# Safety Not Guaranteed:

## `sun.misc.Unsafe` and the quest for safe alternatives

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# The "`Unsafe`" situation

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# `sun.misc.Unsafe`

- Internal class within the JDK
- Used inside and unfortunately outside of the JDK
  - Never intended for outside use!
  - Used by many popular libraries/ applications

# The situation

- We would like to stop outside use of `Unsafe`
- Undermines the safety guarantees offered by Java
- Project Jigsaw will enforce this

# `Unsafe` vs. Java culture

- Java developers rely on safety
  - https://blogs.oracle.com/jrose/entry/the_isthmus_in_the_vm
- Understatement that this is important
  - You are not supposed to worry about SEGV or memory corruption!
- Safety enables an ecosystem of libraries

# Is this code safe?

src/java/org/apache/cassandra/utils/FastByteComparisons.java

```
182         int minLength = Math.min(length1, length2);
183         int minWords = minLength / Longs.BYTES;
184         int offset1Adj = offset1 + BYTE_ARRAY_BASE_OFFSET;
185         int offset2Adj = offset2 + BYTE_ARRAY_BASE_OFFSET;
186
187         /*
188          * Compare 8 bytes at a time. Benchmarking shows comparing 8 bytes at a
189          * time is no slower than comparing 4 bytes at a time even on 32-bit.
190          * On the other hand, it is substantially faster on 64-bit.
191          */
192         for (int i = 0; i < minWords * Longs.BYTES; i += Longs.BYTES) {
193           long lw = theUnsafe.getLong(buffer1, offset1Adj + (long) i);
194           long rw = theUnsafe.getLong(buffer2, offset2Adj + (long) i);
195           long diff = lw ^ rw;
```

# Answer

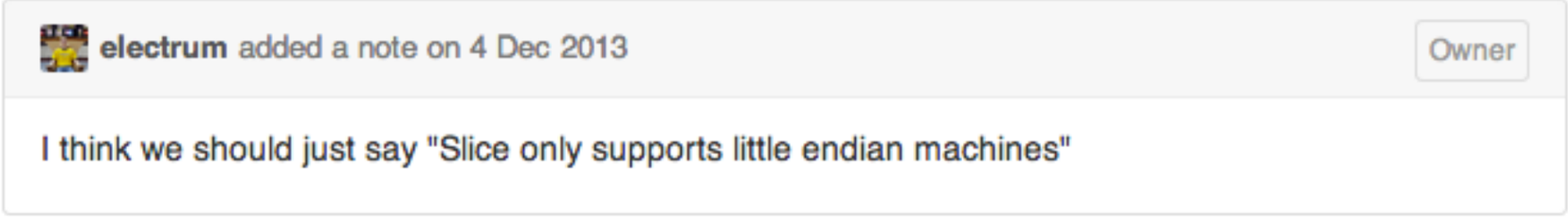
- It is now but was not before Feb 2014
  - Can cause JVM crash on Solaris/Sparc
  - Bug has been present for over 2 years
  - Introduced in 1.1.3 fixed in 2.0.5
- Bug: CASSANDRA-6628
- Code diff

# What about this?

https://github.com/airlift/slice/blob/master/src/main/java/io/airlift/slice/Slice.java

```
public long getLong(int index)
{
    checkIndexLength(index, SIZE_OF_LONG);
    return unsafe.getLong(base, address + index);
}
```

# Answer

- No, does not account for alignment and native byte order
- Pull request is ~7 months old
- 

# What about this?

http://hg.openjdk.java.net/jdk9/dev/jdk/file/tip/src/share/classes/java/util/concurrent/atomic/AtomicLong.java

```
public class AtomicLong extends Number implements java.io.Serializable {
    ...
    private volatile long value;
    ...
    public final void set(long newValue) {
        value = newValue;
    }
    ...
    public final boolean compareAndSet(long expect, long update) {
        return unsafe.compareAndSwapLong(this, valueOffset, expect, update);
    }
    ...
}
```

