Bringing Object-orientation to Security Programming

Mark S. Miller and the Cajadores

Google 

Overview: Bottom up by Layers

Composing Networks of Games

Smart Contracts as Games

Dimensions & Taxonomy of Electronic Rights

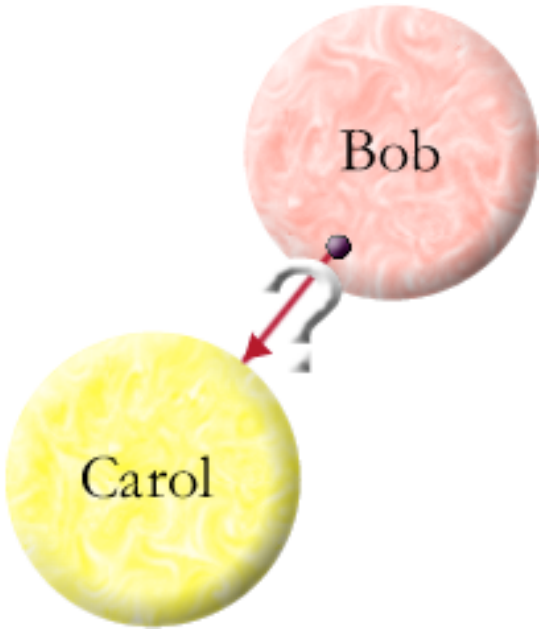
Patterns of Safe Cooperation

Access Abstractions and Compositions

Object-capabilities (ocaps)

Objects, References, Messages

How do I designate thee?

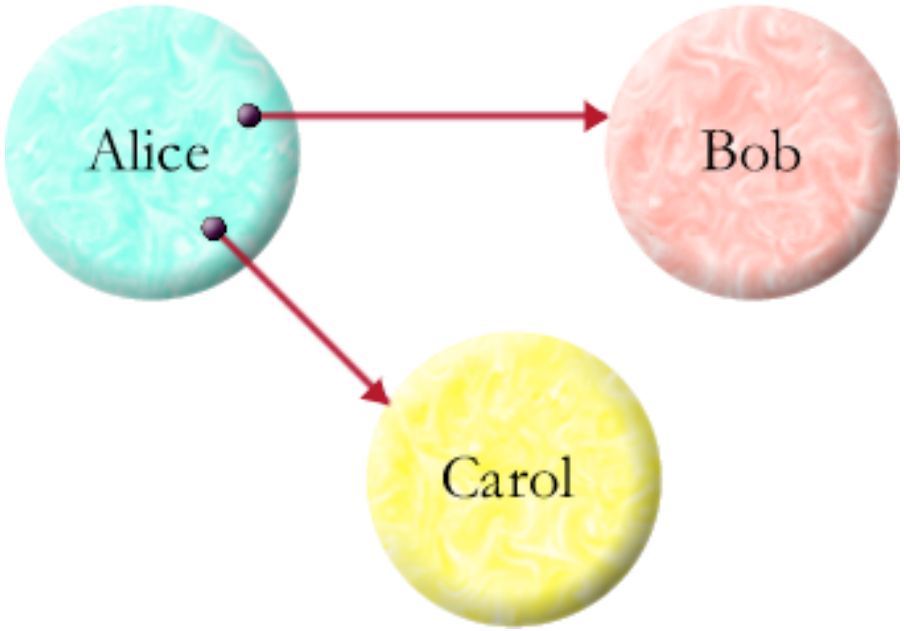


- by Introduction
  - ref to Carol
  - ref to Bob
  - decides to share
- by Parenthood
- by Endowment
- by Initial Conditions

How might object Bob come to know of object Carol?

How do I designate thee?

Alice says: bob.foo(carol)



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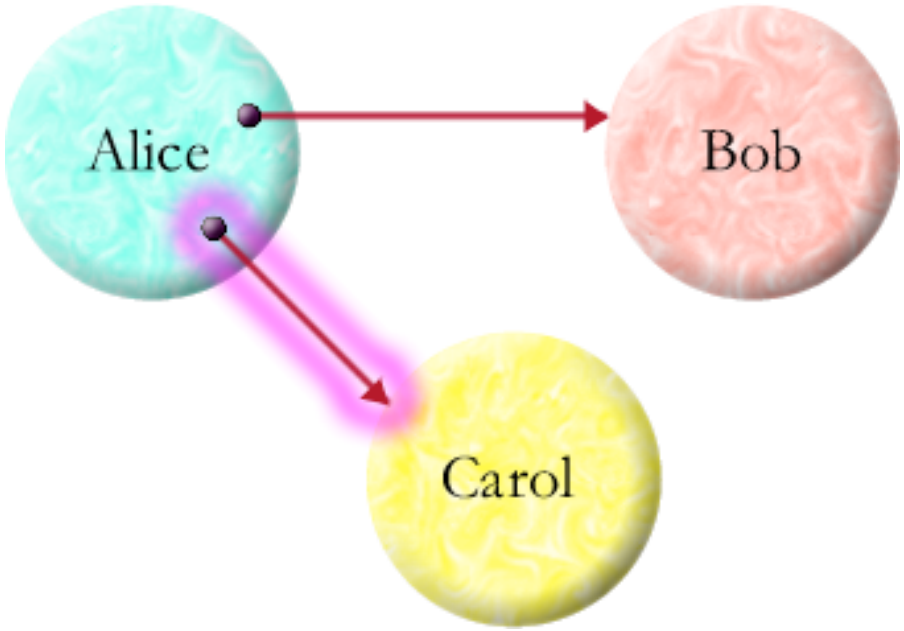

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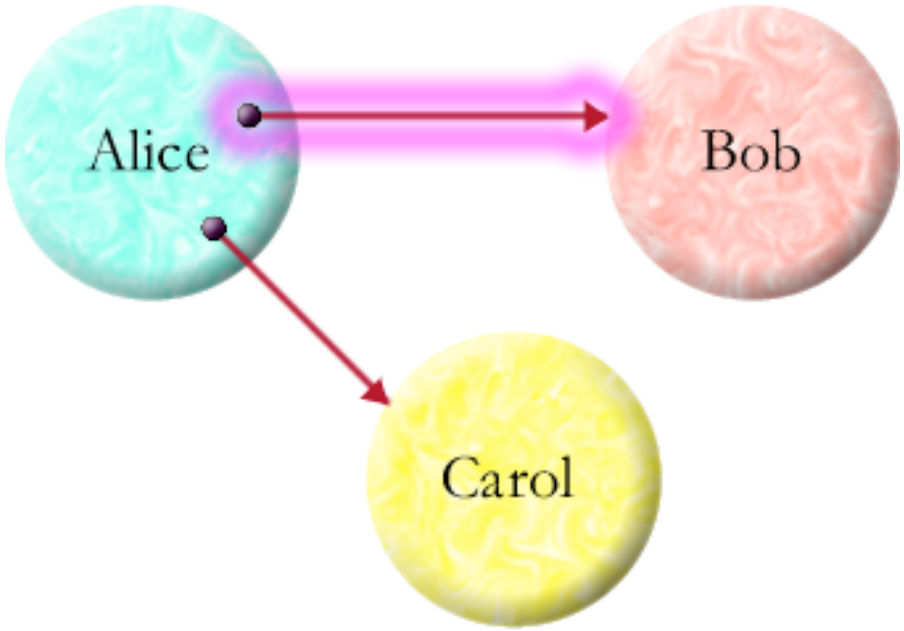

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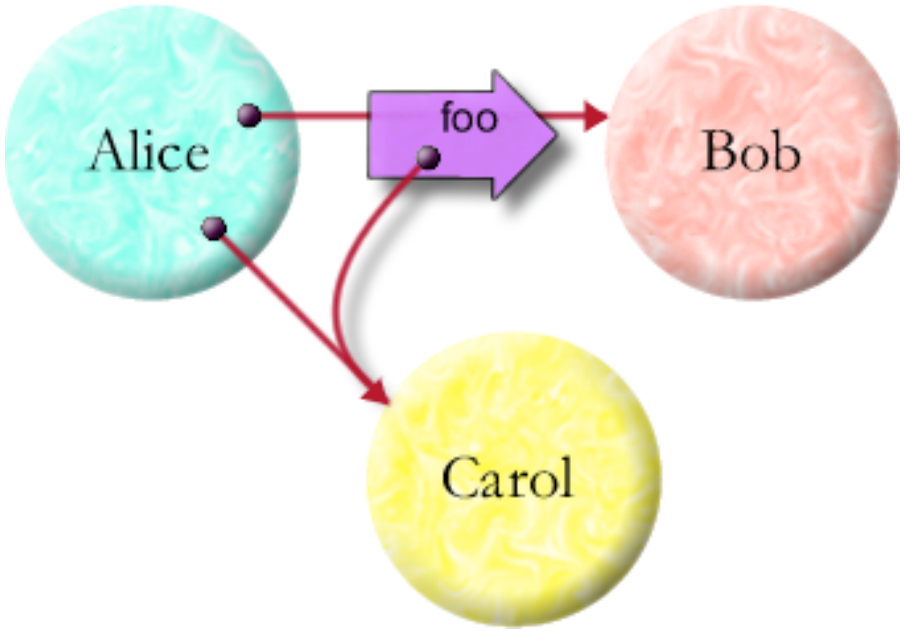


by Introduction

- *ref to Carol*
- *ref to Bob*
- ***decides to share***

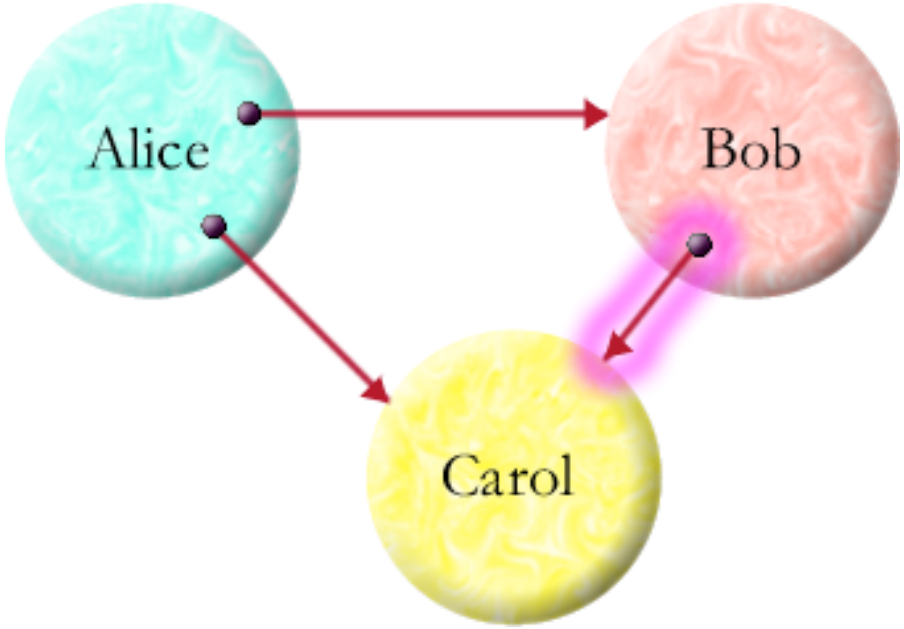
by Parenthood

by Endowment

by Initial Conditions

How do I designate thee?

Alice says: bob.foo(carol)



by Introduction

ref to Carol

ref to Bob

decides to share

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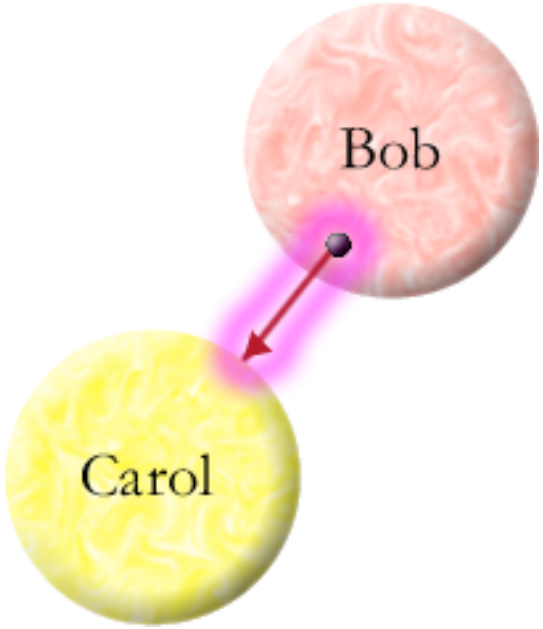
How do I designate thee?

Bob says: var *carol* = { ... };



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- ref to Bob
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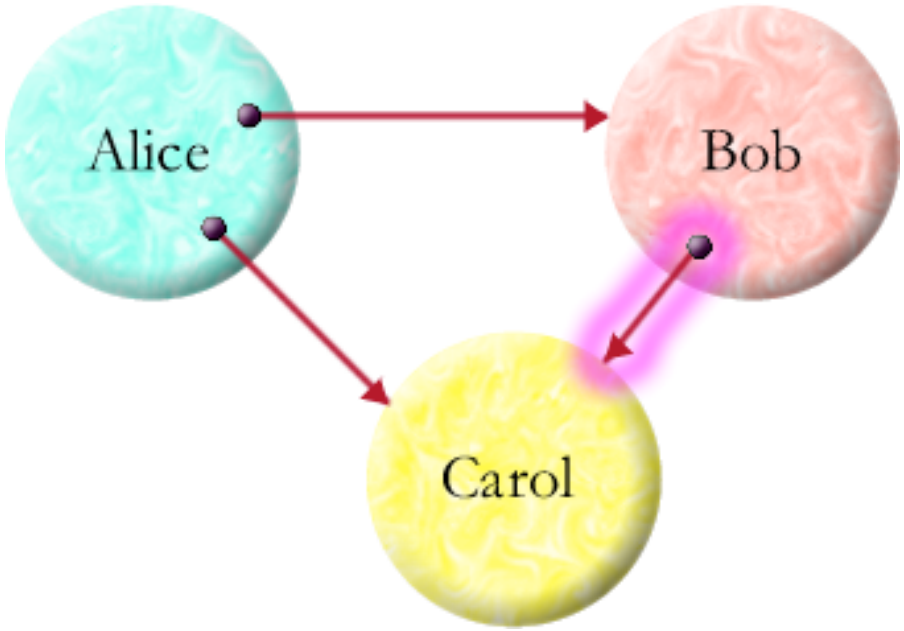
How do I designate thee?

Alice says: var *bob* = { ... carol ... };



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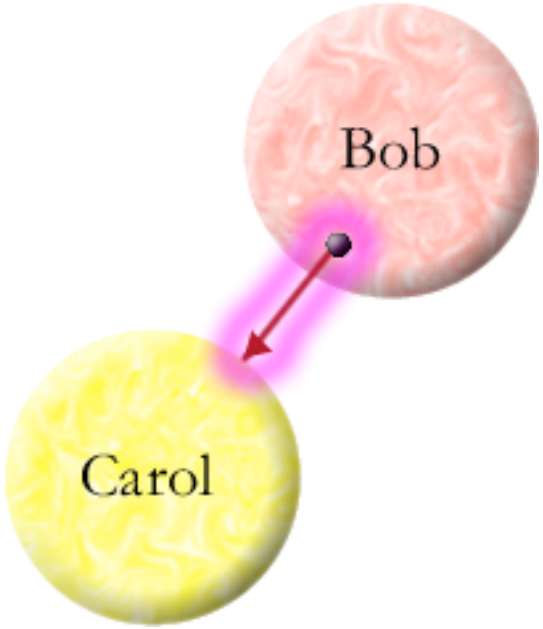
by Initial Conditions

How do I designate thee?

At t_0:



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OCaps: Small step from pure objects

Memory safety and encapsulation

\+ Effects ***only*** by using held references

\+ No powerful references by default

OCaps: Small step from pure objects

Memory safety and encapsulation

\+ Effects ***only*** by using held references

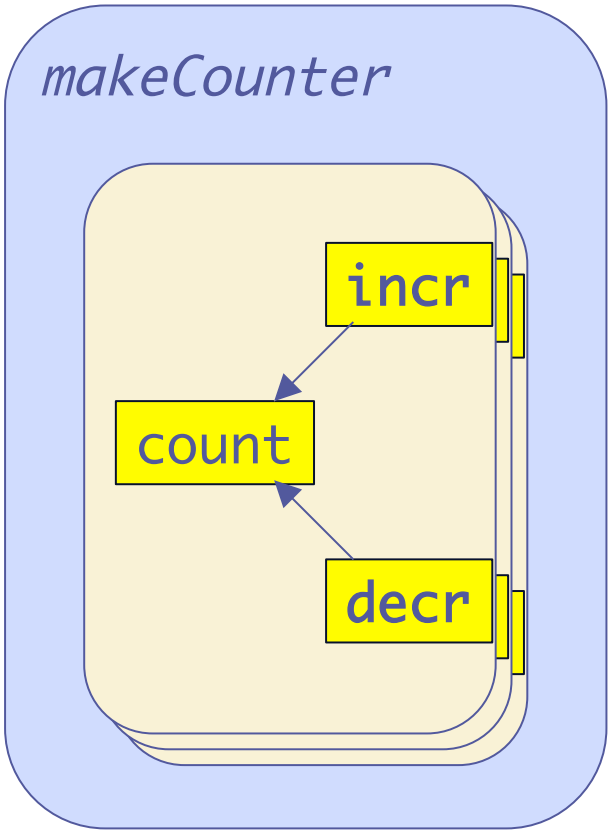
\+ No powerful references by default

Reference graph ≡ Access graph

Only connectivity begets connectivity

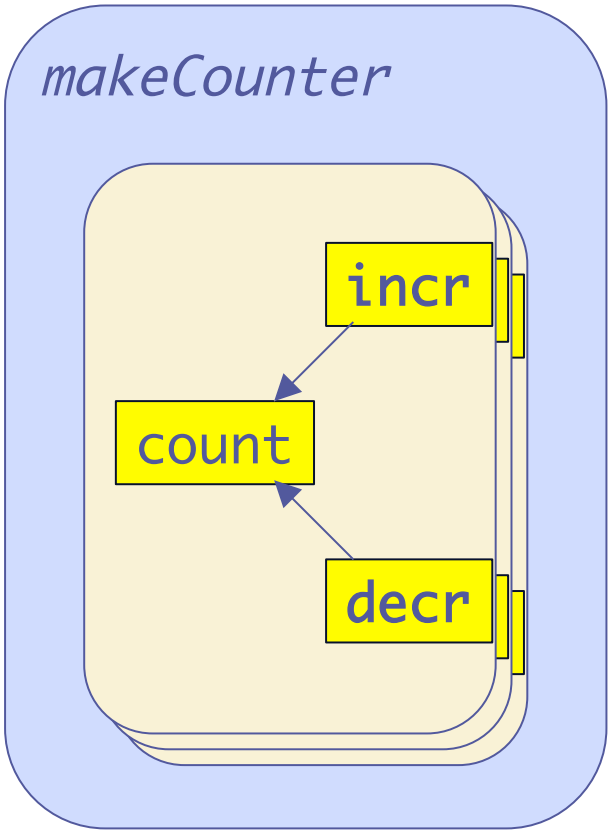
OO expressiveness for security patterns

Objects as Closures




```
function makeCounter() {
    var count = 0;
    return {
        incr: function() { return ++count; },
        decr: function() { return --count; }
    };
}
```

