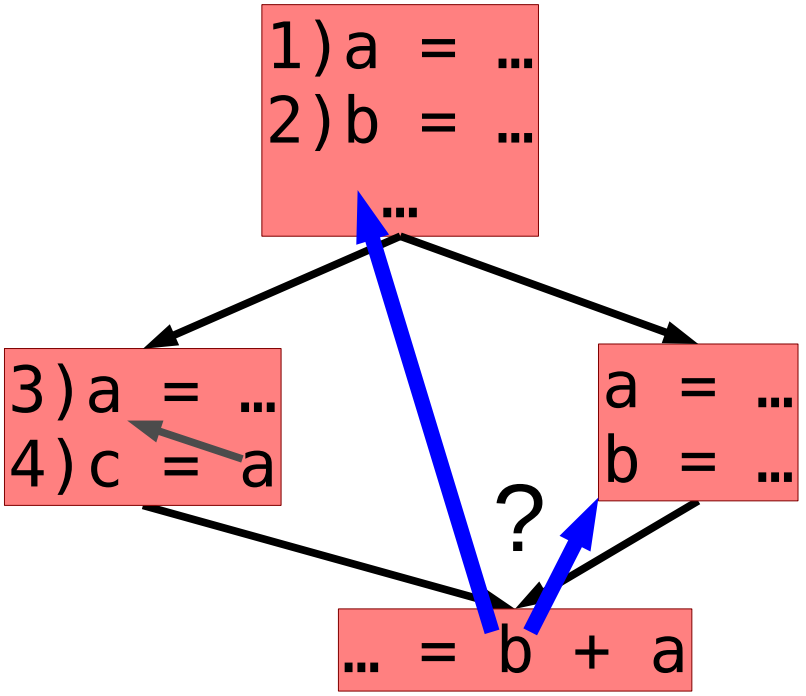

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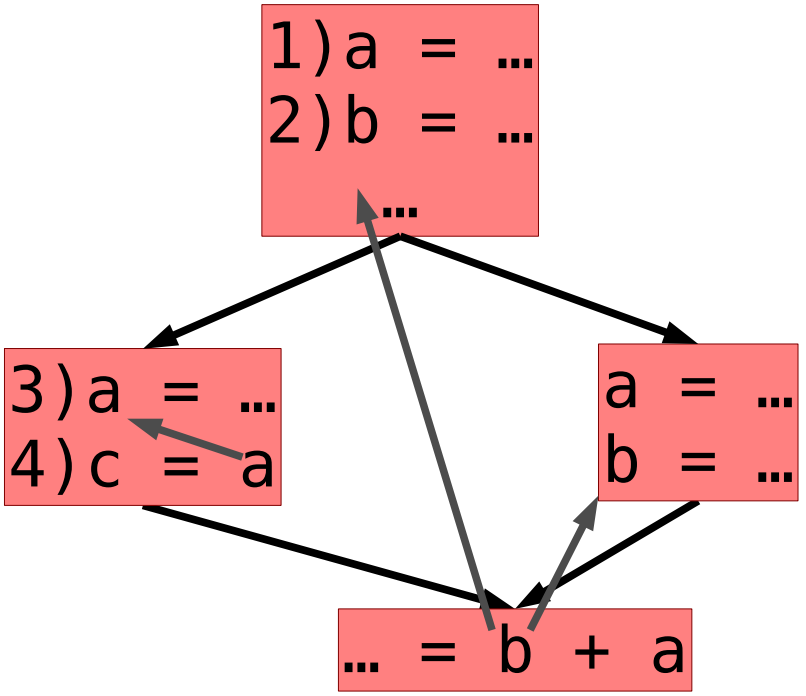

Control Dependence

Recall:
Control dependence captures how decisions influence program behavior.

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We need a way of capturing this via graphs….

Control Dependence

Preliminary: X dominates Y if

- every path from the entry node to Y passes X

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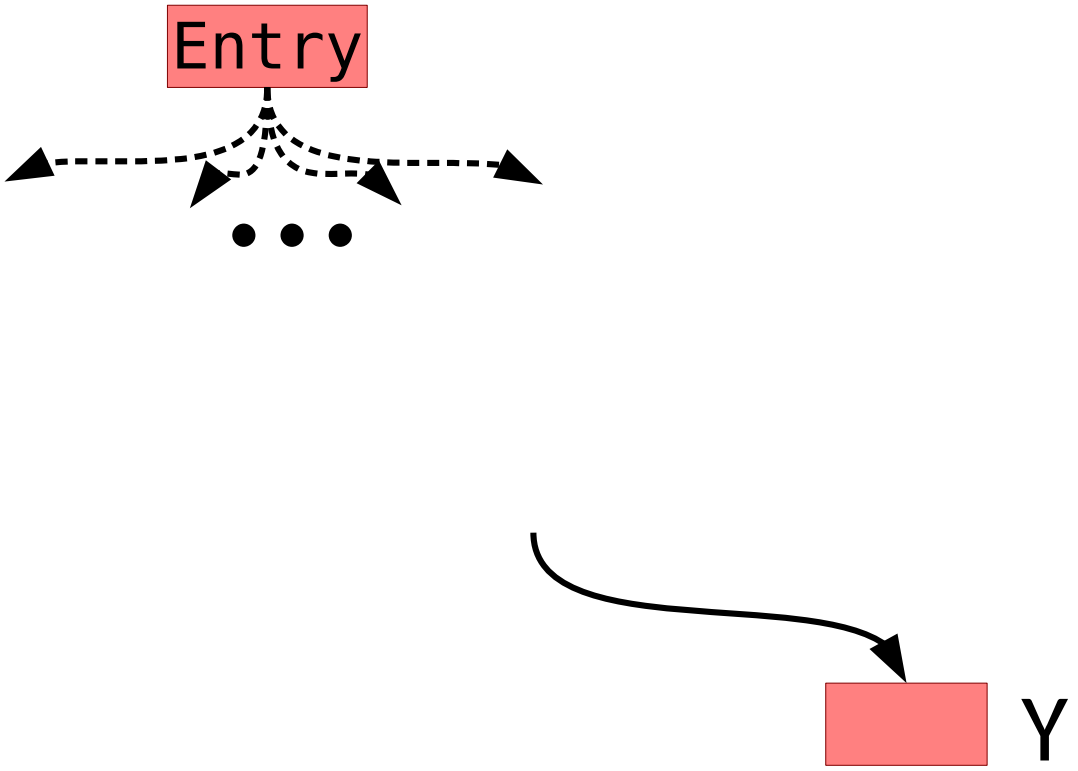

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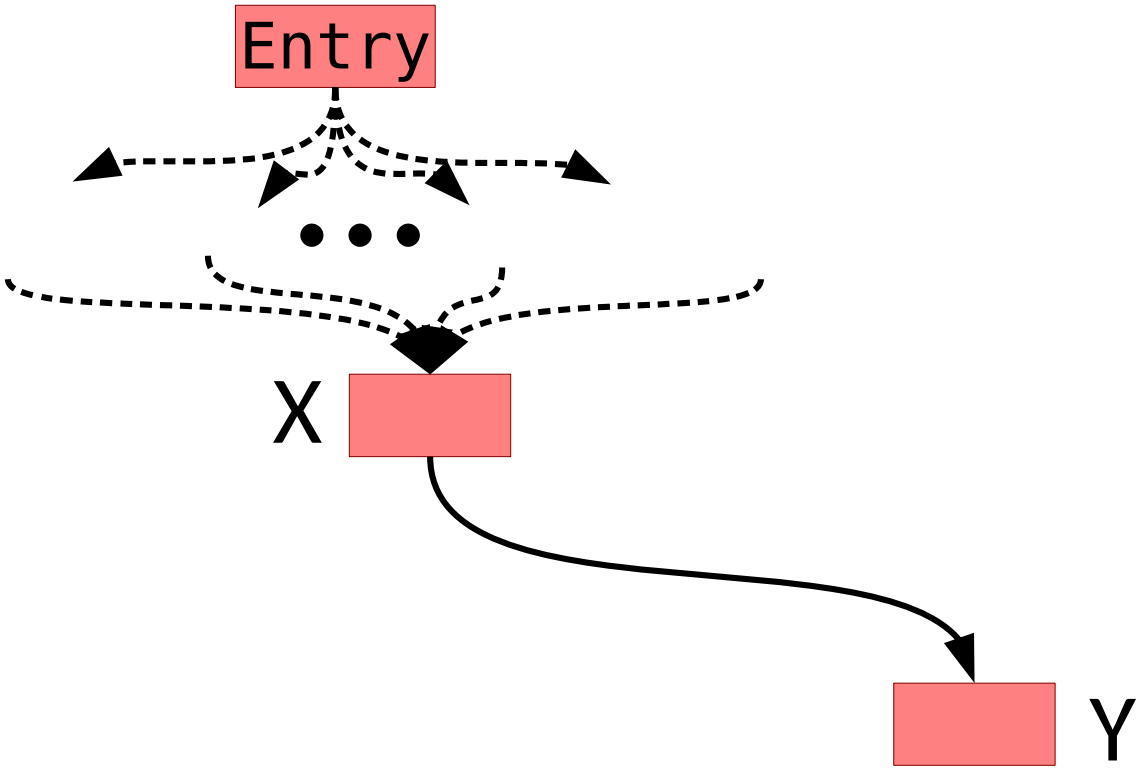

