bitcoin

CS1699: Blockchain Technology and Cryptocurrency

8. Mechanics of Bitcoin

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Bitcoin Consensus

- Append-only ledger (via blockchain)
- Decentralized consensus (via consensus mechanisms)
- Validation of transactions (via miners & proof-of-work)

Account-Based Ledger:

Fungible Coins – Signatories And Account Balances

BLOCK	**ACTION**	SIGNATORY
1	CREATE 25 COINS; TRANSFER ALL TO ALICE	MINER
2	TRANSFER 10 COINS TO BOB	ALICE
3	TRANSFER 5 COINS TO CAROL	ALICE
4	TRANSFER 2 COINS TO DAN	BOB

Account-Based Ledger

- Accounts (could still be delineated by public keys) would have a certain number of bitcoins
- A transaction would e.g. take five coins from Alice and give five coins to Bob

Account-Based Ledger:
Efficiency Issues

Q: Is the transaction in red valid? A: May have to track back to genesis block!

BLOCK	ACTION	SIGNATORY
1	CREATE 25 COINS; TRANSFER ALL TO ALICE	MINER
2	TRANSFER 10 COINS TO BOB	ALICE
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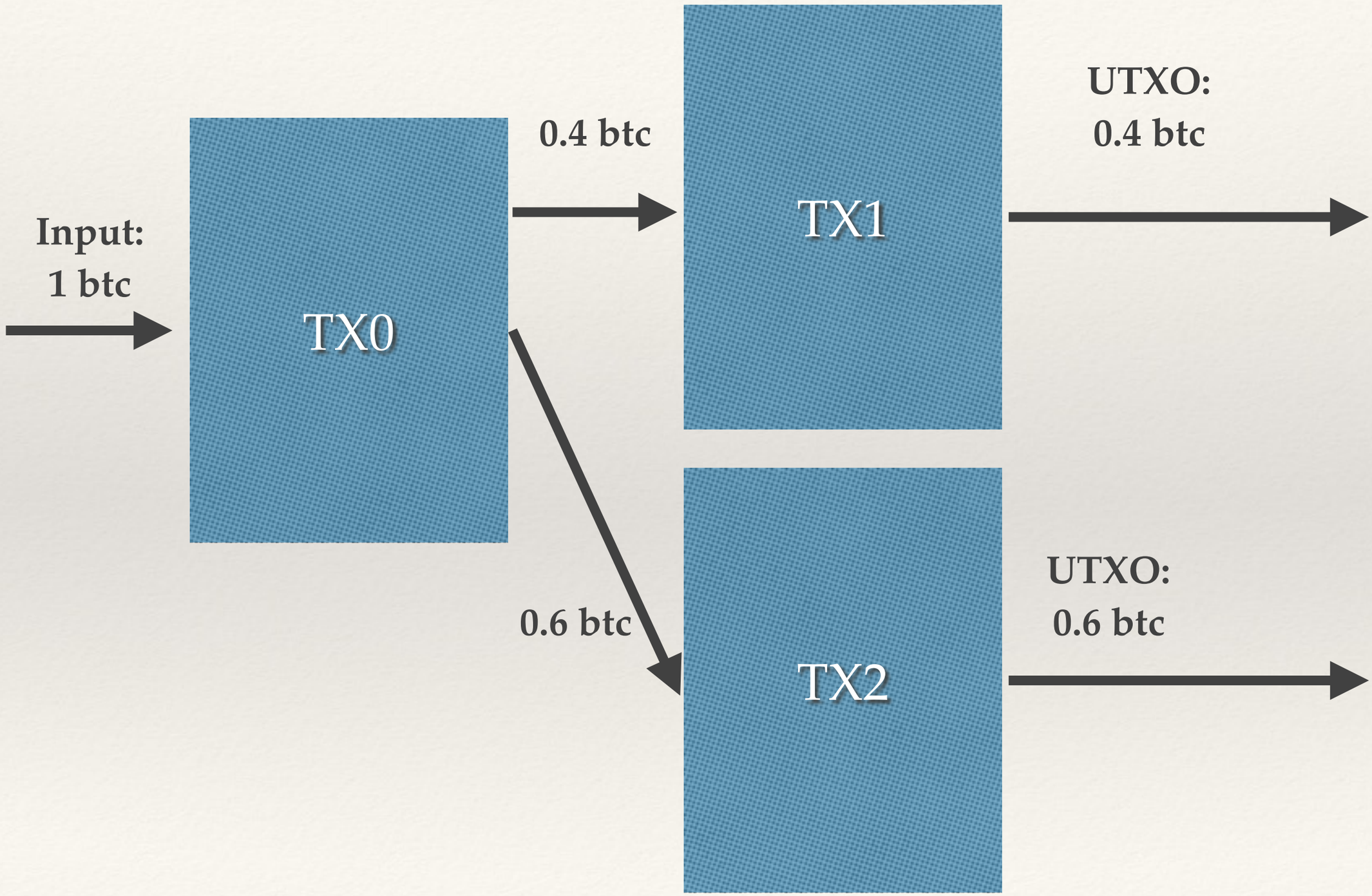
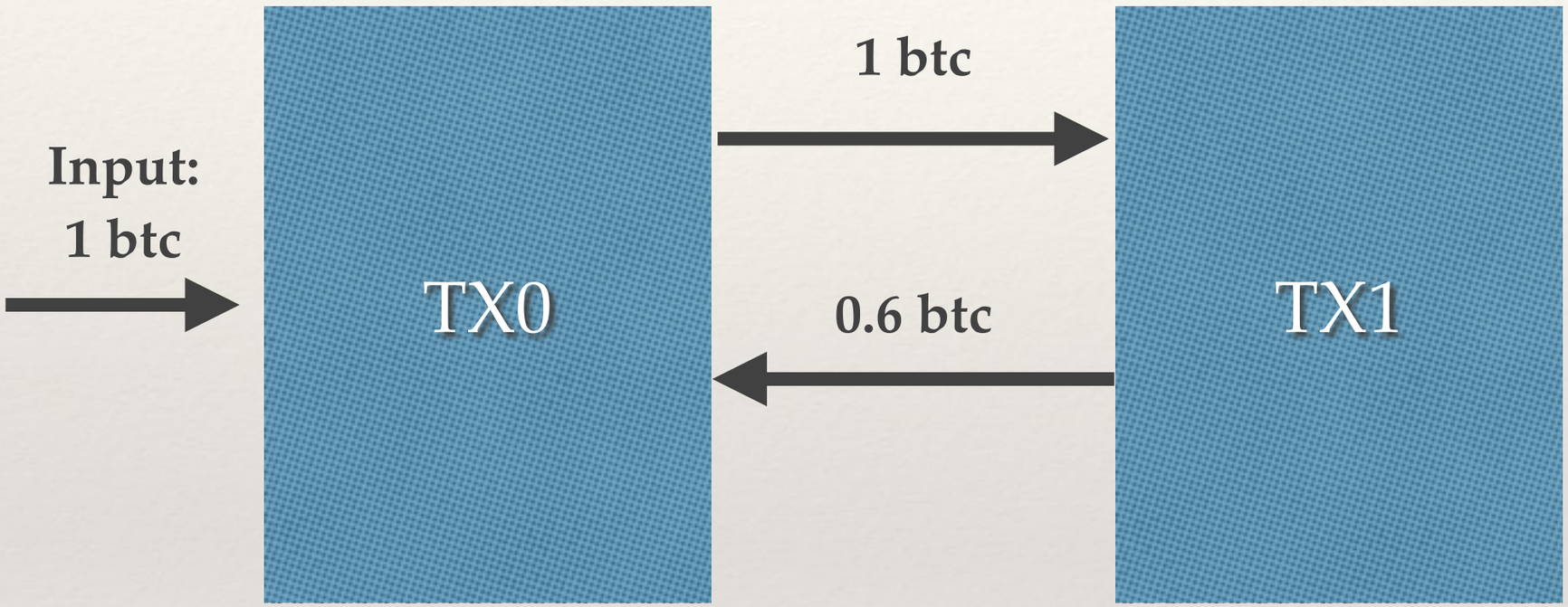
Transaction-Based Model (Bitcoin)

