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- Static Binary Rewriting
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  - Applies to arbitrary binaries
  - Imprecise IR info, but more complete *binary* behavior
- Dynamic Binary Instrumentation
  - Valgrind, Pin, Qemu (& other Vms)
  - Can adapt at runtime, but less info than IR

Phases of Dynamic Analysis

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Very, ***very*** common mistake to mix 1 & 2.

Static Instrumentation

1) Compile whole program to IR
2) Instrument / add code directly to the IR
3) Generate new program that performs tracing/analysis
4) Execute

Dynamic Binary Instrumentation

1) Compile program as usual
2) Run program under analysis framework

(Valgrind, PIN, Qemu, etc)

3) Instrument & execute in same command:
   - Fetch & instrument each basic block individually
   - Execute each basic block

```
valgrind --tool=memcheck ./myBuggyProgram
```

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- Static instrumentation
- Finds:
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  - {heap,stack,global}-buffer overflows
- Used extensively in Google programs like Chrome

Example: Address Sanitizer

How?

- Replaces `malloc` & `free`

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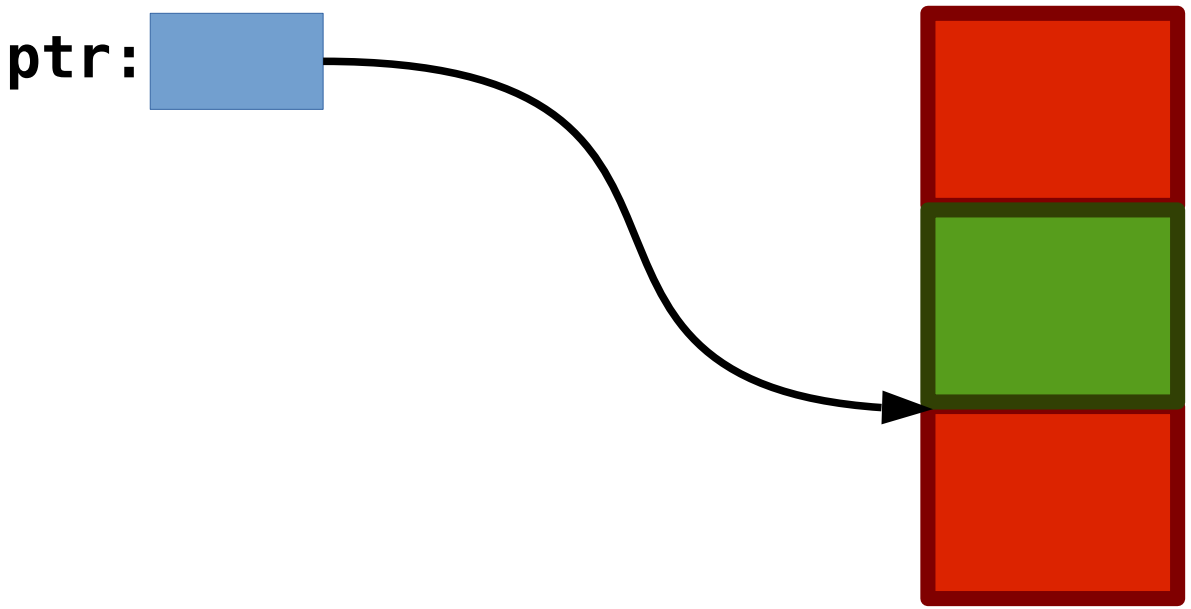
How?