# Answer

- Yes, on all mainline OpenJDK platforms
- No, on a platform not supporting compare-and-set of 64 bit values
  - Issue JDK-8044616
  - Compare-and-set requires a lock
  - Cannot enforce atomicity w.r.t direct stores

# `Unsafe` is a sharp tool

- Even advanced developers can get things wrong or assumptions change
  - Perhaps some developers don't care
- Many other pitfalls
  - Especially security and serialization related

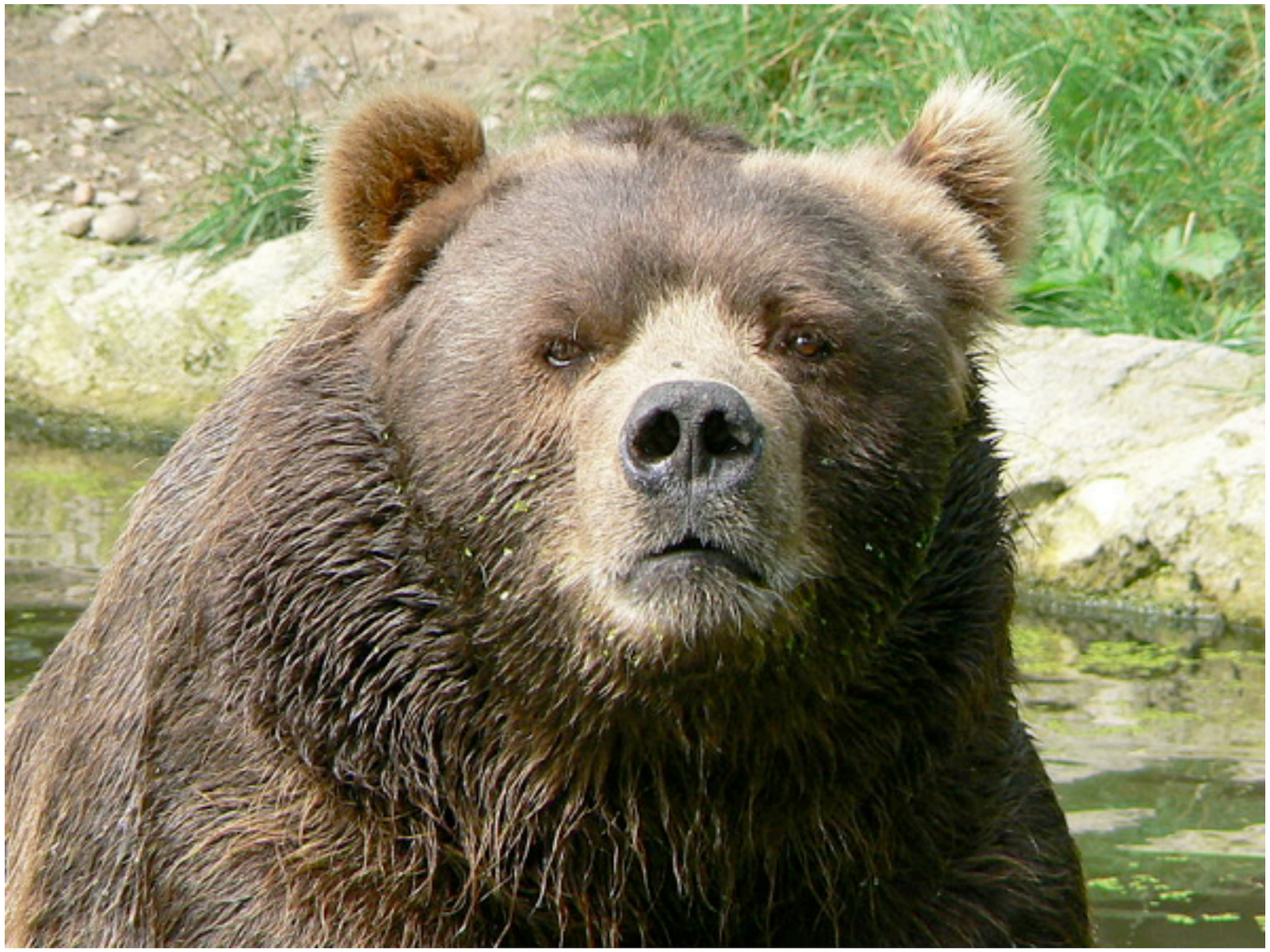
# Developer distinctions

- 99% of Java developers don't use, and have probably never heard of, and have no need to use, **`Unsafe`**
- 1% of Java developers use **`Unsafe`**
  - Often write widely-used libraries
  - Therefore much of that 99% transitively use **`Unsafe`** too without knowing it

# The 1% mix

- Developers who think they need to use it but probably don't really need to
- Advanced developers with a genuine need and don't care about cross platform safety
- Advanced developers with a genuine need and align with Java's culture
- Developers working on the JDK itself

# Poke the bear



http://en.wikipedia.org/wiki/Wikipedia:Don't_poke_the_bear#mediaviewer/File:Male_kodiak_bear_face.JPG

# Poke!
# Focus on

- ~~Developers who think they need to use it but probably don't~~
- ~~Advanced developers with a genuine need and don't care about cross platform safety~~
- Advanced developers with a genuine need and align with Java's culture
- Developers working on the JDK itself

# Advanced `Unsafe` Developers

- Pushing the boundaries of where and how the JVM is used
- Often vocal & innovative
- Develop popular libraries
- Good for the Java community

# The Unsafe survey

**6. Do you have an optional dependency on Unsafe to ensure code is portable across multiple Java platforms?**

| | | Response Percent | Response Count |
|---|---|---|---|
| Yes | | 30.4% | 96 |
| **No** | | **69.6%** | **220** |

