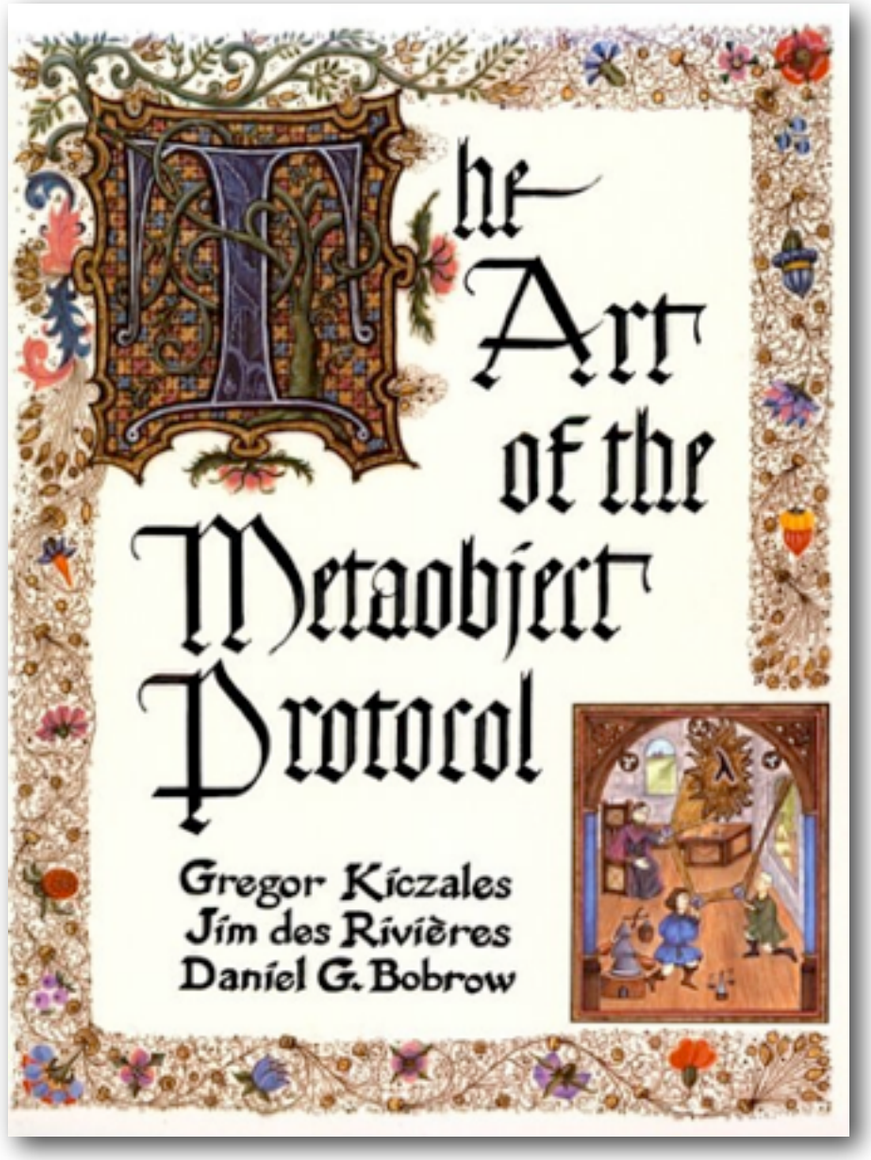
Tradeoffs in language design: The case of Javascript proxies

Tom Van Cutsem
(joint work with Mark S. Miller, with feedback from many others)

What do these have in common?



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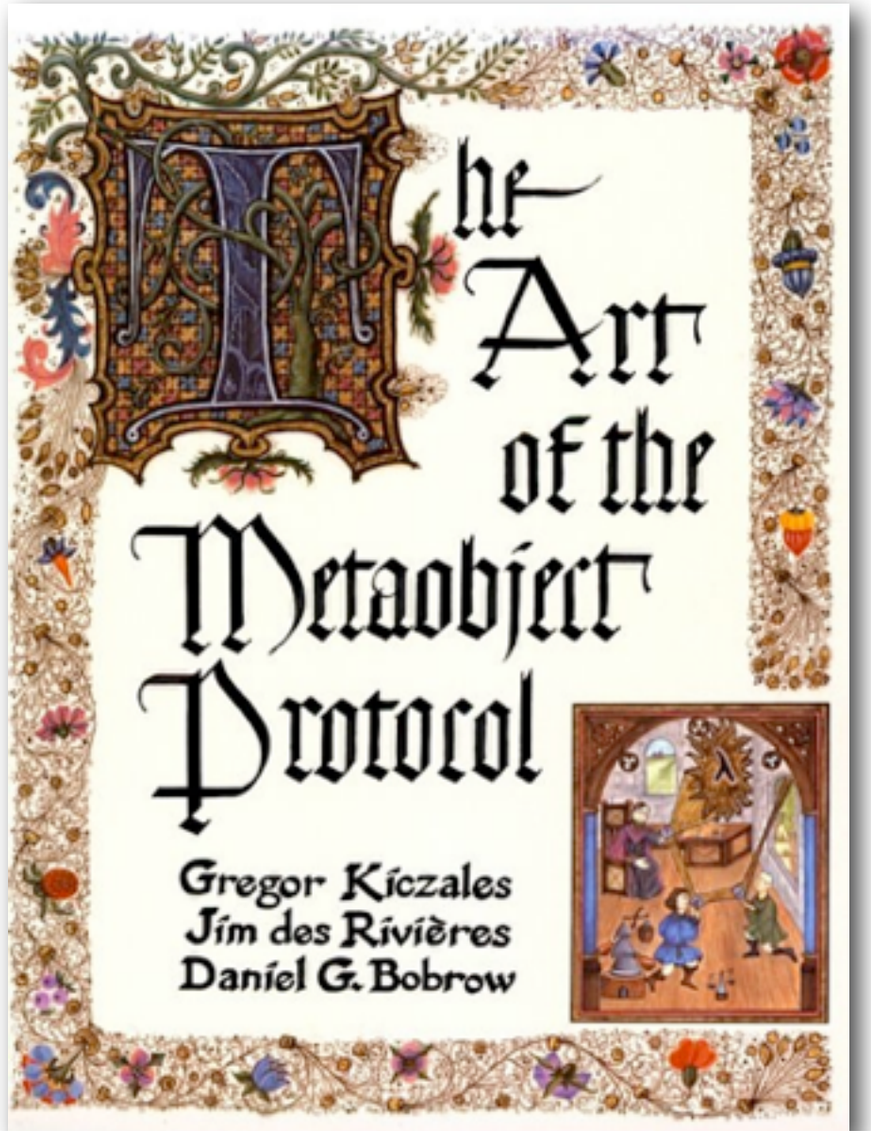
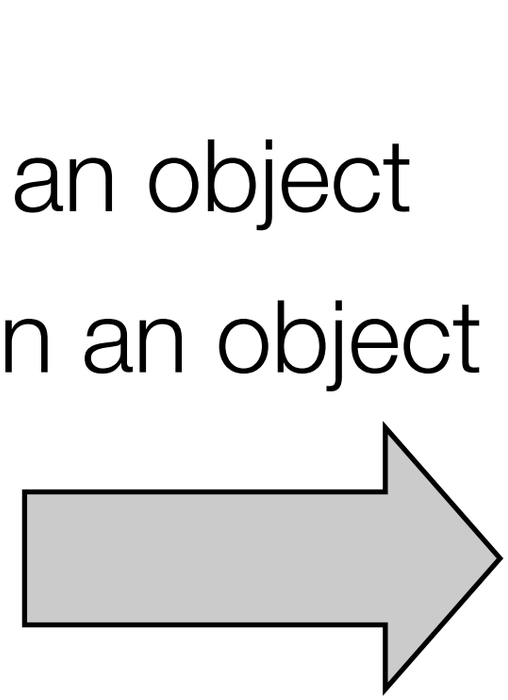


