BITCOIN, TRANSACTIONS UTXO MODEL

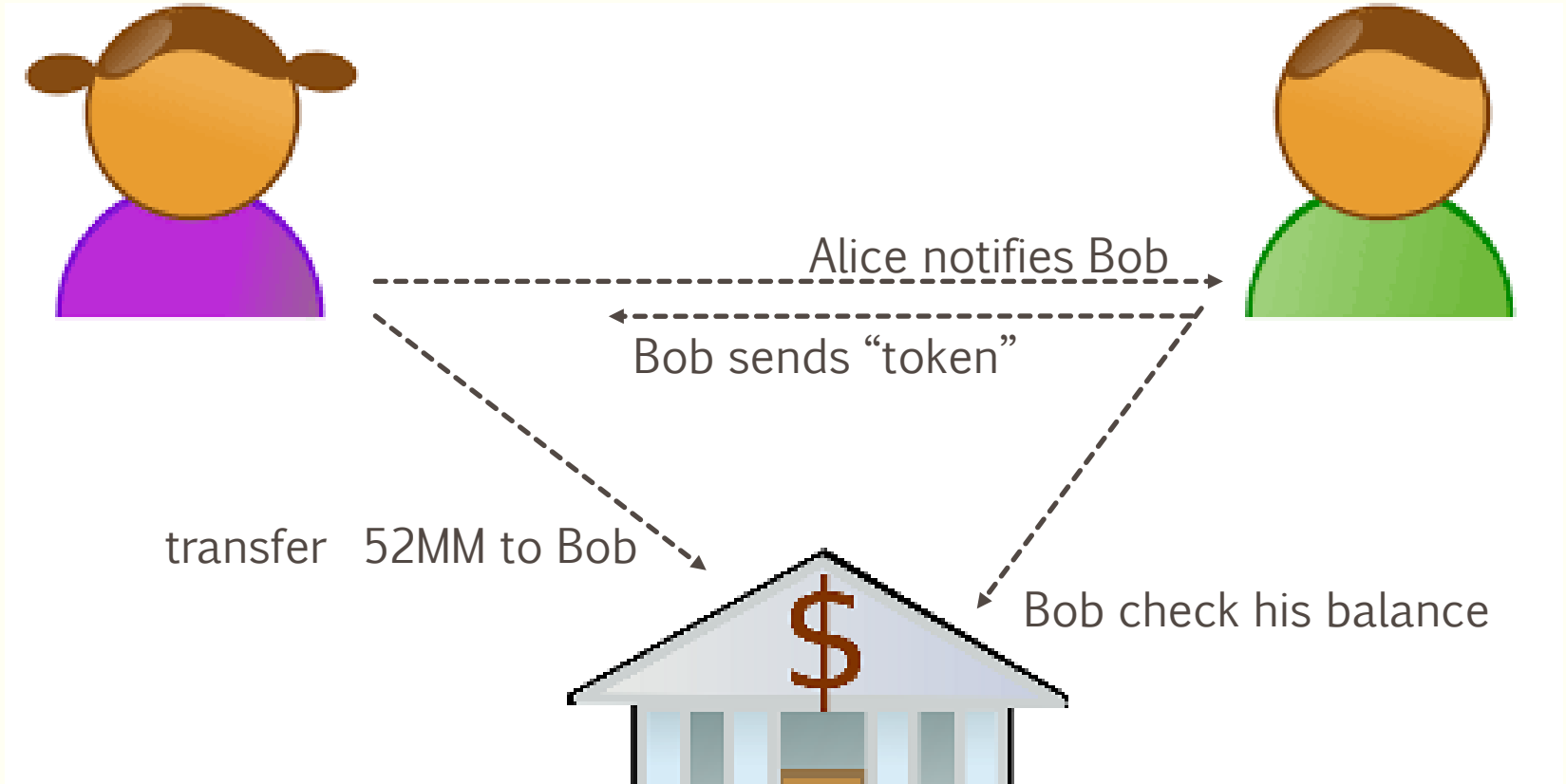
Blockchain technologies, **lecture 2**

Course overview

- Blind signatures/zero-knowledge proofs
- UTXO model
