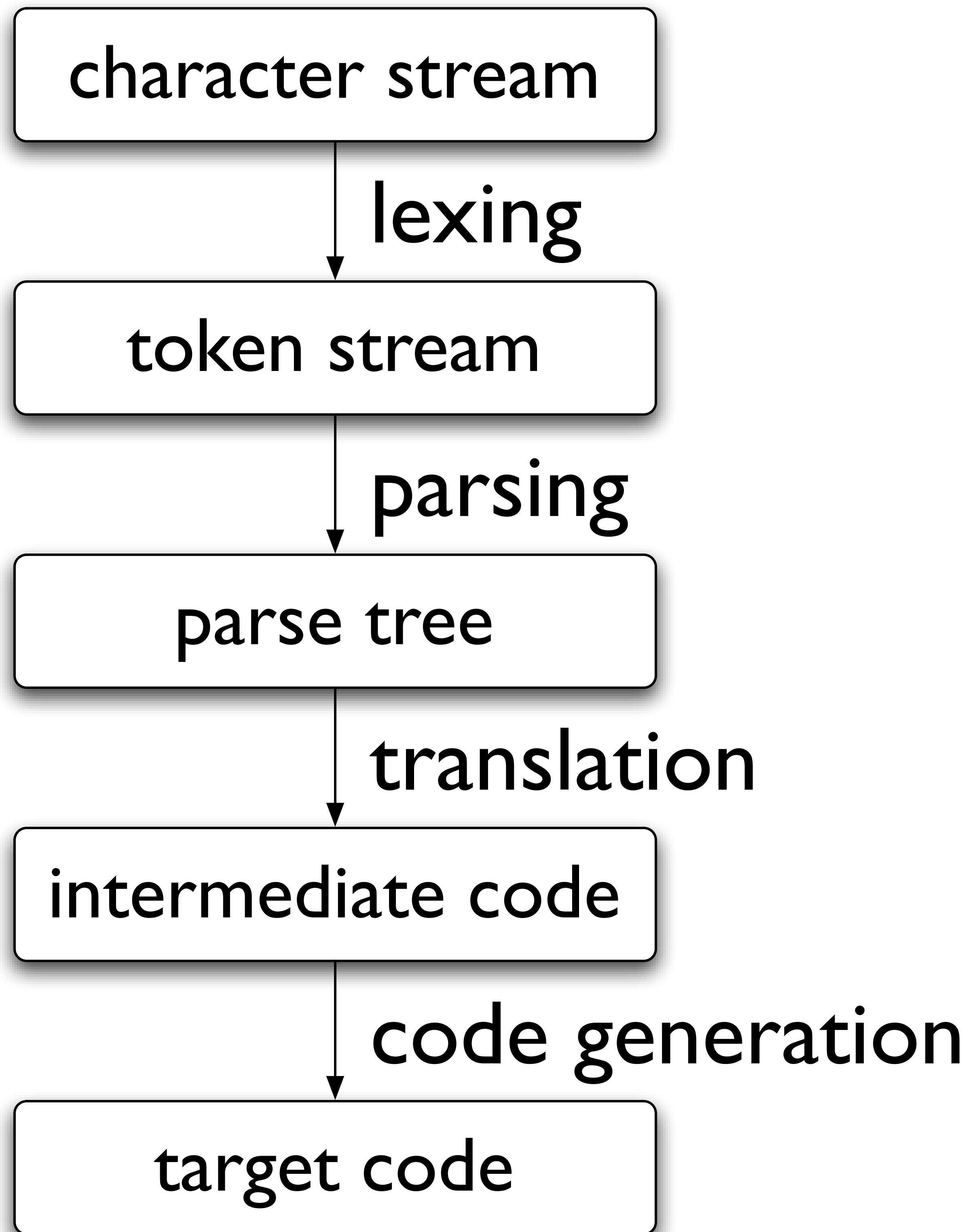
Optimising Compilers

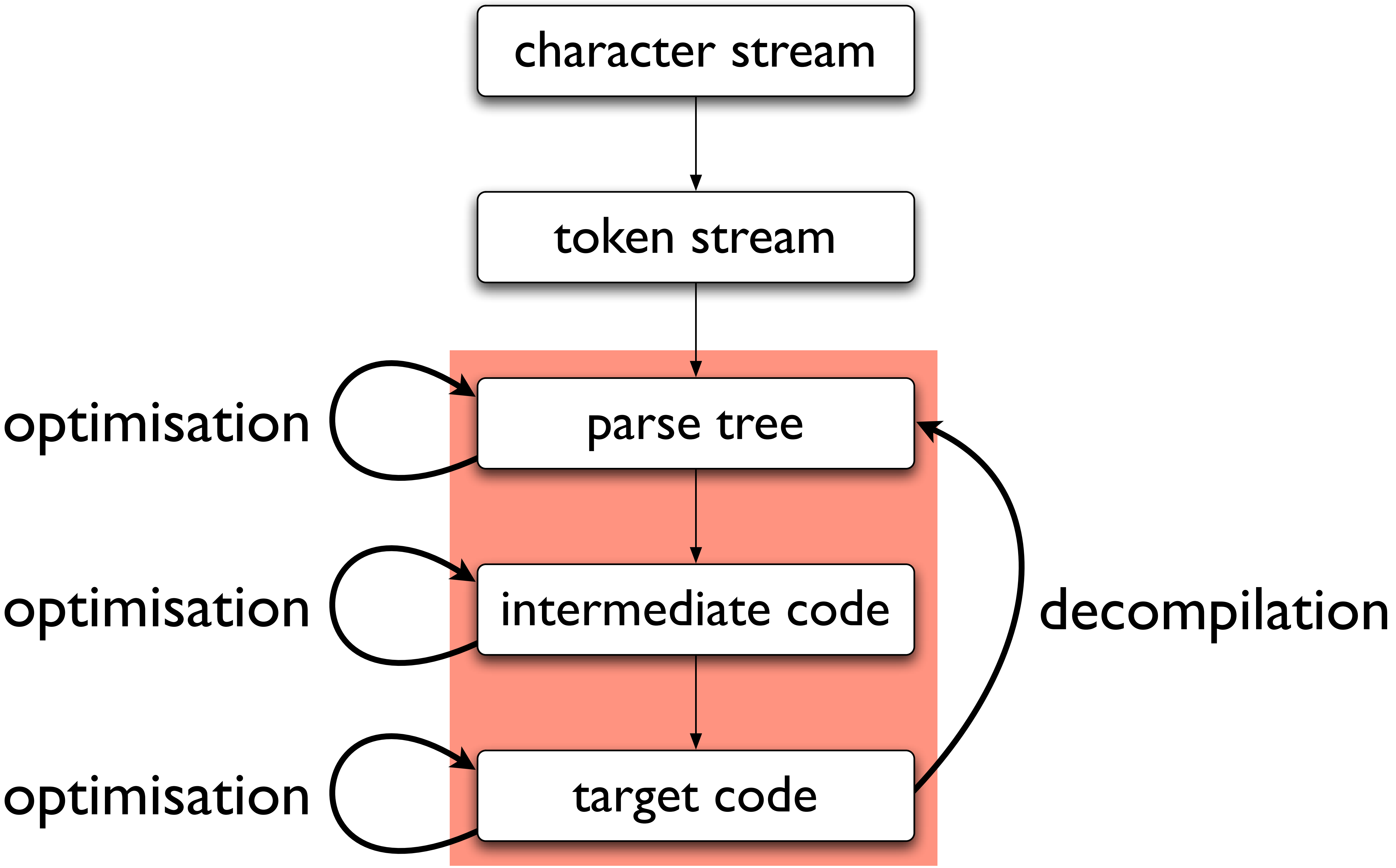
Computer Science Tripos Part II - Lent 2007

Tom Stuart

A non-optimising compiler



An optimising compiler



Optimisation

(really “amelioration”!)

Good humans write simple, maintainable, *general* code.

Compilers should then *remove unused generality*, and hence hopefully make the code:

- Smaller
- Faster
- Cheaper (e.g. lower power consumption)

Optimisation

=

Analysis

+

Transformation

Analysis + Transformation

- Transformation *does something dangerous*.
- Analysis determines *whether it's safe*.

Analysis + Transformation

- An analysis shows that your program has some property...
- ...and the transformation is designed to be safe for all programs with that property...
- ...so it's safe to do the transformation.