- Every transaction has ***valid*** inputs and outputs
  - Properly signed
  - Inputs must be consumed entirely
  - Total value of outputs < inputs
- "Accounts" are just a collection of *UTXOs (unspent transaction outputs)*

Transactions Behind the Scenes

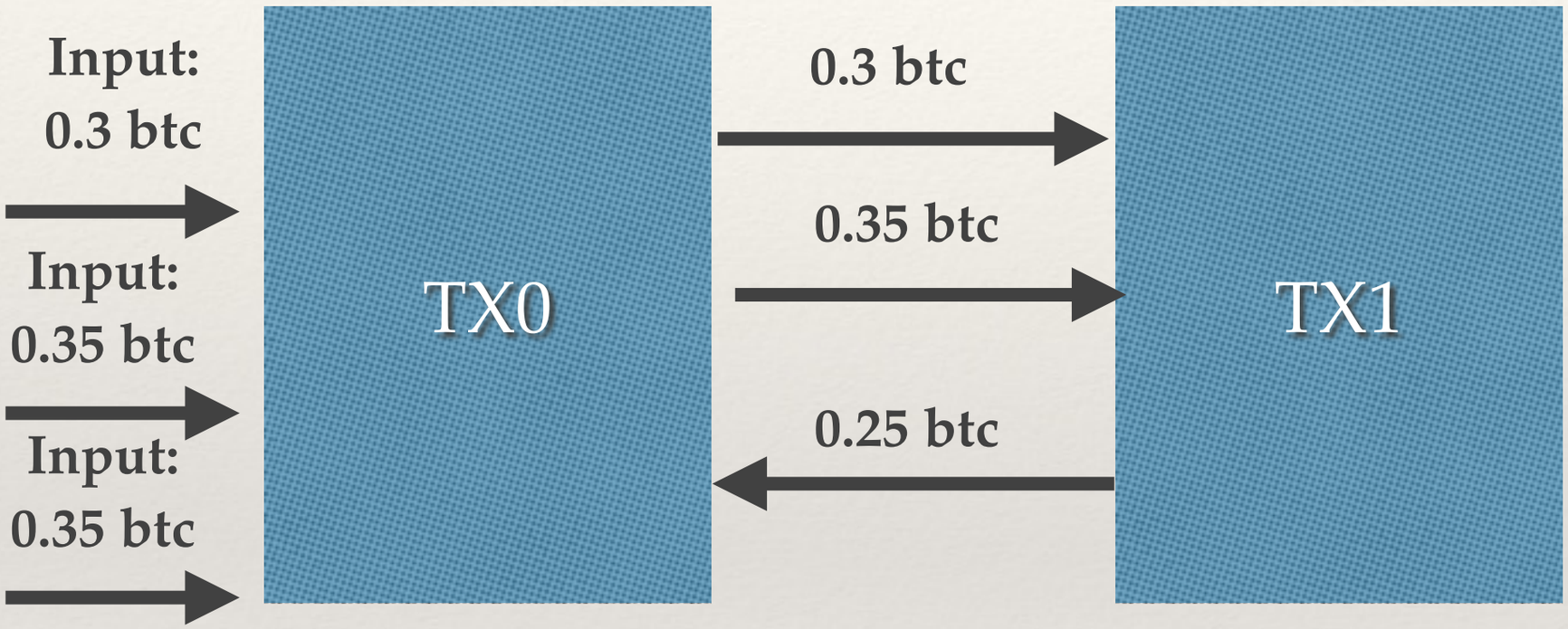


Splitting TXs - Sending 0.4 btc



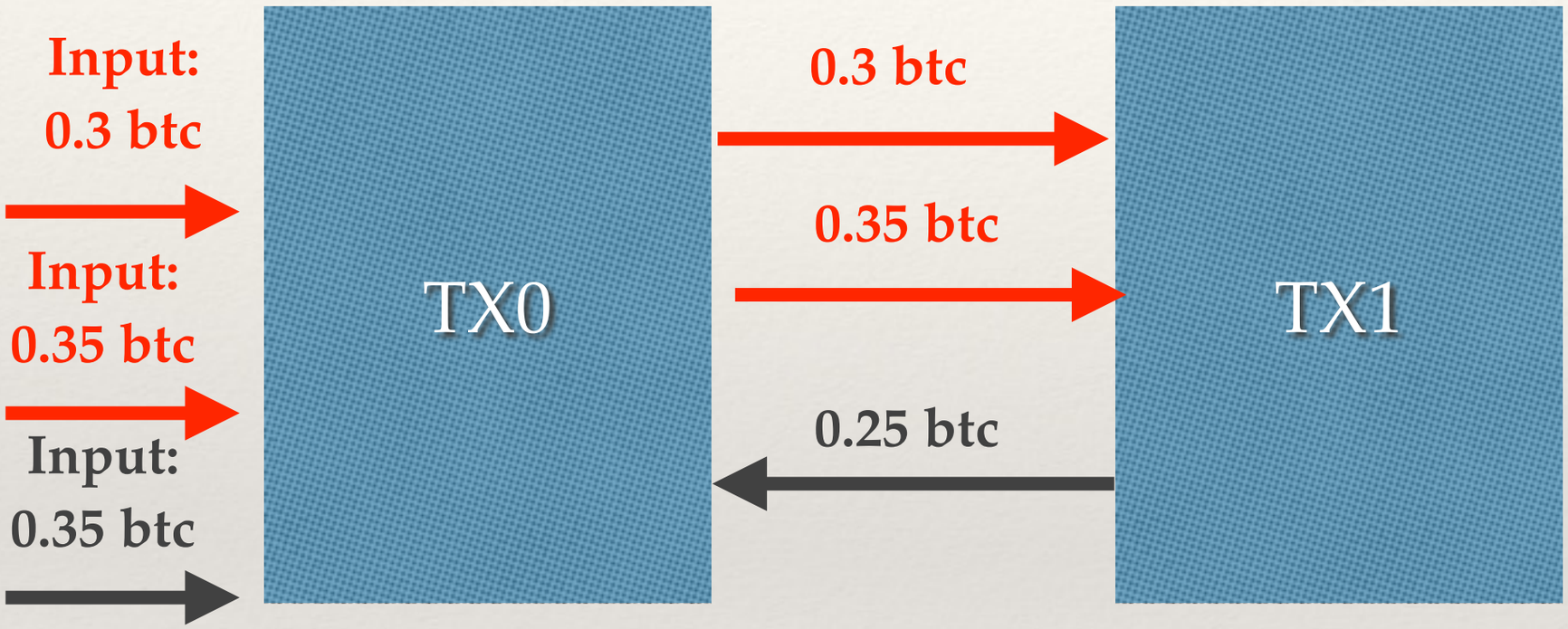
Multiple TX Input/Output

Sending 0.4 btc



Spent vs Unspent Tx's

Sending 0.4 btc



Generator of TX0 now has two UTXOs: 0.35 btc and 0.25 btc

Most bitcoin wallets will just show you 0.35 + 0.25 = 0.6 btc

1 btc - 0.4 btc = 0.6 btc

Transaction-Based Ledger

BLOCK	INPUTS/OUTPUTS	SIGNATORY
1	***INPUTS:*** ∅ ***OUTPUTS:*** **25 -> ALICE**	N/A
2	***INPUTS:*** **1[0]** ***OUTPUTS:*** **10 -> BOB; 15 -> ALICE**	ALICE
3	***INPUTS:*** **2[1]** ***OUTPUTS:*** **15 -> CAROL; 10 -> ALICE**	ALICE
4	***INPUTS:*** **2[0]** ***OUTPUTS:*** **10 -> DAN; 8 -> BOB**	BOB

