The lojikil center for kids who don't blockchain good and want to learn how to do other things good too

stefan edwards, blockchain nihilist

overview

a long walk off the short pier of blockchain

- this slide
- background on me
- background on ToB
- what are blockchains
- simple testing: languages & environments
- actually testing

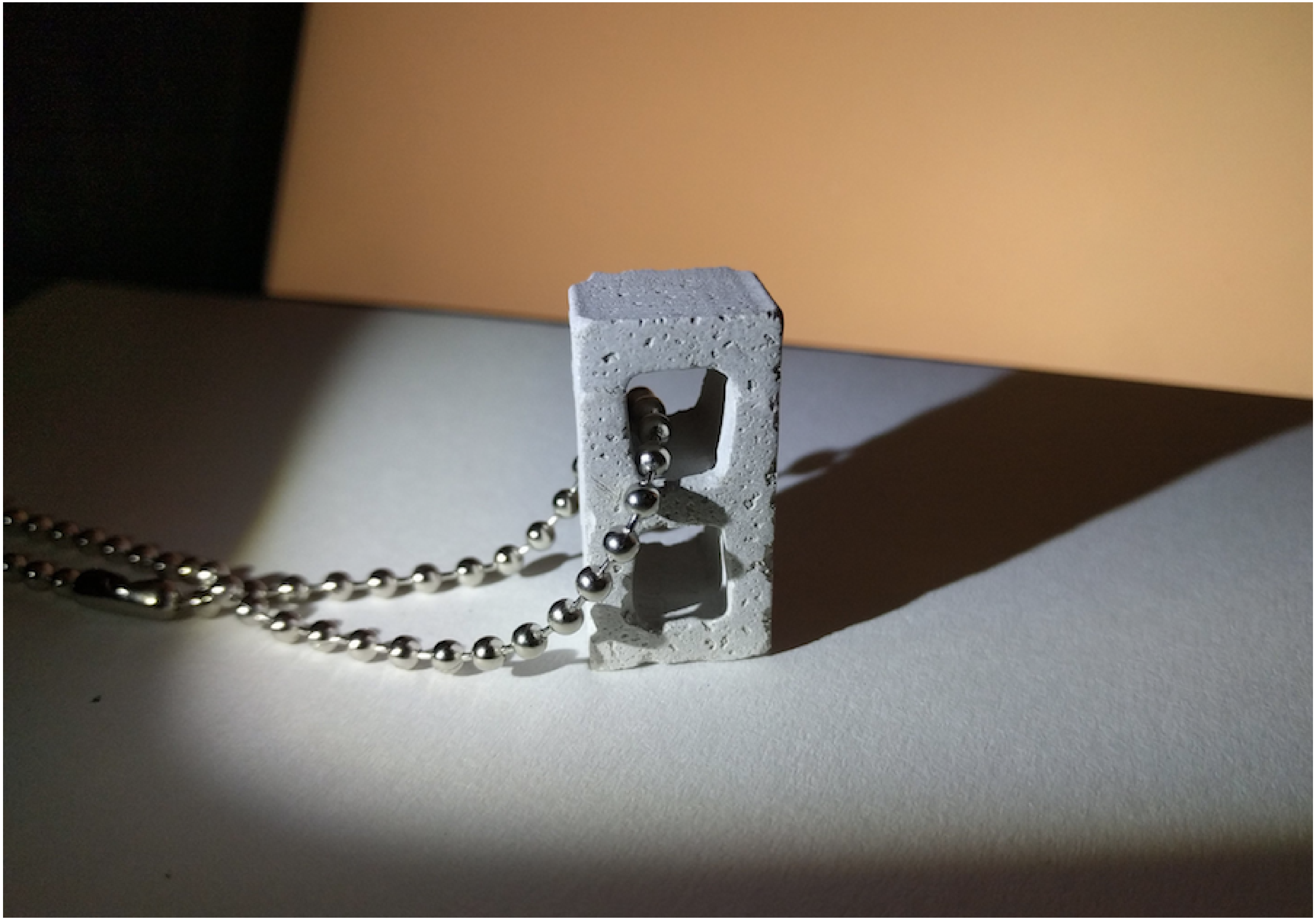
```
$ finger stefan.edwards@trailofbits.com
```

```
[trailofbits]
Stefan Edwards (lojikil) is not presently logged in.

Senior Security Consultant @trailofbits
Twitter/Github/Lobste.rs: lojikil
Works in: Blockchain, IoT, compilers, vCISO
Previous: net, web, adversary sim, &c.
Infosec philosopher, amateur^wprofessional programming
language theorist, everyday agronomer, father (doge,
human), future-husband.

WARNING: DEAF
WARNING: Noo Yawk
```