Analysis + Transformation

```
int main(void)
{
  return 42;
}

int f(int x)
{
  return x * 2;
}
```

Analysis + Transformation

```
int main(void)
{
  return 42;
}
```

Analysis + Transformation

```
int main(void)
{
  return f(21);
}

int f(int x)
{
  return x * 2;
}
```

Analysis + Transformation

```
int main(void)
{
  return f(21);
}
```

Analysis + Transformation

```
while (i <= k*2) {
  j = j * i;
  i = i + 1;
}
```

Analysis + Transformation

```
int t = k * 2;
while (i <= t) {
  j = j * i;
  i = i + 1;
}
```

✓

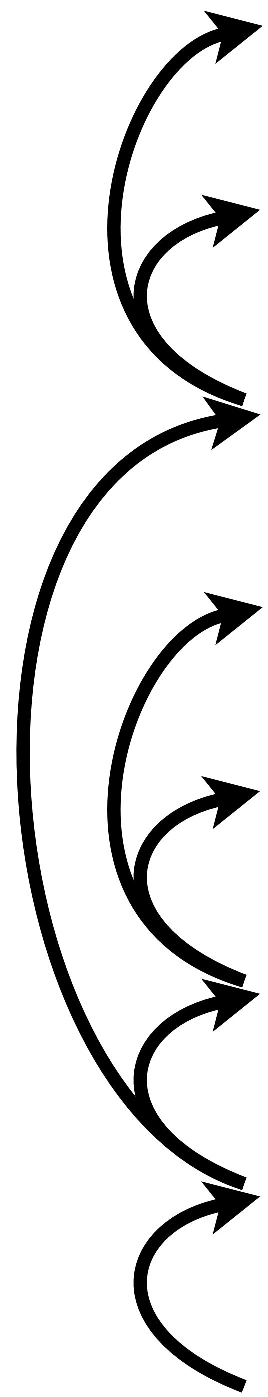
Analysis + Transformation

```
while (i <= k*2) {
  k = k - i;
  i = i + 1;
}
```

Analysis + Transformation

```
int t = k * 2;
while (i <= t) {
  k = k - i;
  i = i + 1;
}
```

Stack-oriented code



```
iload 0
iload 1
iadd
iload 2
iload 3
iadd
imul
ireturn
```

?

3-address code

```
MOV t32,arg1
MOV t33,arg2
ADD t34,t32,t33
MOV t35,arg3
MOV t36,arg4
ADD t37,t35,t36
MUL res1,t34,t37
EXIT
```

C into 3-address code

```
int fact (int n) {
  if (n == 0) {
    return 1;
  } else {
    return n * fact(n-1);
  }
}
```

