Sorting integer arrays: security, speed, and verification

D. J. Bernstein

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From: Alice


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Bob assumes this message is something Alice actually sent.

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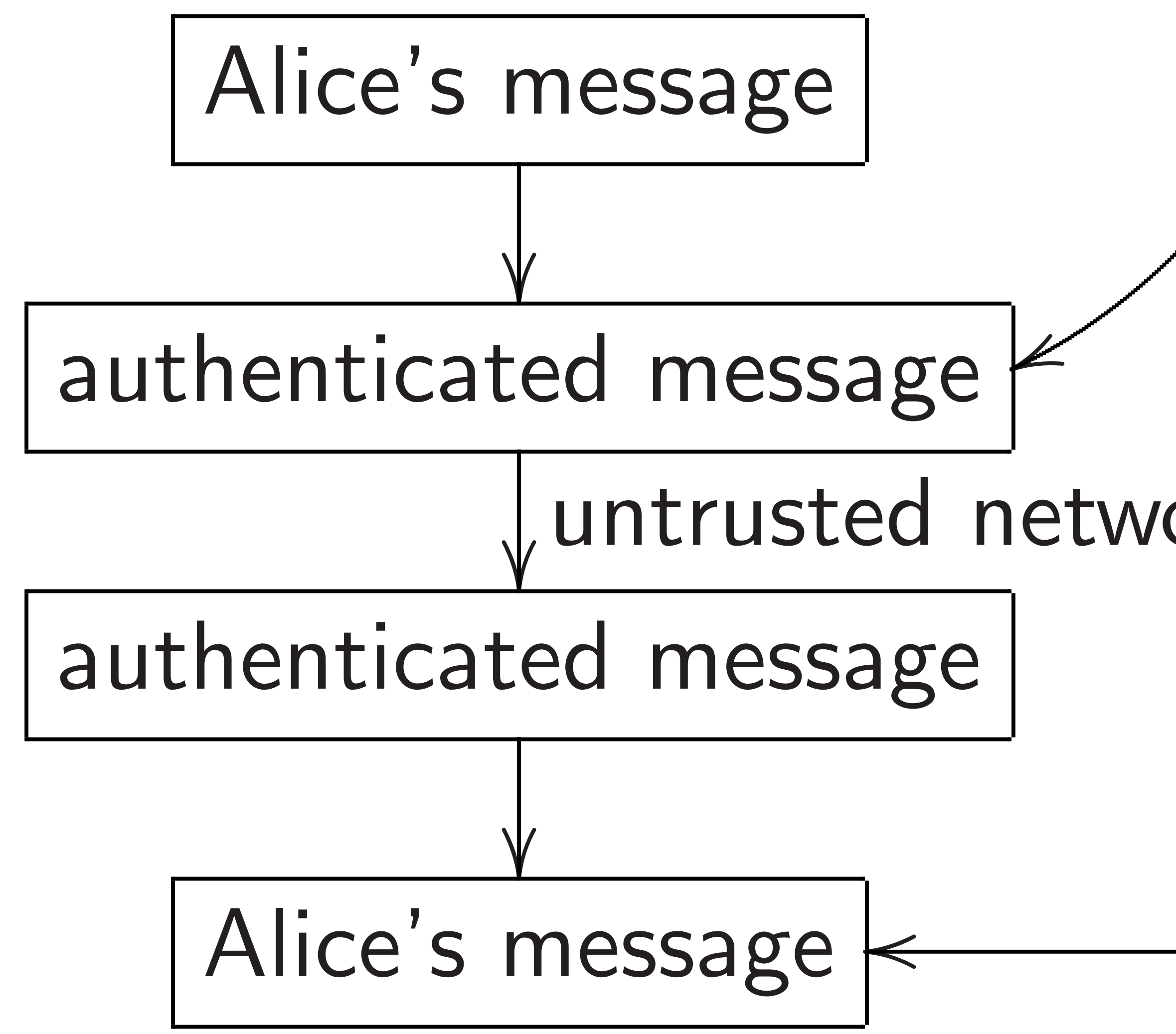

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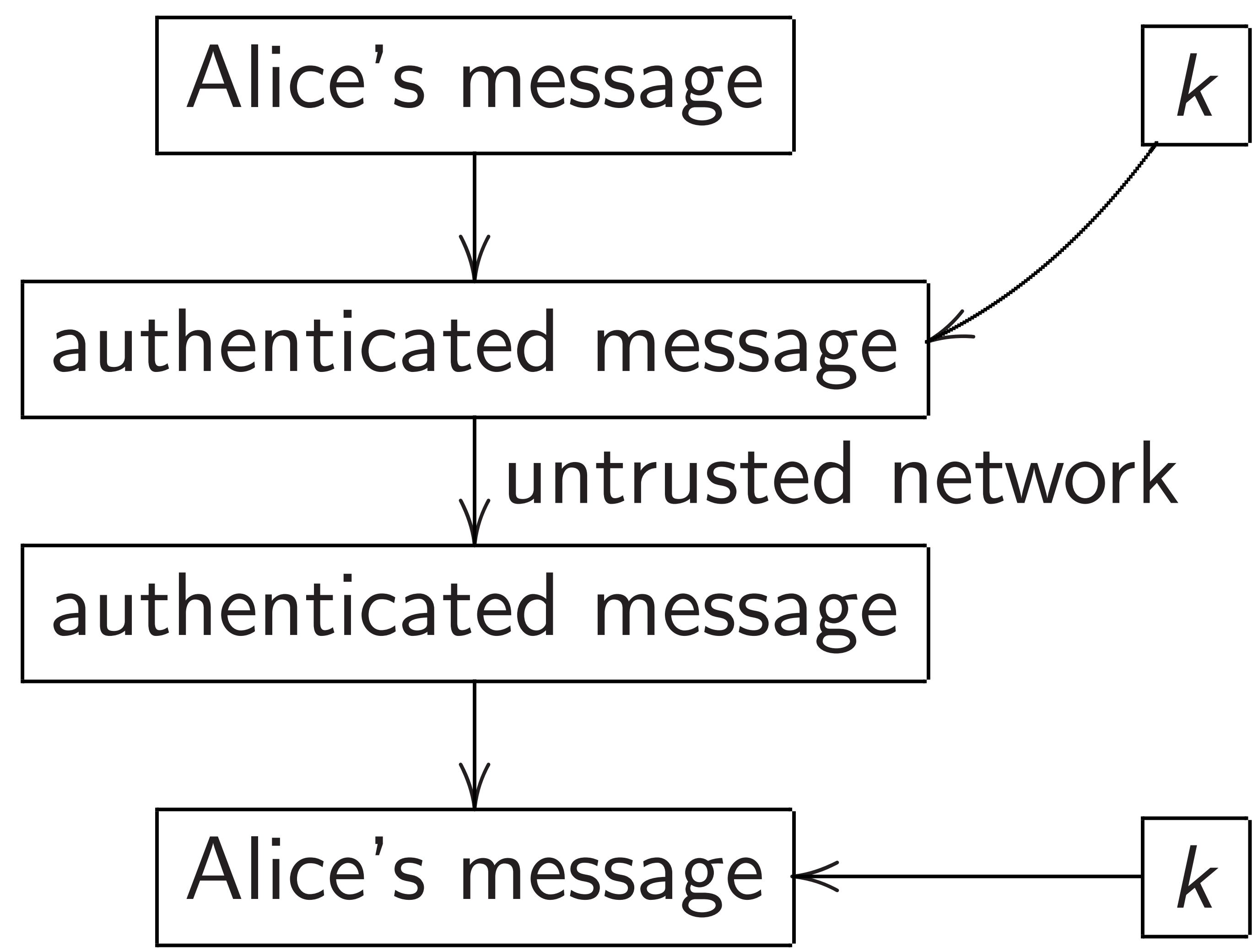

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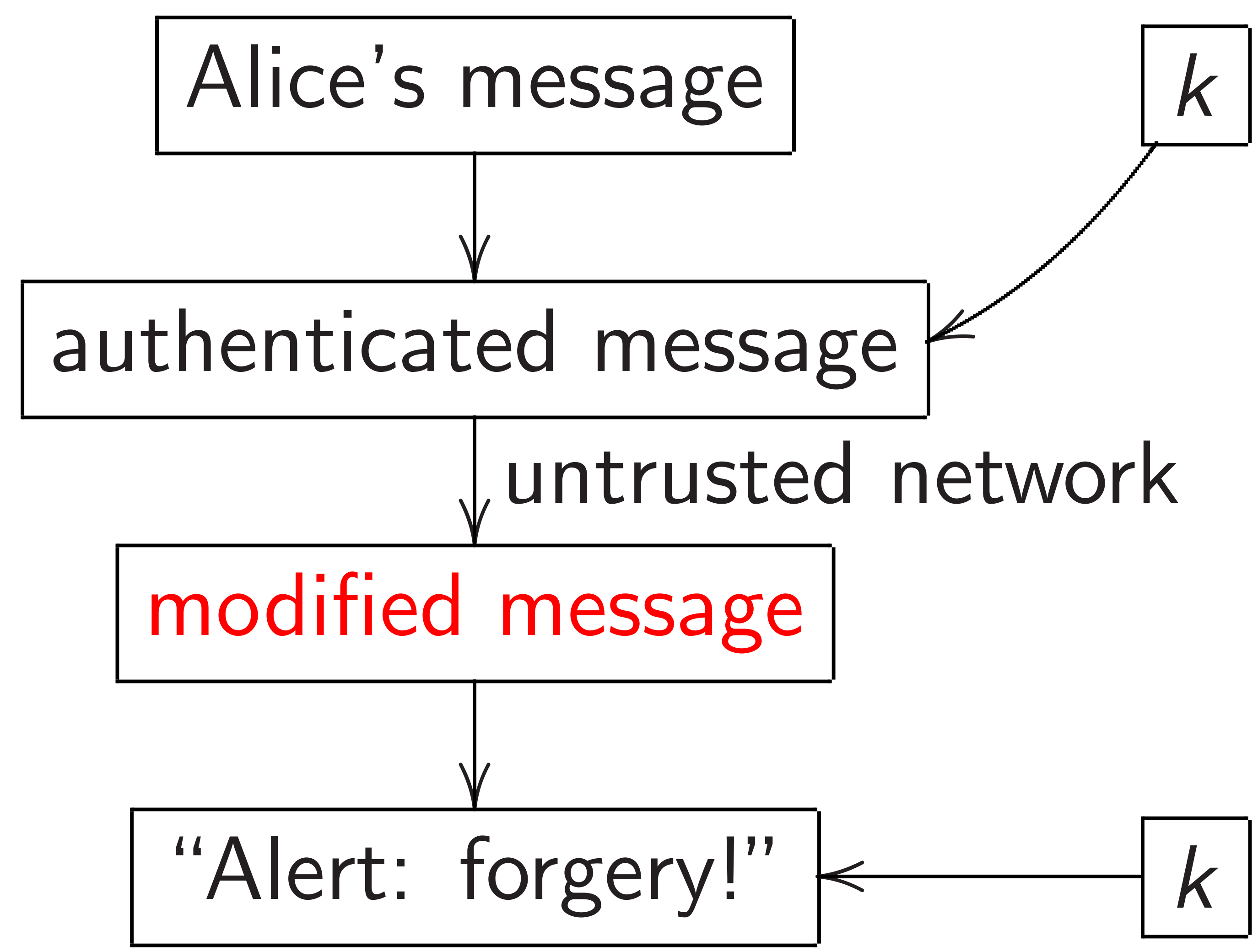

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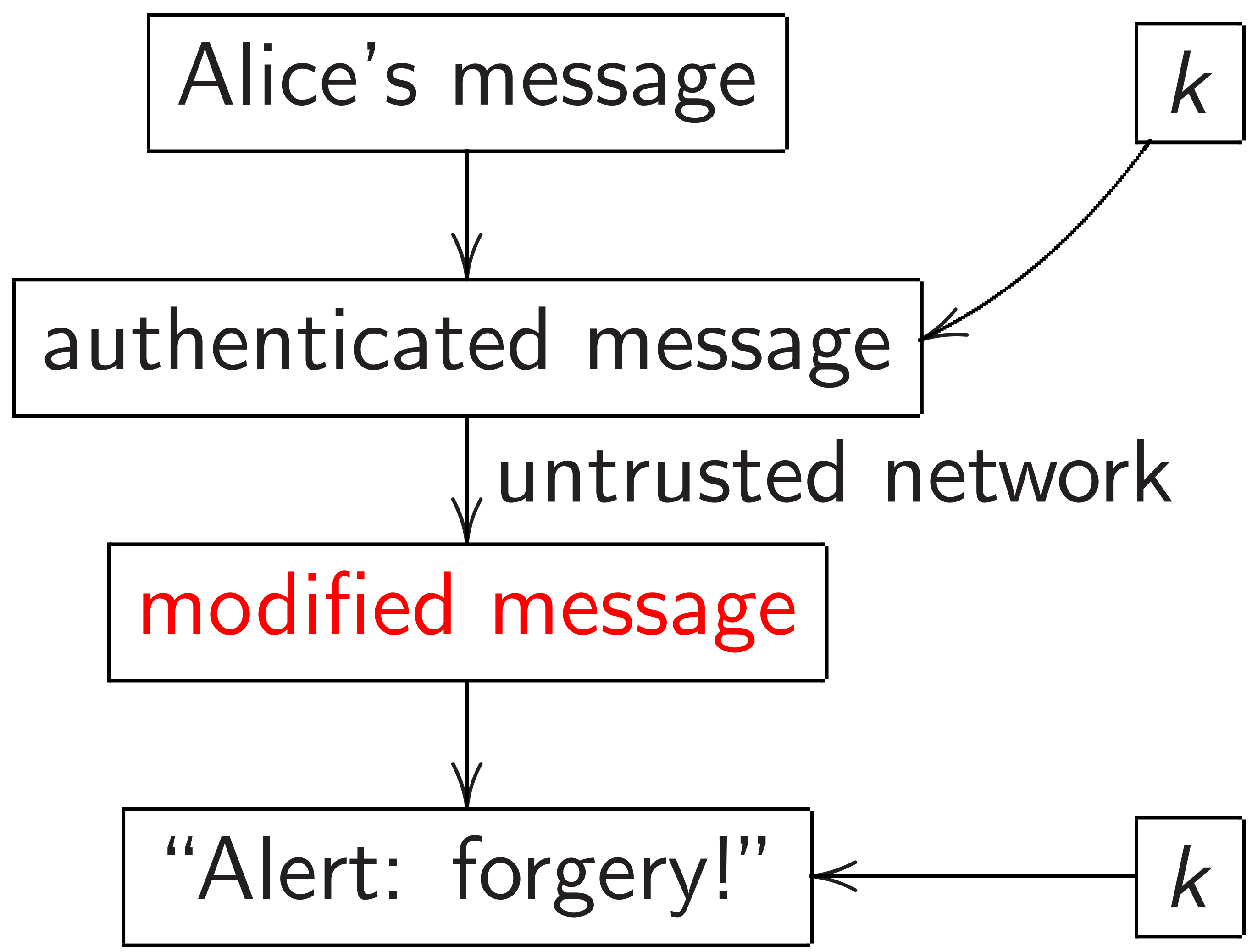

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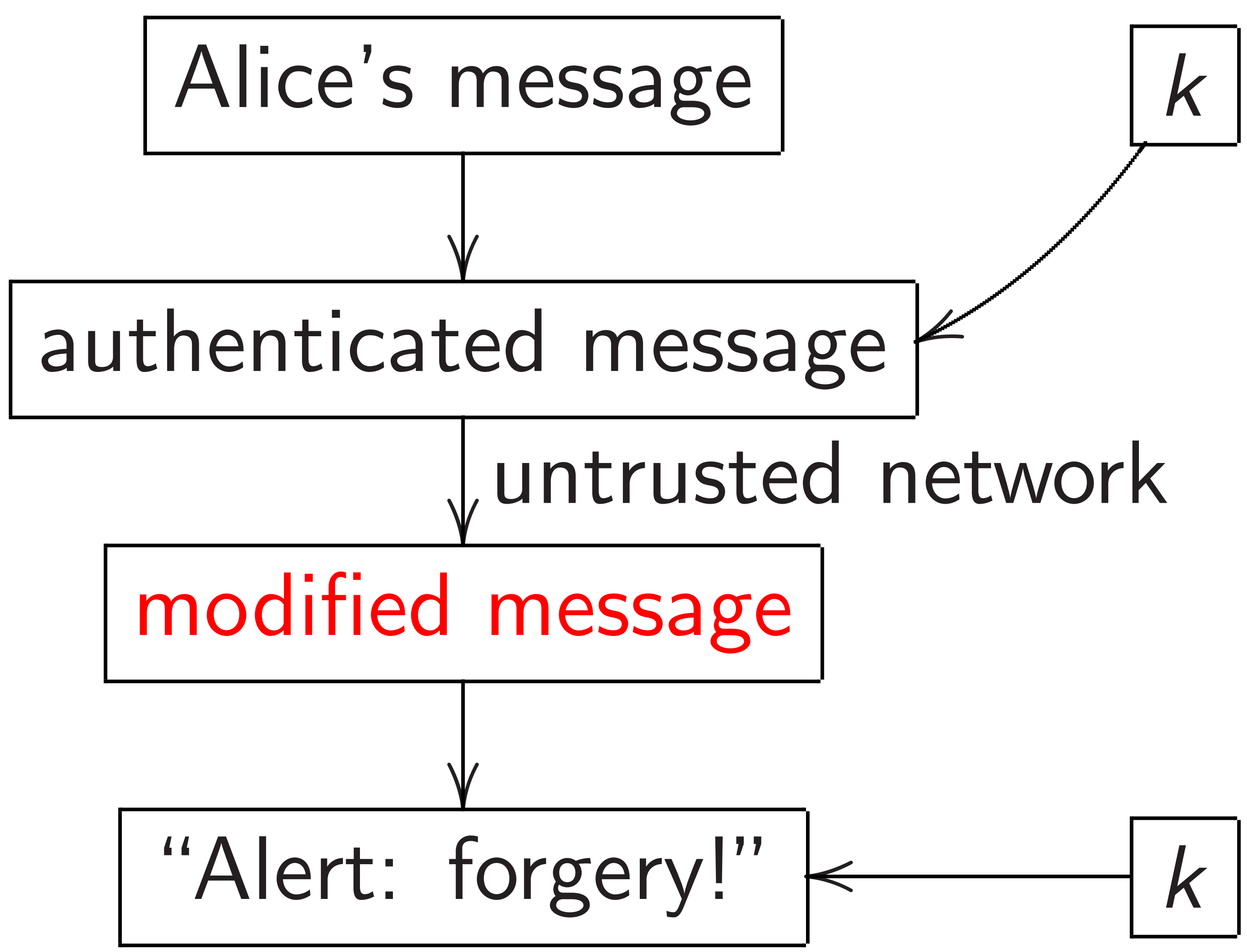

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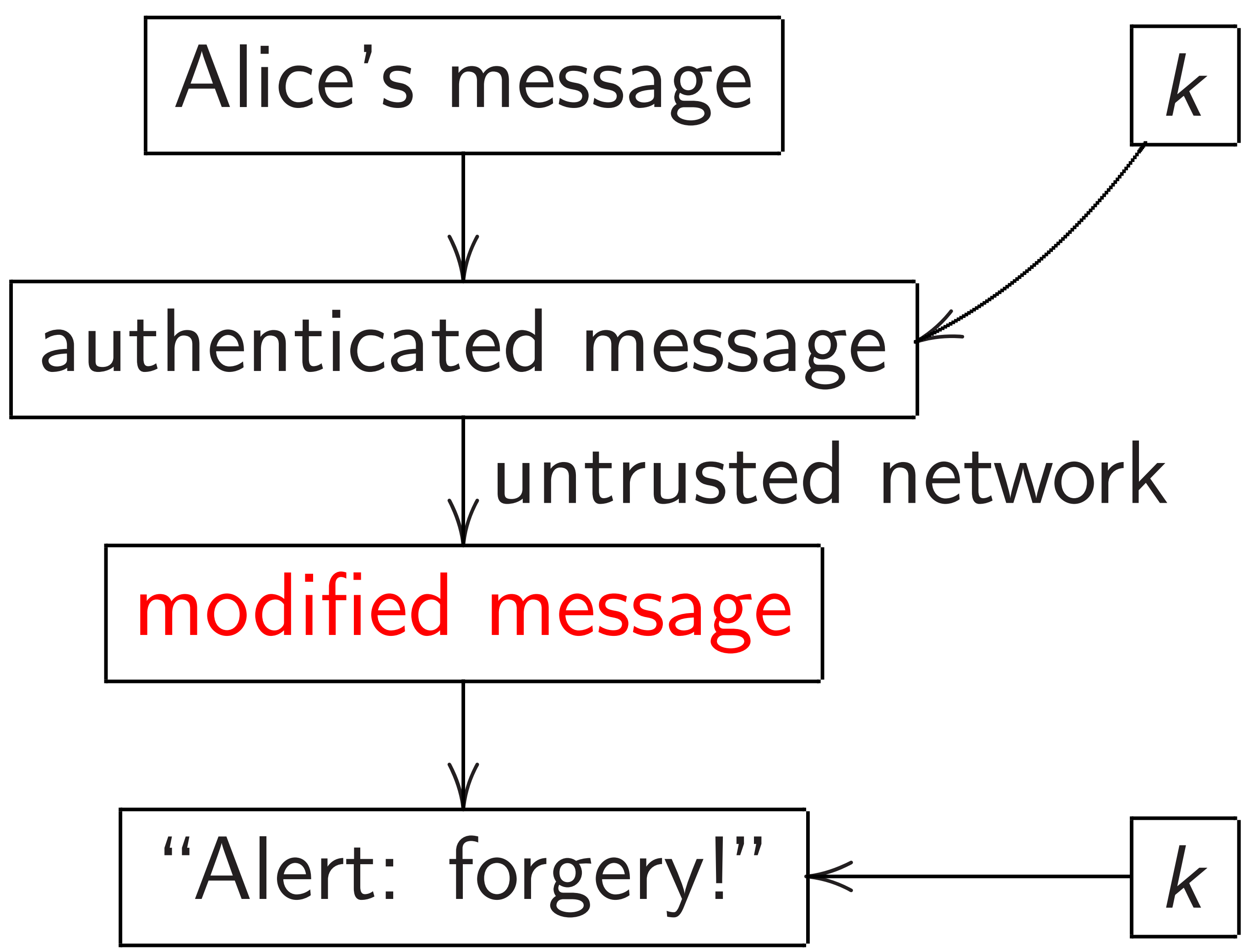

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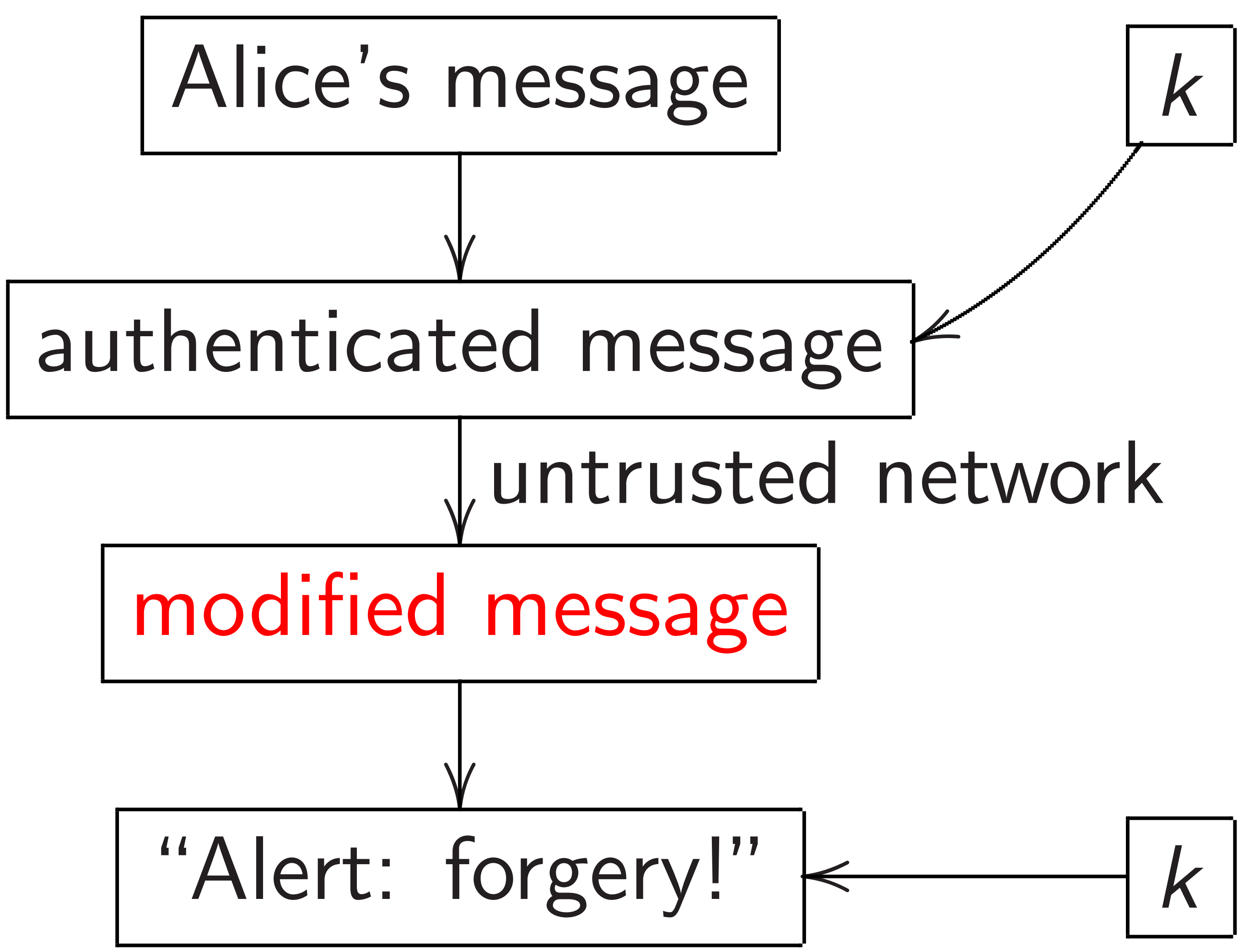