- Transactions

BLIND SIGNATURES

Bitcoin transactions' history

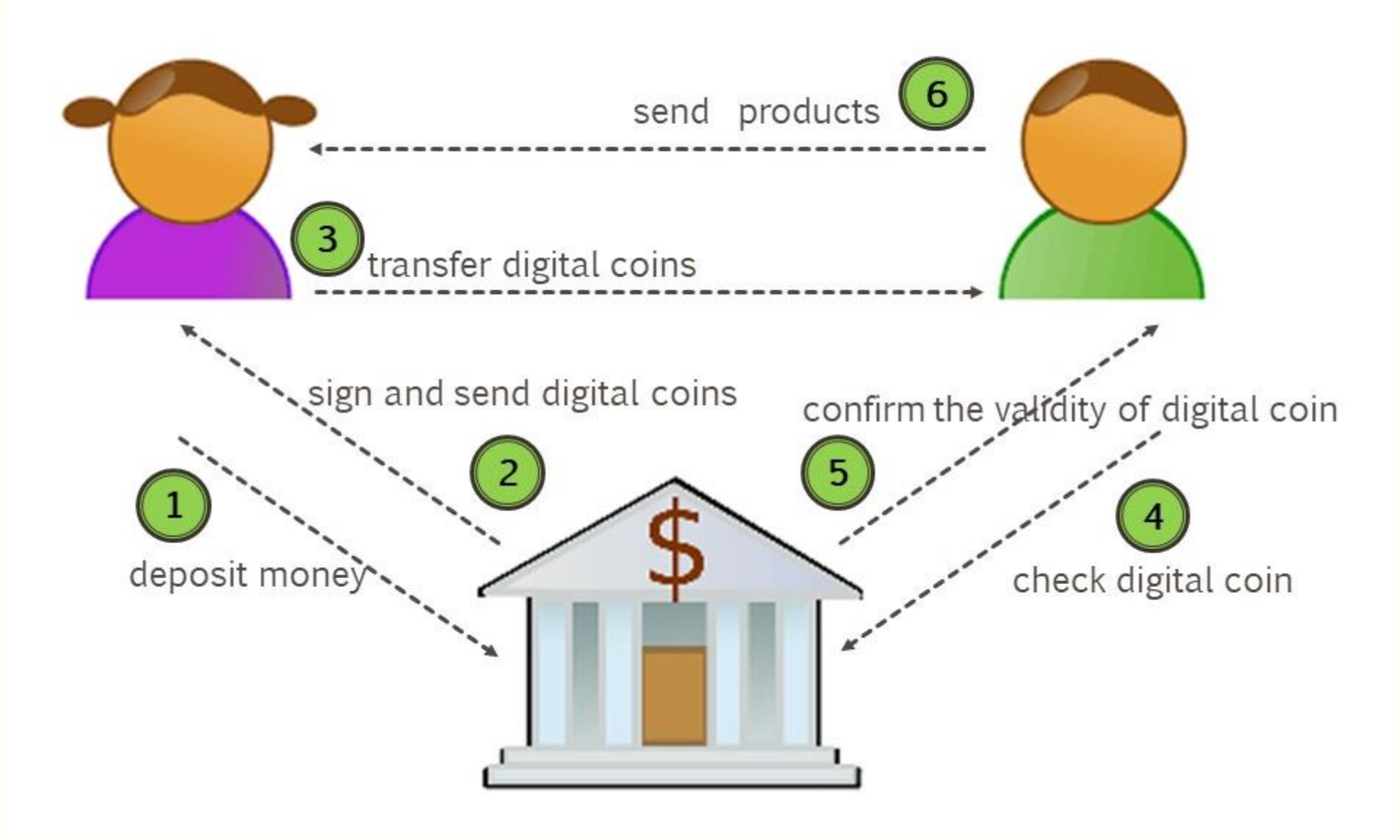


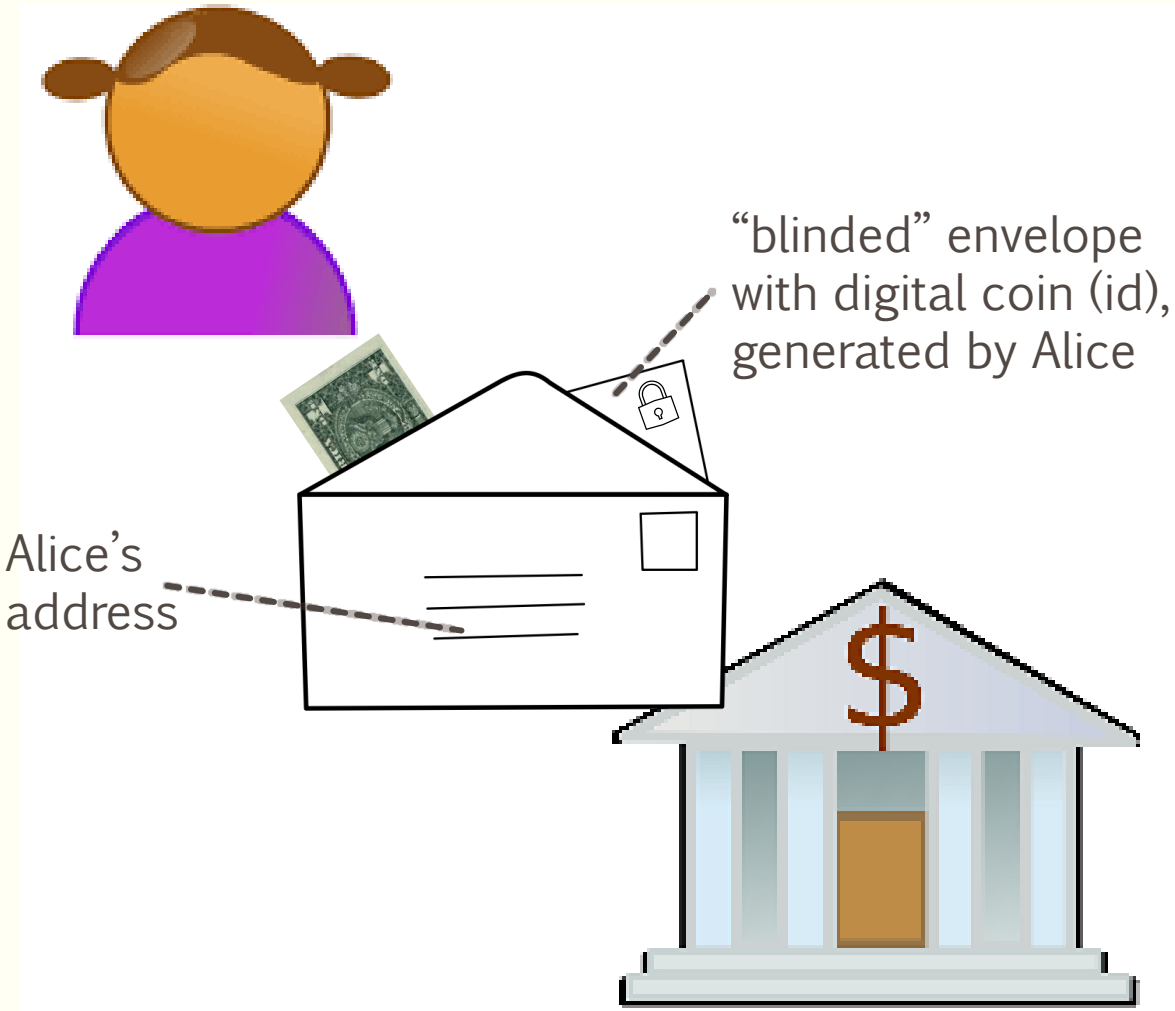
account	balance
Alice	$72,000,000
Bob	$0

