Inside a JVM

With Cliff Click

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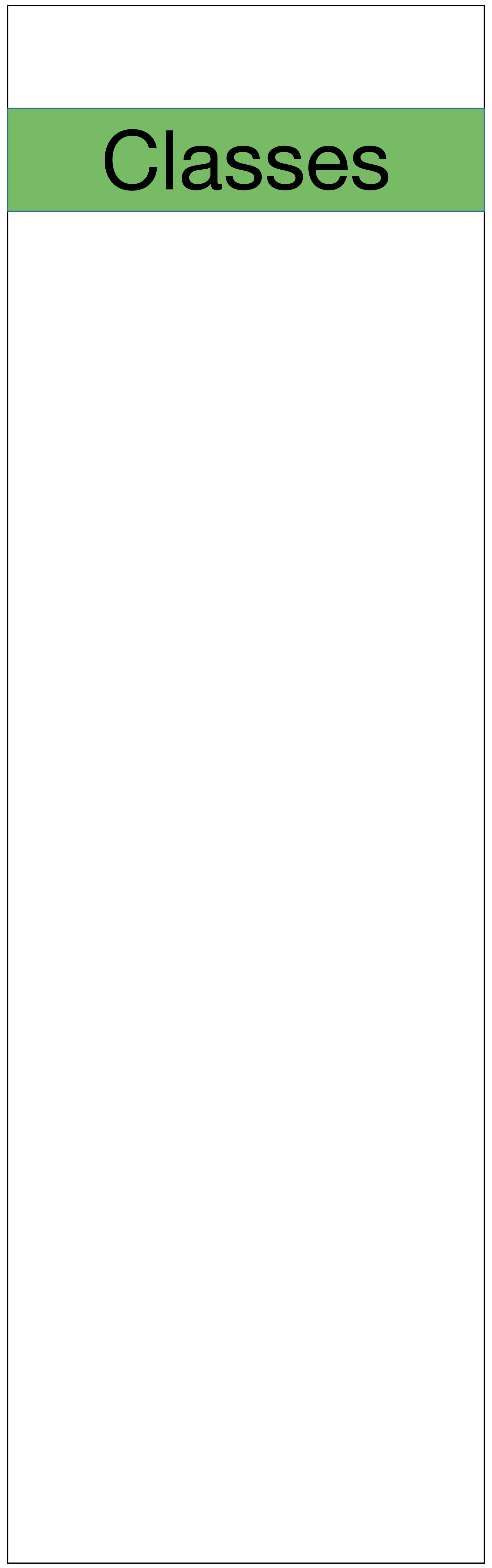

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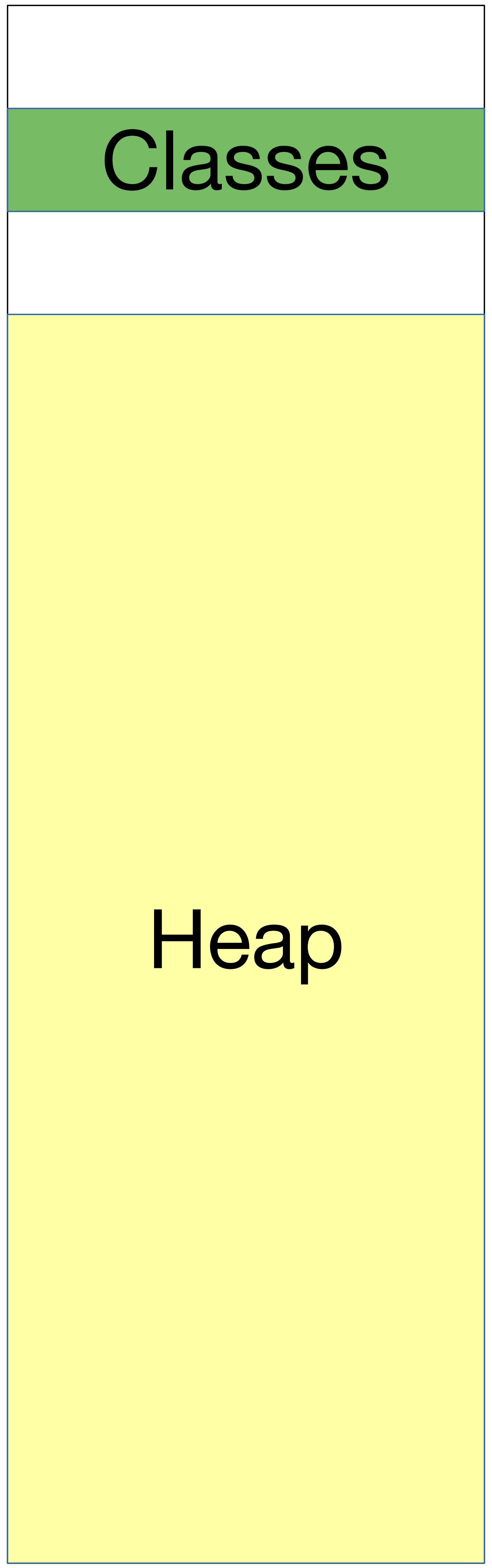

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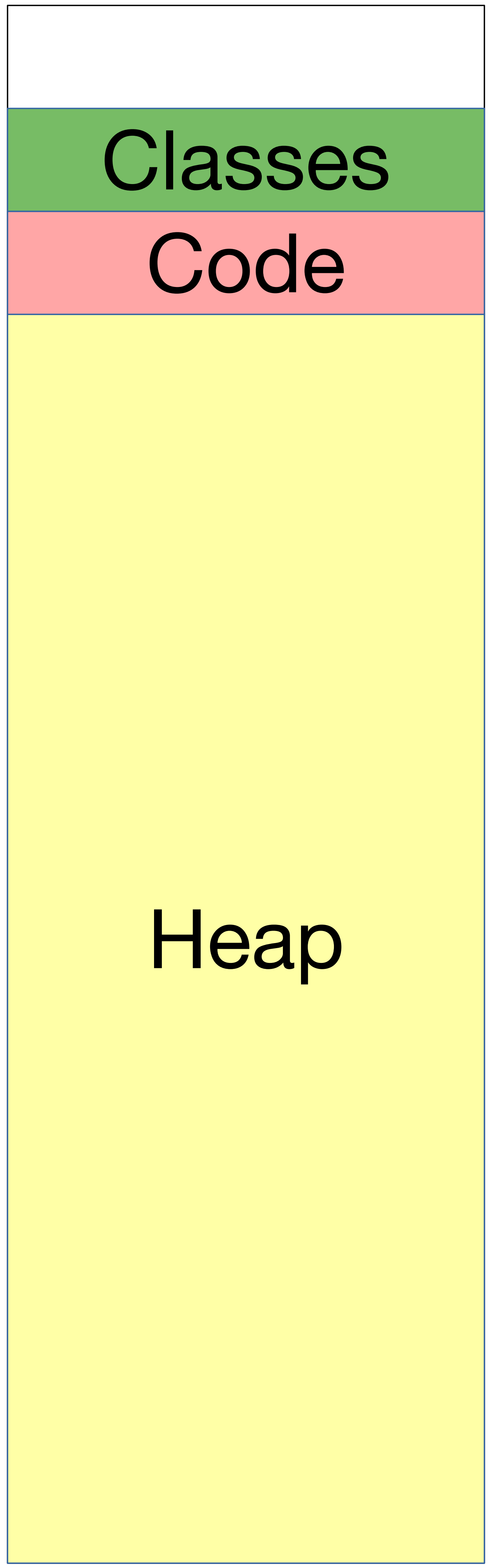

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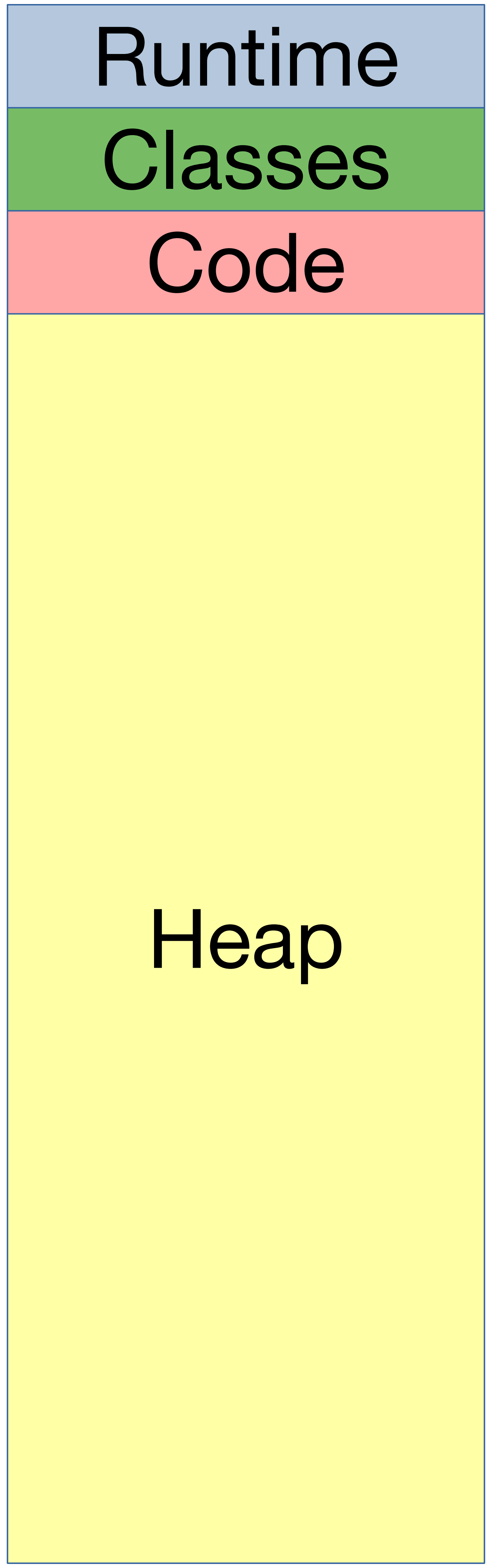
Runtime, Locks & Threads, OS access (files,JNI,Time), Debugging



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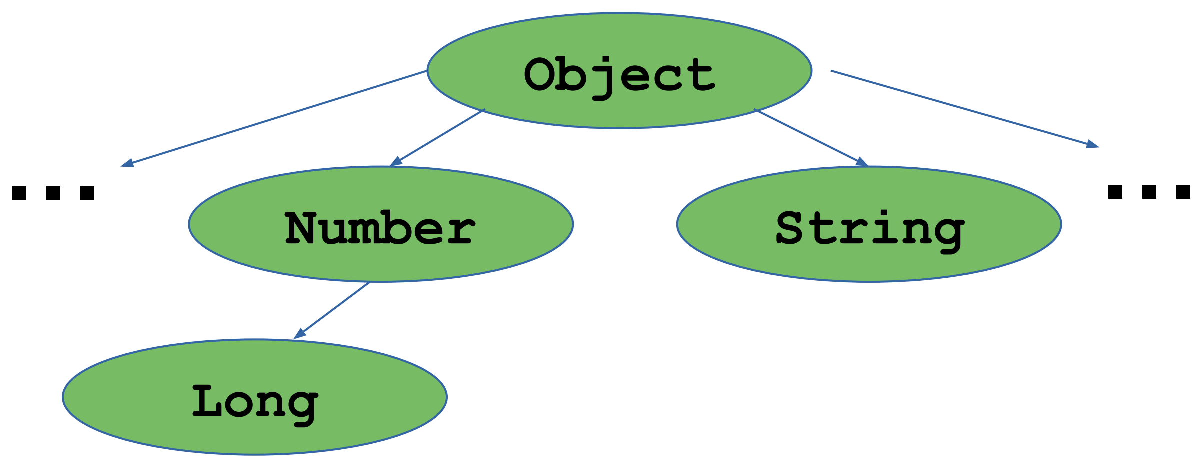

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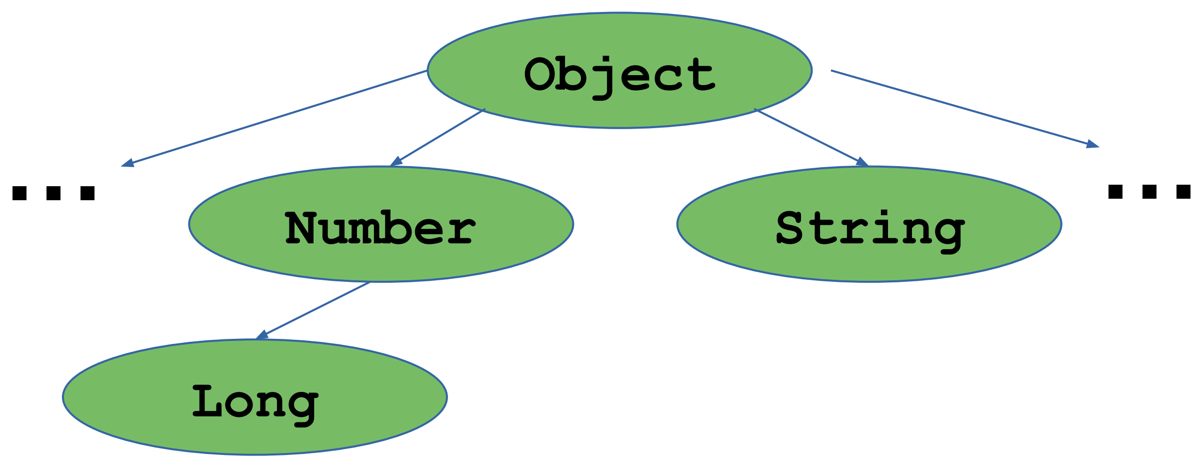

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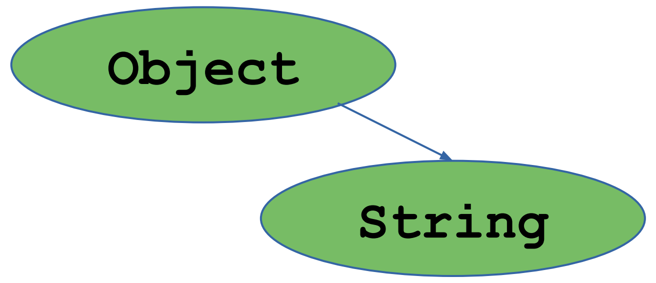

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Classes form a tree, rooted at Object. They have a super-class and some subclasses (and interfaces). They have fields and methods.

```
public final class String implements ... {
   /** The value is used for character storage. */
   private final char value[];

   /** Cache the hash code for the string */
   private int hash; // Default to 0

...
```

```
/**
 * Returns a hash code for this string.
 * @return  a hash code value for this object.
 */
public int hashCode() {
   int h = hash;
   if (h == 0 && value.length > 0) {
      char val[] = value;

      for (int i = 0; i < value.length; i++) {
         h = 31 * h + val[i];
      }
      hash = h;
   }
   return h;
}
```

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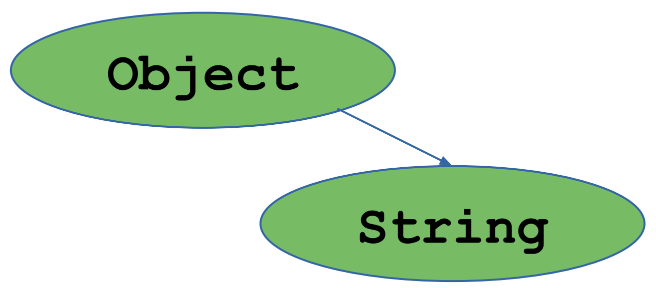

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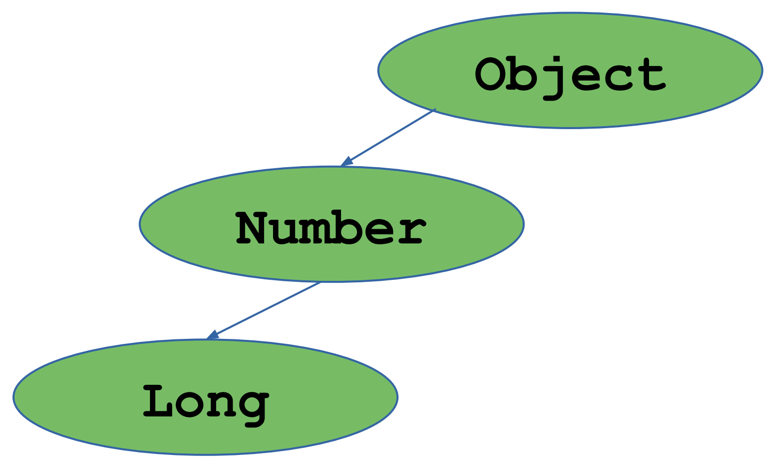
```
/** use serialVersionUID from JDK 1.0.2 for interoperability */
private static final long serialVersionUID = -6849794470754667710L;

/**
 * Class String is special cased within the Serialization Stream Protocol.
 *
 * A String instance is written into an ObjectOutputStream according to
 * <a href="{@docRoot}/../platform/serialization/spec/output.html">
 * Object Serialization Specification, Section 6.2, "Stream Elements"</a>
 */
private static final ObjectStreamField[] serialPersistentFields =
    new ObjectStreamField[0];
```