- Replaces `malloc` & `free`
- Memory around malloced chunks is *poisoned*

```
ptr = malloc(sizeof(MyStruct));
```



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- Replaces `malloc` & `free`
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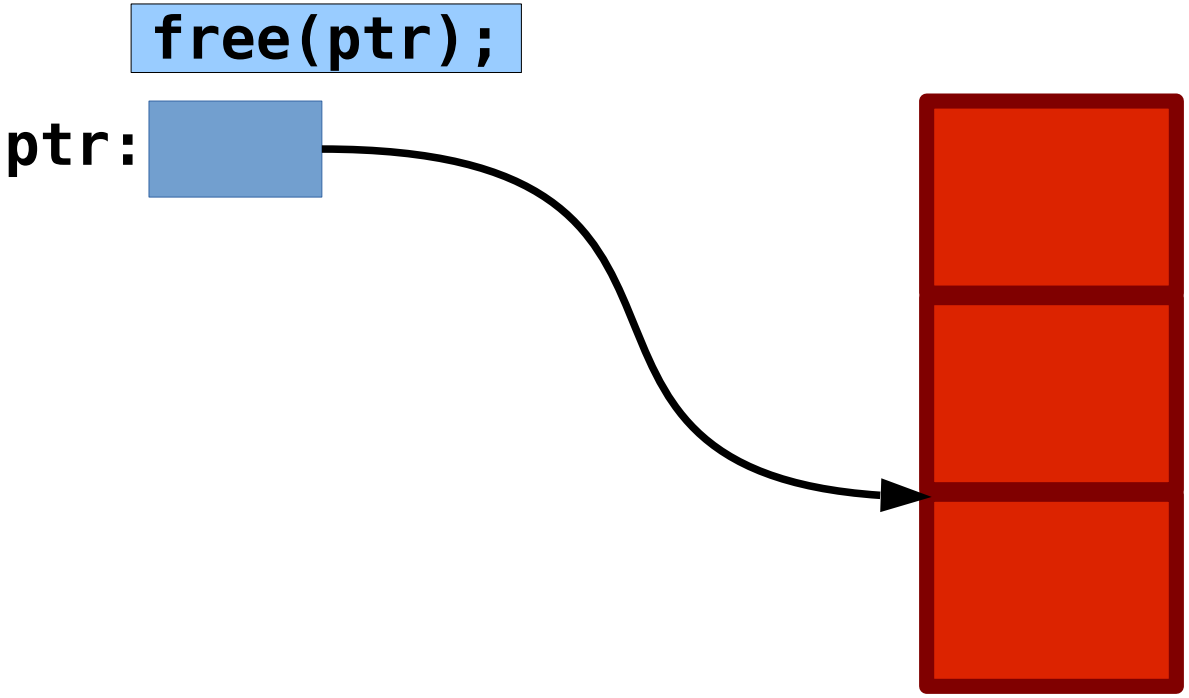
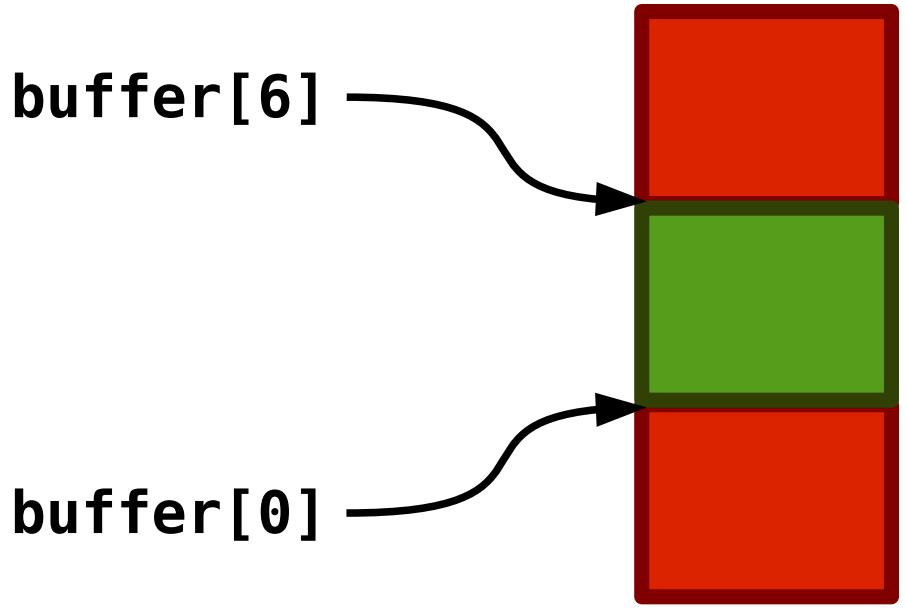


Example: Address Sanitizer

How?