account	balance
Alice	$20,000,000
Bob	$52,000,000

traditional payments

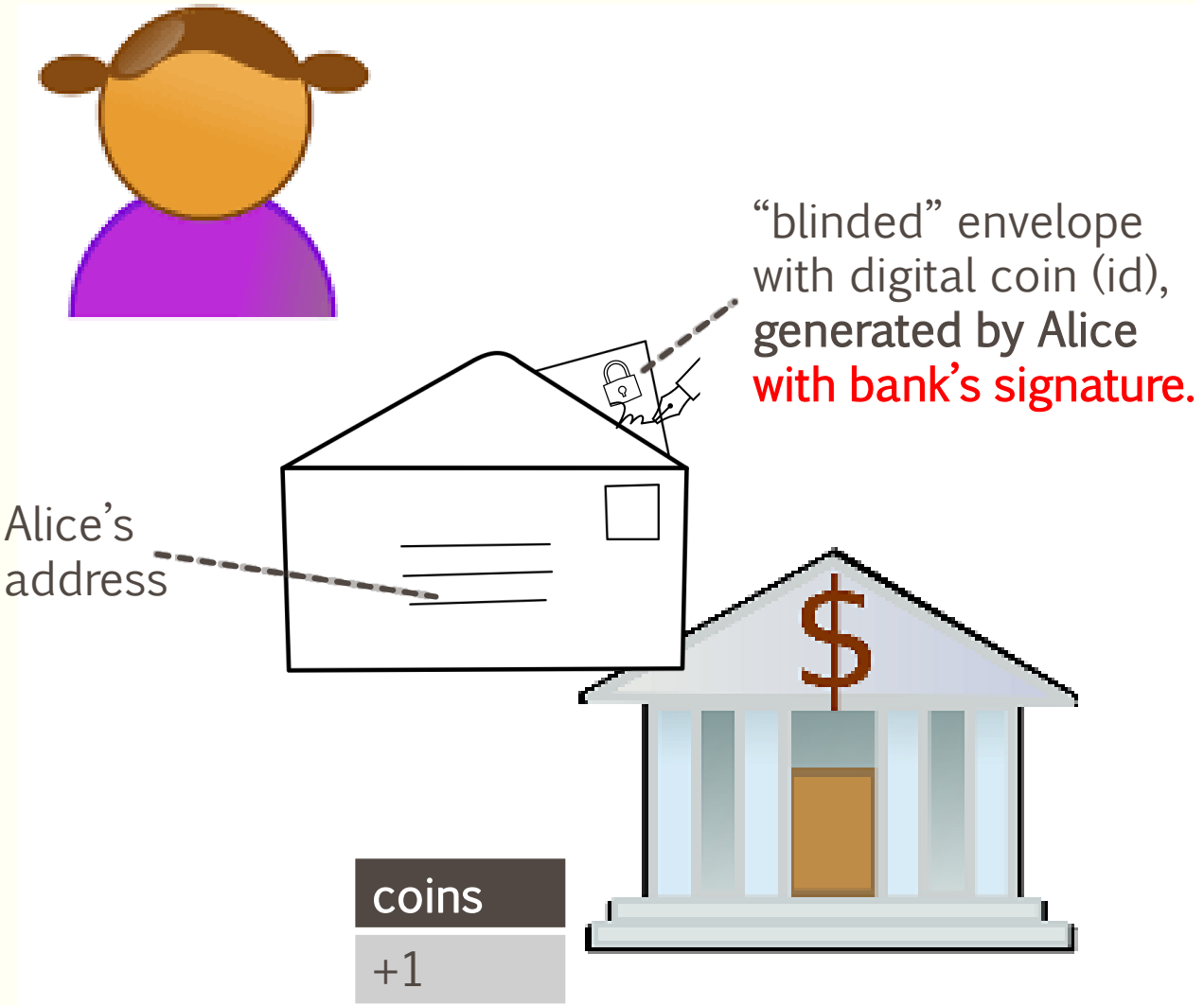
- Single point of failure, not peer-to-peer.
- Delayed or refused transactions.
- Security and privacy issues.
- **Digital payments**


send products
6
3
transfer digital coins
sign and send digital coins
2
confirm the validity of digital coin
5
1
deposit money
4
check digital coin
$



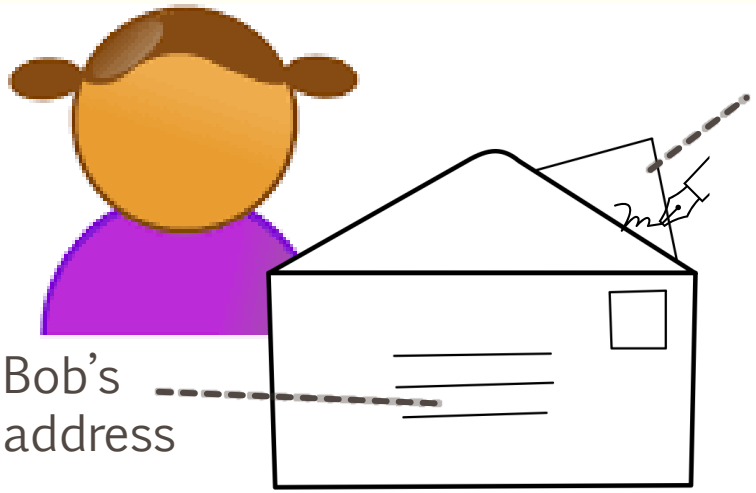
Chaum e-cash
Blind signatures (1983)

- Alice sends a dollar to the bank and a blinded id, representing the digital coin she will be authorized to use in further transactions.
- Imagine an encrypted envelope or carbon paper nested in an envelope with Alice's address on it.
- Envelope can encrypt coins or voting ballots.



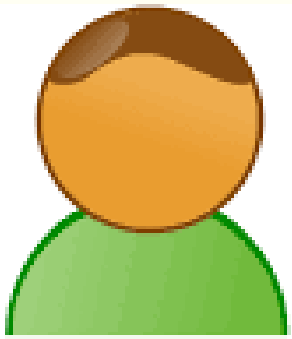
Chaum e-cash (1983)
Blind signatures

- Bank is not able to discover the id, it can only register how many coins are signed and sign Alice's blinded id.
- Bank has no record of Alices balance or transactions.
- Alice can recognize/recover the id she generated.
- Anyone can recognize the signature of the bank.



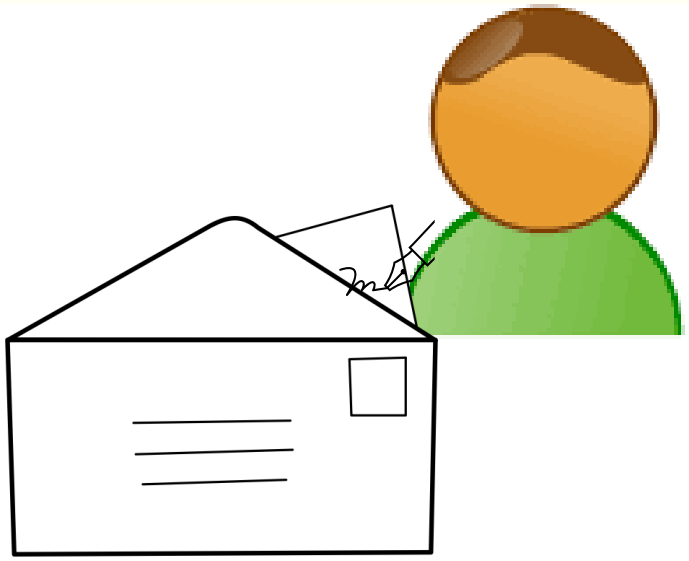
digital coin (id), generated by Alice with bank's signature.