Verification Only Back Until Coin Creation

BLOCK	INPUTS/OUTPUTS	SIGNATORY
1	***INPUTS:*** ∅ ***OUTPUTS:*** **25 -> ALICE**	N/A
2	***INPUTS:*** **1[0]** ***OUTPUTS:*** **10 -> BOB; 15 -> ALICE**	ALICE
3	***INPUTS:*** **2[1]** ***OUTPUTS:*** **15 -> CAROL; 10 -> ALICE**	ALICE
4	***INPUTS:*** **2[0]** ***OUTPUTS:*** **10 -> DAN; 8 -> BOB**	BOB

Outputs Must Be Entirely Consumed

BLOCK	INPUTS/OUTPUTS	SIGNATORY
1	*INPUTS:* ∅ *OUTPUTS:* 25 -> ALICE	N/A
2	*INPUTS:* 1[0] *OUTPUTS:* 10 -> BOB; 15 -> ALICE	ALICE
3	*INPUTS:* 2[1] *OUTPUTS:* 15 -> CAROL; 10 -> ALICE	ALICE
4	*INPUTS:* 2[0] *OUTPUTS:* 10 -> DAN; 8 -> BOB	BOB

Change addresses

Joint Payment - 10 Bitcoin To Carol From Bob & Alice

BLOCK	INPUTS/OUTPUTS	SIGNATORY
1	*INPUTS:* ∅ *OUTPUTS:* **25 -> ALICE**	N/A
2	*INPUTS:* **1[0]** *OUTPUTS:* **10 -> BOB; 15 -> ALICE**	ALICE
3	*INPUTS:* **2[0], 2[1]** *OUTPUTS:* **10 -> CAROL; 10 -> ALICE; 5 -> BOB**	ALICE, BOB

A Look at a Raw Block

- That was conceptual - let's look at an actual block (in JSON - key: value format)
- Blocks generally indicated by hash or height
- Latest Block (as of Sunday, 3:38 PM EST) 000000000000000000f462731f00e4e600469893990c896dba86fa5fb0c1990
- https://blockchain.info/rawblock/000000000000000000f462731f00e4e600469893990c896dba86fa5fb0c1990

Anatomy of a Block

- NOTE: The textbook's description of blocks is slightly outdated, in at least two ways:
  - Block metadata is slightly off due to SegWit
  - Does not take into account BIP-34 changes
- Information in these slides is correct as of the slides' creation date! Bitcoin block structure is liable to change even more in the future.

Anatomy of a Block

- **Metadata**
  - ***Information about the block (size, block number, Merkle root, nonce, etc.)***
- **Transactions**
  - ***Array of all transactions in this block***
  - ***Number of transaction must be >= 1! (coinbase transaction always present)***

Block Metadata


```
"hash":"00000000000000000f462731f00e4e600469893990c896dba86fa5fb0c1990",
"ver":536870912,
"prev_block":"00000000000000000005f3c0b802ac8b85488d4f88d7a60a20ee4ea3984c1394",
"mrkl_root":"a65164b813a723570c7d65fad61987036a566d341a0efce4872836a72cb0b934",
"time":1537728446,
"bits":388454943,
"fee":5310126,
"nonce":2278125992,
"n_tx":1236,
"size":498546,
"block_index":1724700,
"main_chain":true,
"height":542728,
"received_time":1537728446,
"relayed_by":"0.0.0.0",
```

Compare to Genesis Block

Missing received_time and relayed_by attributes , added later…


```
"hash":"000000000019d6689c085ae165831e934ff763ae46a2a6c172b3f1b60a8ce26f",
"ver":1,
"prev_block":"0000000000000000000000000000000000000000000000000000000000000000",
"mrkl_root":"4a5e1e4baab89f3a32518a88c31bc87f618f76673e2cc77ab2127b7afdeda33b",
"time":1231006505,
"bits":486604799,
"fee":0,
"nonce":2083236893,
"n_tx":1,
"size":285,
"block_index":14849,
"main_chain":true,
"height":0,
```


https://blockchain.info/rawblock/000000000019d6689c085ae165831e934ff763ae46a2a6c172b3f1b60a8ce26f

Transactions

- **Metadata**
  - *Information about the transaction (hash, size, number of inputs, number of outputs, lock time)*
- **Inputs**
  - *Previous output (all inputs are previous outputs, except coinbase) to be consumed, signature*
- **Outputs**
  - *Value of output, a Script script (note: no recipient address directly specified here!)*