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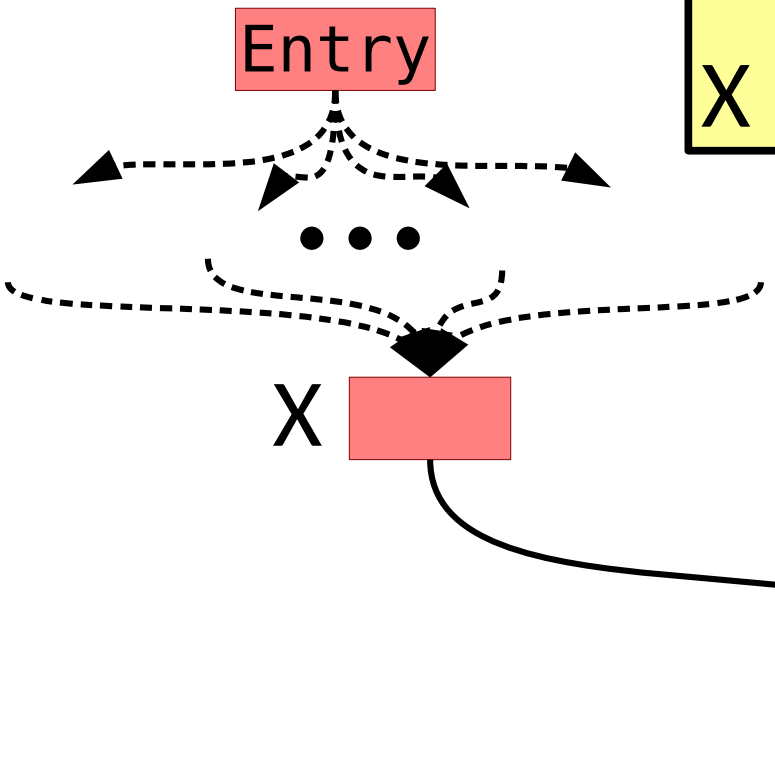

Intuitively,
X is a *gatekeeper* for Y.

Zuul the Gatekeeper.
Ghostbusters, 1982.
Columbia Pictures

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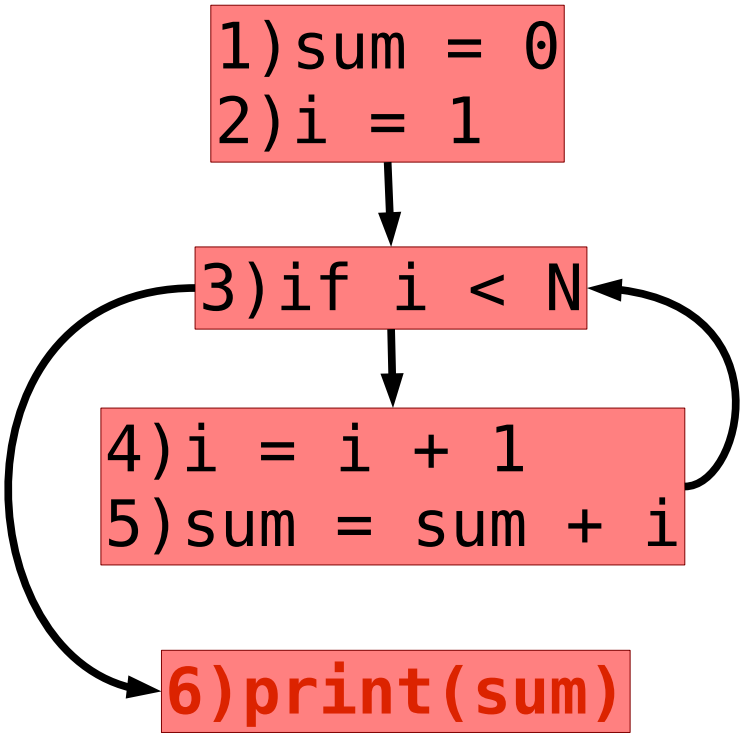

DOM(6)= ?

IDOM(6)= ?

Control Dependence

Preliminary: X dominates Y if

- every path from the entry node to Y passes X
  - strict, normal, & immediate dominance

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1)sum = 0
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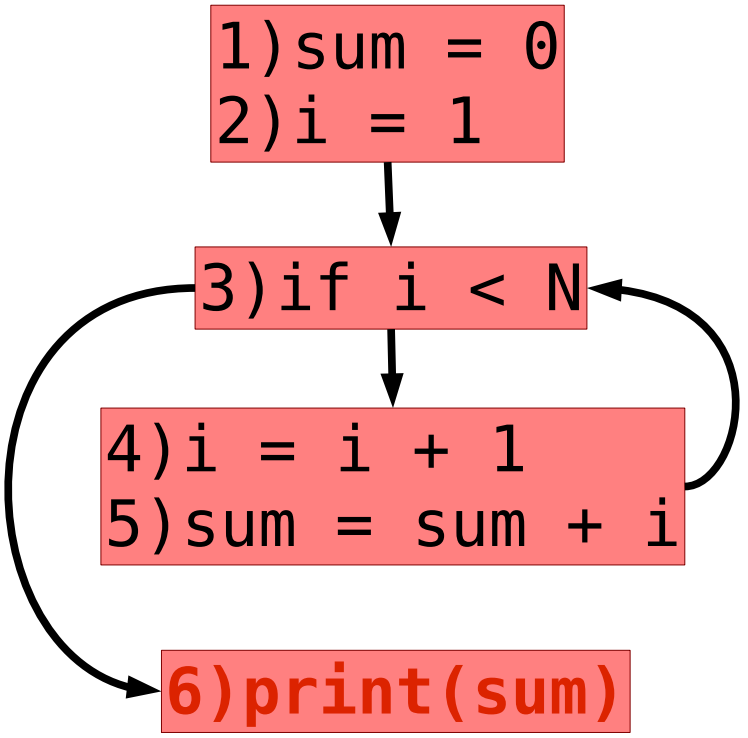

DOM(6)={1,2,3,6} IDOM(6)=3

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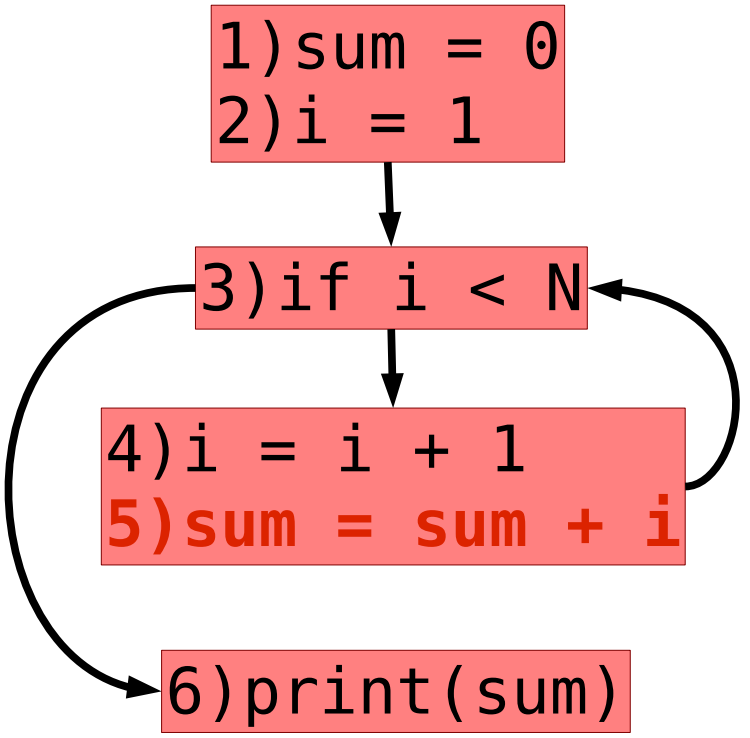

PDOM(5)= ? IPDOM(5)= ?

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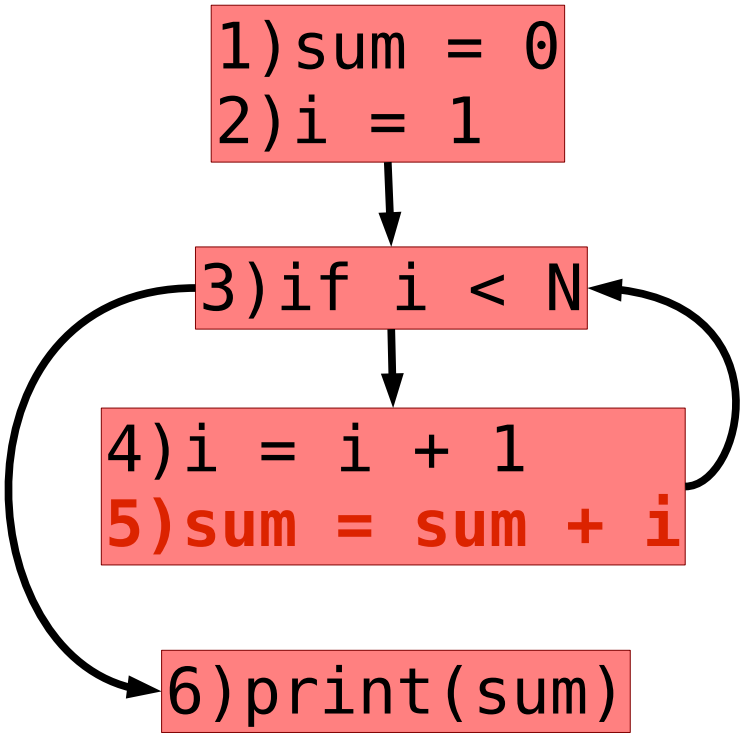

PDOM(5)={3,5,6} IPDOM(5)=3

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What does this mean intuitively?