Bob's address



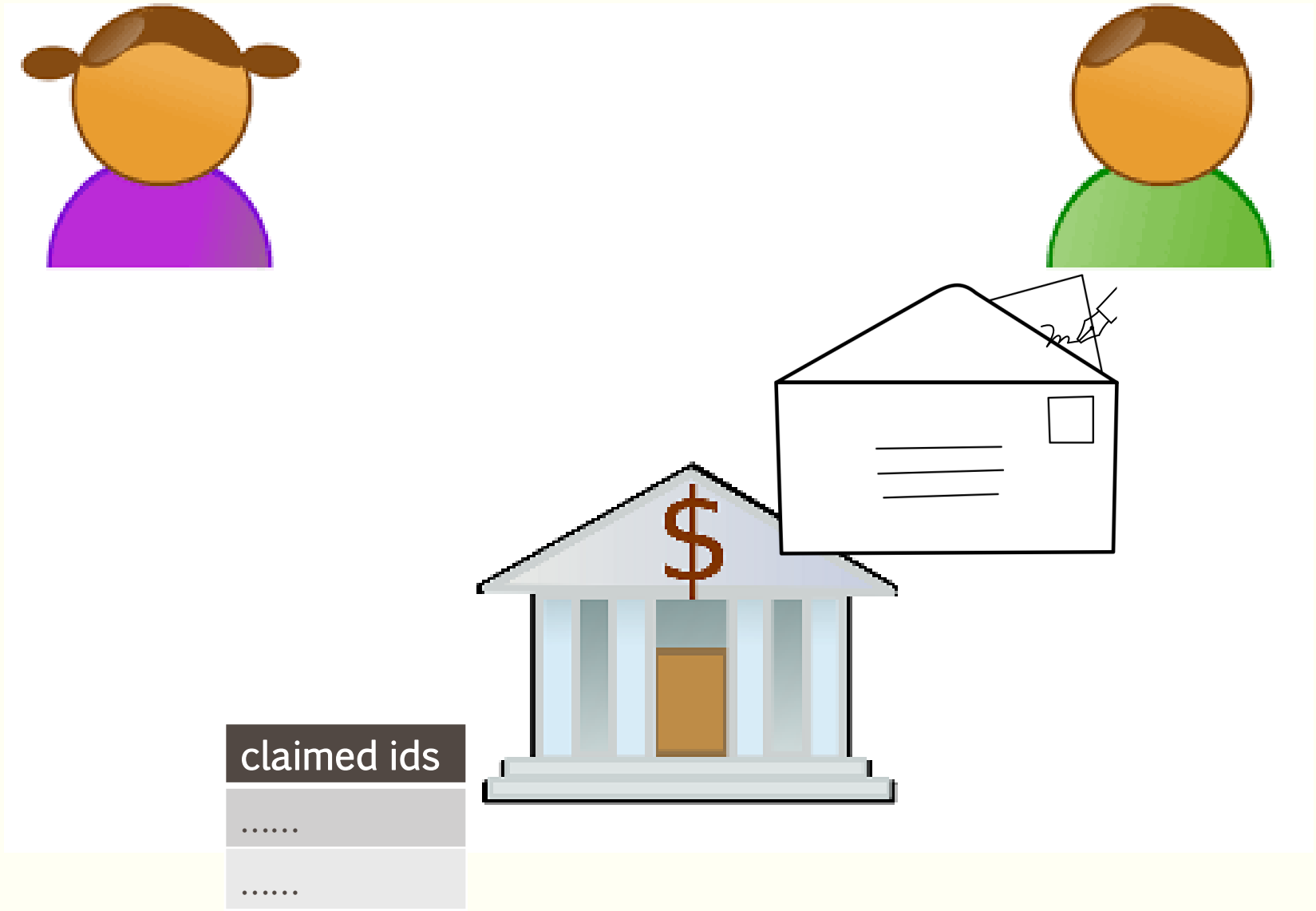
Chaum e-cash
Blind signatures

- Alice sends the signed, **not blinded digital coin to Bob**.



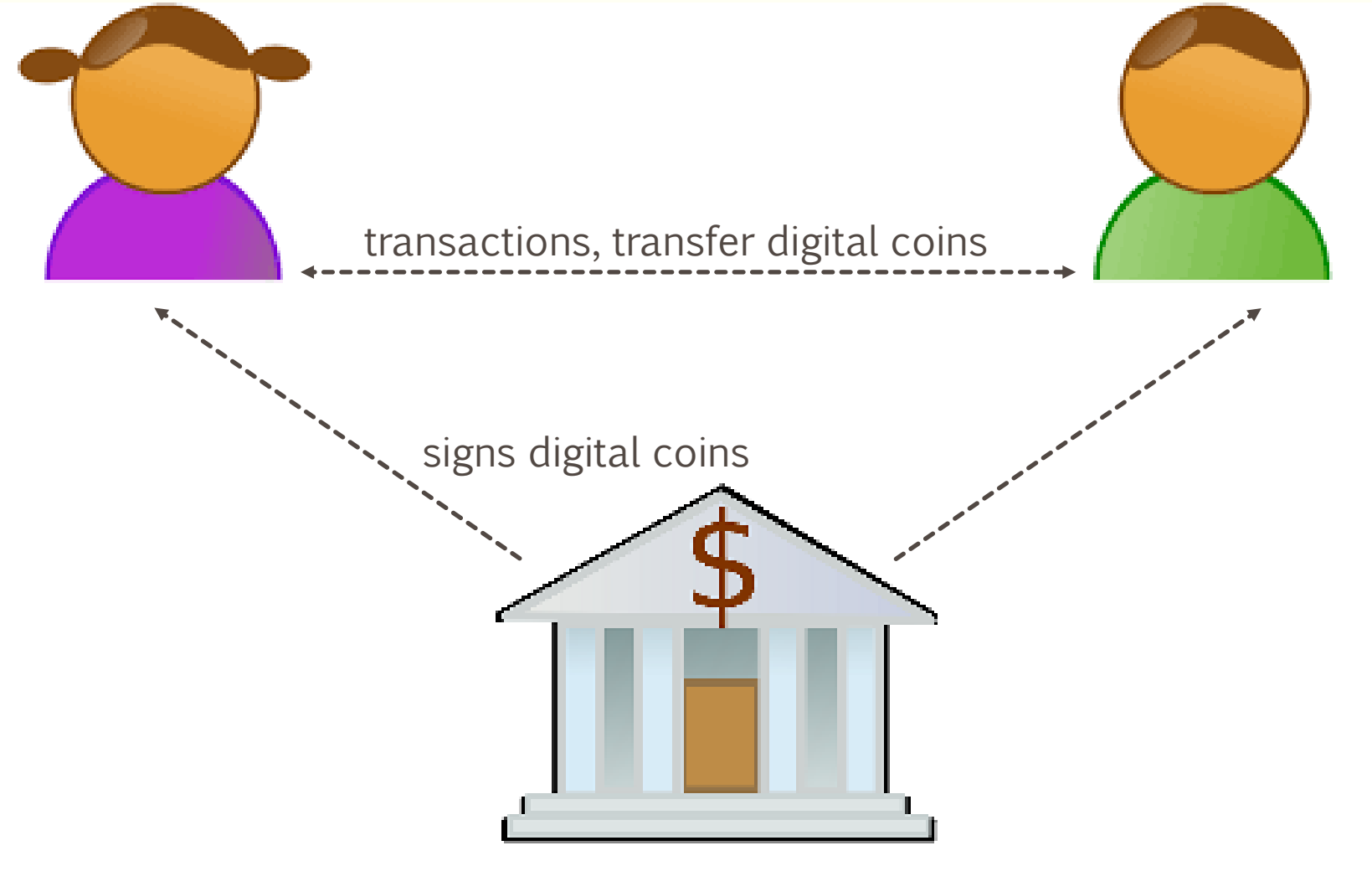
Chaum e-cash
Blind signatures

- Bob receives from Alice the id signed by the bank.
- Bob recognize the signature of the bank.