VIRTUALIZATION

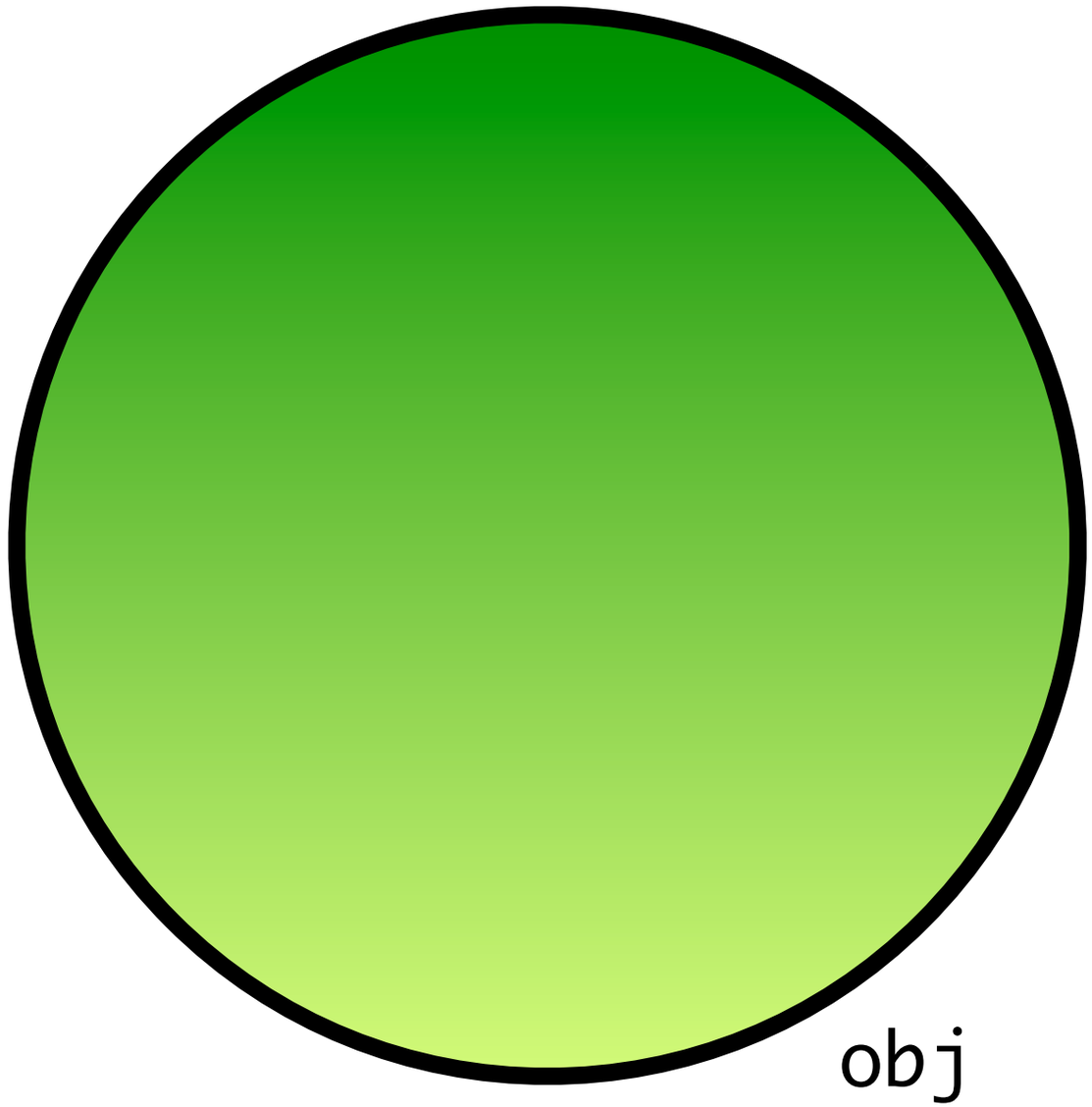
Virtualizing objects

querying an object

acting upon an object

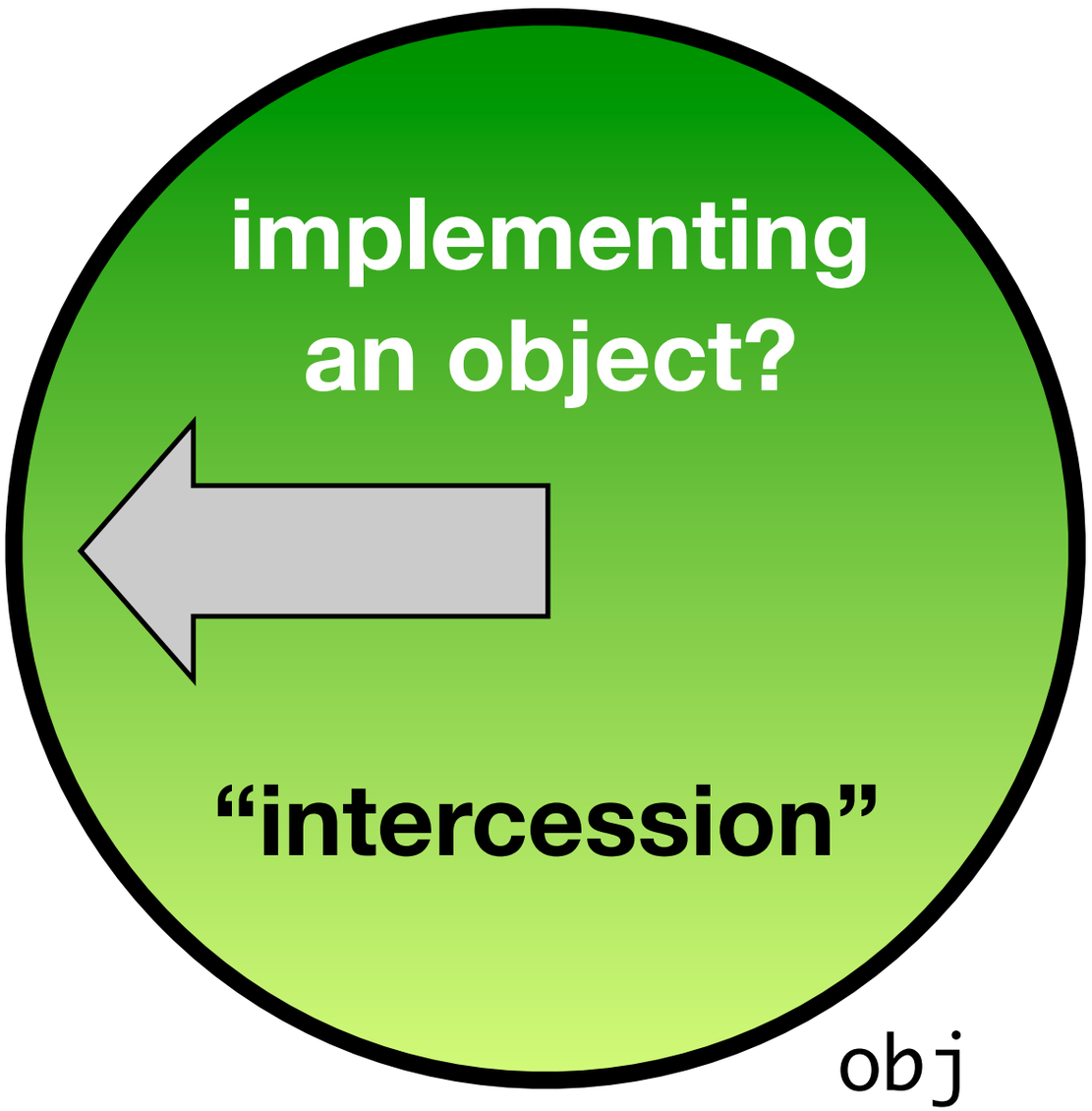


“introspection”




```
obj[“x”]
delete obj.x
“x” in obj
```

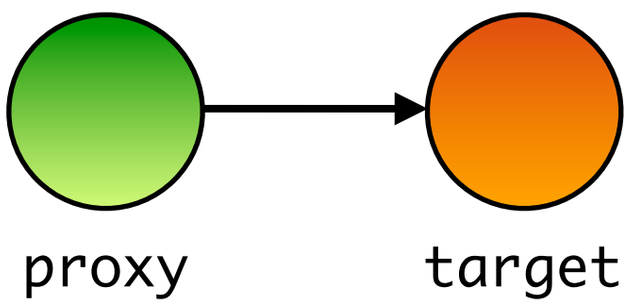
Virtualizing objects



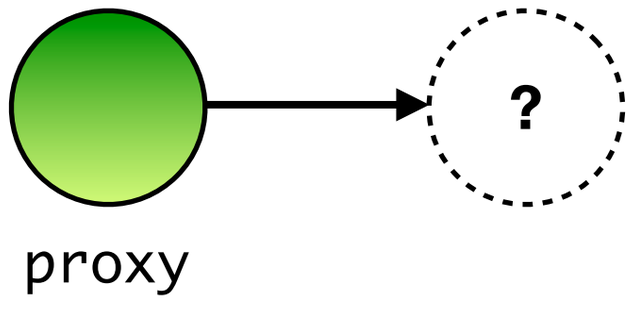

```
obj[“x”]
delete obj.x
“x” in obj
```

Why implement your own objects?

- Generic wrappers around existing objects: access control wrappers (security), tracing, profiling, contracts, taint tracking, decorators, adaptors, ...

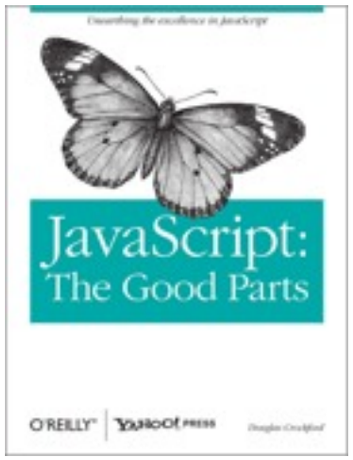


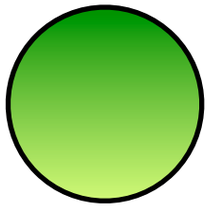
- Virtual objects: remote objects, mock objects, persistent objects, promises / futures, lazily initialized objects, ...