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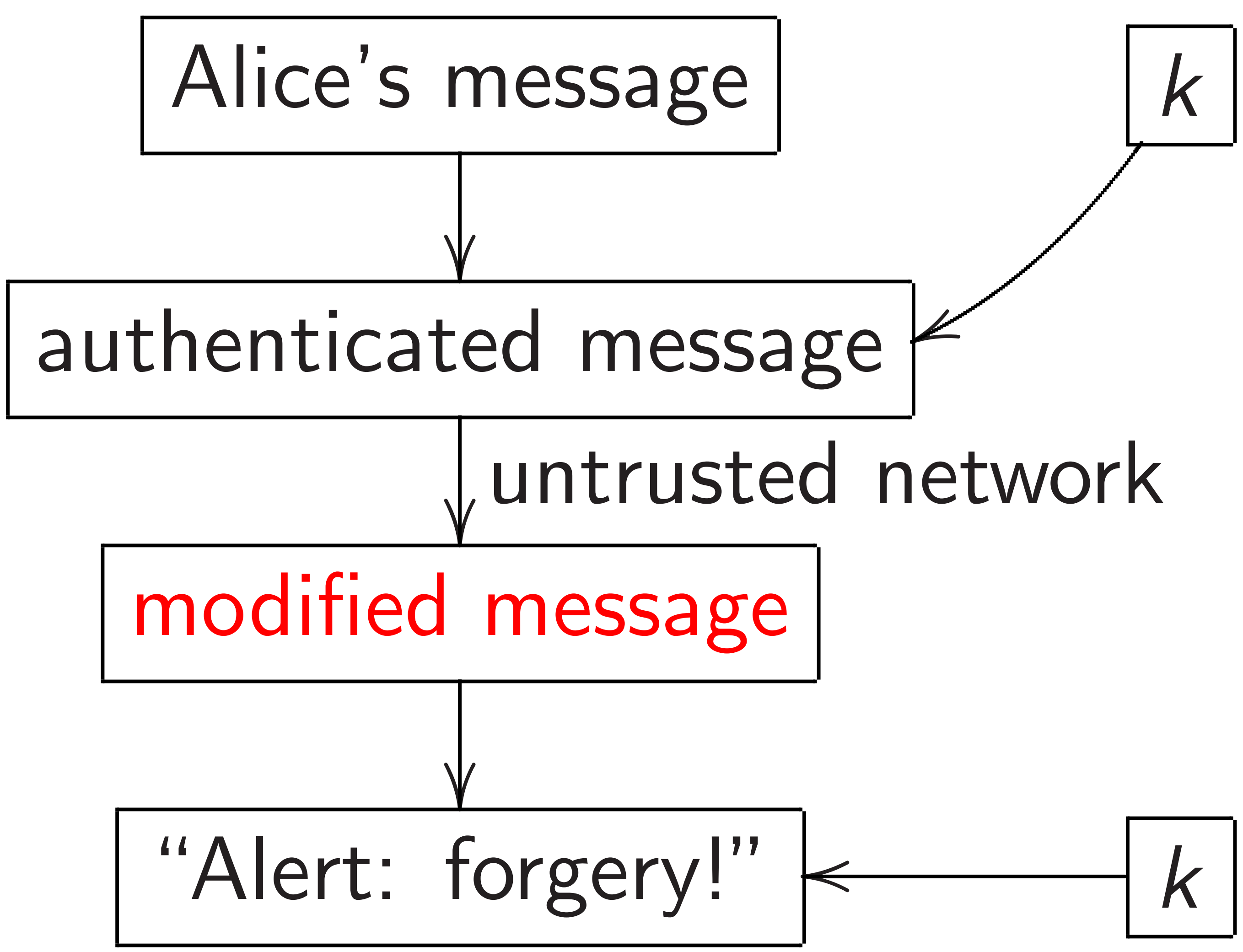

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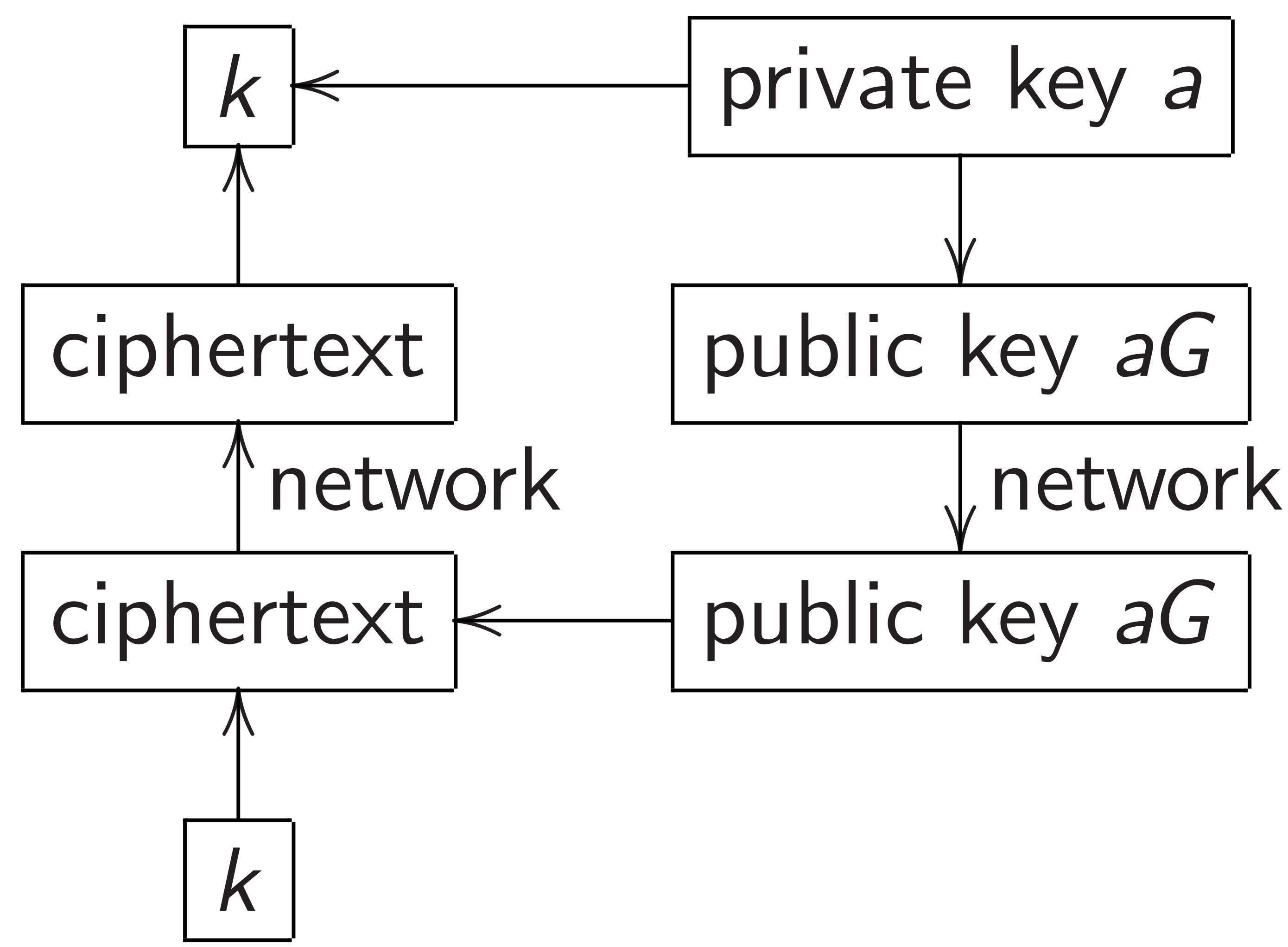

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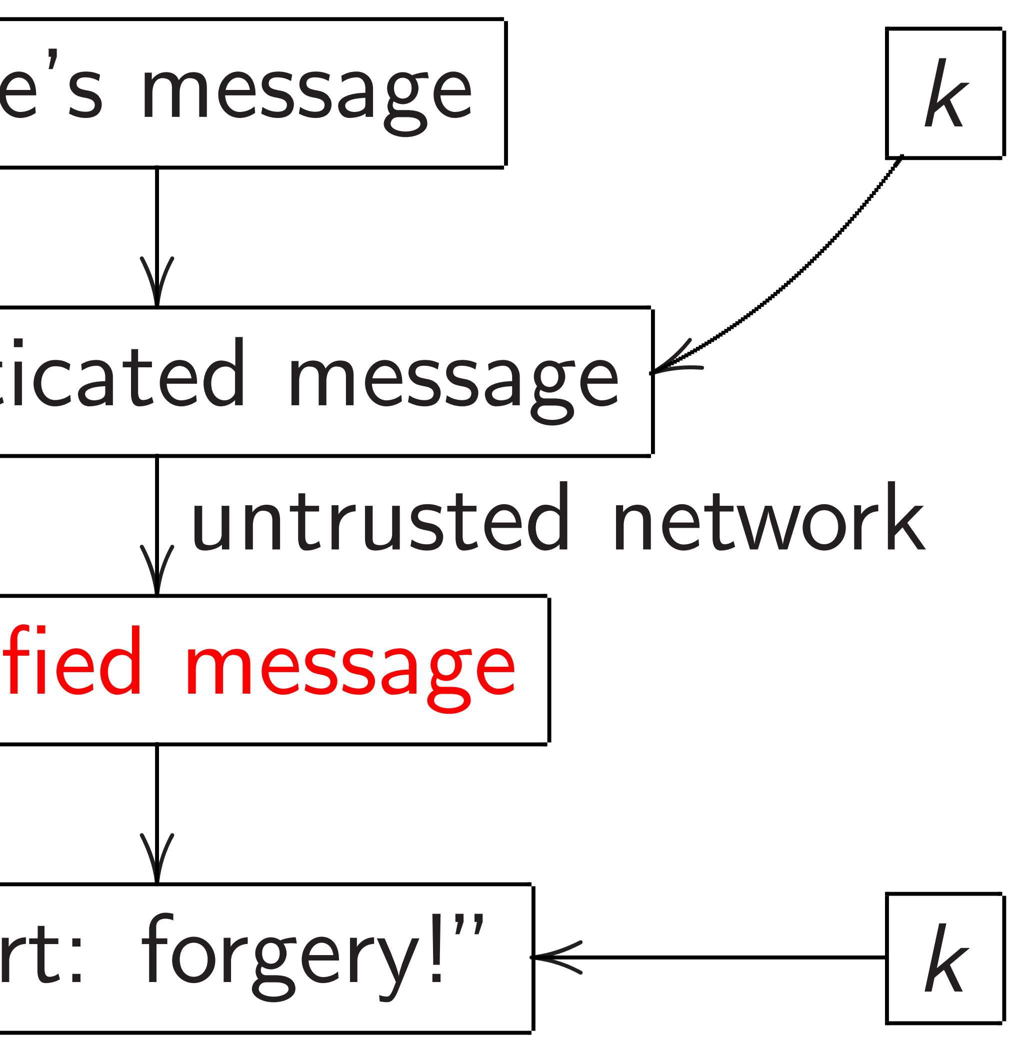

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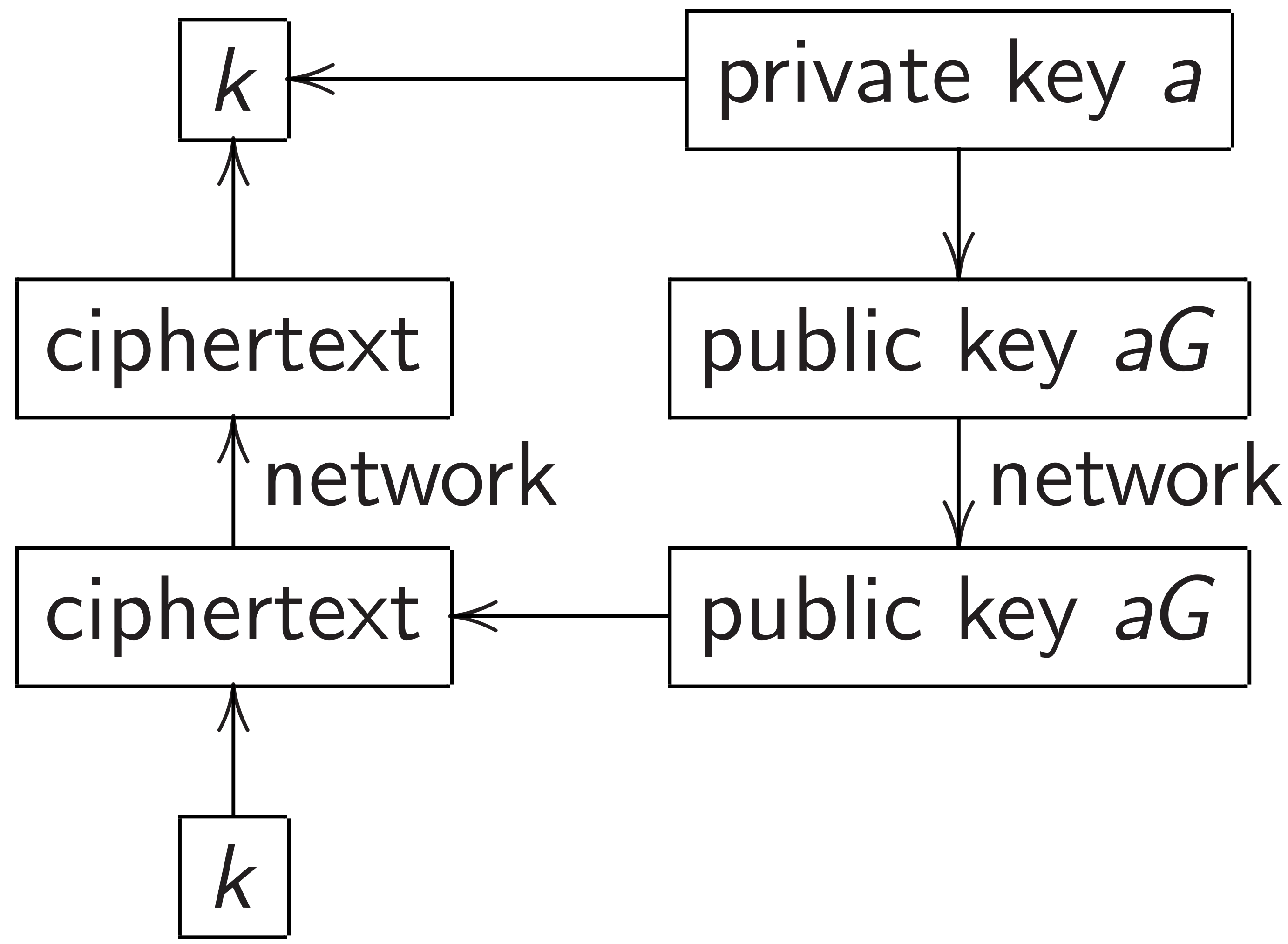

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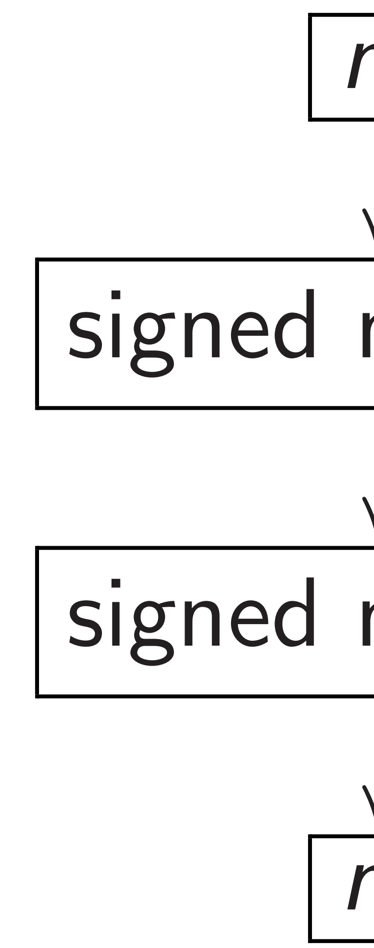

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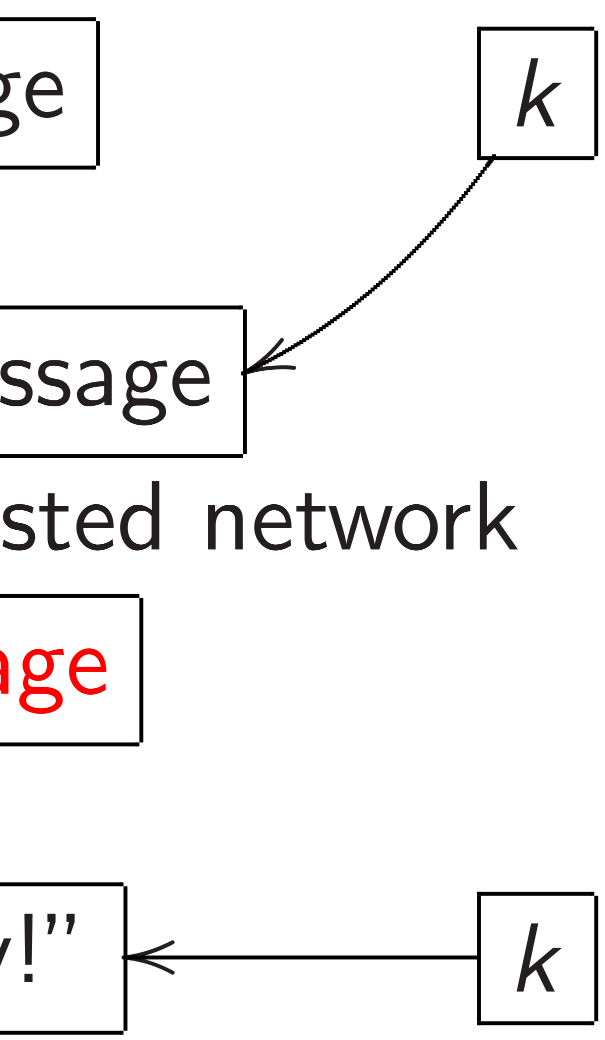

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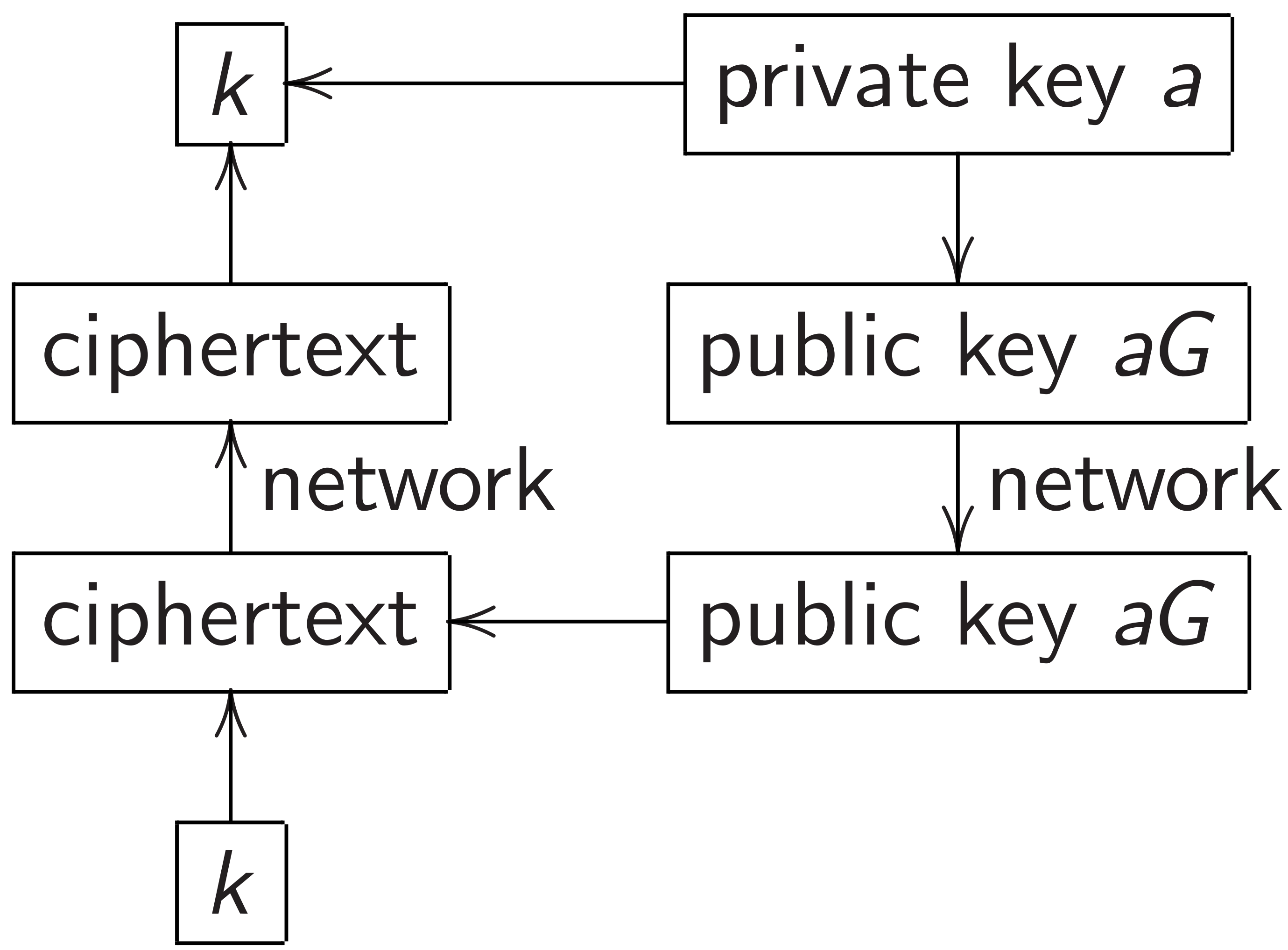

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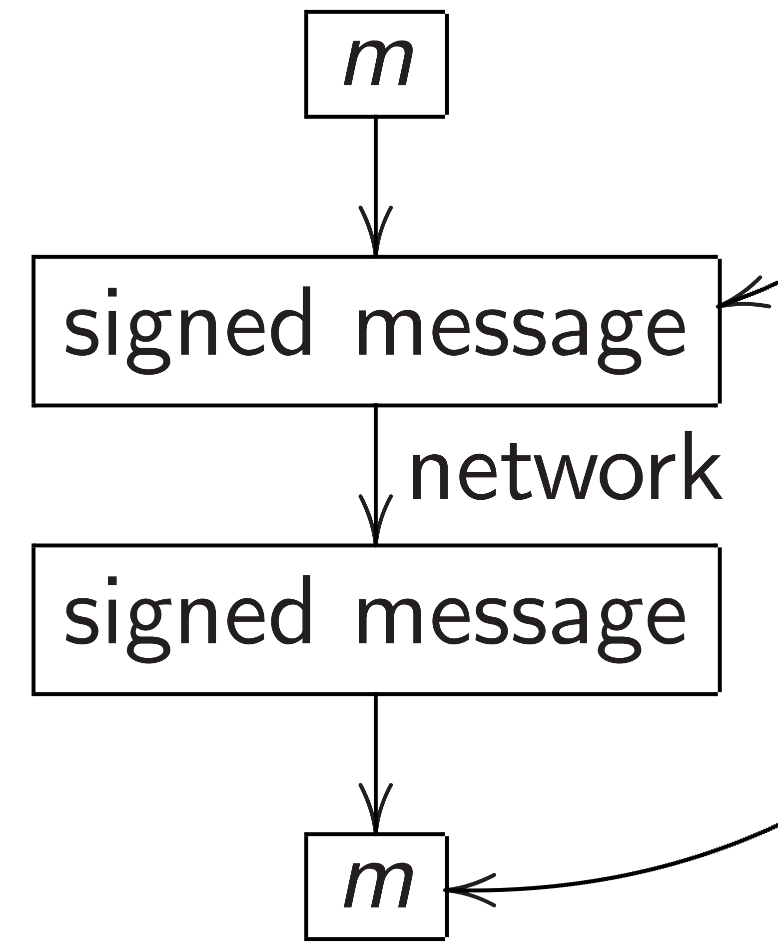

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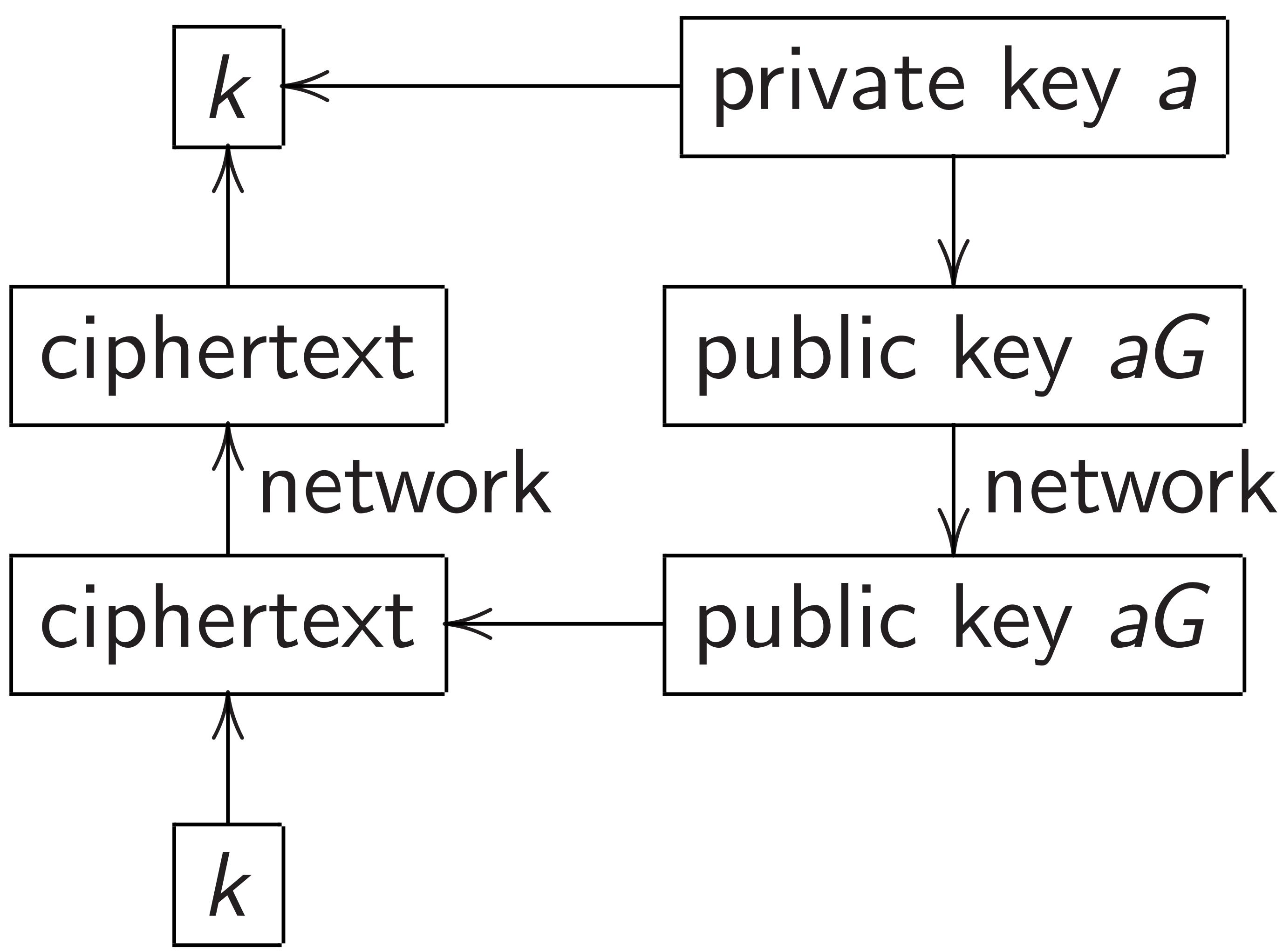