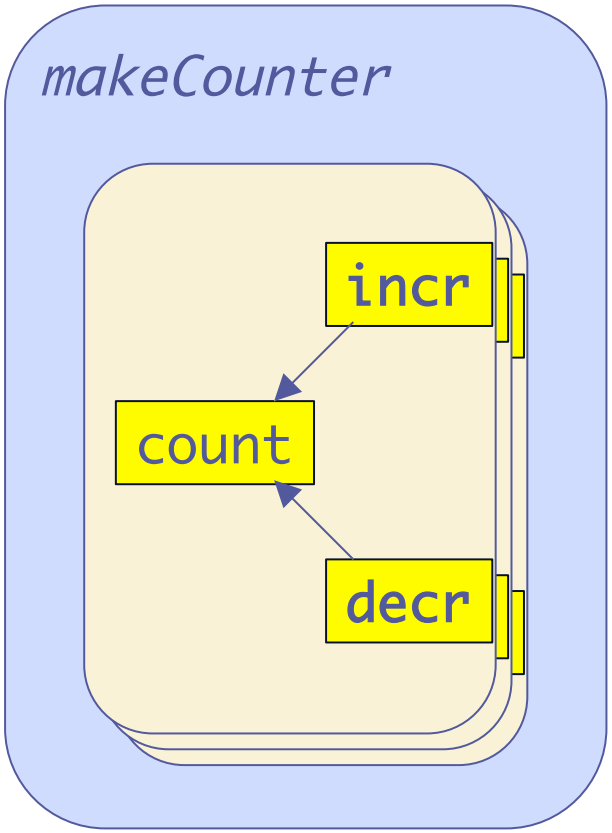
Objects as Closures




```
function makeCounter() {
    var count = 0;
    return {
        incr: function() { return ++count; },
        decr: function() { return --count; }
    };
}
```

A *record* of *closures* hiding *state*
is a fine representation of an
object of *methods* hiding *instance vars*

Objects as Closures in SES on ES5




```
"use strict";
function makeCounter() {
    var count = 0;
    return def({
        incr: function() { return ++count; },
        decr: function() { return --count; }
    });
}
```

A *tamper-proof* record of *lexical* closures *encapsulating* state is a *defensive* object

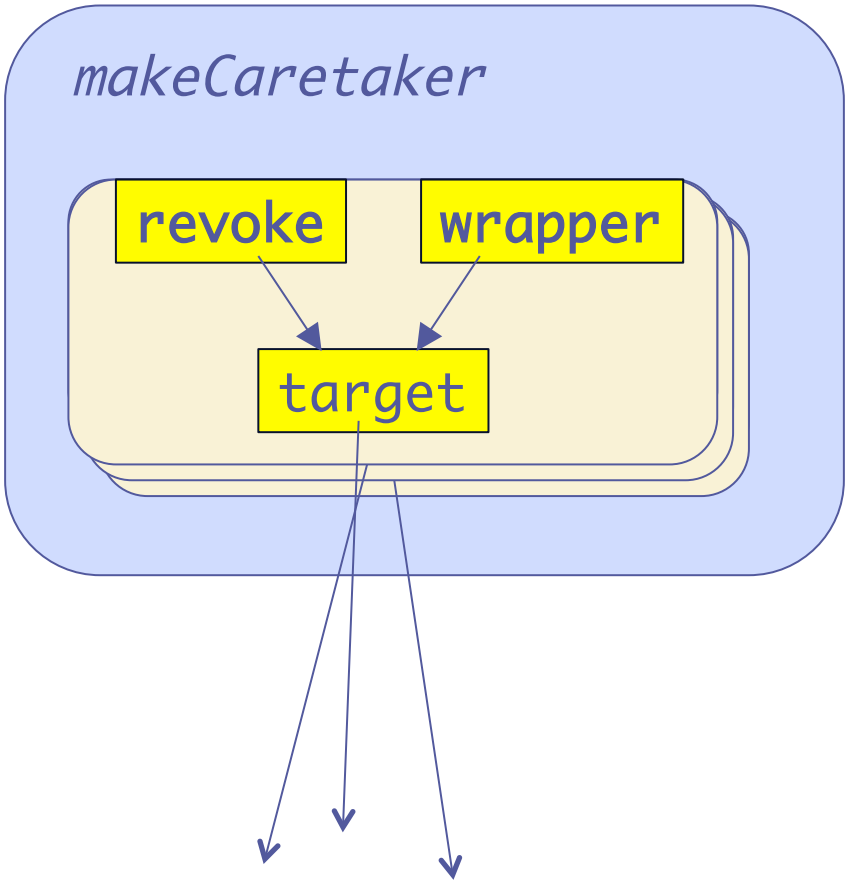
Turning EcmaScript 5 into SES

```
<script src="initSES.js"></script>
```

Monkey patch away bad non-std behaviors
Remove non-whitelisted primordials
Install leaky WeakMap emulation
Make virtual global root
Freeze whitelisted global variables

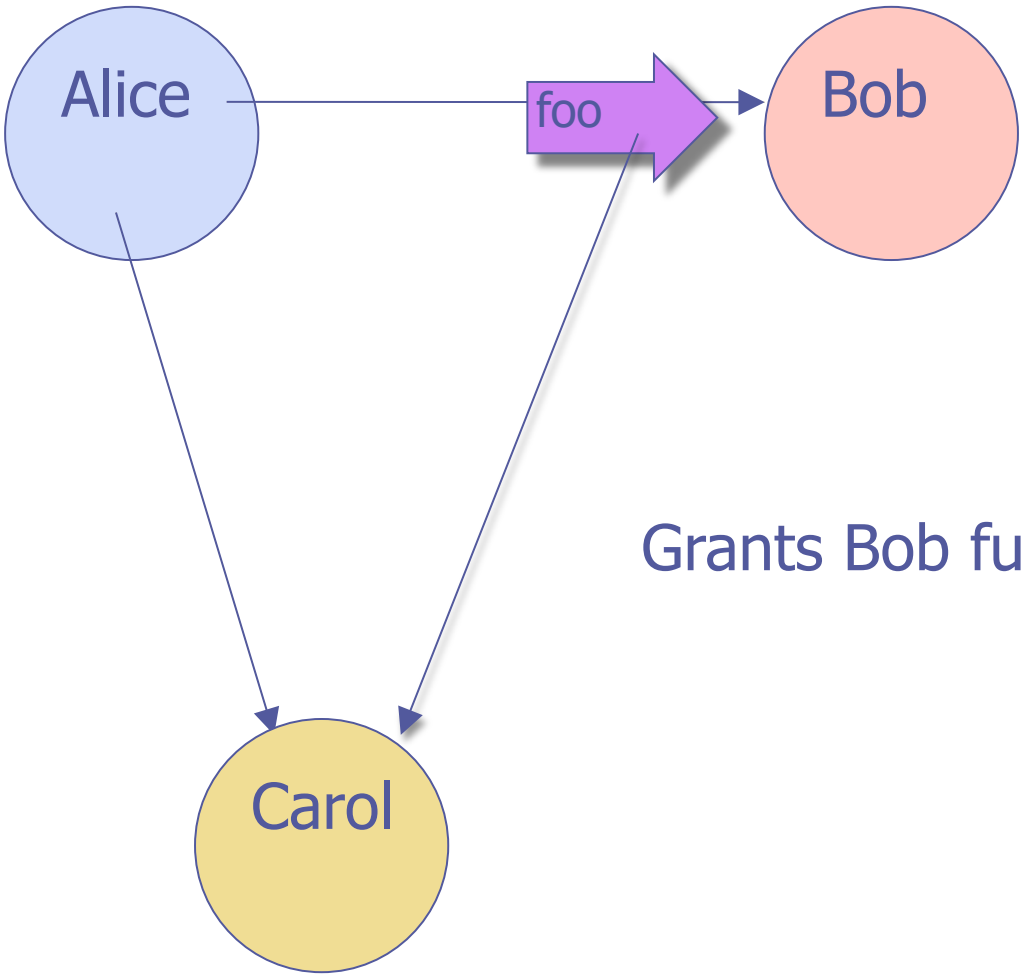
- Replace **eval** & Function with safe alternatives
  Freeze accessible primordials

Revocable Function Forwarder




```
function makeFnCaretaker(target) {
    return def({
        wrapper: function(…args) {
            return target(…args);
        },
        revoke: function() { target = null; }
    });
}
```

Unconditional Access

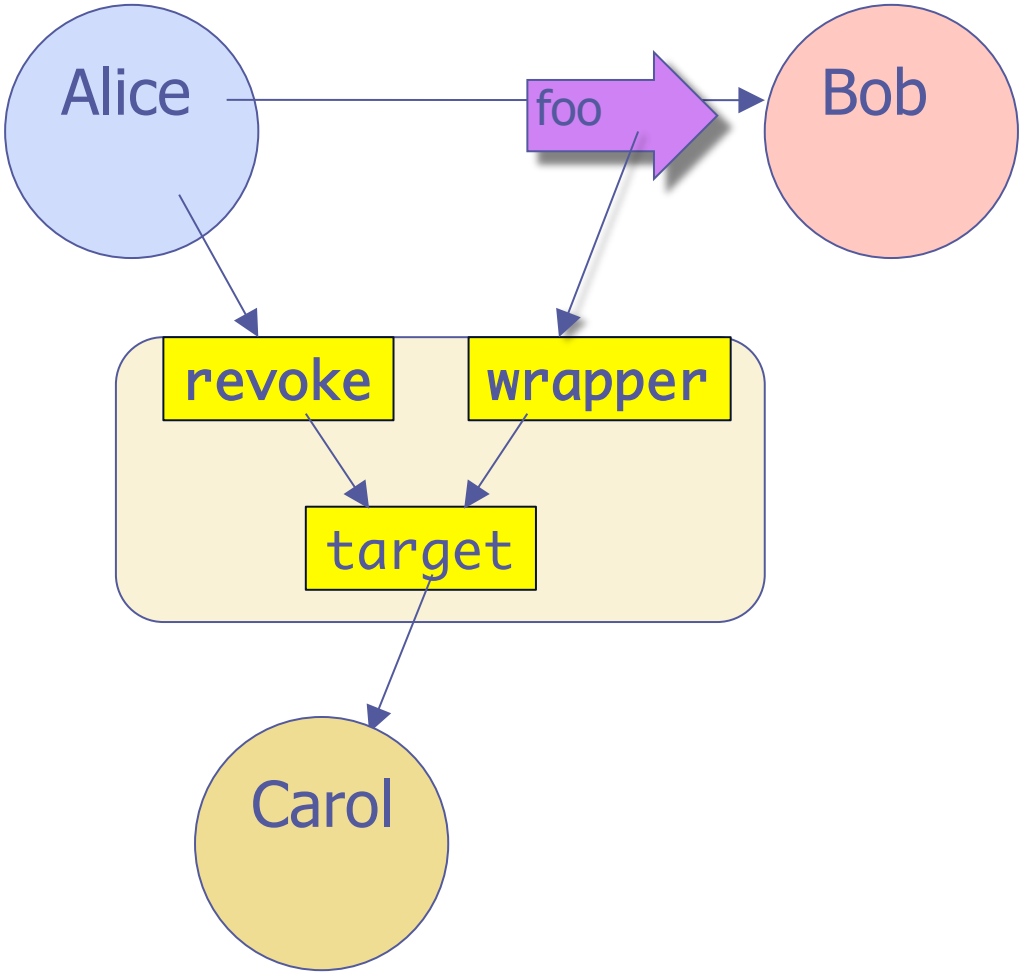


Alice says:

bob.foo(carol);