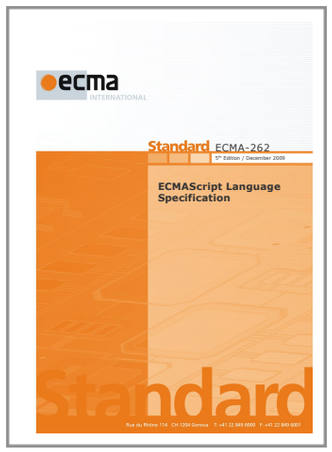
The Javascript object zoo

Native objects
(provided by ECMAScript engine)





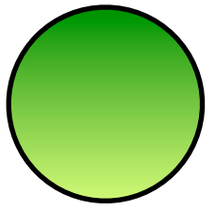
an Object



an Array

W3C®

The “DOM”

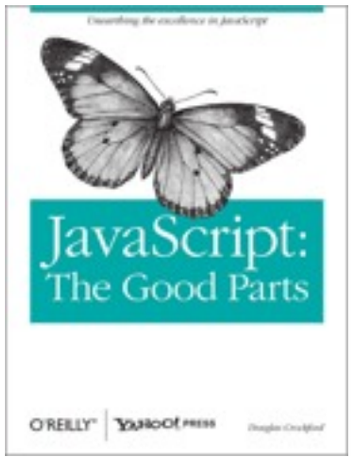


a NodeList

Normal objects
(implementable in Javascript)

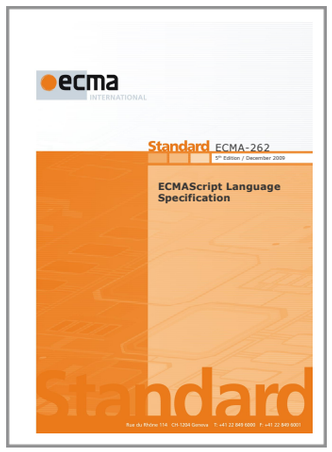
Host objects
(provided by the embedding environment, usually the browser)

The Javascript object zoo



+ proxies

an Object



an Array

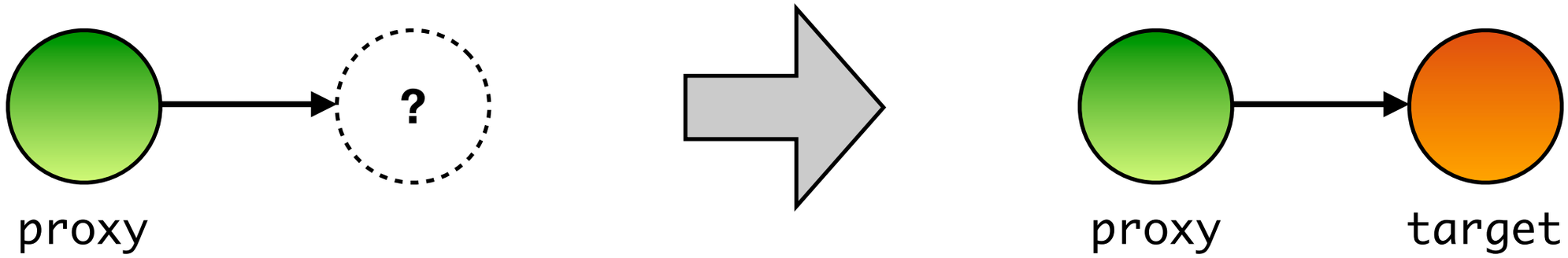
W3C®

The “DOM”

a NodeList

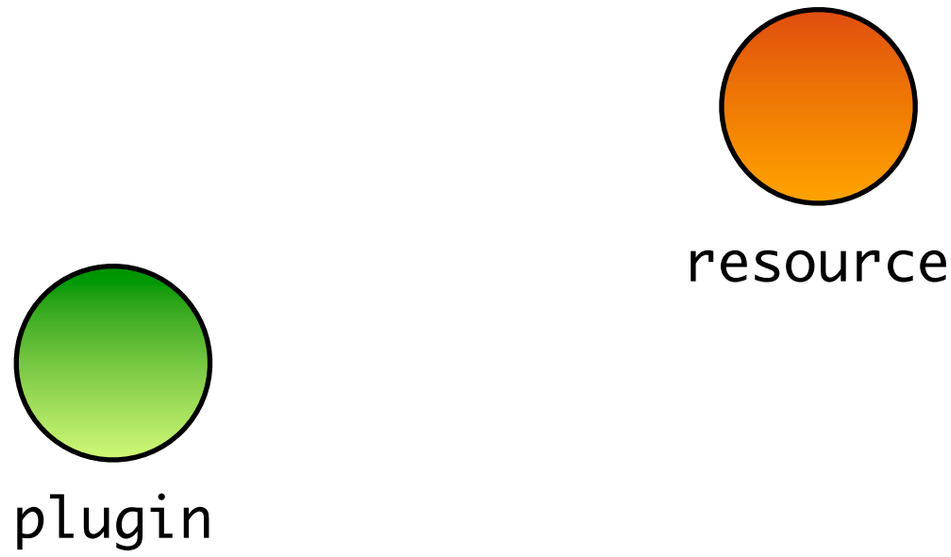
can be implemented using proxies

The rest of this talk



Example: revocable references

- Provide temporary access to a resource
- Useful for explicit memory management or expressing security policy



Example: revocable references

- Provide temporary access to a resource
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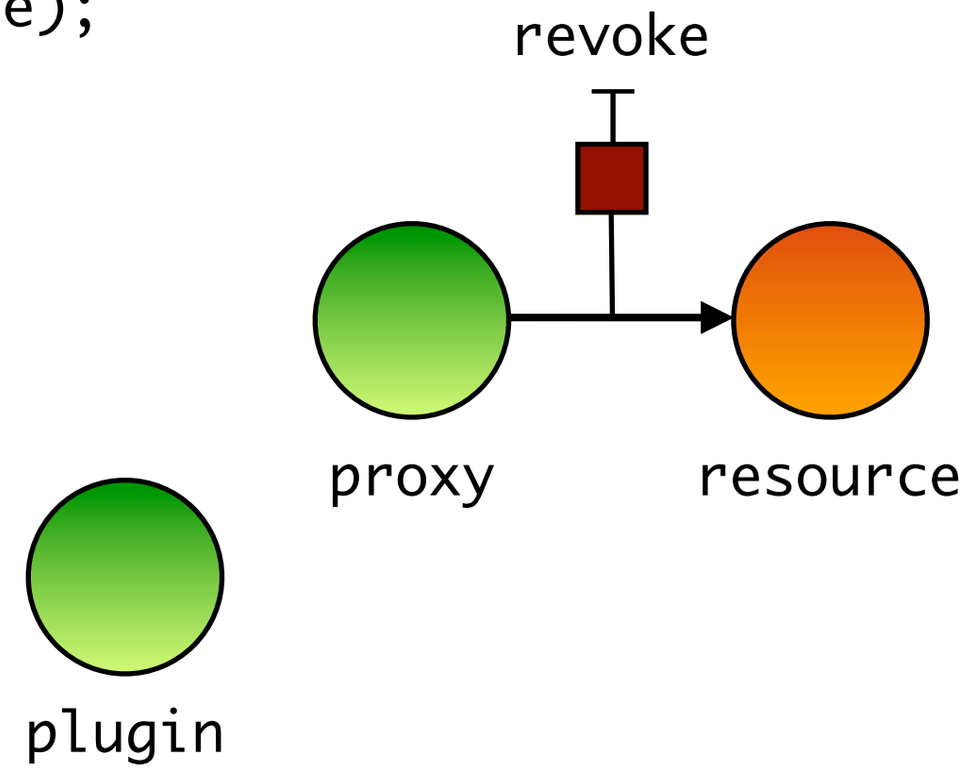
```
var {proxy,revoke} = makeRevocable(resource);
```