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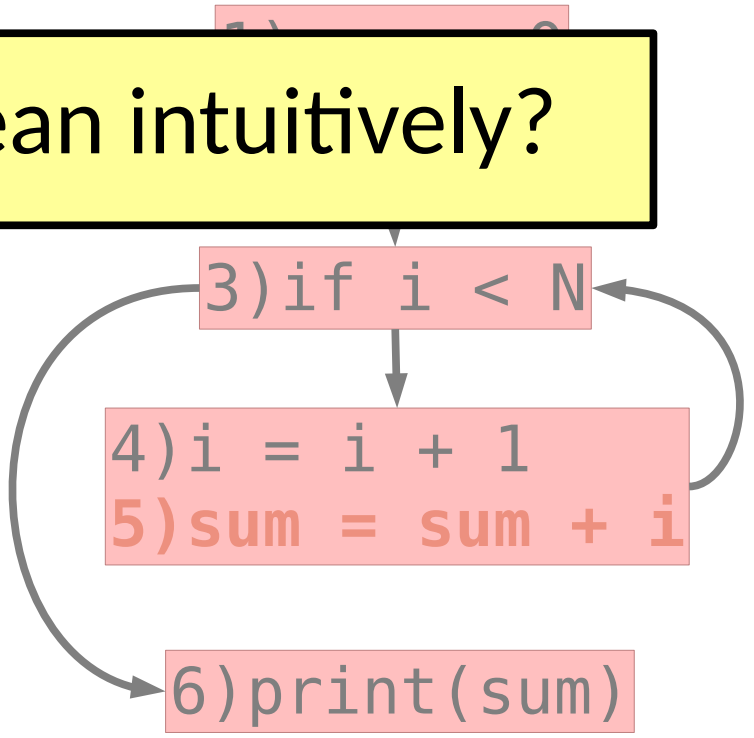

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```

Doc Brown.
Back to the Future, 1985.
Universal Pictures

```
3)if i < N
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```

PDOM(5)={3,5,6} IPDOM(5)=3

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- Definition 1:

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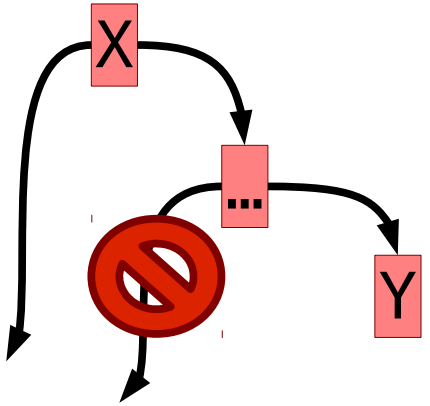

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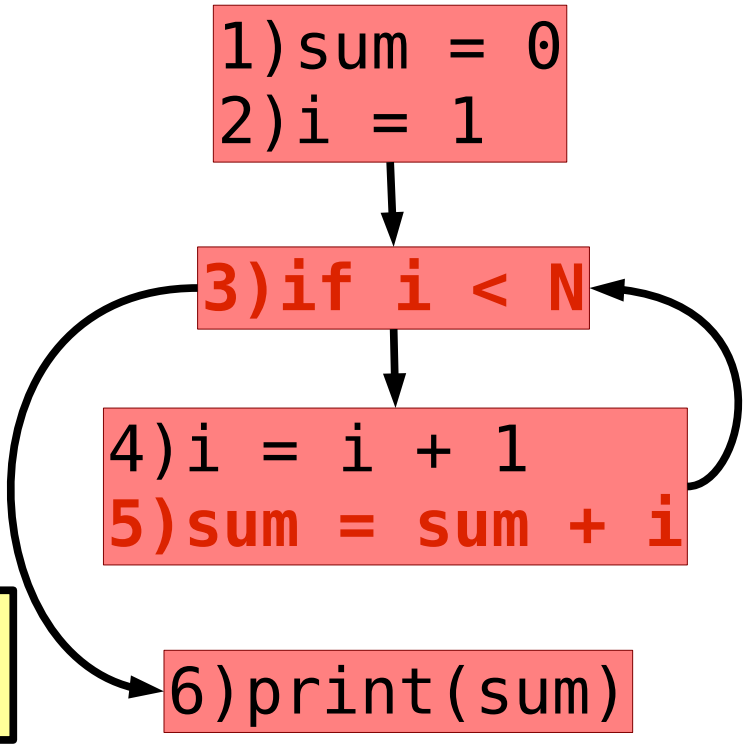

What is CD(5)? CD(3)

Control Dependence

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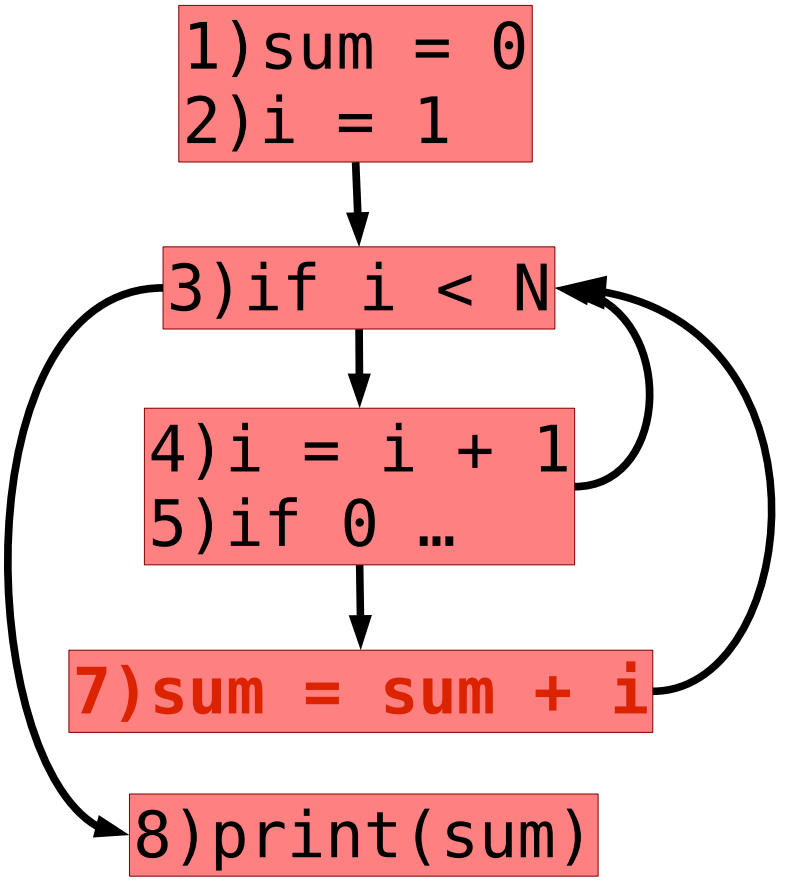
```
1)sum = 0
2)i = 1
3)while i < N:
4)   i = i + 1
5)   if 0 == i%2:
6)      continue
7)   sum = sum + i
8)print(sum)
```

What is CD(7)?



Control Dependence

- There exists a path from X to Y s.t. Y post dominates every node between X and Y.
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```
1)if X or Y:
2)   print(X)
3)print(Y)
```

What is CD(2)?

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```
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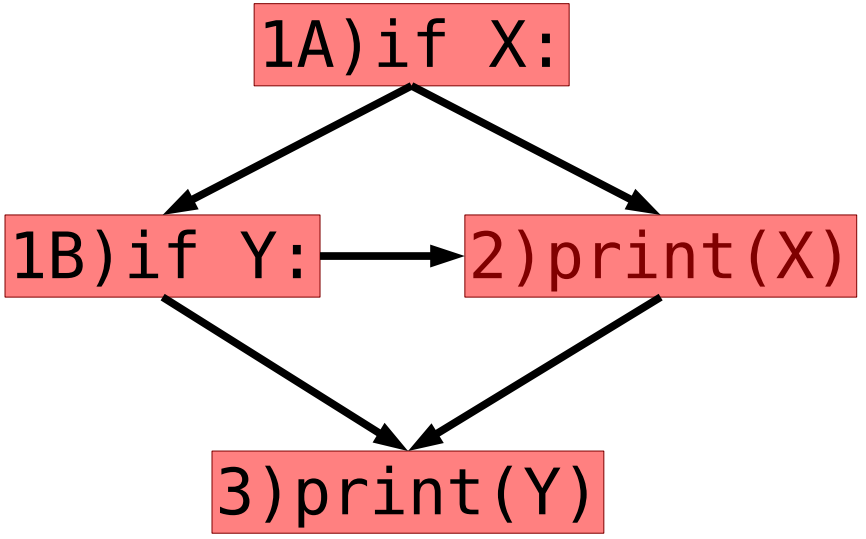

What is CD(2)?