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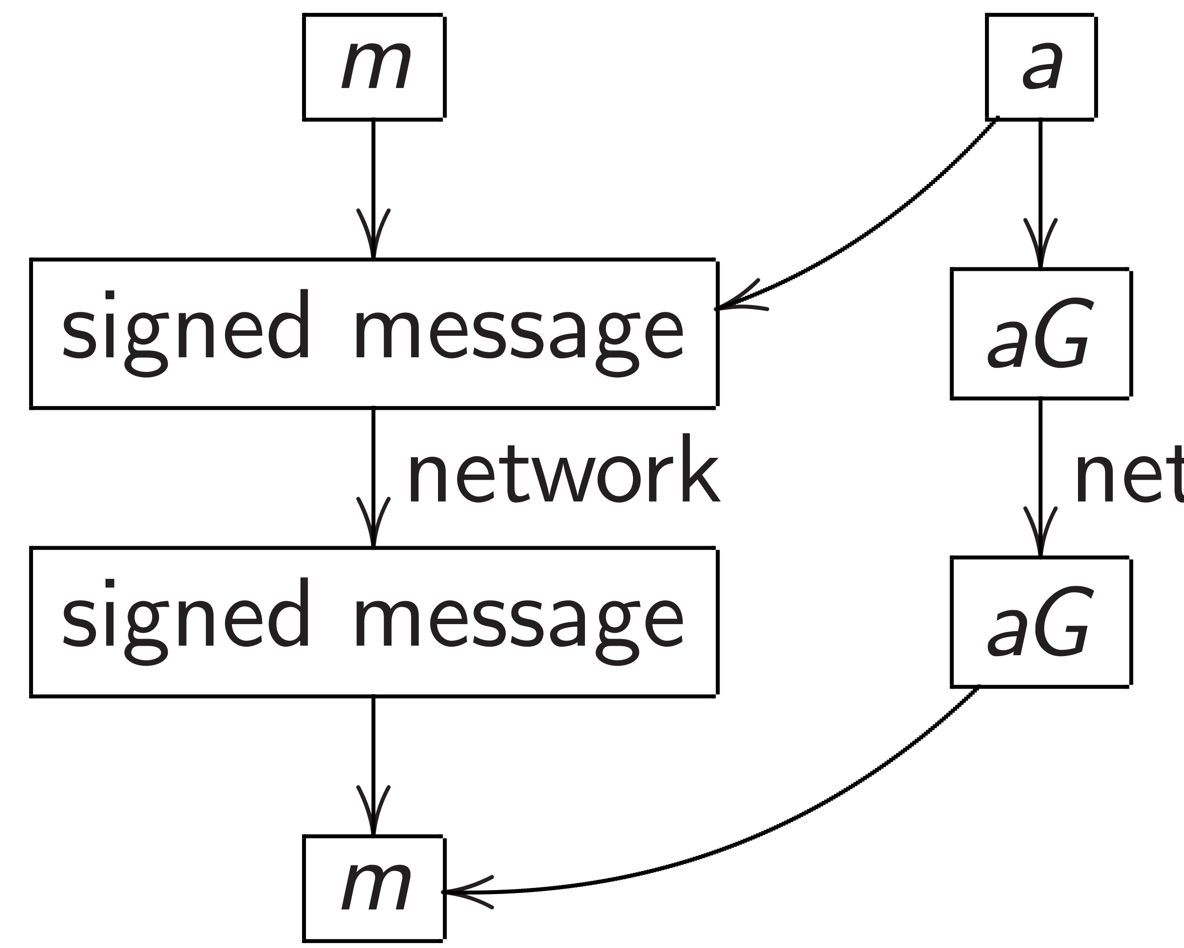

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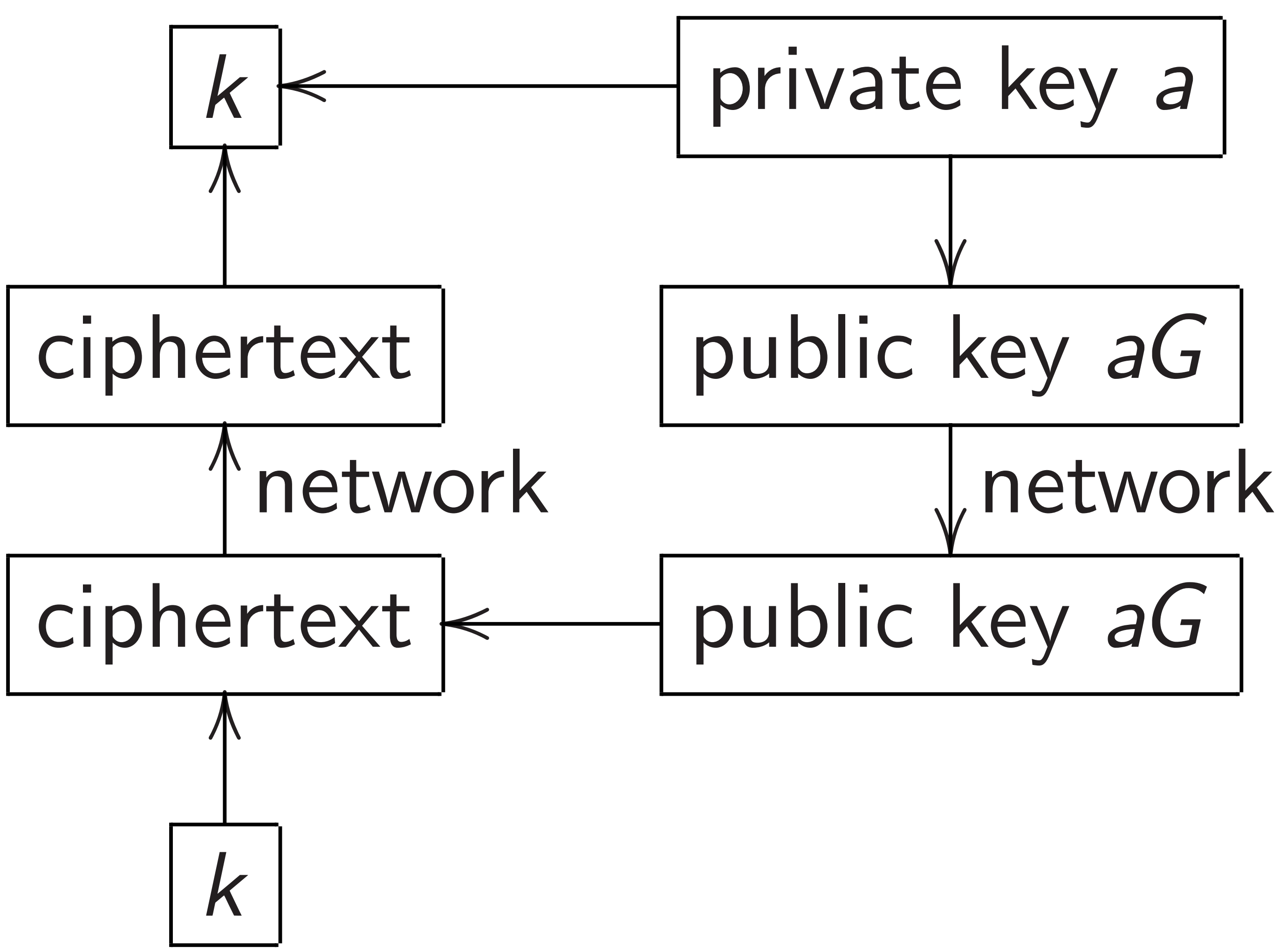

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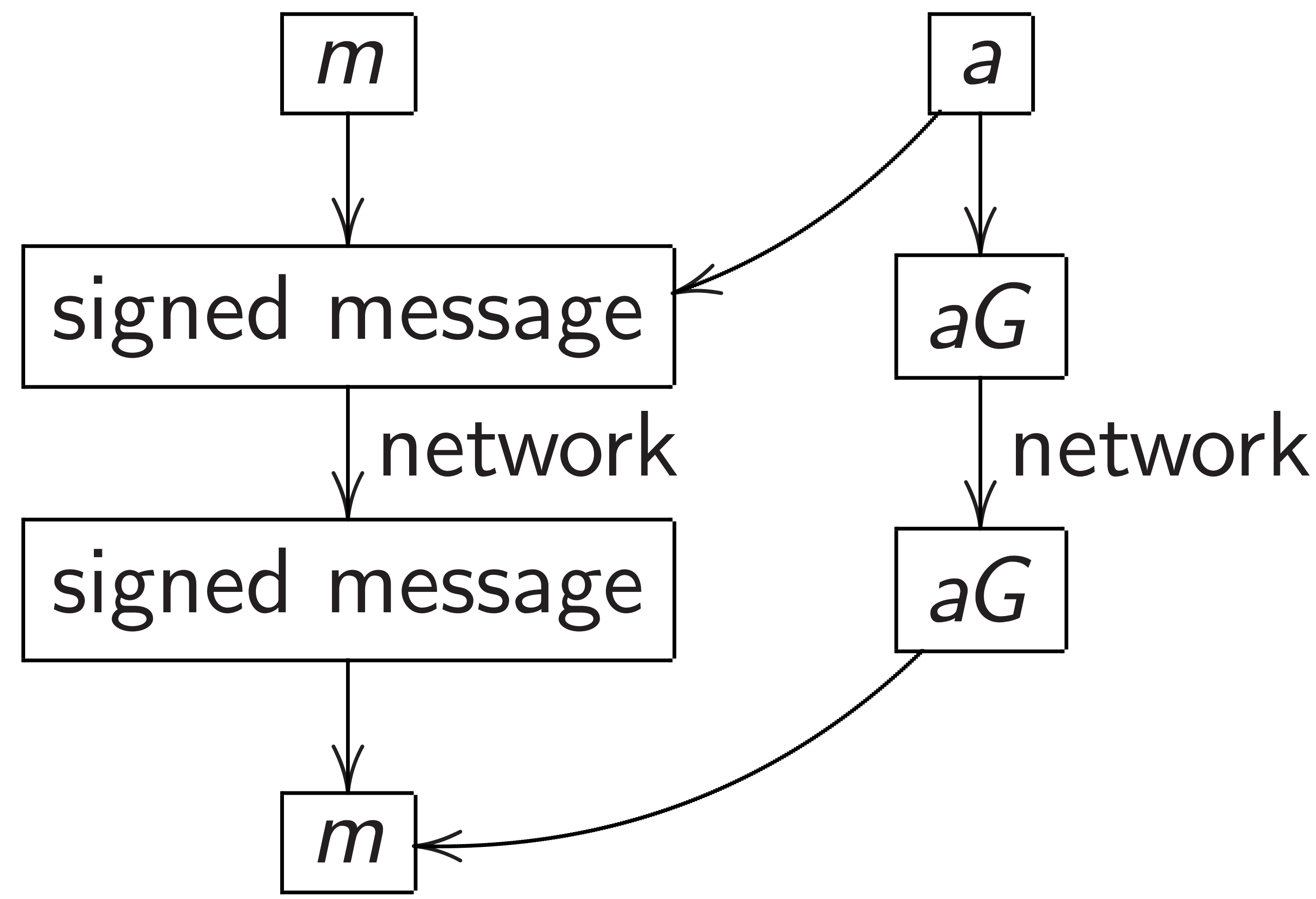

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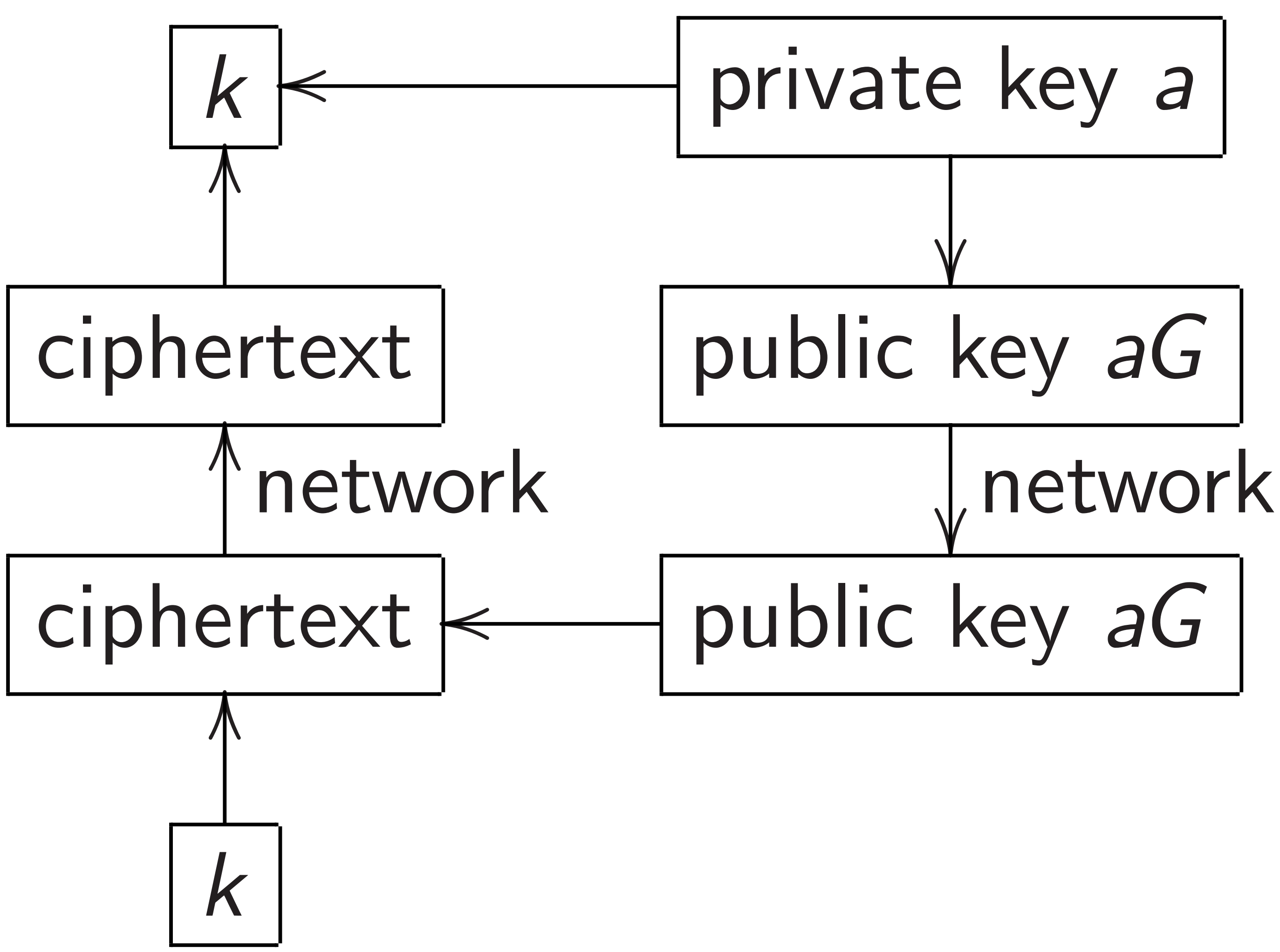

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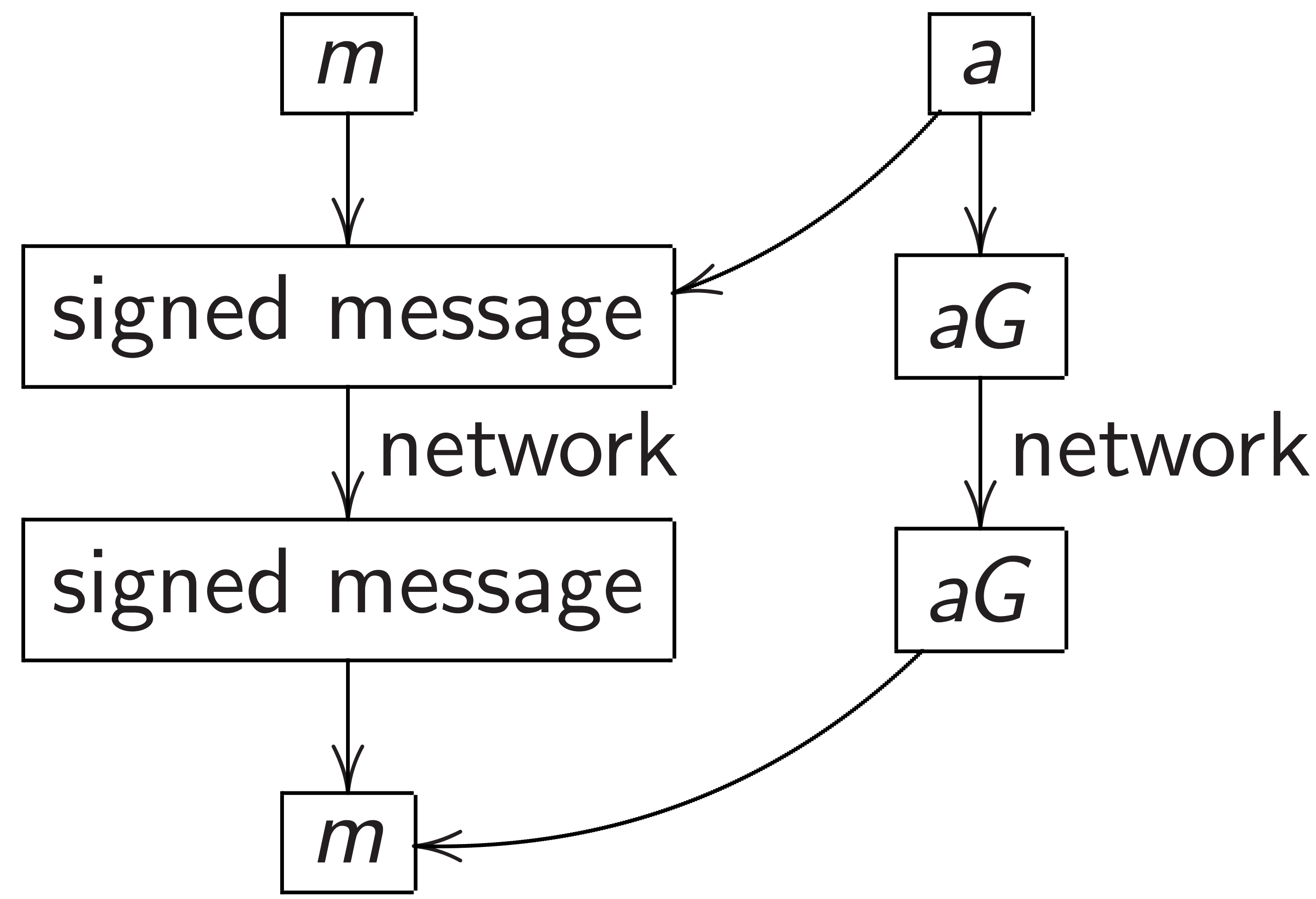

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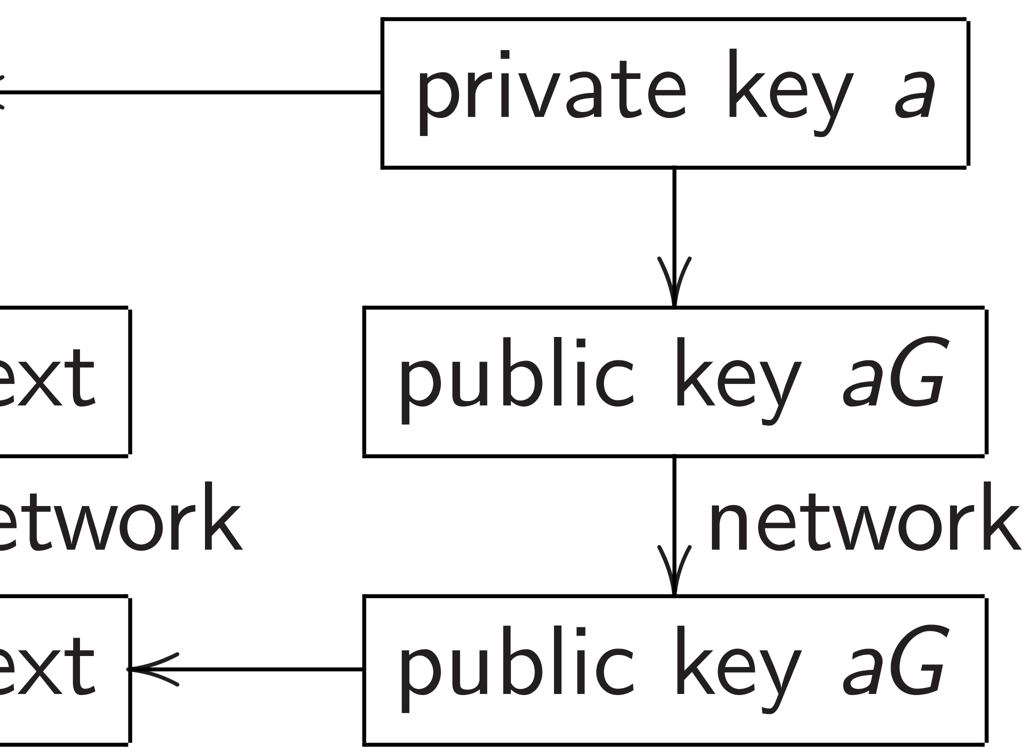

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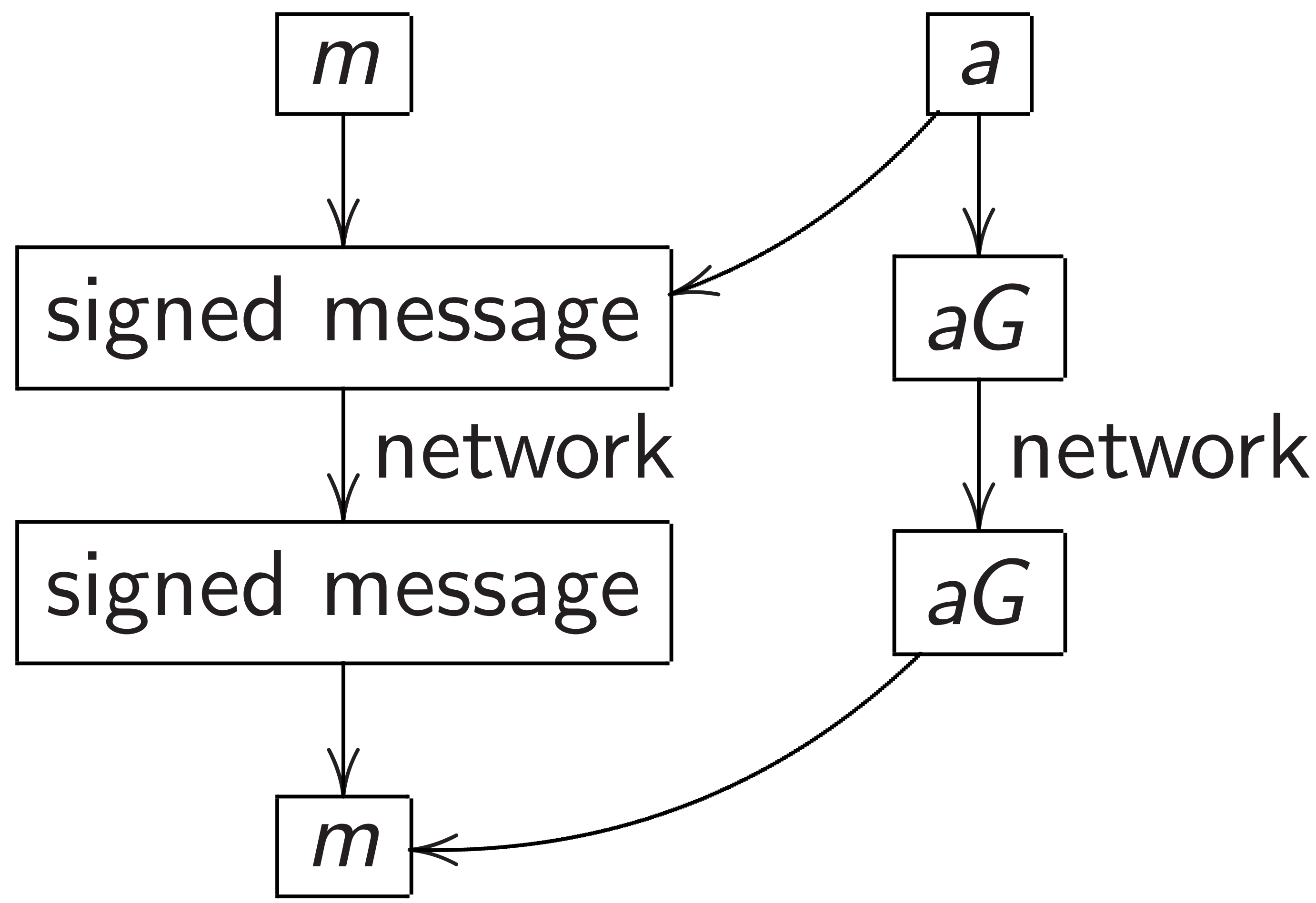

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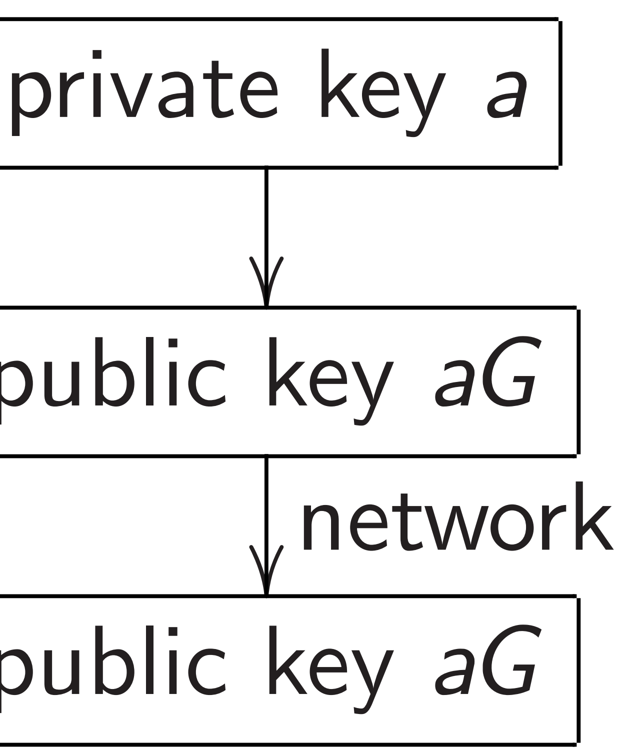

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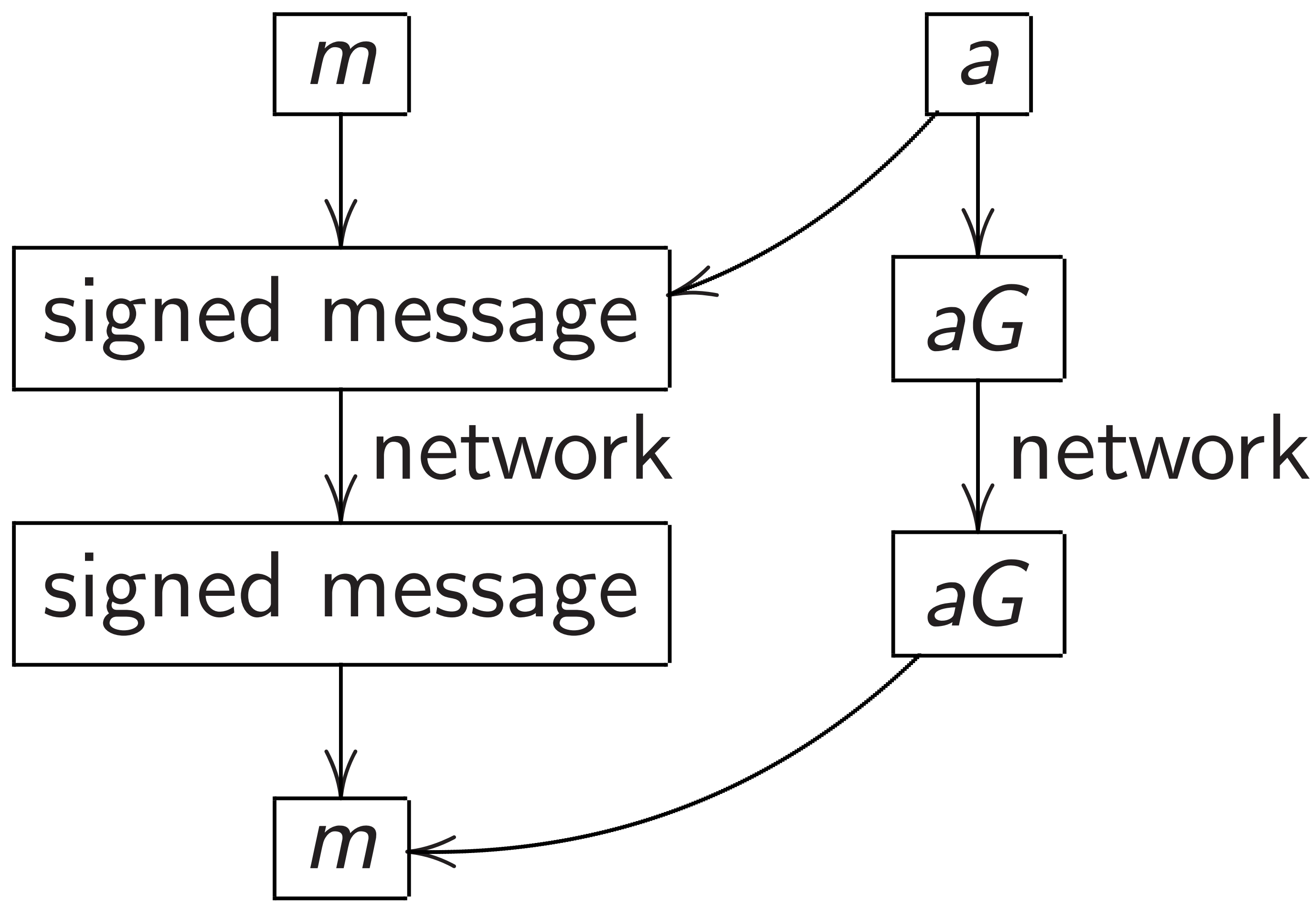