C into 3-address code

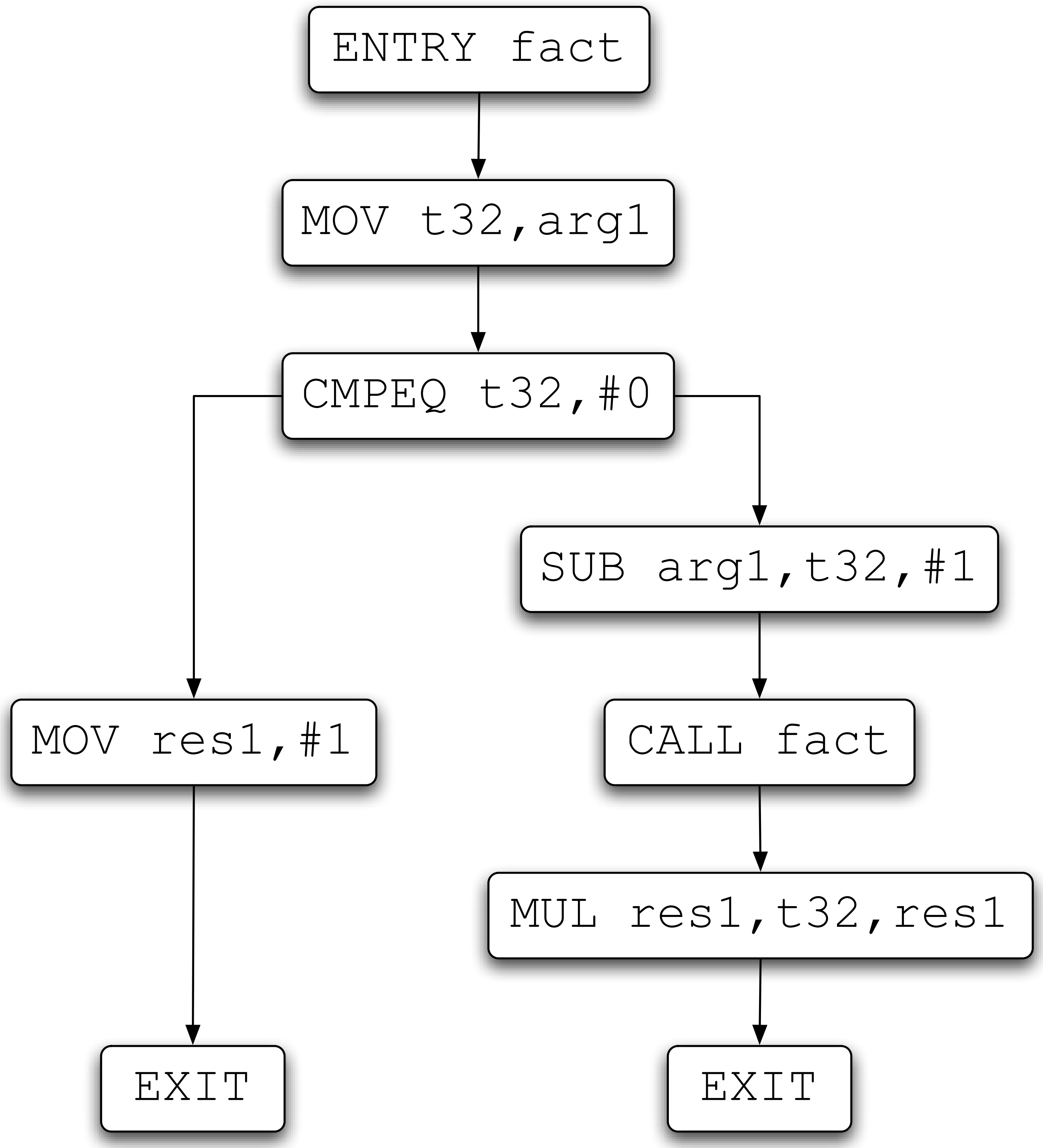
```
       ENTRY fact
       MOV t32,arg1
       CMPEQ t32,#0,lab1
       SUB arg1,t32,#1
       CALL fact
       MUL res1,t32,res1
       EXIT
lab1:  MOV res1,#1
       EXIT
```

Flowgraphs

- A graph representation of a program
- Each node stores 3-address instruction(s)
- Each edge represents (potential) control flow:

$$
\begin{aligned}
pred(n) &= \{n' \mid (n', n) \in edges(G)\} \\
succ(n) &= \{n' \mid (n, n') \in edges(G)\}
\end{aligned}
$$