Grants Bob full access to Carol forever

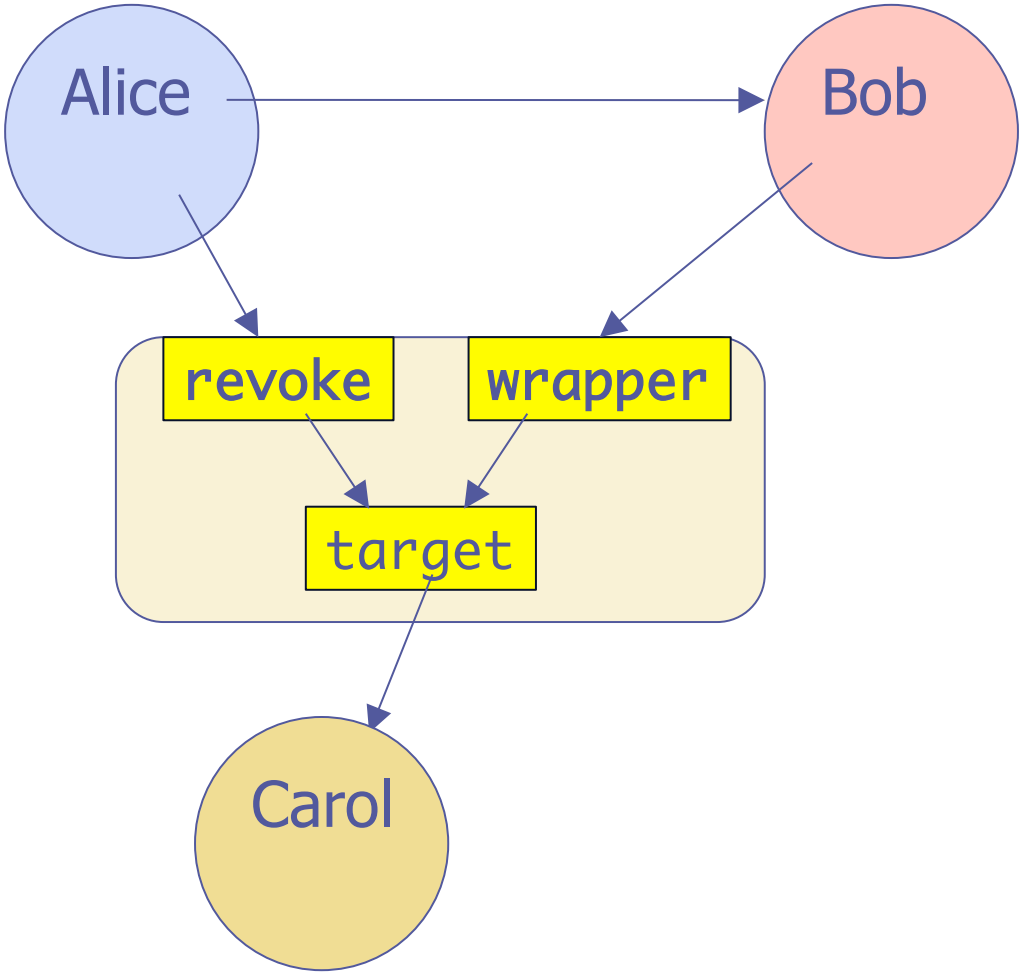
Revocability ≡ Temporal attenuation



Alice says:

```
var ct = makeCaretaker(carol);
bob.foo(ct.wrapper);
```

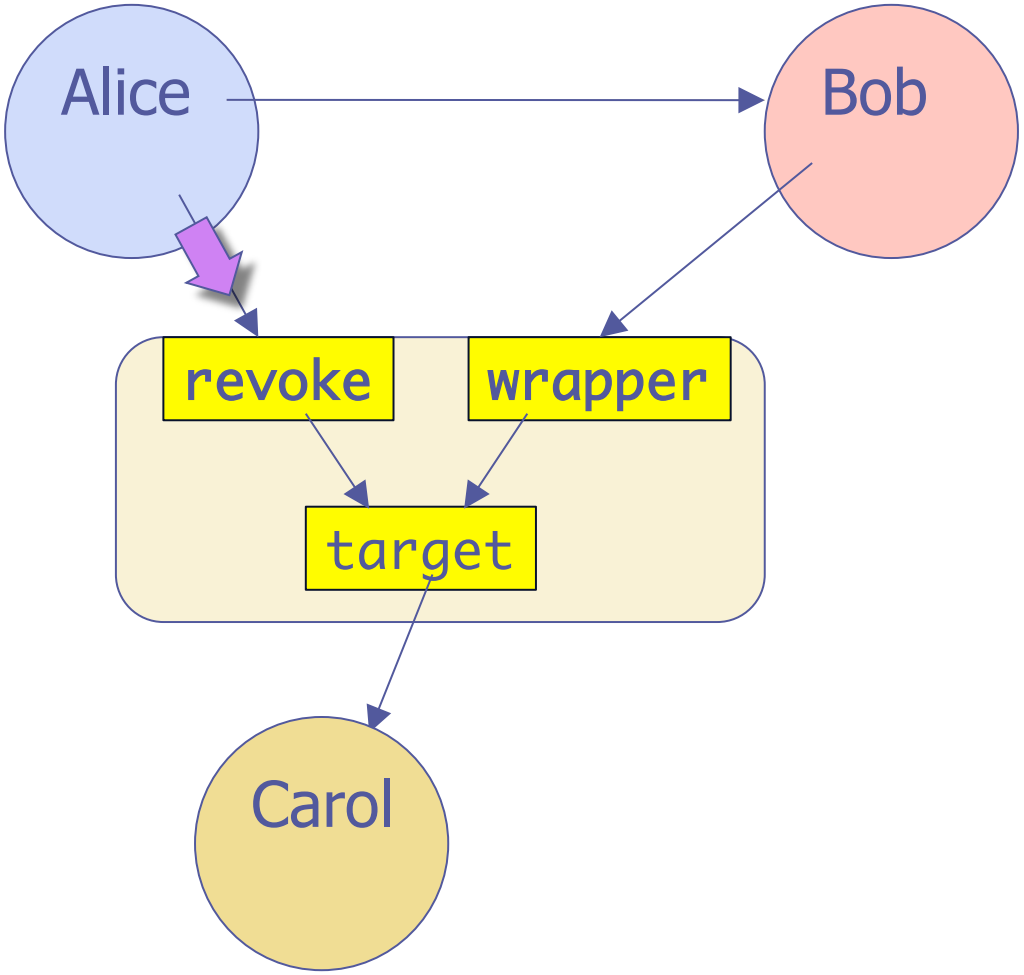
Revocability ≡ Temporal attenuation



Alice says:

```
var ct = makeCaretaker(carol);
bob.foo(ct.wrapper);
//…
```

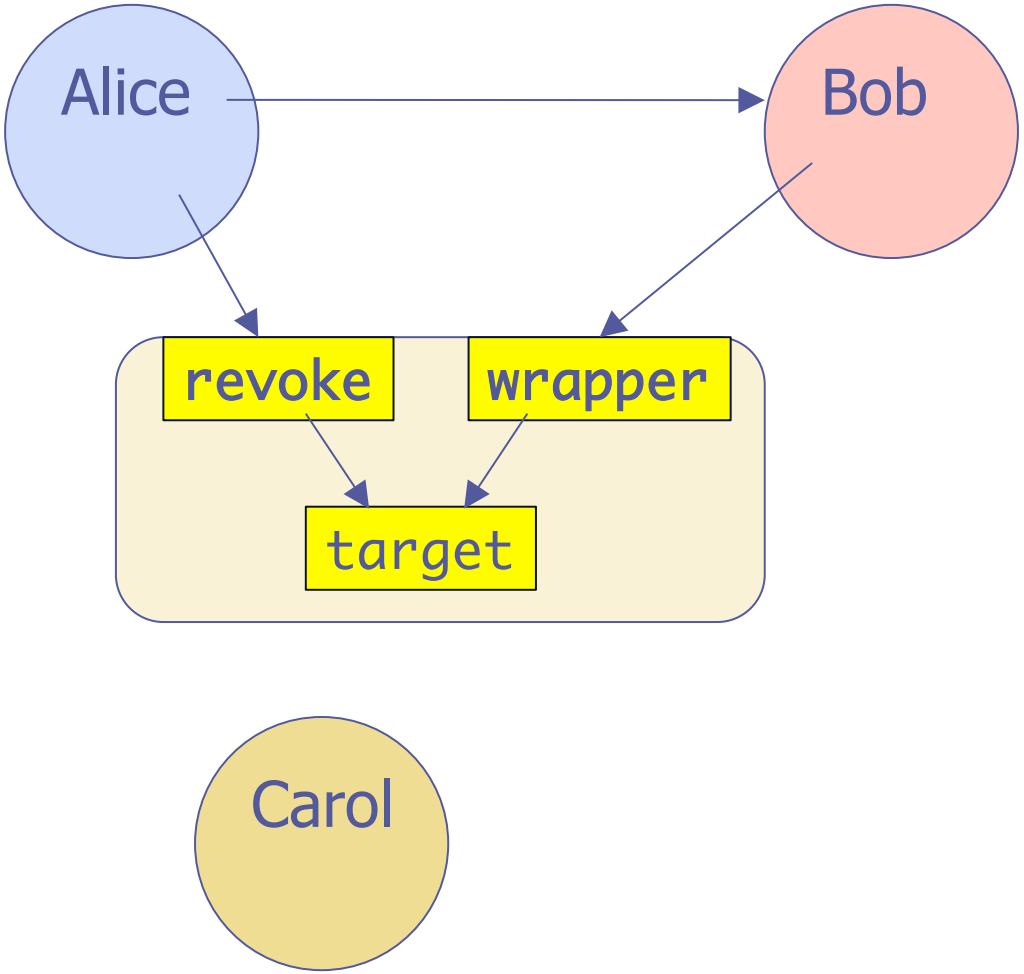
Revocability ≡ Temporal attenuation



Alice says:

```
var ct = makeCaretaker(carol);
bob.foo(ct.wrapper);
//…
ct.revoke();
```

Revocability ≡ Temporal attenuation



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```
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```
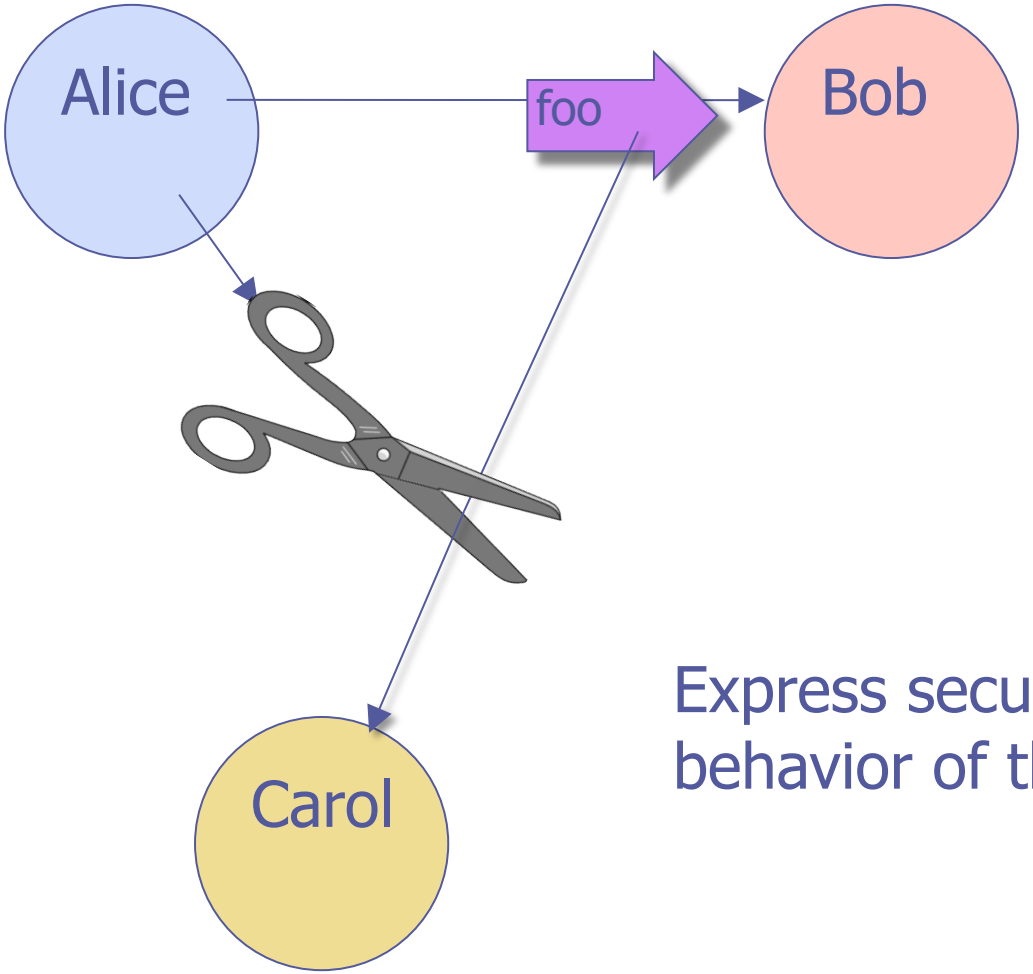

Attenuators ≡ Access Abstractions



Alice says:

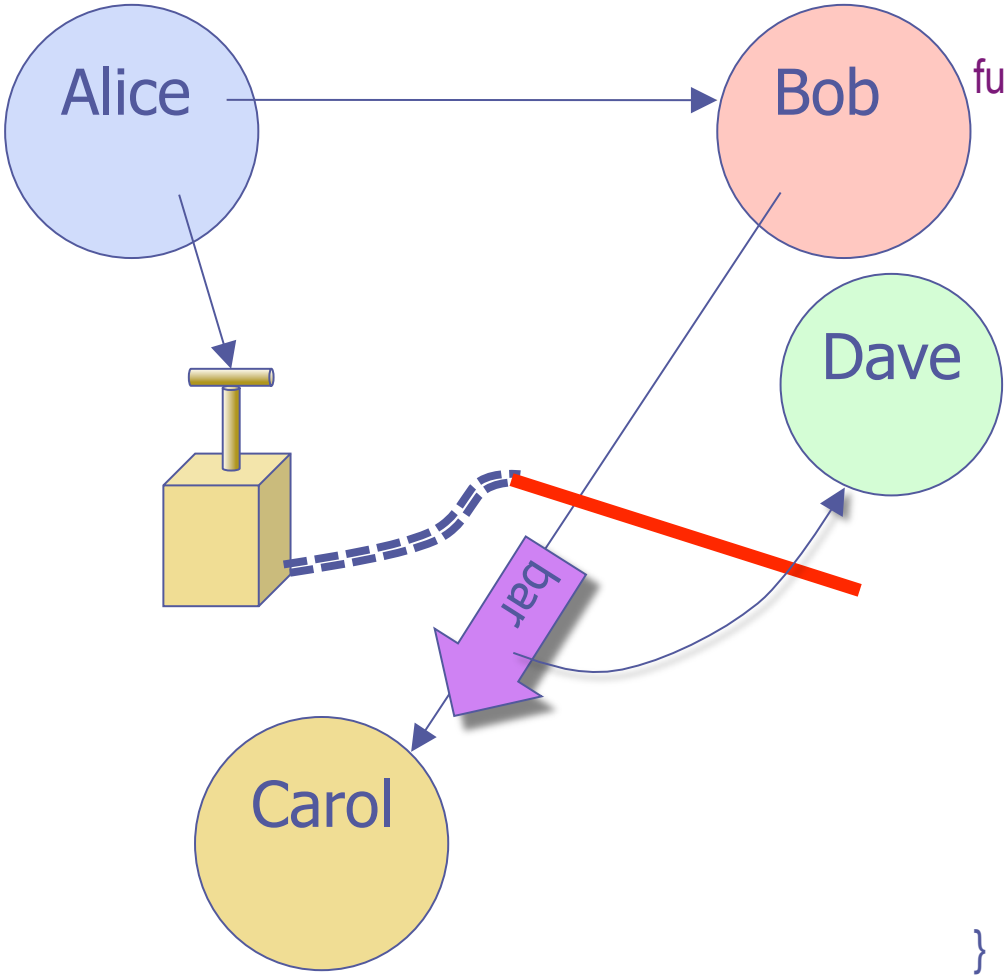
```
var ct = makeCaretaker(carol);
bob.foo(ct.wrapper);
```

Express security policy by the behavior of the objects you provide

Abstractions extend vocabulary

Primitives	**Abstraction Forms**	**Extended Vocabulary**
+, ., []	*procedural abstraction*	foo(bar, baz), …
int, struct, array	*data abstraction*	Point, Window, …
if, while, switch	*control abstraction*	addListener, visitor, …
points-to	*access abstraction*	caretaker, membrane, …

Membranes: Transitive Interposition

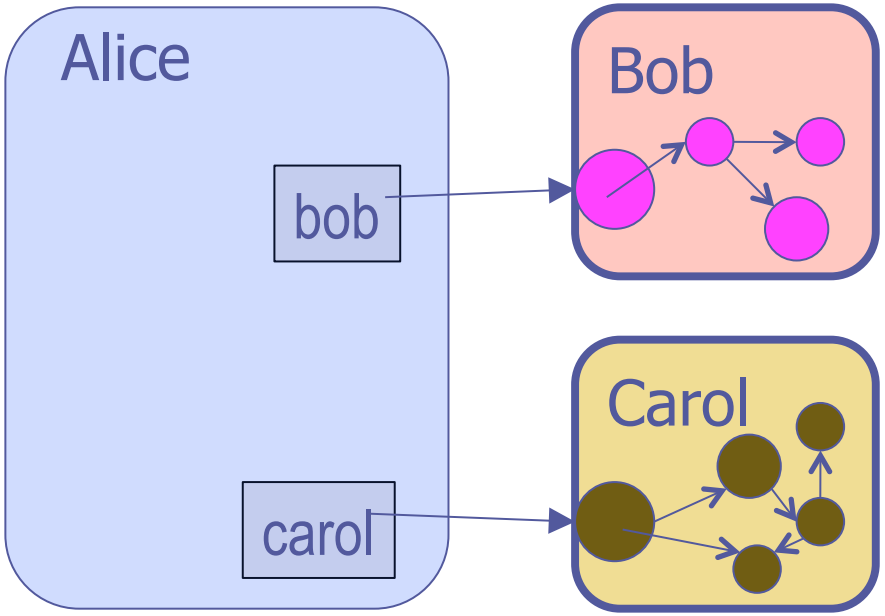



```
function makeFnMembrane(target) {
    var enabled = true;
    function wrap(wrapped) {
        if (wrapped !== Object(wrapped)) {
            return wrapped;
        }
        return function(…args) {
            if (!enabled) { throw new Error("revoked"); }
            return wrap(wrapped(…args.map(wrap));
    } }
    return def({
        wrapper: wrap(target),
        revoke: function() { enabled = false; }
    });
}
```

Attenuators Compose

```
function makeROFile(file) {
    return def({
        read: file.read,
        getLength: file.getLength
    });
}
var rorFile = makeROFile(revocableFile);
```

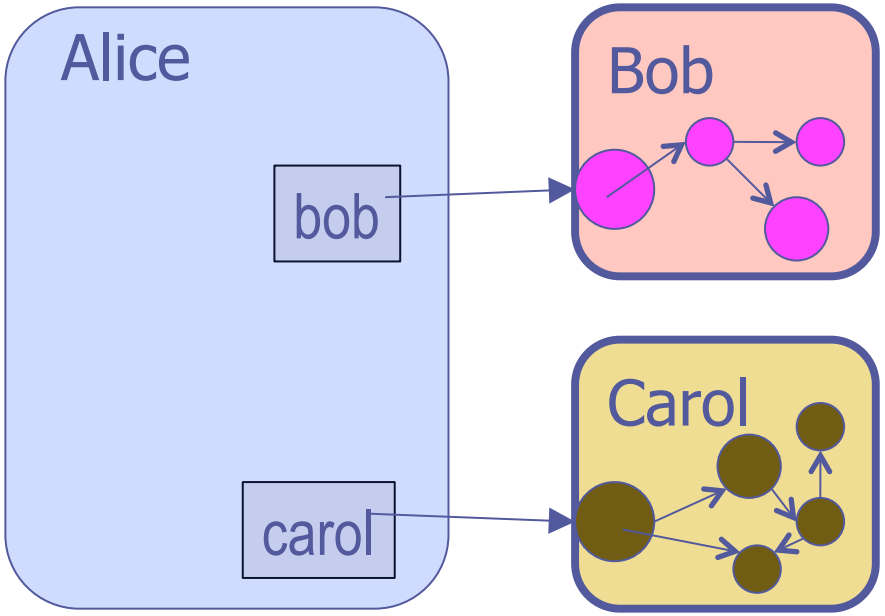
No powerful references by default



Alice says:

```
var bobSrc = //site B
var carolSrc = //site C
var bob = eval(bobSrc);
var carol = eval(carolSrc);
```

No powerful references by default



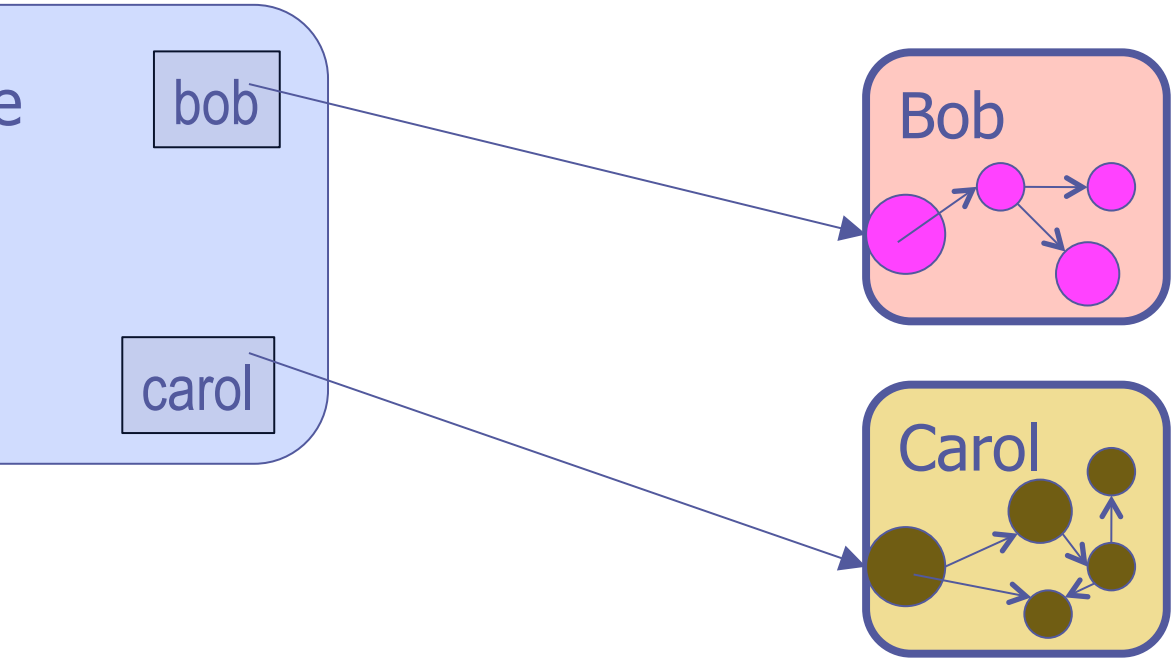
Alice says:

```
var bobSrc = //site B
var carolSrc = //site C
var bob = eval(bobSrc);
var carol = eval(carolSrc);
```

Bob and Carol are ***confined***.

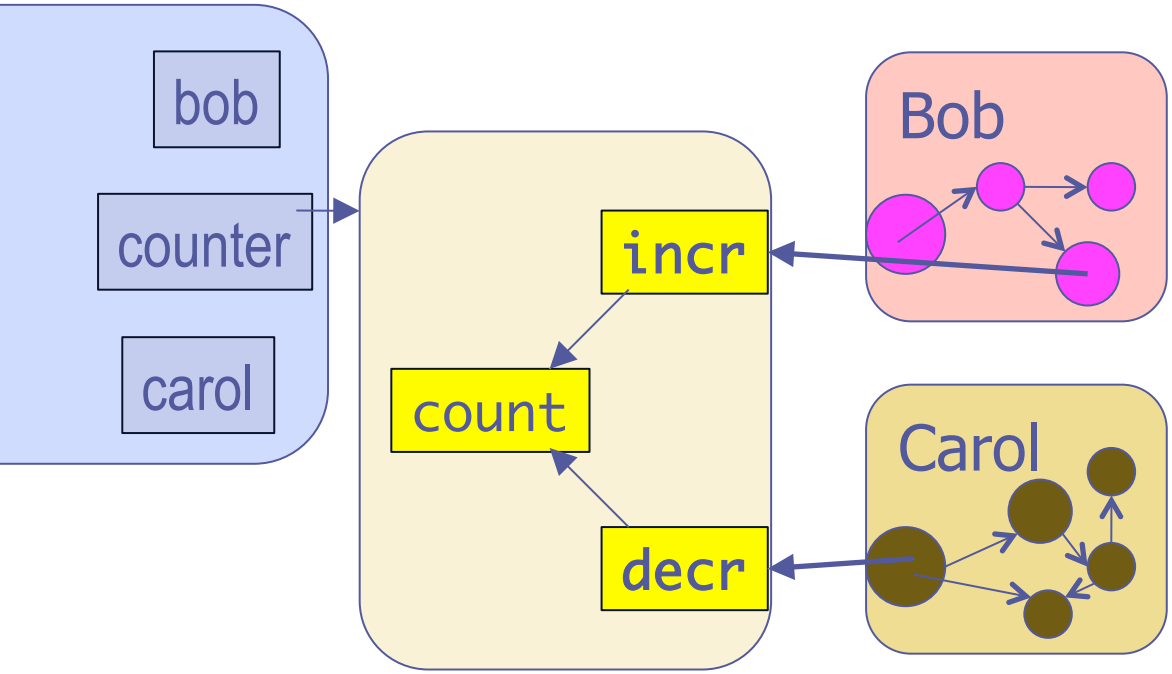
Only Alice controls how they can interact or get more connected.

