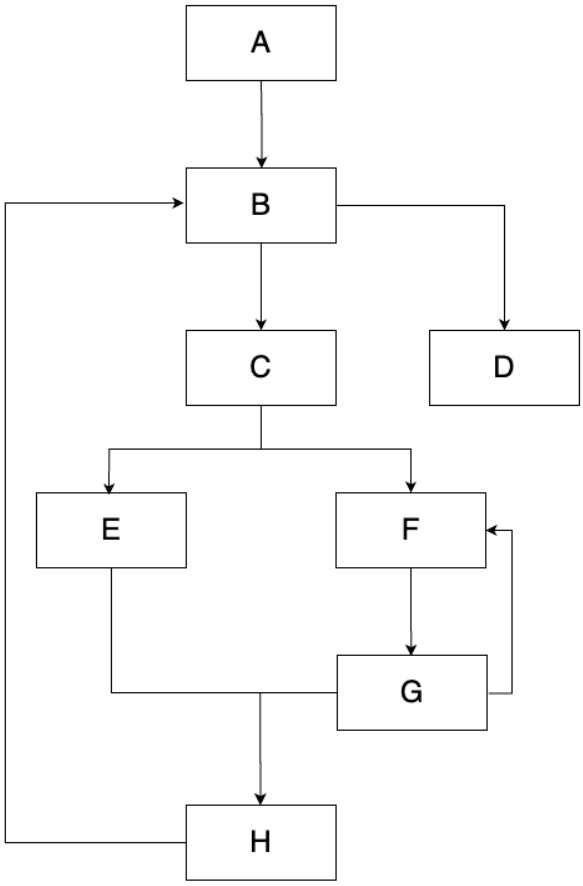
1 Dominance

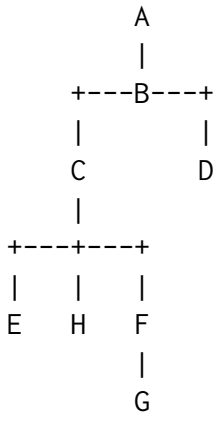
In the following CFG, `A` is the entry node and `D` is the exit node.



1.1 Dominator Tree

Draw the dominator tree of the CFG.

Answer:



1.2 Finding Loops

There are two loops in this CFG. Identify loop header and nodes of each loop.

Loop	Header	Nodes
1		
2		

Answer:

Loop	Header	Nodes
1	B	B, C, E, F, G, H
2	F	F, G

1.3 Decaf Detective

Using just control flow keywords, write the skeleton of a function body that could produce this CFG.

Answer: There are many possible answers. One is:

```
...
for (...) {
    if (...) {
        ...
    } else {
        while (...) {
            ...
        }
    }
}
```

2 Loop Optimizations

Consider the following Decaf snippet:

```
int a = 4;
int d = 24;
while (a < 12) {
    int b = (d + 72) / d;
    int c = 4 * a + 8;
    printf("Lick 'em %d %d\n", c, b);
    a += 2;
}
```

2.1 Which variable is the base induction variable?

Answer: a is the base induction variable.

2.2 Which variable(s) are derived induction variables?

Answer: c is a derived induction variable with triple $\langle a, 4, 8 \rangle$.

2.3 Which statement(s) are loop-invariant?

Answer: `b = (d + 72) / d;`

2.4 Putting it All Together

Using your answers to previous parts, write an optimized Decaf snippet that produces the same results.

Answer:

```
int cc = 24;
int d = 24;
int b = (d + 72) / d;
```

```
while (cc < 56) {
  printf("Lick 'em %d %d\n", cc, b);
  cc += 8;
}
```

3 Parallelization

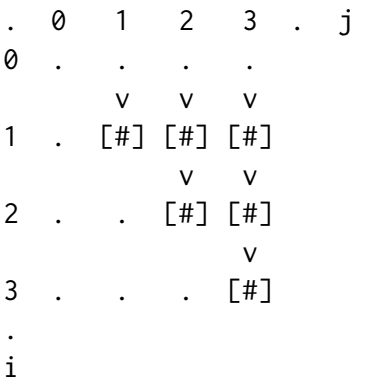
Consider the following loop nest:

```
for (int i = 0; i < n; i++) {
    for (int j = n - 1; j >= i; j--) {
        A[i][j] = A[i - 1][j] * 2025;
    }
}
```

3.1 Iteration Space

Assuming $n = 4$, draw the iteration space and distance vector(s) for this loop nest.

Answer:



3.2 Distance Vectors

What is the distance vector for this loop nest?

Answer: $(1, 0)$.

3.3 Speeding it Up

Which loop(s) can run in parallel?

Answer: The inner (j) loop can be parallelized.