Flowgraphs



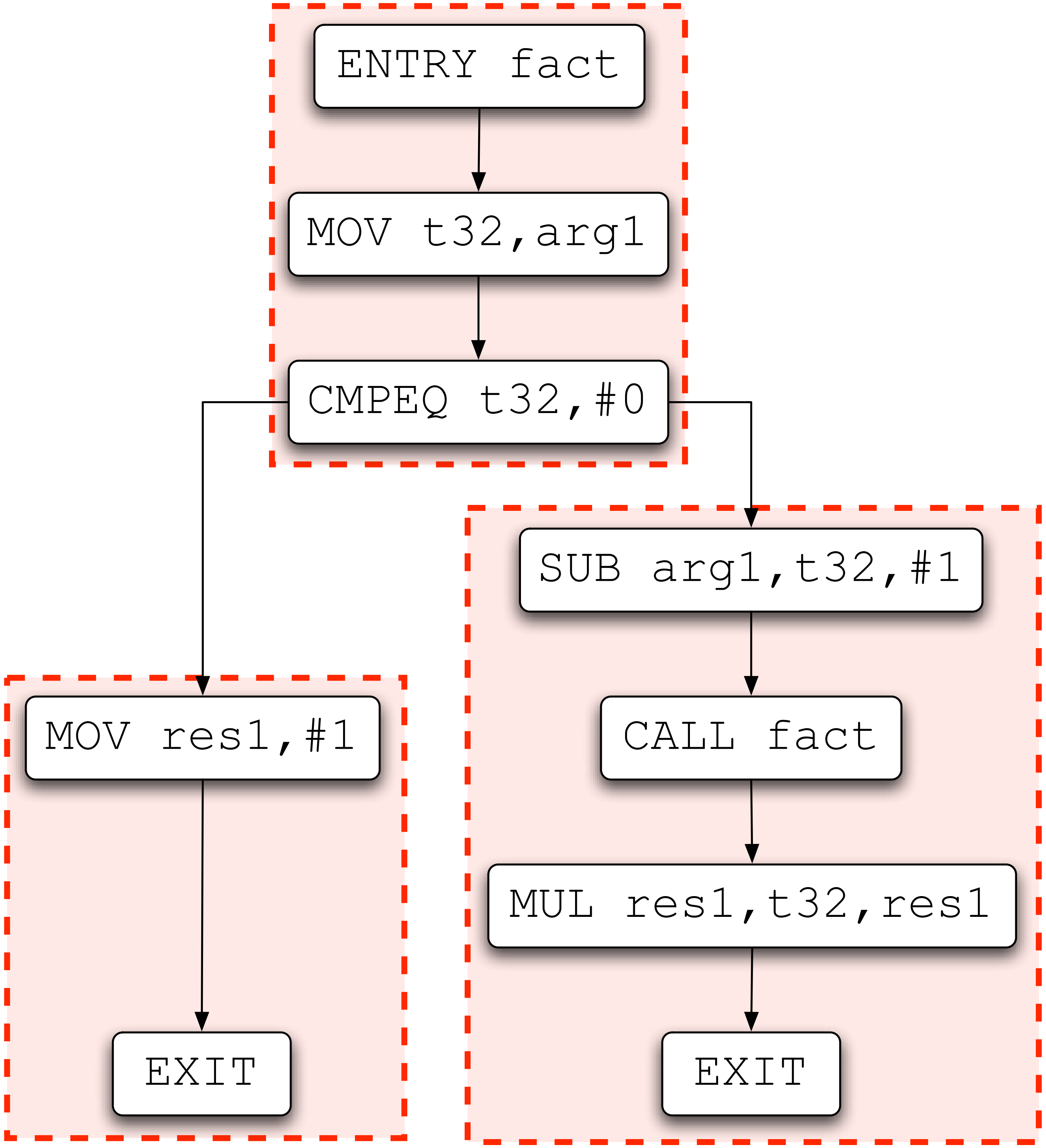
ENTRY fact
MOV t32,arg1
CMPEQ t32,#0
SUB arg1,t32,#1
MOV res1,#1
CALL fact
MUL res1,t32,res1
EXIT
EXIT