Chaum e-cash
Blind signatures

- Bobs claims 1$ in return for his digital coin.
- Bank registers the id.
- Bank doesn't know that the id came from Alice and it has no information about the transaction.
- Bank is able to detect **double spending** by keeping track of the ids claimed before.



Chaum e-cash
Blind signatures

- Peer-to-peer, but not decentralized.
- bank signs all digital coins.
- Advantages:
  - Privacy.
  - Digital payments.
  - Double spending detection.

RSA

- RSA: find three large positive integers e, d, and n, such that: knowing e and n (the public key), it can be computationally difficult to find d (the private key);
- Anyone knowing the public key may send encoded messages that can be decoded only by someone knowing the private key, provided that $(m^e)^d = m \pmod n$.

1. Choose p and q, two large prime numbers and calculate $n = pq$.
2. Calculate $\lambda(n) = \text{lcm}(p-1, q-1)$.
3. Choose e such that $\gcd(e,\lambda(n)) = 1$ and $1 < e < \lambda(n)$
4. Find d such that $ed \equiv 1 \pmod{\lambda(n)}$
5. Set public key (e, n). Set private key (d).

Set **coding** function $c(m) = m^e \pmod n$

Set **decoding** function $d(c) = c^d \pmod n$

Blind signatures

1. a signing function s' known only by the signer, and the corresponding inverse s, such that $s(s'(x)) = x$ without revealing information bout x;

Signature of the Bank, Bank can't reveal any information about the id sent by Alice.

2. a commuting (or blinding) function c and its inverse c', known only by the provider, such that $c'(s'(c(x))) = s'(x)$, and c and c' does not leak any information about x. Informally, function c' recovers the signed message from the blinding envelope;

c is the blinded envelope. Bank signs the envelope. Alice is able to recover from the envelope the id with a valid signature of the bank.

RSA - Blind signatures

Set **coding** function $c(m) = m^e \pmod{n}$

Set **decoding** function $d(c) = c^d \pmod{n}$

1. a signing function s' known only by the signer, and the corresponding inverse s, such that $s(s'(x)) = x$ without revealing information bout x;

$$s'(x) = (x)^d \pmod{n}.$$

Signature of the Bank, Bank can't reveal any information about the id sent by Alice.

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$$c(x) = xr^e \quad \gcd(r, n) = 1.$$

c is the blinded envelope. Bank signs the envelope. Alice is able to recover from the envelope the id with a valid signature of the bank.
x is the token to be signed by the bank.

Notice that $c'(s'(c(x))) \equiv s'(x) \pmod{n}$ holds, since
$c'(s'(c(x))) \equiv (xr^e)^d r^{-1} \equiv x^d r^{ed} r^{-1} \equiv s'(x) \pmod{n}$

1. a signing function s' known only by the signer, and the corresponding inverse s, such that $s(s'(x)) = x$ without revealing information bout x;

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UTXO UNSPENT TRANSACTIONS OUTPUT

Bitcoin transactions

UTXO

- **Public key – private key:** Alice and Bob both keep a set of public/private key pairs. Alice can send coins that only Bob will be able to reuse, without the intervention of a third party.

- **Wallet**: A wallet is associated with a pair of private/public keys. Each user pseudonymously may store a set of pairs of key.

- **UTXO:** coins are placed in a wallet, being associated with a public key. Only the owner of the corresponding private key will be able to spend the UTXOs.

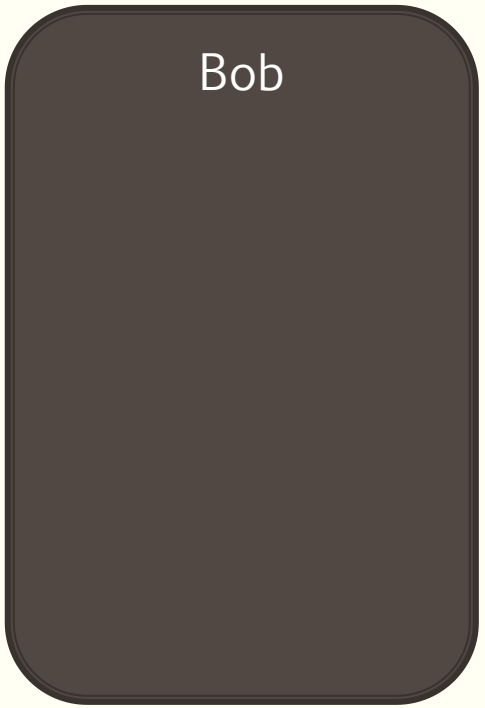
UTXO vs ACCOUNT model

- Bitcoin does not memorize users' balances, i.e. UTXO model does not memorize the sum of all unspent UTXOs owned by a wallet.

- **Ethereum** has a state transition model. In each state of the blockchain, an account has a balance. A transactions is a state transition, i.e after a transaction the account balance of the sender and the account balance of the receiver are changed.