$ whois trailofbits.com

```
% whois trailofbits.com
organization: Trail of Bits
founded: 2012
size: 50
purpose: cybersec r&d
focus: security research, development, and assessments
focus: correctness & security
verticals: finance (fintech/finsrv), tech, gov
```

what is this talk?



what *are* blockchains?

besides just a fancy ledger

three things:

1. a collection of data
2. stored in an authenticated datastructure
3. with some sort of consensus protocol

what are blockchains: simple example

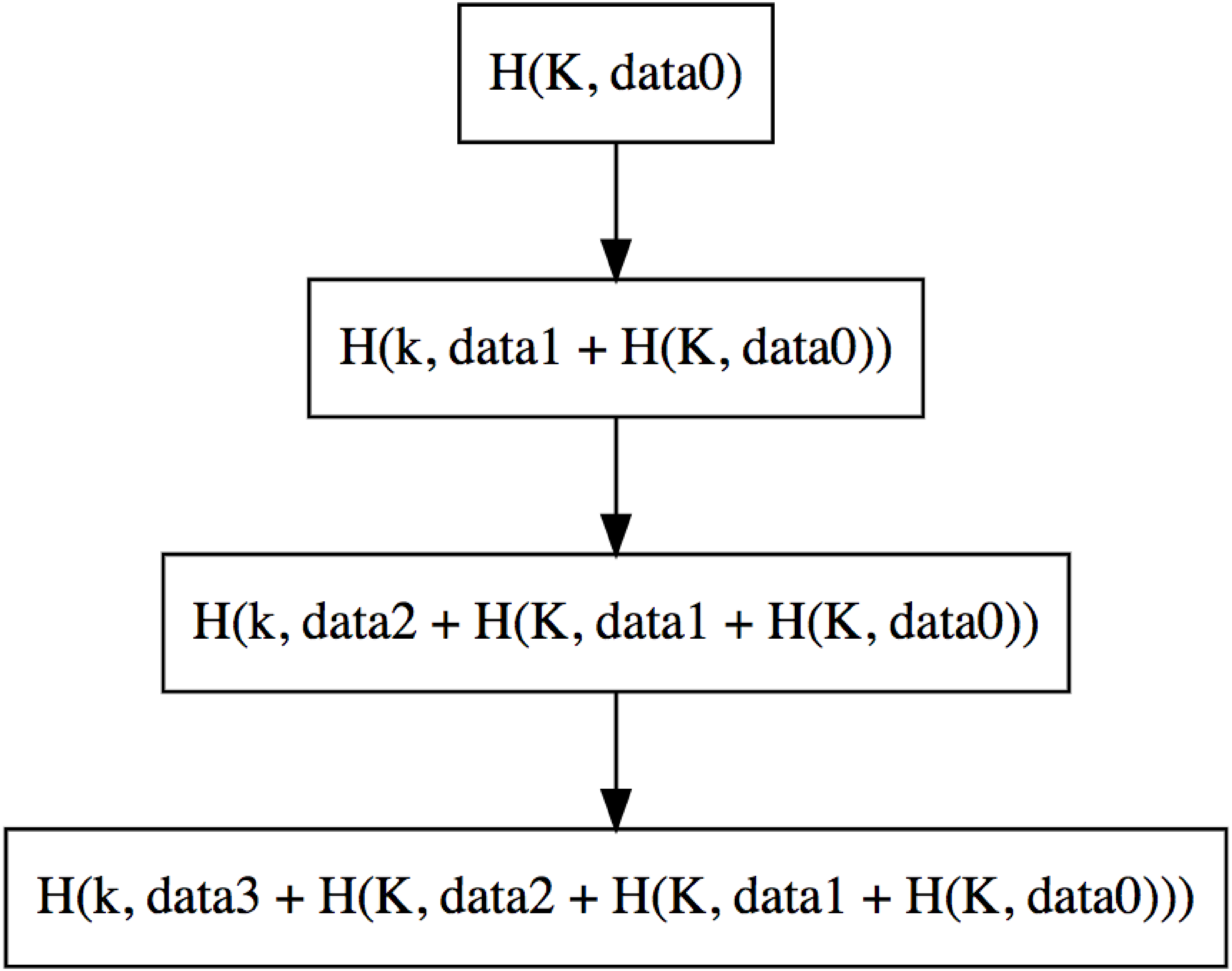
let's design a system...

- easy to prove I authored something
- easy to prove that data hasn't been tampered with
- difficult to forge

what are blockchains: simple example

what we need is...