3)Program Dependence Graph(PDG)

The PDG is the combination of

- The control dependence graph
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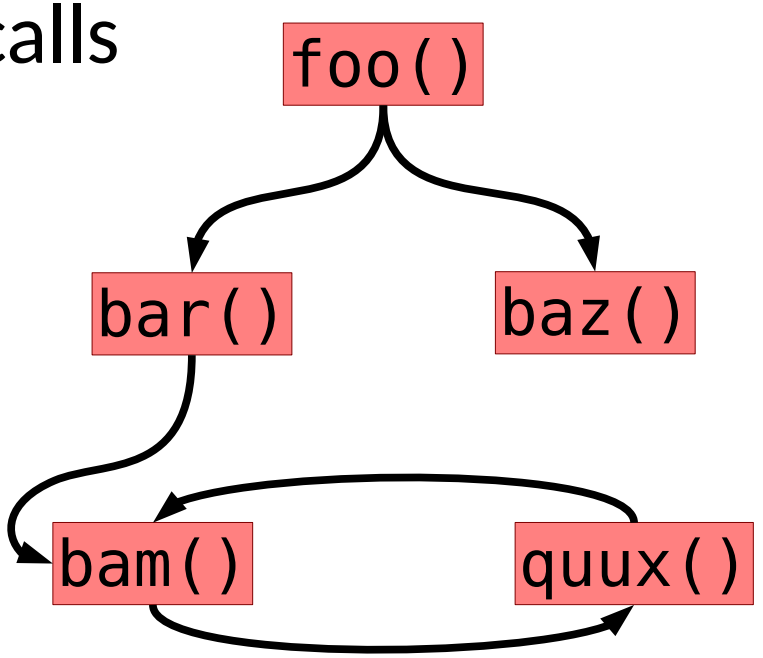
- …

4) Call Graph (Multigraph)

- Captures the composition of a program
  - Nodes are functions
  - Edges show possible calls



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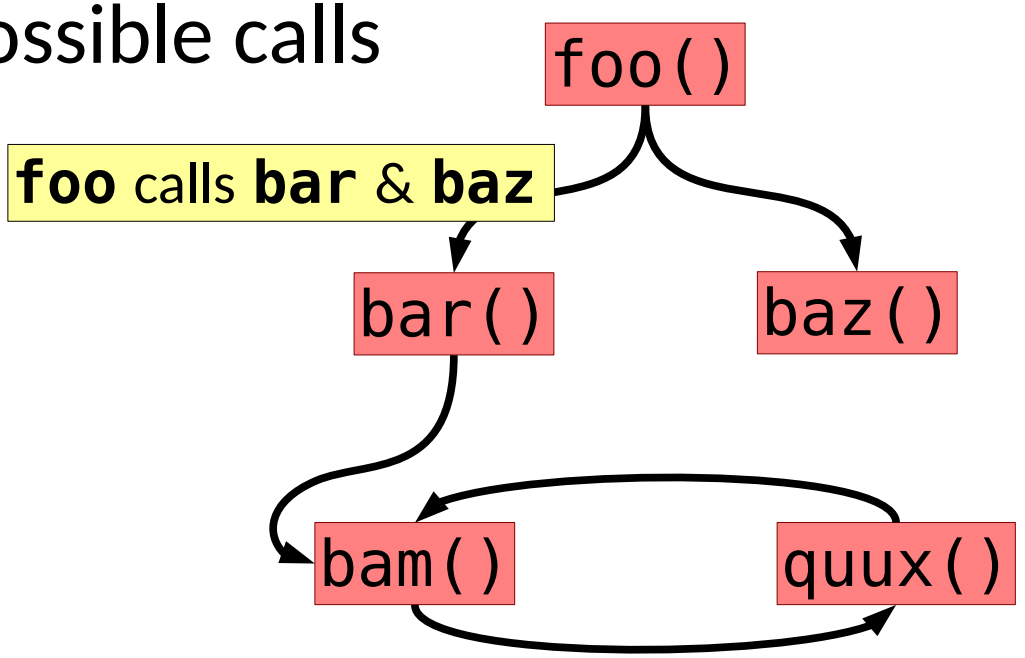

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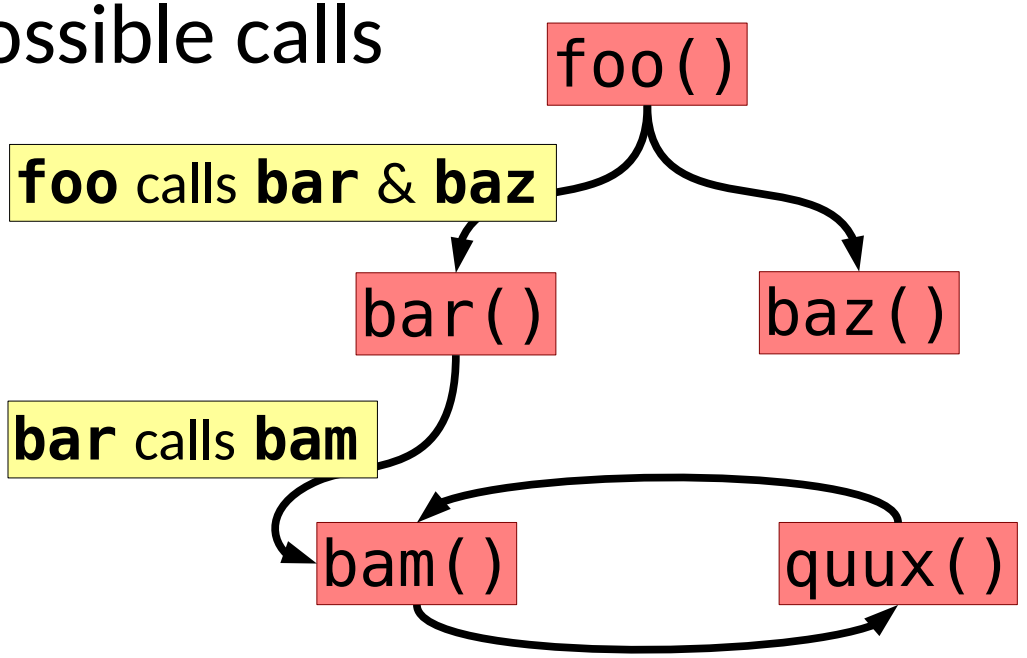

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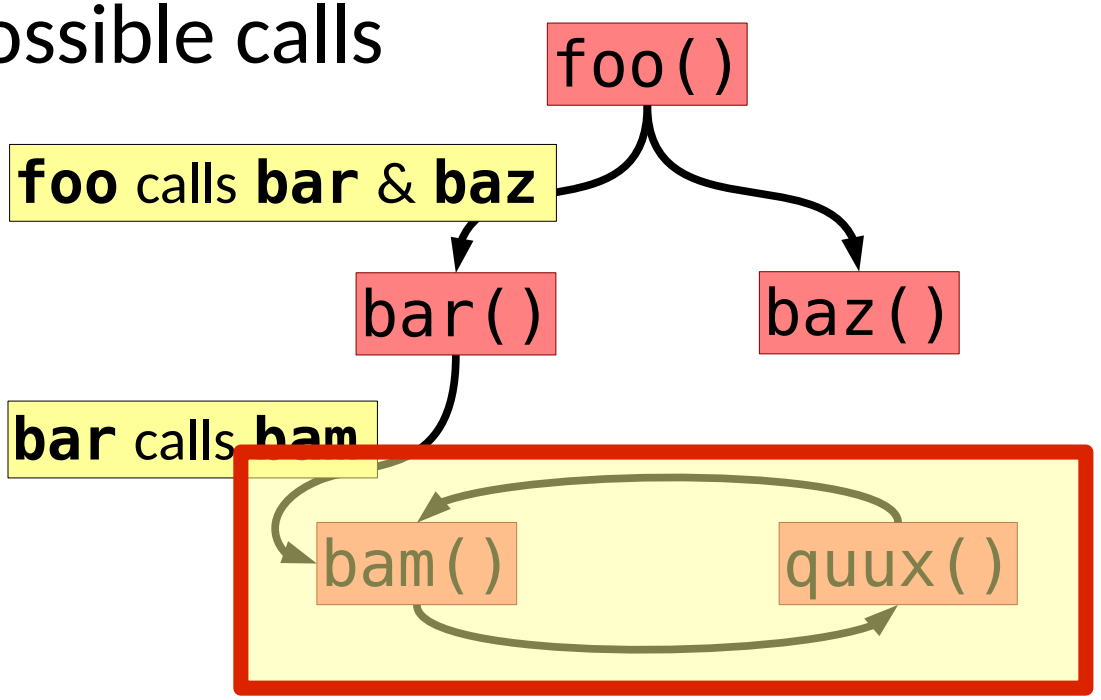

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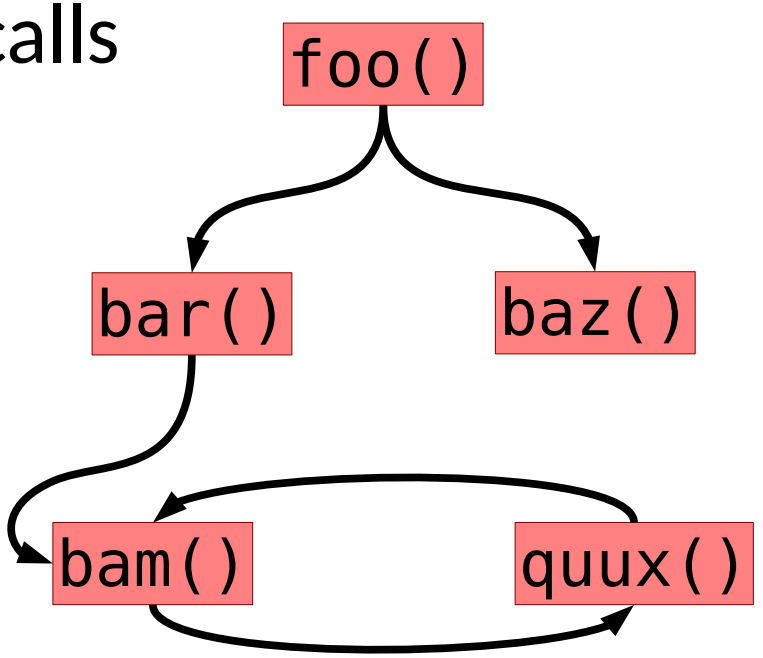
How should we handle function pointers?