Classes & Meta-data



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public final class Long extends Number implements Comparable<Long> {
...
  private static class LongCache {
      private LongCache(){}

      static final Long cache[] = new Long[-(-128) + 127 + 1];

      static {
          for(int i = 0; i < cache.length; i++)
              cache[i] = new Long(i - 128);
      }
  }
```

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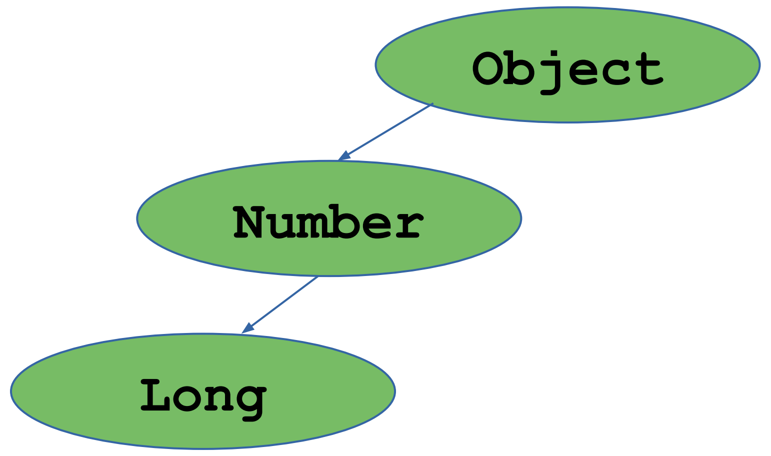

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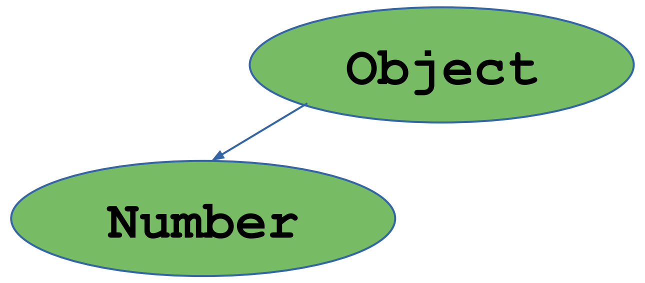

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```
 * @jls 5.1.2 Widening Primitive Conversions
 * @jls 5.1.3 Narrowing Primitive Conversions
 * @since   JDK1.0
 */
public abstract class Number implements java.io.Serializable {
    /**
     * Returns the value of the specified number as an {@code int},
     * which may involve rounding or truncation.
```

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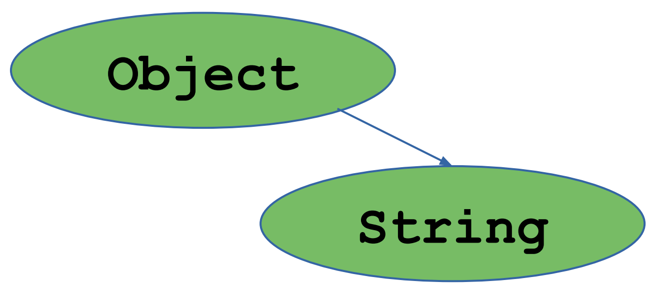

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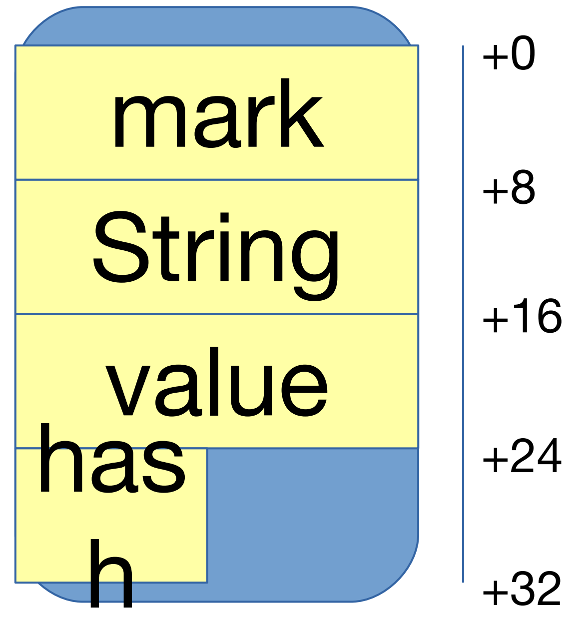

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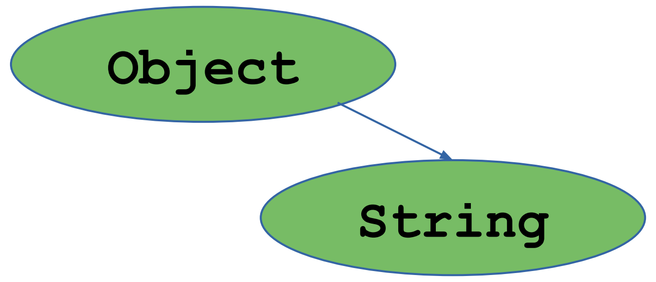

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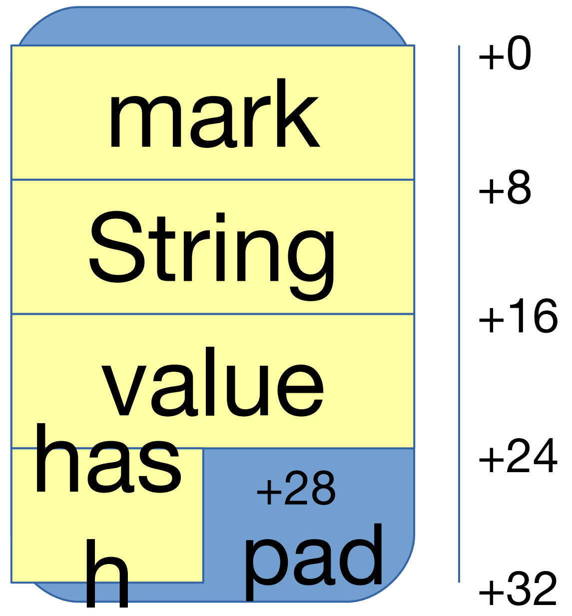

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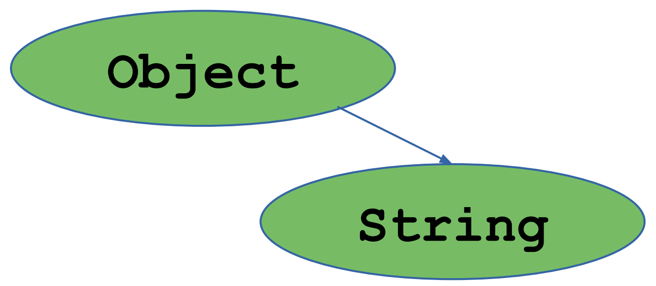