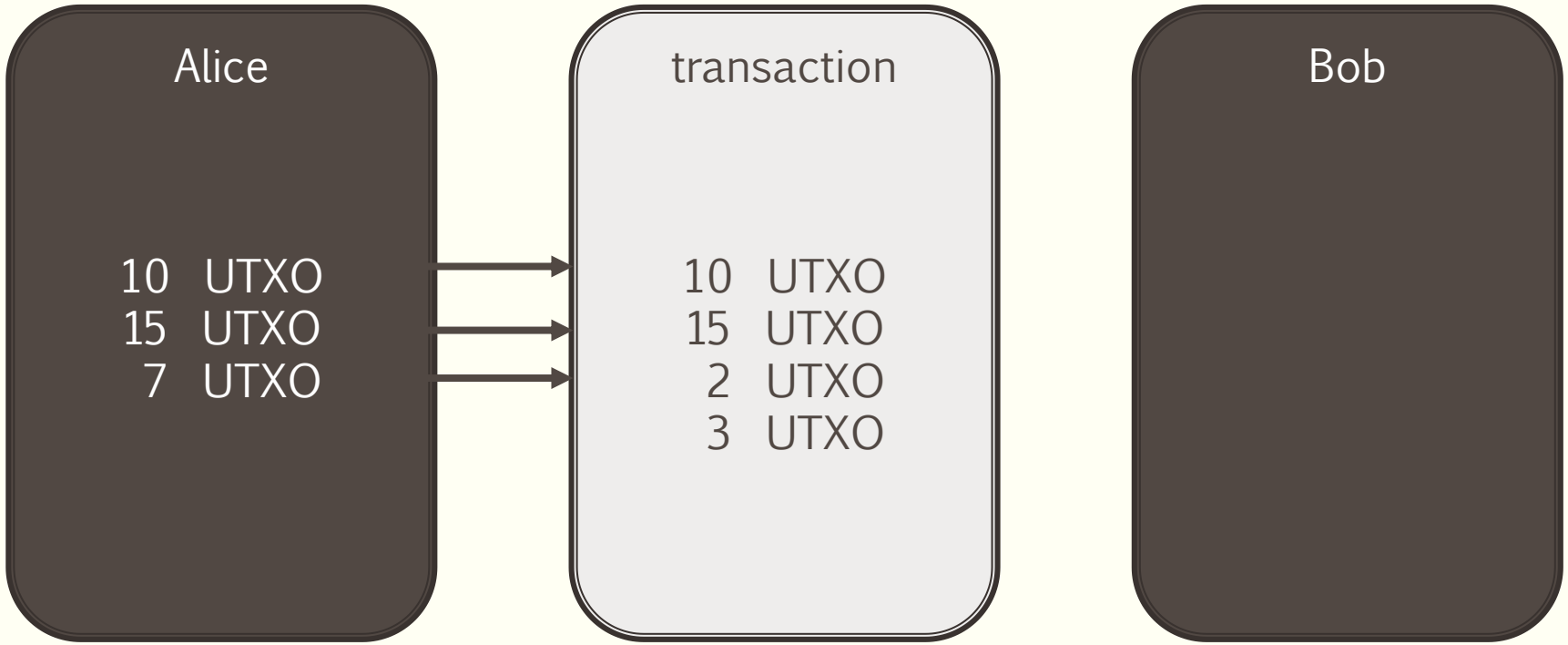
Bitcoin UTXO model

Bob is selling a product price 27



Bitcoin UTXO model

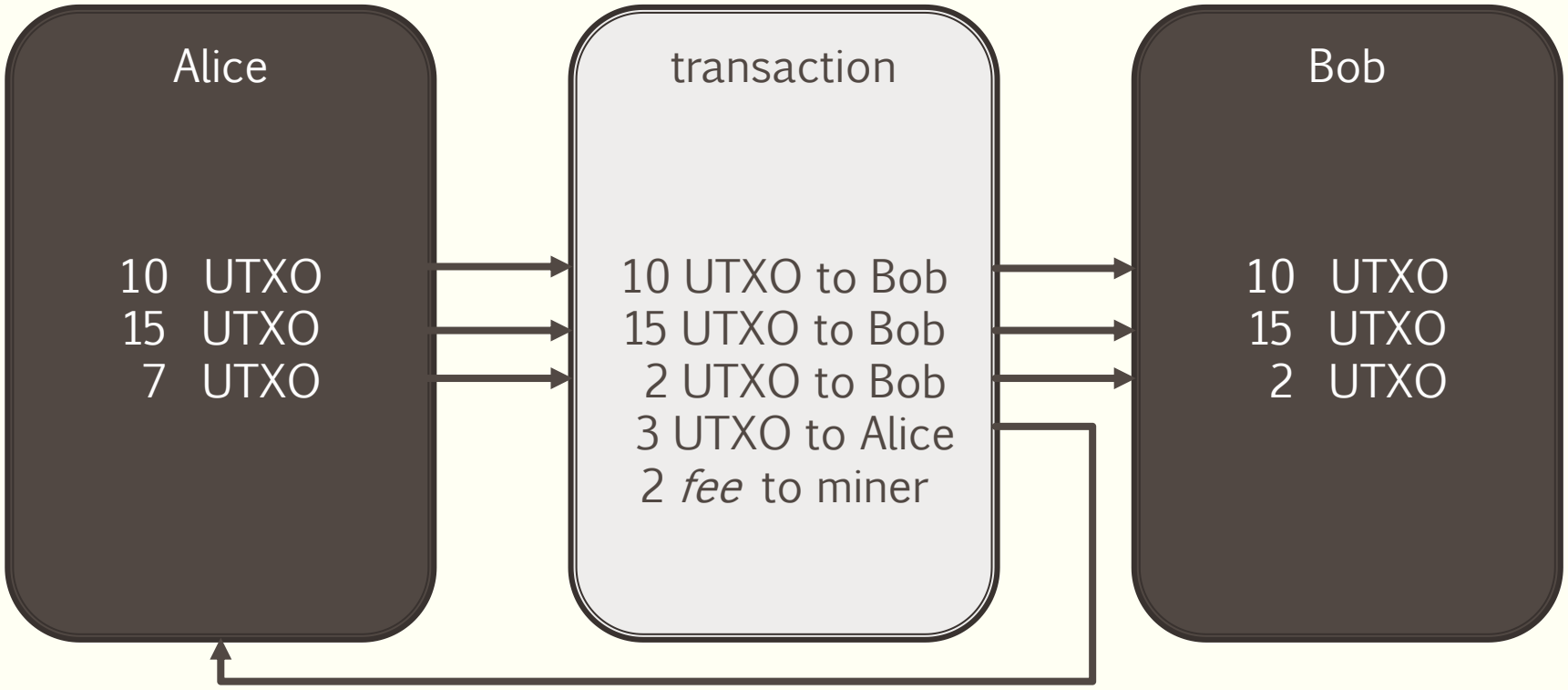
- multiple inputs
- coins have different values
- a coin may be spent only once



Bitcoin UTXO model

- multiple outputs
- some outputs are placed
- in the sender's wallet as change

some outputs represent fees



Bitcoin UTXO model

- Bitcoin Balance = sum of the unspent transaction outputs “owned”, not memorized!

  pay with previous unspent transaction outputs

  “change” is considered unspent transaction output locked to payer himself

- no double spending:

  total input of a transaction = equal total output + fees

  in a transaction coins are consumed and replaced with new ones.

Bitcoin UTXO model

- New coins are also created by mining
- transactions without input: Coinbase transaction -- miners reward!
- Coinbase transaction is the first transaction in a block.
- The reward halves each four year (after 210,000). Since 2024 block reward is 3.125BTC