- Replaces `malloc` & `free`
- Memory around malloced chunks is *poisoned*
- Freed memory is *poisoned*
- Space around buffers is *poisoned*

```
void foo() {
  int buffer[5];
}
```



Example: Address Sanitizer

How?

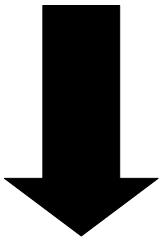
- Replaces `malloc` & `free`
- Memory around malloced chunks is *poisoned*
- Freed memory is *poisoned*
- Space around buffers is *poisoned*
- Any access of a poisoned value reports an error.

...

Example: Address Sanitizer

How?

```
*address = ...
```



Instrumentation

```
if (IsPoisoned(address)) {
  ReportError(address, kAccessSize, kIsWrite);
}
*address = ...;
```

Example: Address Sanitizer

How?

```
*address = ...
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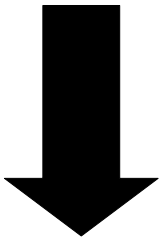

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Difficult! Why?

- Instrumenting every memory access is costly
- Tracking the status of *all memory* is tricky

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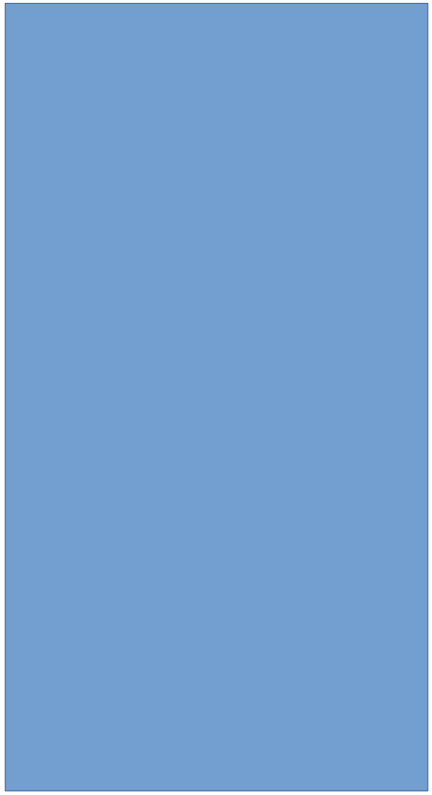
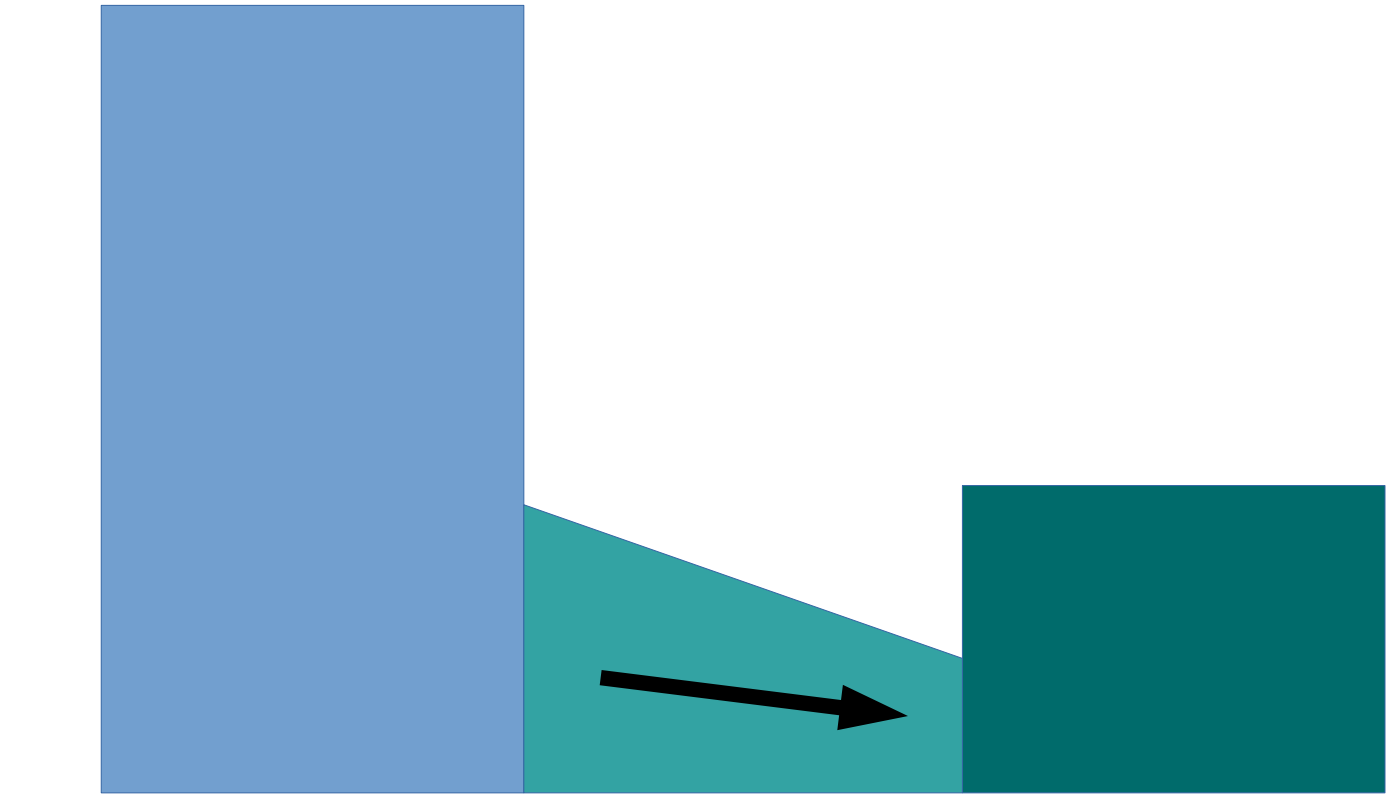


Application Memory

Need to know whether *any byte* of application memory is poisoned.

Example: Address Sanitizer