Transaction Metadata


```
"weight":900,
"time":1537728260,
"tx_index":376130660,
"vin_sz":1,
"hash":"1887e38e63ecfcb1490b4adb21b6410b4
e60454fe09502fb2aa2503b69f3e3c0",
"vout_sz":2,
"relayed_by":"0.0.0.0",
"lock_time":542727,
“ver":2"
"size":225,
```

Transaction Inputs

Where is the signature?


```
"inputs":[{
  "sequence":4294967294,
  "witness":"",
  "prev_out":{
    "spent":true,
    "tx_index":376128954,
    "type":0,
    "addr":"17pGR12CGLzhiMzUr18RZzVoEoaUbT8LTa",
    "value":3108223,
    "n":1,
    "script":"76a9144ac12bf46ceb296f3c98d19186088b12cb21162688ac"
  },
"script":"473044022063bfe6f169acd12f4329e6e63b09c1c79856ee07fb0d1
29f9eeb10eccb1ec350022037c94f02090b27047bc882360b4a832b0eaef21bd4
ce239f5332615c5889fec0012103e78877a7225046ff0f9de99d91d0632f1411f
0ad8e7d4e70622bfcc39b616573"
}],
```

Transaction Outputs


```
"out":[{
         "spent":true,
         "tx_index":376130660,
         "type":0,
         "addr":"1CXpe1tQQKpeUc89kUqQC2FuiZc5u5AnTa",
         "value":1017919,
         "n":0,
         "script":"76a9147e7da0fb7c6edce44f0e88b8ea6d0d933d4bc75888ac"
      },{
         "spent":true,
         "tx_index":376130660,
         "type":0,
         "addr":"15JLH7qkwKNJMJfCYrye96hNKqx8SjPkys",
         "value":2044878,
         "n":1,
         "script":"76a9142f27aab77d5e5ebc1853076c29b318c032d9375788ac"
      }]
```

Programmable Money

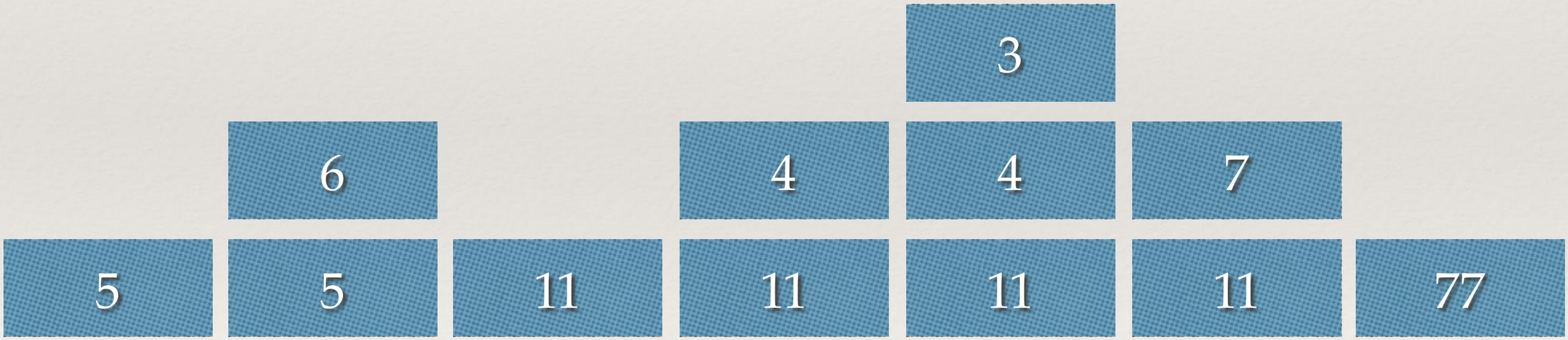
- Bitcoin is programmable money!
- A transaction specifies a script to execute
- The VAST majority of scripts just move previous transaction outputs to a new address, we can (theoretically) do anything that the Script language lets us
  - Although other nodes may have something to say about that…

Script - The Bitcoin Scripting Language

- Inputs contain scripts (scriptSig attribute) and outputs contain scripts (scriptPubKey) - concatenated and executed
- Script
  - Stack-based language
  - Not Turing-complete (purposely limited)
  - Native support for complex cryptographic functions
  - Note: you may see a hex version of this in a blockchain explorer - think of it as the actual bytecode instead of helpful mnemonics

Stack-Based Programming

- Reverse Polish Notation Calculator
- 5 6 + 4 3 + *



Why Not Turing-Complete?