Example: revocable references

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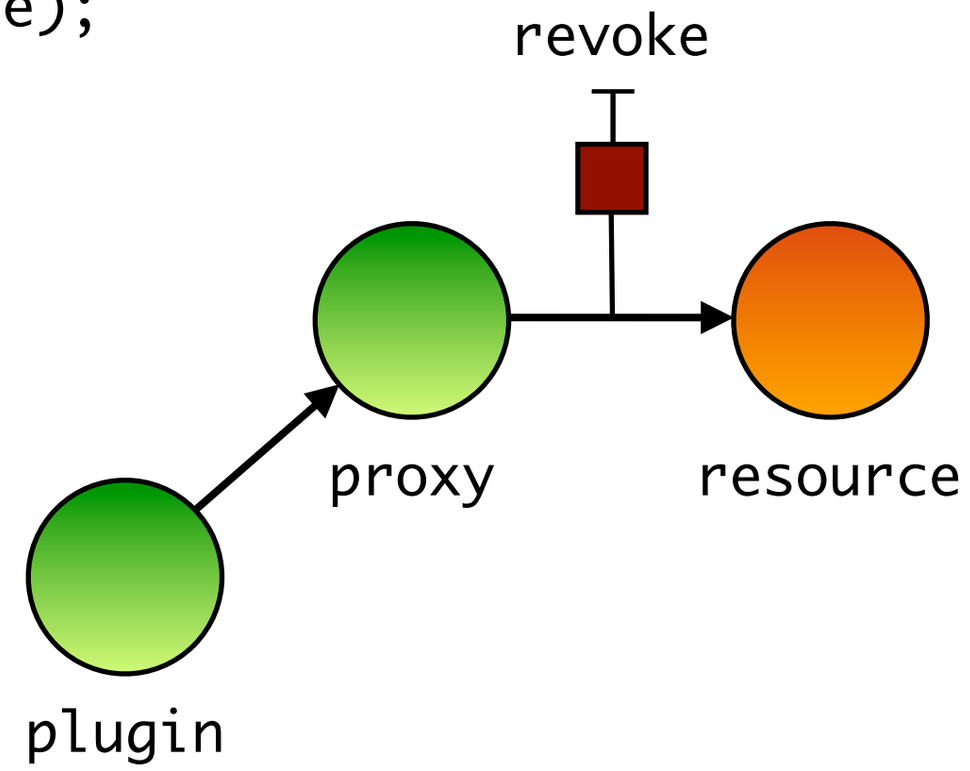
```
var {proxy,revoke} = makeRevocable(resource);

plugin.give(proxy)
```



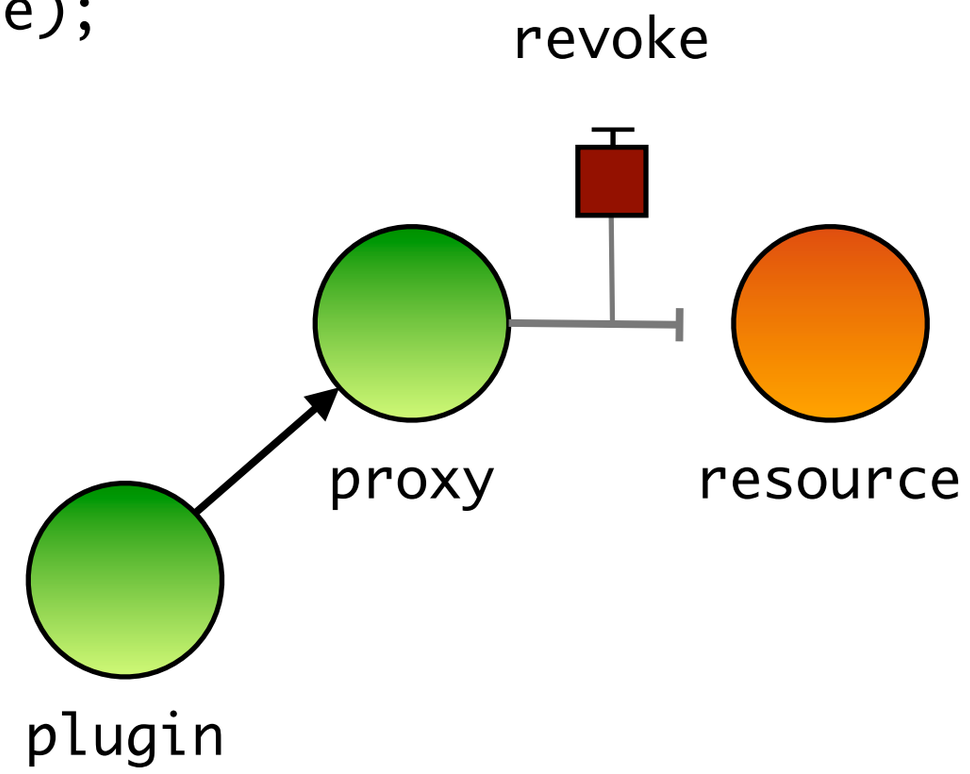
Example: revocable references

- Provide temporary access to a resource
- Useful for explicit memory management or expressing security policy

```
var {proxy,revoke} = makeRevocable(resource);


plugin.give(proxy)

...
revoke();
```



Revocable references

```
function makeRevocable(target) {
  var enabled = true;
  var proxy = Proxy({
  });
  return {
     proxy: proxy,
    revoke: function() { enabled = false; }
  }
}
```

Revocable references

```
function makeRevocable(target) {
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  var proxy = Proxy({
    get: function(rcvr, name) {
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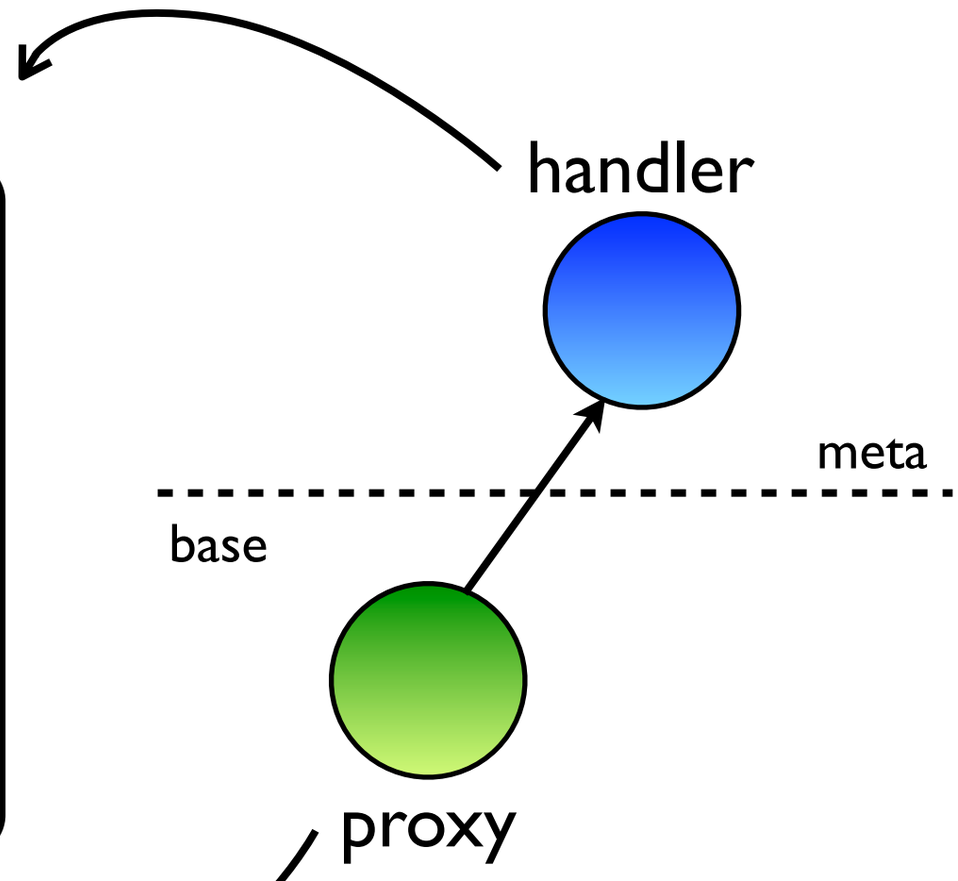
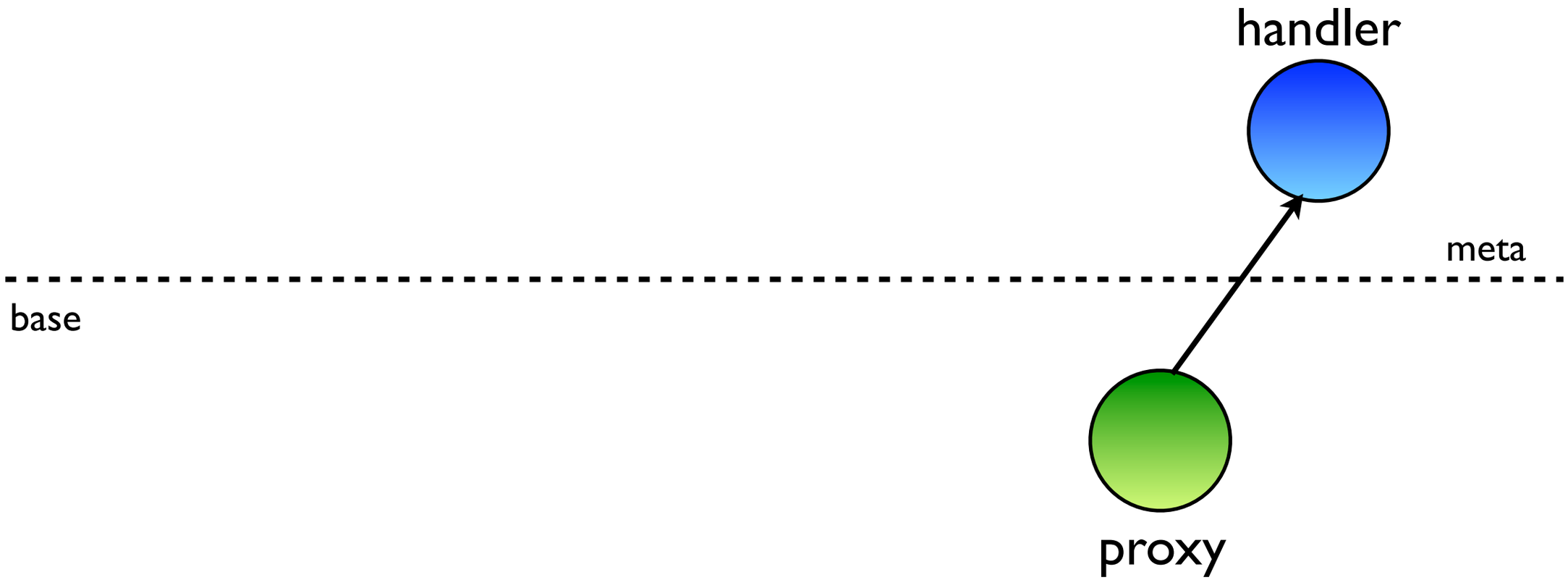
```