- Maintain 2 views on memory:



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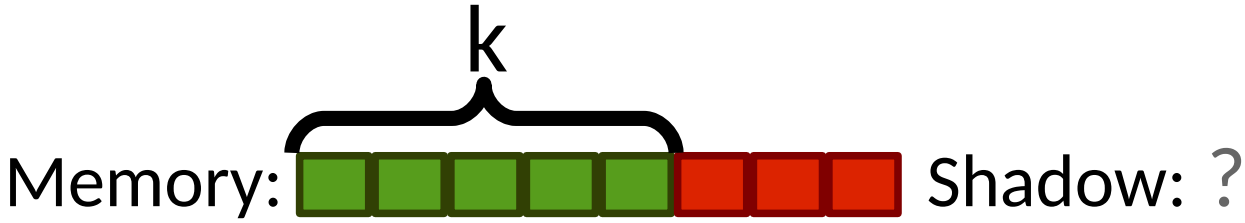
- In Asan:
  - In an 8 byte chunk, only first k may be addressable



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Memory:  Shadow: 0

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  - All 8 bytes poisoned: shadow value is negative.

Memory:  Shadow: -1

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  - For every bit/byte/word/chunk/allocation/page, maintain information in a compact table
  - Common in runtime support: e.g. page tables
- In Asan:
  - In an 8 byte chunk, only first k may be addressable
  - All 8 bytes unpoisoned: shadow value is 0.
  - All 8 bytes poisoned: shadow value is negative.
  - First k bytes are unpoisoned: shadow value is k.

Memory:  Shadow: 5

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- (64bit) Shadow Mapping:
  - Preallocate large block of memory
  - Shadow = (Mem >> 3) + 0x7fff8000;

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- (64bit) Shadow Mapping:
  - Preallocate large block of memory
  - Shadow = (Mem >> 3) + 0x7fff8000;
- The shadow memory itself must also be considered poisoned.

Why?!