No powerful references by default



Alice says:

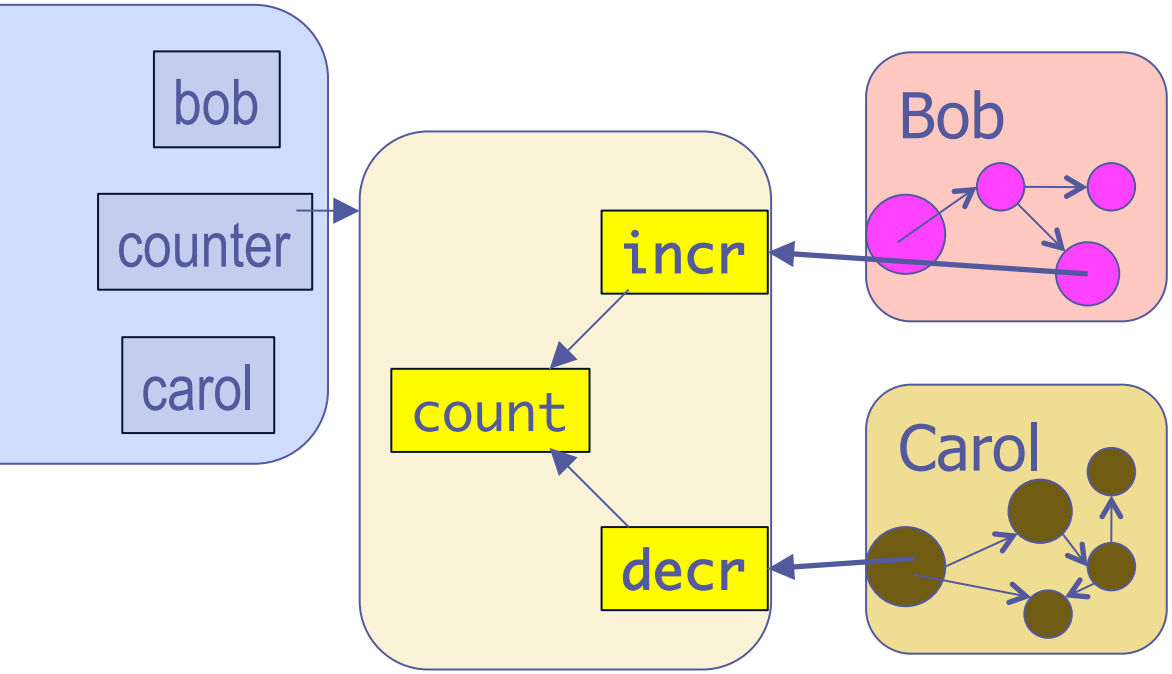
Only connectivity begets connectivity



Alice says:

```
var counter = makeCounter();
bob(counter.incr);
carol(counter.decr);
bob = carol = null;
```

Only connectivity begets connectivity



Alice says:

```
var counter = makeCounter();
bob(counter.incr);
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bob = carol = null;
```
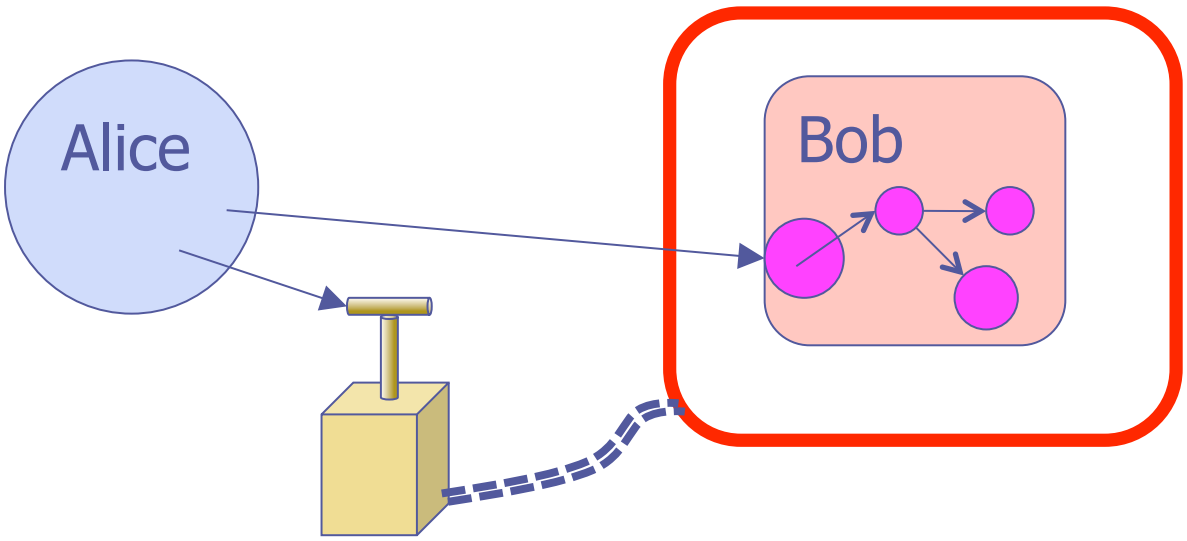

Bob can only count up and see result. Carol only down.

Alice can only do both.

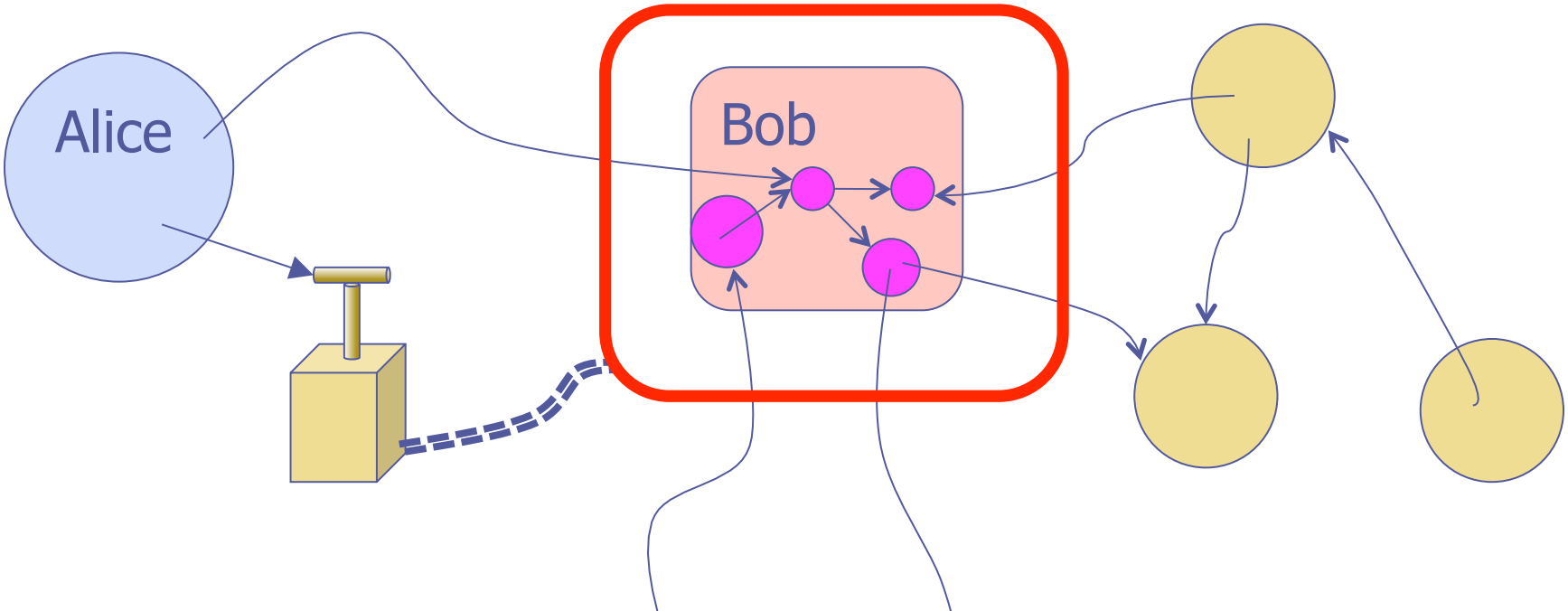
Membrane eval → compartment

var *compartment* = makeMembrane(eval);
var *vbob* = compartment.wrapper(bobSrc);



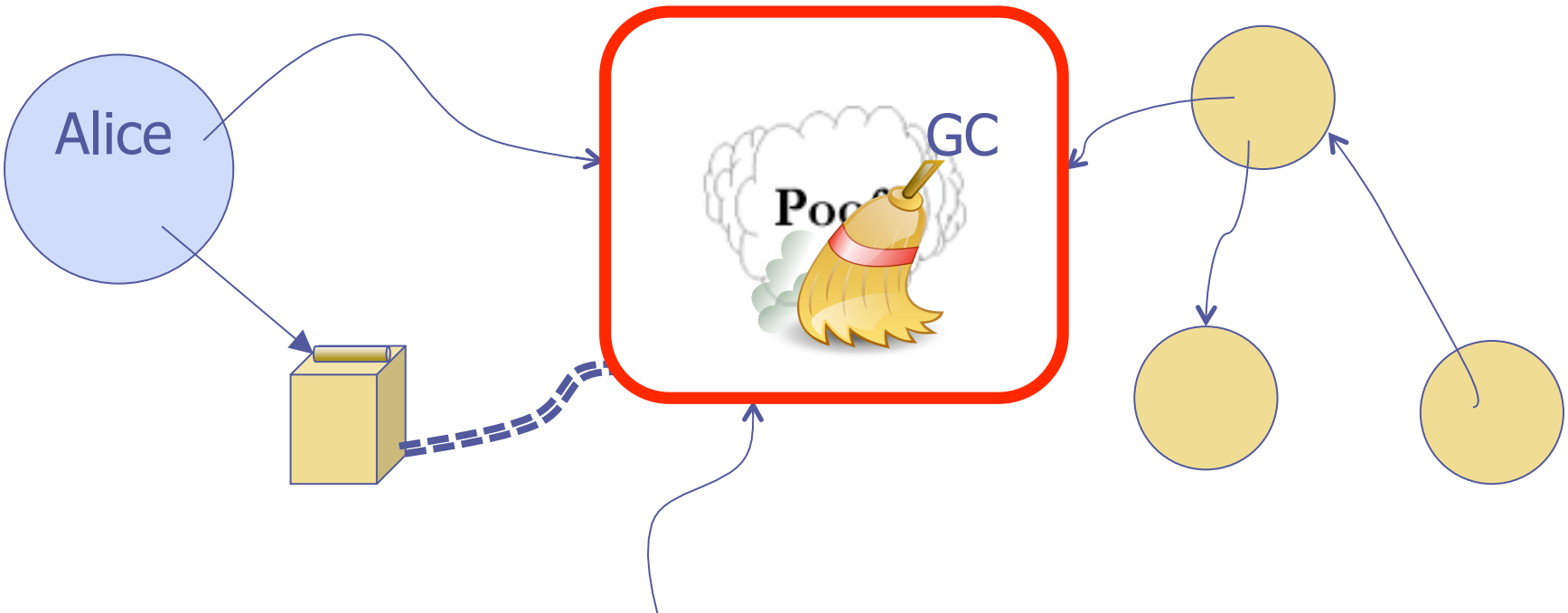
Membrane eval → compartment

```
var compartment = makeMembrane(eval);
var vbob = compartment.wrapper(bobSrc);
//...
```

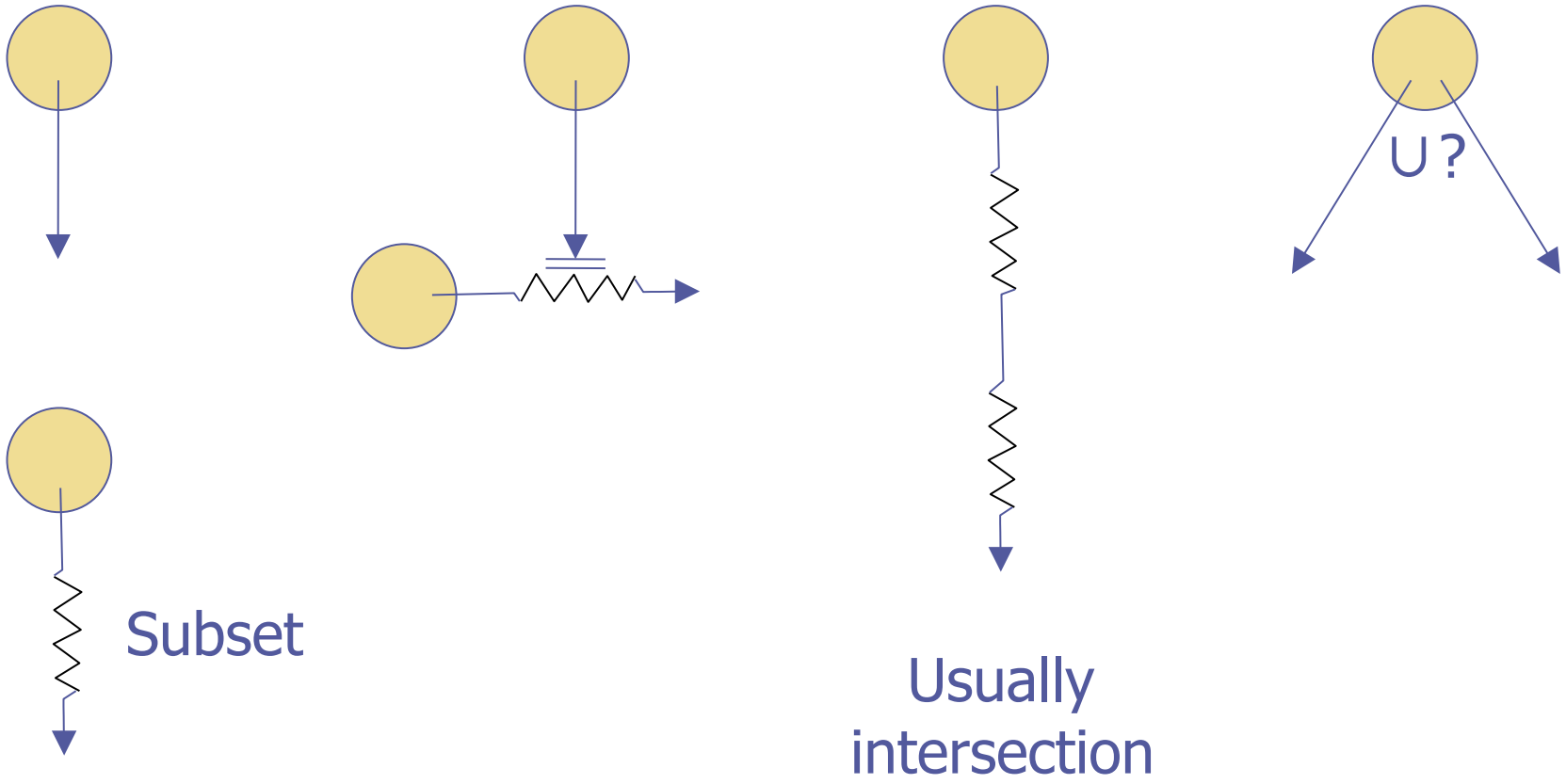


Membrane eval → compartment

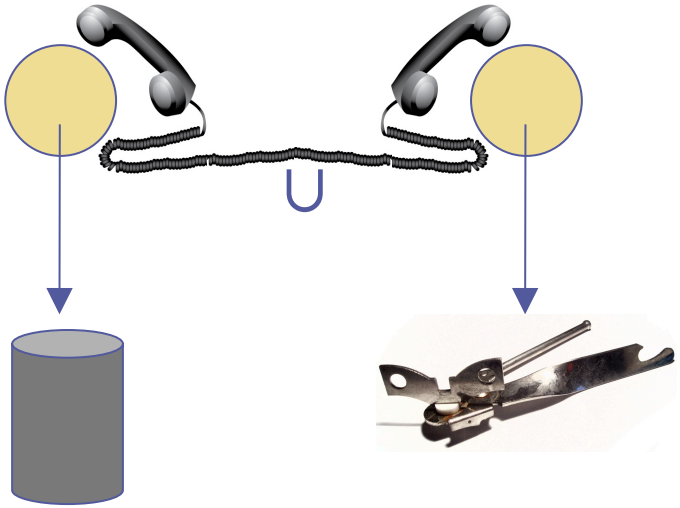
```
var compartment = makeMembrane(eval);
var vbob = compartment.wrapper(bobSrc);
//…
compartment.revoke();
```

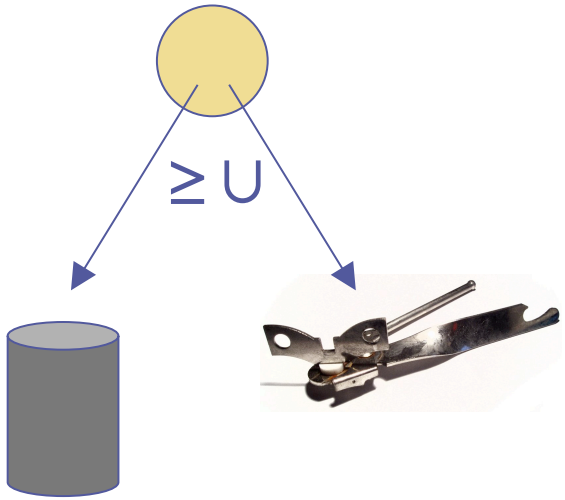


Composing Authority



Rights Amplification

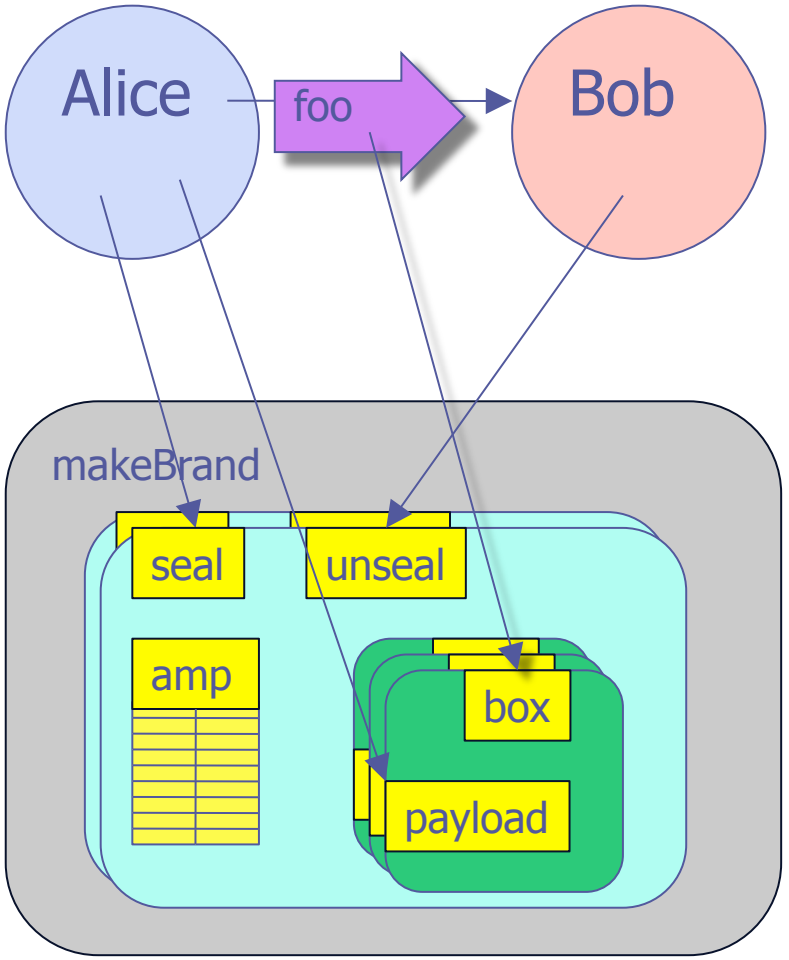




Authority conditional on other possessions.