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```
String.hashCode:
+0: 100
+2: 1000
+4: 1000
+8:...
```

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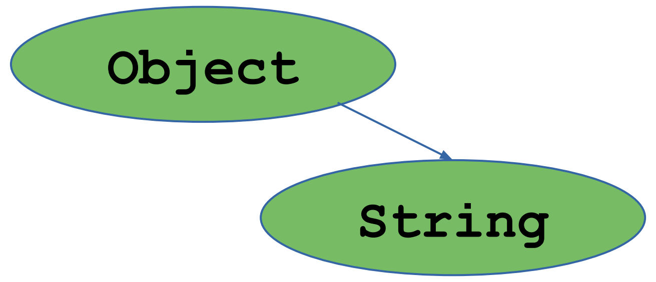

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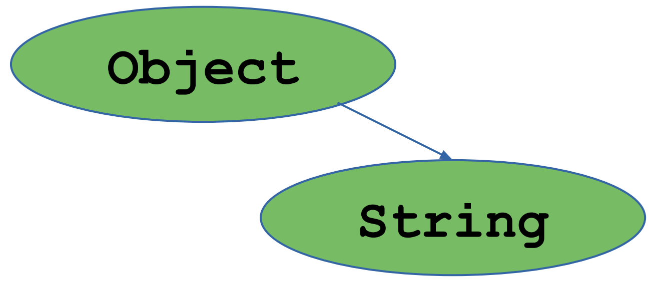

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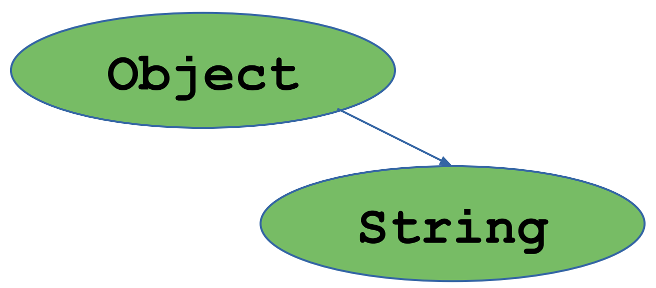

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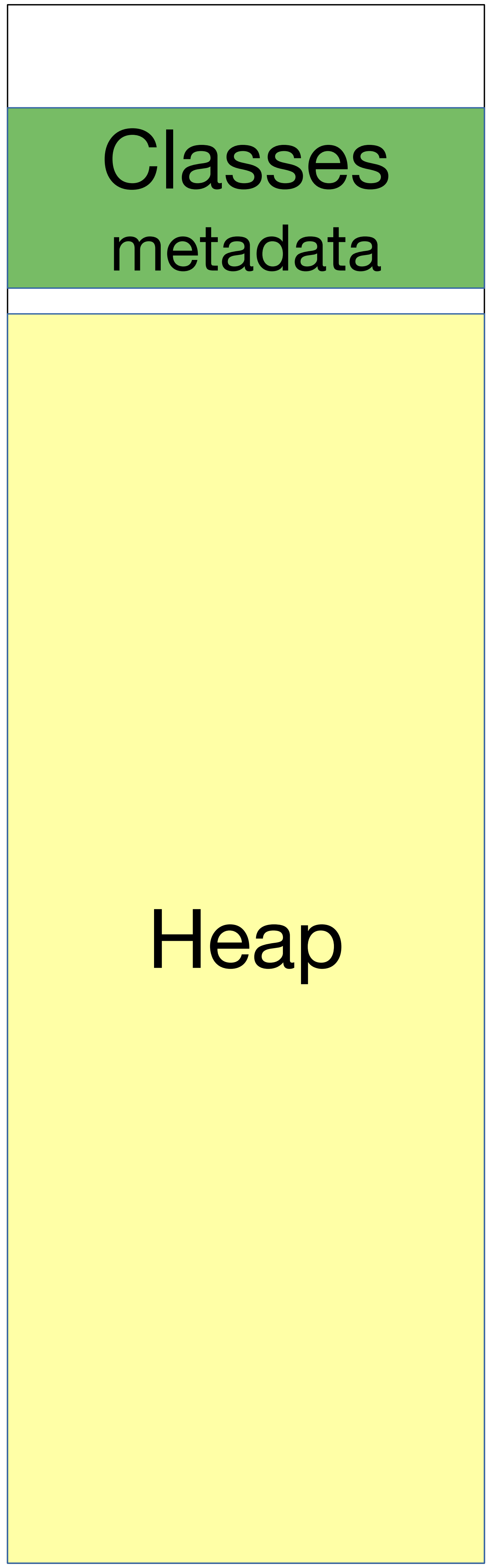

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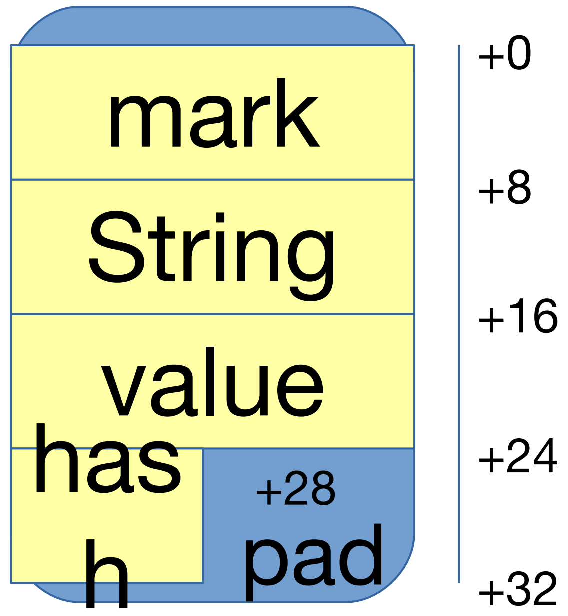
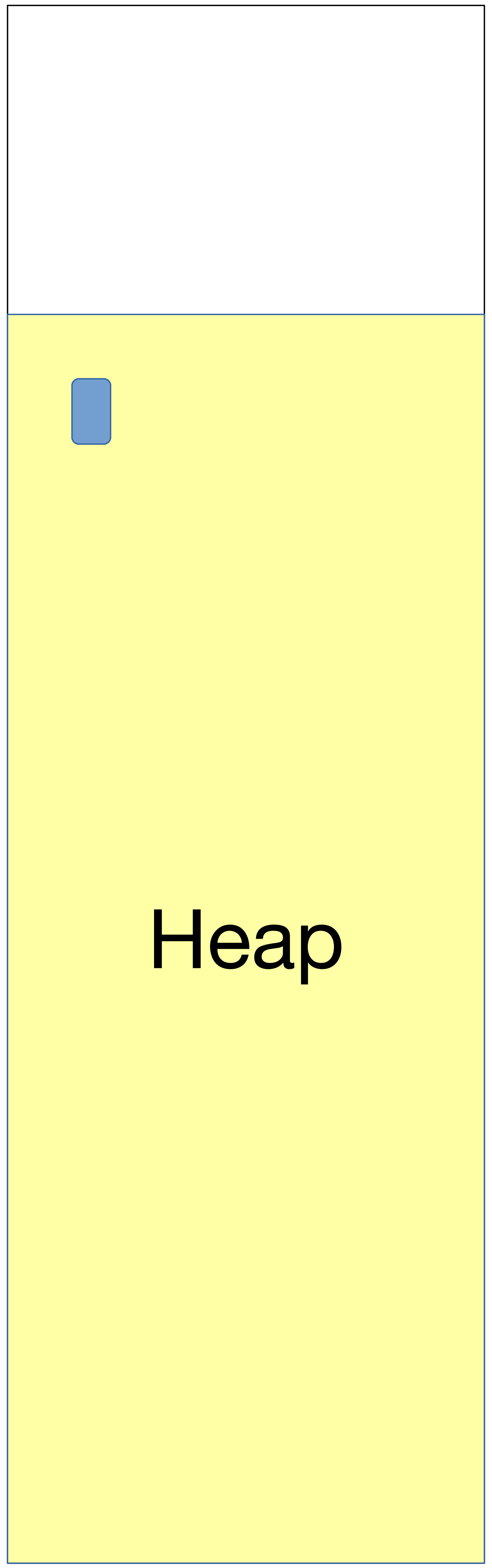
Objects are made with ‘**new**’ and reclaimed with **GC**.





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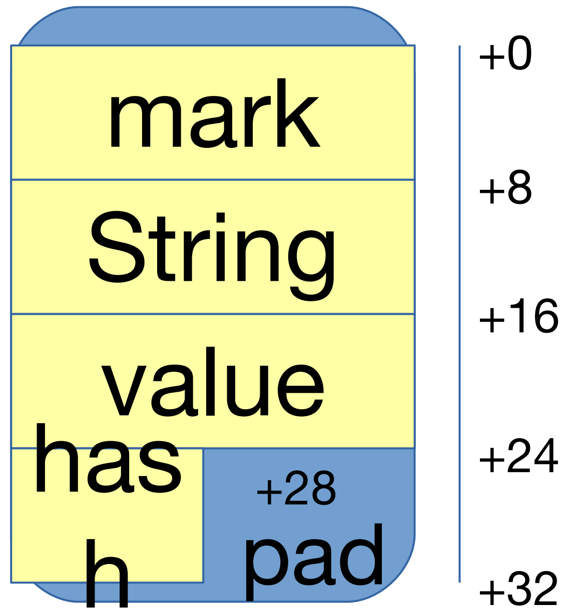

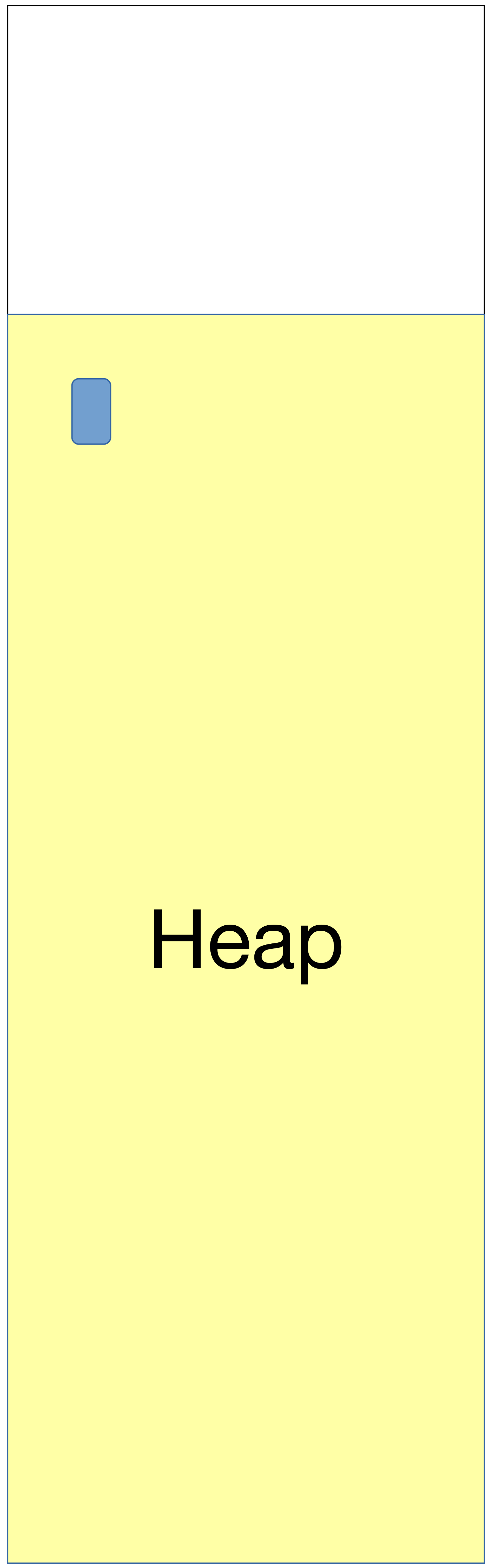

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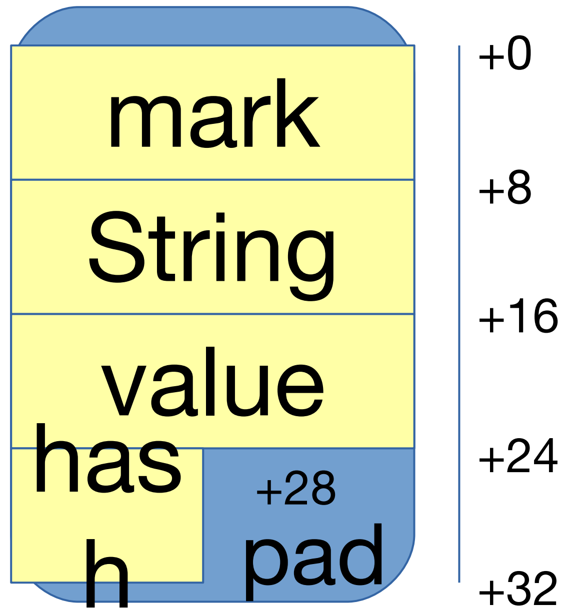

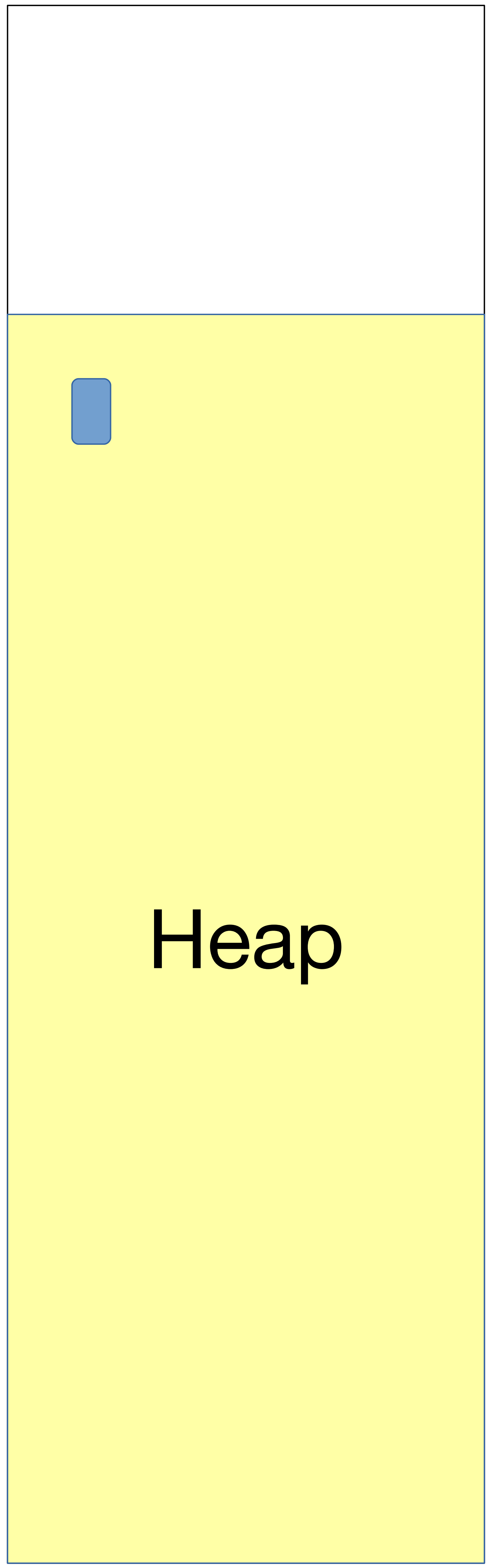

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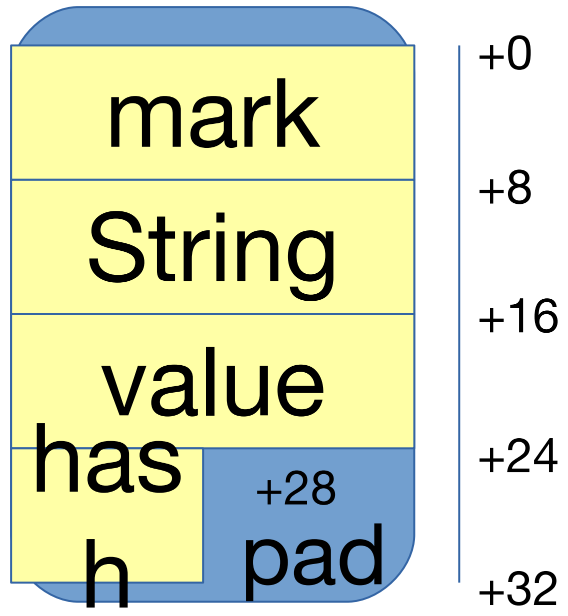
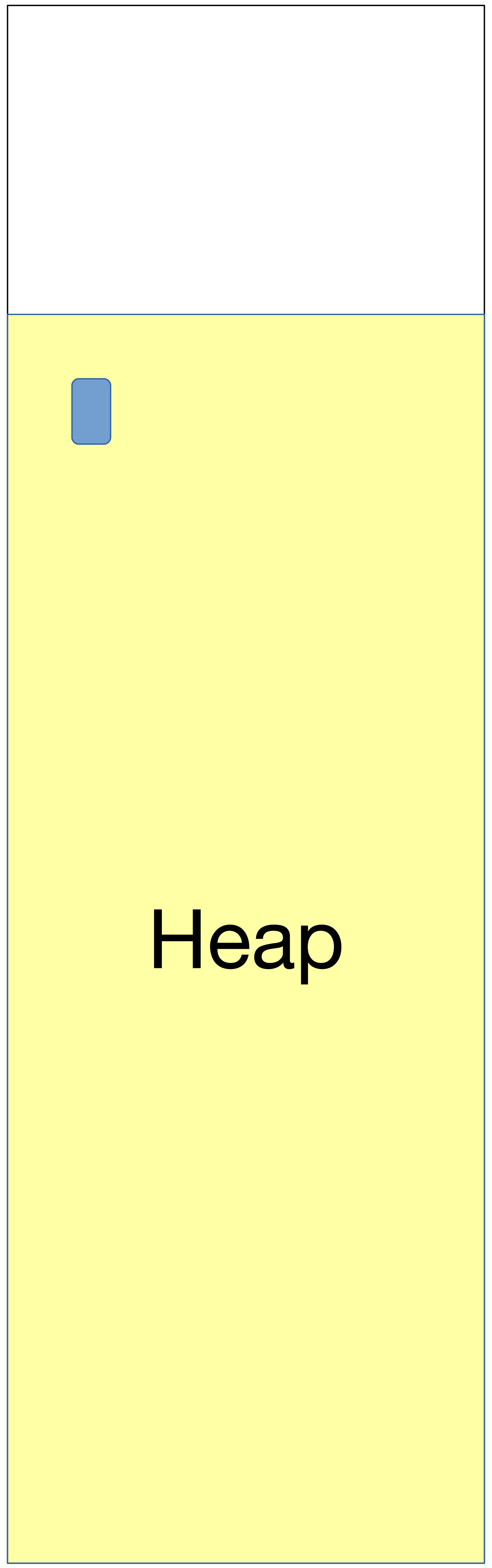
… so here I’ll just present a high-level view of the interaction between your program and **GC**.





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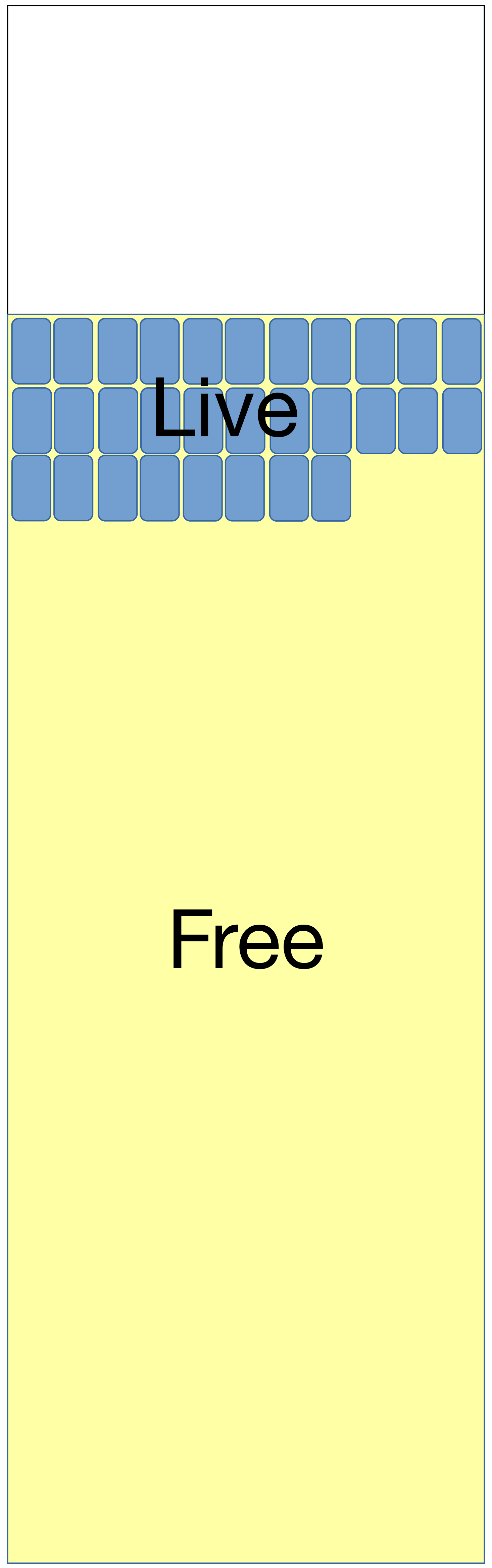