Basic blocks

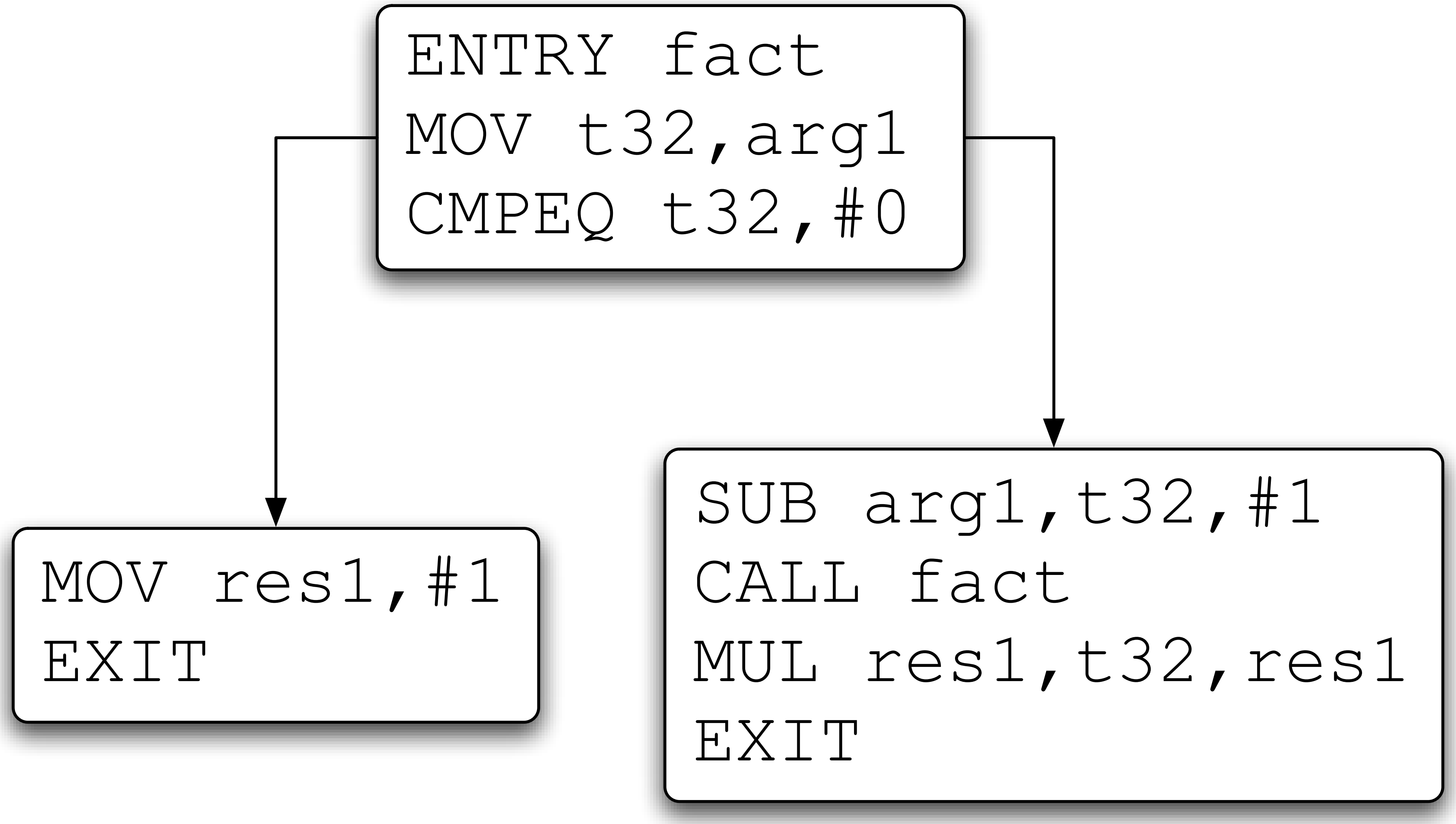
A maximal sequence of instructions $n_1, ..., n_k$ which have

- exactly one predecessor (except possibly for n_1)
- exactly one successor (except possibly for n_k)