- Would never be able to determine if program would end (Halting Problem)
- Could force arbitrary-length execution on validating nodes (denial-of-service attack)
- In practice, only a very few kinds of scripts are allowed by most validating nodes (whitelist)
- See Ethereum (especially concept of *gas*) for one way to have a Turing-complete language running on a blockchain

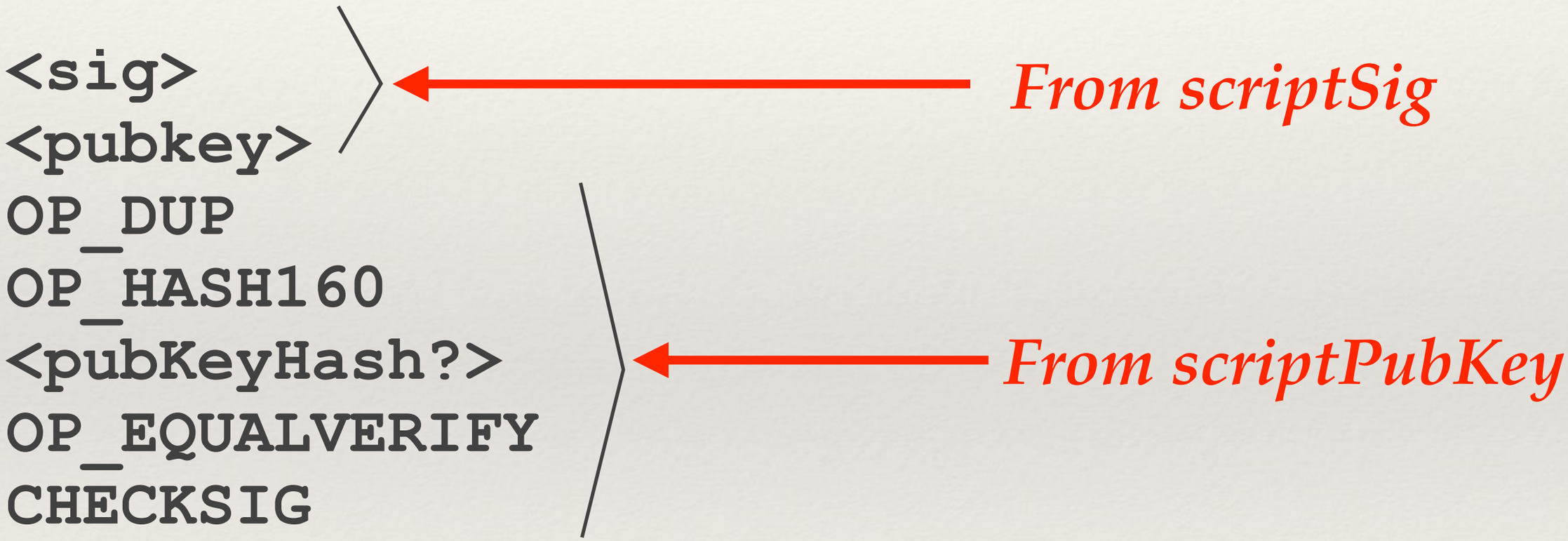
Common Script Commands

- ***VALUE*** - *Put value on top of stack*
- **OP_DUP** - *Duplicate top item on stack*
- **OP_HASH160** - *Hash value on top of stack with SHA-256, then hash again with RIPEMD-160 and put final value back on stack*
- **OP_EQUALVERIFY** - *Return true if top two values of stack are equal, return false and mark transaction if not*
- **OPEN_CHECKSIG** - *Check that the input signature is valid using the input public key for the hash of the current transaction*