Enables more expressive power.

Rights Amplification




```
function makeBrand() {
    var amp = WeakMap();
    return def({
        seal: function(payload) {
            var box = def({});
            amp.set(box, payload);
            return box;
        },
        unseal: function(box) {
            return amp.get(box);
        }
    });
}
```

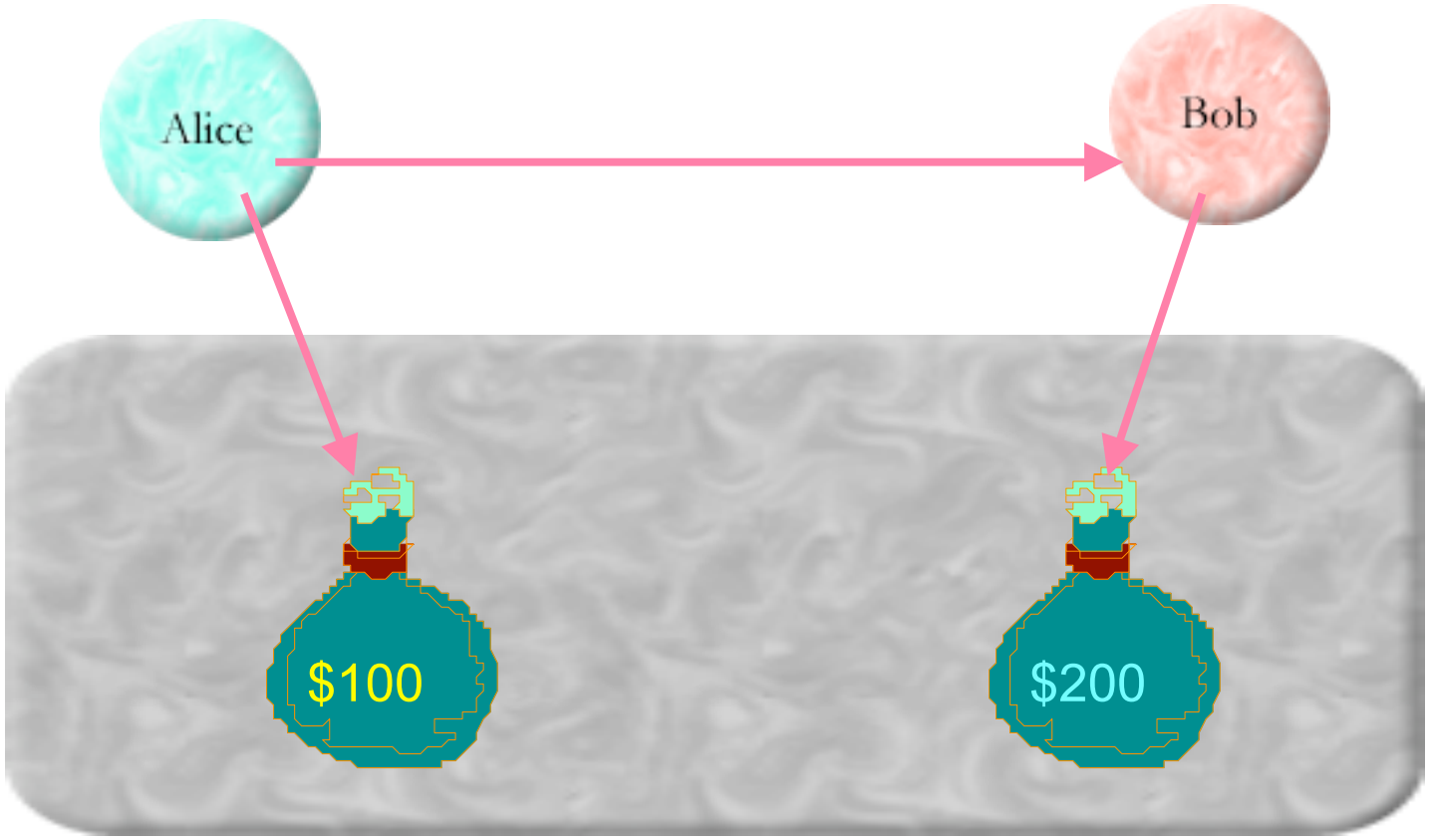
Rights Amplification

Crypto patterns without crypto

makeBrand()	generate key pair
seal method	encryption key
unseal method	decryption key
payload	plaintext
box	cyphertext

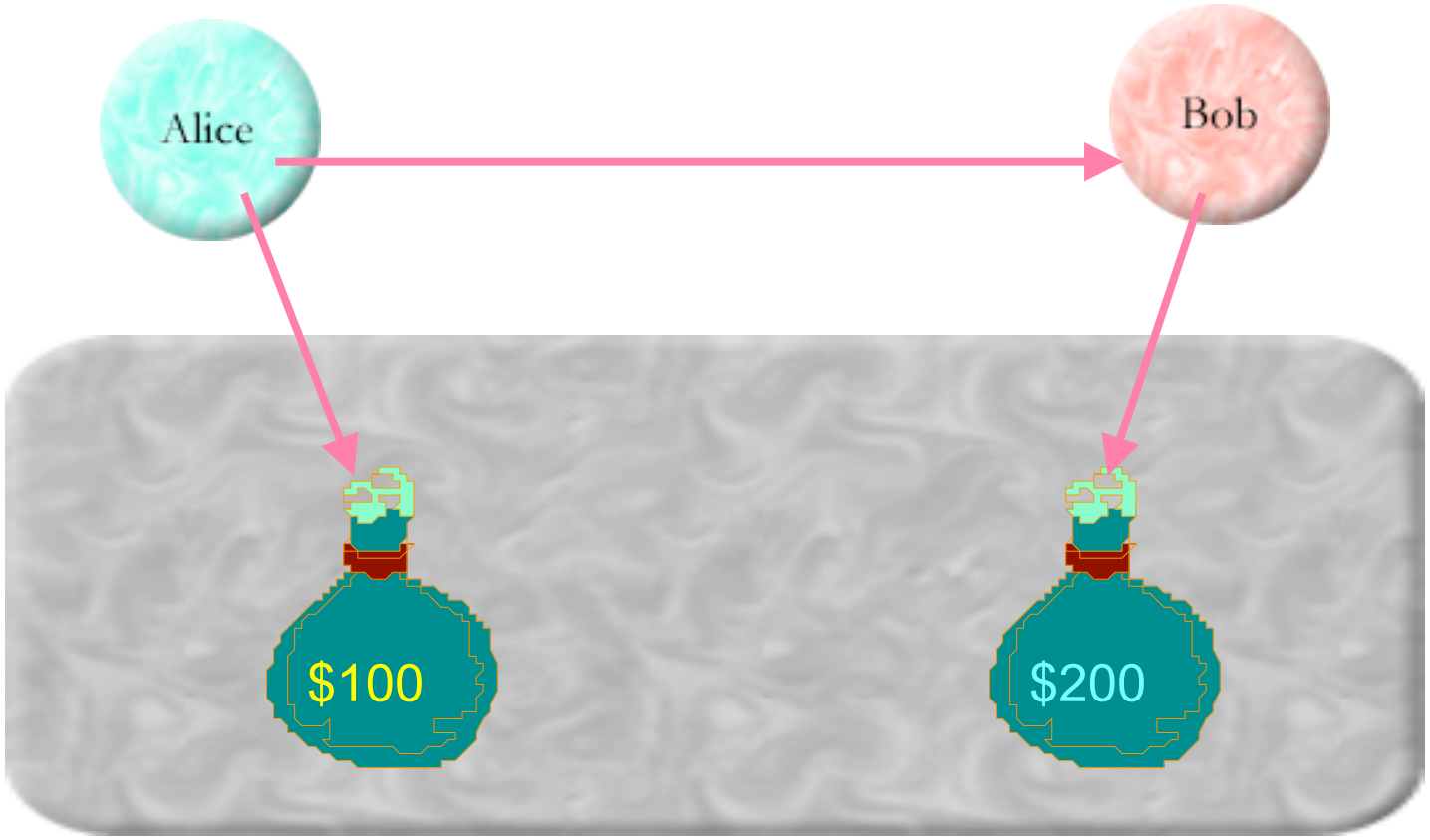
```
function makeBrand() {
    var amp = WeakMap();
    return def({
        seal: function(payload) {
            var box = def({});
            amp.set(box, payload);
            return box;
        },
        unseal: function(box) {
            return amp.get(box);
        }
    });
}
```

Distributed Secure Currency



Distributed Secure Currency

var *paymentP* = myPurse ! makePurse();



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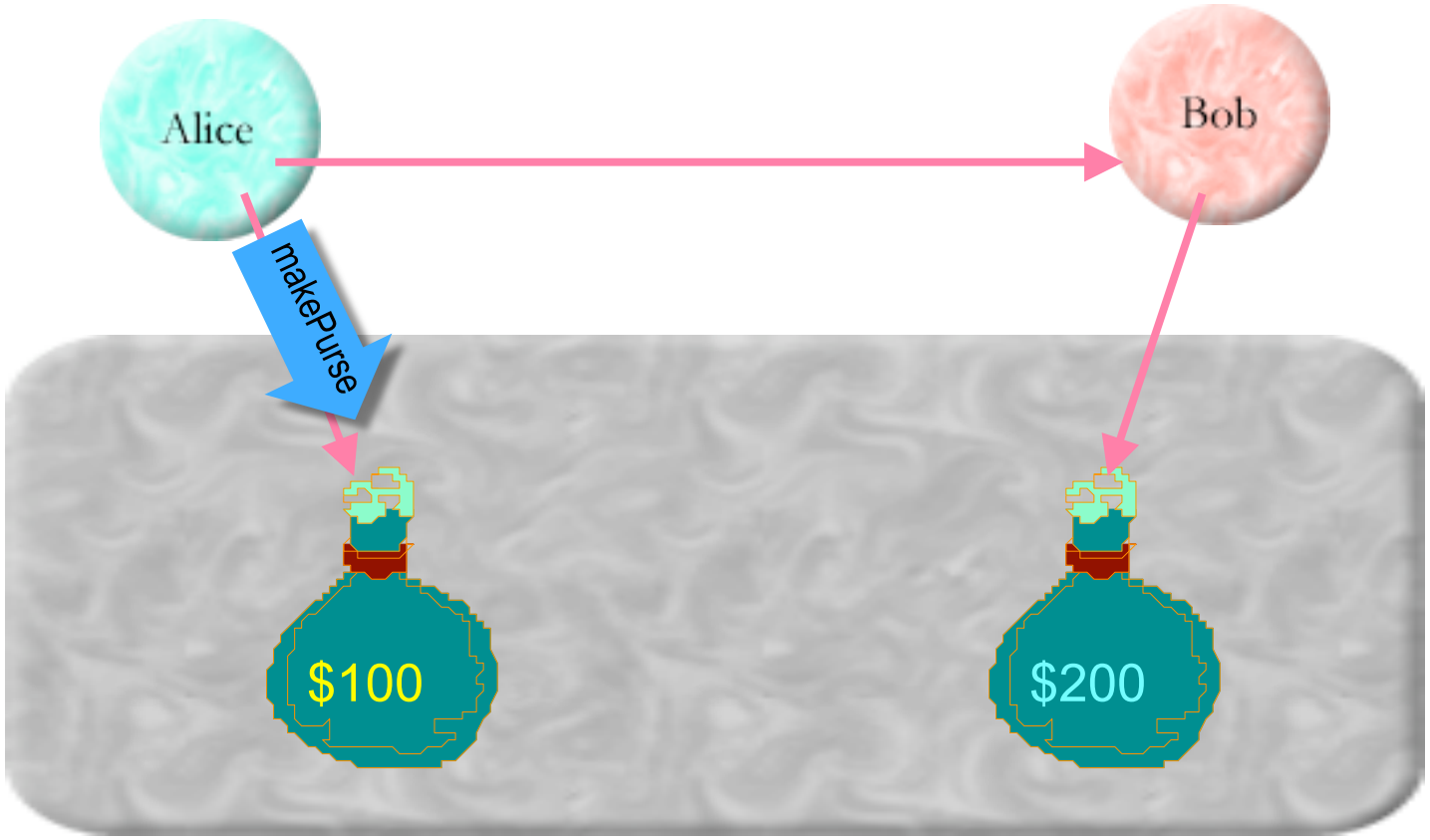

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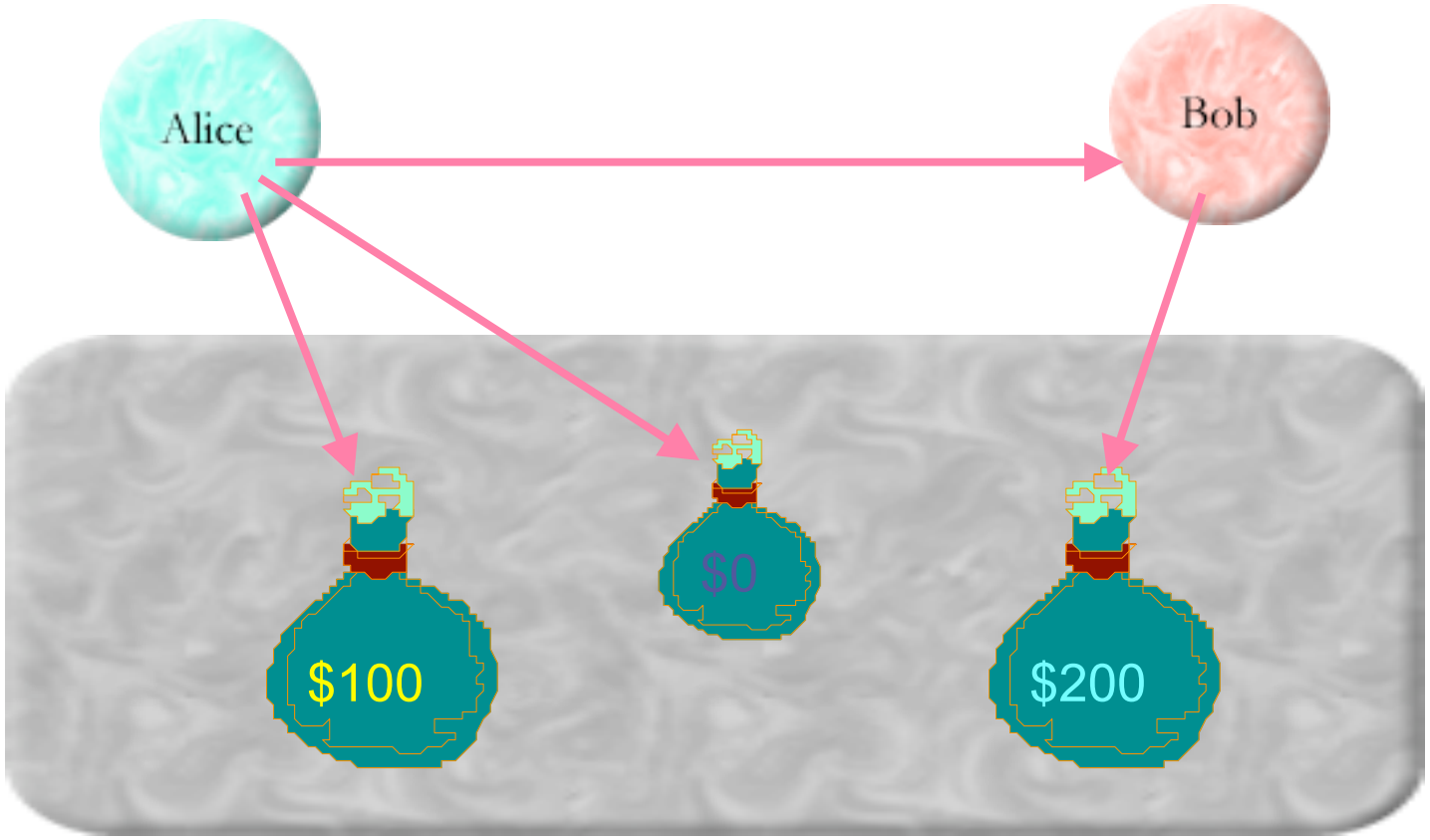
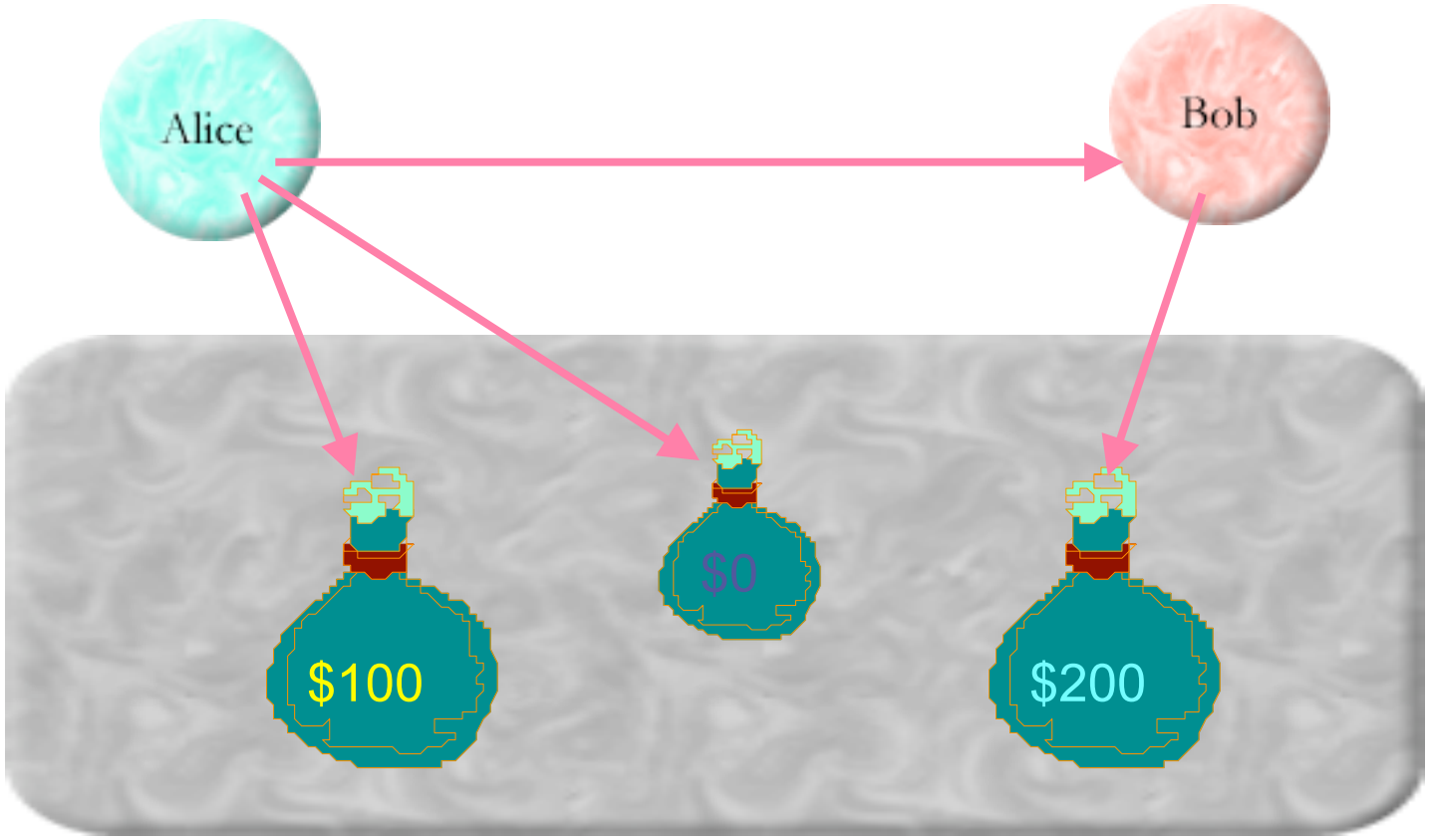