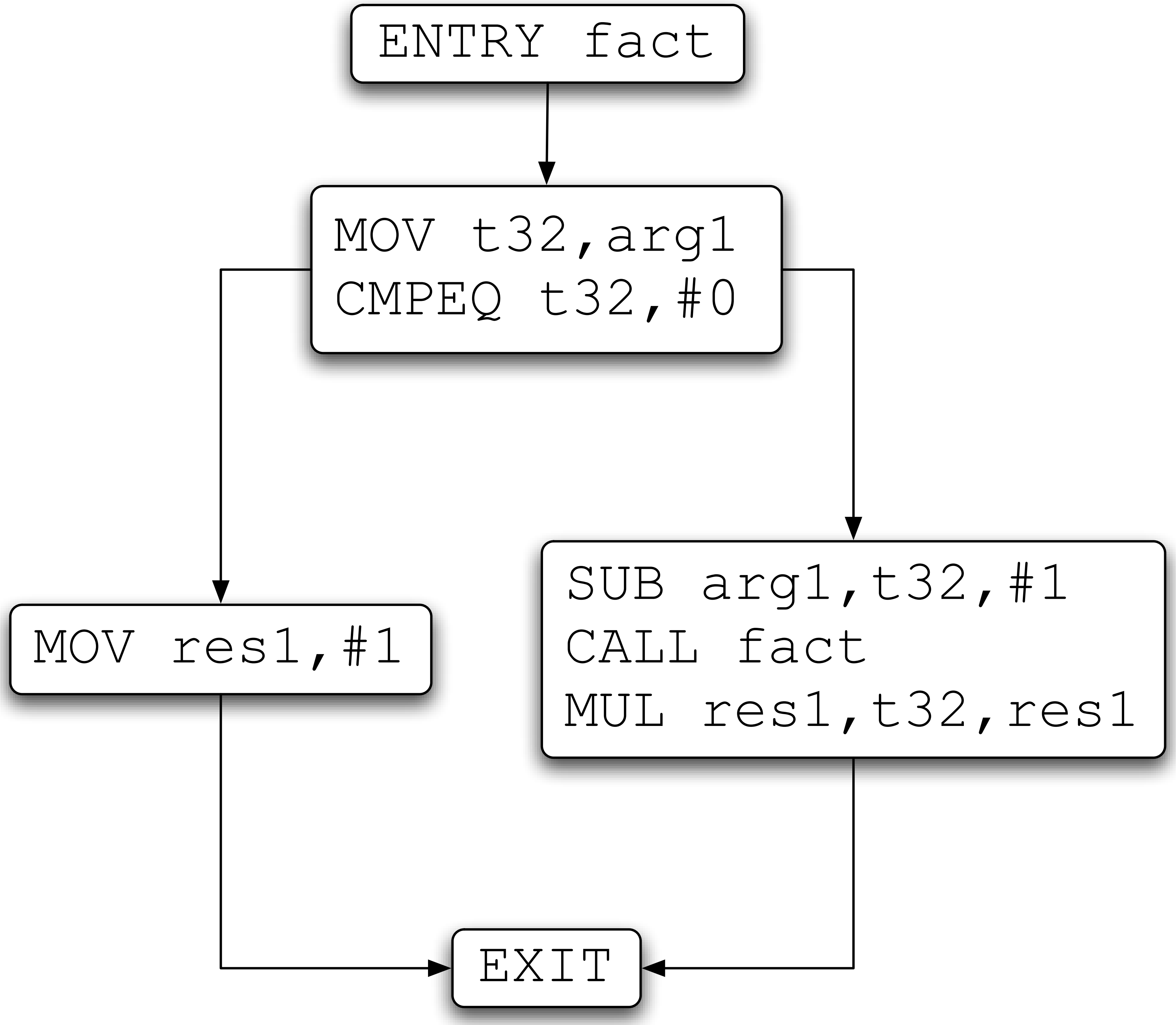
Basic blocks



Basic blocks



Basic blocks



Basic blocks

A basic block doesn’t contain any interesting control flow.

Basic blocks

Reduce time and space requirements

for analysis algorithms

by calculating and storing data flow information

once per block

(and recomputing within a block if required)