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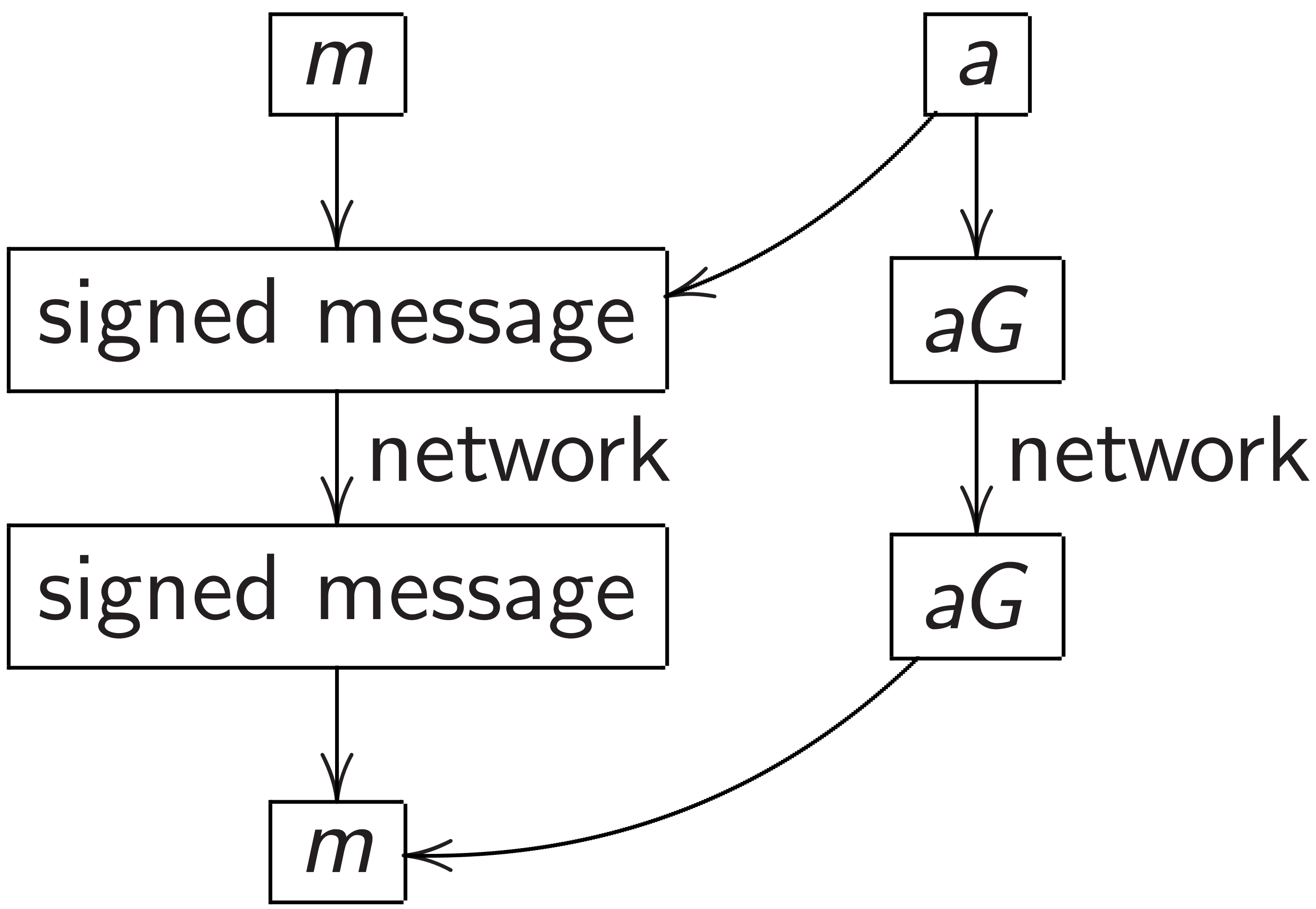

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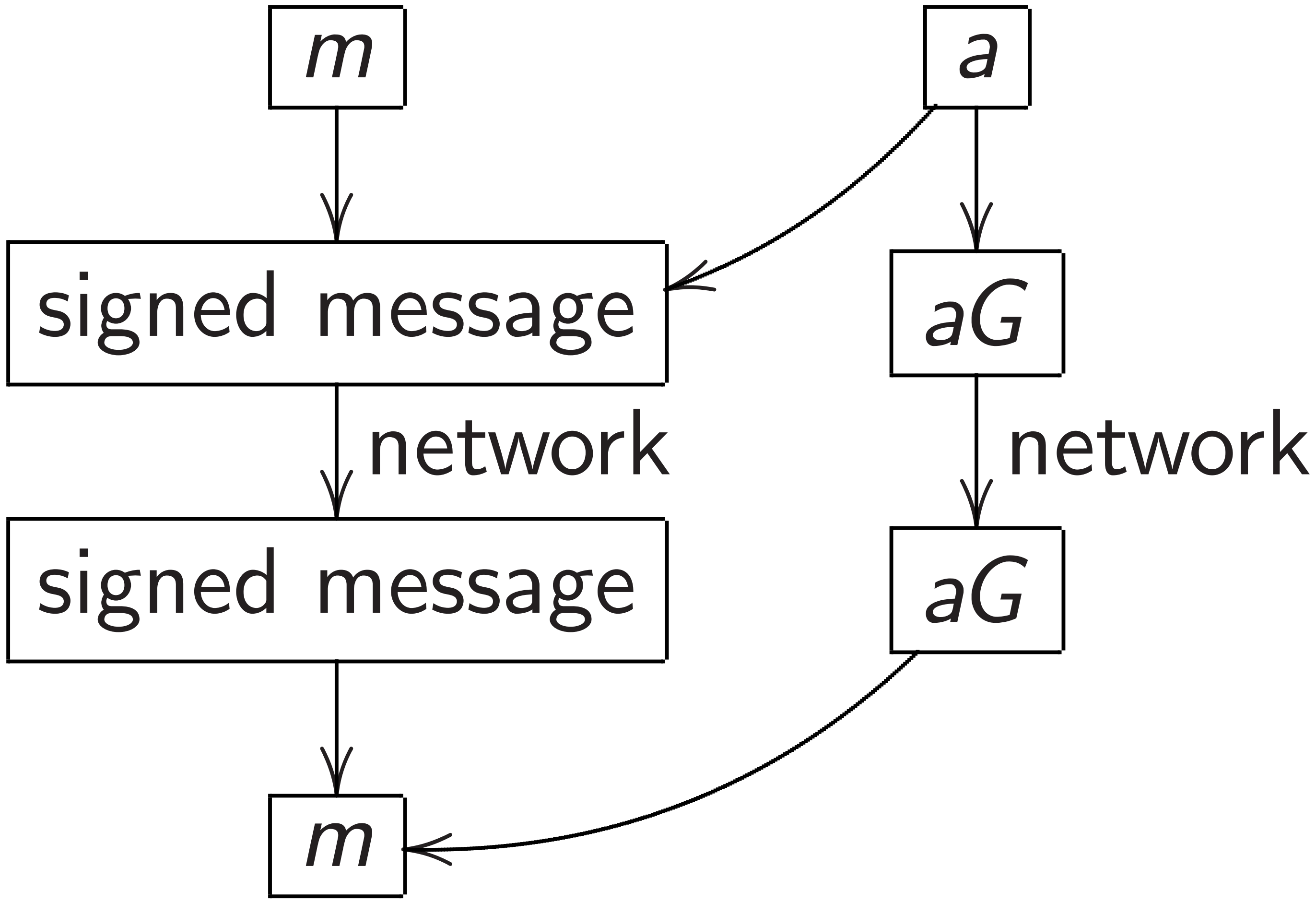

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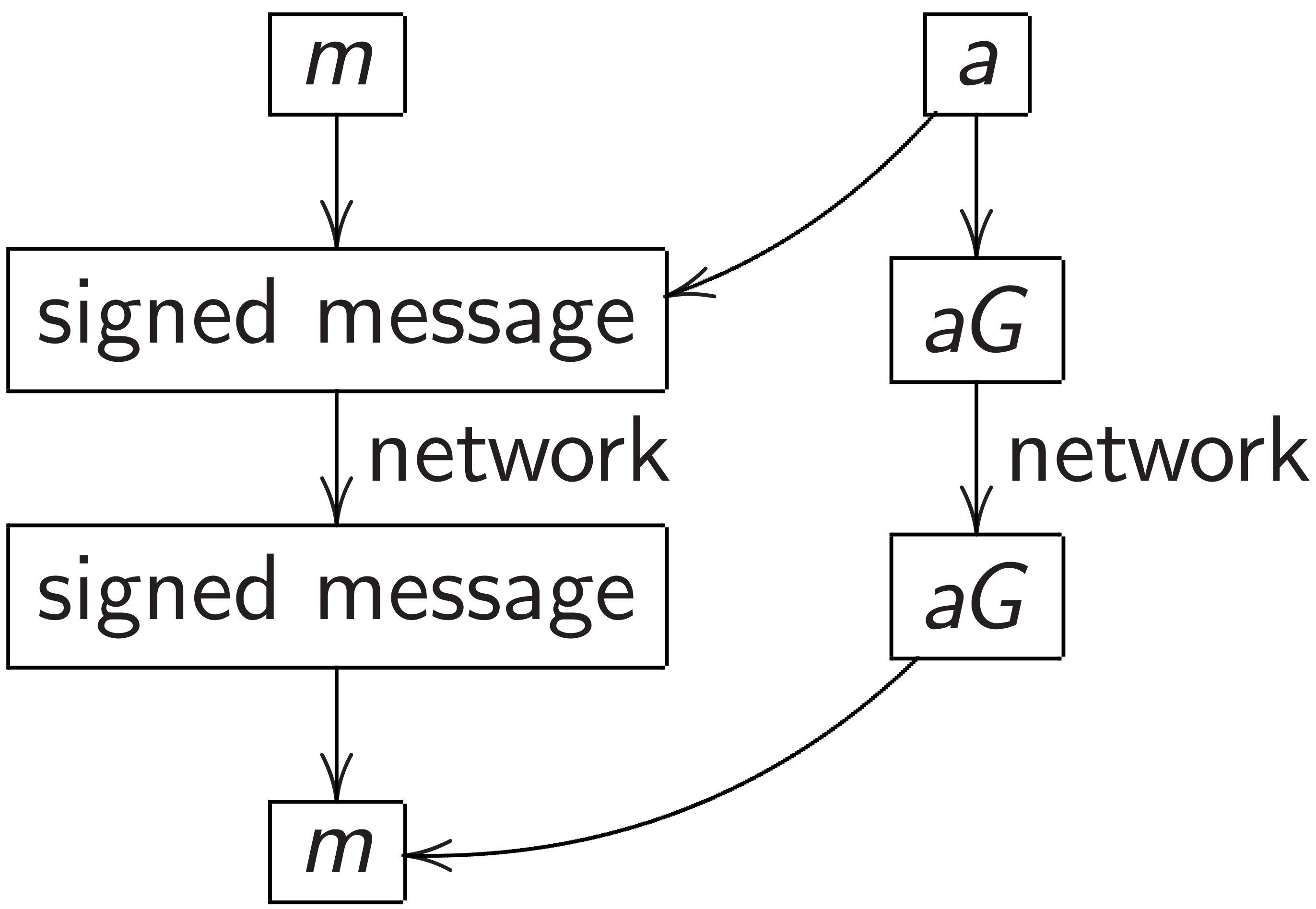

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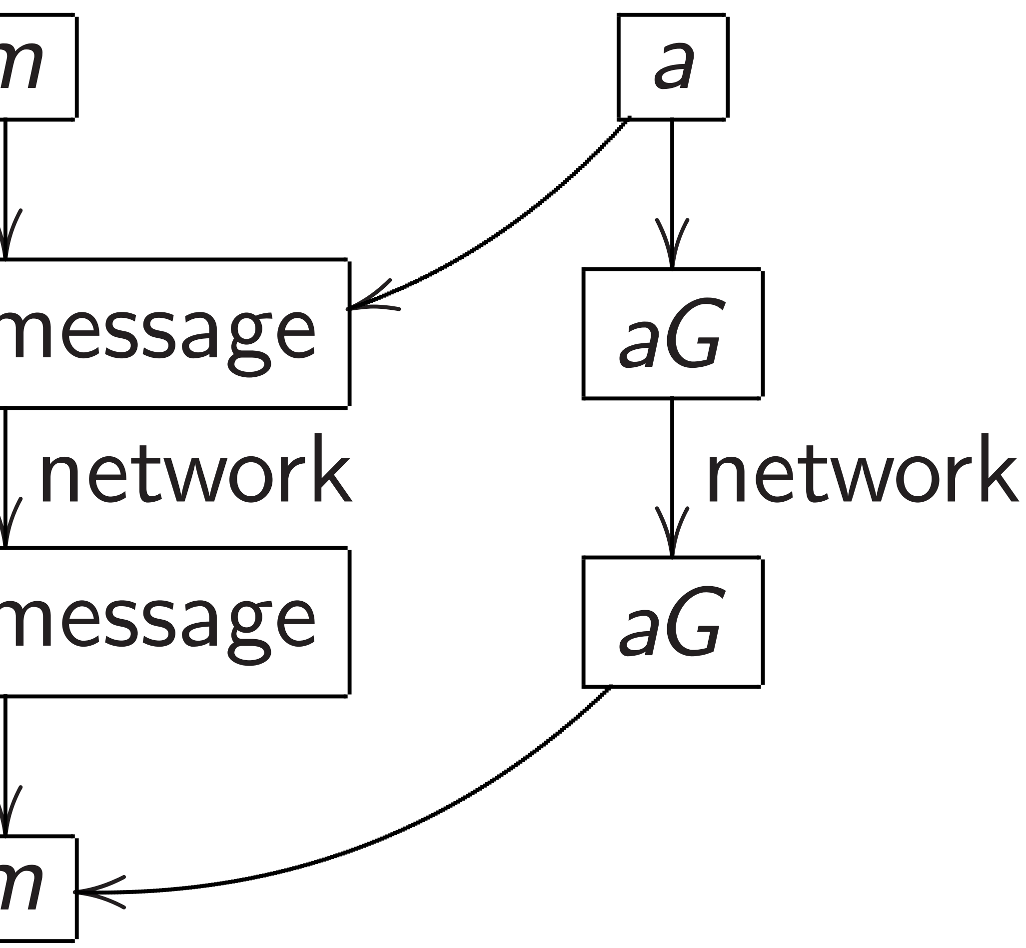

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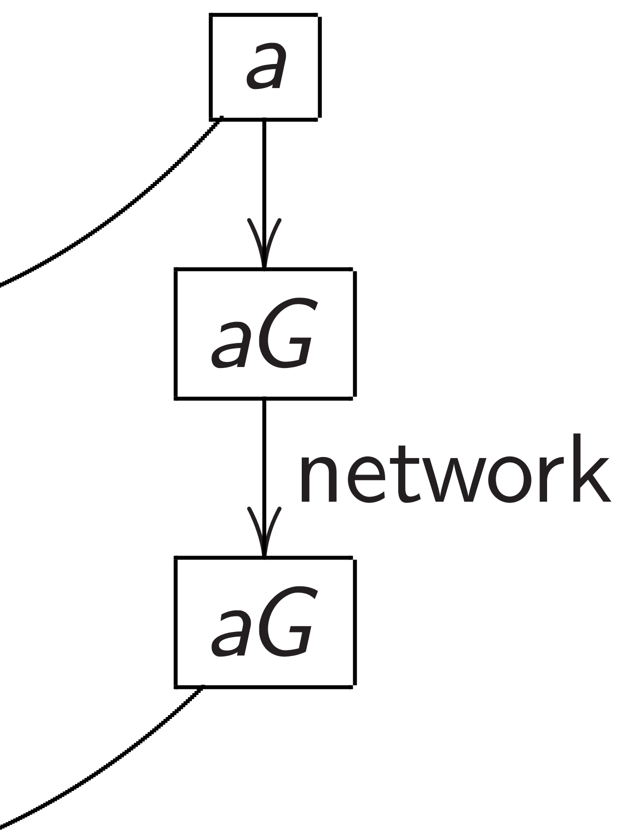

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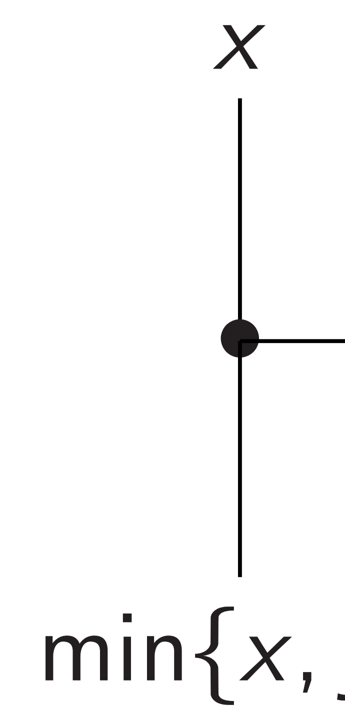

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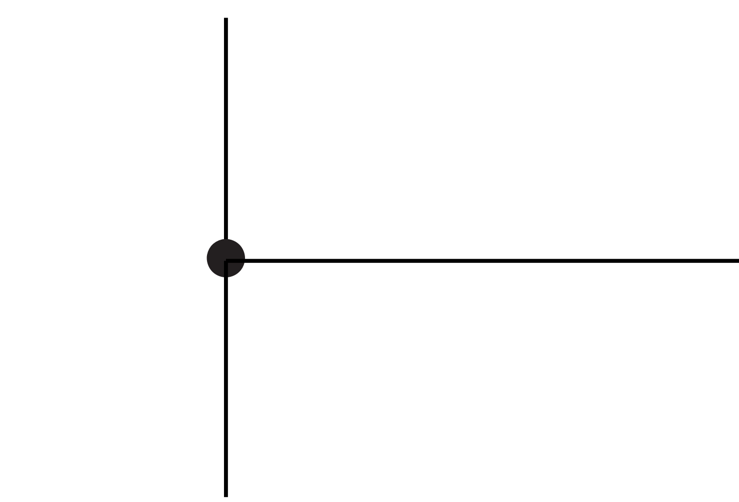

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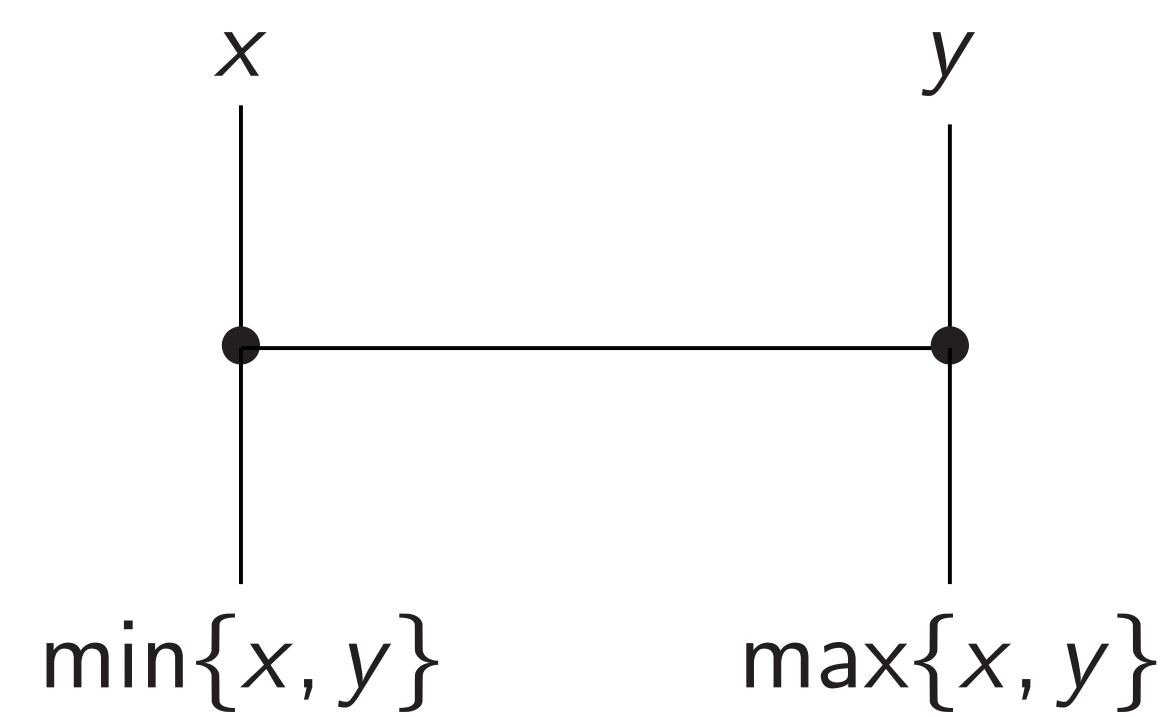

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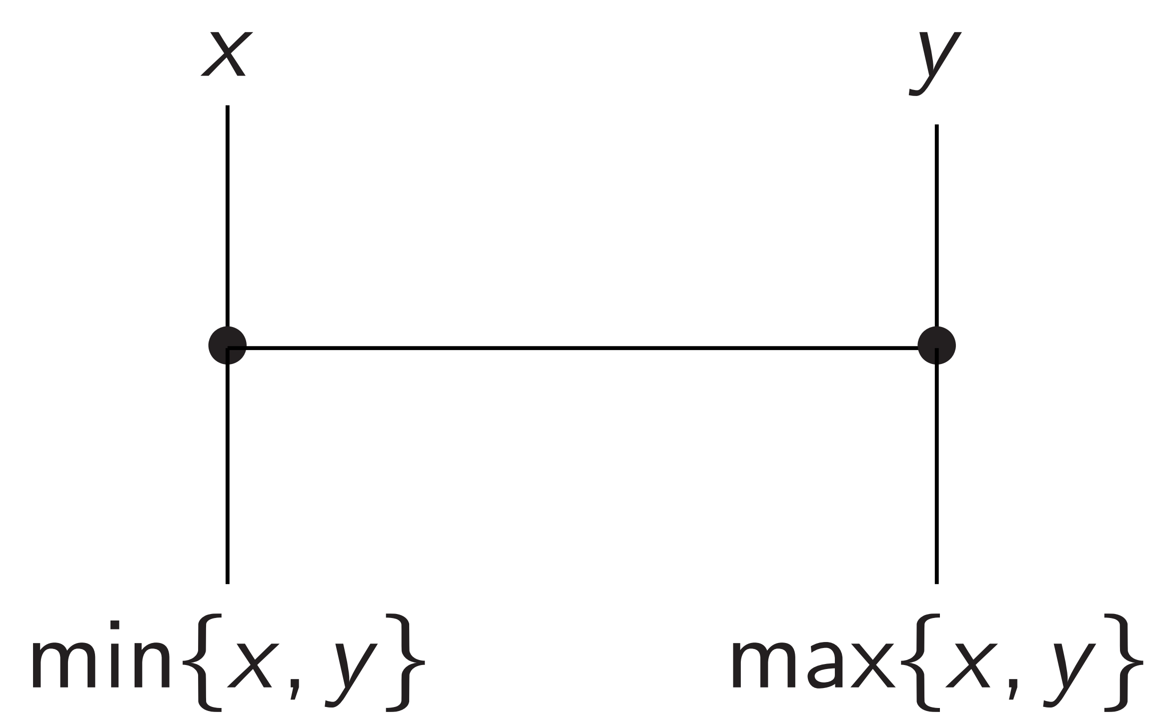

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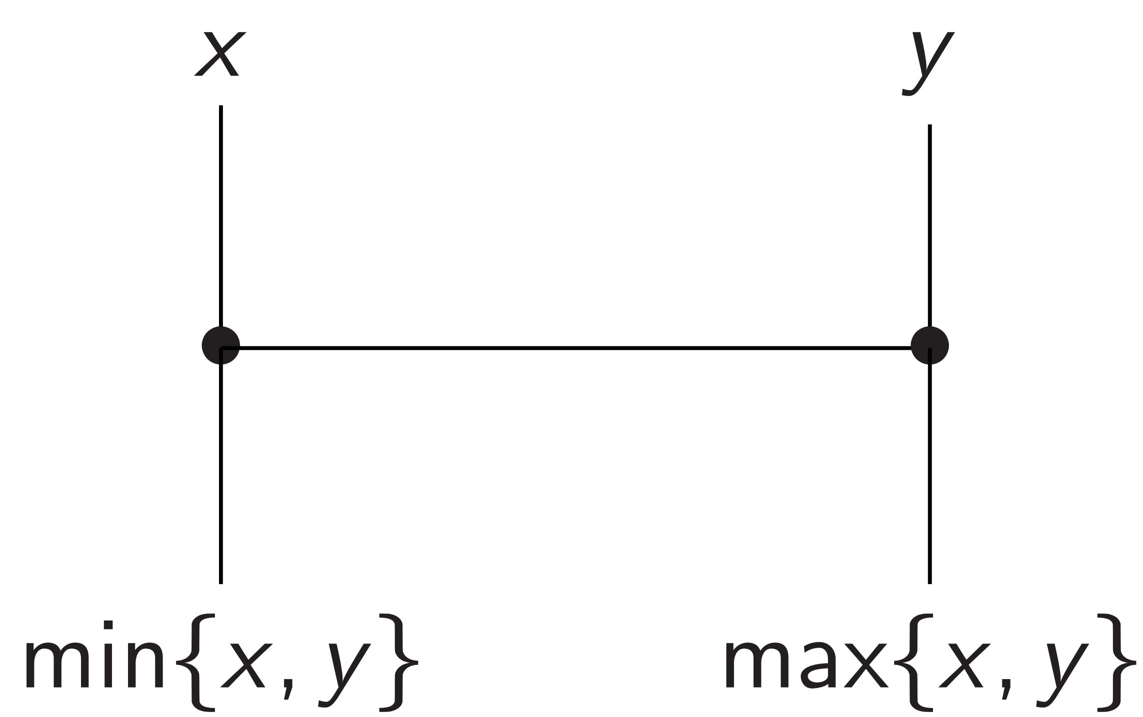

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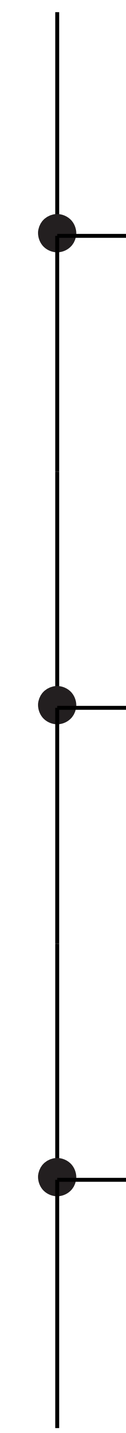