Distributed Secure Currency

```
var paymentP = myPurse ! makePurse();
paymentP ! deposit(10, myPurse);
```



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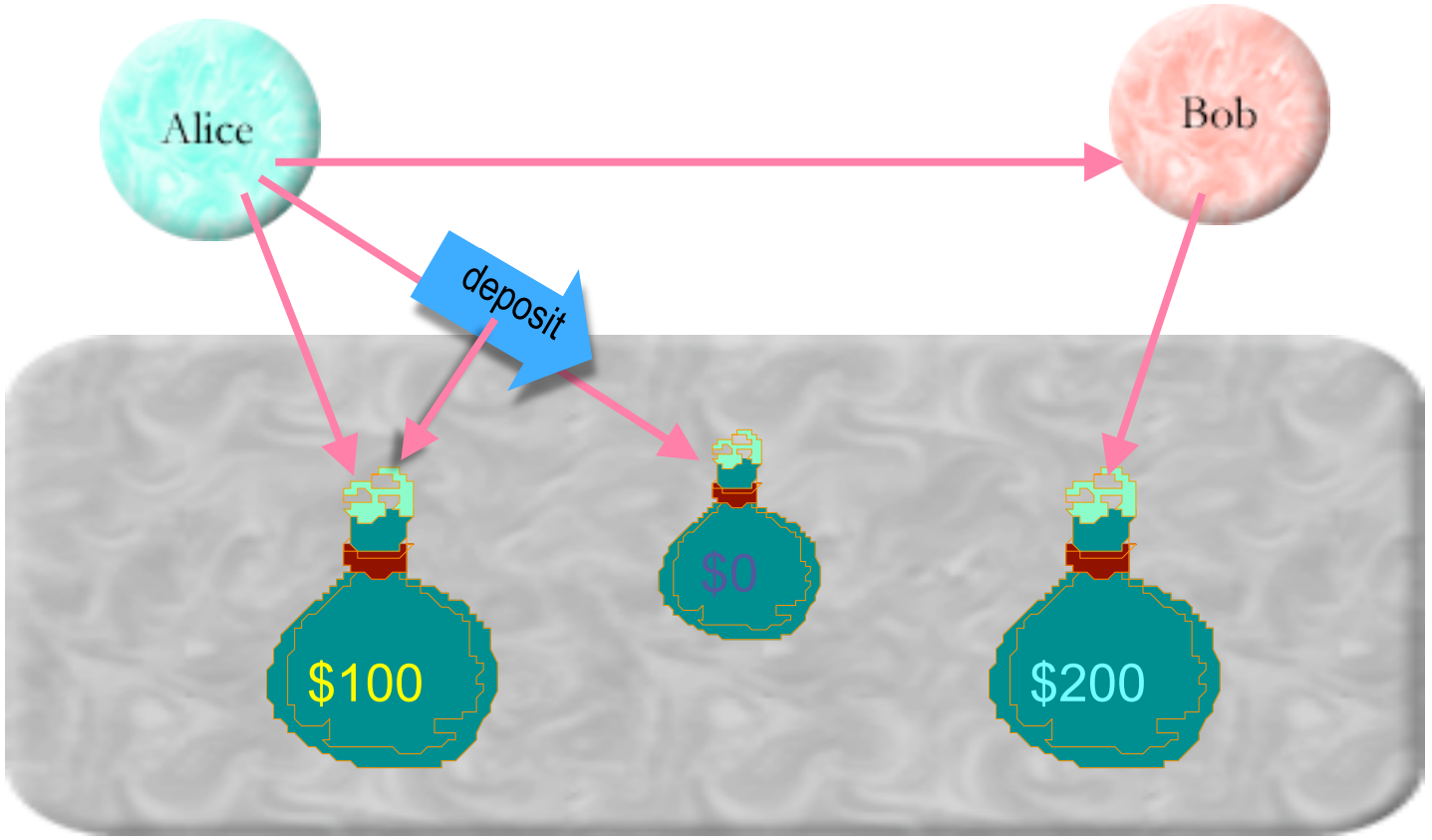

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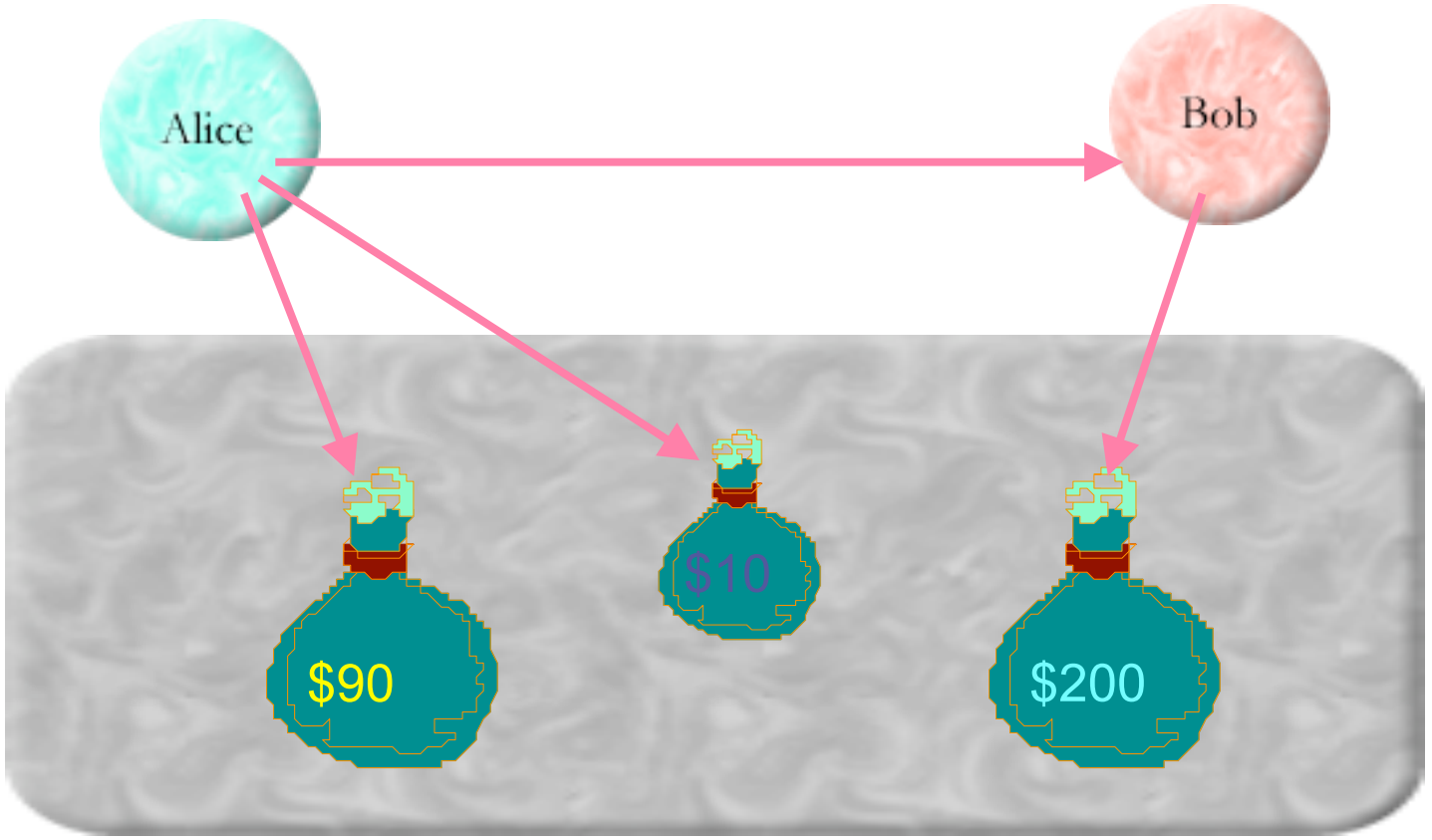

Distributed Secure Currency

```
var paymentP = myPurse ! makePurse();
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var goodP = bobP ! buy(desc, paymentP);
```

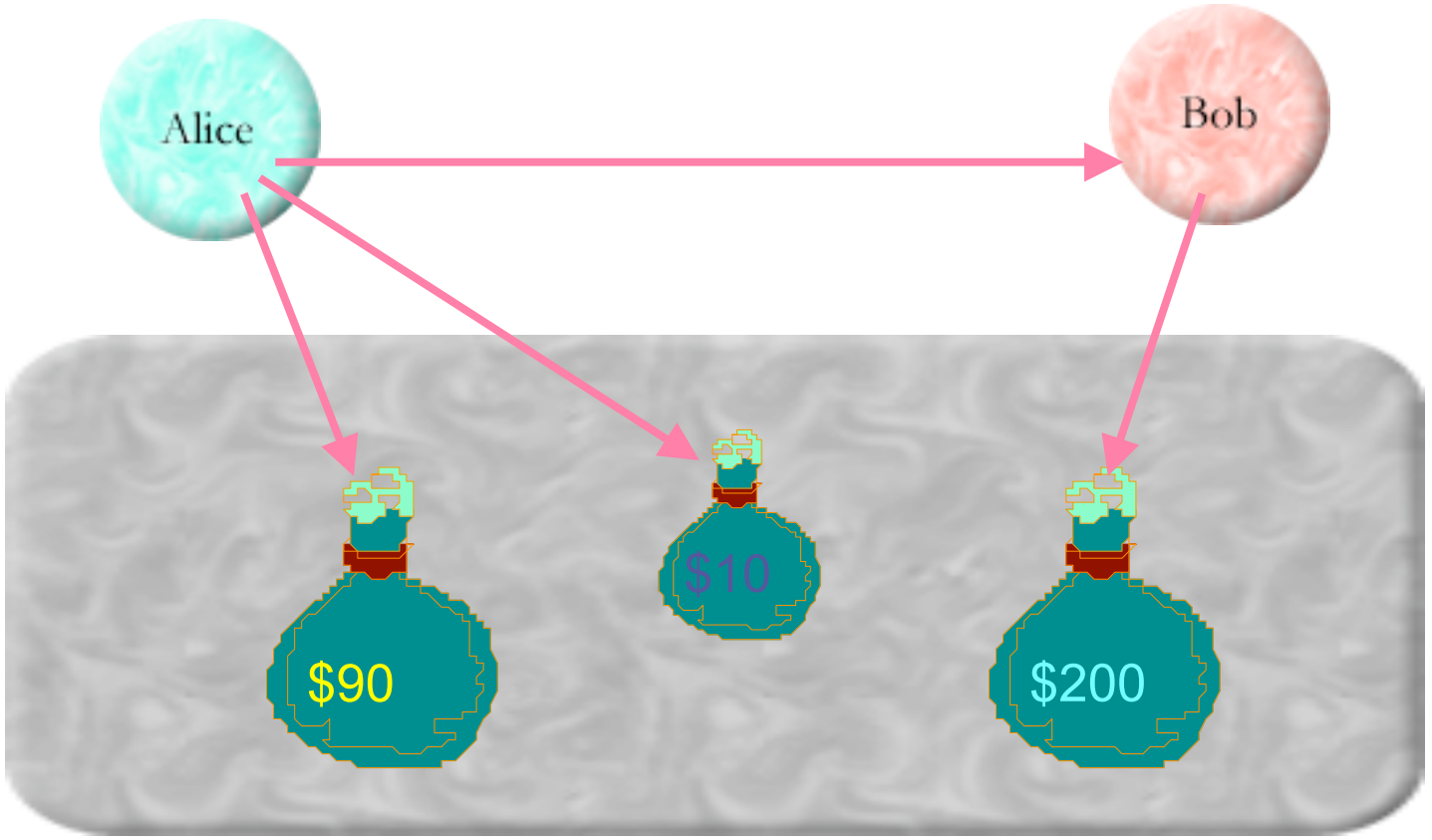

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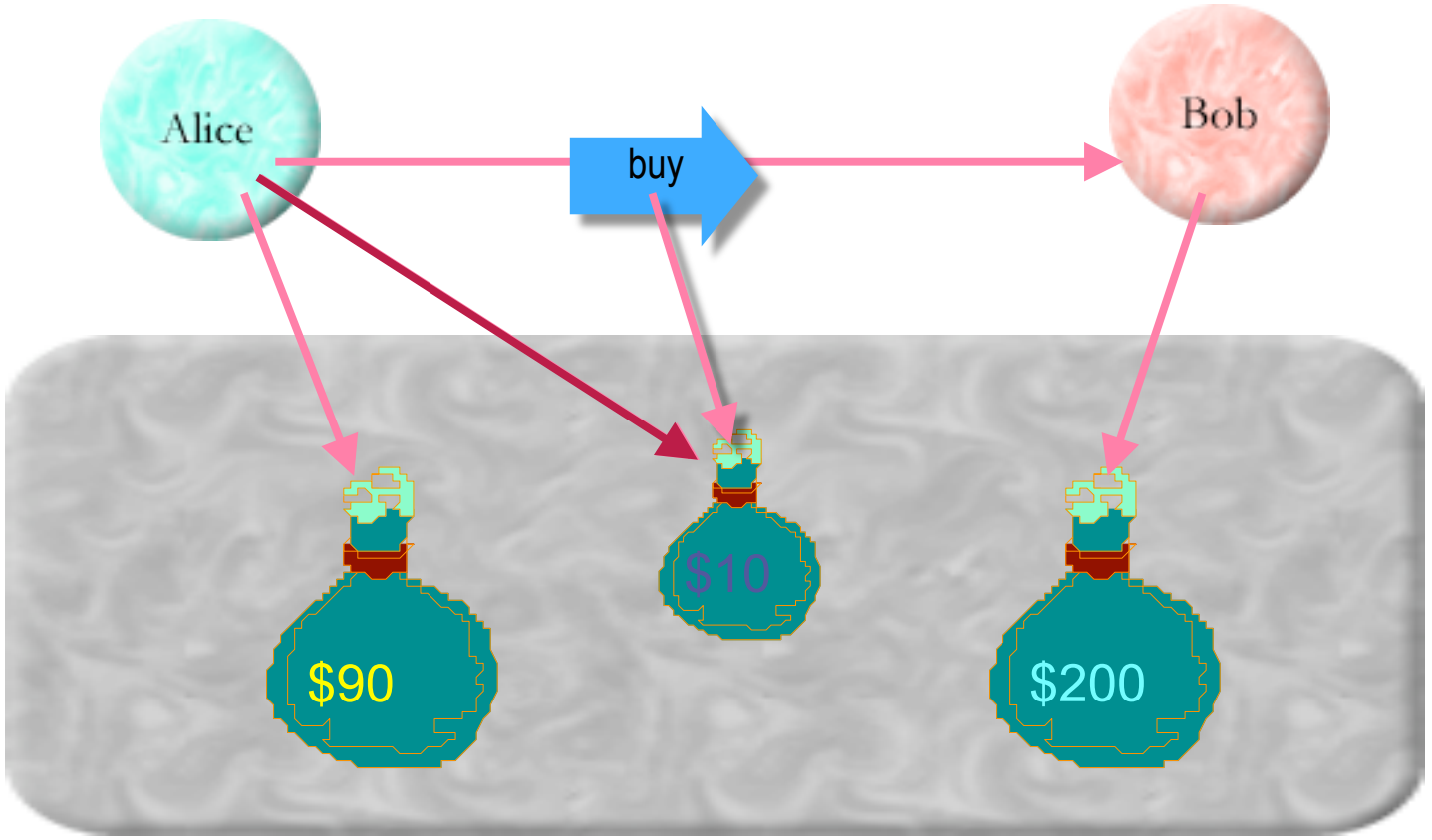