- Some function `H`
- Some key `K`
- a calculated result: `H(K, data) == some unique value`
- Blockchains: repeated applications of `H` over new data
- including previous data



H(K, data0)

H(k, data1 + H(K, data0))

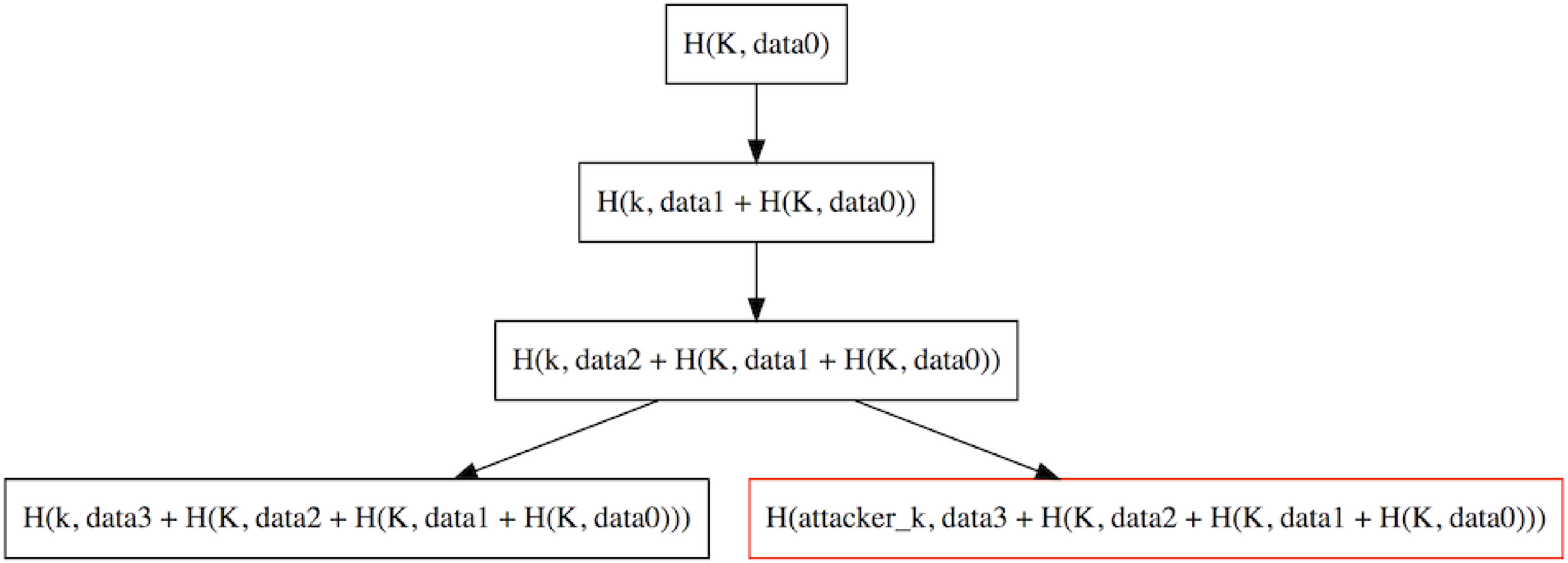
H(k, data2 + H(K, data1 + H(K, data0))

H(k, data3 + H(K, data2 + H(K, data1 + H(K, data0)))

please calculate...

```
H(K, "why do I care")
```

why do I care?


H(K, data0)
H(k, data1 + H(K, data0))
H(k, data2 + H(K, data1 + H(K, data0))
H(k, data3 + H(K, data2 + H(K, data1 + H(K, data0)))
H(attacker_k, data3 + H(K, data2 + H(K, data1 + H(K, data0)))

- can easily verify that a block with key `attacker_k` is invalid
- additionally, I cannot later modify `data1`

... isn't that obvious?

- Merkle Trees (1979)
- Linked Time Stamps (1992)
- Direct Acyclical Graphs (< 1960's)

where this becomes cool...

for some value of the word "cool"