Stratified API

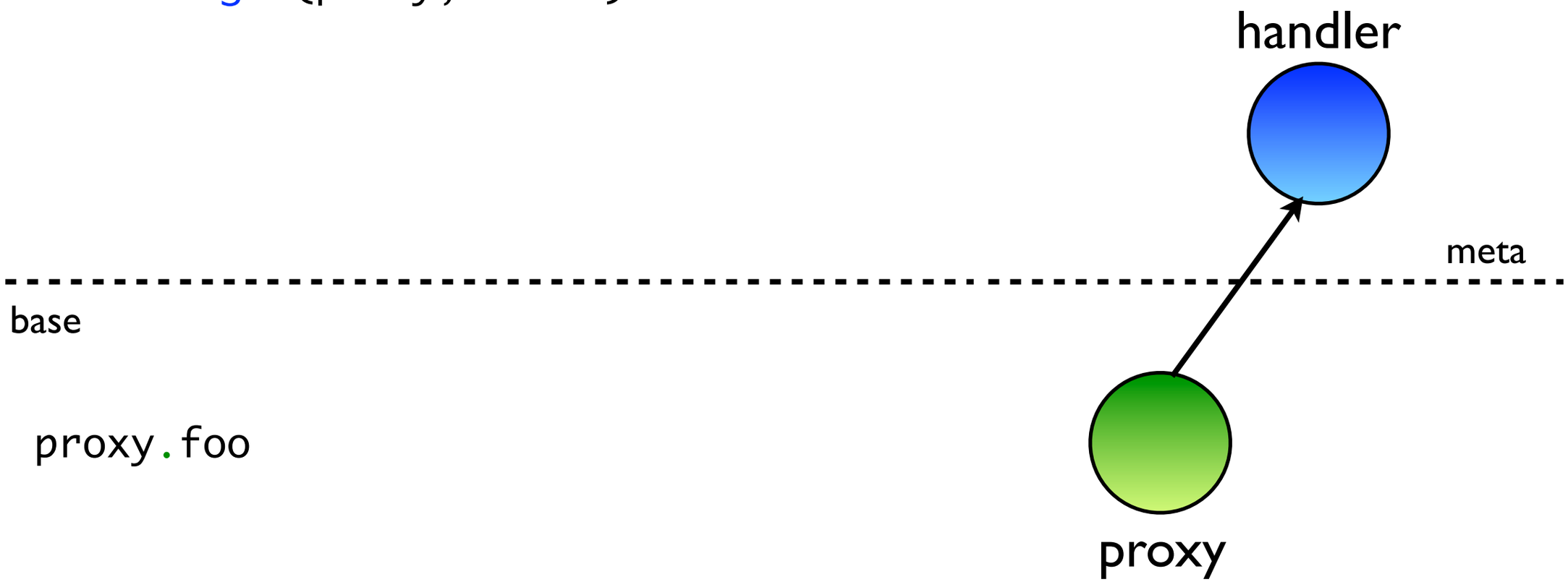
```
var proxy = Proxy(handler);
```



Stratified API

```
var proxy = Proxy(handler);

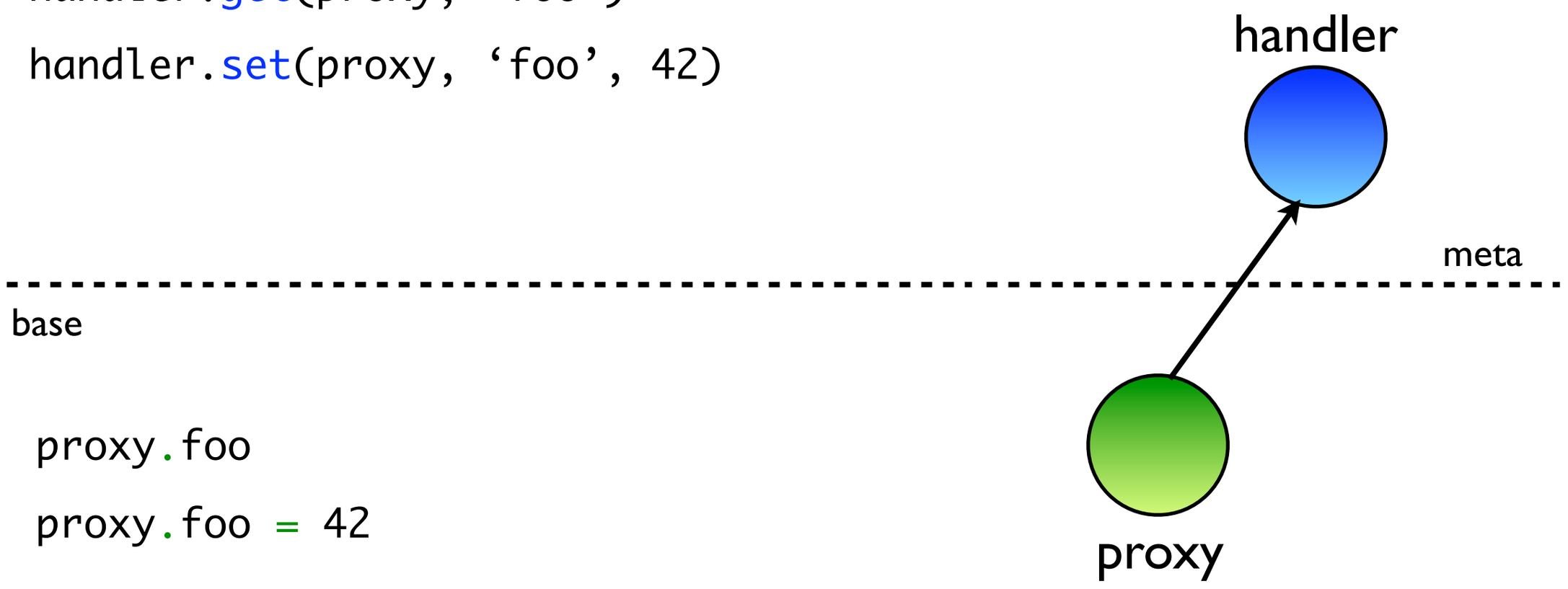
handler.get(proxy, ‘foo’)
```



Stratified API

```
var proxy = Proxy(handler);

handler.get(proxy, ‘foo’)
handler.set(proxy, ‘foo’, 42)
```