Generally Live is further split into generations, not pictured here.



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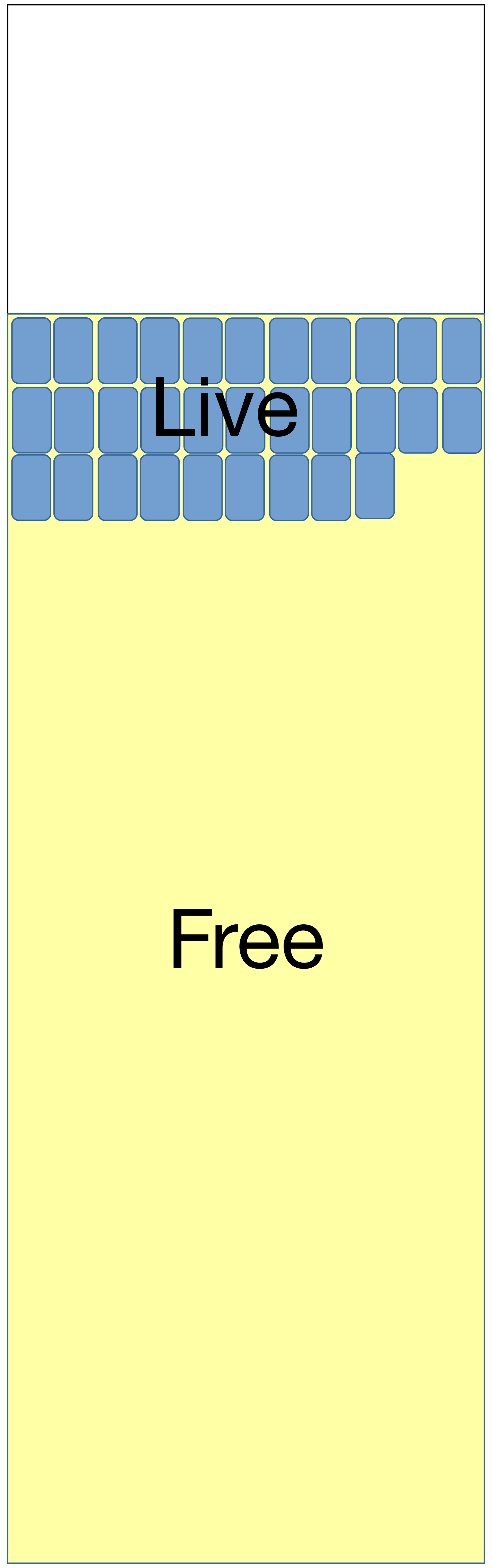

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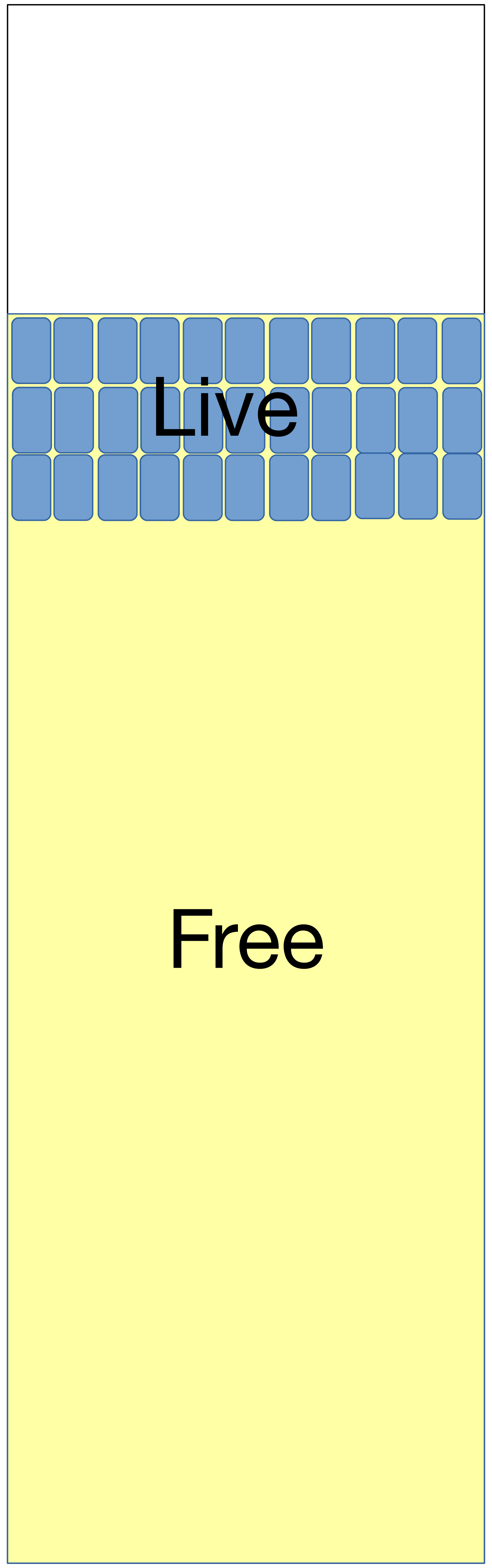

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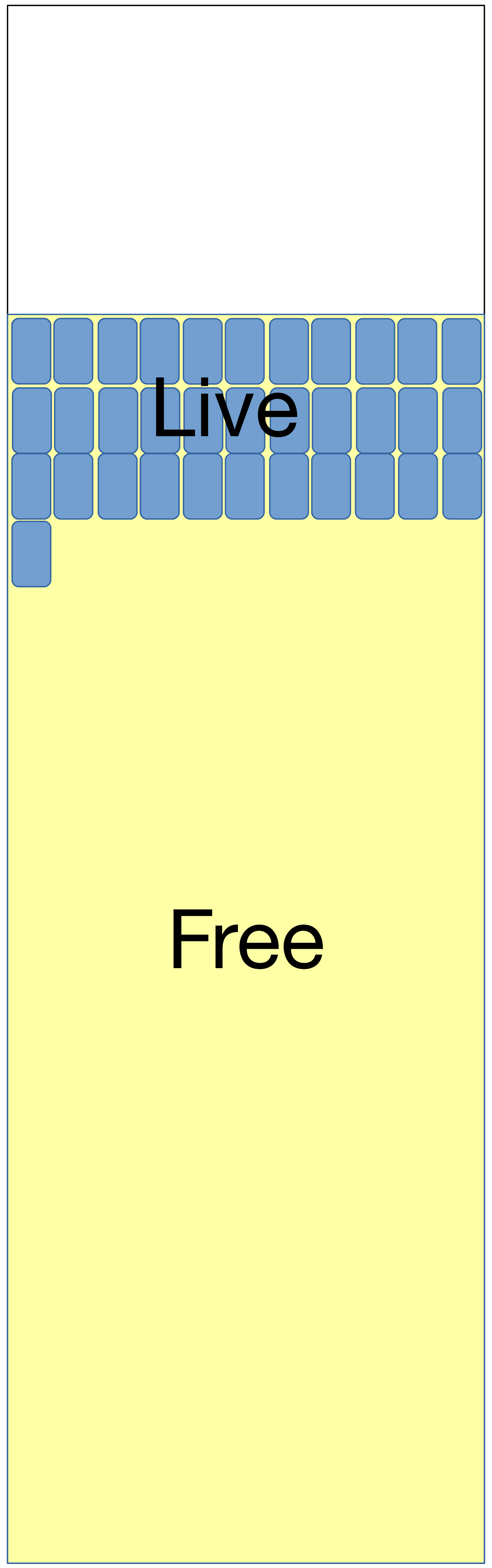

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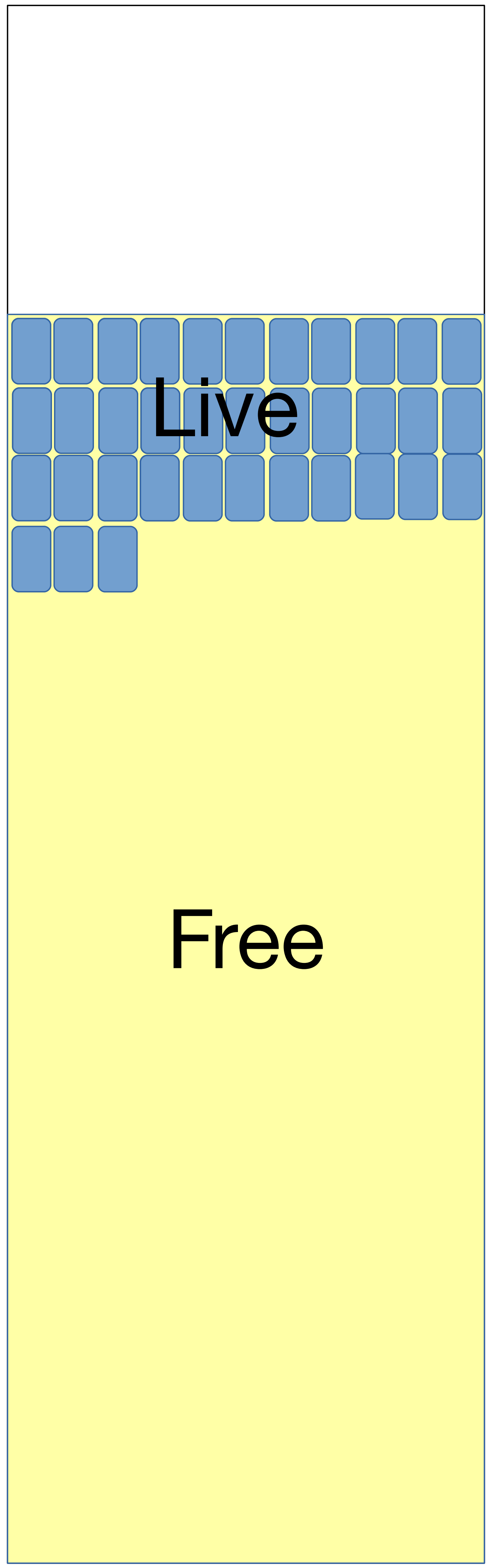

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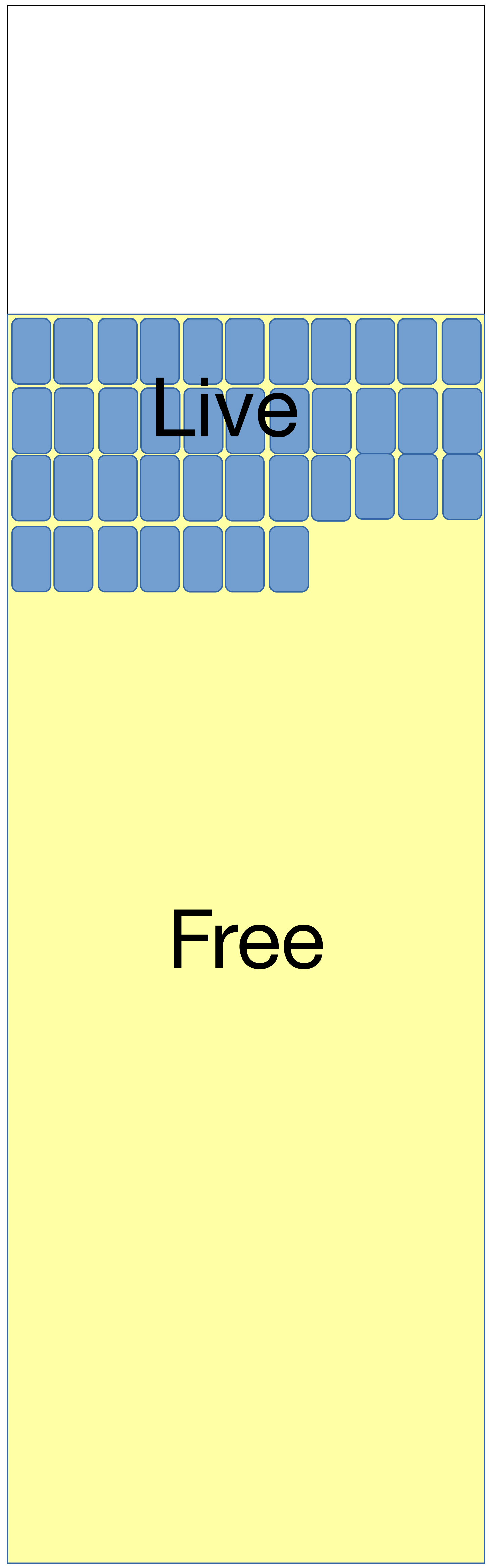

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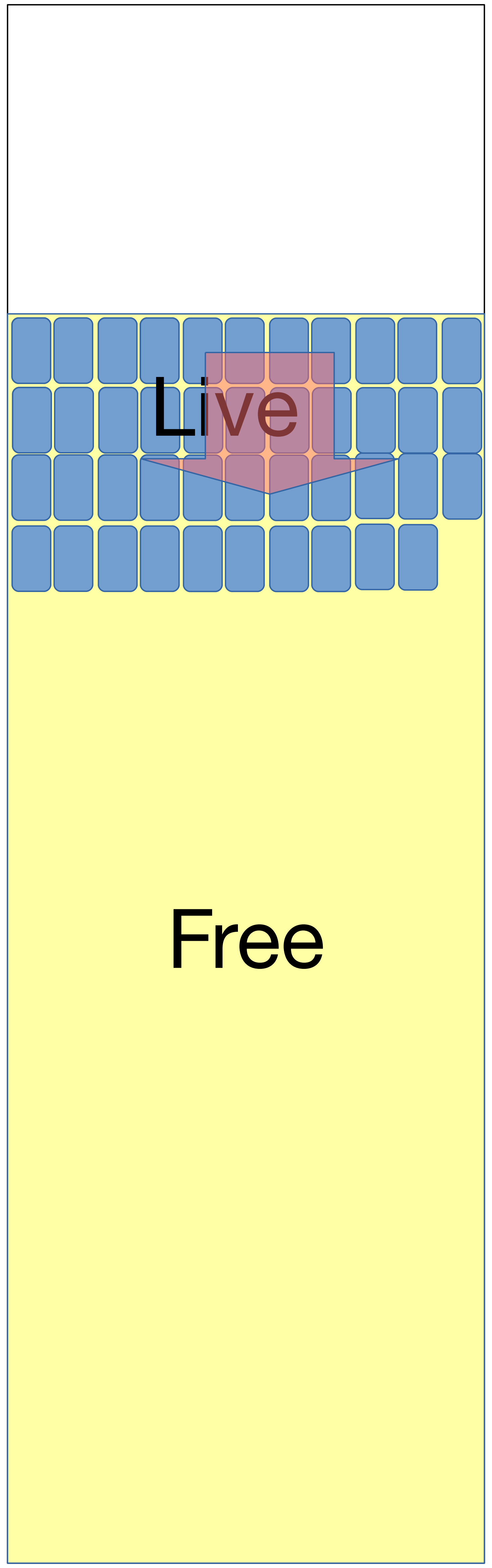

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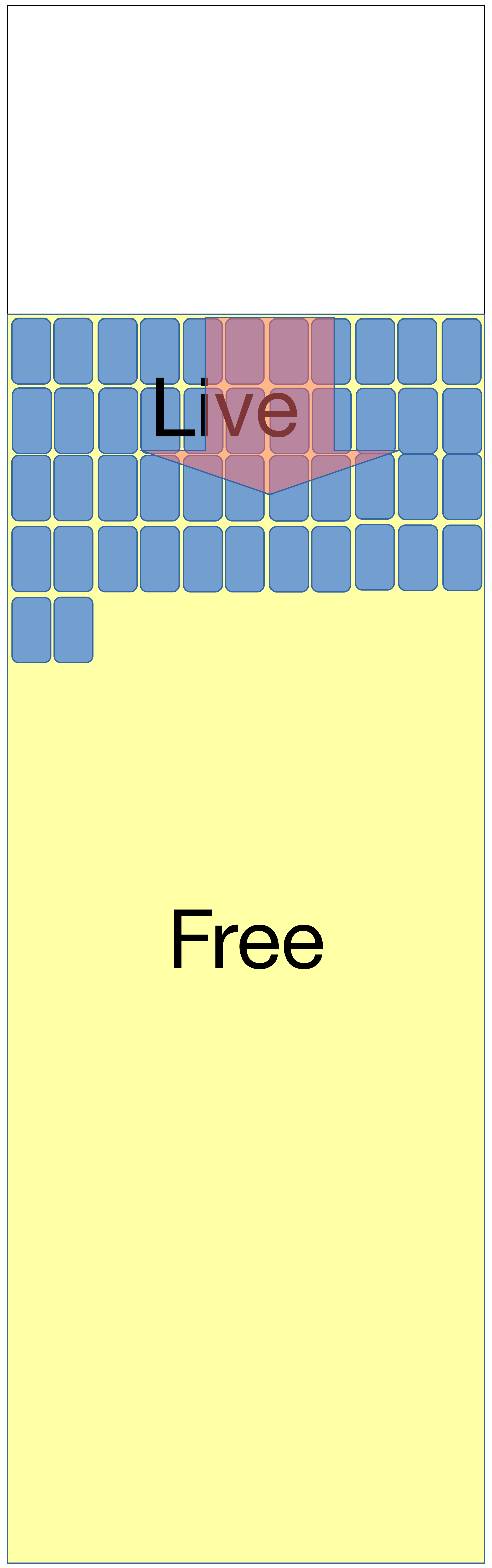

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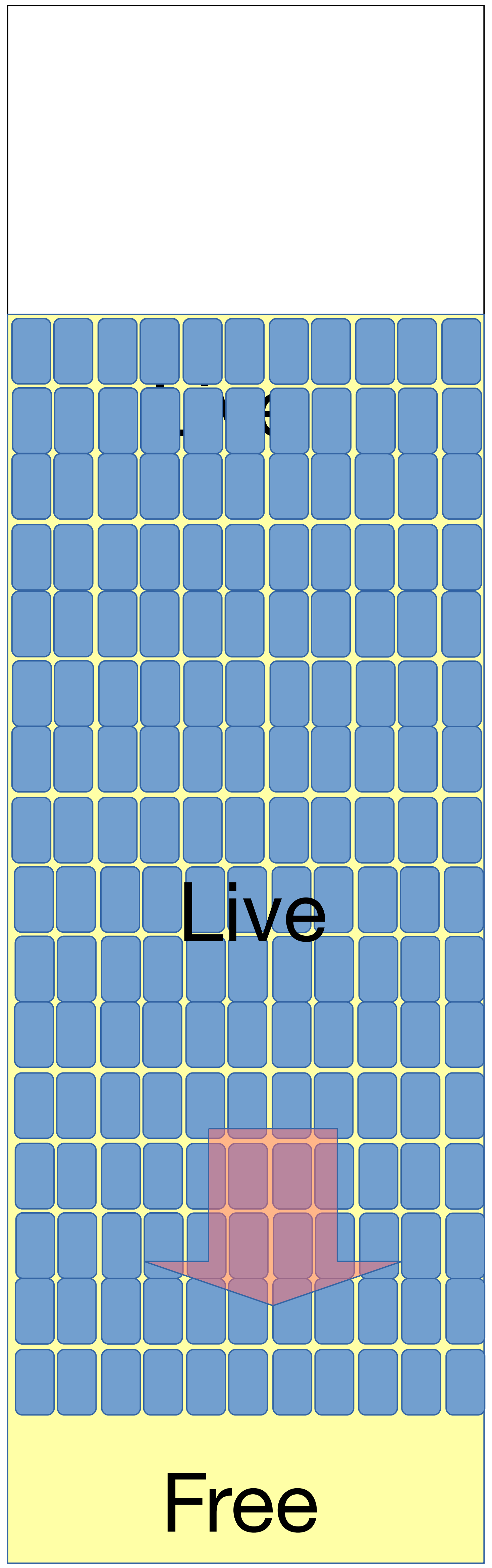

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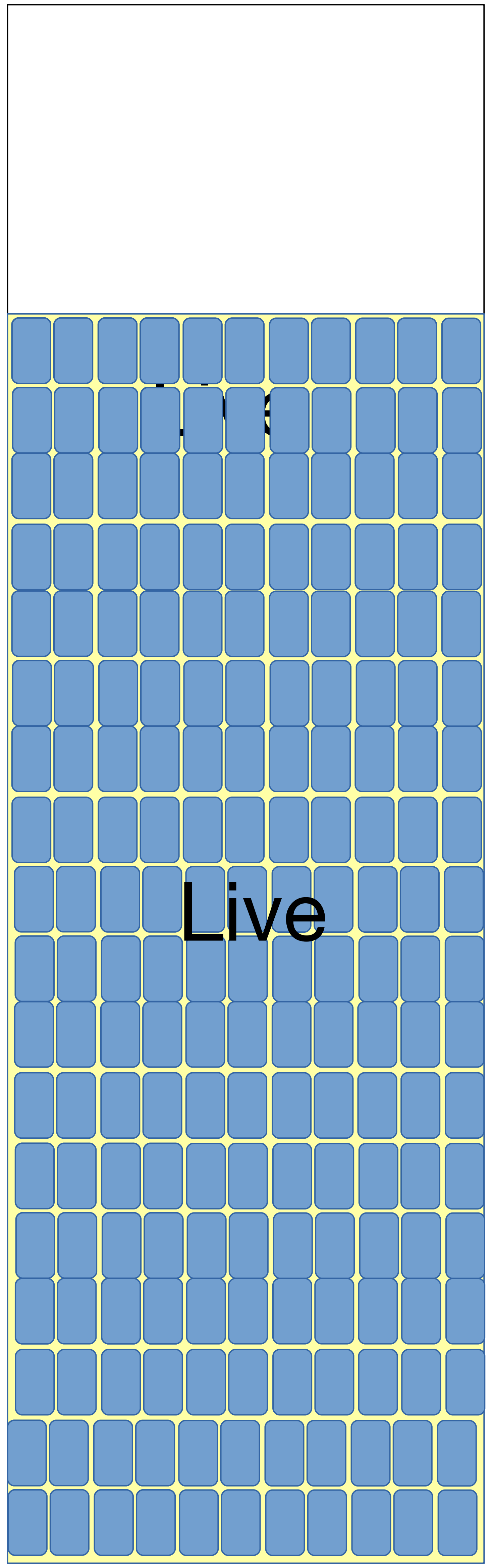

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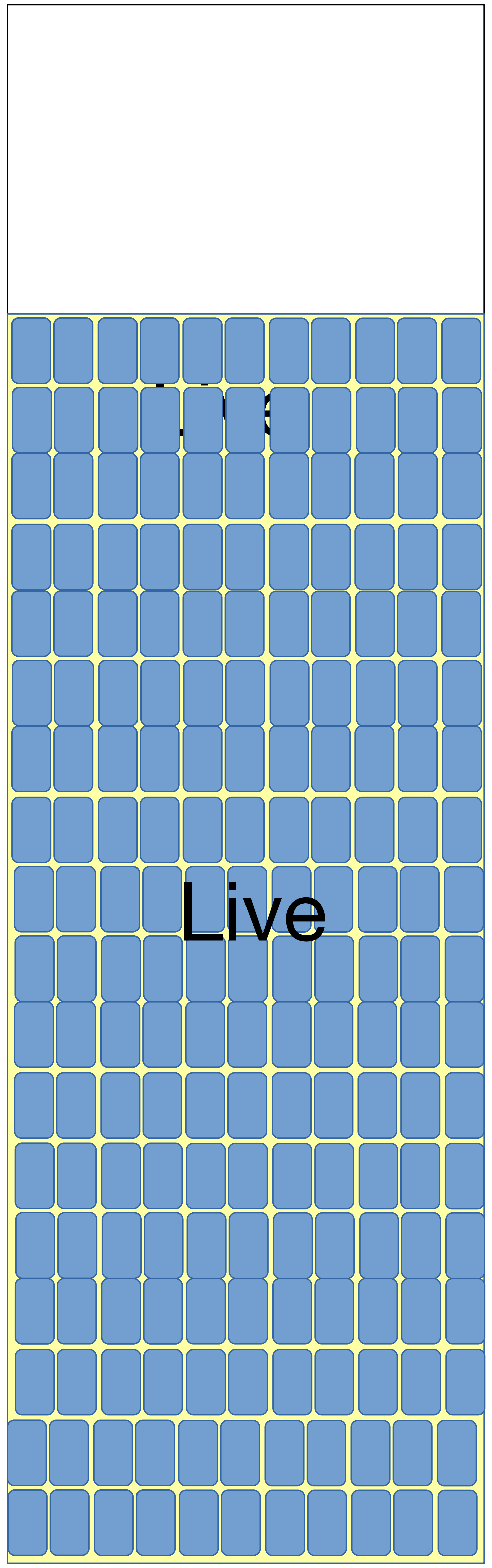

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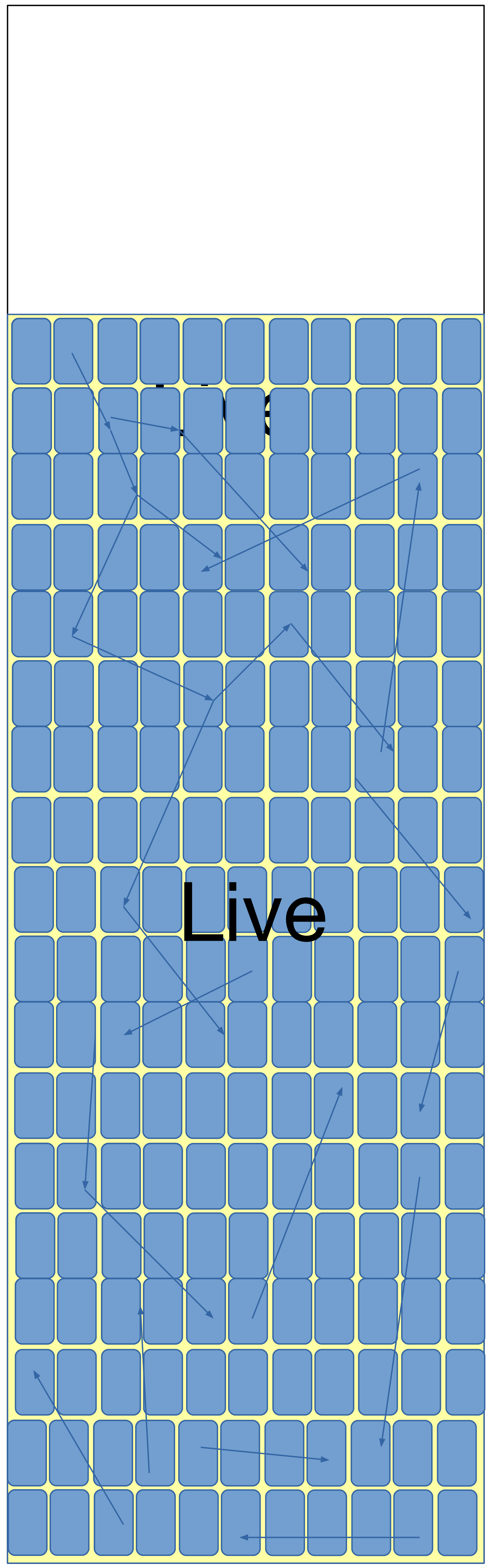

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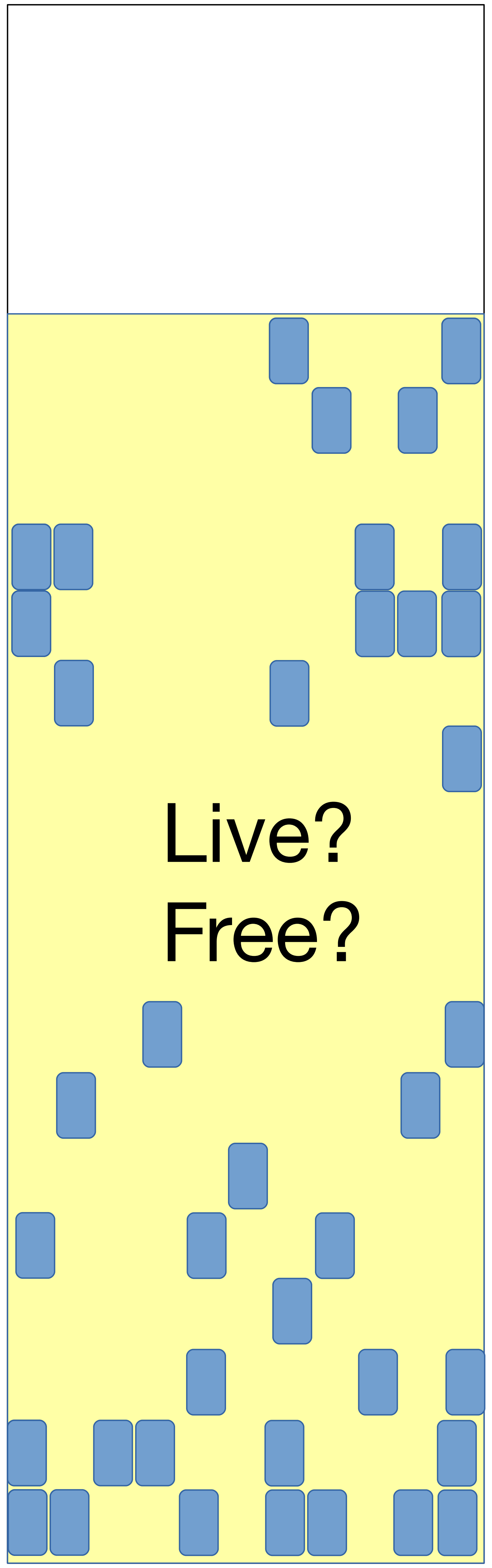

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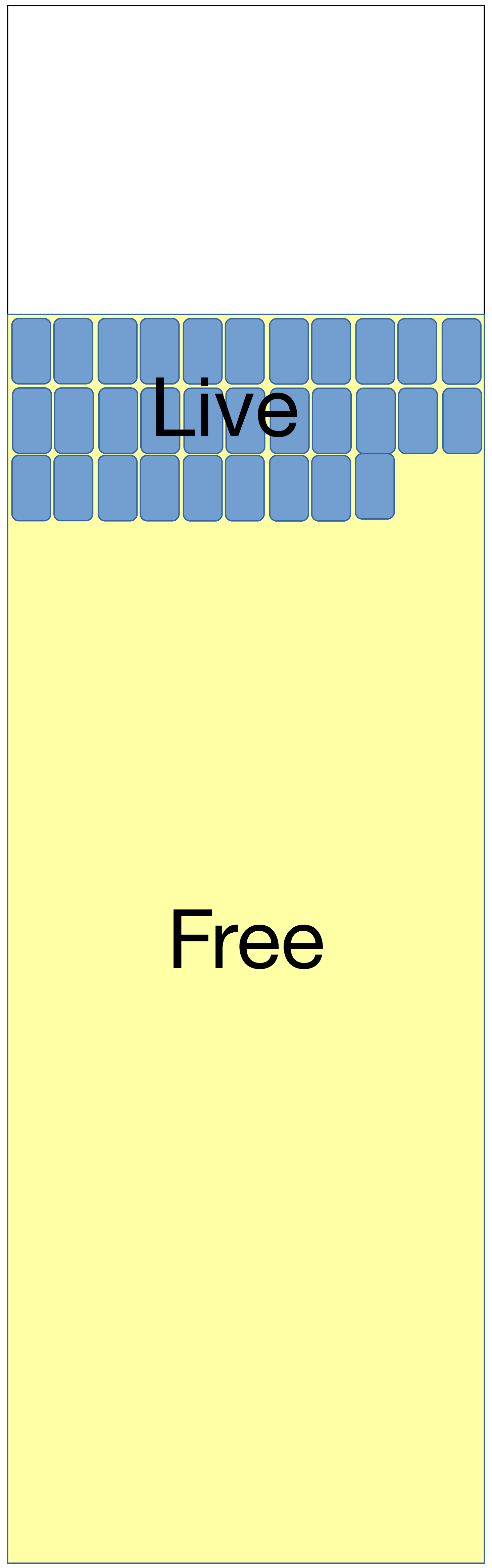

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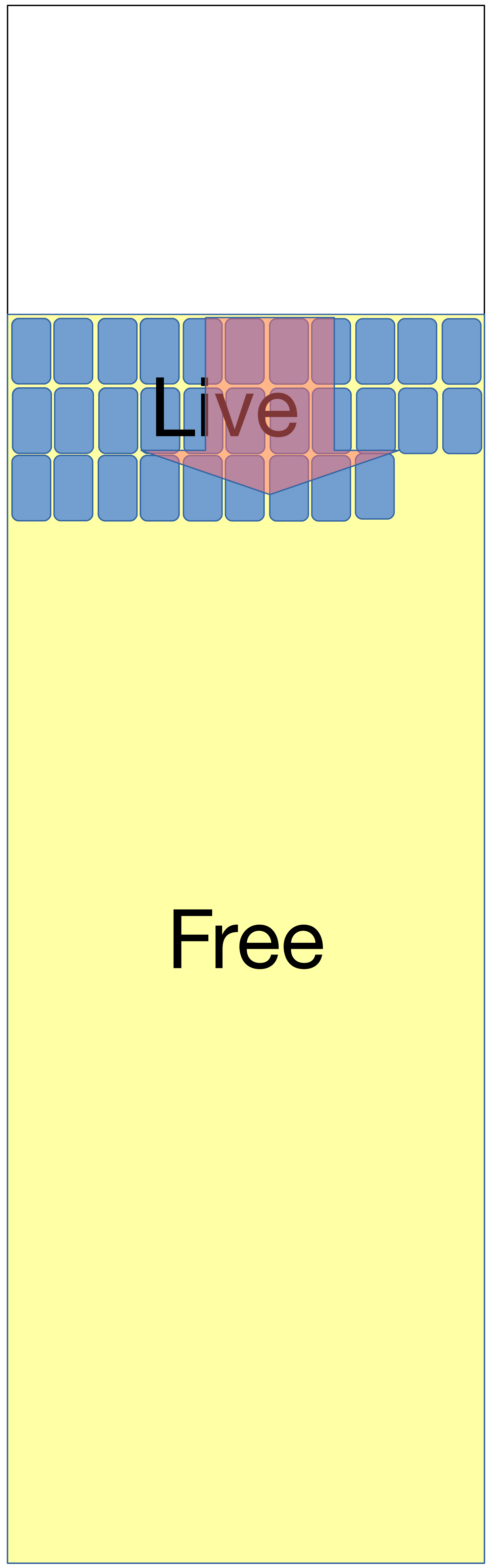