Consensus

con-sen-sus

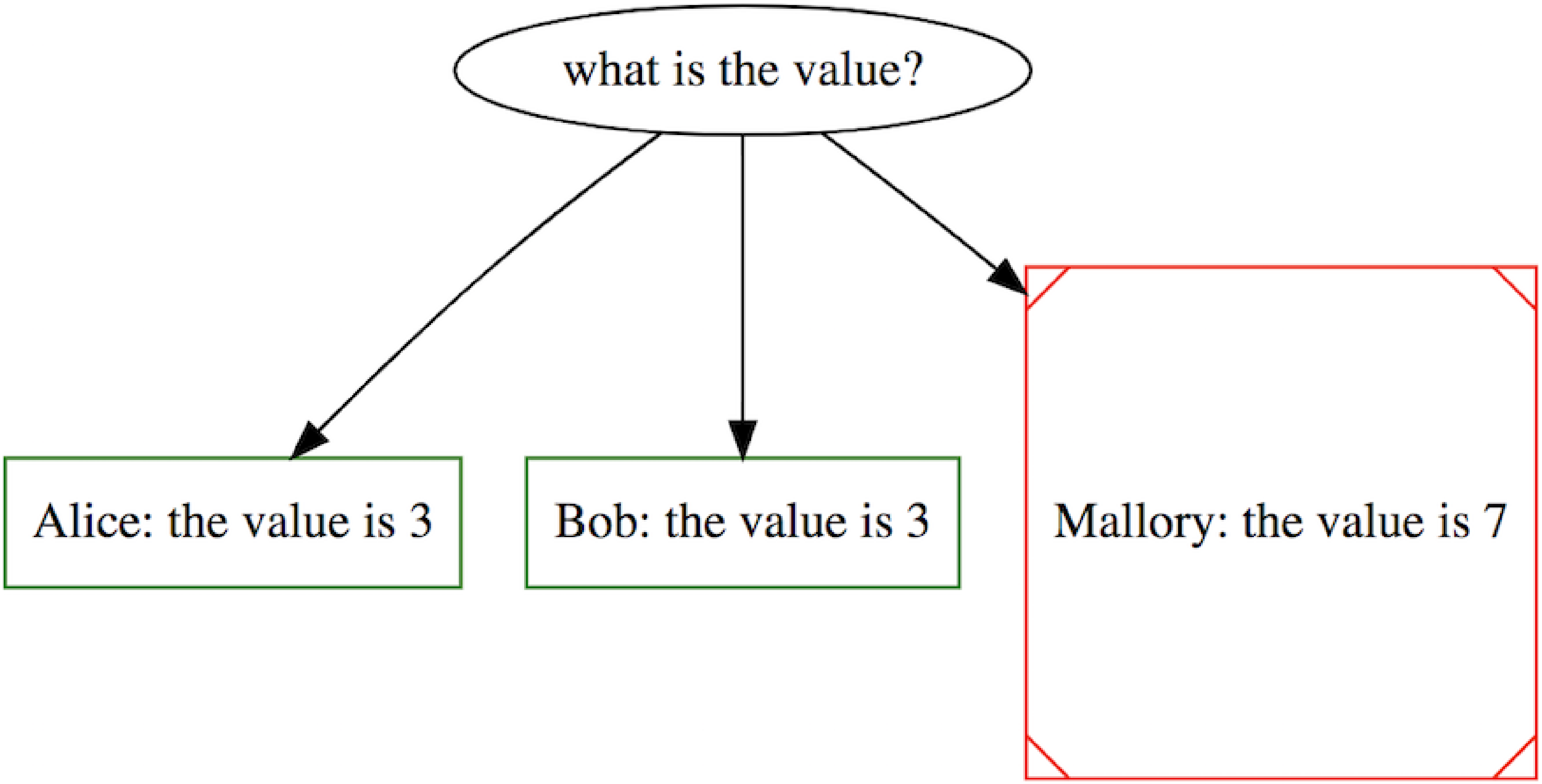
> general agreement (Merriam Webster)