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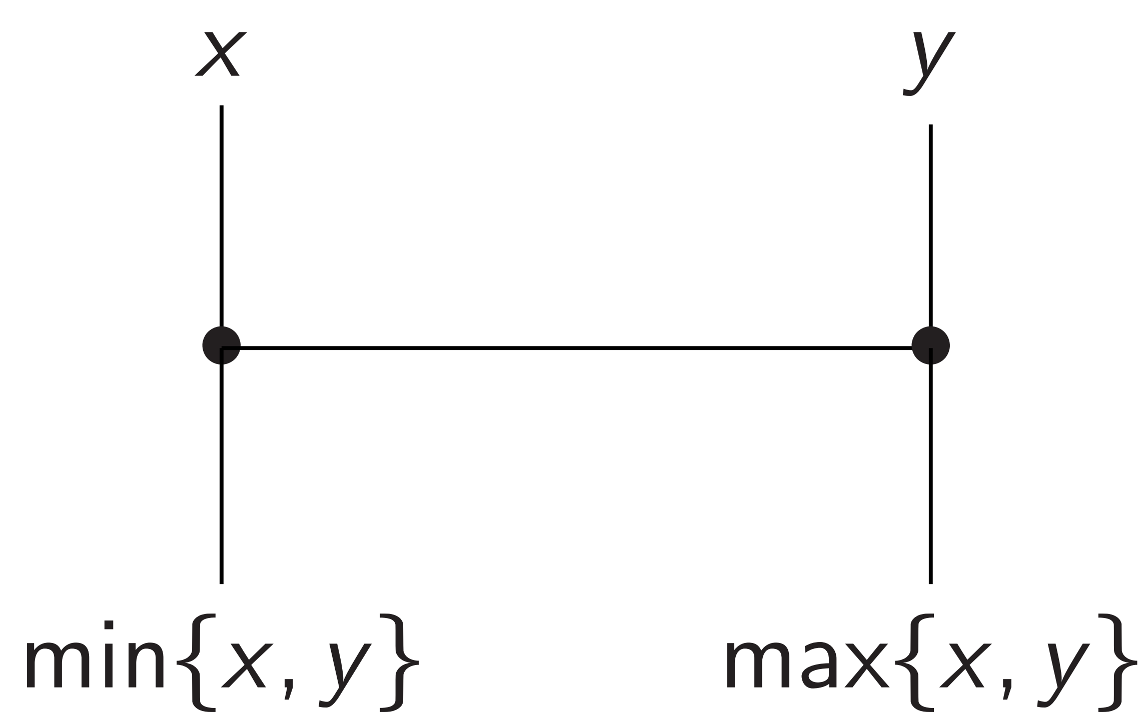

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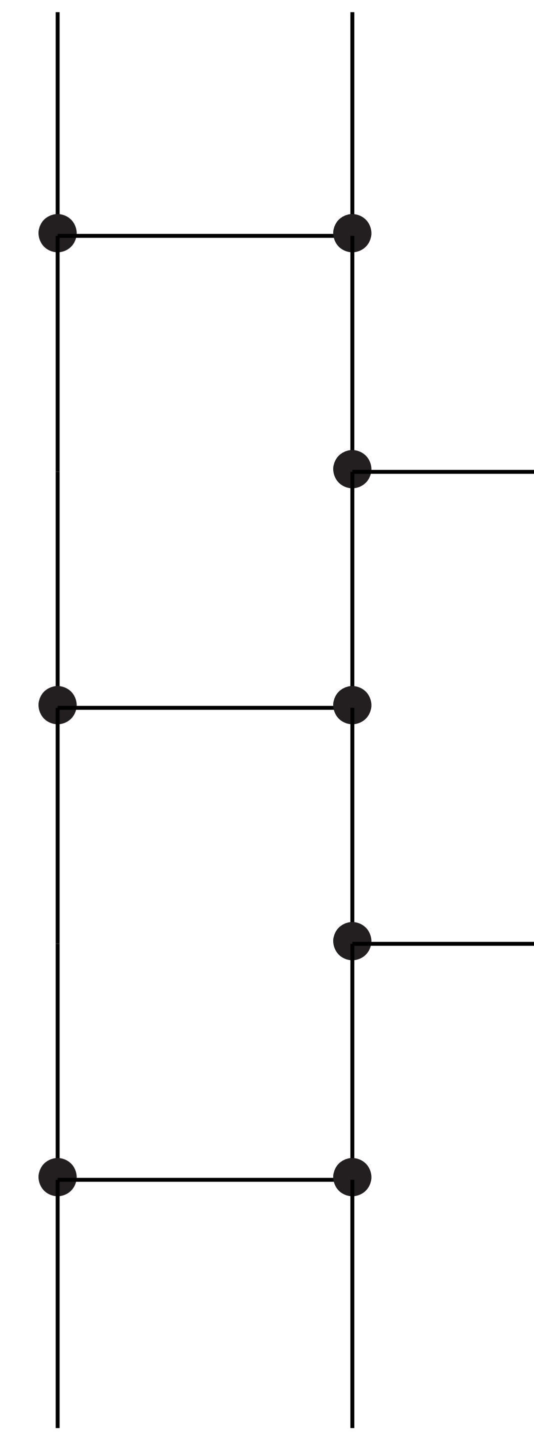

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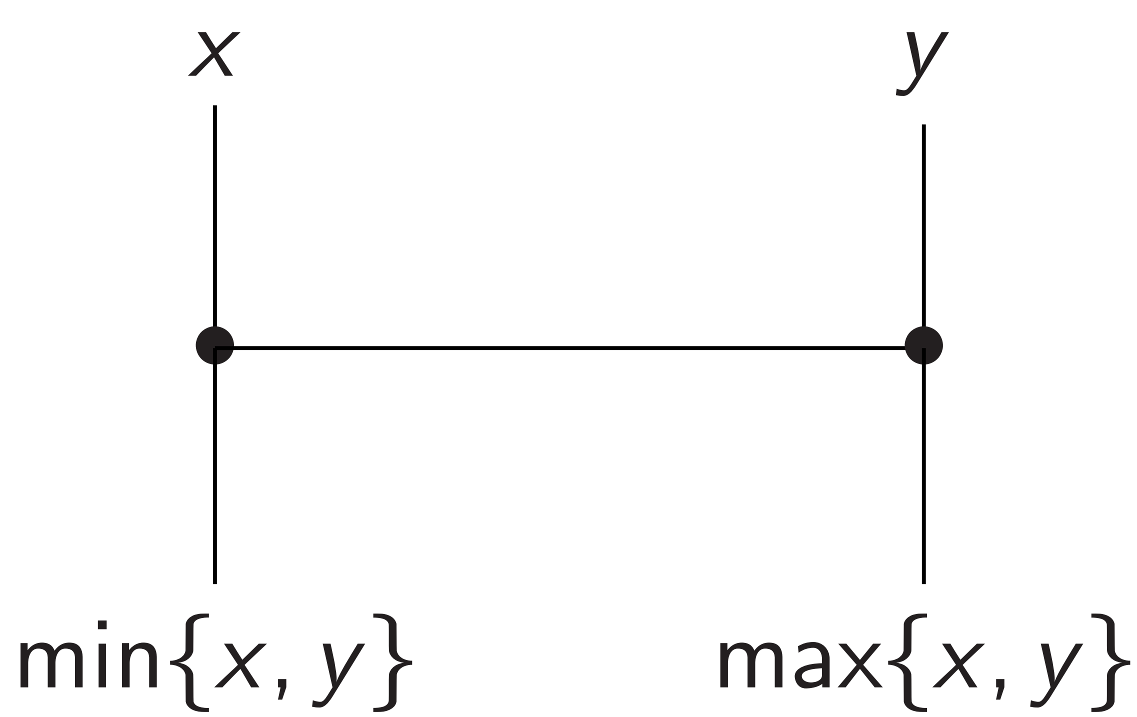

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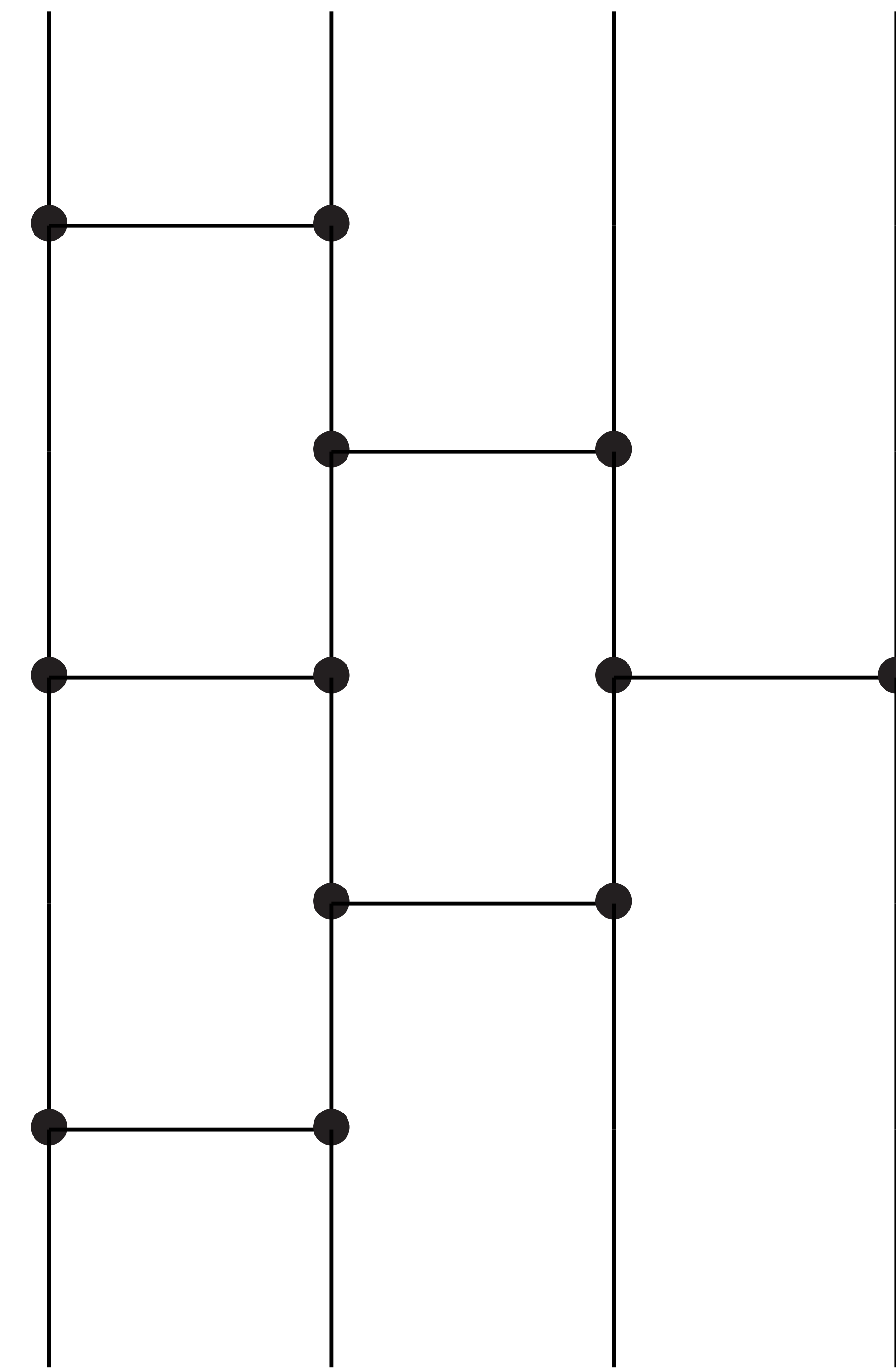

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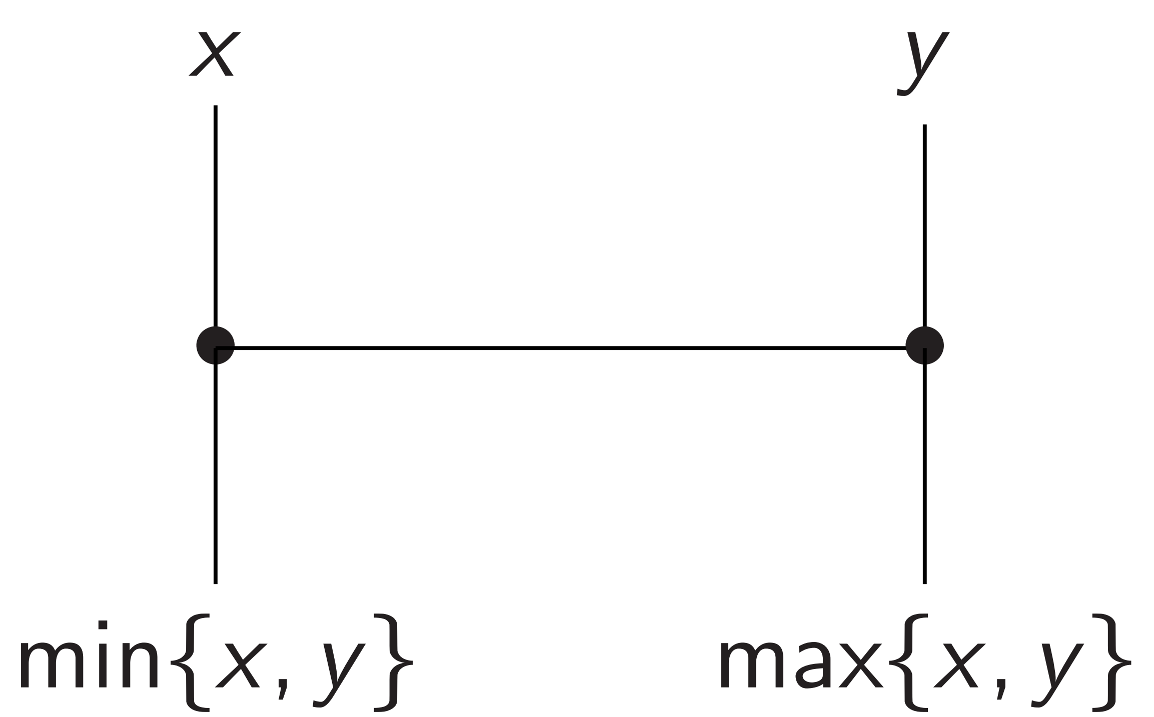

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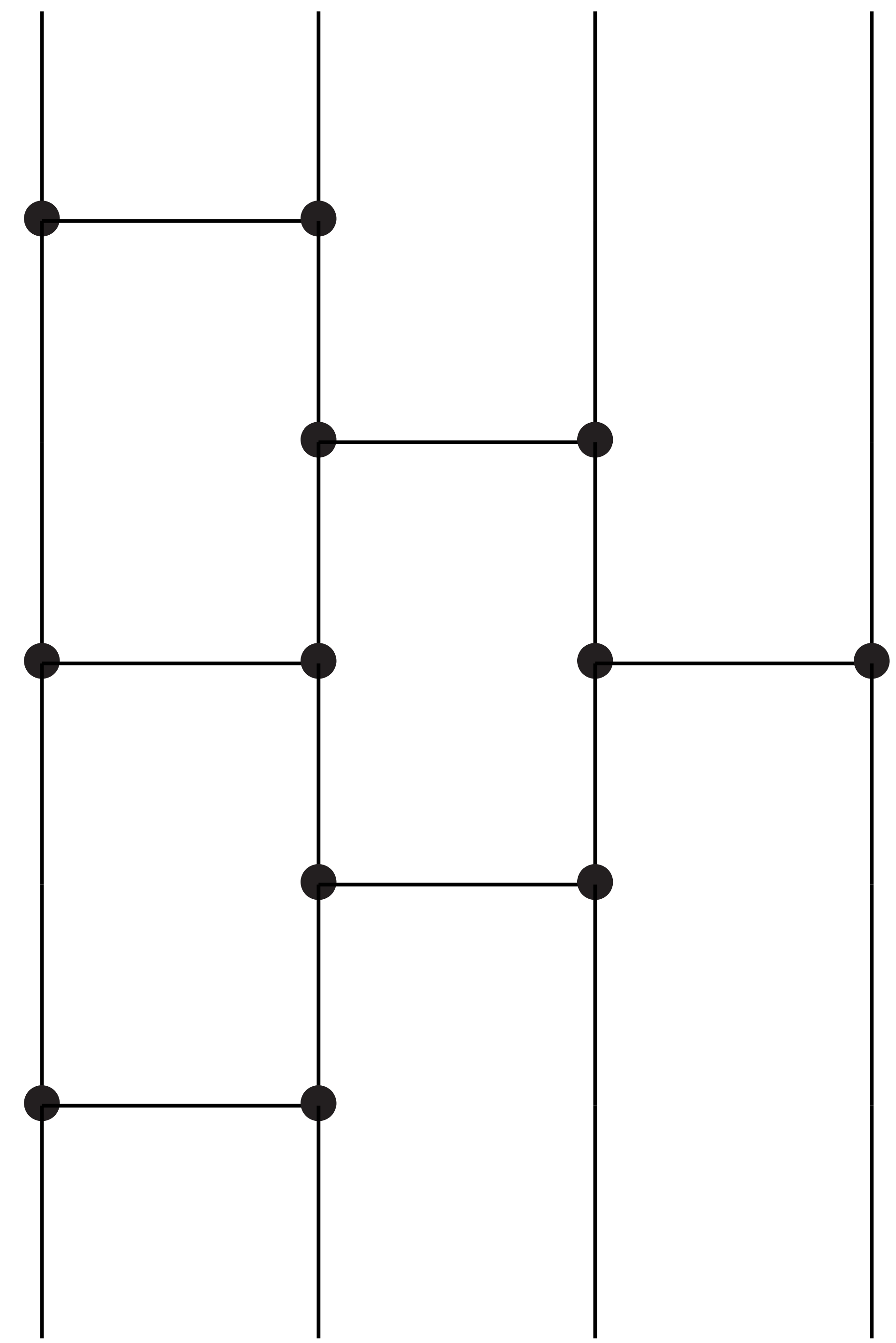

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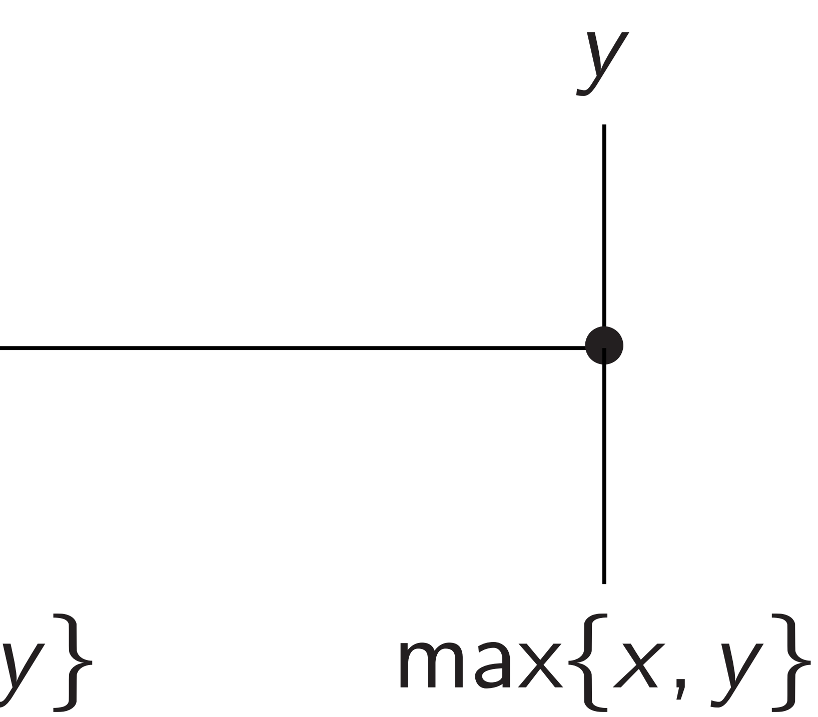

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Combine comparators into a **sorting network** for more inputs.

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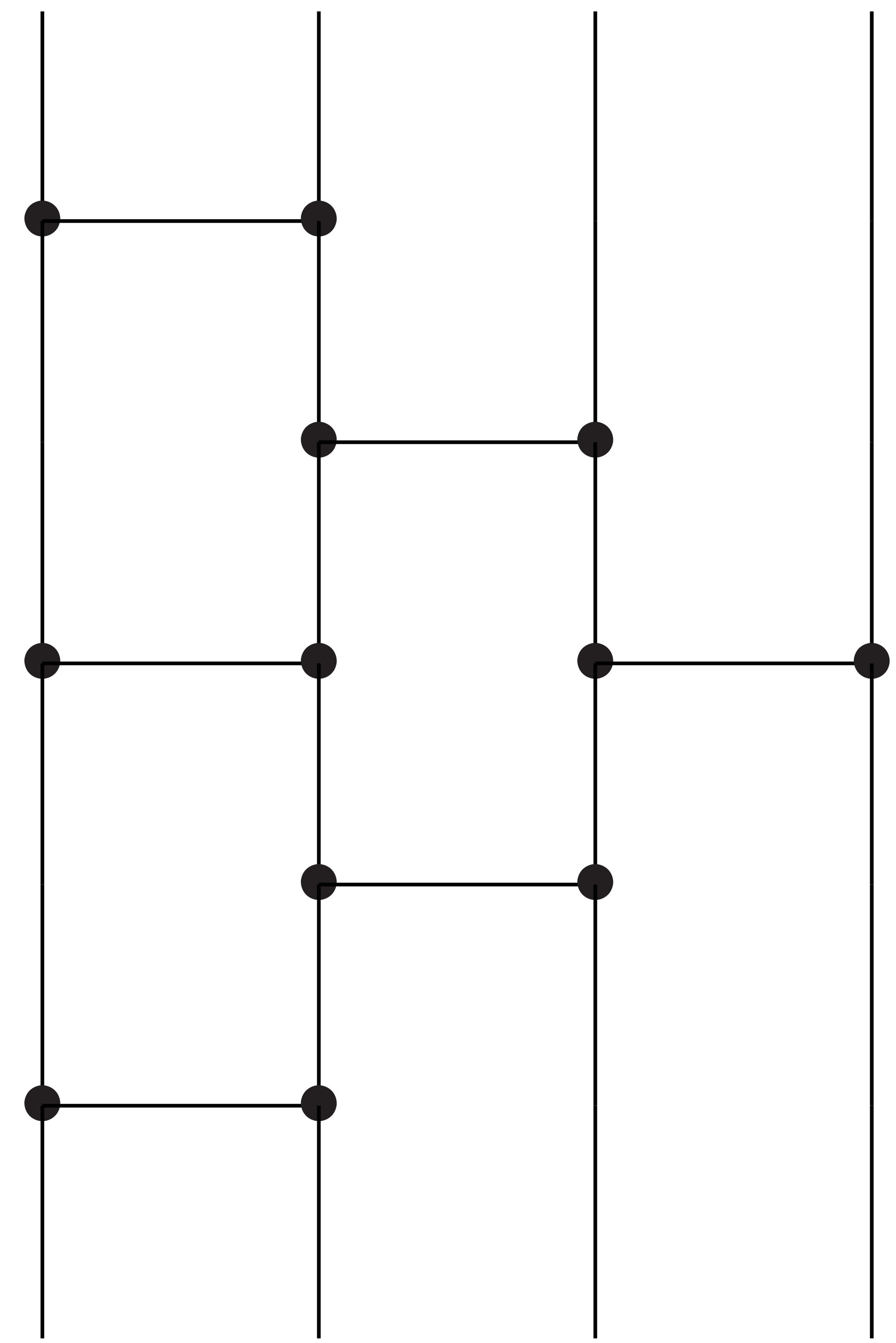

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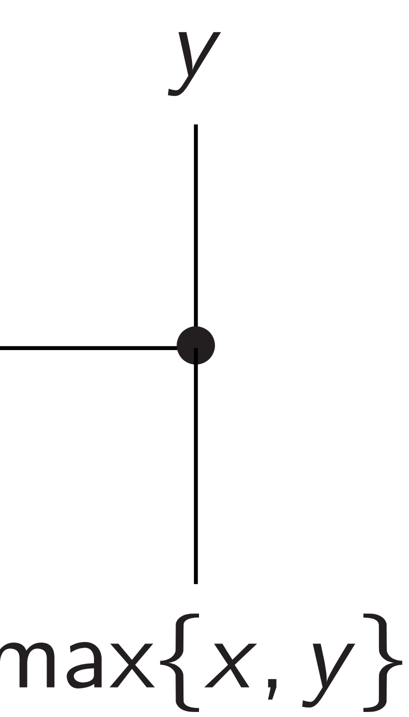

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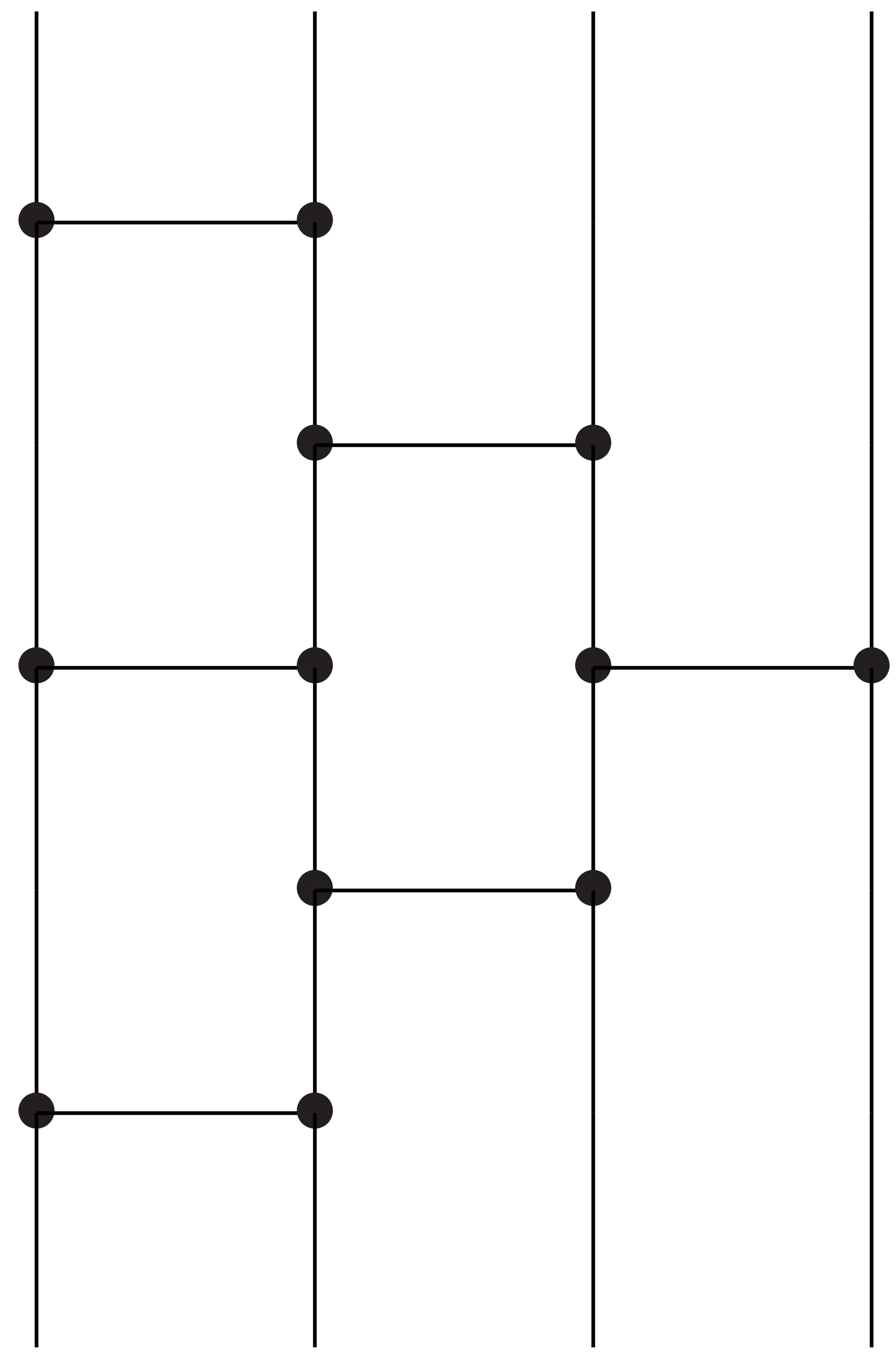