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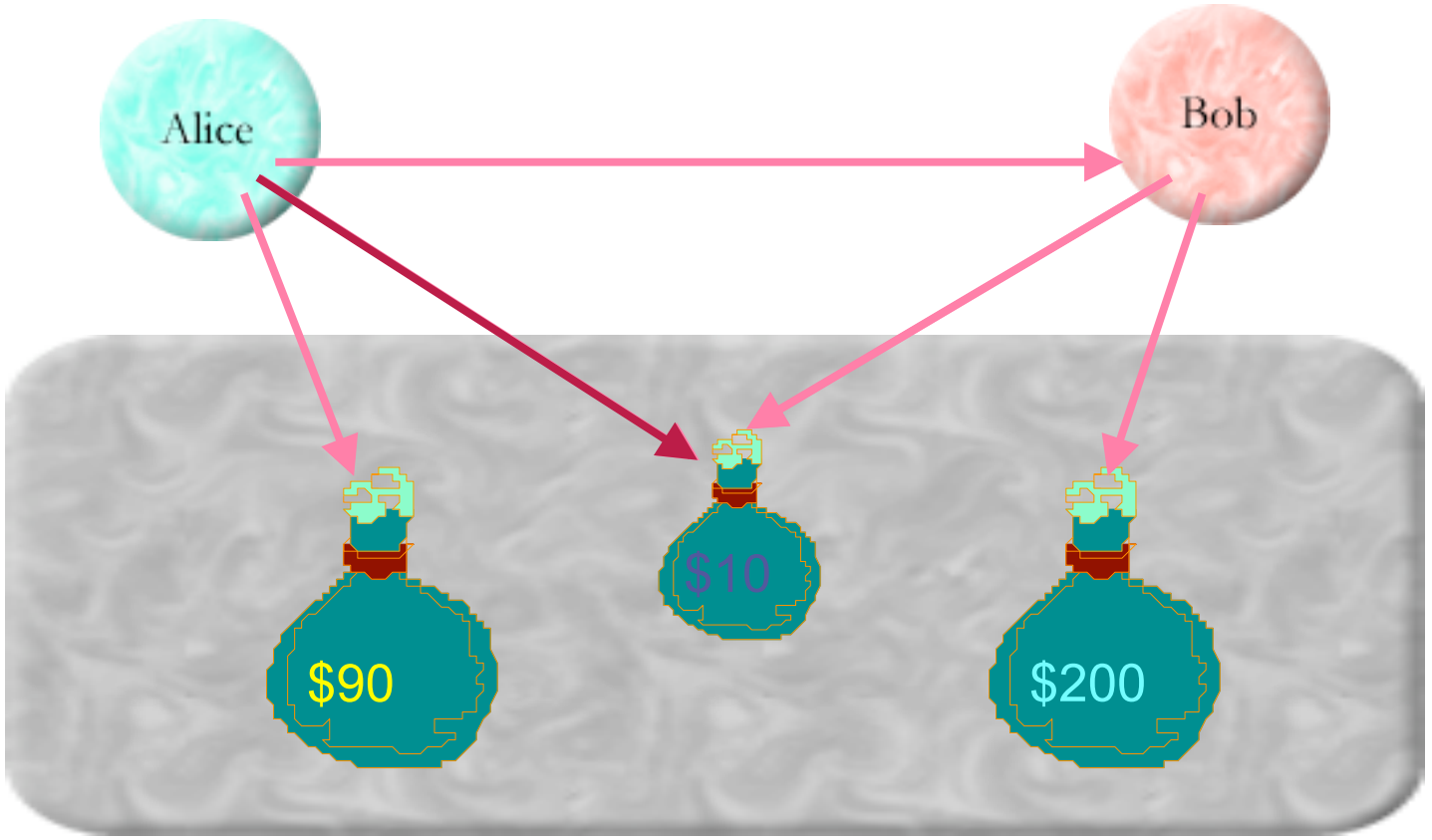
paymentP ! deposit(10, myPurse);
var goodP = bobP ! buy(desc, paymentP);
```

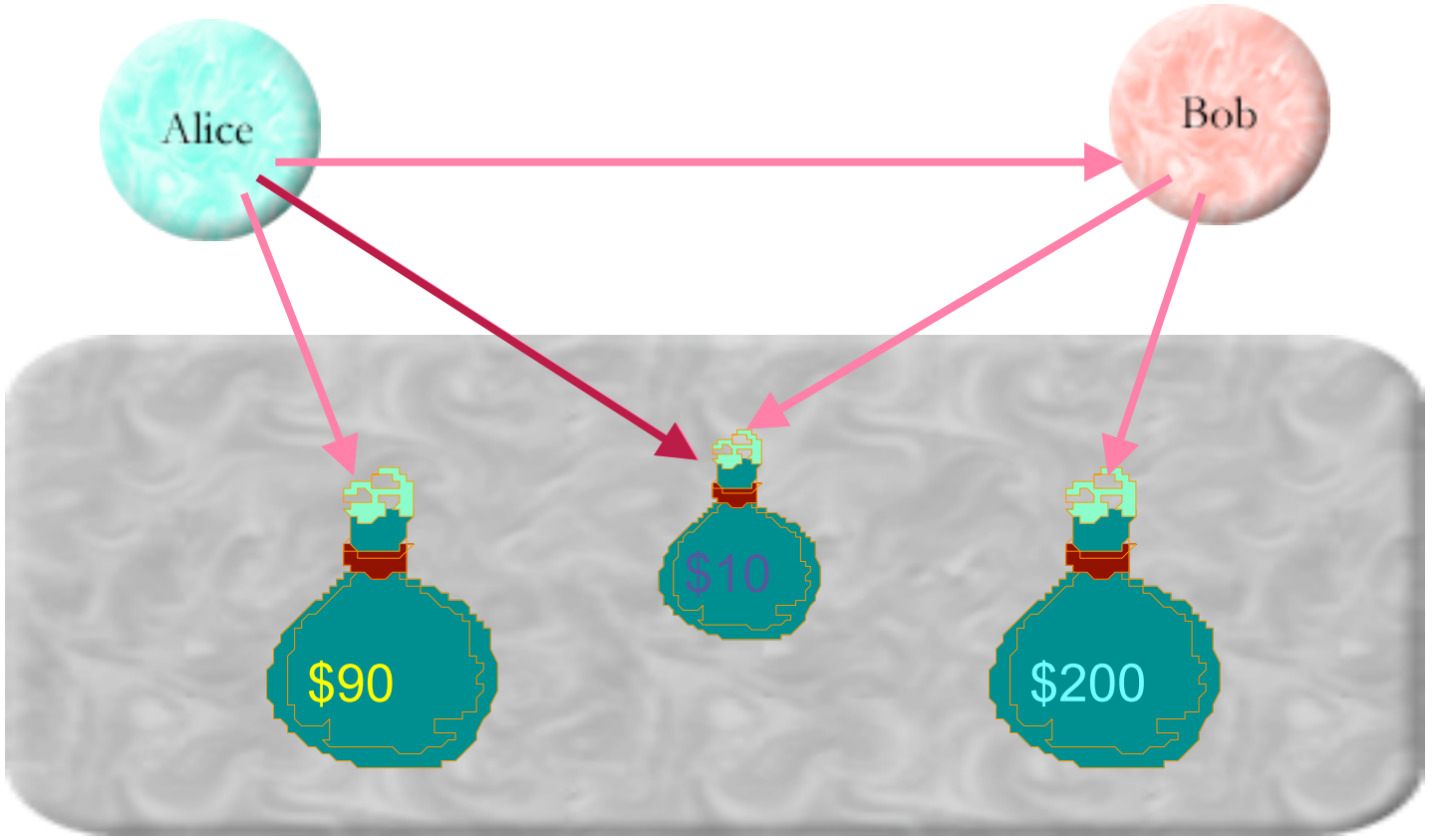
```
return Q(paymentP).when(function(p) {
```



Distributed Secure Currency

```
var paymentP = myPurse ! makePurse();
paymentP ! deposit(10, myPurse);
var goodP = bobP ! buy(desc, paymentP);
```

```
return Q(paymentP).when(function(p) {
    return Q(myPurse ! deposit(10, p)).when(function(_) {
```



Distributed Secure Currency

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var paymentP = myPurse ! makePurse();
paymentP ! deposit(10, myPurse);
var goodP = bobP ! buy(desc, paymentP);
```
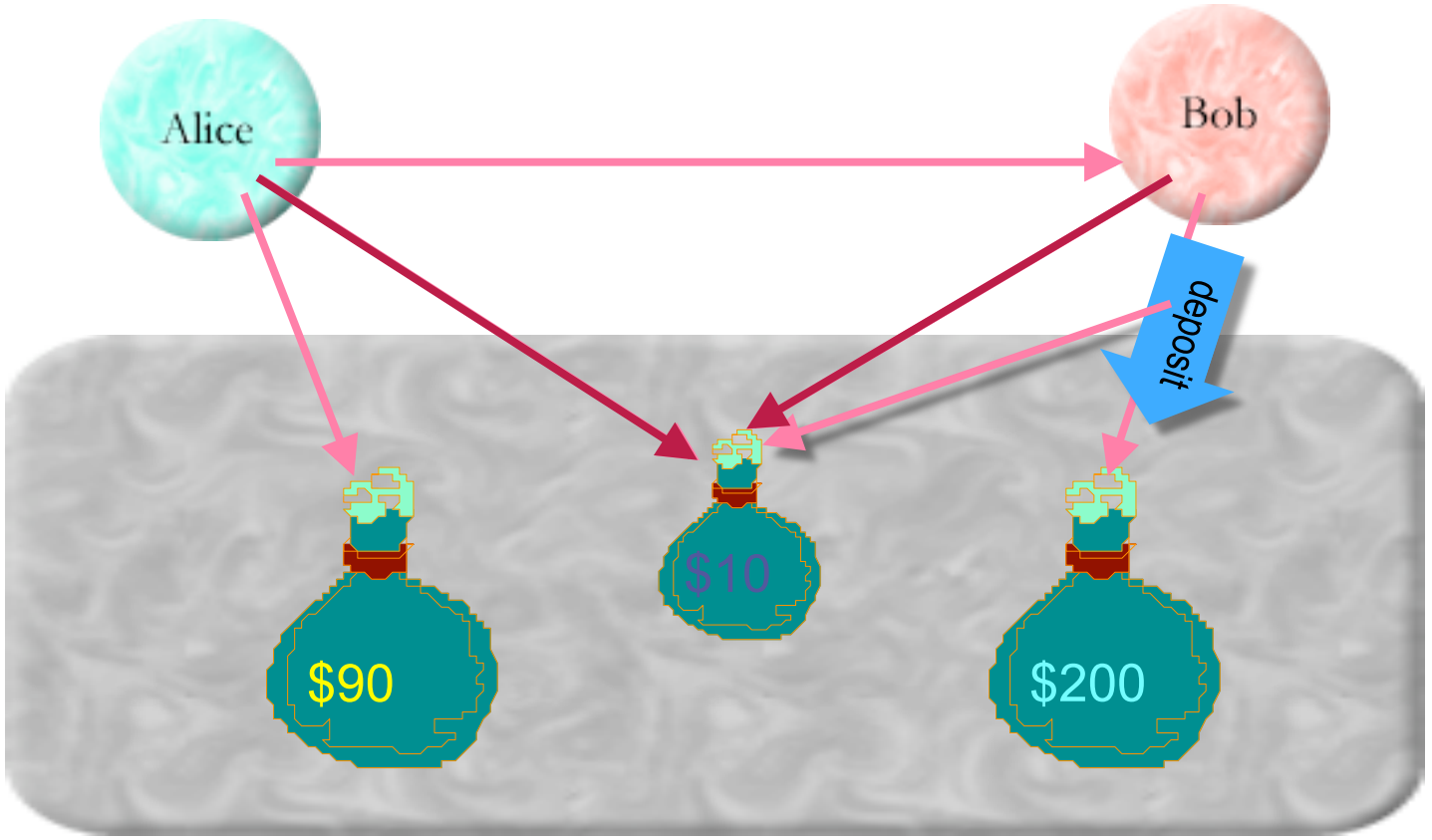
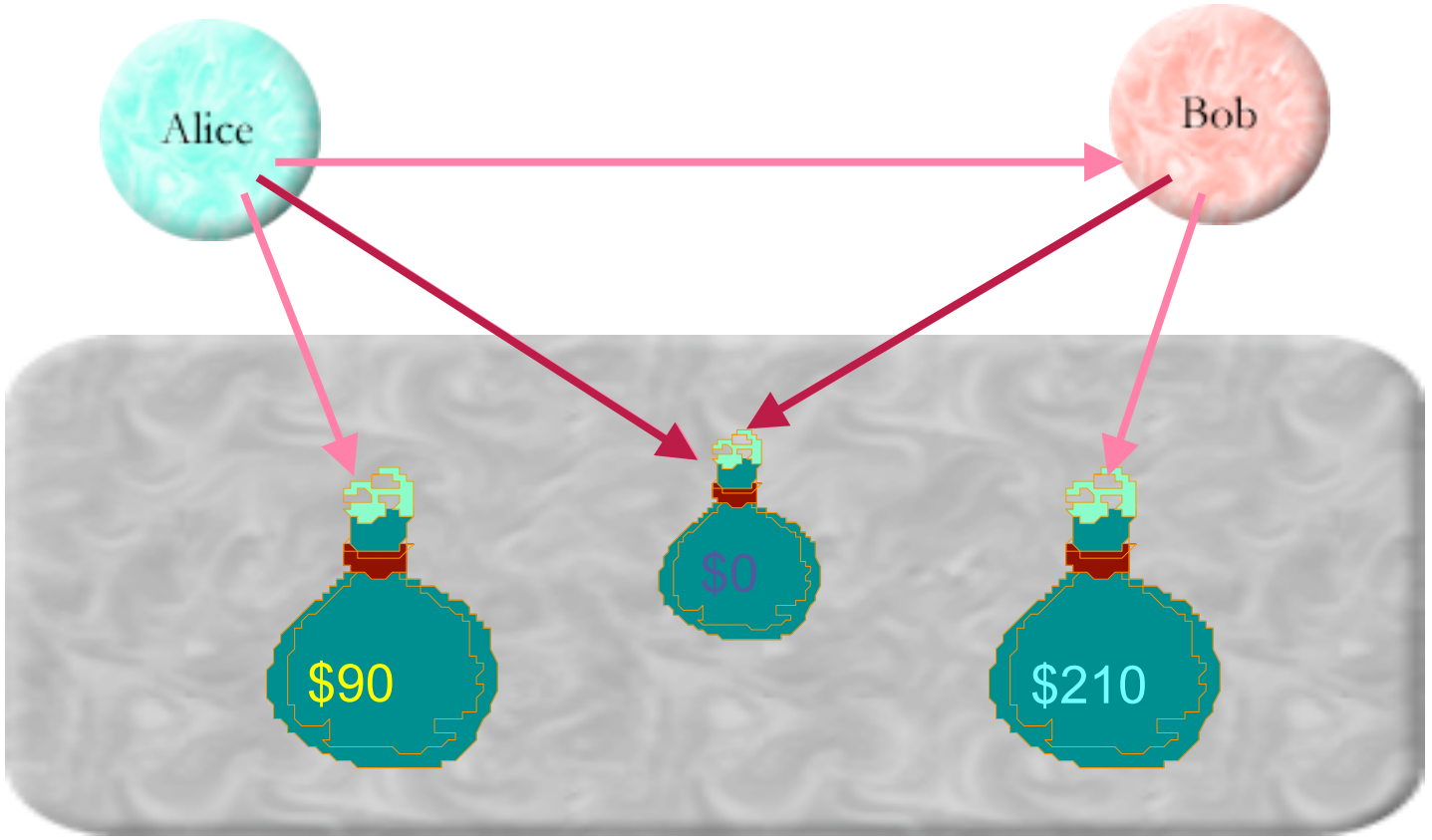

```
return Q(paymentP).when(function(p) {
    return Q(myPurse ! deposit(10, p)).when(function(_) {
```



Distributed Secure Currency

```
var paymentP = myPurse ! makePurse();
paymentP ! deposit(10, myPurse);
var goodP = bobP ! buy(desc, paymentP);
```

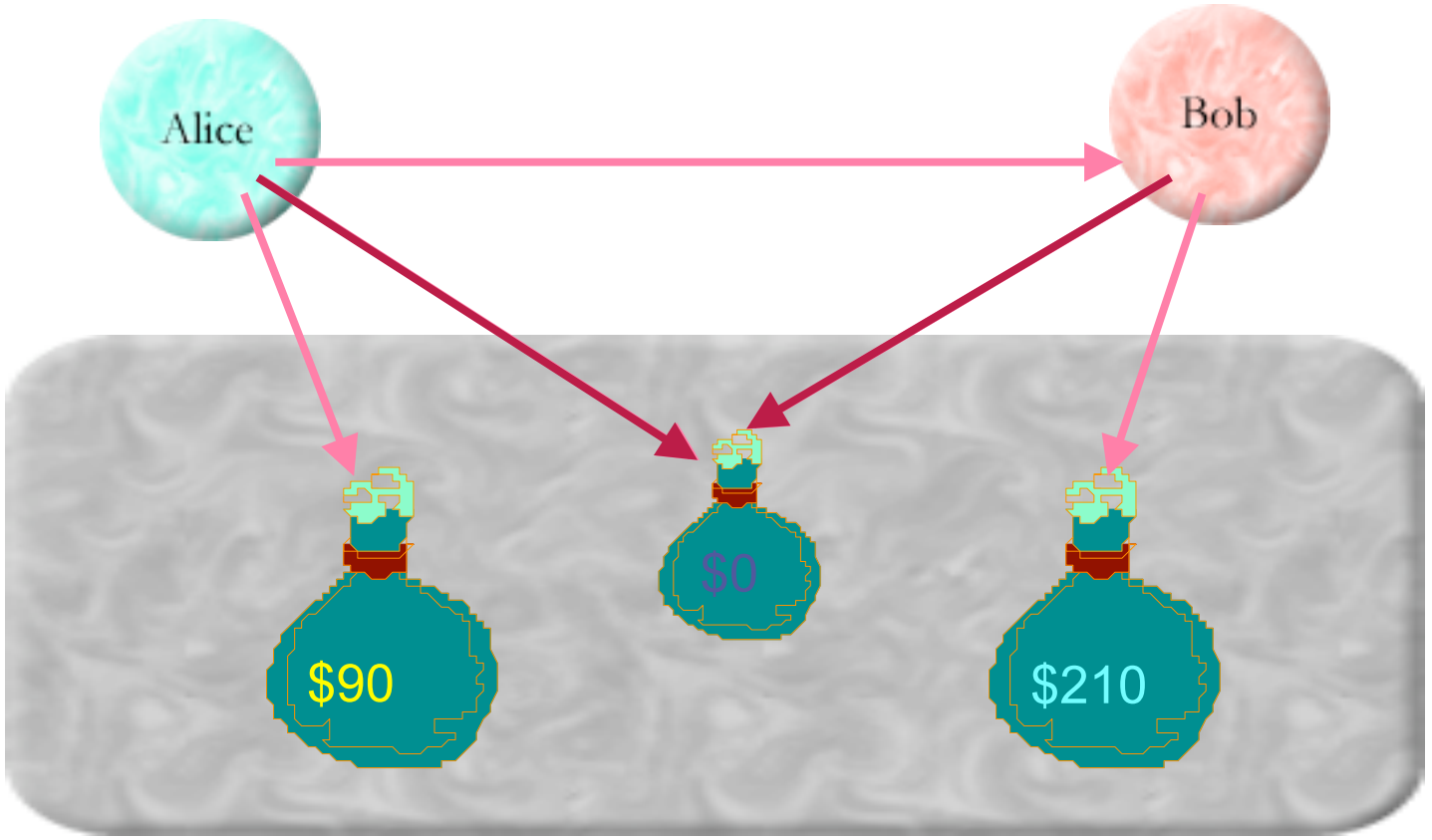
```
return Q(paymentP).when(function(p) {
    return Q(myPurse ! deposit(10, p)).when(function(_) {
```