or

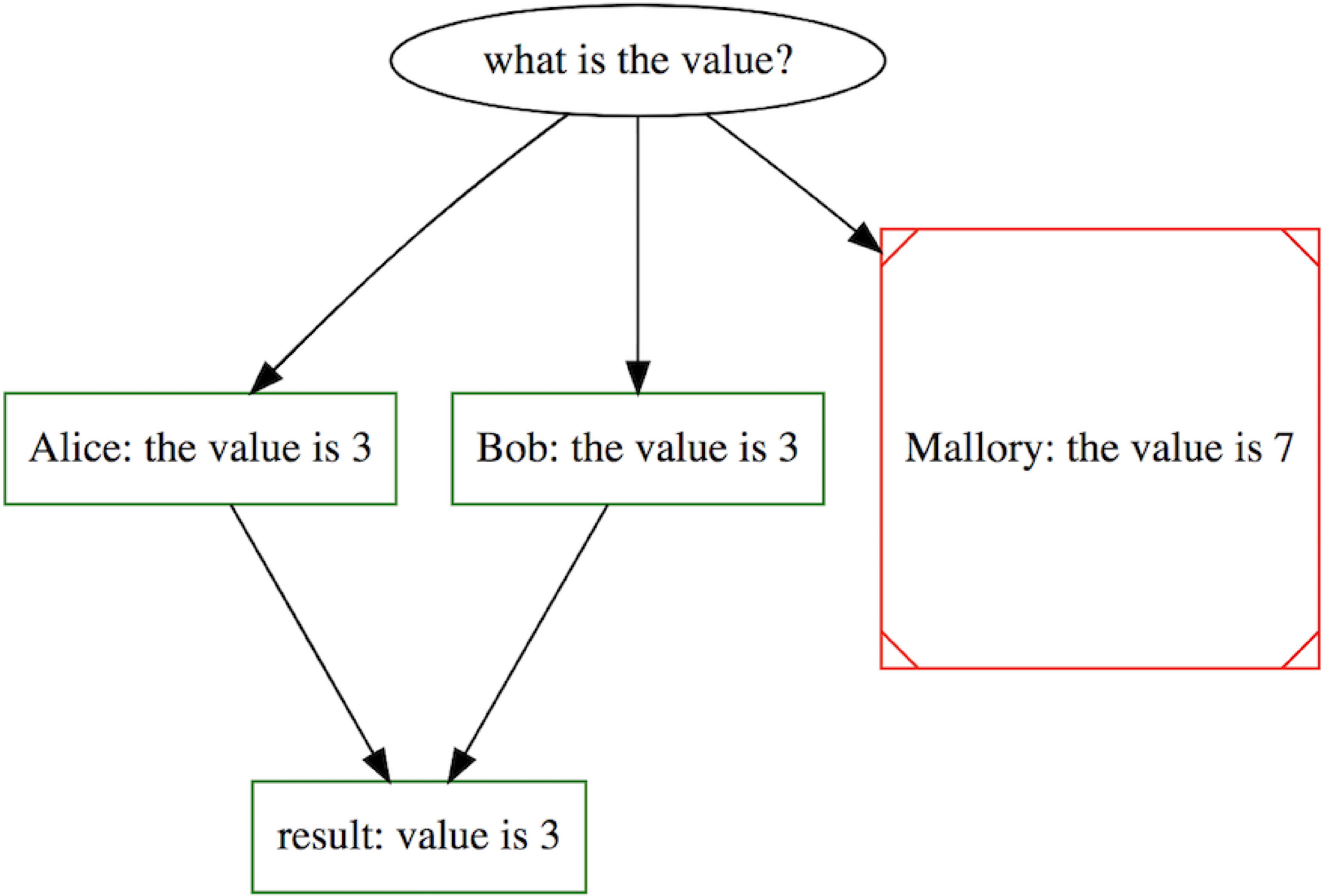
> probably a vulnerability (me, looking at most consensus protocols)

consensus

- easy to get wrong
- a common algorithm (BFT) even has the word "Byzantine" in it
- effectively a giant statemachine
- many different styles (PoW, PoA, PoS, DPoS...)
- but basically: we all calculate the same thing and present a value
- if the *majority* of us agree on that value, then it's the value



what is the value?
Alice: the value is 3
Bob: the value is 3
Mallory: the value is 7



what is the value?