5) Points-to Graphs

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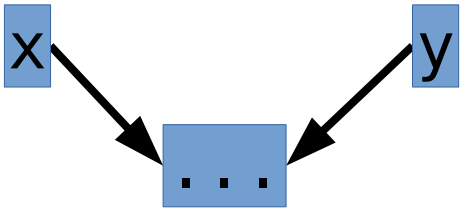

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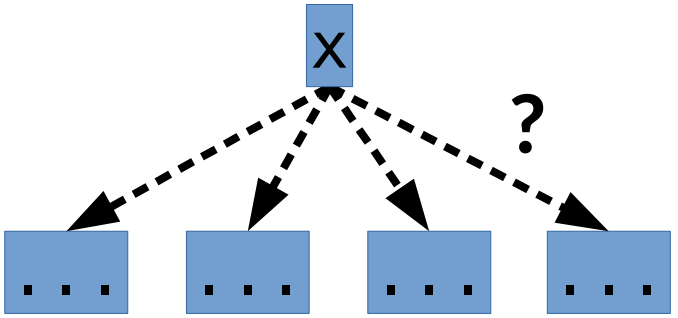

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```
x.lock()
…
y.unlock()
```

```
x = password
…
broadcast(y)
```

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Points-to graphs capture this points-to relation

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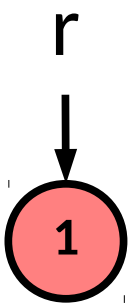

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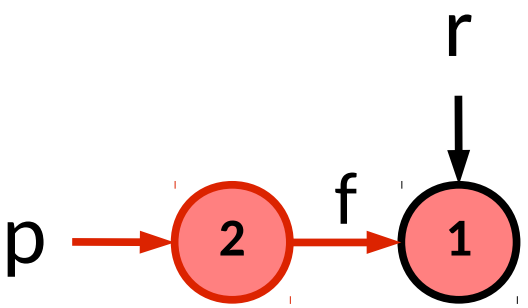

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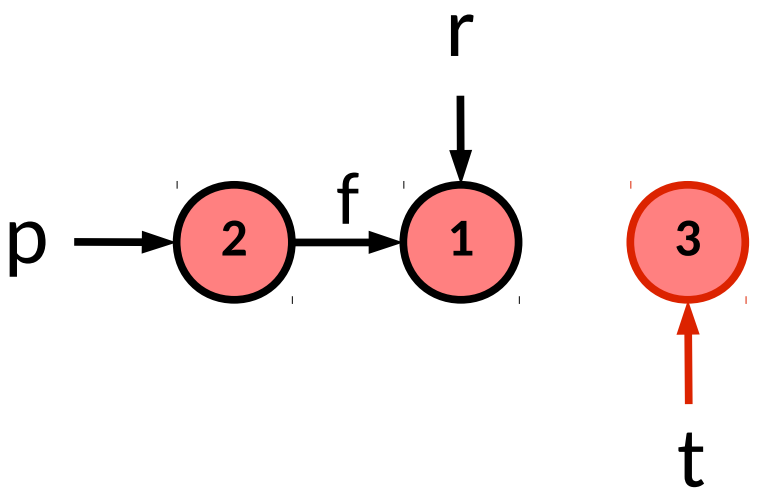

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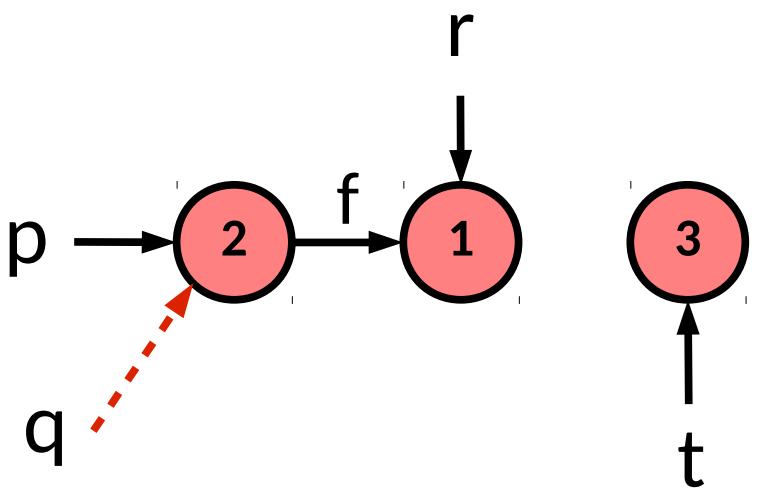

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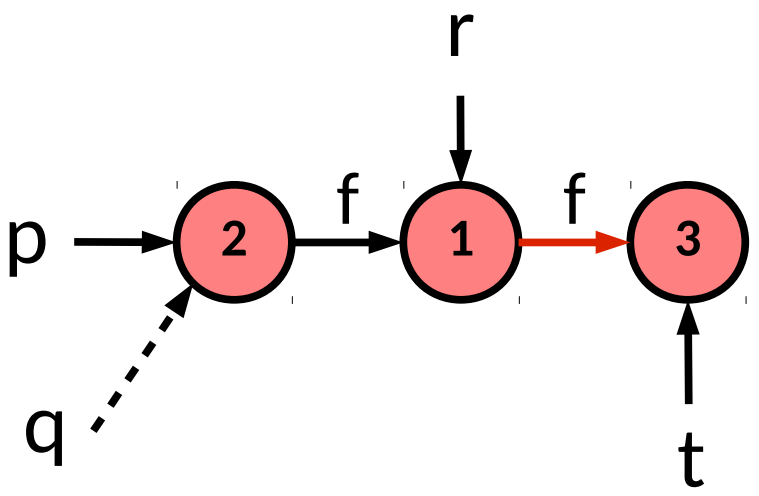

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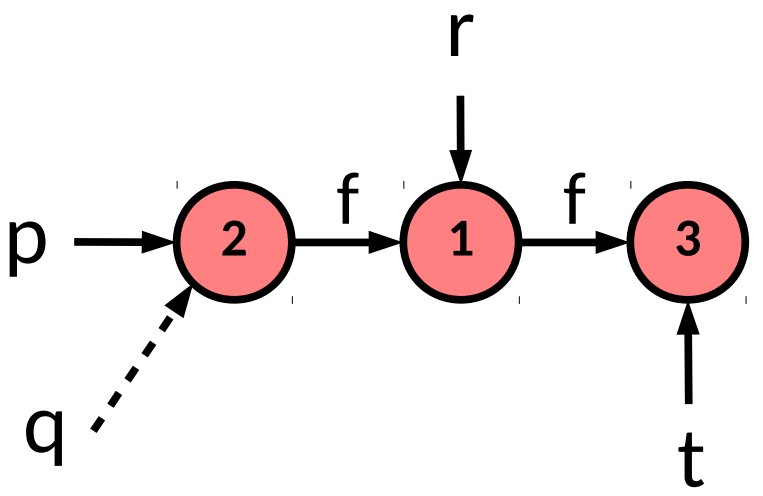

p.f.f MUST ALIAS t
q MAY ALIAS p

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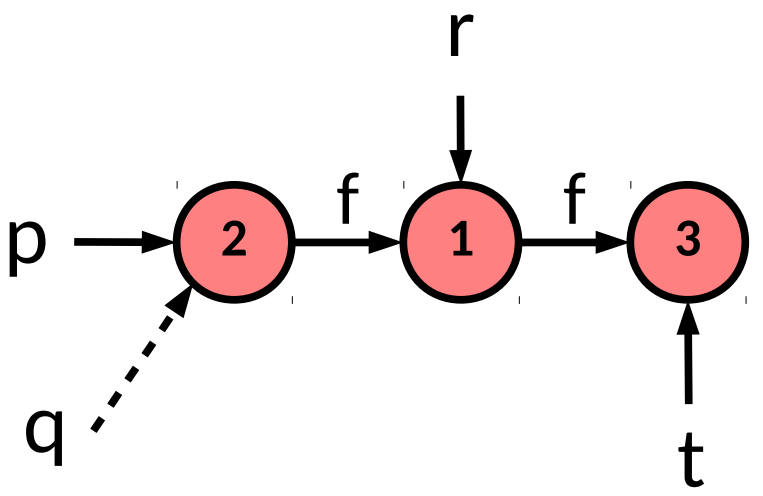

What if we add:
7) q.f = r.f
?

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- ***Program*** representations are *static*
  - All possible program behaviors at once
  - Usually projected onto the CFG

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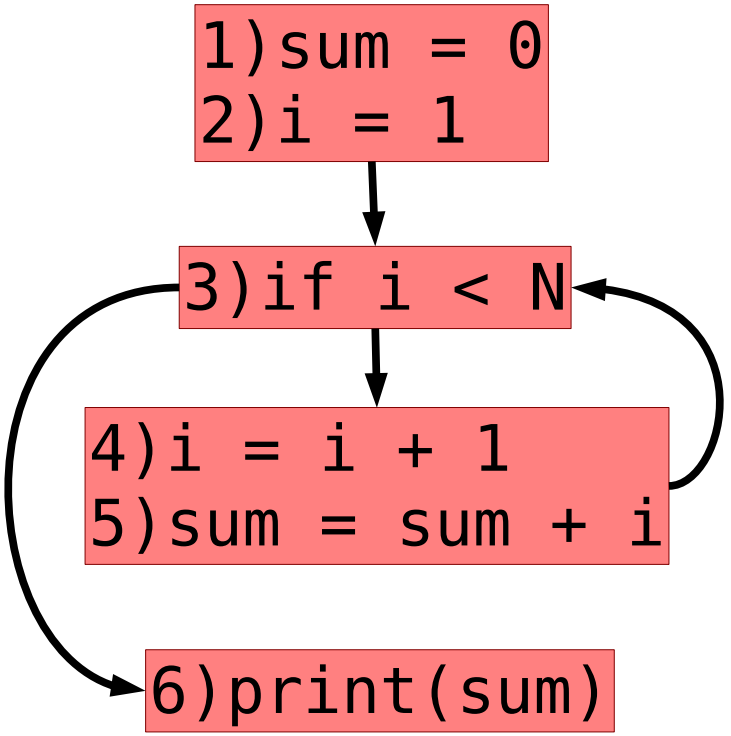
Control Flow Trace



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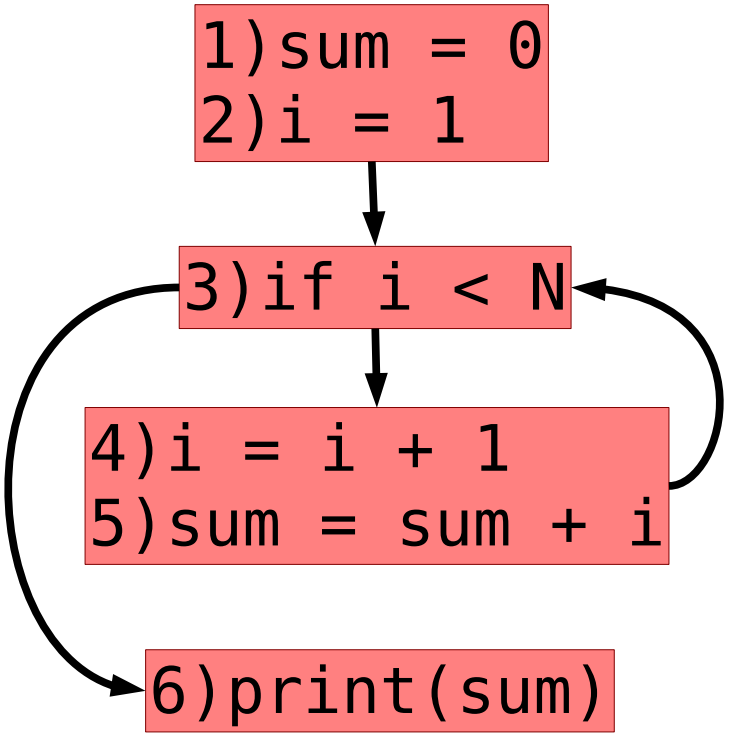