UTXO set

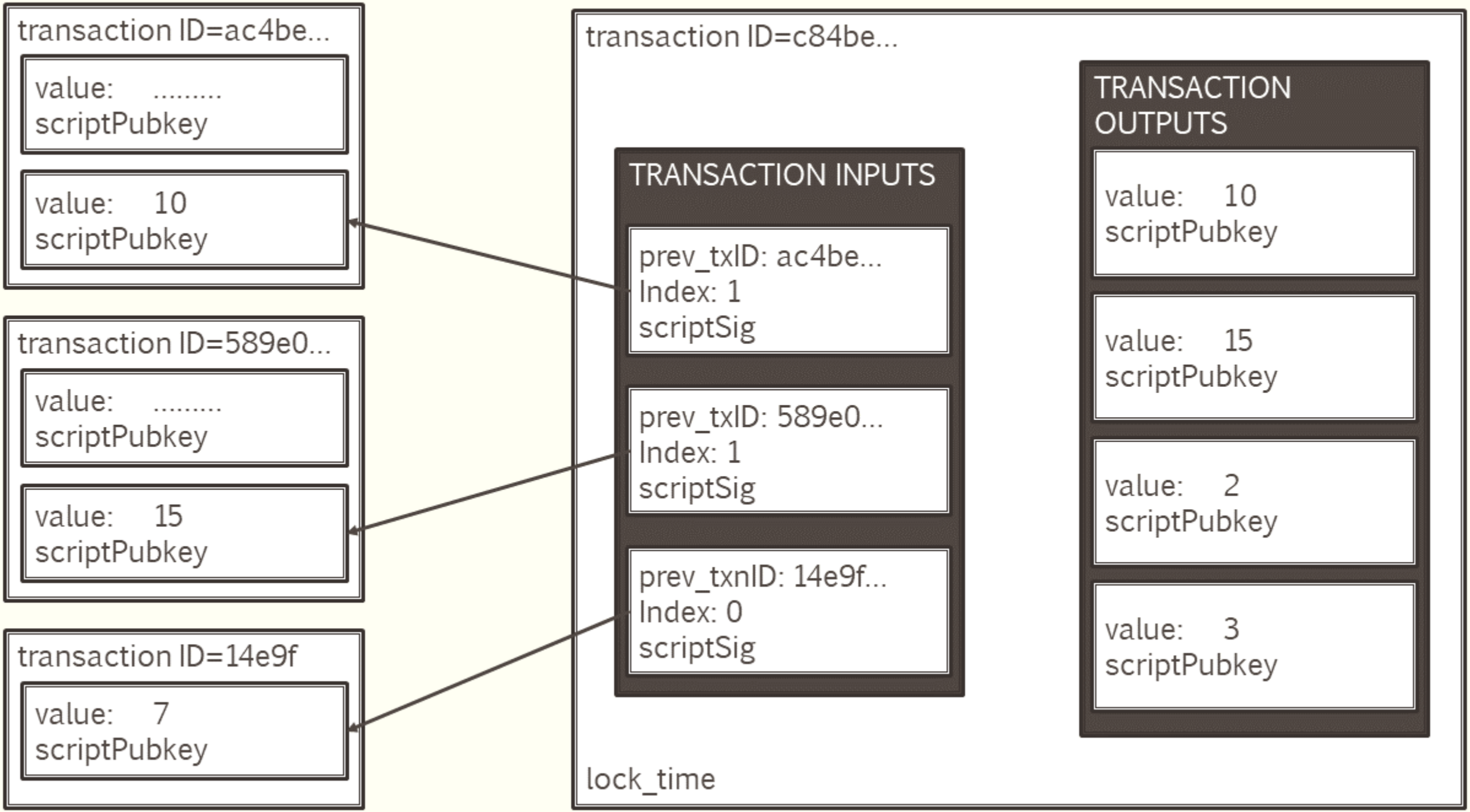
- **Set of UTXO**: the set of all UTXOs is replicated on all full nodes but only the rightful owners are able to use them in transactions.
- UTXO are memorize in a Level DB database: **Chainstate**.
- Chainstate is the set of all unspent transactions as they appear up to the last block added in the blockchain.
- Chainstate is redundant as it can be reconstructed from the date stored in the blockchain, but this would be extremely slow and inefficient

TRANSACTIONS

Bitcoin transactions

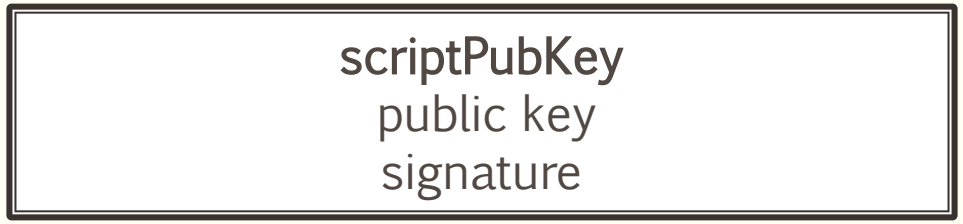
Field	Description	Size
Version	currently 1	4 bytes
In-counter	Number of inputs	1 – 9 bytes
List of inputs	List of inputs	<in-counter>-many inputs
Out-counter	Number of outputs	1 – 9 bytes
List of outputs	List of outputs	<out-counter>-many outputs
lock_time	block height or timestamp when transaction is final	4 bytes

lock_time field -- transaction will not be confirmed until a specific timestamp
or
transaction will be confirmed after 6 confirmations


transaction ID=ac4be...
value: .....
scriptPubkey
value: 10
scriptPubkey
transaction ID=589e0...
value: .....
scriptPubkey
value: 15
scriptPubkey
transaction ID=14e9f
value: 7
scriptPubkey
transaction ID=c84be...
TRANSACTION INPUTS
prev_txID: ac4be...
Index: 1
scriptSig
prev_txID: 589e0...
Index: 1
scriptSig
prev_txnID: 14e9f...
Index: 0
scriptSig
TRANSACTION OUTPUTS
value: 10
scriptPubkey
value: 15
scriptPubkey
value: 2
scriptPubkey
value: 3
scriptPubkey
lock_time

Transactions – Locking script

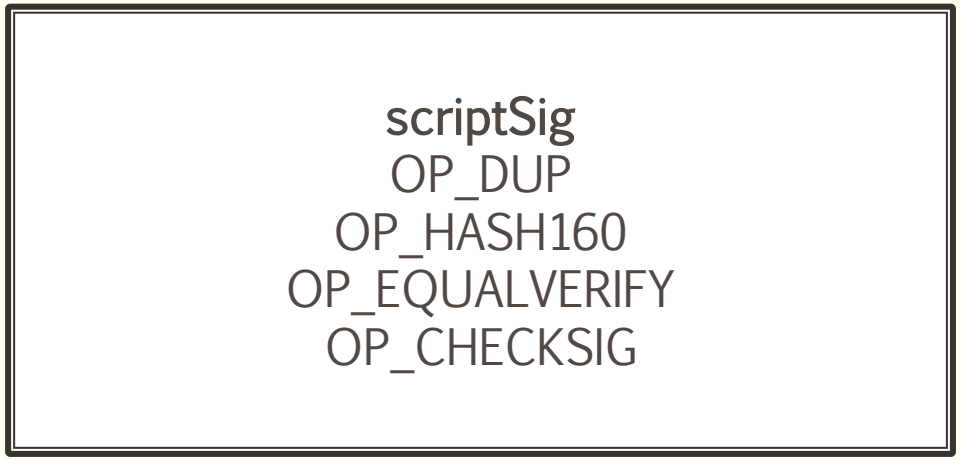
- ECDSA signature => public/private key
- public key => bitcoin address
- Bitcoin address => **scriptPubKey**



- Challenge to users that want to claim a specific output. Only the owner of the UTXO should be able the unlock the UTXO providing the unlocking script **scriptSig.**
- Alice signs the transaction and sends the output to public key.