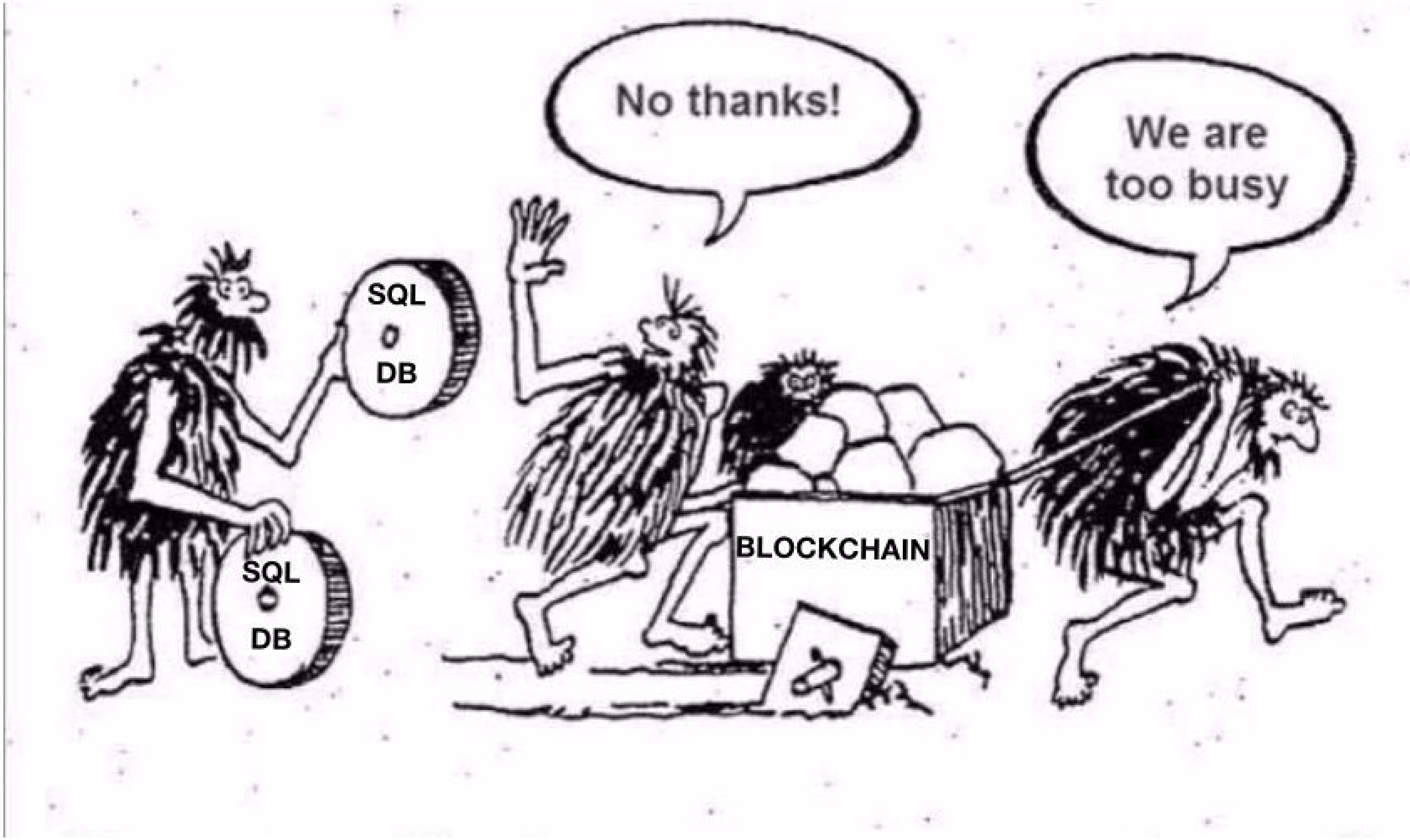
Alice: the value is 3

Bob: the value is 3

Mallory: the value is 7

result: value is 3

so why?



so why?

- most miss the mark
- Good: counter party risk, "nothing up my sleeve," CAP, money
- Bad: speed, general purpose, environment (electricity usage vs PoW)
- just a giant ledger

take aways:

- blockchains aren't new
- just combining multiple old things
  - authenticated data structures
  - hashing
  - consensus protocols
- really just a giant ledger

what is new?

traditional protections are *dead*

Property	Traditional	Blockchain
Code Visbility	(Web) API	Fully binary to everyone
AuthZ/AuthN	Session Management, WAF, SSO	lol
Channel Privacy	TLS	lol
Updates	Deploy a patch	lol

simple testing

let's look at testing Ethereum

- pretty common (~ 80% of my assessments)
- pretty terrible
- most common "dapp" target

simple testing :: pretty terrible

- EVM: stack machine with terrible numerics
- Most common language? Solidity
    - Solidity takes worst of C + worst of JS
- Terrible ERCs/EIPs
- Written by "enthusiasts"
- Everything is exposed
    - due to the nature of blockchain
    - leads to: hostile environment
- Effectively a target-rich environment

simple testing :: common issues

1. Terrible Mathematics
2. Access Control
3. No Secrecy
4. Terrible Specifications
5. TOCTOU/Re-entrancy

simple testing :: math

- by default, 256bit integers
    - yes, **256** bit
- Terrible decisions by the compiler
- Leads to interesting problems

simple testing :: math

```
uint i = 1;
var j = 2;
var k = i - j;
```

- JavaScript: `i` and `j` are integers, `1 - 2` is `-1`
- Solidity: `k` is `115792089237316195423570985008687907853269984665640564039457584007913129639935`

simple testing :: math

- pitched as "JavaScript-like"
    - it's not
- has nuances in semantics like C
- None of the benefits of either

simple testing :: math :: real world

- why do we care?

```
function withdraw(uint amount) {
    require(balances[msg.sender] - amount > 0);
    // ...
}
```

- amount is `uint`, cannot be < 0 ever

simple testing :: math :: real world

```
uint i = 0xdeadbeef;
for(var j = 0; j < i; j++) {
    // ...
}
```

- `j` is typed as `uint8`
- max value of `uint8` is `255`
- 255 is **always** less than `0xdeadbeef`
- loop exhaustion

simple testing :: math :: take aways

- manually size your variables
- never rely on Solidity to do the right thing (it won't)
- always verify your execution semantics and `require` statements
    - esp when variables of different sizes are in play

simple testing :: access control

- Addresses (users, wallets, contracts)
- Transactions (function calls, sending money, deploying code...)
- uses public key encryption throughout

simple testing :: access control

- by default, everything is public
- anyone on the blockchain can call/view `public` functions/data

```
function sensitive_func(...) {
    // defaults to public
    // anyone can call this
}
```