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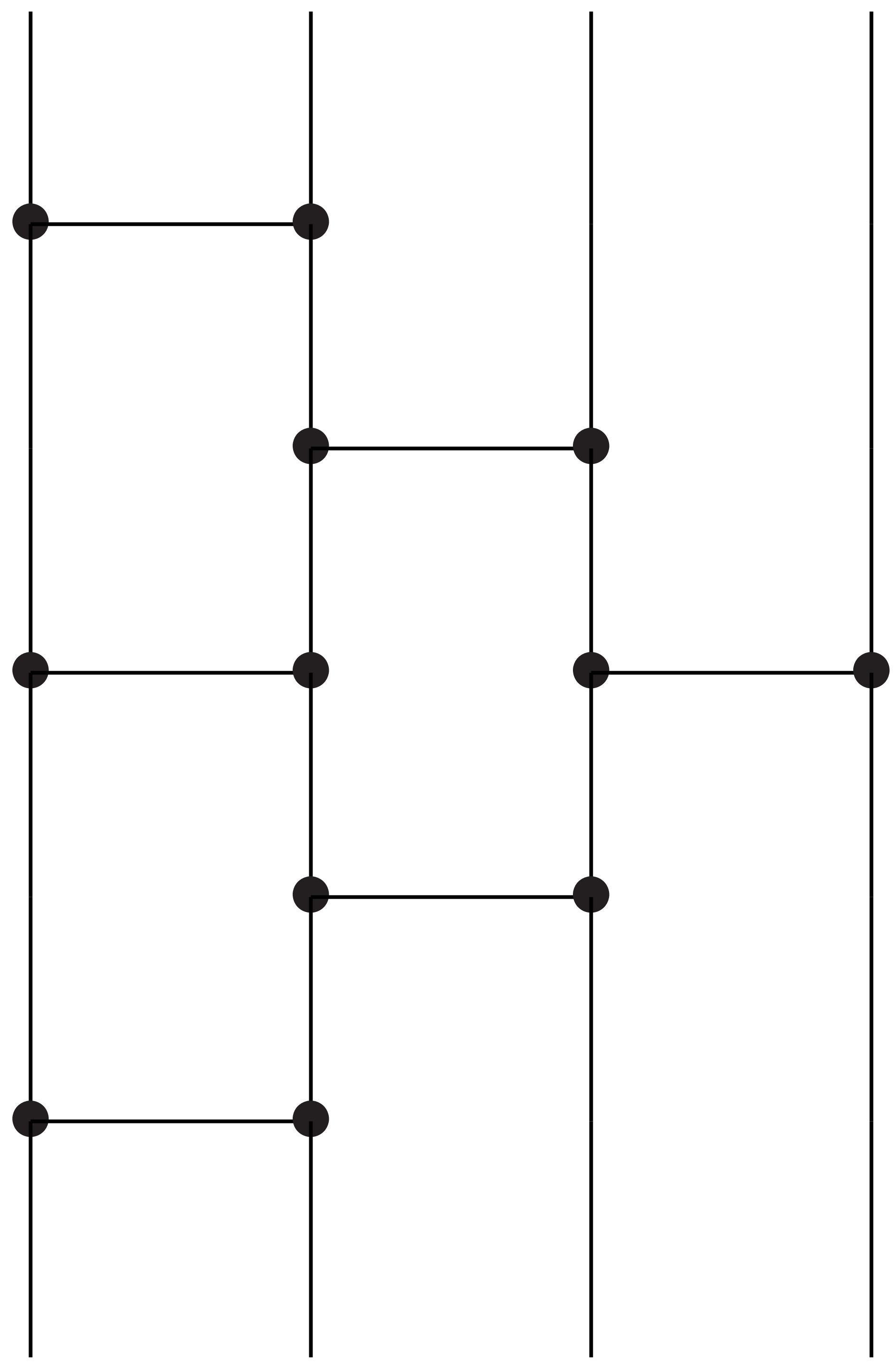

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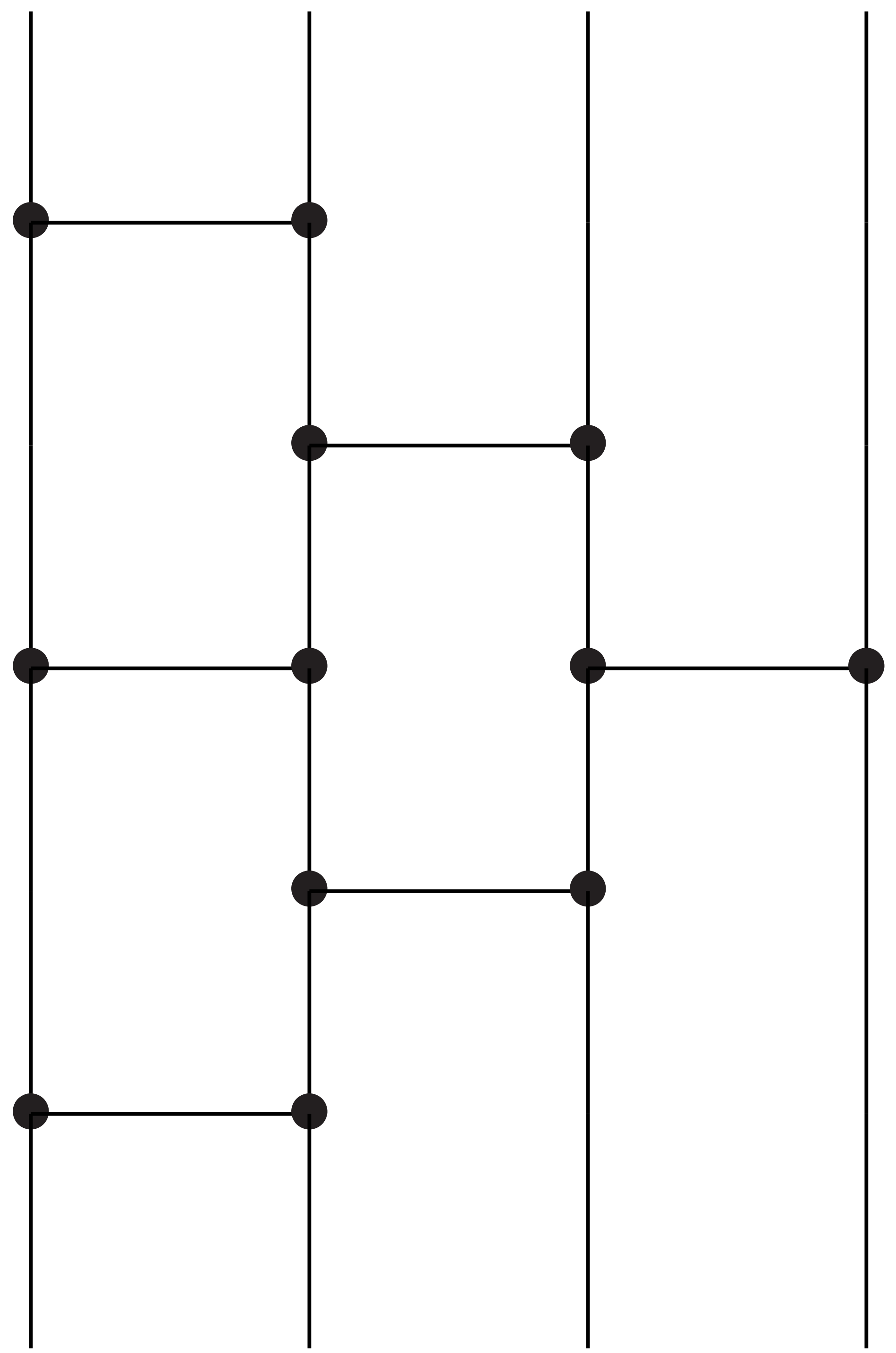

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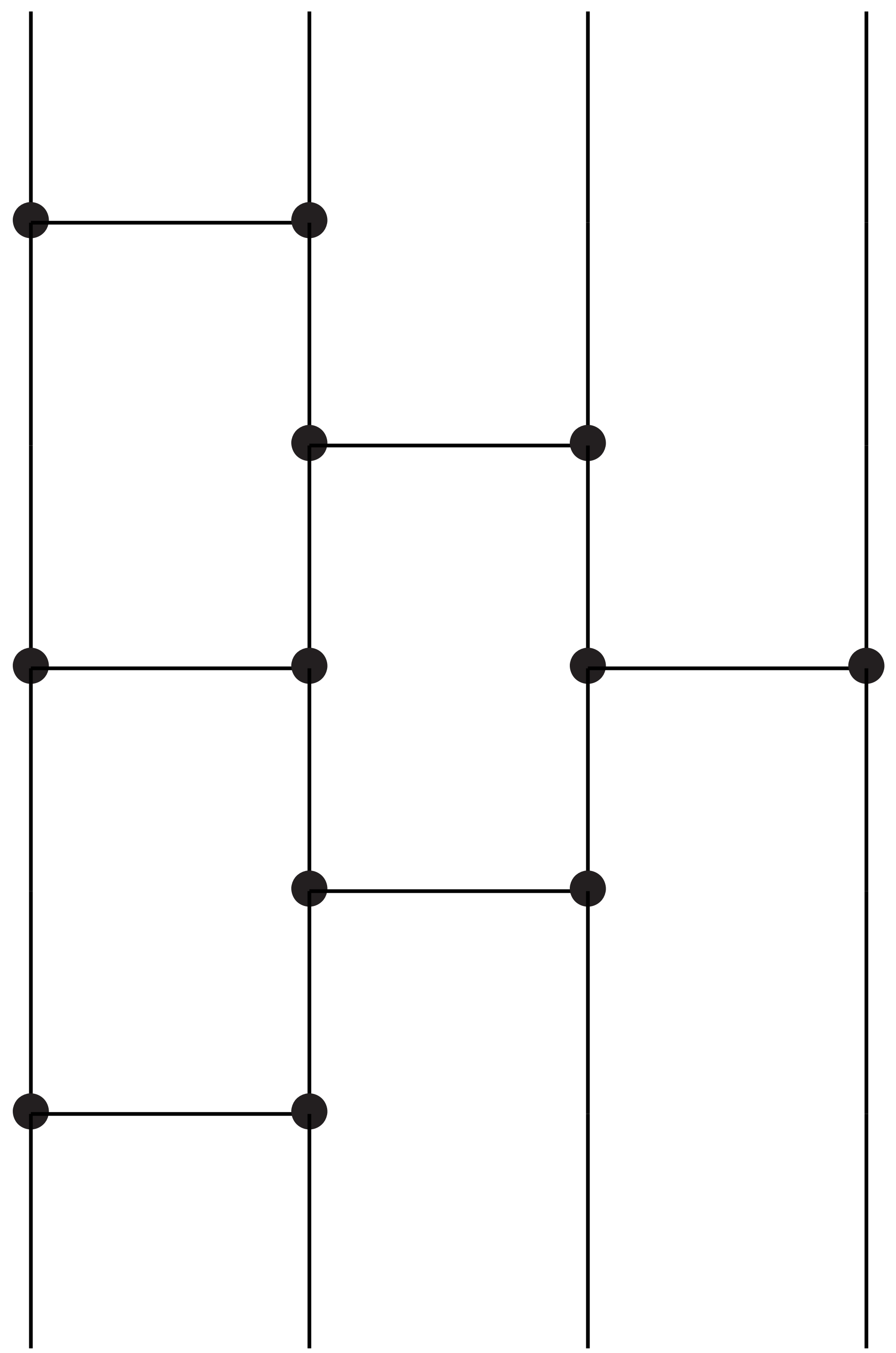

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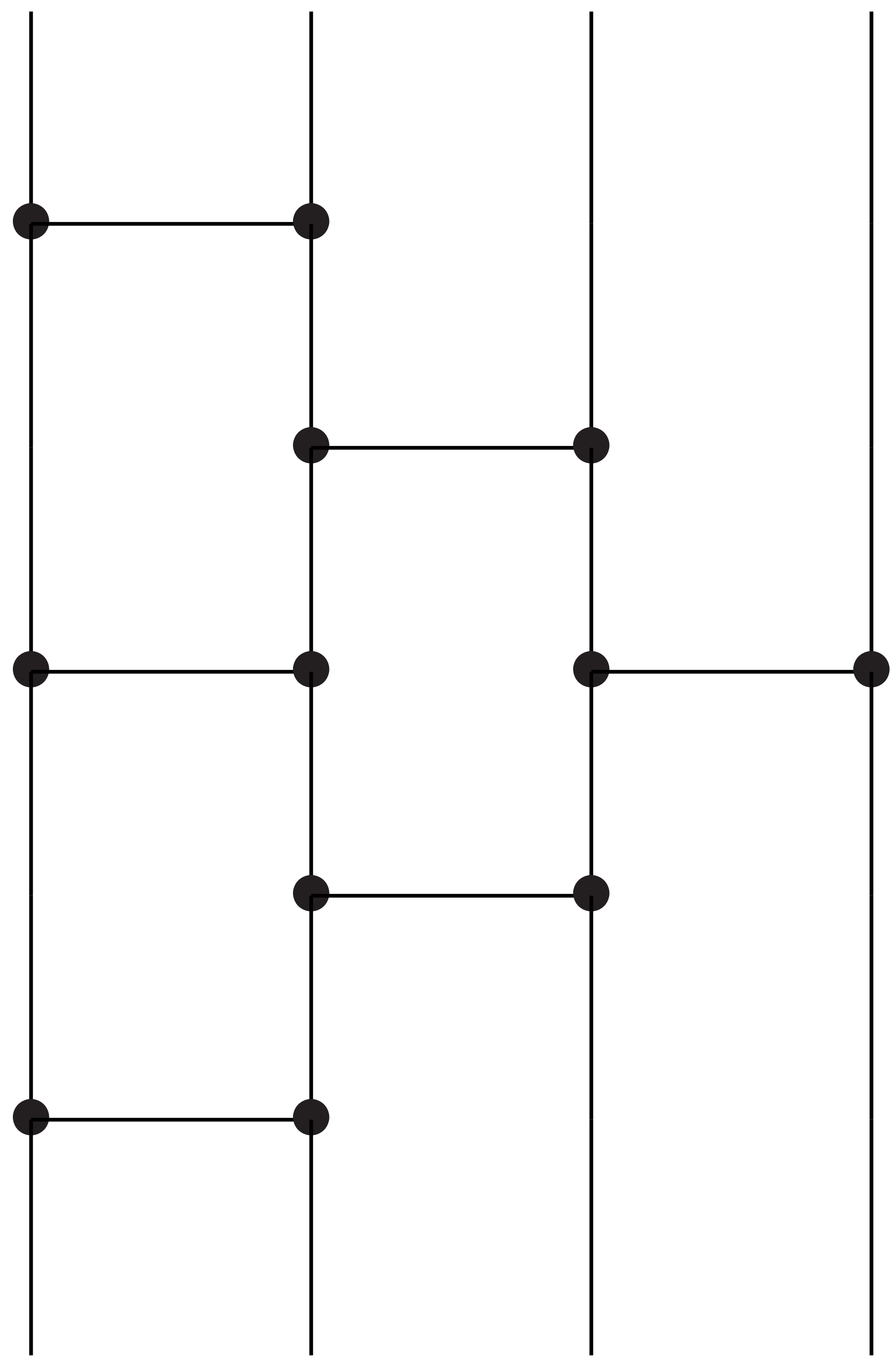

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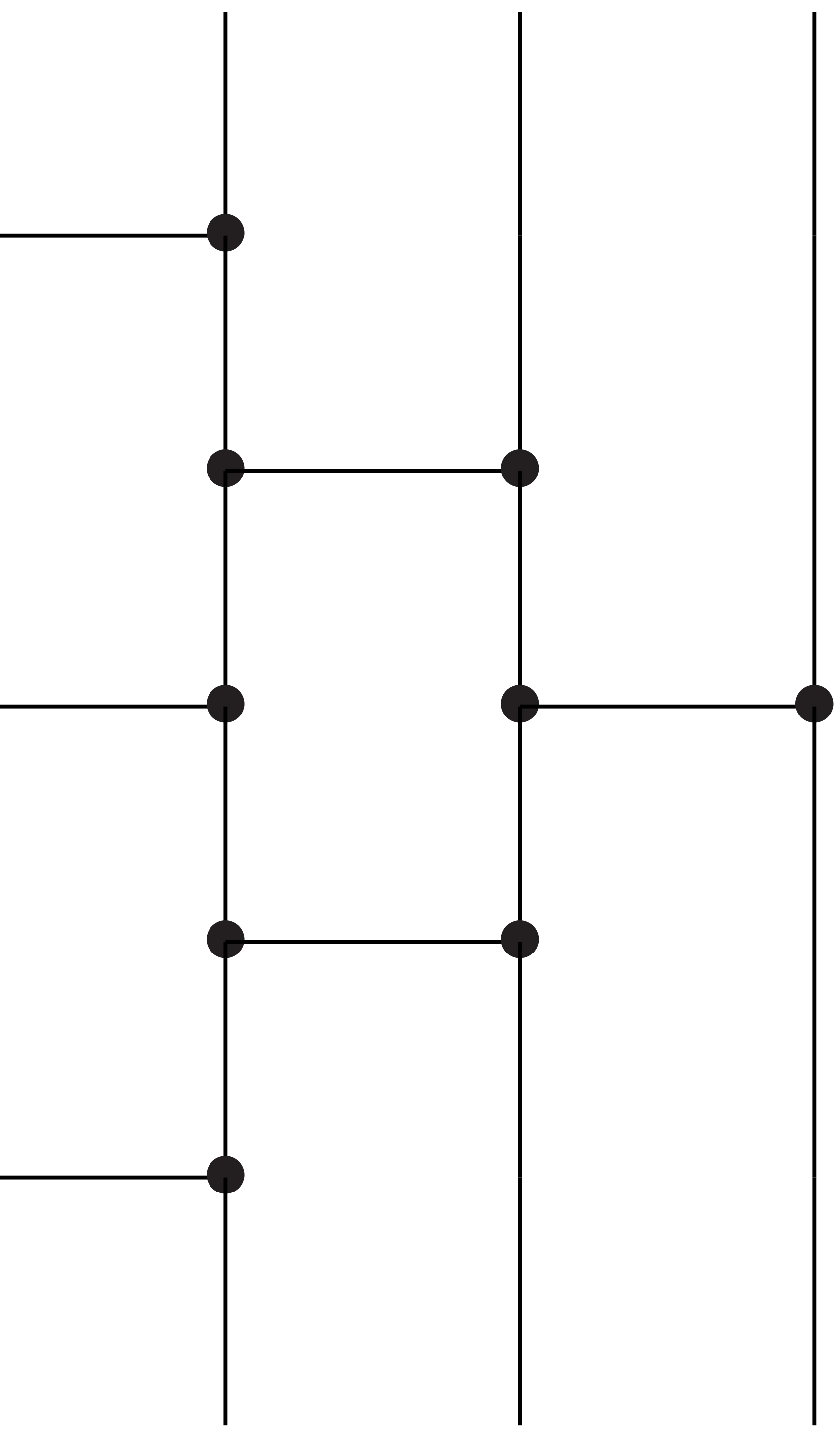

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```
void in
{ int64
  if (n
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  }
}
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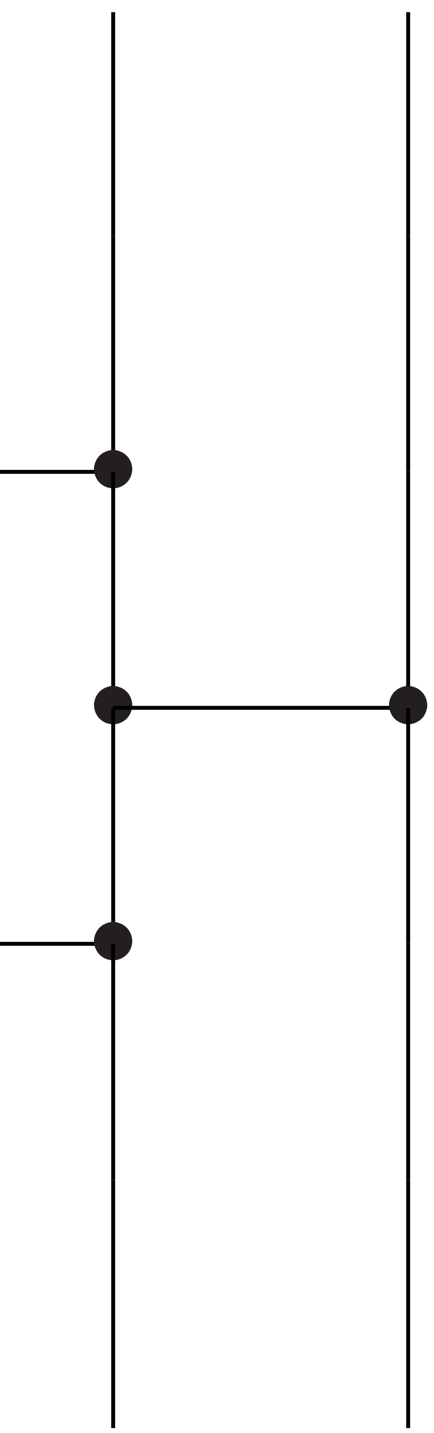

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```
void int32_sort(
{ int64 t,p,q,i;
  if (n < 2) ret
  t = 1;
  while (t < n -
  for (p = t;p >
    for (i = 0;i
      if (!(i &
        minmax(x
    for (q = t;q
      for (i = 0
        if (!(i
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  }
}
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```
void int32_sort(int32 *x,
{ int64 t,p,q,i;
  if (n < 2) return;
  t = 1;
  while (t < n - t) t +=
  for (p = t;p > 0;p >>=
    for (i = 0;i < n - p;
      if (!(i & p))
        minmax(x+i,x+i+p)
    for (q = t;q > p;q >>
      for (i = 0;i < n -
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  if (n < 2) return;
  t = 1;
  while (t < n - t) t += t;
  for (p = t;p > 0;p >>= 1) {
    for (i = 0;i < n - p;++i)
      if (!(i & p))
        minmax(x+i,x+i+p);
    for (q = t;q > p;q >>= 1)
      for (i = 0;i < n - q;++i)
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  if (n < 2) return;
  t = 1;
  while (t < n - t) t += t;
  for (p = t;p > 0;p >>= 1) {
    for (i = 0;i < n - p;++i)
      if (!(i & p))
        minmax(x+i,x+i+p);
    for (q = t;q > p;q >>= 1)
      for (i = 0;i < n - q;++i)
        if (!(i & p))
          minmax(x+i+p,x+i+q);
  }
}
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```
t32_sort(int32 *x,int64 n)
 t,p,q,i;
 < 2) return;
;
 (t < n - t) t += t;
p = t;p > 0;p >>= 1) {
 (i = 0;i < n - p;++i)
f (!(i & p))
 minmax(x+i,x+i+p);
 (q = t;q > p;q >>= 1)
or (i = 0;i < n - q;++i)
 if (!(i & p))
   minmax(x+i+p,x+i+q);
```


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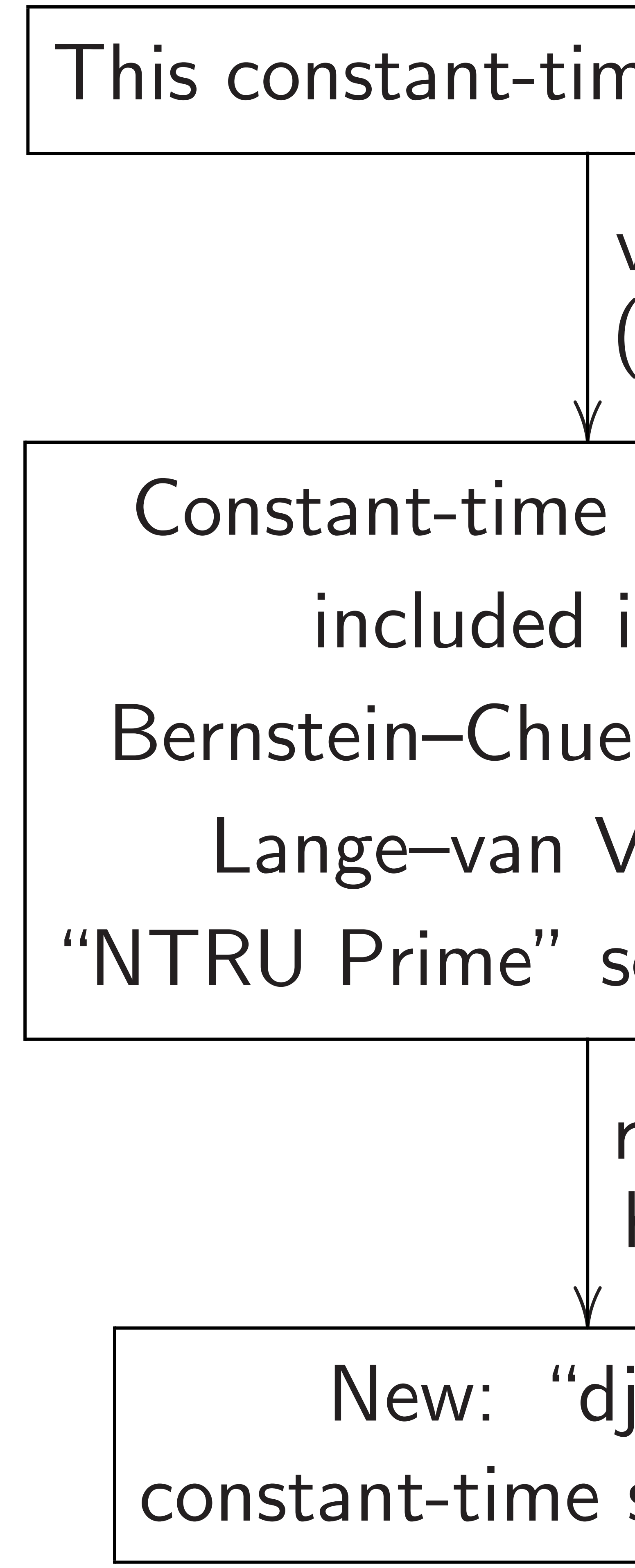

```
int64 n)

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++i)