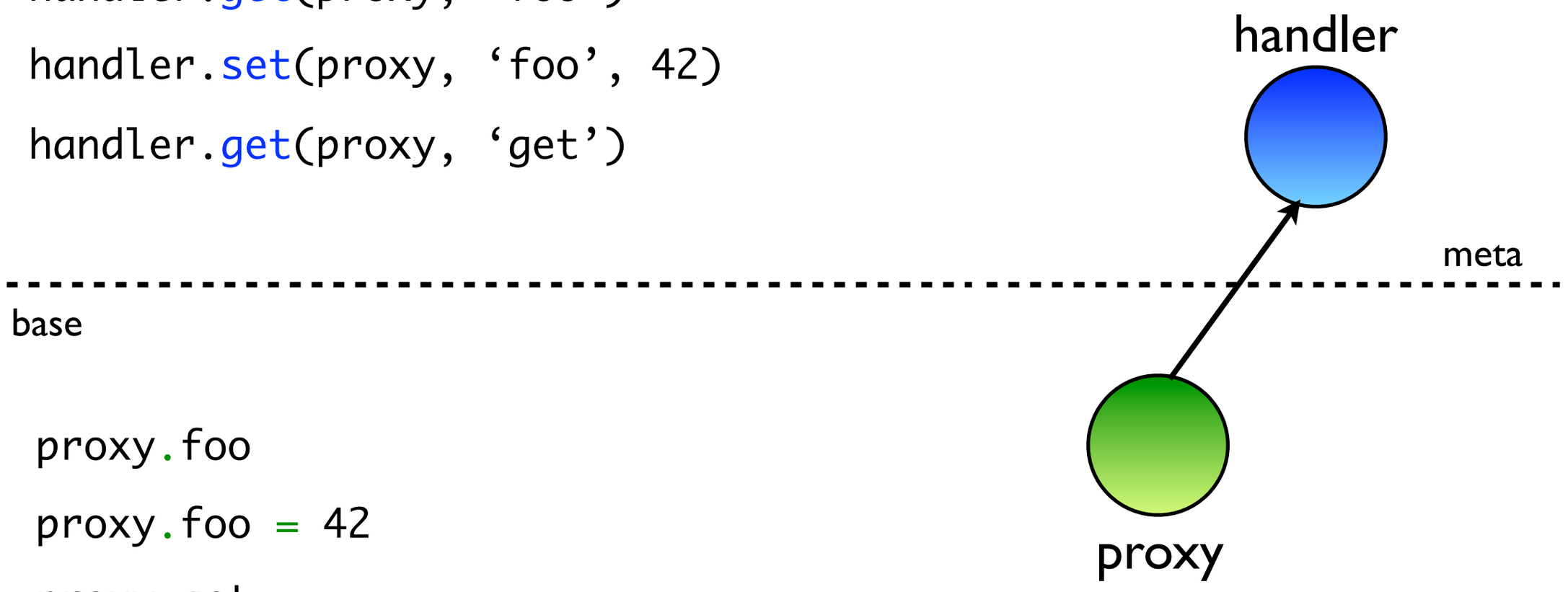



```
proxy.foo
proxy.foo = 42
```

Stratified API

```
var proxy = Proxy(handler);
```

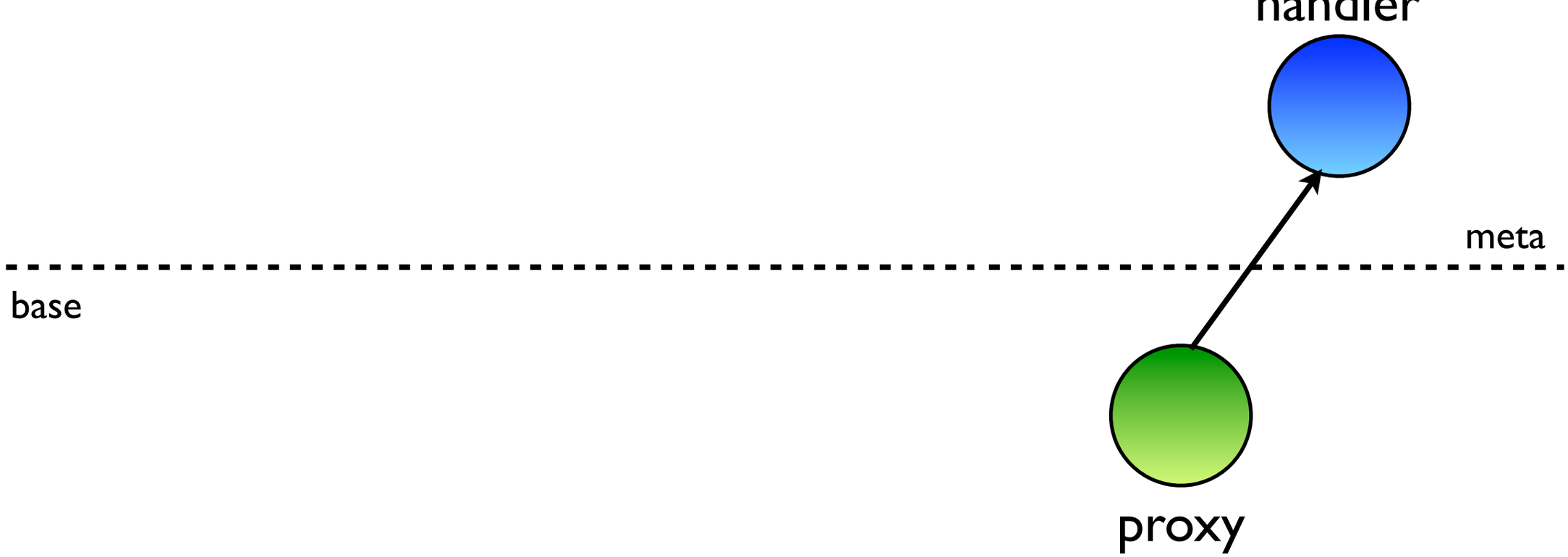
```
handler.get(proxy, ‘foo’)
handler.set(proxy, ‘foo’, 42)
handler.get(proxy, ‘get’)
```




```
proxy.foo
proxy.foo = 42
proxy.get
```

Not just property access...

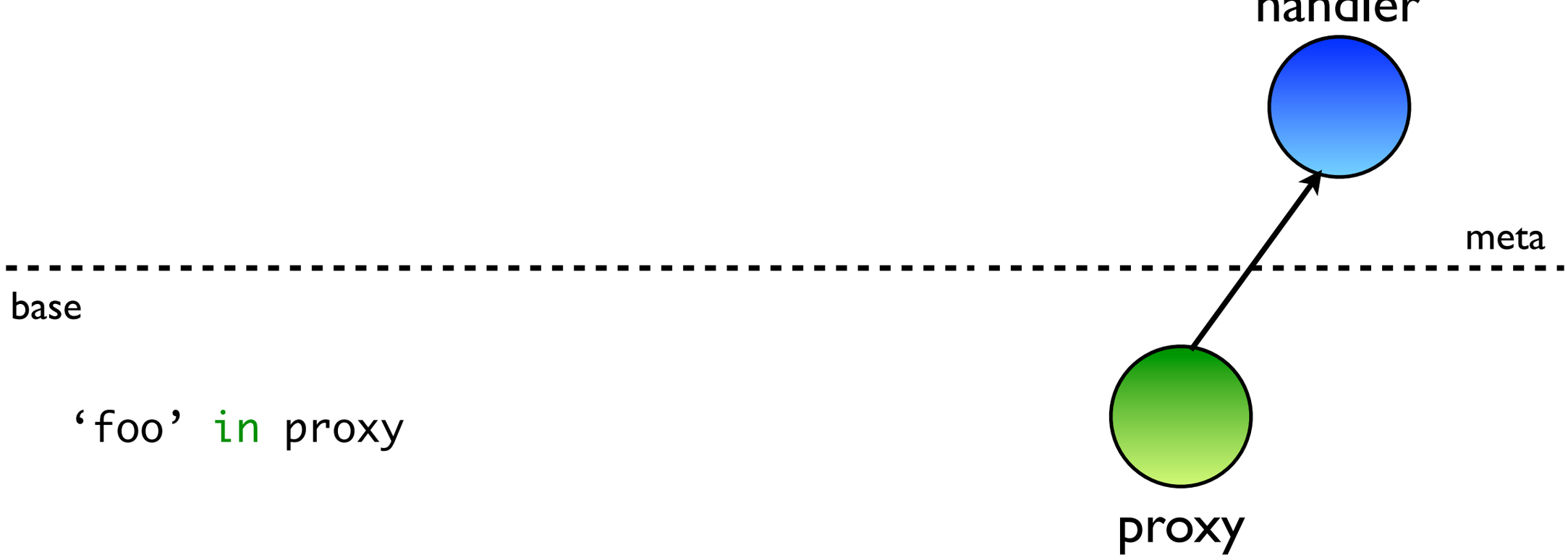
```
var proxy = Proxy(handler);
```



Not just property access...

```
var proxy = Proxy(handler);

  handler.has('foo')
```



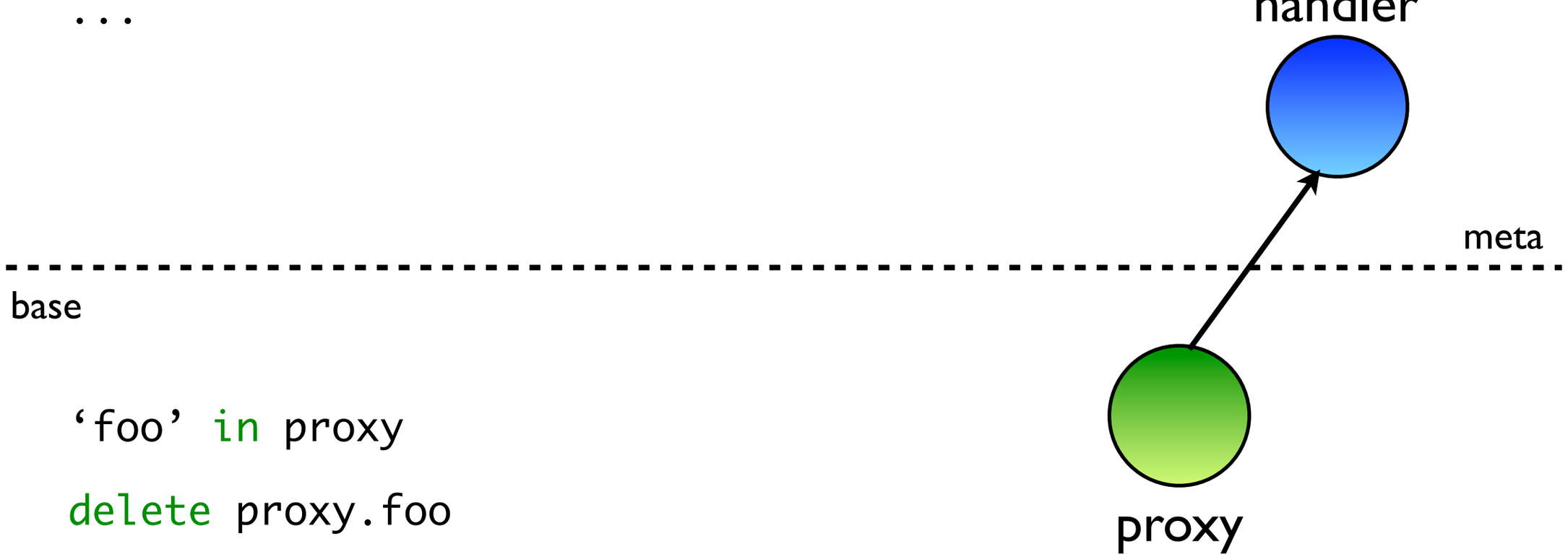
Not just property access...

```
var proxy = Proxy(handler);
```

```
  handler.has('foo')

  handler.delete('foo')

  ...
```