Distributed Secure Currency

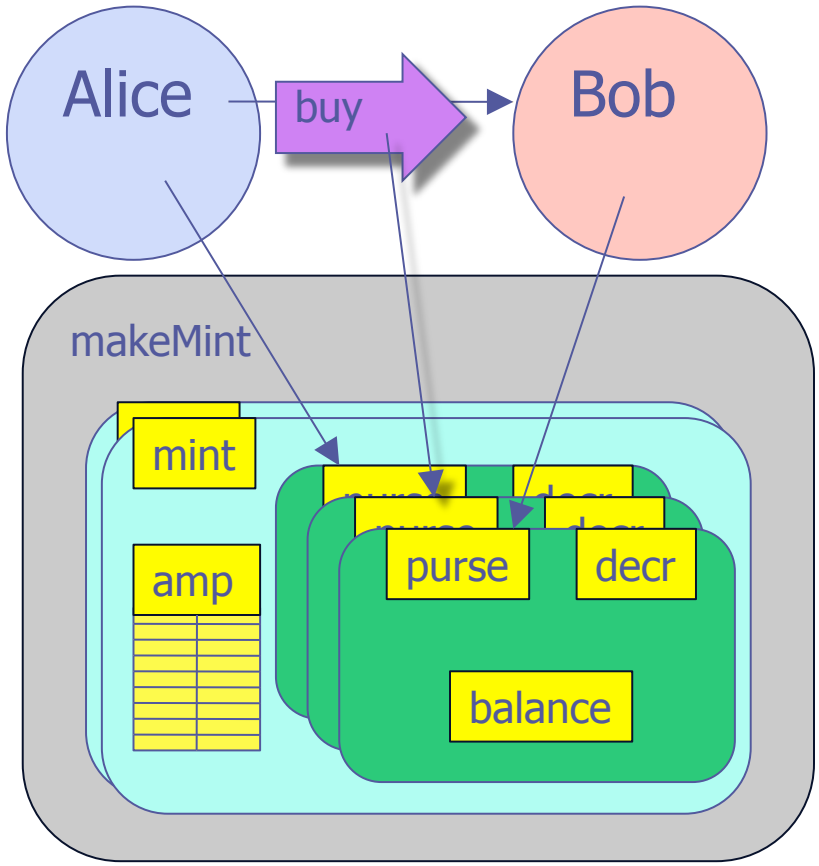
```
var paymentP = myPurse ! makePurse();
paymentP ! deposit(10, myPurse);
var goodP = bobP ! buy(desc, paymentP);
```

```
return Q(paymentP).when(function(p) {
    return Q(myPurse ! deposit(10, p)).when(function(_) {
        return good; }, …
```



Money as "factorial" of secure coding

No explicit crypto




```
function makeMint() {
    var amp = WeakMap();
    return function mint(balance) {
        var purse = def({
            getBalance: function() { return balance; },
            makePurse: function() { return mint(0); },
            deposit: function(amount, src) {
                Nat(balance + amount);
                amp.get(src)(Nat(amount));
                balance += amount;
        } });
        function decr(amount) {
            balance = Nat(balance – amount);
        }
        amp.set(purse, decr);
        return purse;
    }
}
```

Dimensions of Electronic Rights

Object reference

- Shared
- Specific
- Opaque
- Exercisable

Money

- Exclusive
- Fungible
- Assayable
- Symbolic

Smart Contracts as Board Games

Negotiation

- Design a game both expect to win

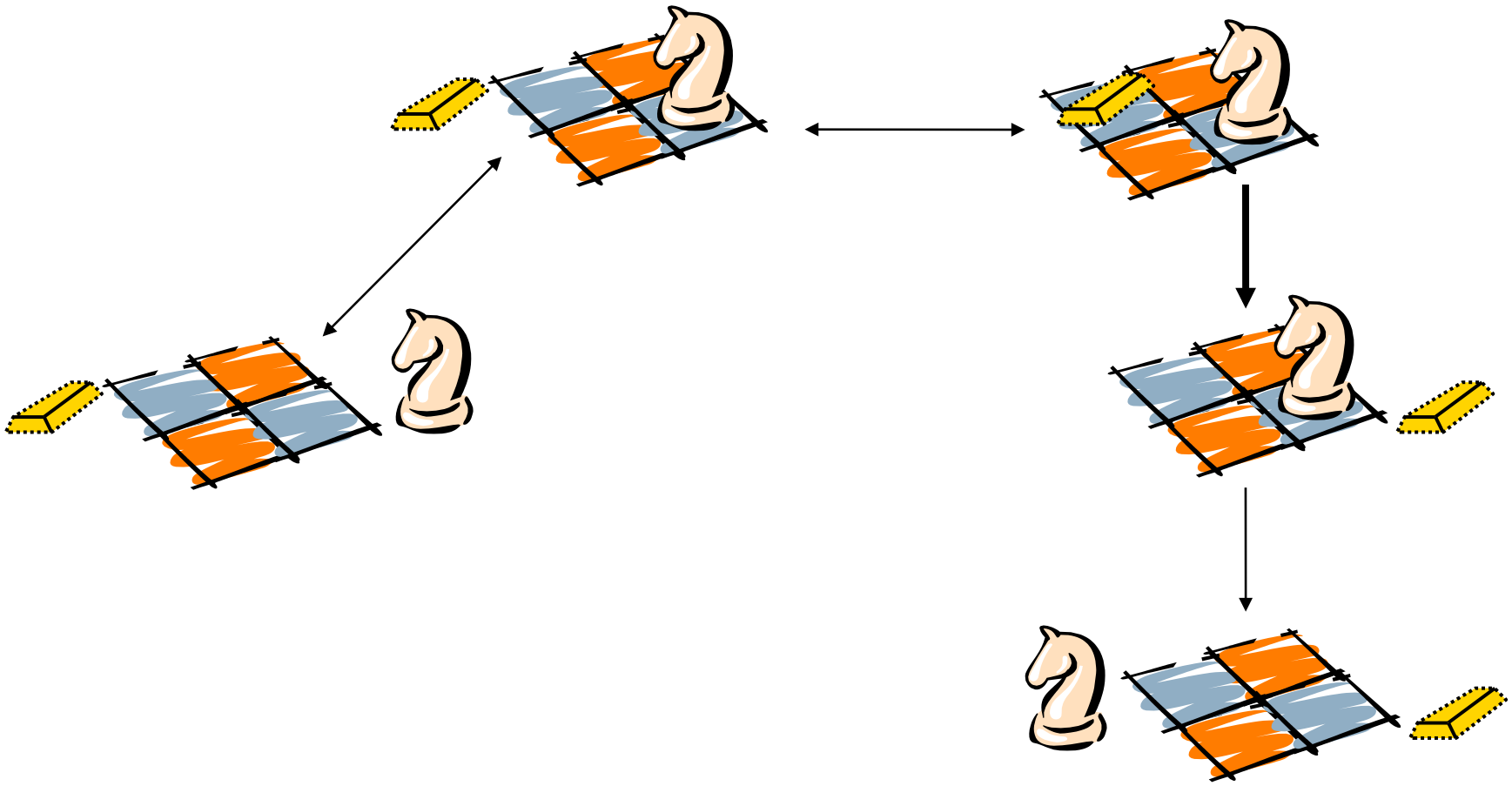
Players make moves, but only “legal” ones

- Move changes state of board
- Board-state determines move “legality”

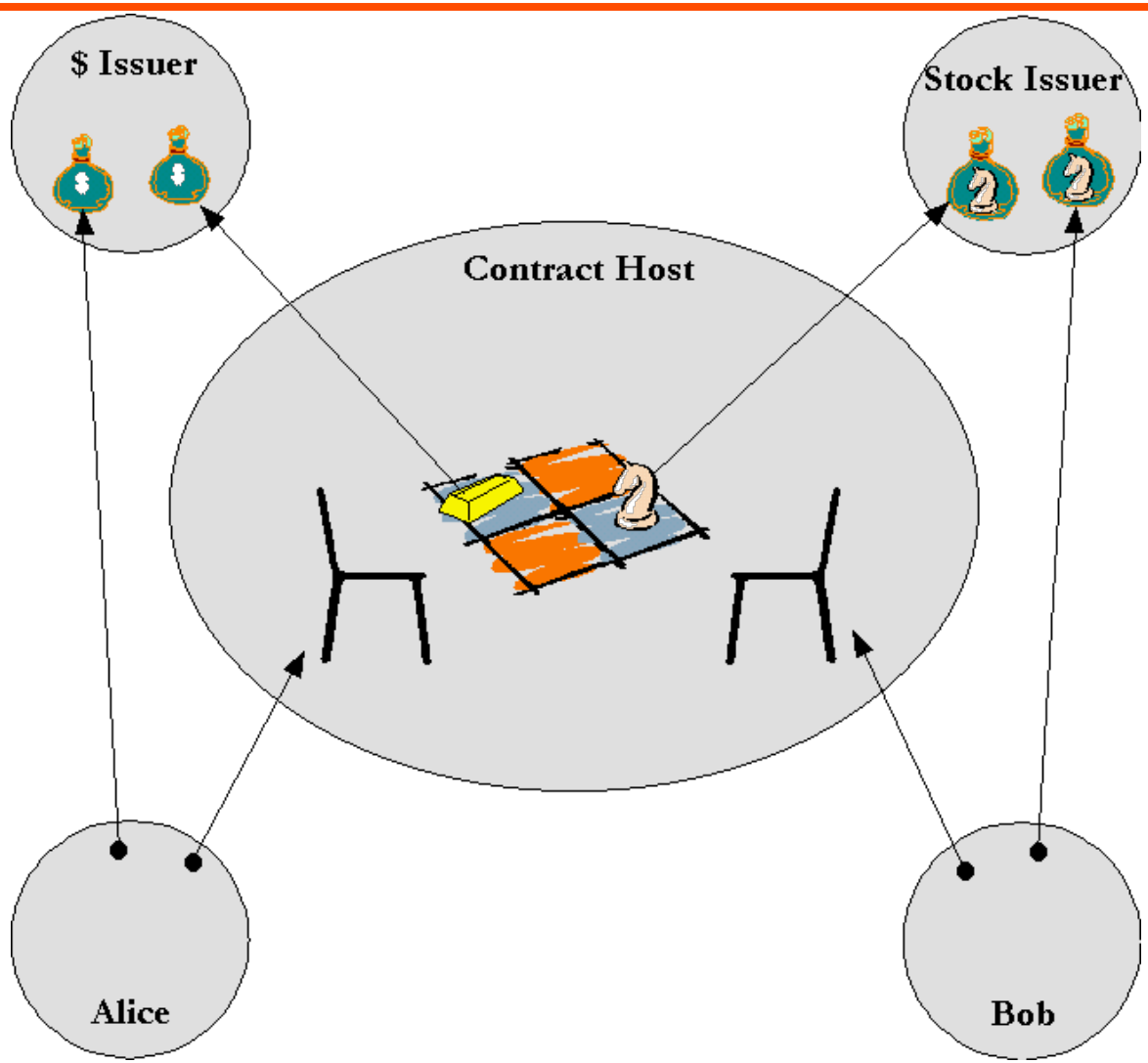
ERights are “pieces” placed on board

- Game escrows pieces,
- Pieces/ERights released only by play

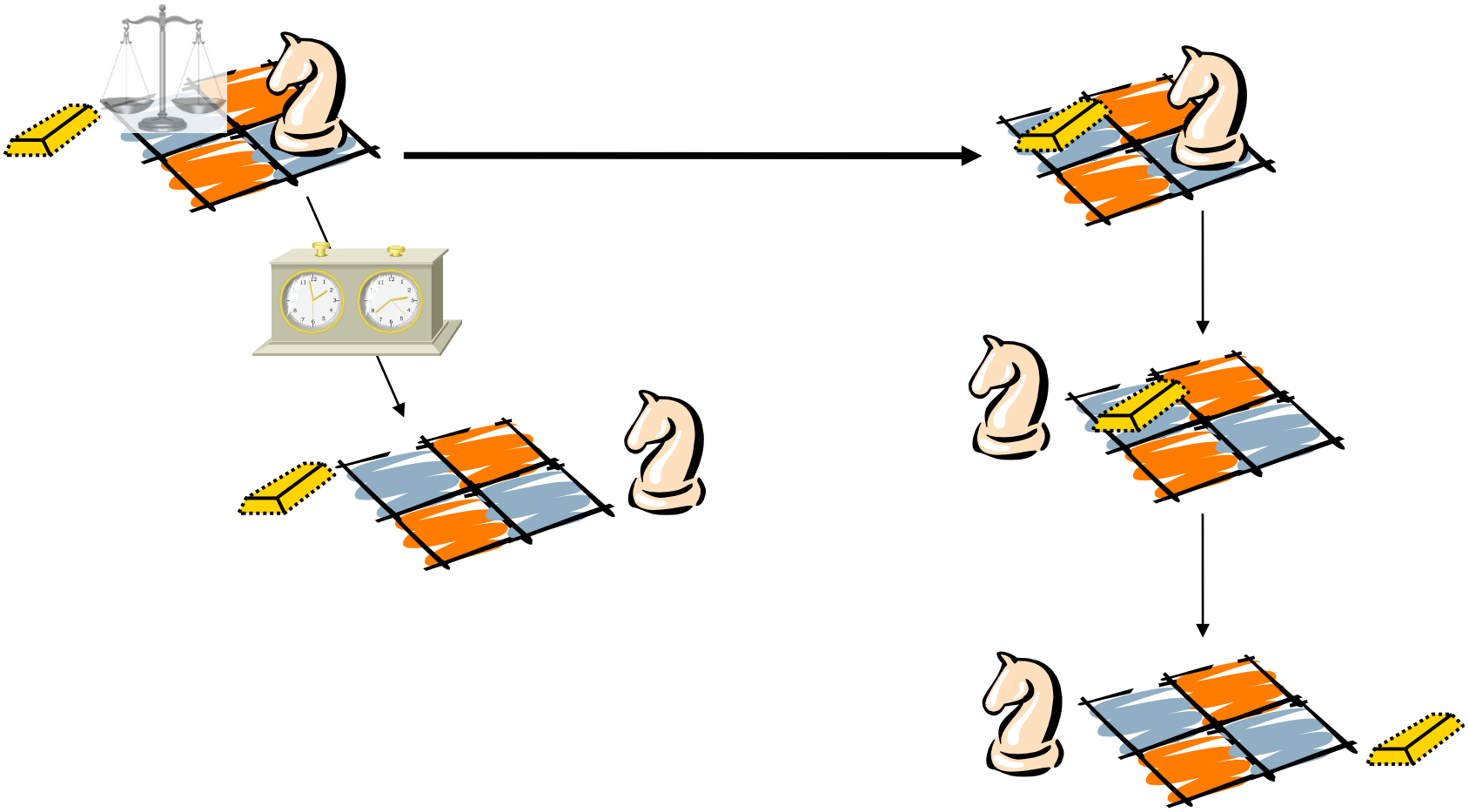
A Simple Exchange Game



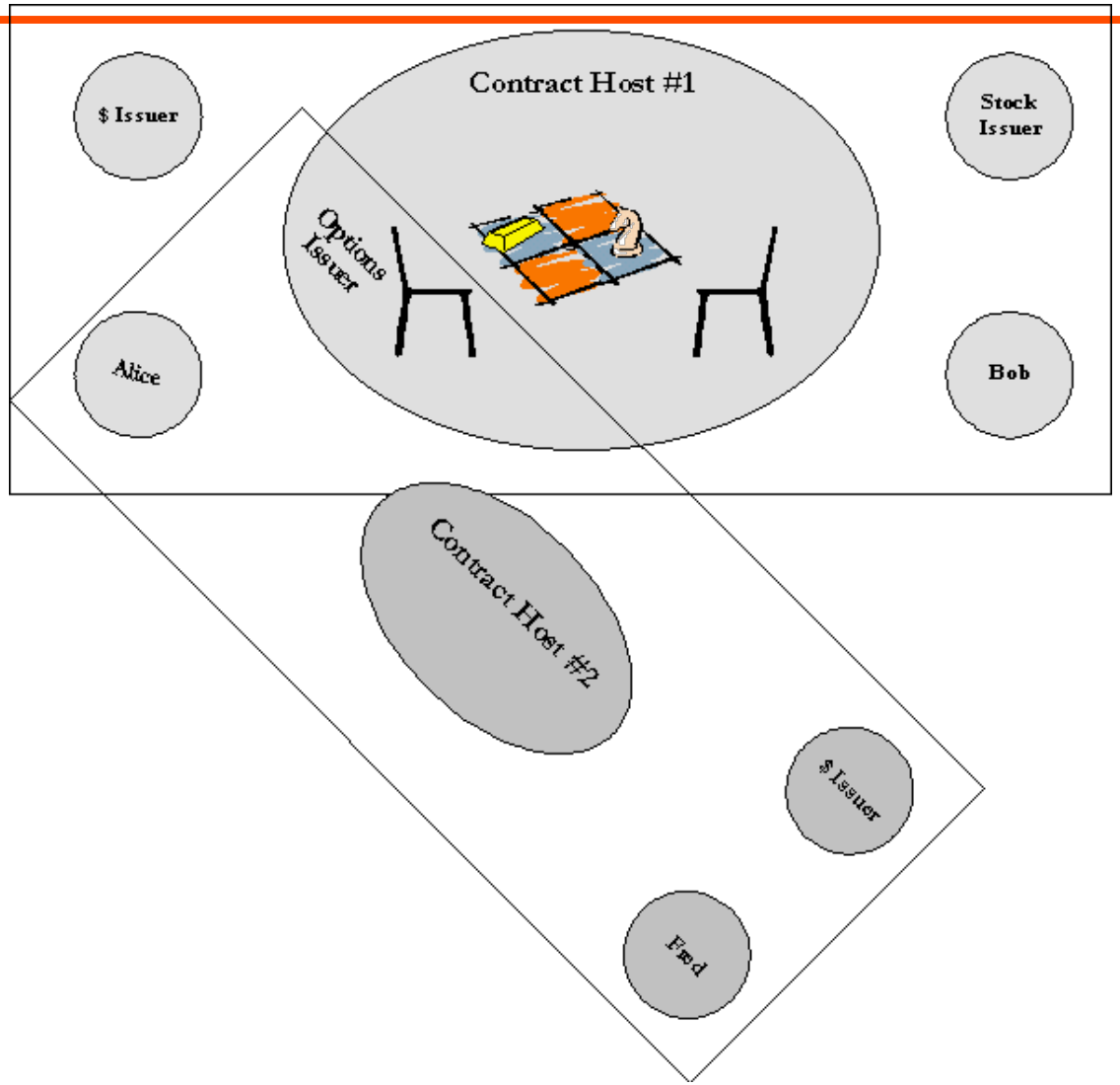
The Five Players



A Covered Call Option



Composing Networks of Games



Questions?

Composing Networks of Games

Smart Contracts as Games

Dimensions & Taxonomy of Electronic Rights

Patterns of Safe Cooperation

Access Abstractions and Compositions

Object-capabilities (ocaps)

Objects, References, Messages