- Multiple flaws (Parity several times, Ruibixi...)
- Thousands/millions of $ in ETH
- fix? `... sensitive_func(...) private {`

simple testing :: access control

- like web apps, admin functionality
- more complex than `public` / `private` dichotomy
  - admin **must** remotely call something? `public`
- fix? ownership check

simple testing :: access control

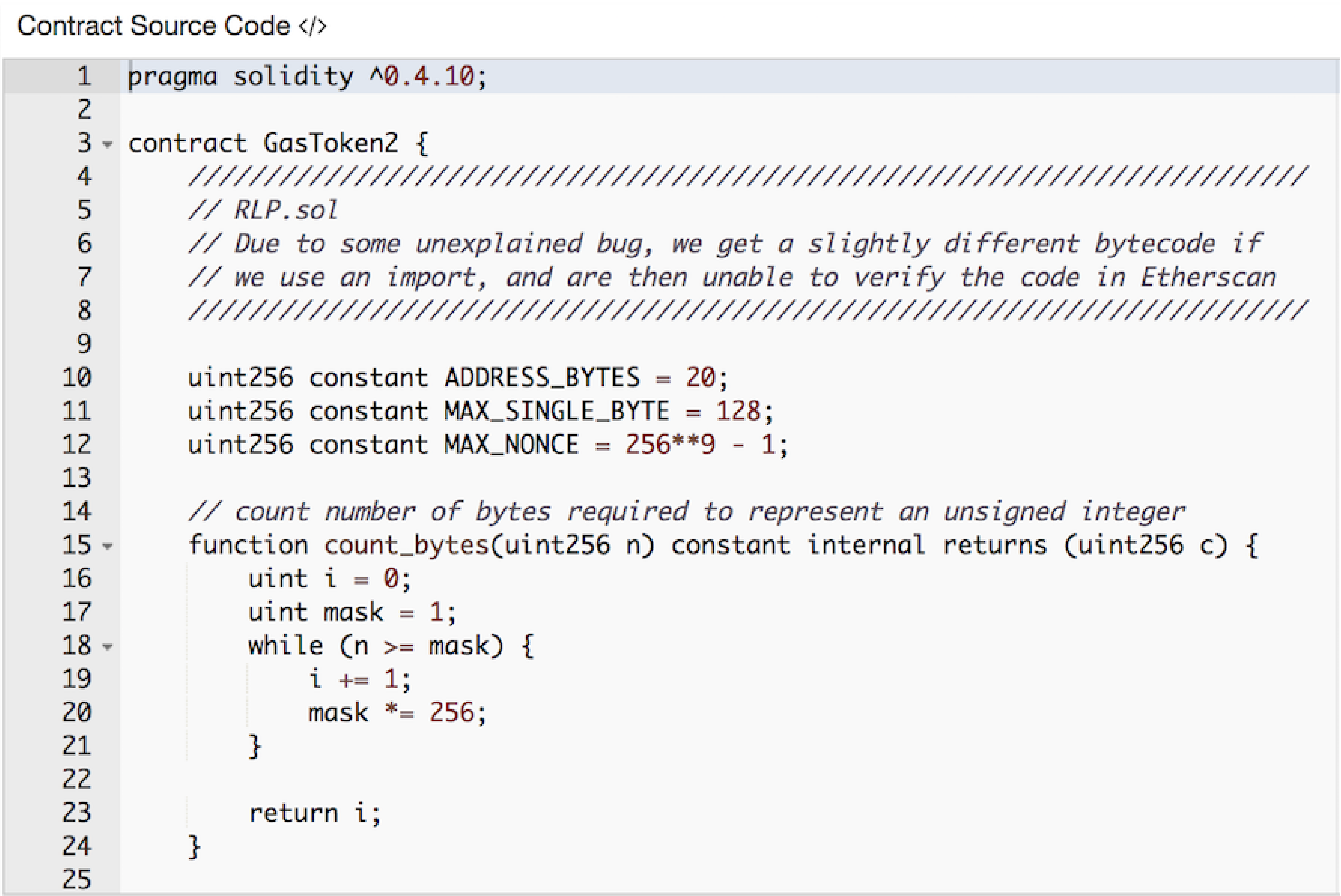
```
contract Foo {
    address owner;

    modifier isOwner() {
      require(msg.sender == owner);
      _;
    }
    // ...
    function sensitive_function() public isOwner {
       // ...
    }

    function another_sensitive_function() public {
       // ... whoops ...
    }
}
```

simple testing :: AC :: take aways

- review contracts for public/private
- understand when things should be public, but restricted
- ensure that you actually have methods of setting `owner` *sighs*

simple testing :: secrecy

- blockchain is meant to be public
- even `private` in Solidity isn't *secret*
- again... literally meant to be **public**
- sites like etherscan exist for exploration
- unconfirmed blocks are public