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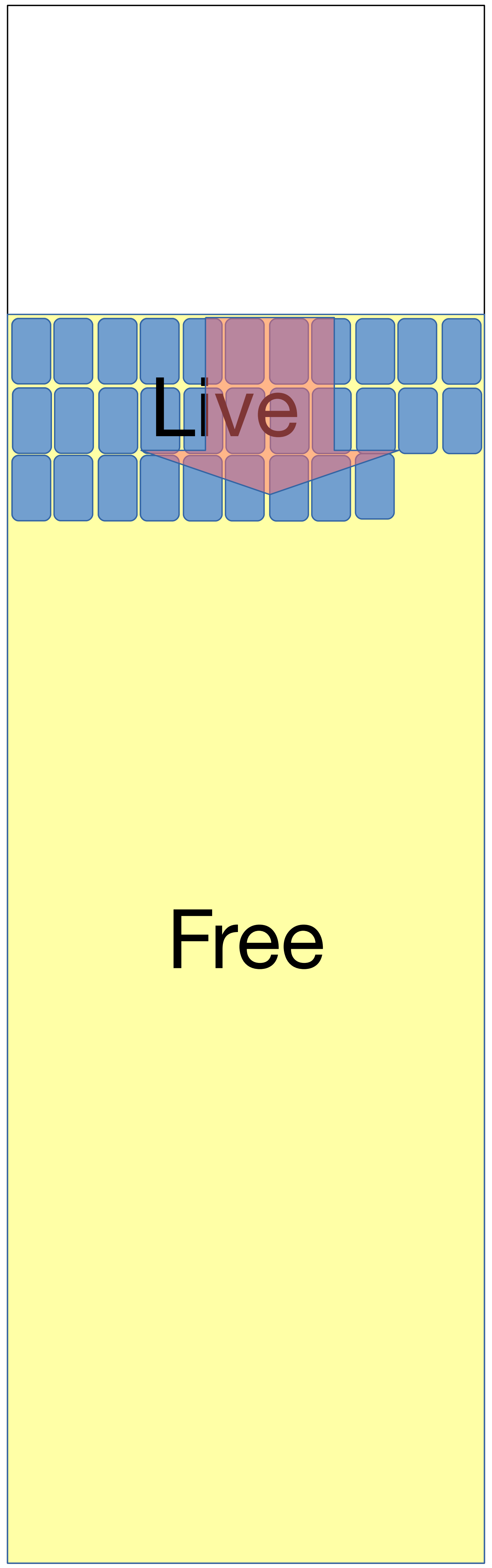

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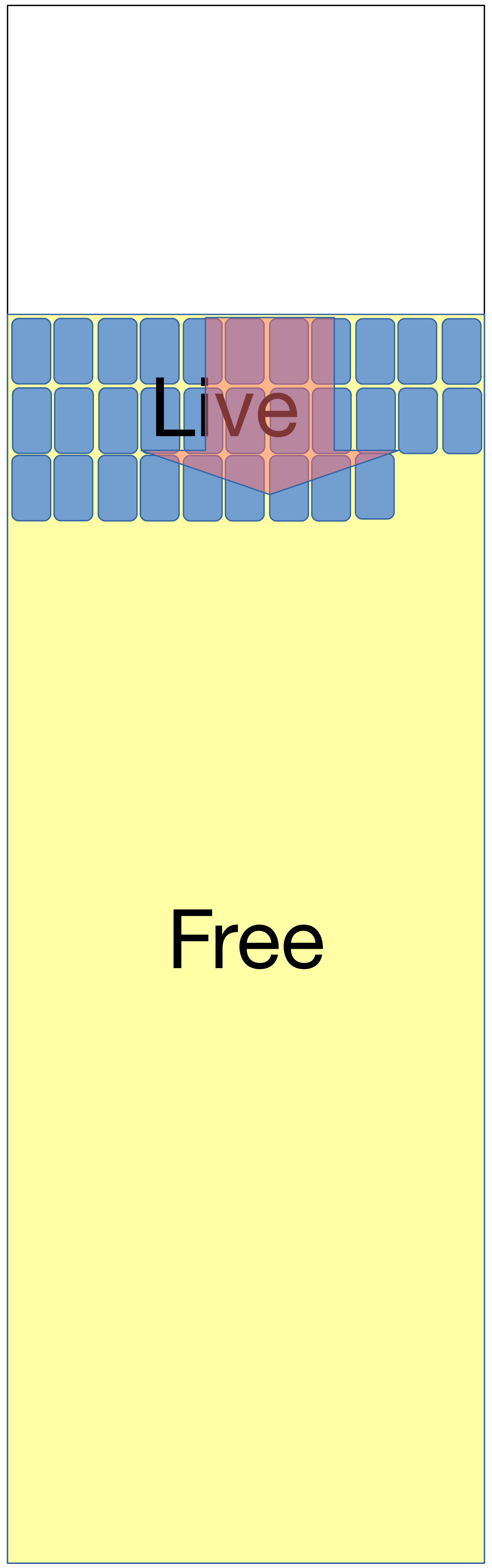

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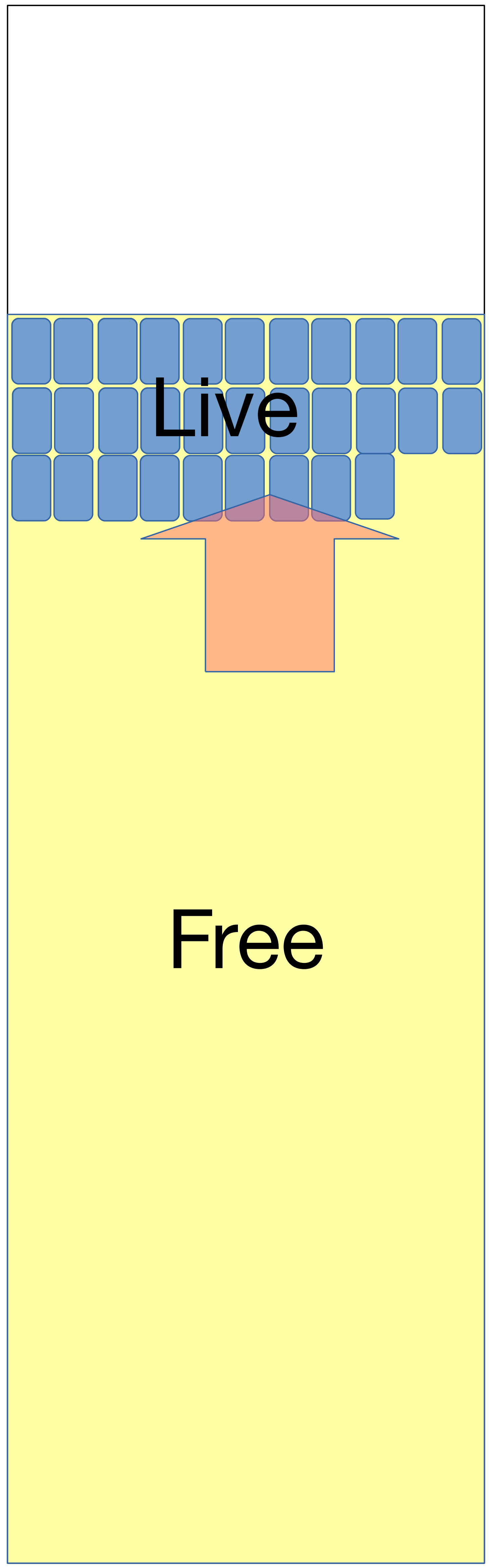

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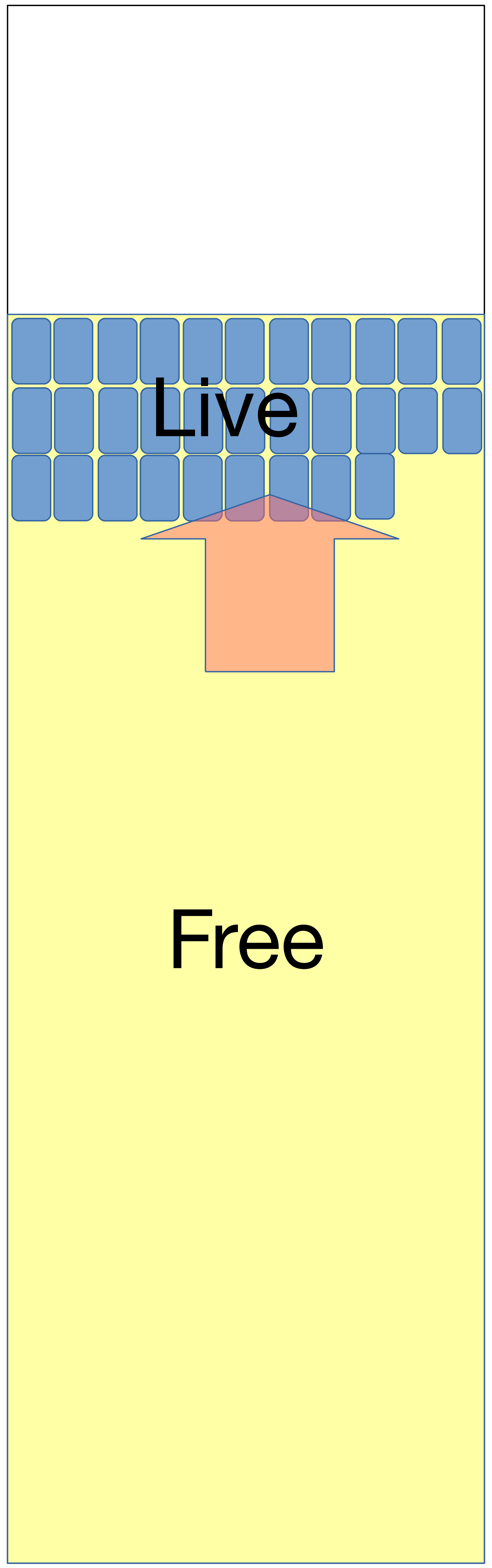

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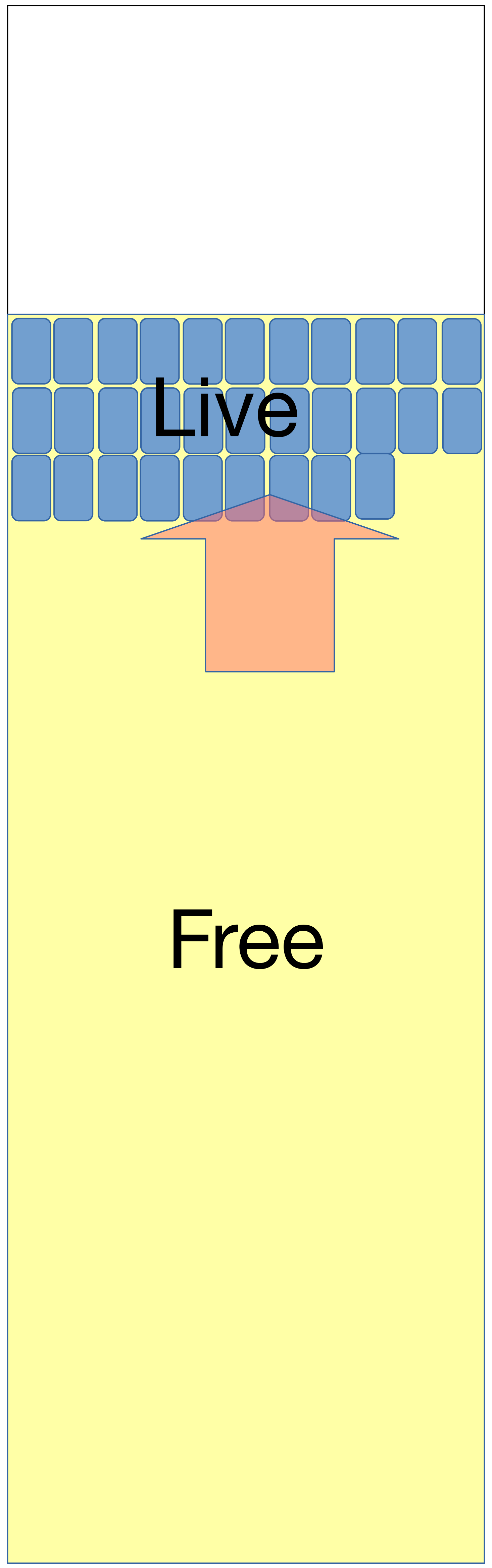

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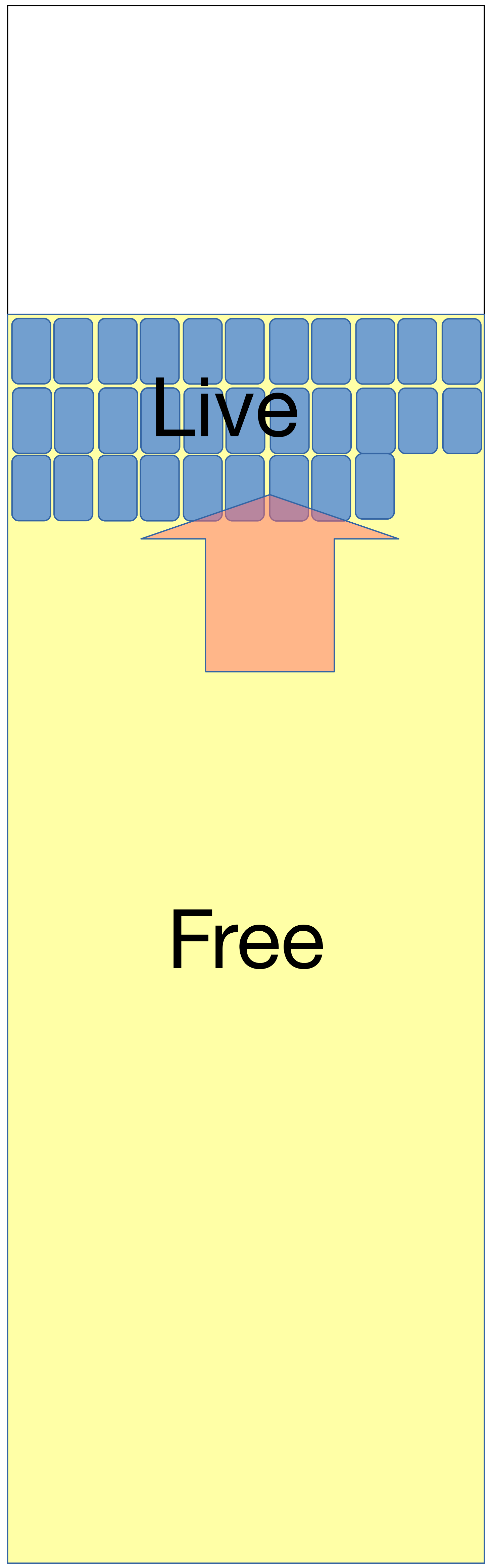
The GC costs depend on the **structure of the heap**,

and that structure is also up to the developer.



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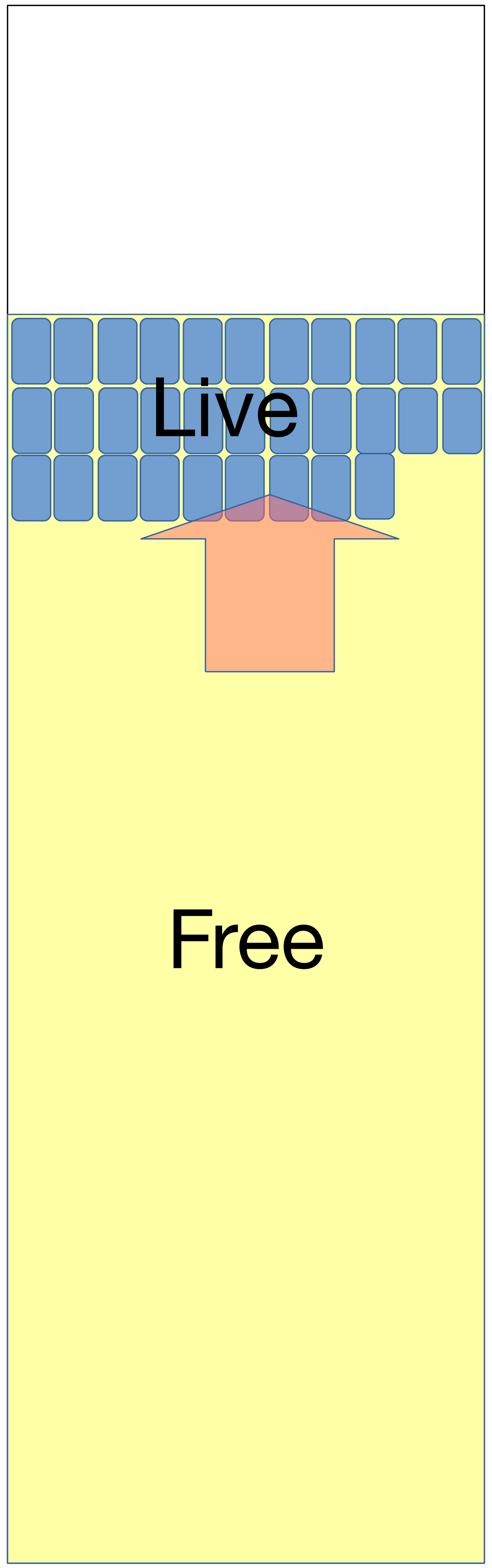

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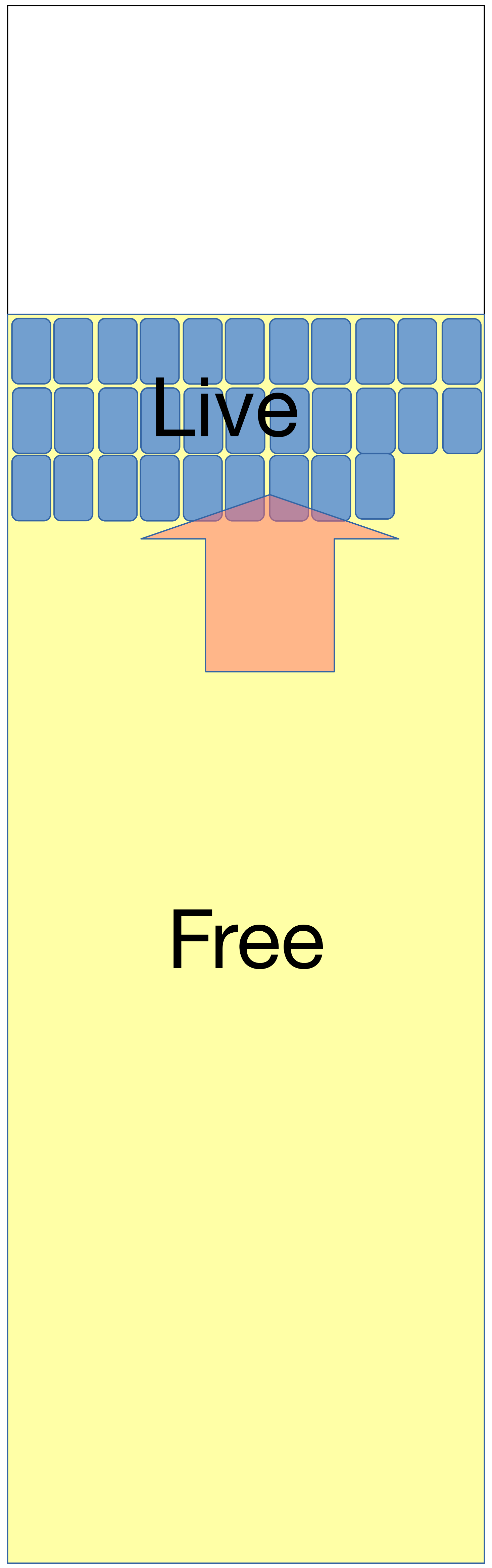

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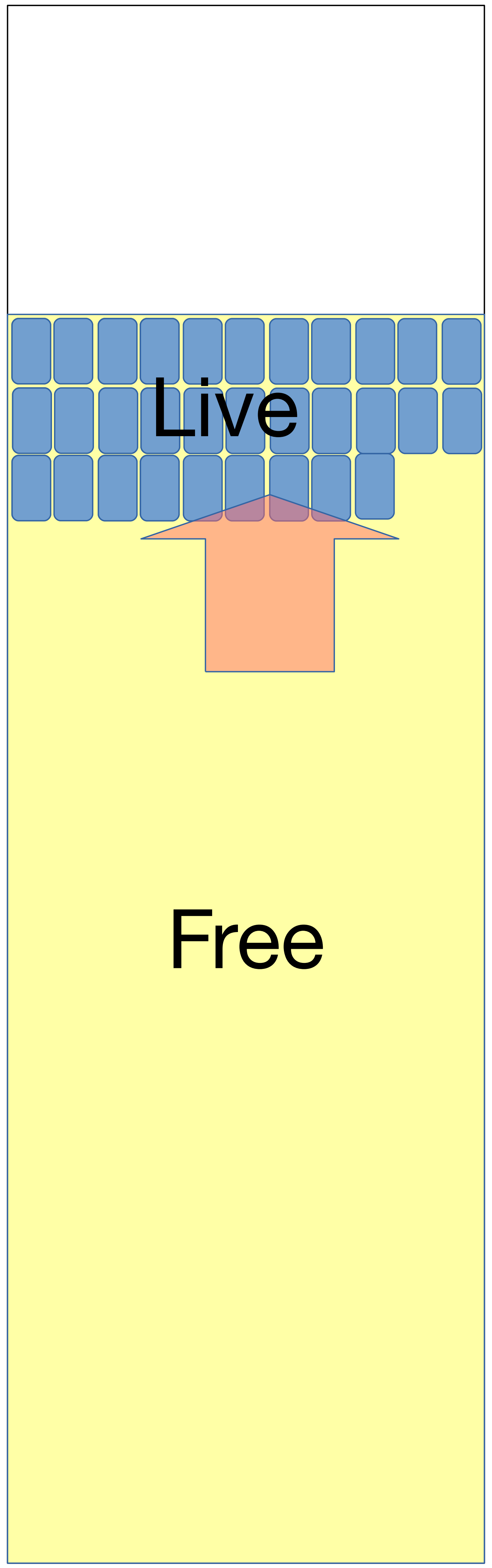
But always, fewer objects & pointers cost less than more of either.

A million **`Long`**s are hugely more expensive than a single **`long[1000000]`**



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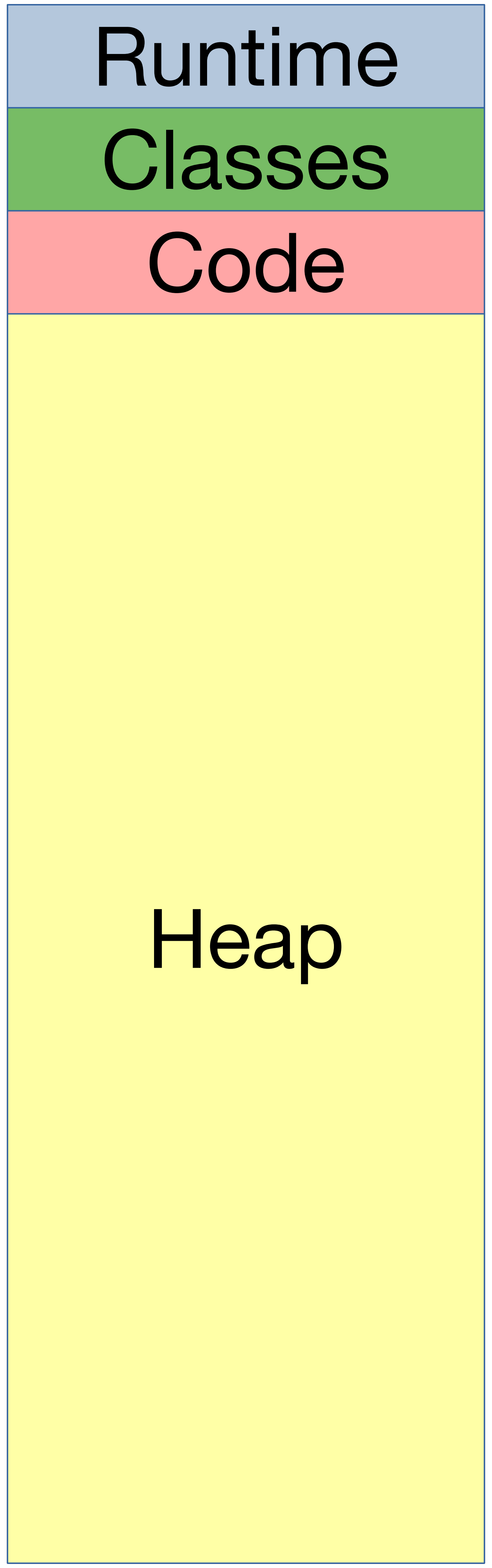

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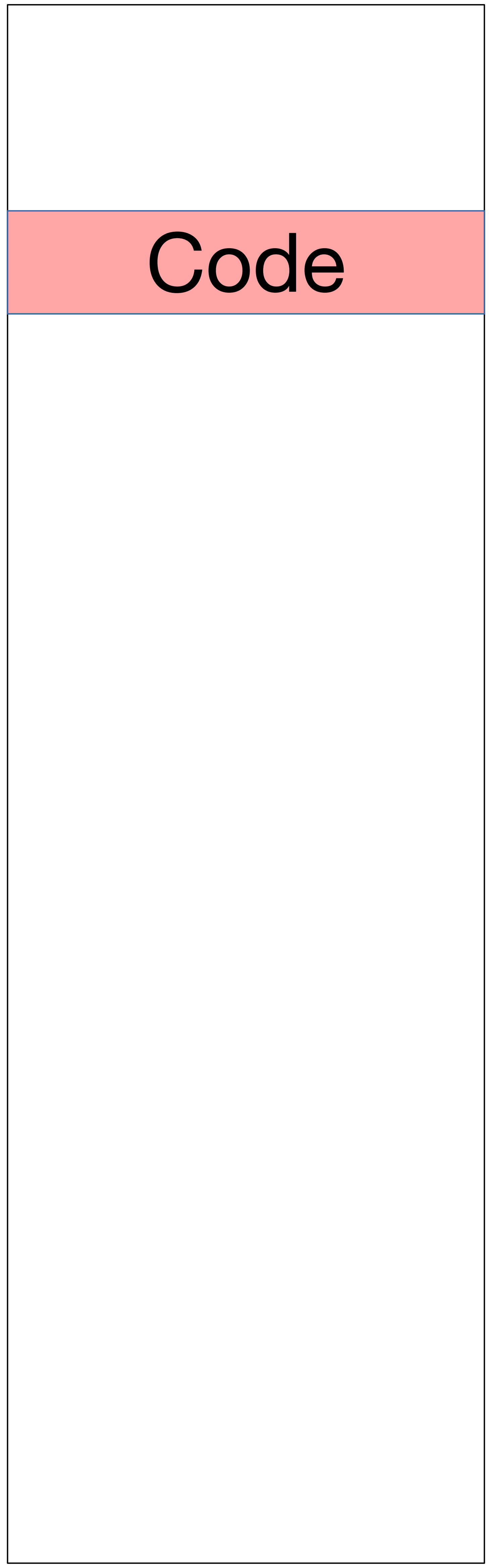