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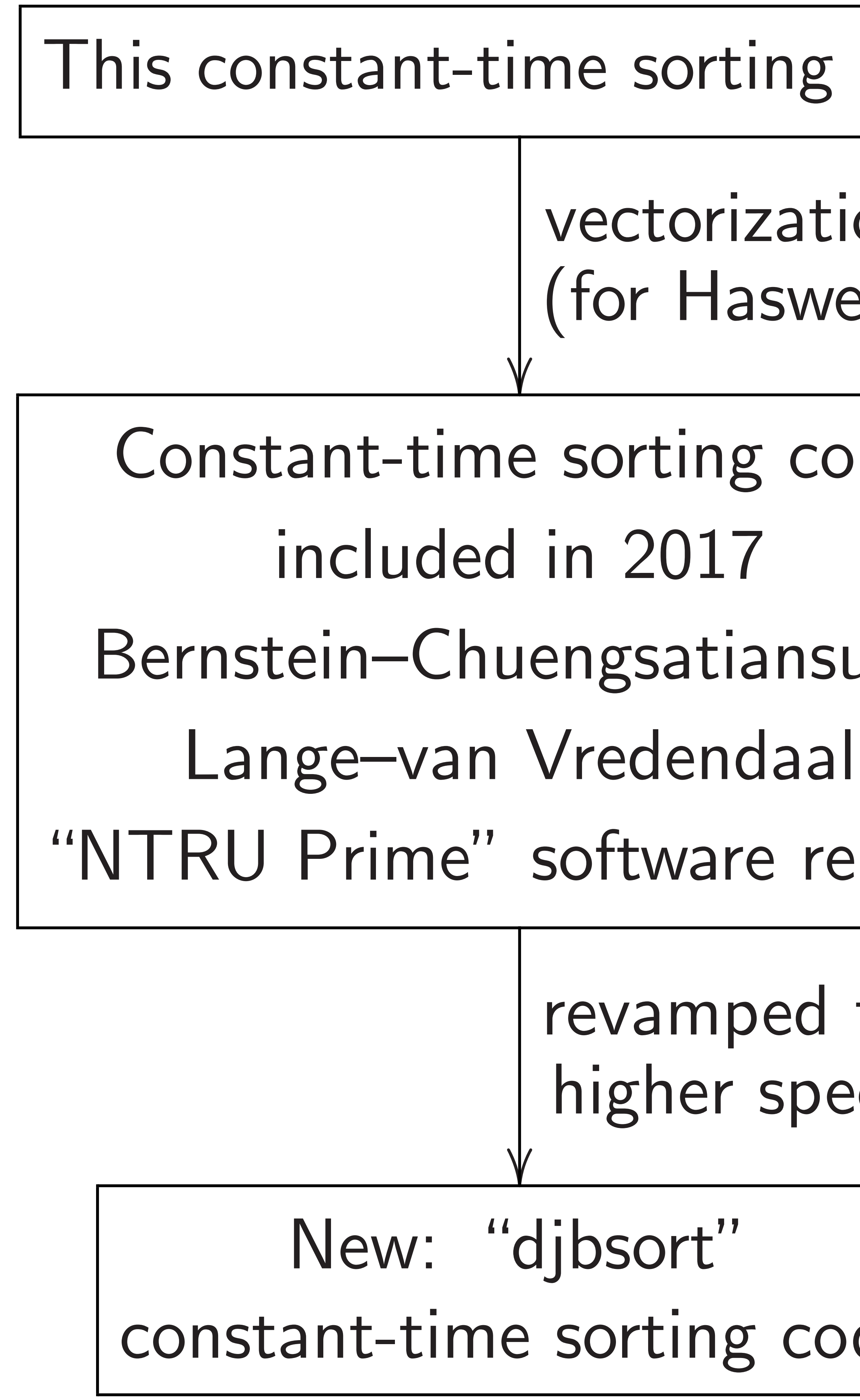

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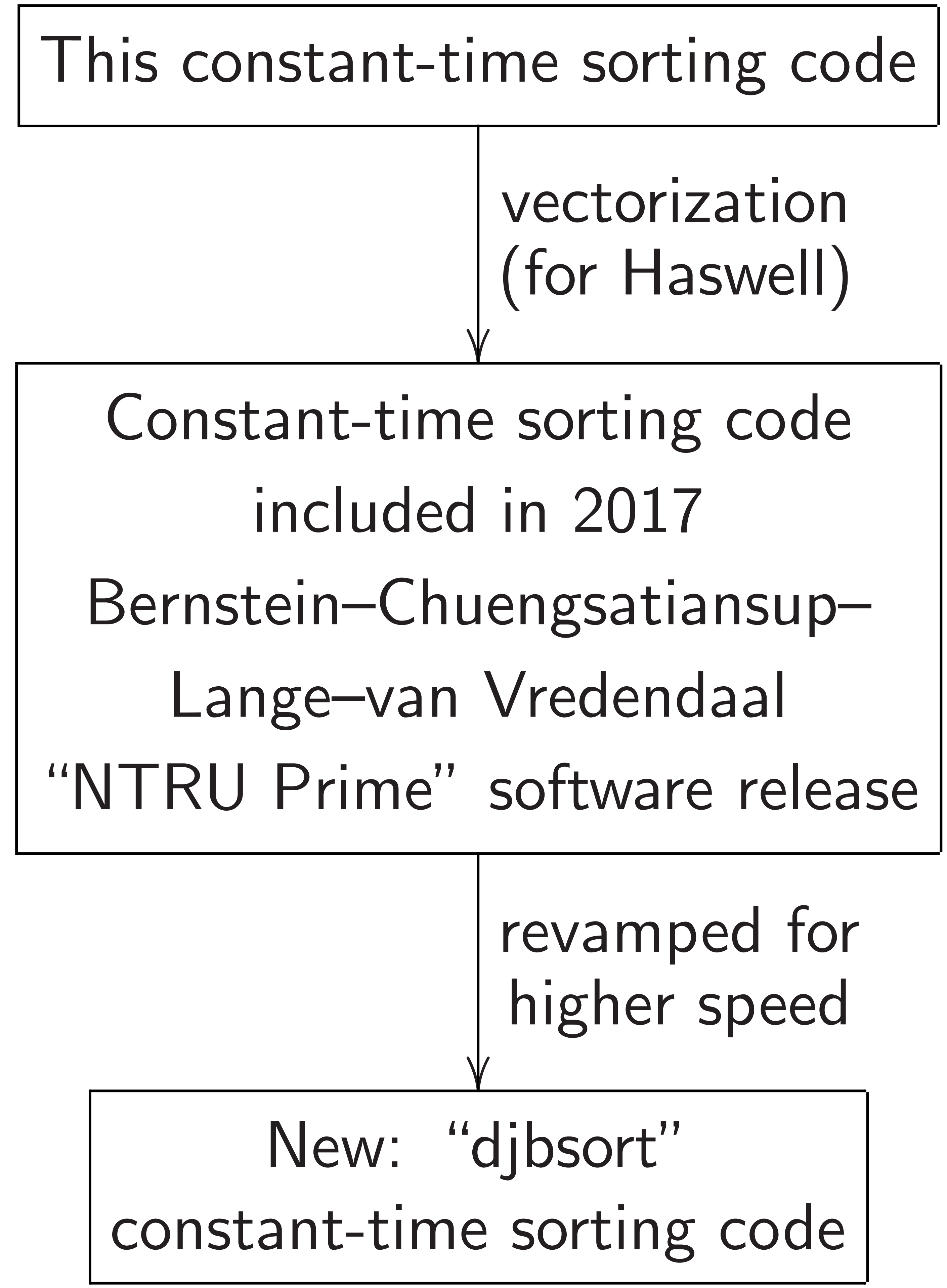

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This constant-time sorting code

↓ vectorization (for Haswell)

Constant-time sorting code included in 2017 Bernstein–Chuengsatiansup–Lange–van Vredendaal "NTRU Prime" software release

↓ revamped for higher speed

New: "djbsort" constant-time sorting code

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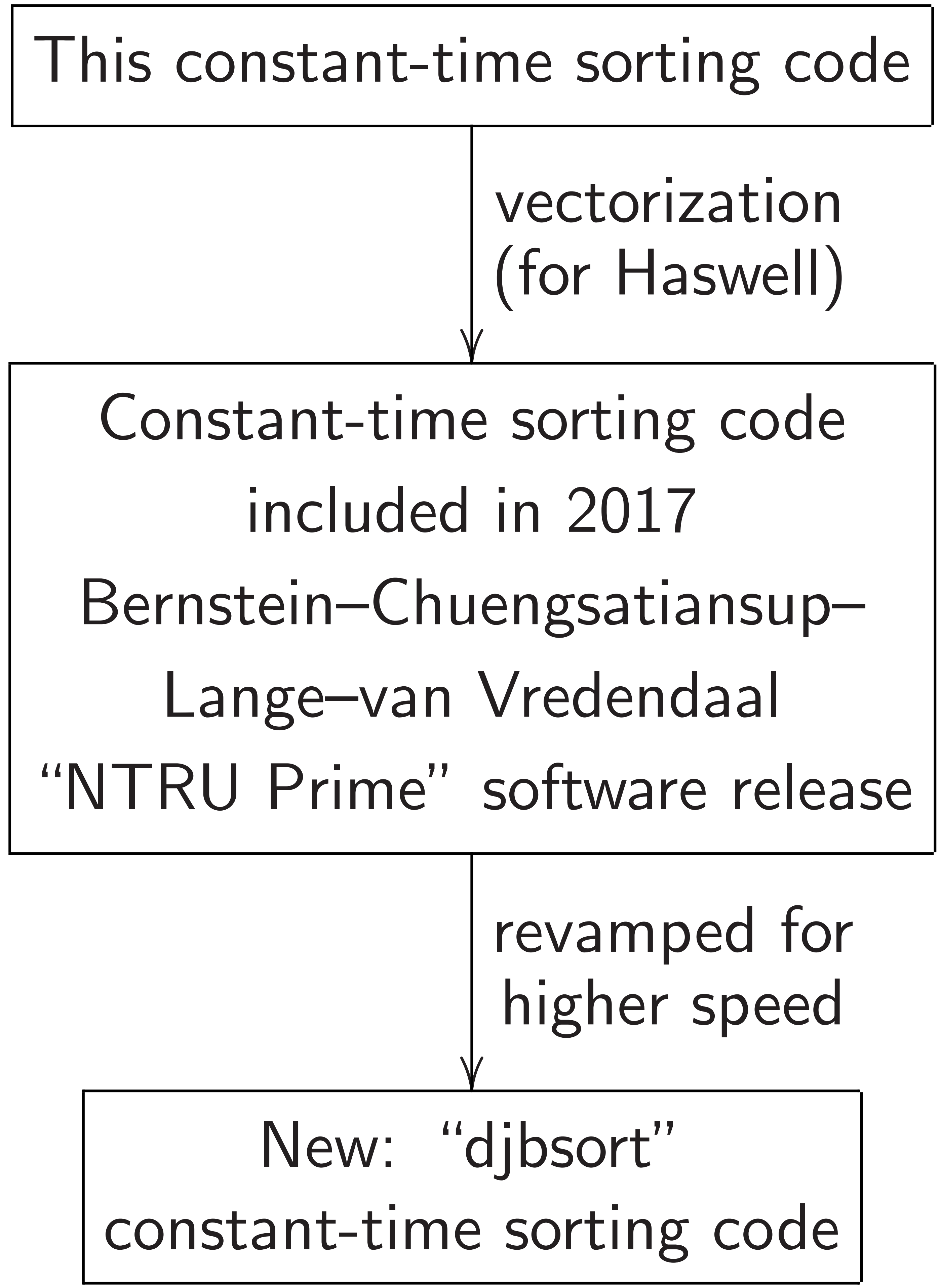

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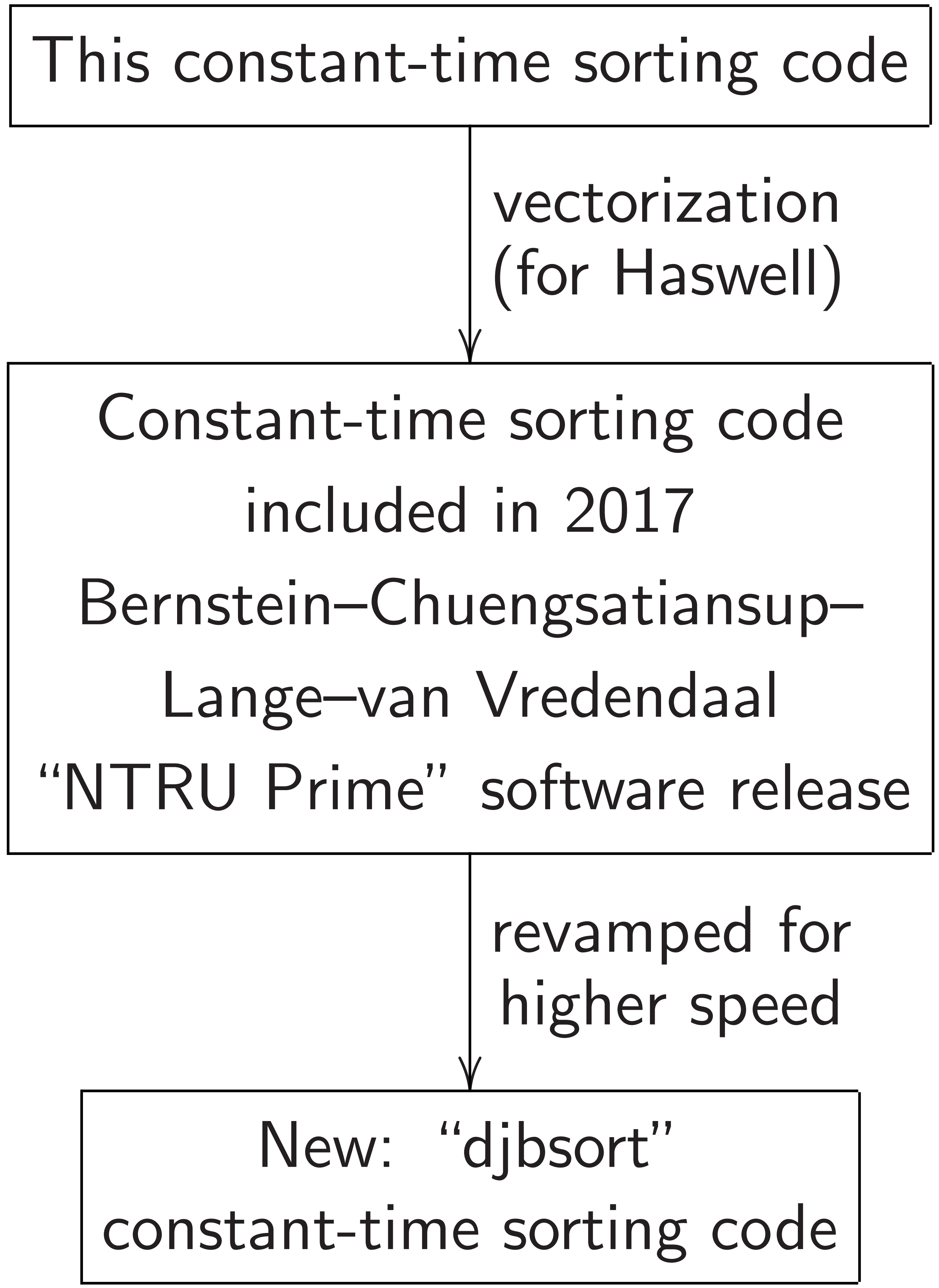

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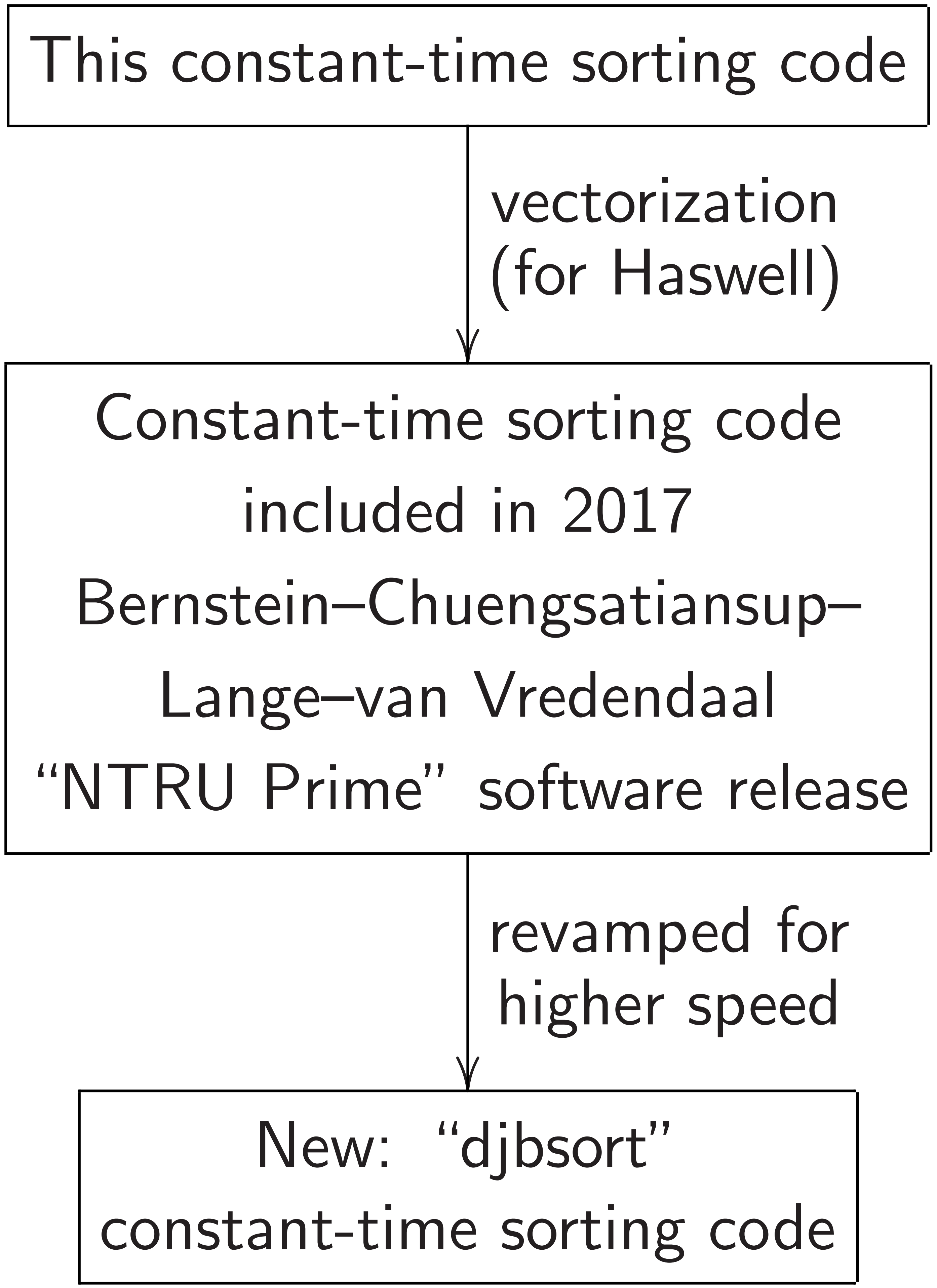

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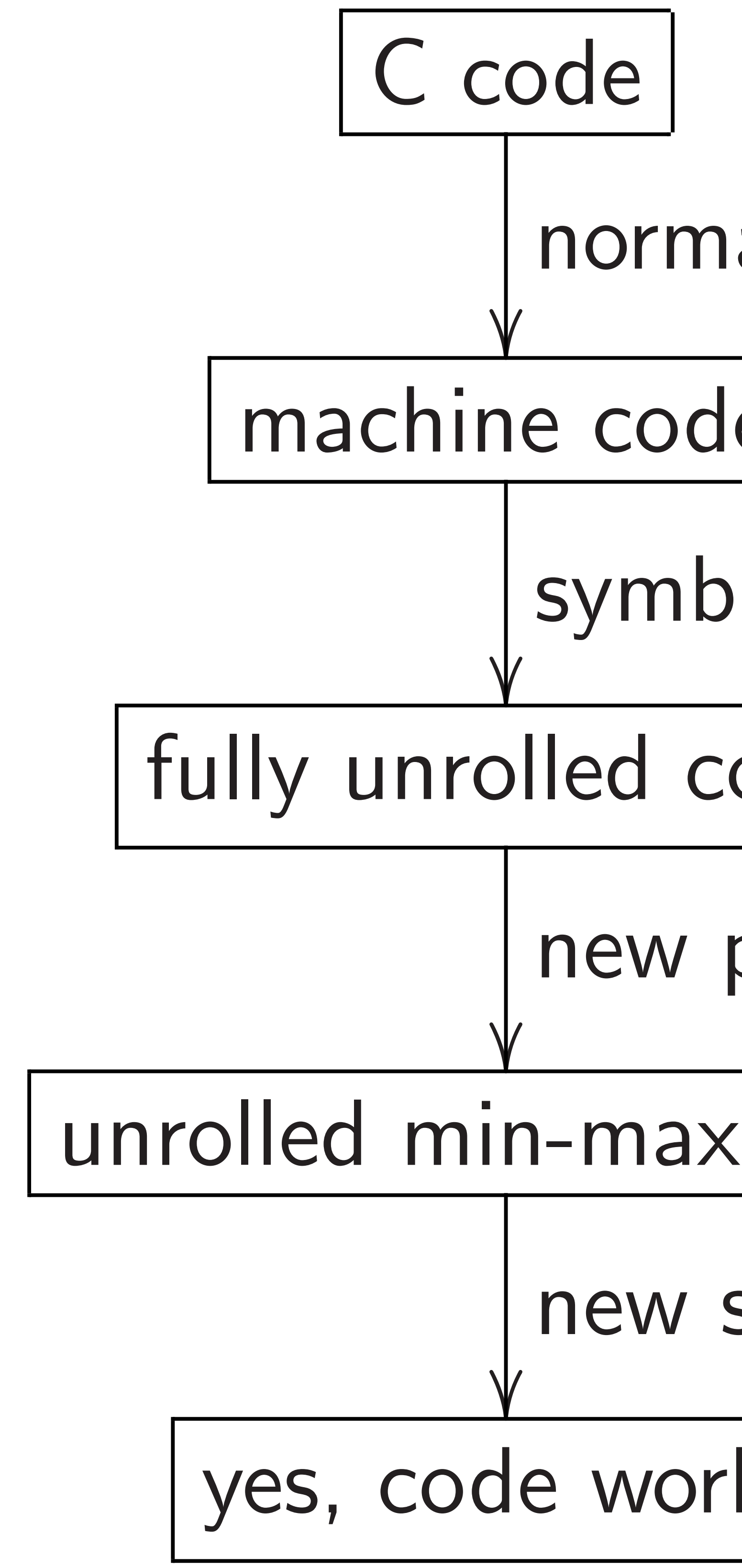

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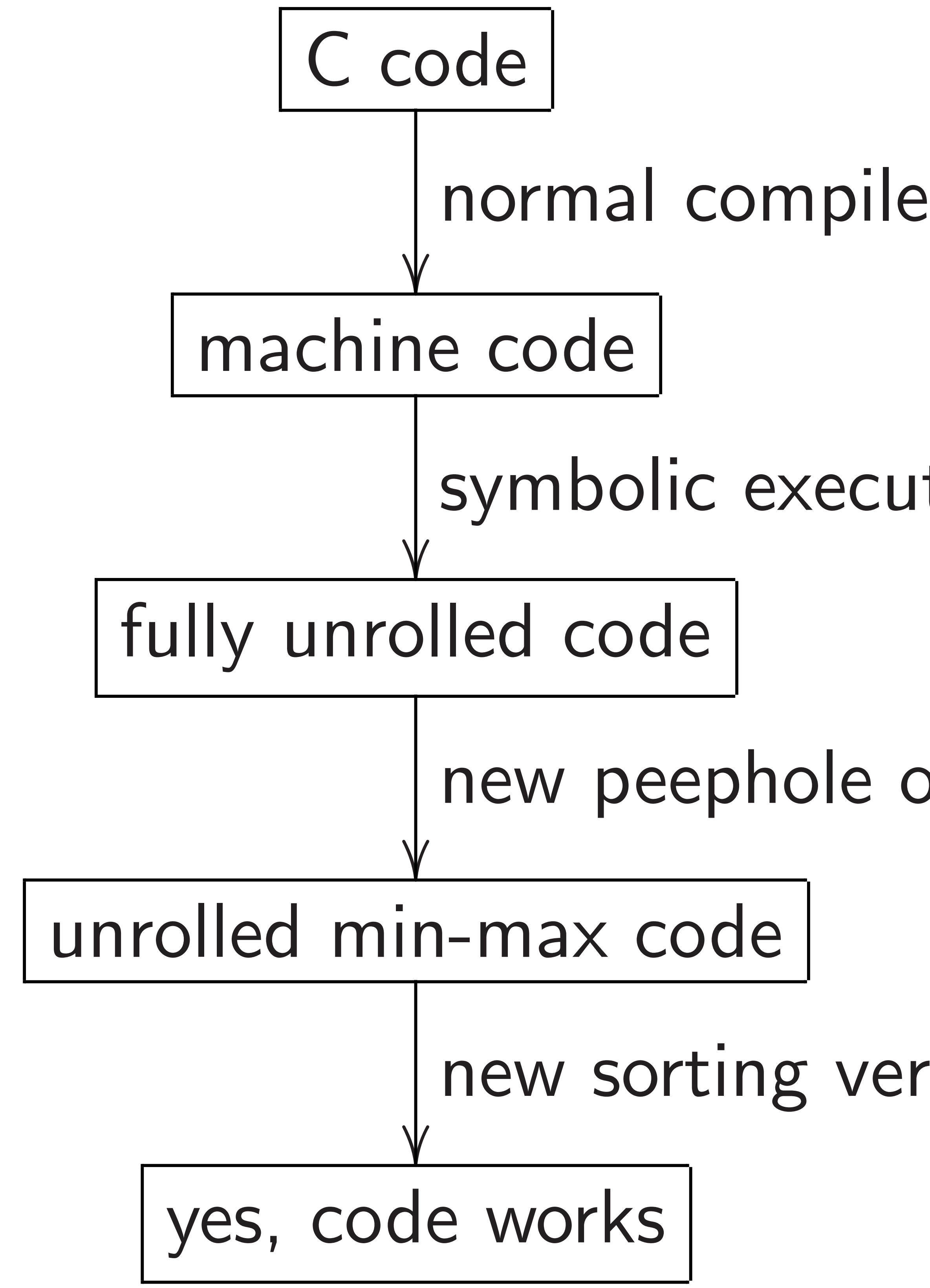

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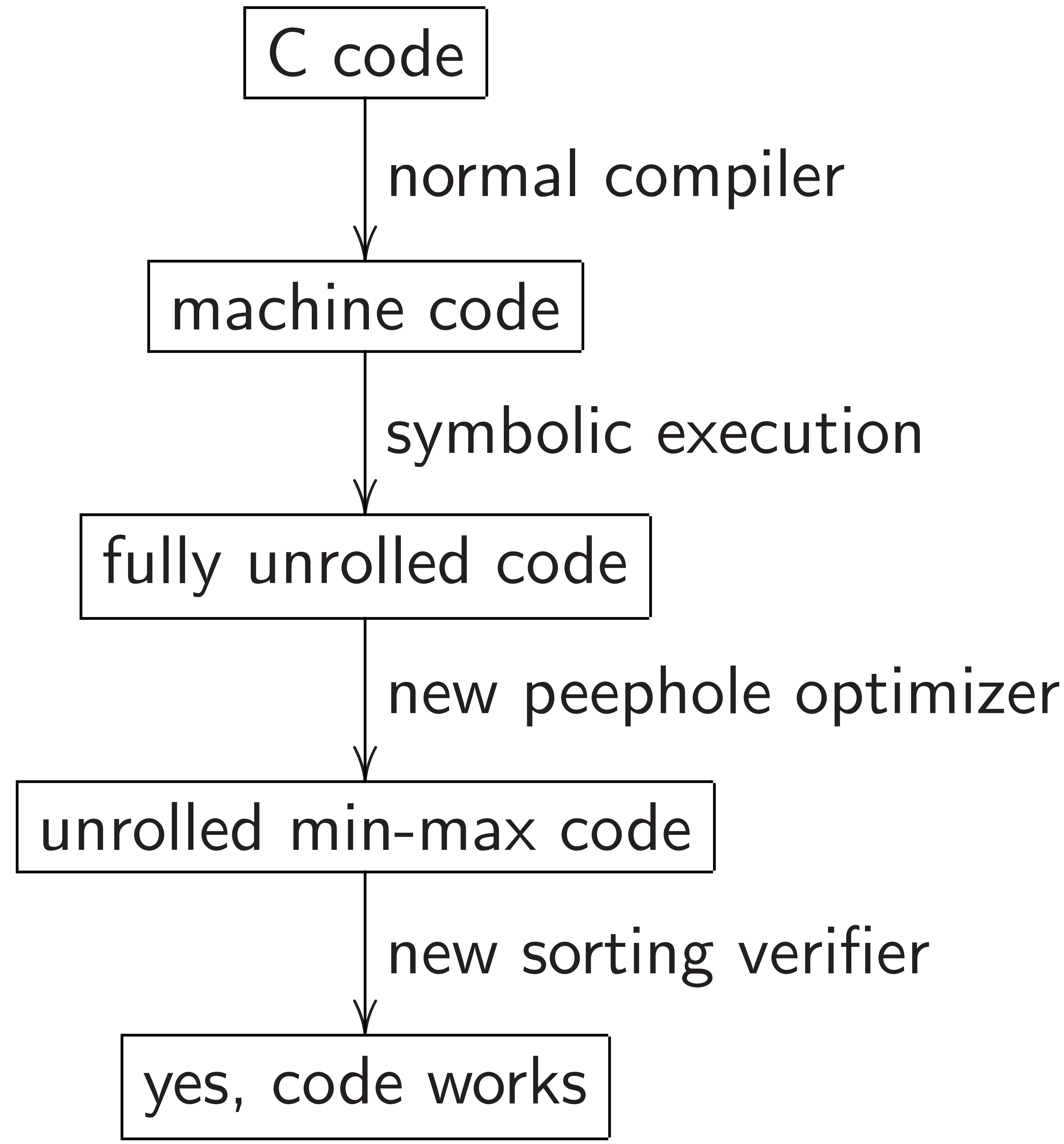