```
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6)print(sum)
```
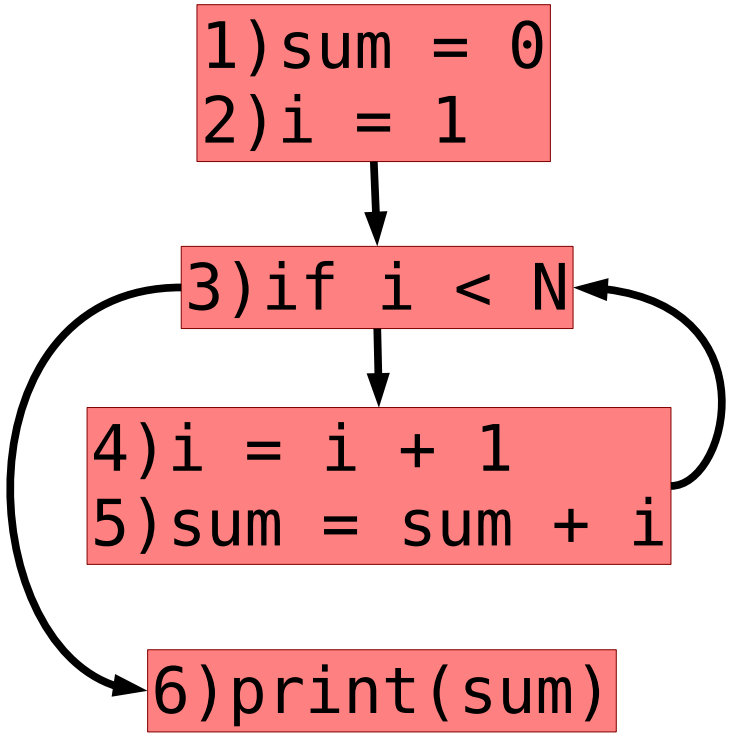

Control Flow Trace



$1_1\ 2_1\ 3_1\ 4_1\ 5_1\ 3_2\ 4_2\ 5_2\ 3_3\ 6_1$

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TTF

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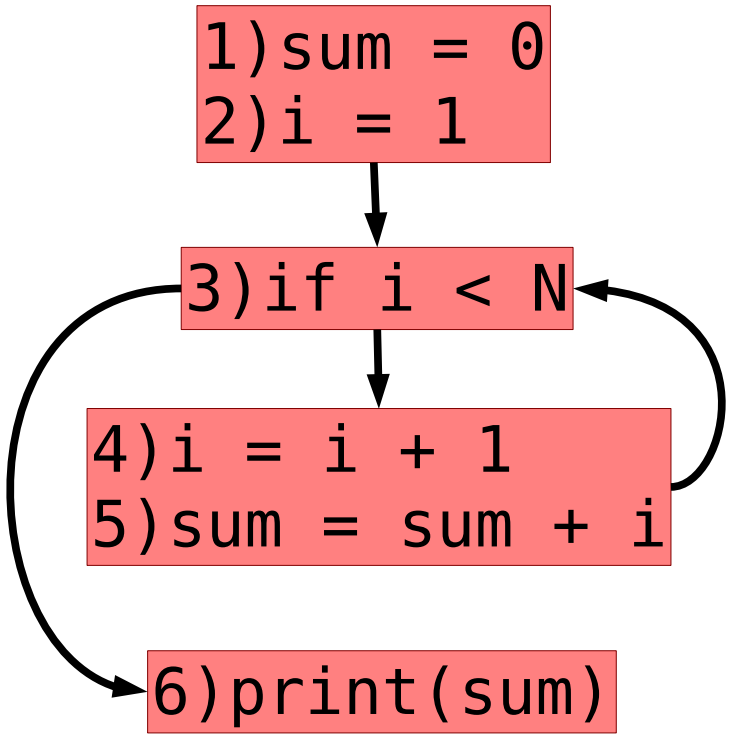


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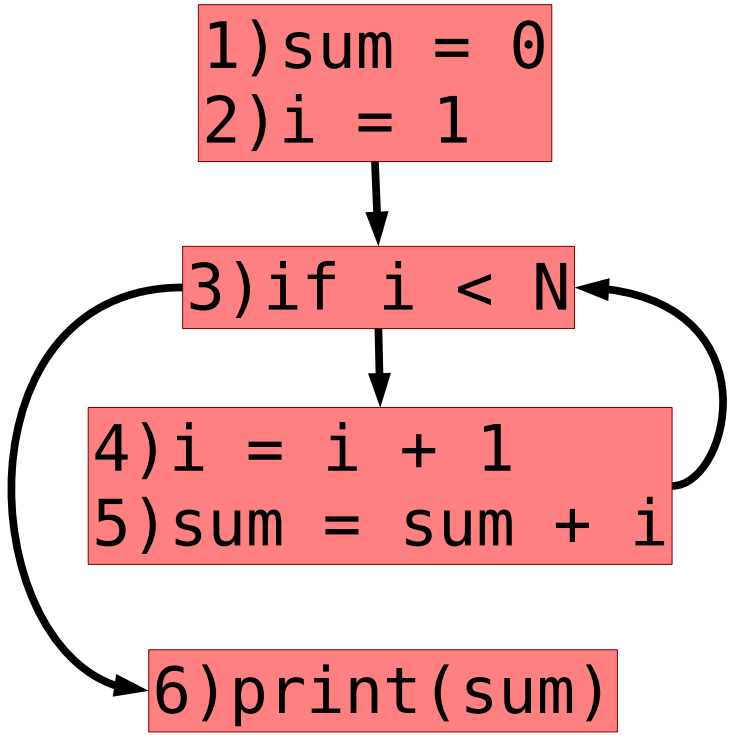