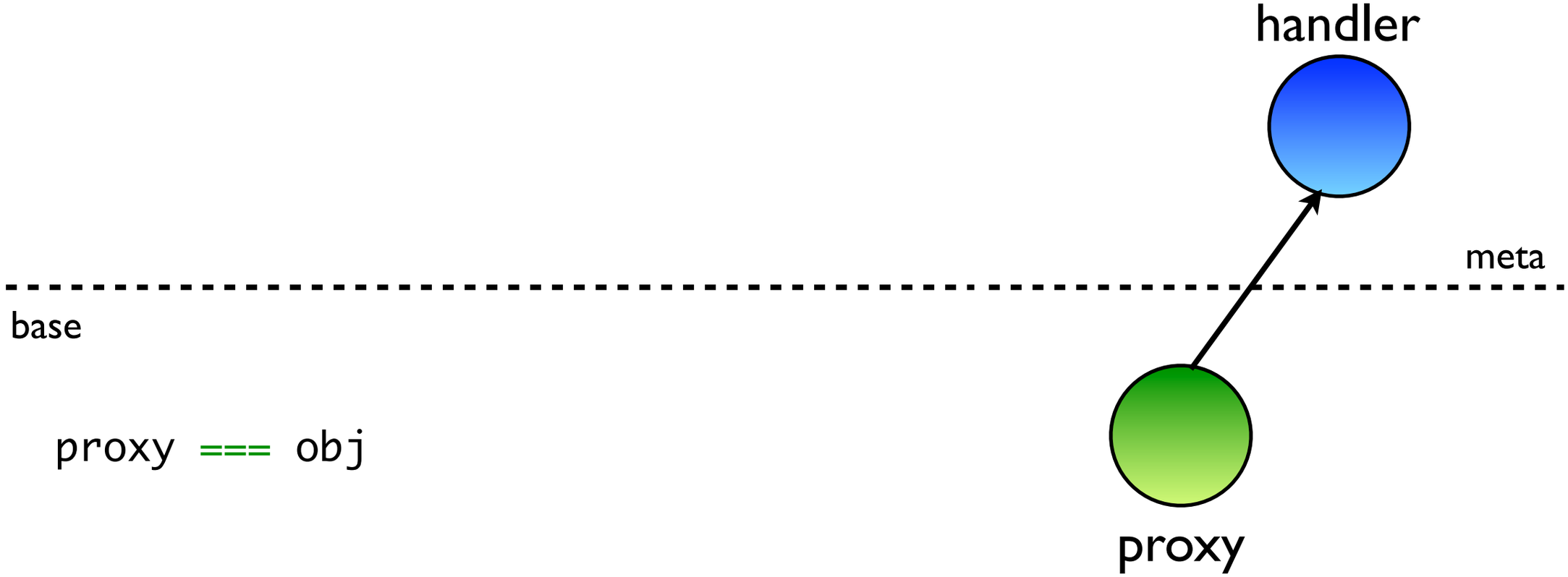

```
  'foo' in proxy

  delete proxy.foo

  ...
```

... but not quite everything either

```
var proxy = Proxy(handler);
```




```
proxy === obj
```

Frozen objects (new since ECMAScript 5)

```
var point = { x: 0, y: 0 };

Object.freeze(point);

point.z = 0;     // error: can't add new properties
delete point.x; // error: can't delete properties

point.x = 7;     // error: can't assign properties

Object.isFrozen(point) // true
```

guarantee (invariant):
properties of a frozen object are immutable

freezing is permanent - there is no **`defrost`**

How to combine proxies with frozen objects?

- Can a proxy emulate the “frozen” invariant of the object it wraps?

```
var point = { x: 0, y: 0 };
Object.freeze(point);
var {proxy,revoke} = makeRevocable(point);

Object.isFrozen(point) // true
Object.isFrozen(proxy) // ?
```

How to combine proxies with frozen objects?

- Can a proxy emulate the “frozen” invariant of the object it wraps?

```
function wrap(target) {
  return Proxy({
    get: function(rcvr, name) { return Math.random(); }
  });
}

var point = { x: 0, y: 0 };
Object.freeze(point);

var proxy = wrap(point);

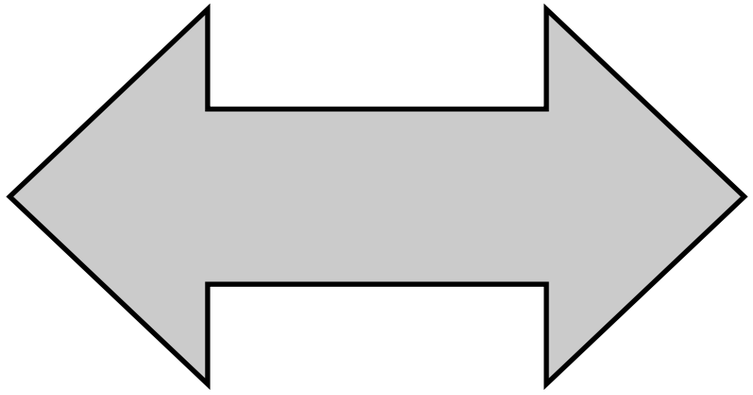
Object.isFrozen(point) // true
Object.isFrozen(proxy) // can’t be true!
```

The “Solution”

- Proxies can’t emulate frozen objects
- `Object.isFrozen(proxy)` always returns `false`
- Safe, but overly restrictive

Language Design Tradeoff

Powerful proxies that can virtualize frozen objects



Strong language invariants that can’t be spoofed

Second iteration: “direct” proxies

- Proxy now has direct pointer to target: `Proxy(target, handler)`
- `Object.isFrozen(proxy)` <=> `Object.isFrozen(target)`

Revocable references (old API)

```
function makeRevocable(target) {
  var enabled = true;
  var proxy = Proxy({
    get: function(rcvr, name) {
      if (!enabled) throw Error(“revoked”)
      return target[name];
    },
    set: function(rcvr, name, val) {
      if (!enabled) throw Error(“revoked”)
      target[name] = val;
    },
    ...
  });
  return {
     proxy: proxy,
    revoke: function() { enabled = false; }
  }
}
```

Revocable references (new API)

```
function makeRevocable(target) {
  var enabled = true;
  var proxy = Proxy(target, {
    get: function(tgt, name) {
      if (!enabled) throw Error(“revoked”)
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```

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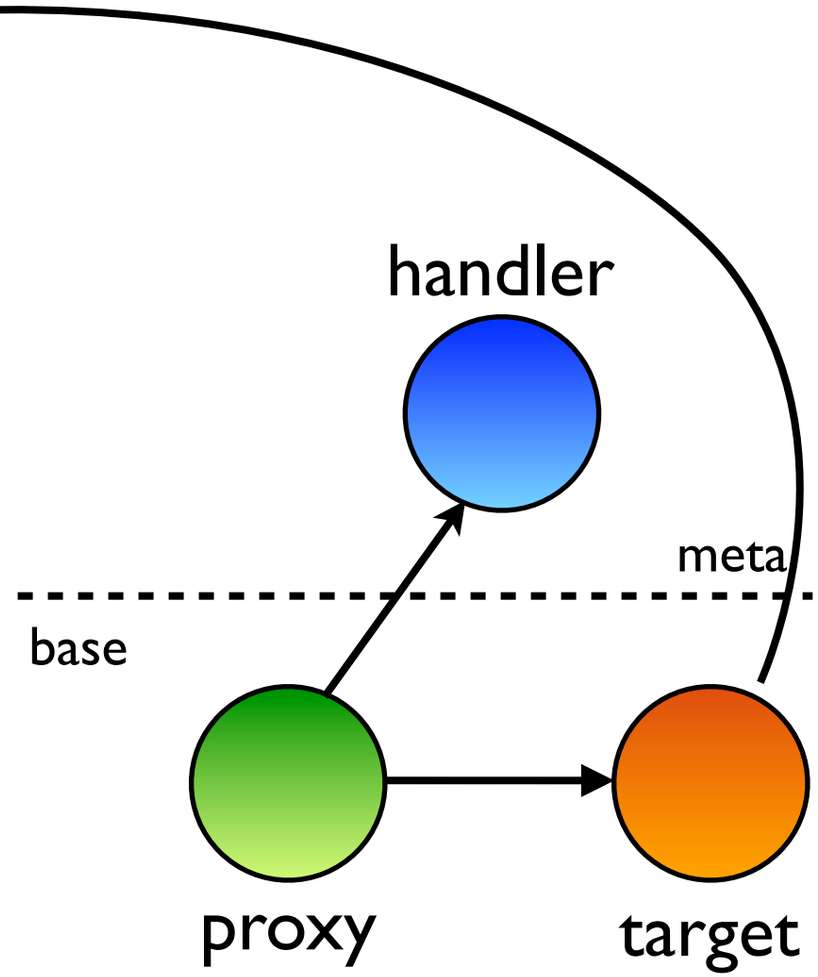
```