# The Unsafe survey

**7. If there was a "safe unsafe" standard (cross-platform) alternative for your use-cases (perhaps a new API, perhaps language changes, or both) would you be prepared to replace Unsafe with that alternative? If so under what conditions?**

| | | Response Percent | Response Count |
|---|---|---|---|
| **Yes (perhaps with conditions, if so please state those conditions)** | | **88.6%** | **280** |
| No | | 11.4% | 36 |

# Why is `Unsafe` in the JDK?

- For low-level VM-based features
  - Often intrinsified by HotSpot
  - JNI is PITA!
- Not directly expressible in byte-code
- Should be the only point between "can't do it" and "officially supported"

# Functionality

- Peek and poke at memory
  both on and off heap
- Define, instantiate and check initialization
  of classes
- Park/unpark threads
- Memory fences
- Some other minor stuff...

# Use-cases

- When you can peek and poke at memory the use-cases are many and varied
- Use-cases come down to two things
  - Performance; and/or
  - Work around JDK restrictions/limitations

# Characterizing use-cases

- A number of vertical use-cases
- Each of which can be tackled independently
  - Some sooner than others
- Wean developers off `Unsafe` step-by-step

# The Unsafe survey

**4. What reasons did you use Unsafe for?**

| | Response Percent | Response Count |
|---|---|---|
| Atomic access to fields and array elements (such as compare-and-swap) | 44.1% | 149 |
| **Off-heap memory operations (such as to emulate structures or packed objects)** | **63.6%** | **215** |
| Deserialization hacks | 36.4% | 123 |
| Fencing (to constrain re-ordering of memory operations) | 22.5% | 76 |
| Access to private fields of another class | 25.1% | 85 |
| Array access without bounds checks | 32.5% | 110 |
| Other (please specify) | 22.2% | 75 |

# Three general cases

- Off-heap
- Enhanced atomic access & fences
- De/Serialization

# Four off-heap use-cases

- Reduce GC
- Efficient memory layout
- Very large collections
- Communicate across JVM boundary