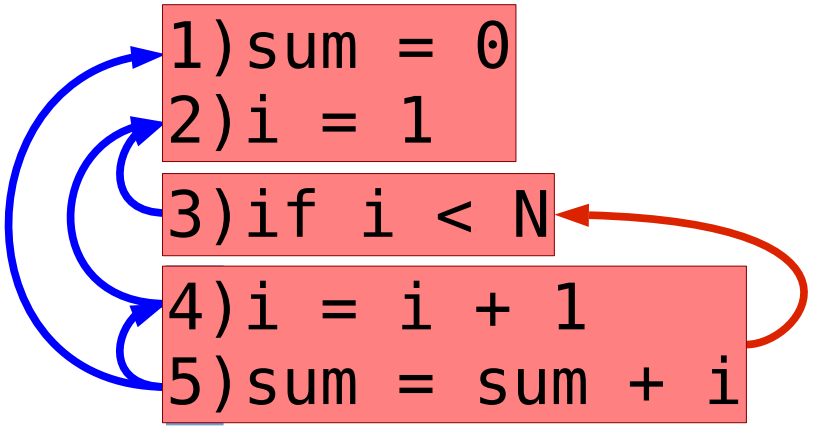
TTF

} All Equivalent

Dynamic Dependence Graph





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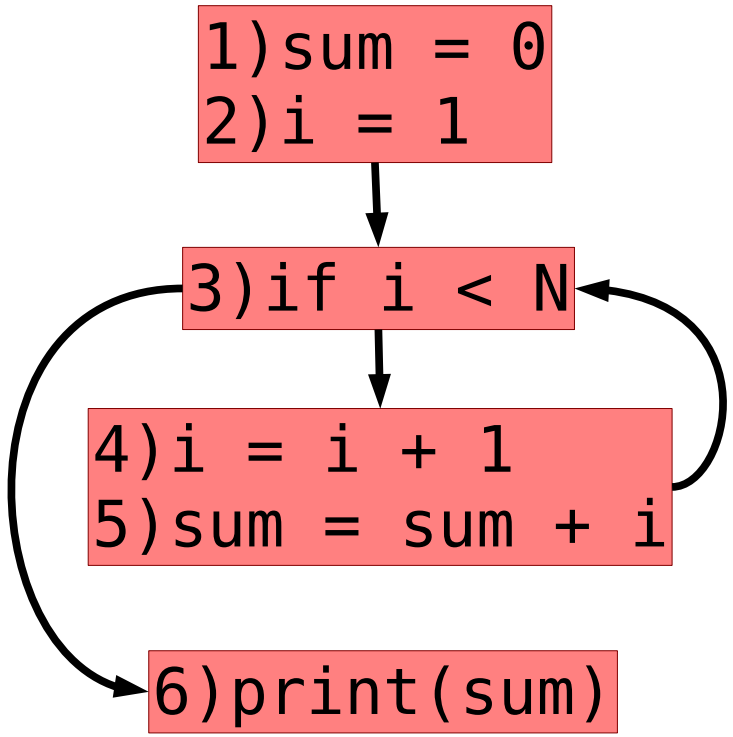

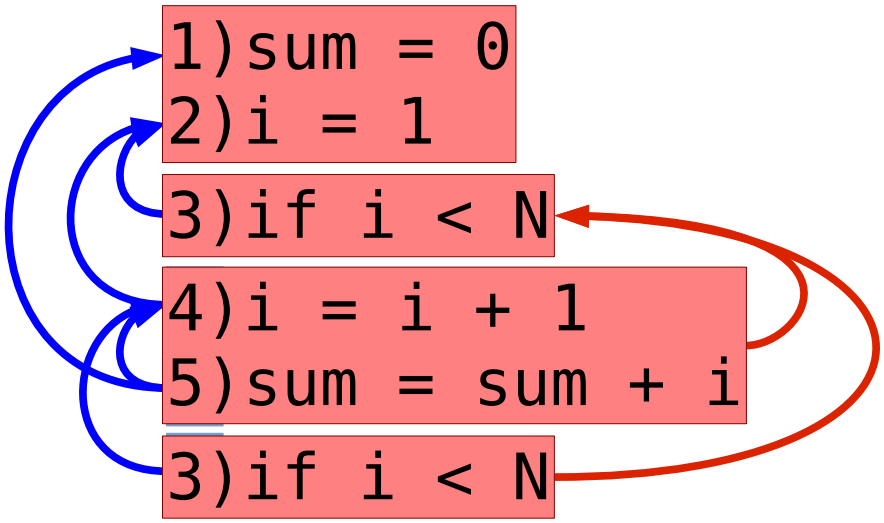

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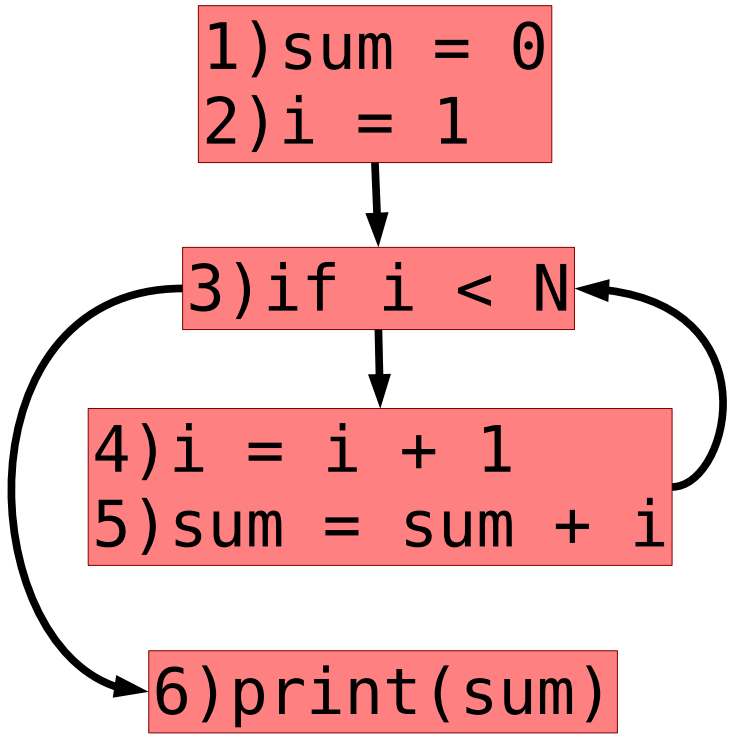

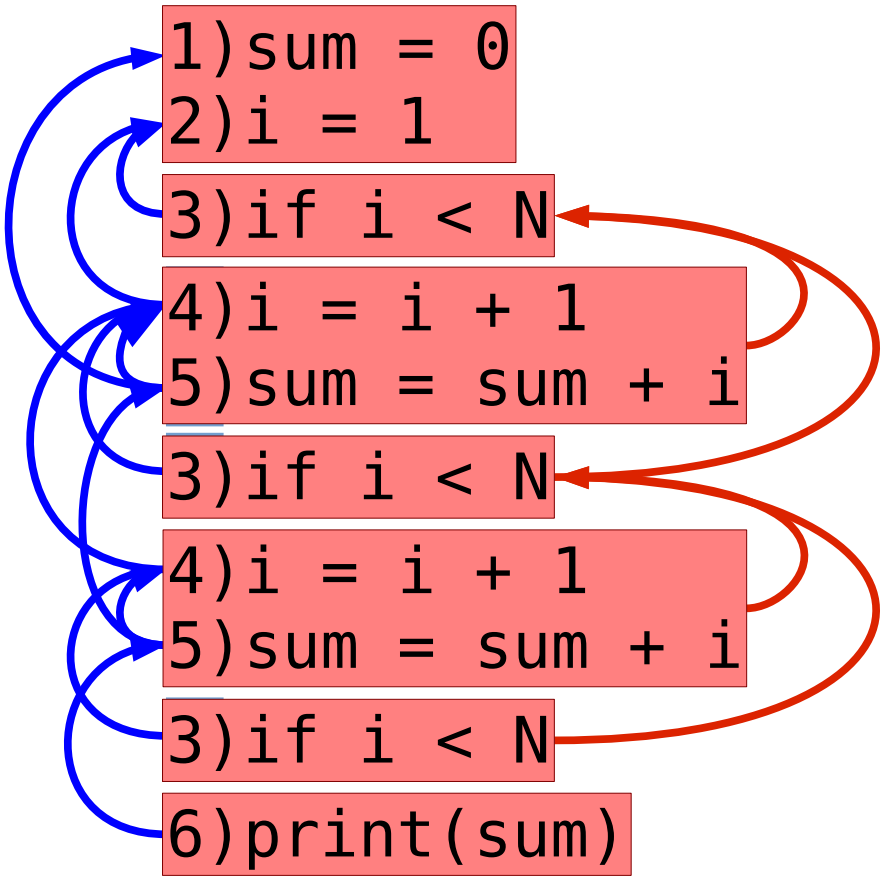

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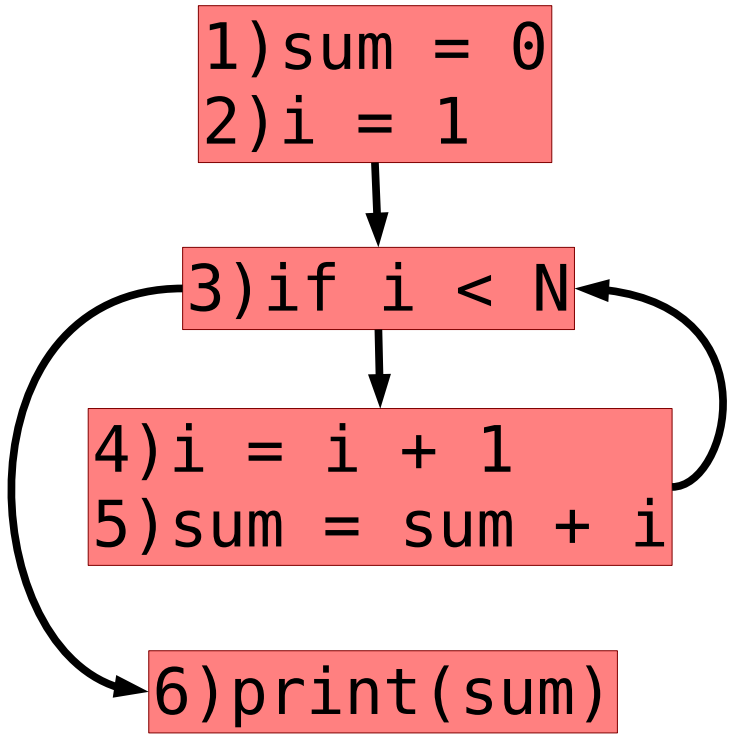