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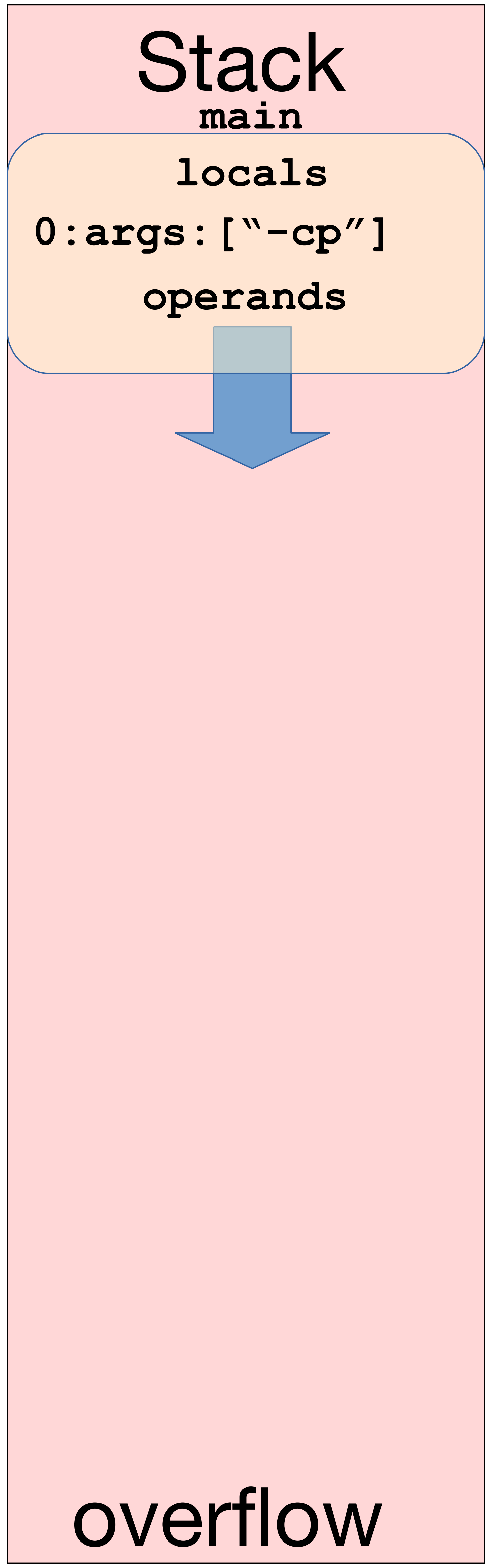

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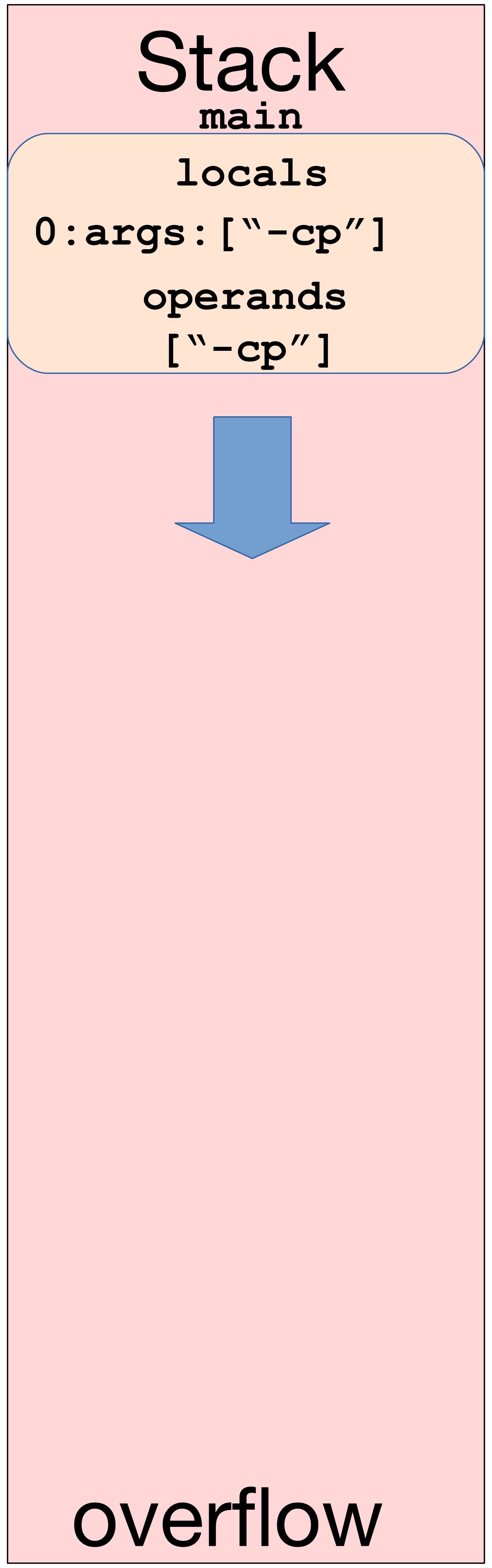

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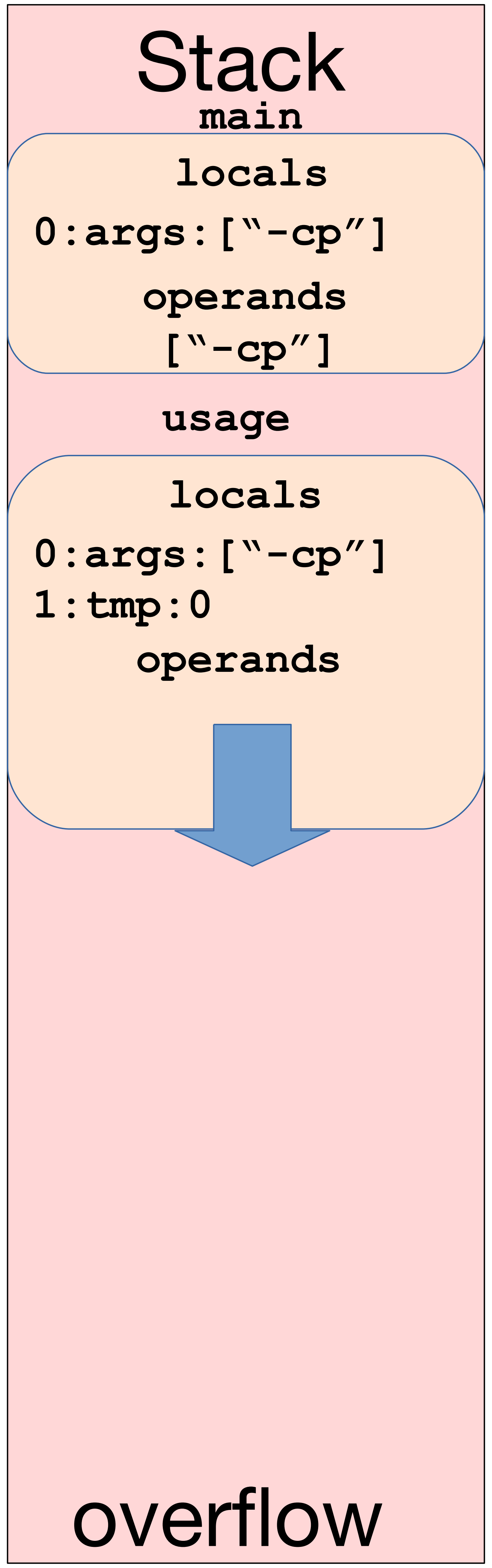

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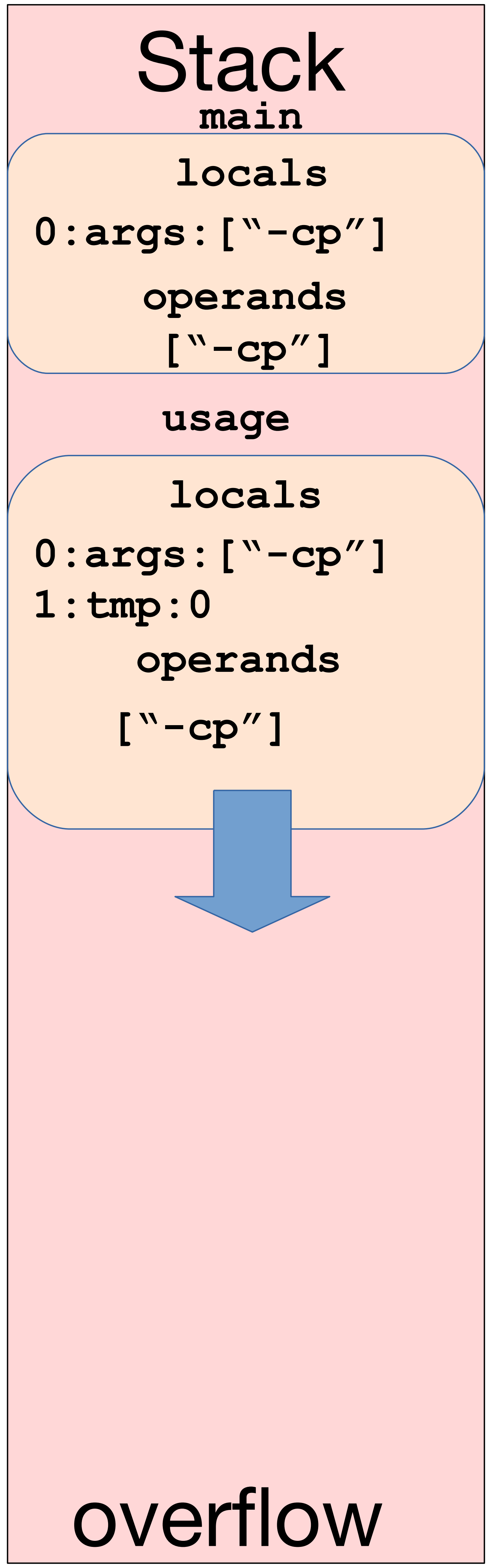

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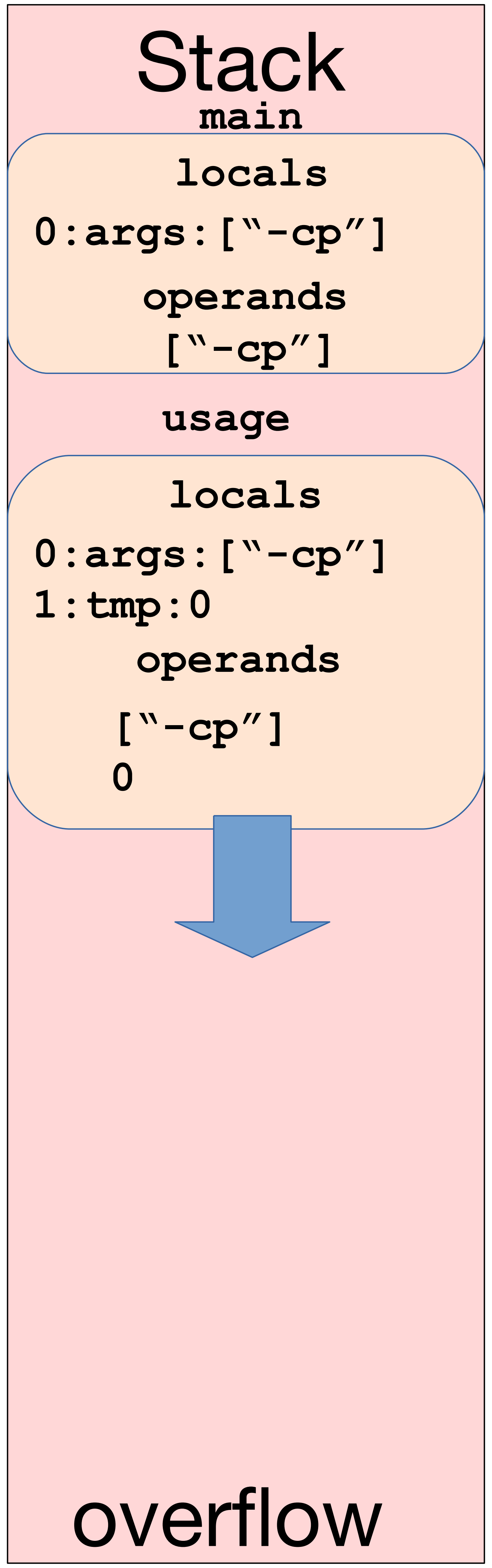

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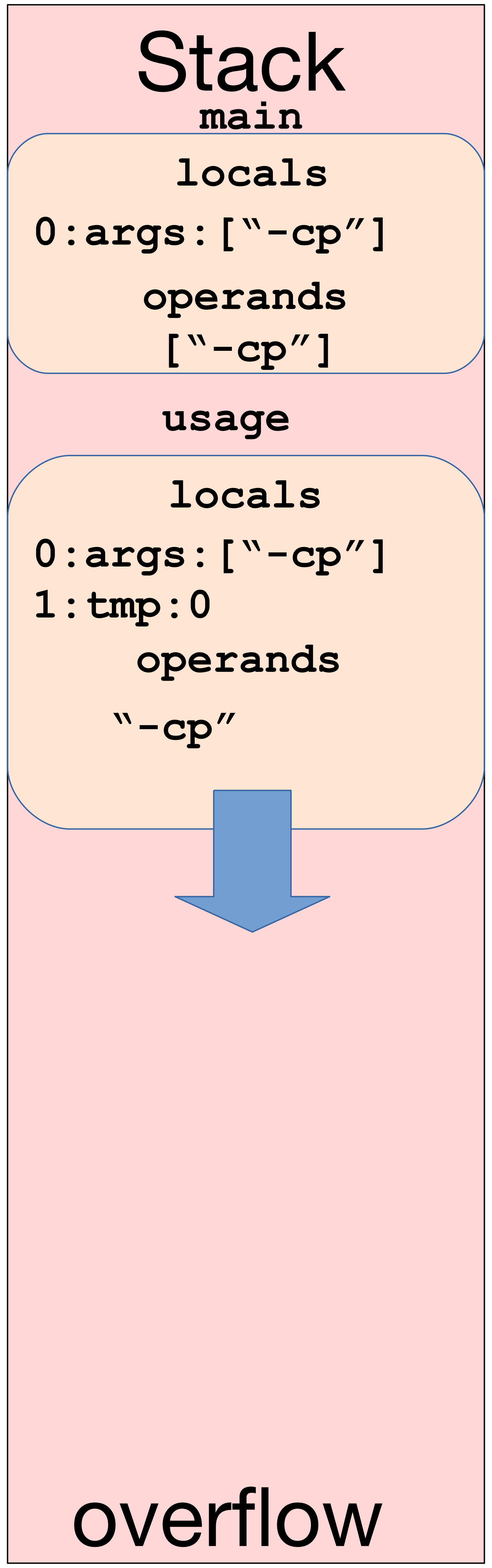

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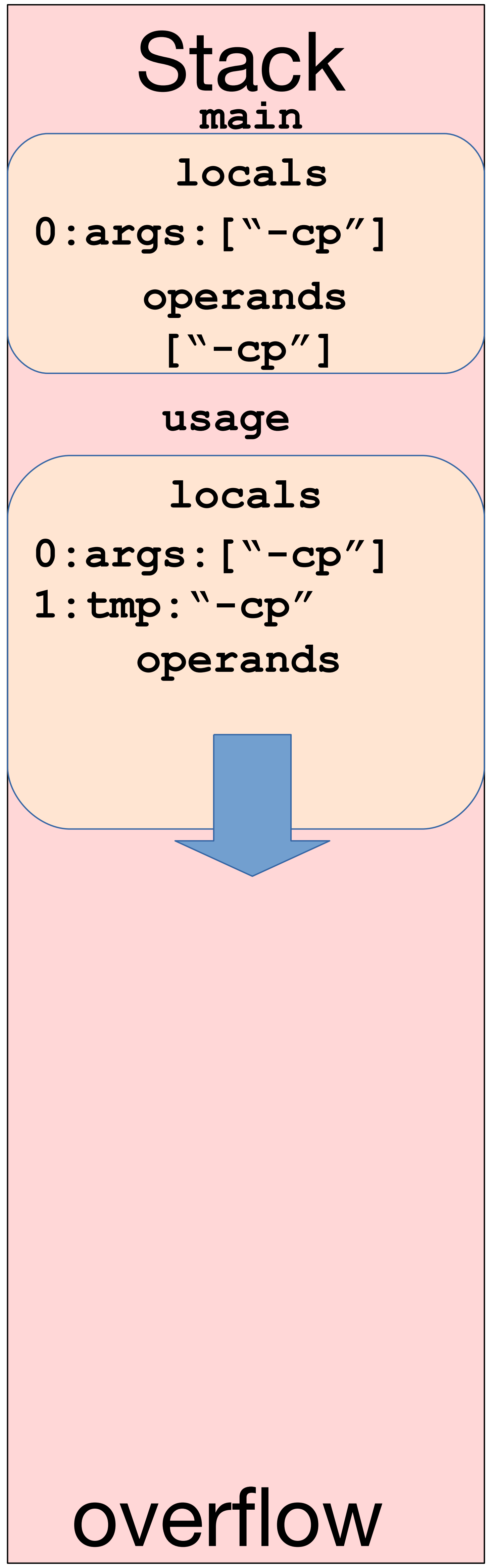

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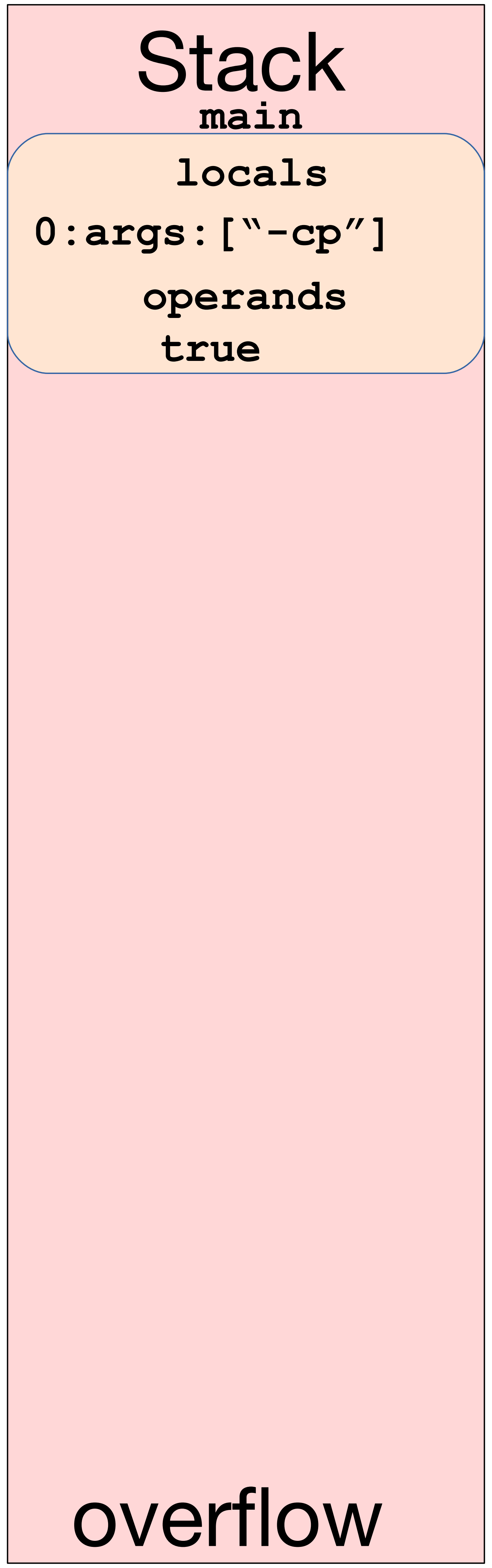

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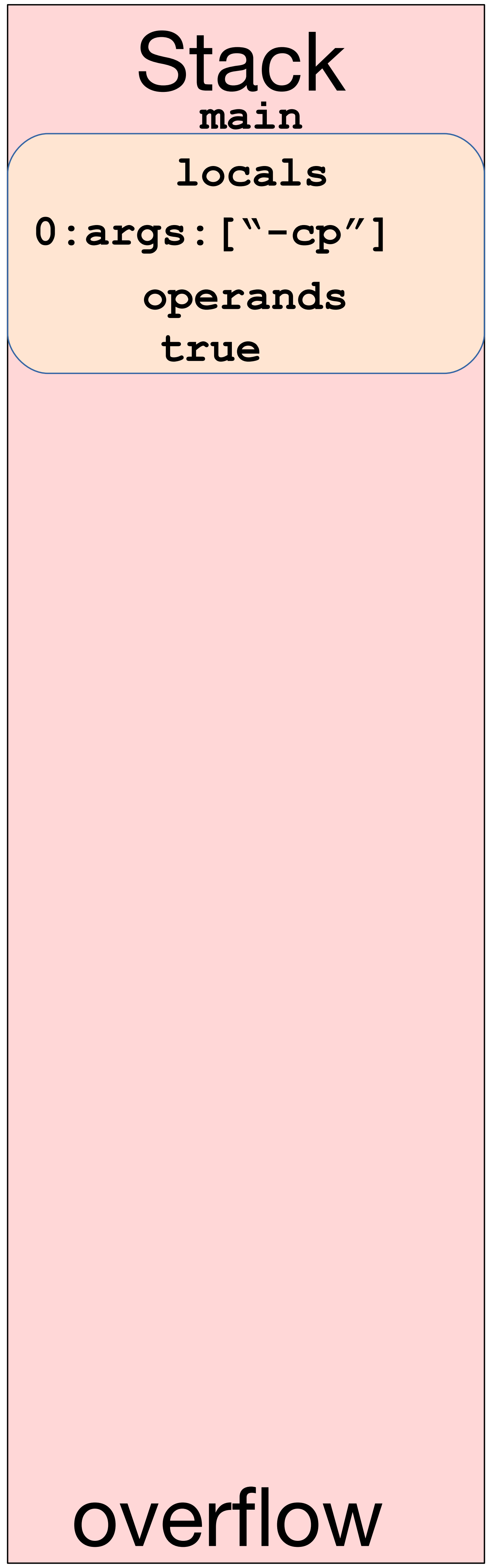


Since no **real** machine runs this, the java **virtual** machine emulates it.

The **interpreter** runs one bytecode at a time, and is fairly slow.

But it can start immediately!

The interpreter also **profiles**: it counts functions (and loops), and when the count is large enough, it triggers a compilation.

The **J**ust **I**n **T**ime compiler, or JIT, compiles hot bytecodes into real machine code. The JIT'd code runs about 10 times faster than the interpreter.