Script Execution Walkthrough

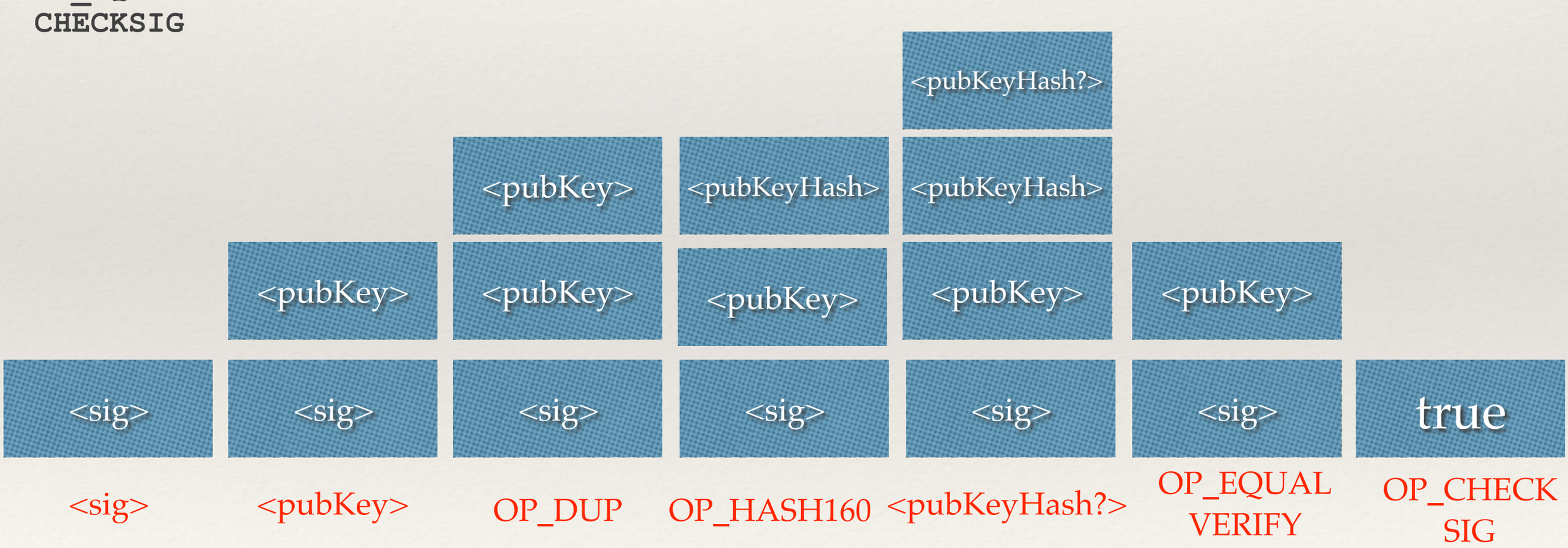
- Concatenate scriptSig and scriptPubKey
- Execute script

Script Execution Walkthrough



Basic Bitcoin Script

```
<sig>
<pubkey>
OP_DUP
OP_HASH160
<pubKeyHash?>
OP_EQUALVERIFY
CHECKSIG
```



Proof Of Burn

- Proof of burn establishes that a transaction(s) has been destroyed
- Why?
  - Destroy bitcoin to generate some other token
- How?
  - Add an OP_RETURN opcode to the scriptPubKey of the transaction - script will always return false

P2PKH vs P2SH

- P2PKH - *Pay to Public Key Hash (remember addresses are actually hashes of hashes of a public key, so "pay to address")*
- P2SH - *Pay to Script Hash (allow easy multisig or other more complex transactions - not part of original Bitcoin spec, added as BIP-16 in 2012)*
- Additional transaction types:
  - *P2PK - "Pay to Public Key" - generally not used since 0.3, not supported since 0.8*
  - *P2WPKH - "Pay To Witness Public Key Hash" - SegWit (Segregated Witness) transaction*