Contract Source Code </>

```
pragma solidity ^0.4.10;

contract GasToken2 {
    ///////////////////////////////////////////////////////////////////////////
    // RLP.sol
    // Due to some unexplained bug, we get a slightly different bytecode if
    // we use an import, and are then unable to verify the code in Etherscan
    ///////////////////////////////////////////////////////////////////////////

    uint256 constant ADDRESS_BYTES = 20;
    uint256 constant MAX_SINGLE_BYTE = 128;
    uint256 constant MAX_NONCE = 256**9 - 1;

    // count number of bytes required to represent an unsigned integer
    function count_bytes(uint256 n) constant internal returns (uint256 c) {
        uint i = 0;
        uint mask = 1;
        while (n >= mask) {
            i += 1;
            mask *= 256;
        }

        return i;
    }

```

simple testing :: secrecy

- unconfirmed blocks are public
- you can see these blocks, including data
- multiple methods of front running, theft, &c.
- takeaway? treat the blockchain as public, nothing is secret

simple testing :: terrible specifications

- Etheum Request (for) Comments or Ethereum Impl Proposal
- poorly specified
  - seriously, uses words like "could"
- written by "enthusiasts"
  - little understanding of impact
- let's pick on one: ERC20 Token Standard

simple testing :: terrible specifications

- ERC20 defines simple token interace
    - tokens are a type of fungible asset
- fairly simple (`transfer`, `approve`, &c.)
- **no** formal specification
- **no** formal test suite
- **at least** 710 on the market
    - largest market cap: 5.02b USD

simple testing :: terrible specifications

- simple interface => complex problems
- codifies a front running attack
- codifies a TOCTOU attack (next section)
- **Per the spec** you can't fix anything
- takeaway? soooo... good luck with guidance

simple testing :: re-entrancy

- anyone can call anything
- at any time
- certain core functionality returns control to other contracts
- TOCTOU bugs... TOCTOU bugs everywhere
    - Time of Check vs Time of Use

simple testing :: re-entrancy

- simple calls return control elsewhere
- `call`, `delegatecall`, `send`, `transfer` &c.
- returning to attacker then modifying state is the attack

simple testing :: re-entrancy

- simple payment system
- can pay an owner

```
function vulnerable_payout(uint payee) public {
    // book keeping
    accounts[payee].transfer(paybook(payee));
    setpaybook(payee, 0);
}
```

- `transfer` returns control to the calling contract...

simple testing :: re-entrancy

normal flow:

- Client: `Bank.vulnerable_payout(my_address);`
- Bank: does bookkeeping, *implicitly* calls `Client.default_function`
- Client: *recieves funds*
- Bank: sets client balance to 0

simple testing :: re-entrancy

attacker flow:

- Attacker: `Bank.vulnerable_payout(attacker_address);`
- Bank: does bookkeeping, *implicitly* calls `Attacker.default_function`
- Attacker: *receives funds*, **calls** **`Bank.vulnerable_payout...`**
- Bank: does bookkeeping *implicitly* calls `Attacker.default_function`
- ... until all funds are drained

simple testing :: re-entrancy

- Not even rare
    - SpankChain (sorry, not my name): two weeks ago
    - DAO Hack: 2016
    - so many in between
- Painfully simple fix
    - and yet...

```
function fixed_payout(uint payee) public {
    // book keeping
    uint payout = paybook(payee);
    setpaybook(payee, 0);
    accounts[payee].transfer(payout);
}
```

simple testing :: take aways

- terrible environment
- terrible languages
- terrible compilers
- and then you die

actually testing

downside?

- the worst parts of tech **PLUS**
- the worst parts of fintech **PLUS**
- minimal market regulation/oversight

upside?

- contracts are small (perfect for formal specification)
- lots of engineering effort in tooling
    - ... by people outside the core solidity team...

actually testing :: tooling

Tool	Type	Traditional	Blockchain	Time
Slither, Mongoose	Static Analysis	Yes, lots of noise	Yes	Minutes
Echidna	Property Checker	Sometimes	Yes	Hours
Manticore, Mythril	Symbolic Execution	No, Path explotion	Yes	Days
K Framework, Lem, &c.	Formal Correctness Proof	No, time	Sometimes	Weeks

actually testing :: take aways

- manual code/app review
- tooling (writing tests, constraining symbolic execution, &c)
- subject matter expertise (asset backed derivatives often, shorting, &c.)
- regulatory expertise (minimal currently, NYSDFS NYCRR 500)
- combined with traditional infosec (Docker, environments, secret management, &c.)
- combined with multiple languages & frameworks (lots of bespoke languages, frameworks, semi-frameworks, &c.)

what is this, a blockchain for ants?

thanks! questions?