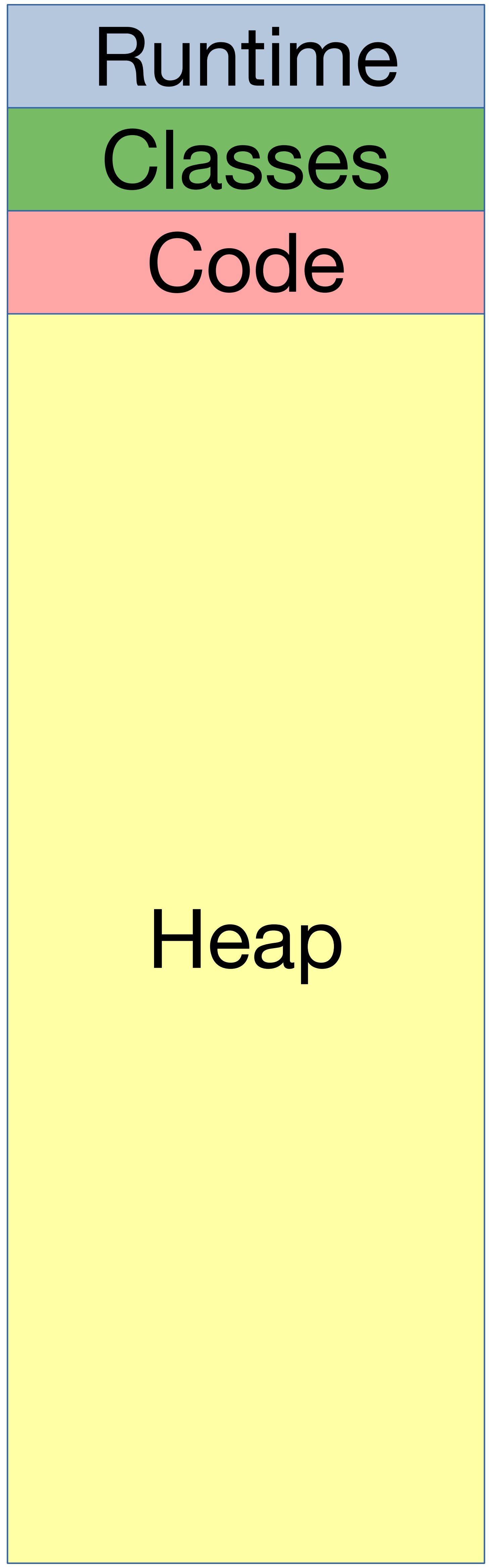
JIT'ing takes a little time, both to profile and to compile.

This means Java programs **accelerate** over time, getting faster on new code after a few seconds.

The JVM Runtime

The JVM Runtime is basically a “catch all” for everything else.

The runtime tracks:



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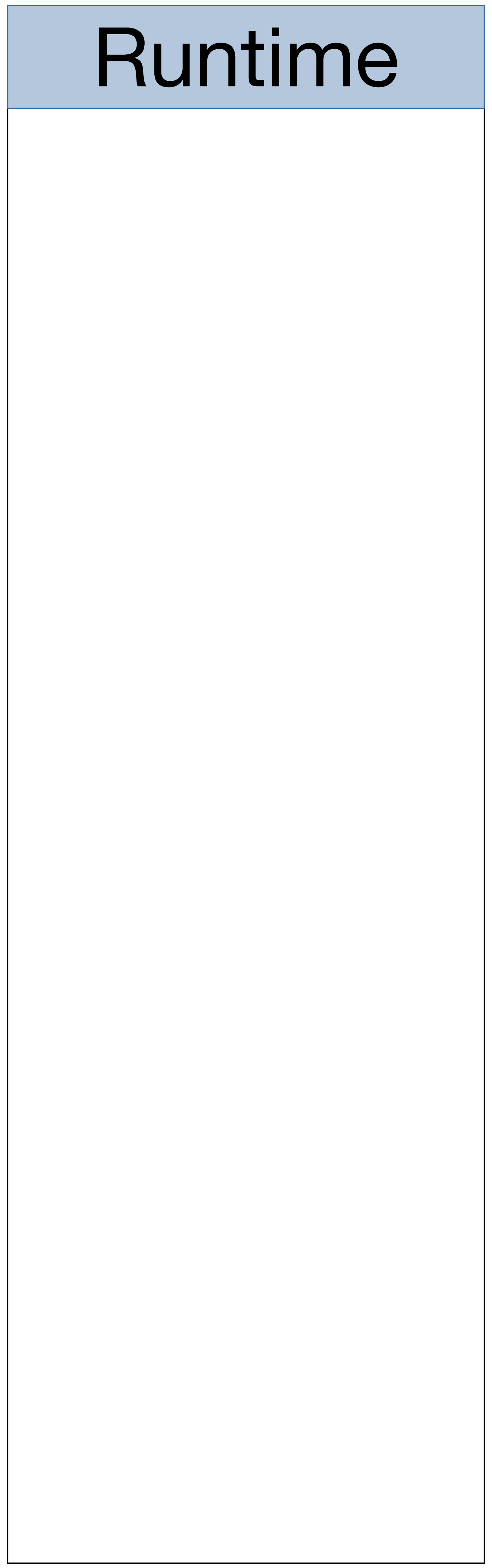

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The runtime tracks:

- Threads & thread stacks
- Classes loaded
- State of the Heap, and triggers GC as needed
- Profiled code, and triggers JIT’ing when needed
- Catches hardware exceptions and turns them into JVM exceptions
- Handles slow-path locking, blocking & waking threads
- Handles I/O and native calls
- … and much much more

Threads and Classes

Threads are newly made via a native OS call.

Threads are tracked for GC (thread stacks rapidly change are are the root of most pointer graphs).

Threads can throw exceptions, can block, sleep and awake.

Threads make objects (can trigger GC), run code (can trigger JIT'ing)

Classes are loaded from files, they have initialization states.

They describe object shapes (for GC), include code to execute.

Reflection can query them, or make objects or calls.

GC and JIT

Runtime

The GC is triggered by the runtime; triggers vary by GC type.

Obviously for being out of Free, but concurrent GCs trigger before being out, based on allocation rate.

JIT’ing is triggered by interpreter profiles, and by breaking heroic assumptions, such as class loading after assuming no-new-classes.

The JIT’d code has fast-path support for special cases such as

- uncontended locks
- allocations when not out of memory
- System.arraycopy & friends (clone, Arrays.copyOf)

Runtime

Exceptions, Locks, I/O & Native Code

JIT’d code (and other places) will use hardware to null-test “for free”.

If the test fails, a hardware exception is raised, instead of a branch.

The Runtime catches these and converts them as needed.

Fast-path locking does not use the Runtime, but a failed lock-acquire does. The thread may spin awhile before failing and sleeping. When the lock releases, the thread needs to be awakened so it can have a turn.

Native code handles most I/O requests, and the runtime handles the smooth hand-off of ByteBuffers between the JVM & OS.

WHAT IS IN A JVM?

Classes, Meta-data, things that describe your program structures.

Data, the Heap, and Garbage Collection to manage it.

Bytecodes, an Execution Model; an Interpreter and JIT(s) to run fast.

Runtime, Locks & Threads, OS access (files,JNI,Time), Debugging