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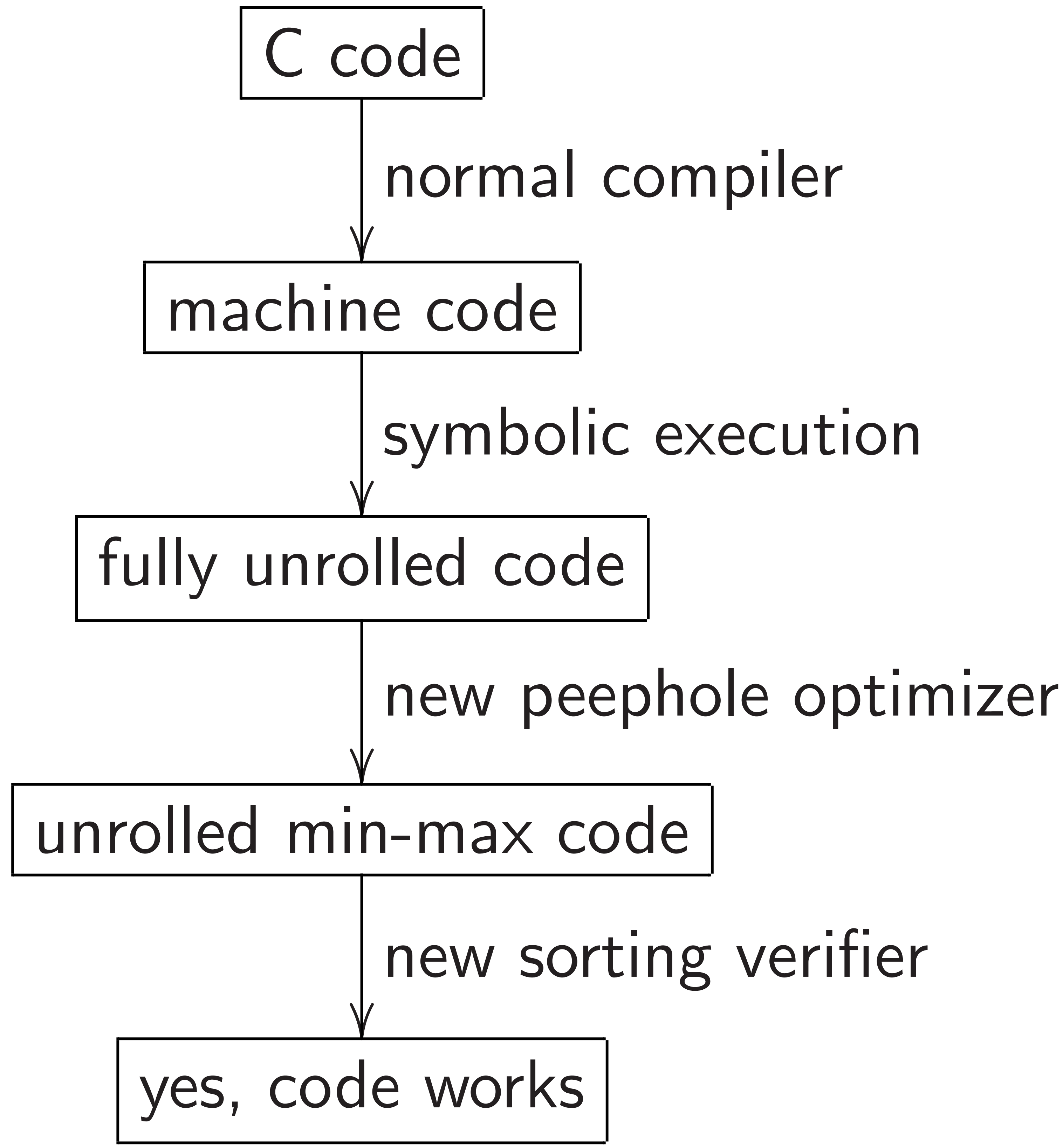

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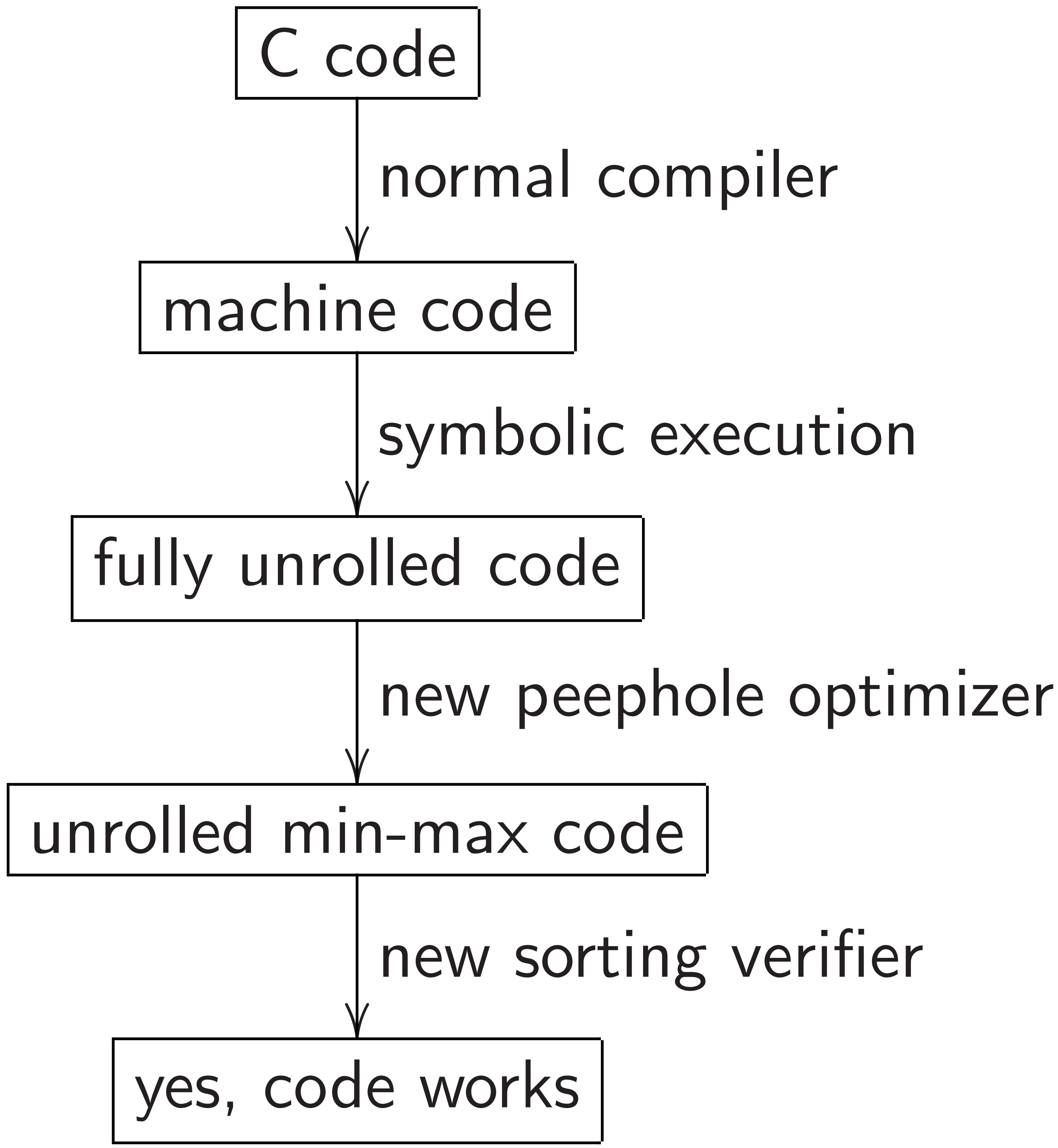

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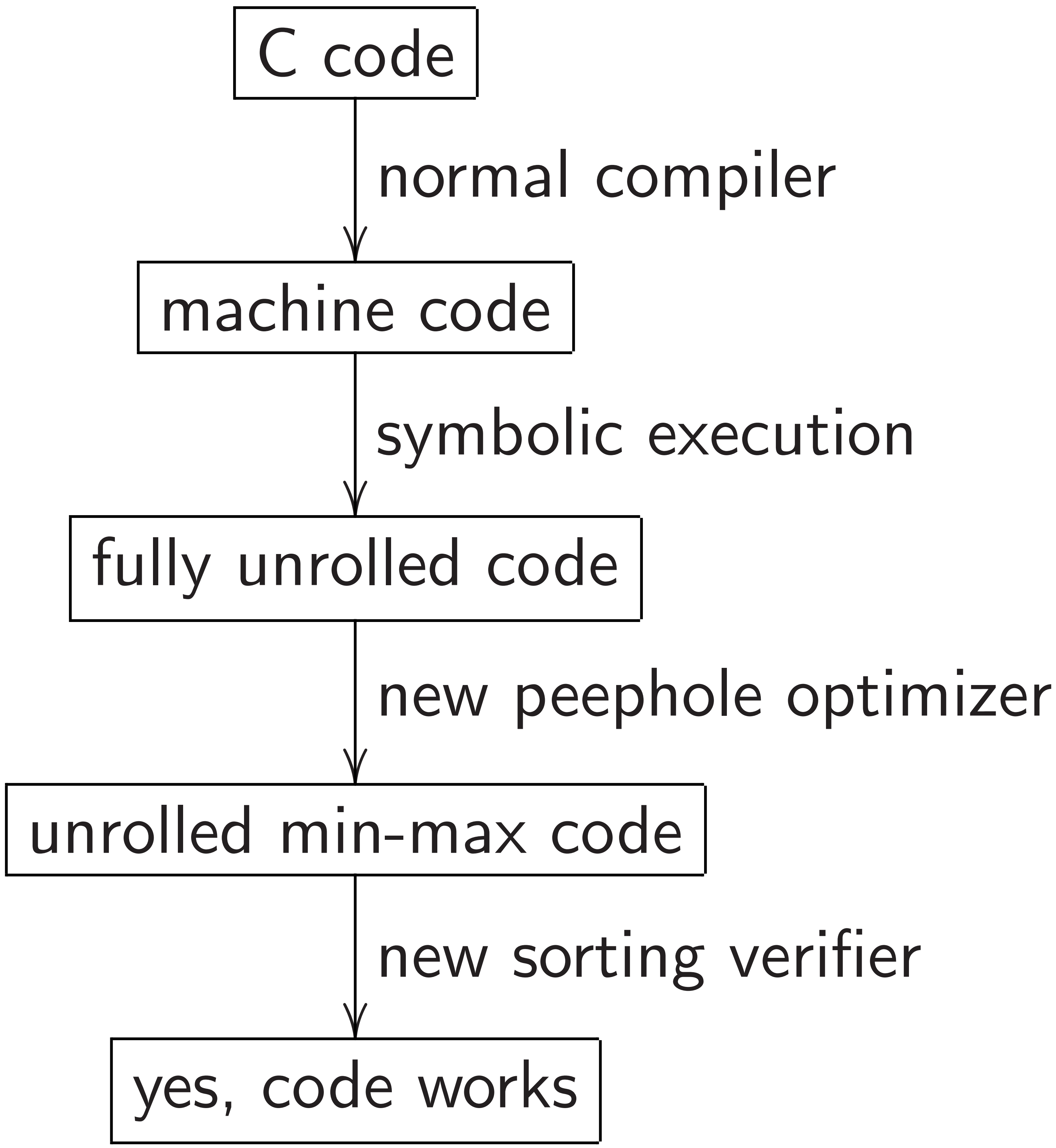

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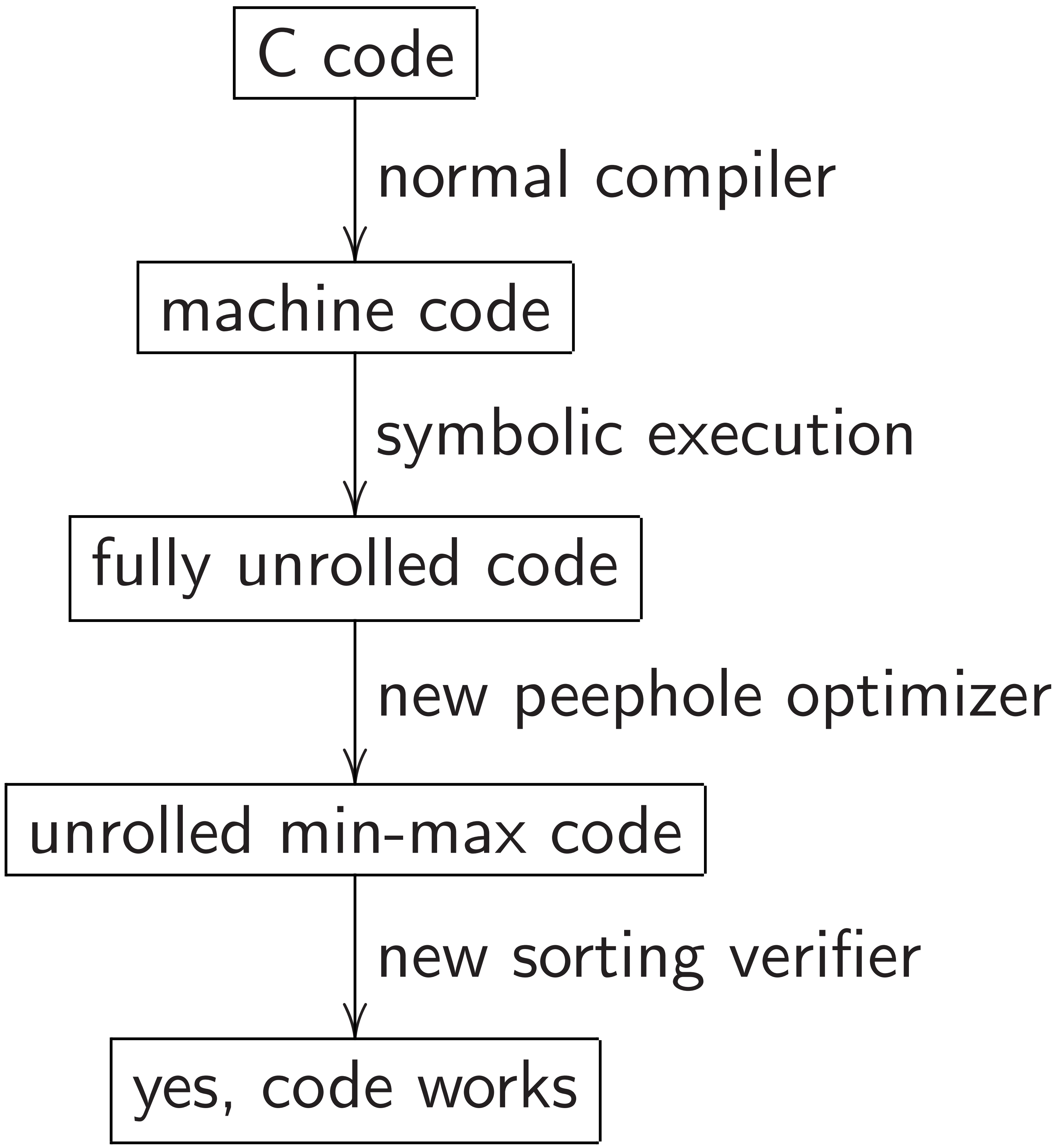

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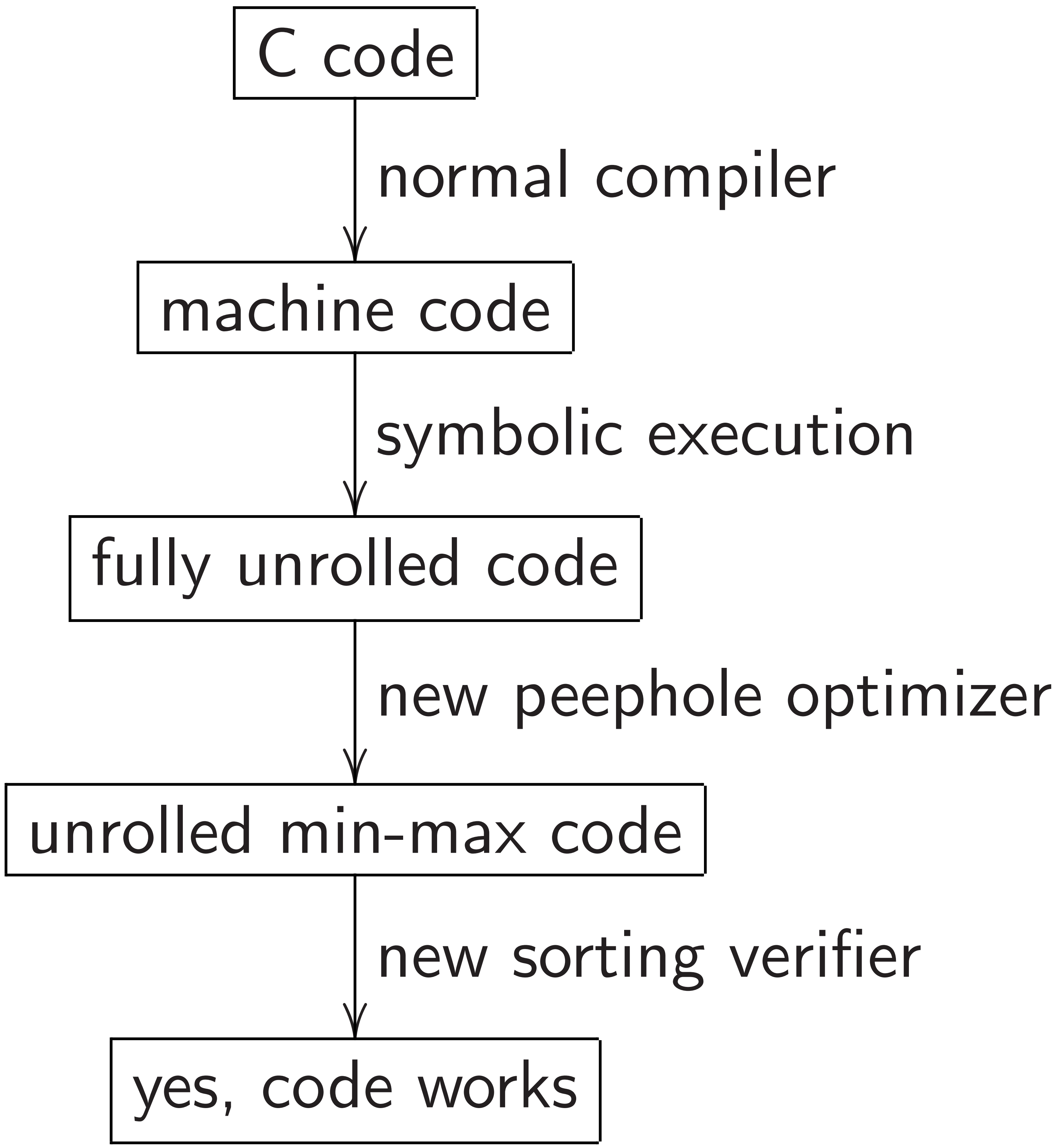

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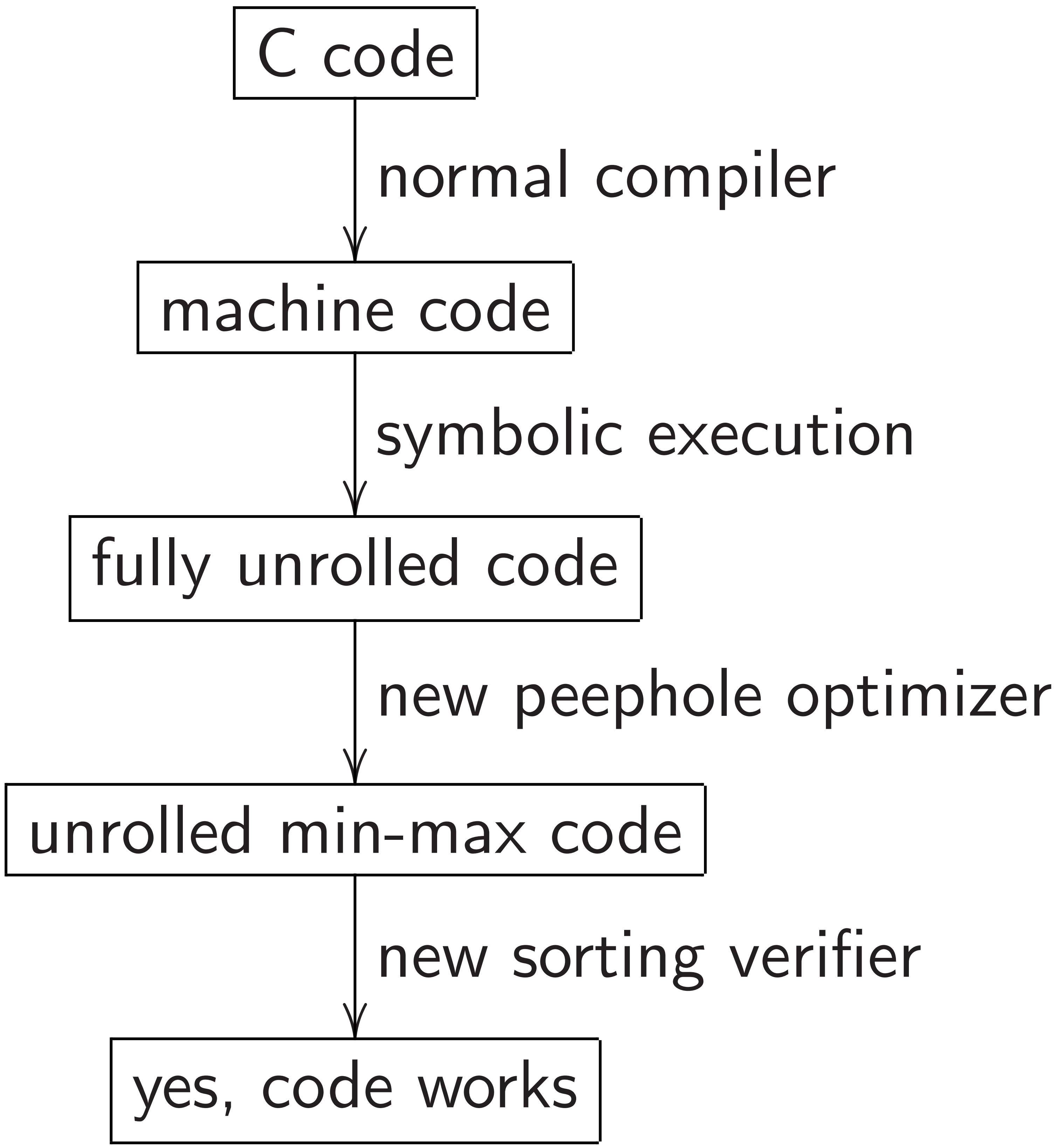

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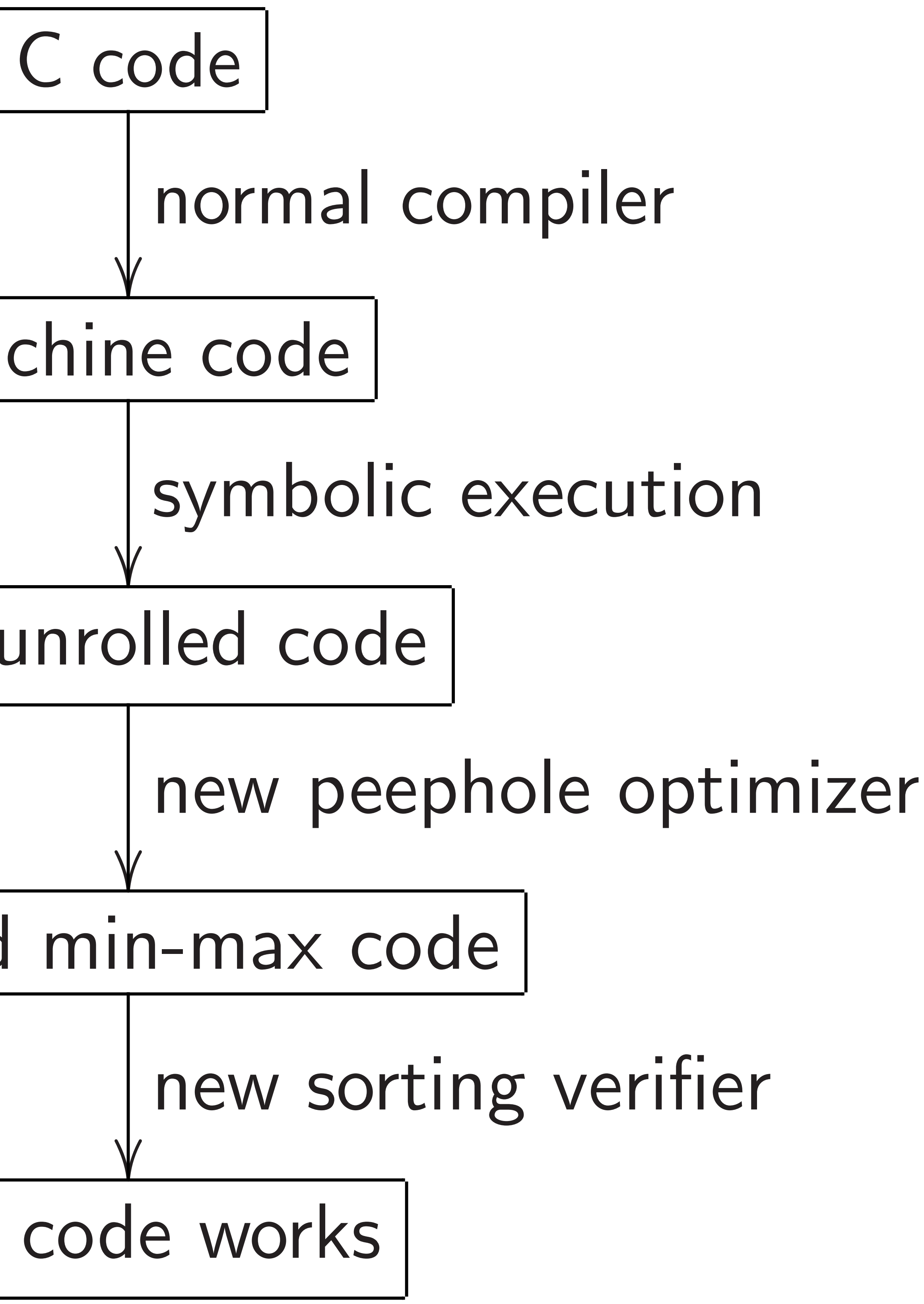

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