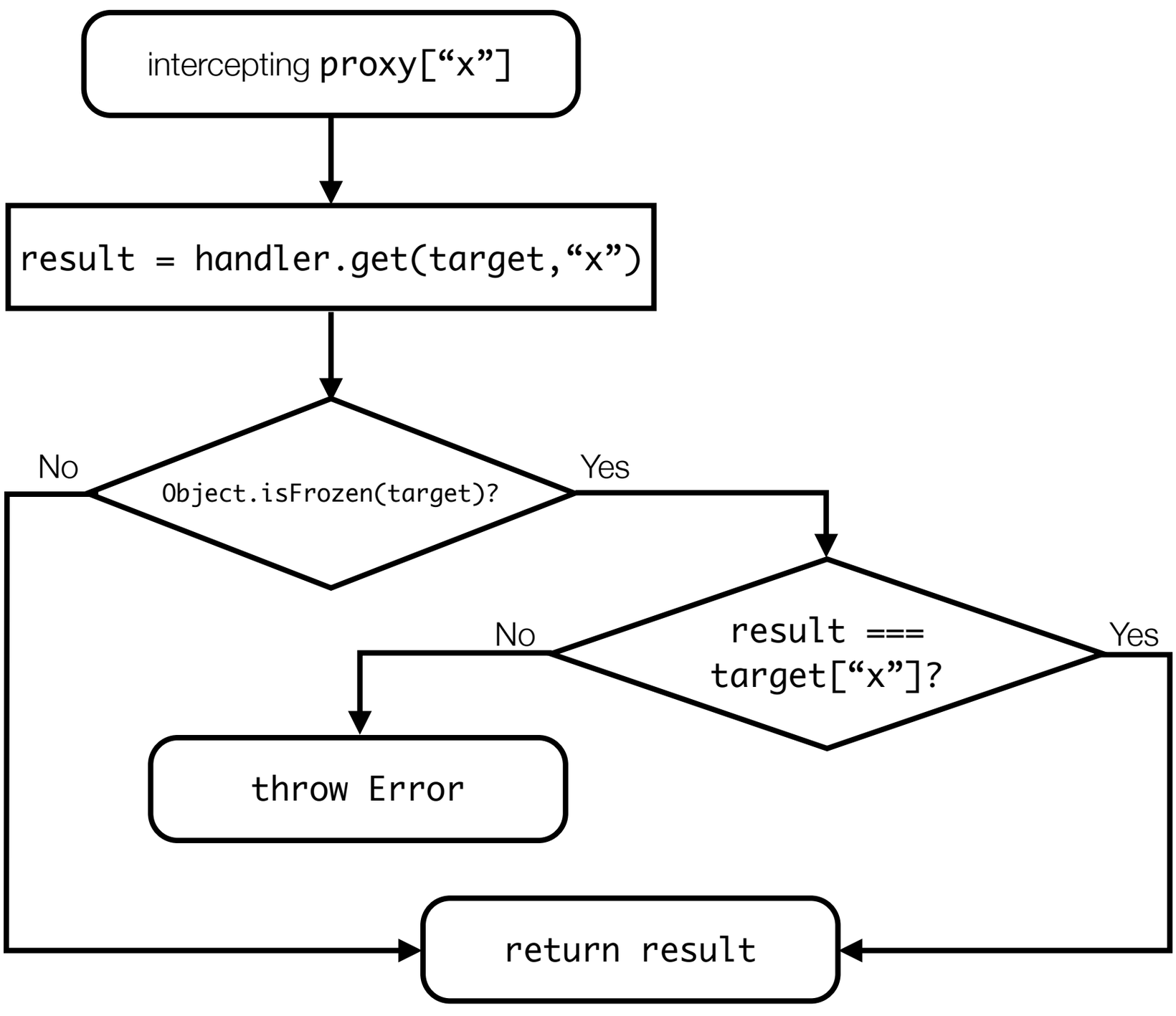
Direct proxies

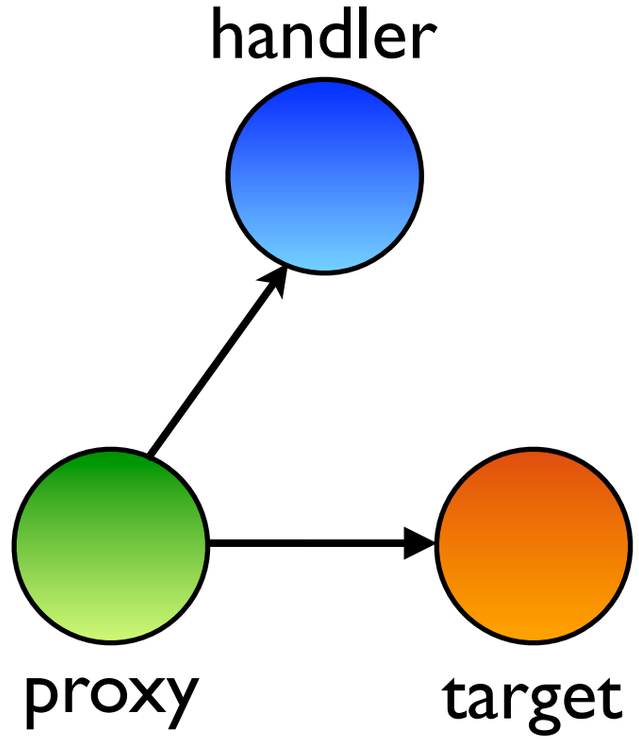
```
var point = { x: 0, y: 0 };
Object.freeze(point);

var {proxy,revoke} = makeRevocable(point);

Object.isFrozen(point) // true
Object.isFrozen(proxy) // true!
```

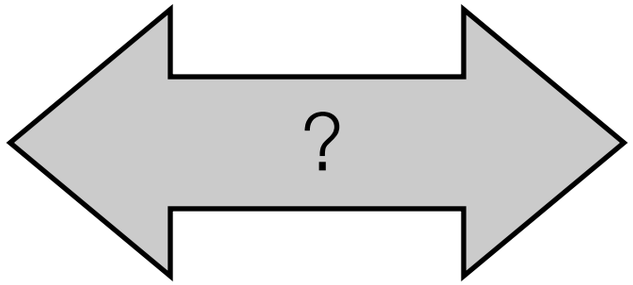
Proxies enforce invariants via runtime assertions



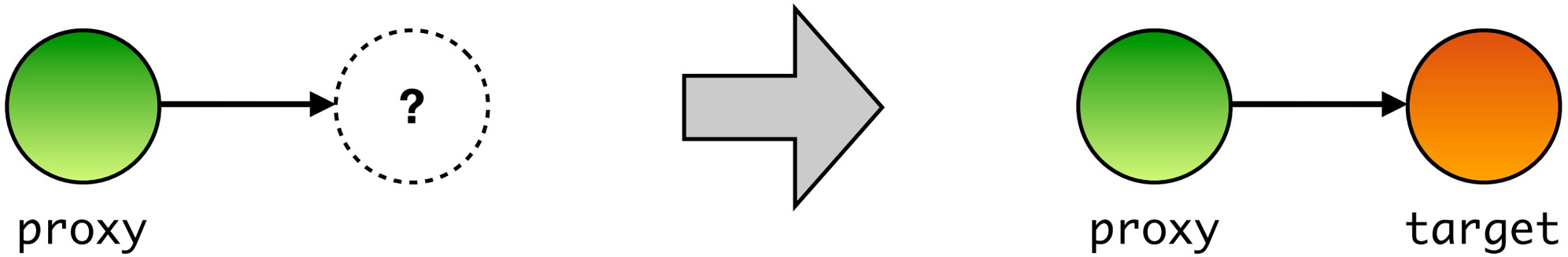


Summary: tradeoffs in language design

Powerful proxies



Strong language invariants



- No free lunch:
  - Direct proxies are more complicated (invariant checks)
  - The two Proxy APIs support dual use cases. But: having *both* virtual and direct proxies in the language further increases complexity.