# Use-case to Feature

| Use-case | Feature |
|---|---|
| Enhanced atomic access | JEP 193 Enhanced Volatiles |
| De/Serialization | JEP 187 Serialization 2.0 |
| Reduce GC | Value types<br>JEP 189 Shenandoah: Low Pause GC |
| Efficient memory layout | Value types,<br>Arrays 2.0 & Layouts |
| Very Large Collections | Value types,<br>Arrays 2.0 & Layouts |
| Communicate across JVM boundary | Project Panama &<br>JEP 191 FFI |

# A Strategy

- Put features in **`Unsafe`**; use them in JDK
- Identify features that really belong in the Java programming model
- Add support for those features
- (Theoretically) garbage-collect them from **`Unsafe`**

# Carrot and Stick

- Removing key functionality can hurt
- We need to make it easier for library/ framework developers to migrate gradually
  - From release N with `Unsafe` to release N+1 without `Unsafe`

# Enhanced Volatiles

- **Safe** enhanced atomic access to field and array elements
- Without the dynamic overhead of **`Atomic*{Updater|Array}`** classes
- Replace nearly all usages of **`Unsafe`** in **`java.util.concurrent`** classes

# Success Metrics

- API should be at least as good as **`Unsafe`**
- Performance results should be close to **`Unsafe`**, and faster than **`Atomic*`** classes
  - Good enough to replace **`Unsafe`** usages in **`java.util.concurrent`** classes
- Eat our own dog food updating classes in the JDK

# Code in ForkJoinPool

```
final ForkJoinTask<?> poll() {
    ForkJoinTask<?>[] a; int b; ForkJoinTask<?> t;
    while ((b = base) - top < 0 && (a = array) != null) {
        int j = (((a.length - 1) & b) << ASHIFT) + ABASE;
        t = (ForkJoinTask<?>)U.getObjectVolatile(a, j);
        if (t != null) {
            if (U.compareAndSwapObject(a, j, t, null)) {
                U.putOrderedInt(this, QBASE, b + 1);
                return t;
            }
        }
        else if (base == b) {
            if (b + 1 == top)
                break;
            Thread.yield(); // wait for lagging update (very rare)
        }
    }
    return null;
}
```

# Possible solution: `MethodHandle`

- A `MethodHandle` is a reference to an underlying method, constructor, or field
  - Supports volatile access to a field
  - Invocations inline surprisingly well
- With some tweaks can support other forms of access

# Code in ForkJoinPool

```
final ForkJoinTask<?> poll() {
    ForkJoinTask<?>[] a; int b; ForkJoinTask<?> t;
    while ((b = base) - top < 0 && (a = array) != null) {
        int j = (a.length - 1) & b;
        t = (ForkJoinTask<?>)ABASE_getVolatile.invokeExact(a, j);
        if (t != null) {
            if ((boolean) ABASE_compareAndSet.invokeExact(
                                a, j, t, (ForkJoinTask) null)) {
                QBASE_setRelease.invokeExact(this, b + 1);
                return t;
            }
        }
        else if (base == b) {
            if (b + 1 == top)
                break;
            Thread.yield(); // wait for lagging update (very rare)
        }
    }
    return null;
}
```

# `MethodHandle`: Success Metrics

✗ API should be at least as good as **`Unsafe`**, preferably better

✓ Performance results should be close to **`Unsafe`**, and faster than **`Atomic*`** classes

# Low Hanging Fruit

- The methods **`monitorEnter`**/ **`monitorExit`**/**`tryMonitorEnter`** can be removed
  - No one is using them
- Add a lexicographical byte comparator to **`{Direct|Heap}ByteBuffer`**
  - Cassandra, Guava, ...

# In Safety...

- `sun.misc.Unsafe` is going away
  - Accessible only from within the JDK
- Safe supported features planned that replace common unsafe use
  - Preserving Java's culture