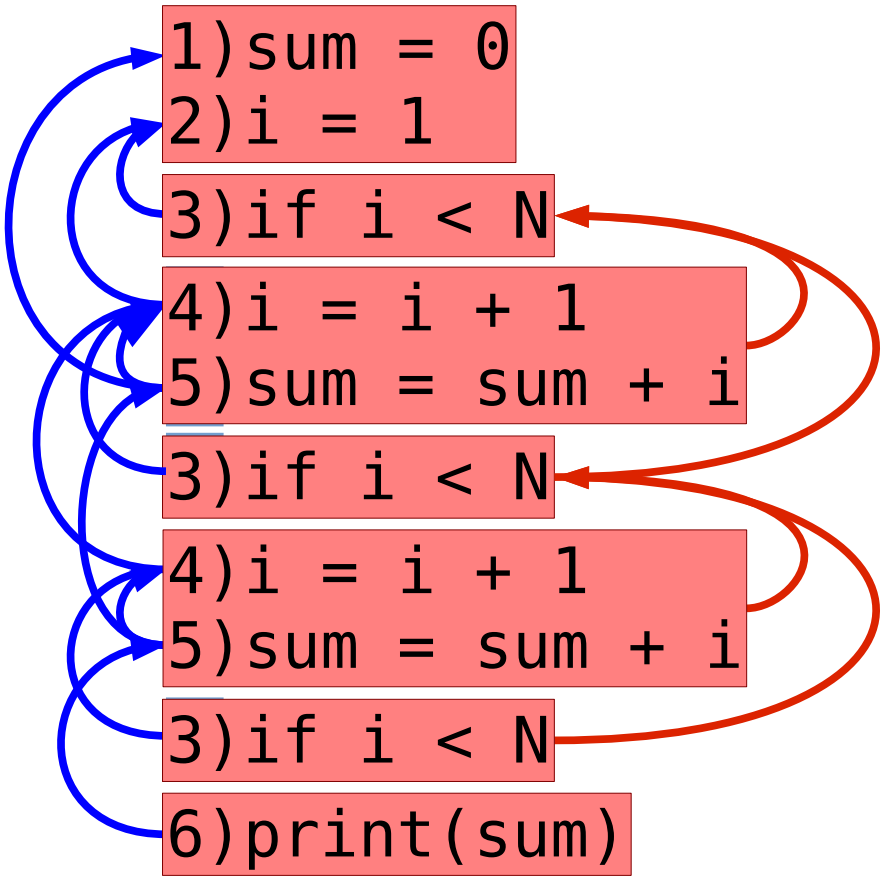
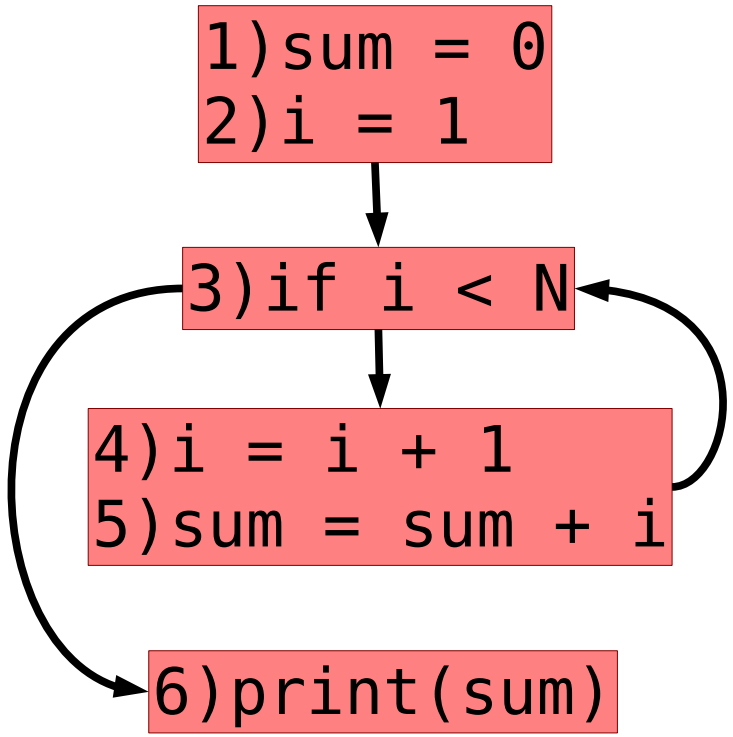
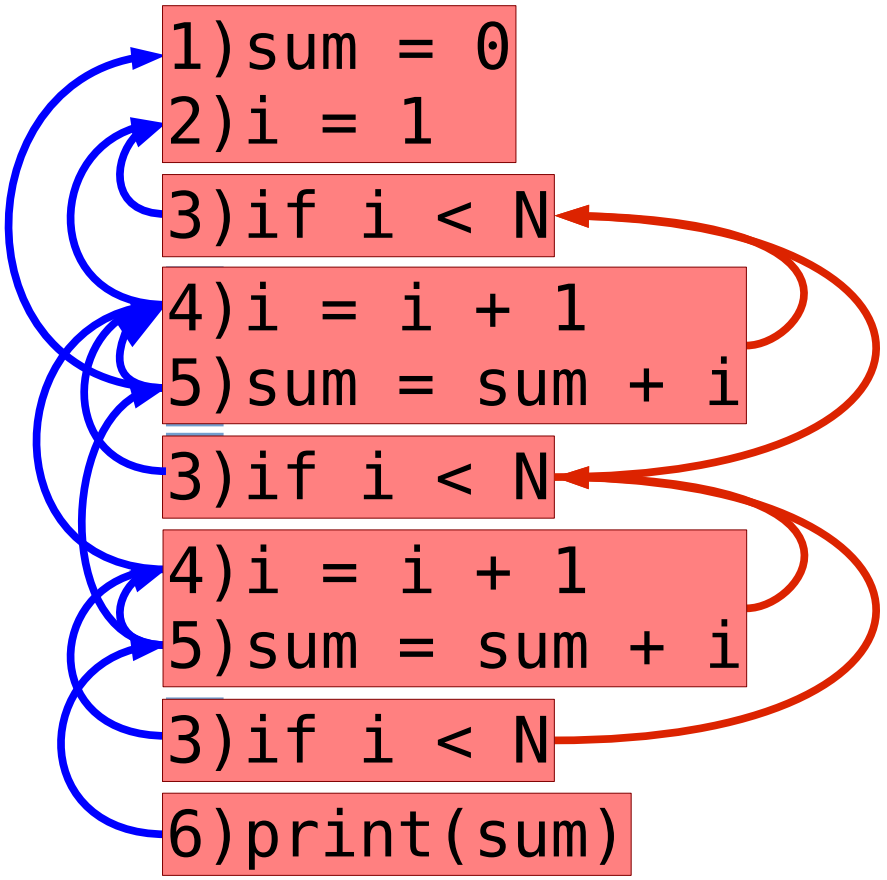




Notably a *bit* difficult for a human to wade through.

Dynamic Dependence Graph





Notably a *bit* difficult for a human to wade through.

If only we could focus on the parts that interest us…

Program Representations

Given these models, we can start to discuss interesting transformations and analyses on real programs.

Such as… slicing