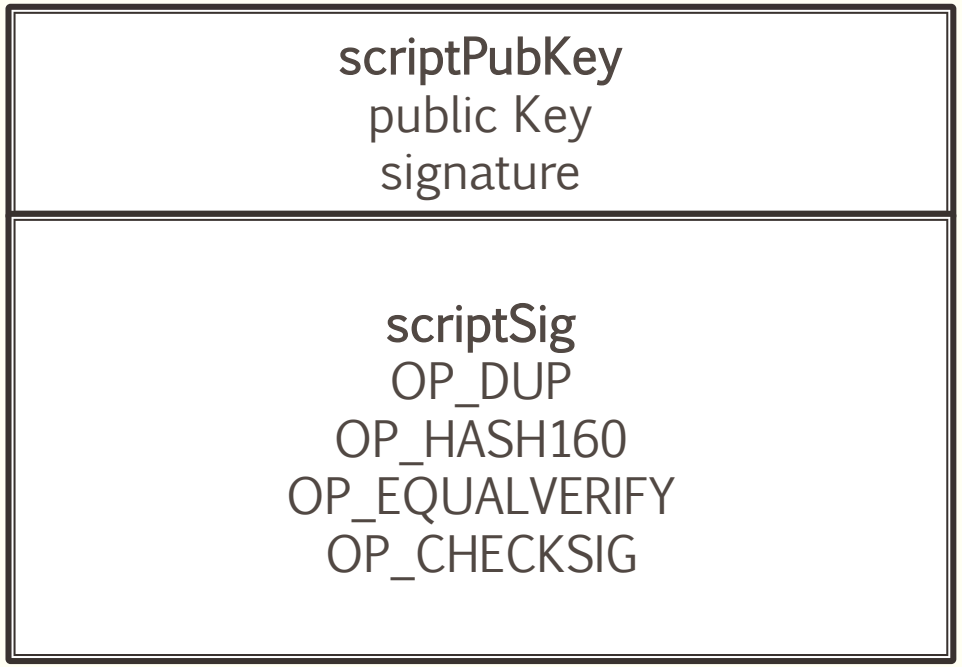
Transactions -- Unlocking Script

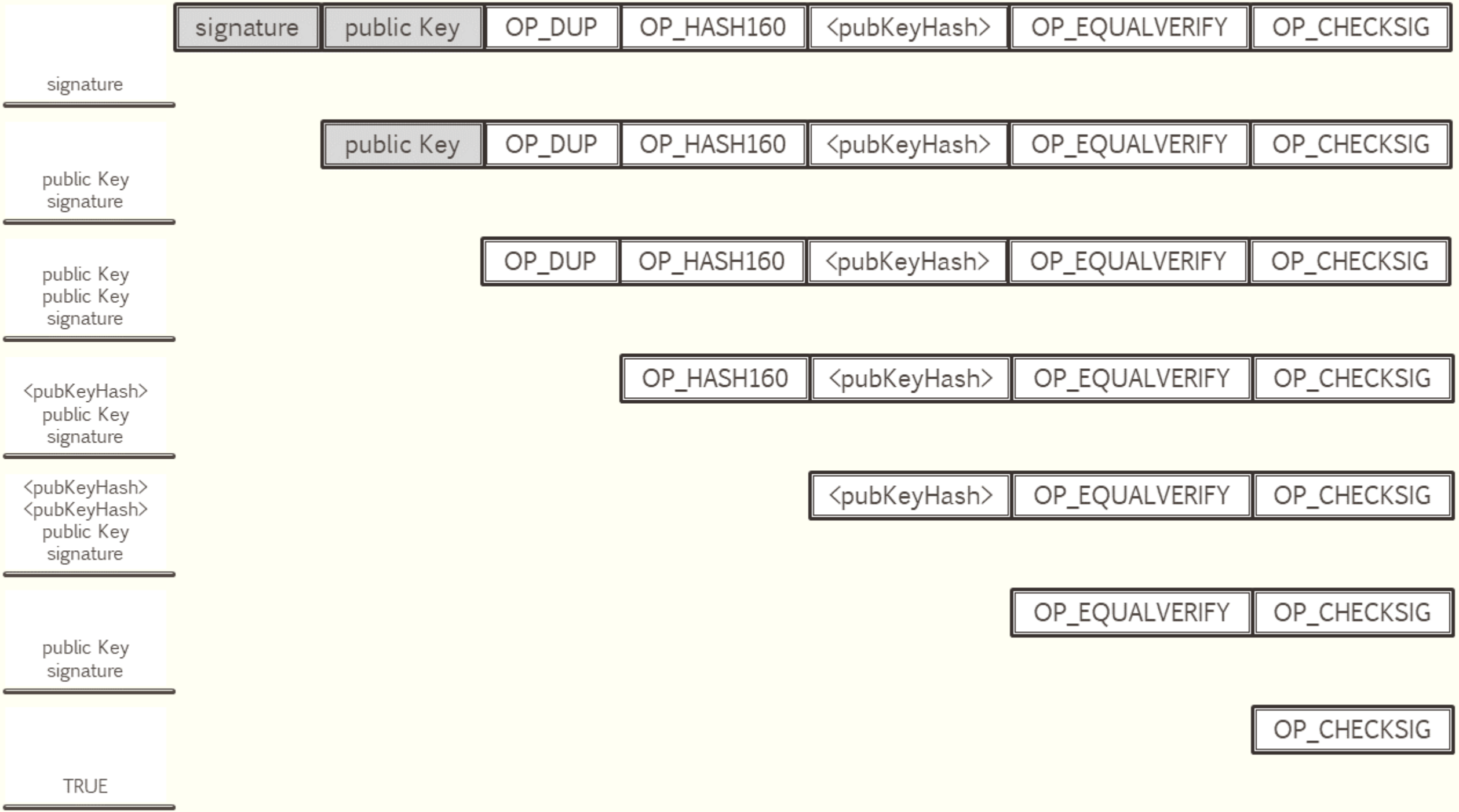
- scriptSig
  - include receiver public key hash
  - instructions (op_codes) to verify public key



Bitcoin UTXO model

- P2PKH pay to public key hash




signature
public Key
OP_DUP
OP_HASH160
<pubKeyHash>
OP_EQUALVERIFY
OP_CHECKSIG
signature
public Key
OP_DUP
OP_HASH160
<pubKeyHash>
OP_EQUALVERIFY
OP_CHECKSIG
public Key
signature
OP_DUP
OP_HASH160
<pubKeyHash>
OP_EQUALVERIFY
OP_CHECKSIG
public Key
public Key
signature
OP_HASH160
<pubKeyHash>
OP_EQUALVERIFY
OP_CHECKSIG
<pubKeyHash>
public Key
signature
<pubKeyHash>
OP_EQUALVERIFY
OP_CHECKSIG
<pubKeyHash>
<pubKeyHash>
public Key
signature
OP_EQUALVERIFY
OP_CHECKSIG
public Key
signature
OP_CHECKSIG
TRUE

UTXO model

- Simple
- Verify transactions in parallel,
  - a UTXO affected by only one transaction
- Privacy (wallets)
- Limited smart contract capabilities