instead of

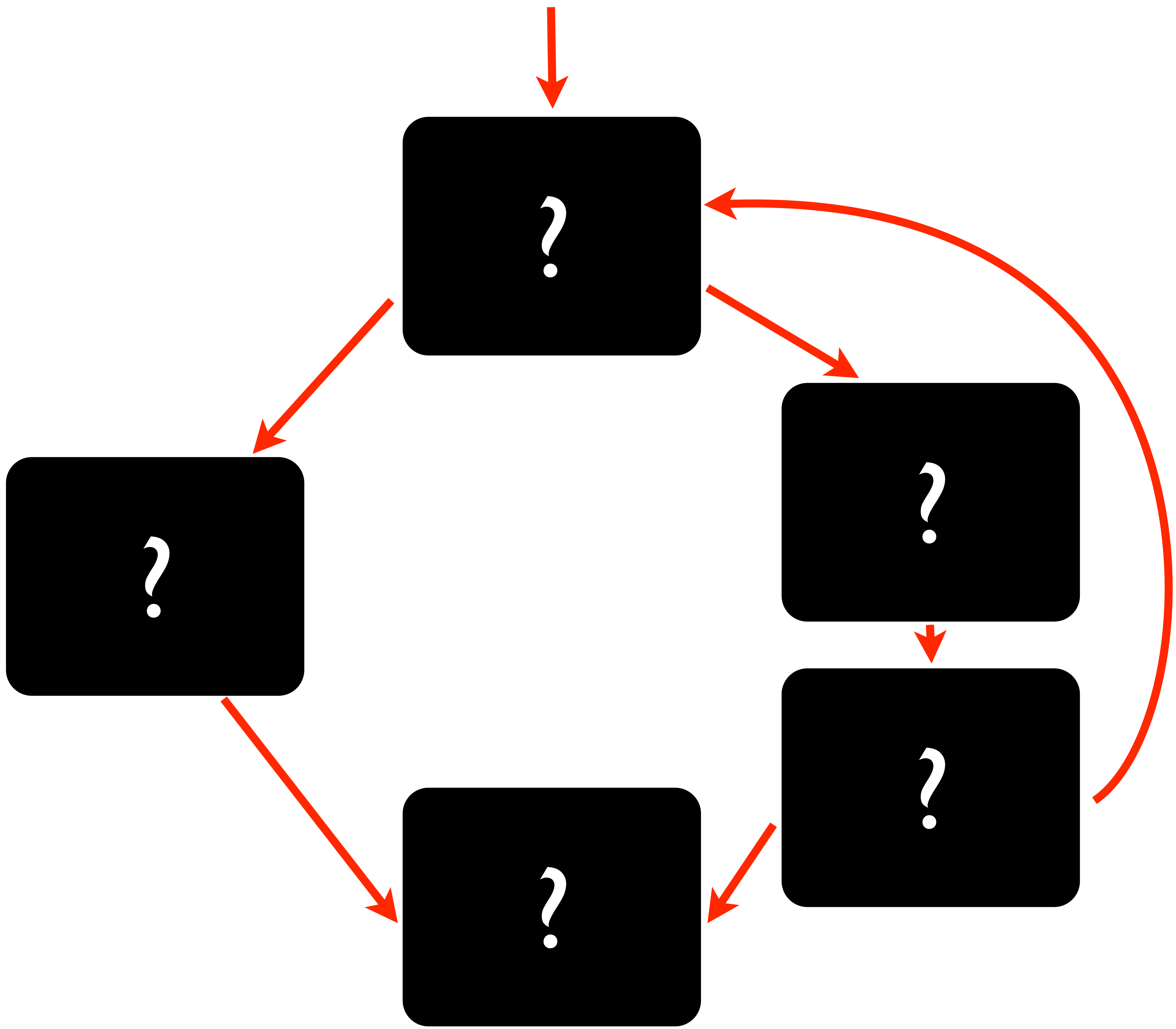
once per instruction.

Basic blocks

```
MOV t32,arg1
MOV t33,arg2
ADD t34,t32,t33
MOV t35,arg3
MOV t36,arg4
ADD t37,t35,t36
MUL res1,t34,t37
```

Basic blocks

Basic blocks



Types of analysis

(and hence optimisation)

Scope:

- Within basic blocks ("local" / "peephole")
- Between basic blocks ("global" / "intra-procedural")
  - e.g. live variable analysis, available expressions
- Whole program ("inter-procedural")
  - e.g. unreachable-procedure elimination

Peephole optimisation

```
ADD t32,arg1,#1
MOV r0,r1
MOV r1,r0
MUL t33,r0,t32
```

matches

replace

```
MOV x,y
MOV y,x
```

with

```
MOV x,y
```

↓

```
ADD t32,arg1,#1
MOV r0,r1
MUL t33,r0,t32
```

Types of analysis

(and hence optimisation)

Type of information:

- Control flow
  - Discovering control structure (basic blocks, loops, calls between procedures)
- Data flow
  - Discovering data flow structure (variable uses, expression evaluation)

Finding basic blocks

1. Find all the instructions which are *leaders*:
   - the first instruction is a leader;
   - the target of any branch is a leader; and
   - any instruction immediately following a branch is a leader.
2. For each leader, its basic block consists of itself and all instructions up to the next leader.

Finding basic blocks

```
       ENTRY fact
       MOV t32,arg1
       CMPEQ t32,#0,lab1
       SUB arg1,t32,#1
       CALL fact
       MUL res1,t32,res1
       EXIT
lab1:  MOV res1,#1
       EXIT
```

Finding basic blocks

```
        ENTRY fact
        MOV t32,arg1
        CMPEQ t32,#0,lab1
        SUB arg1,t32,#1
        CALL fact
        MUL res1,t32,res1
        EXIT
lab1:   MOV res1,#1
        EXIT
```

Summary

- Structure of an optimising compiler
- Why optimise?
- Optimisation = Analysis + Transformation
- 3-address code
- Flowgraphs
- Basic blocks
- Types of analysis
- Locating basic blocks