Lesson 16 - Auditing / Course Review / Directions

Noir Example Projects

See this list of resources

- Anonymous proof of token ownership on Aztec (for token-gated access)
  - Sequi
  - Cyclone

Governance - MeloCafe
Circuits - Anonymous on-chain voting

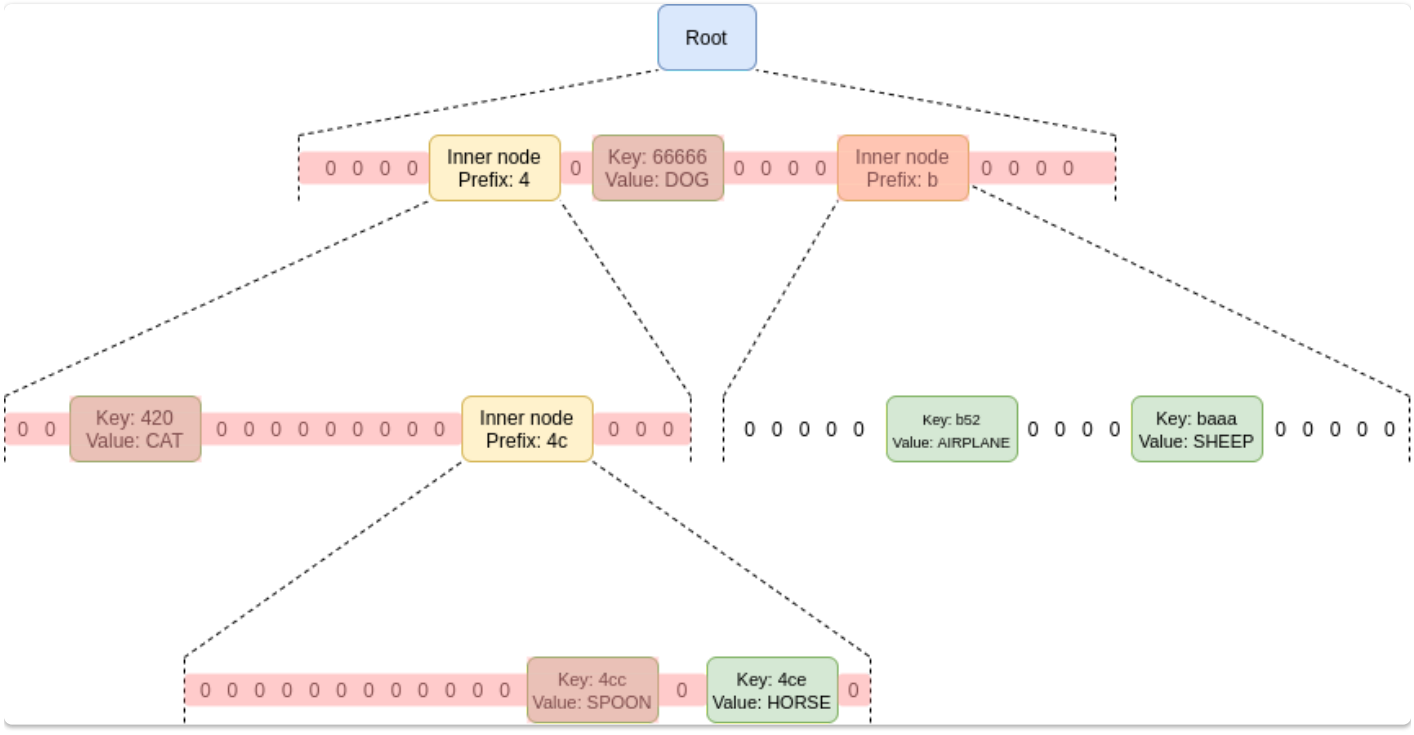
Verkle trees

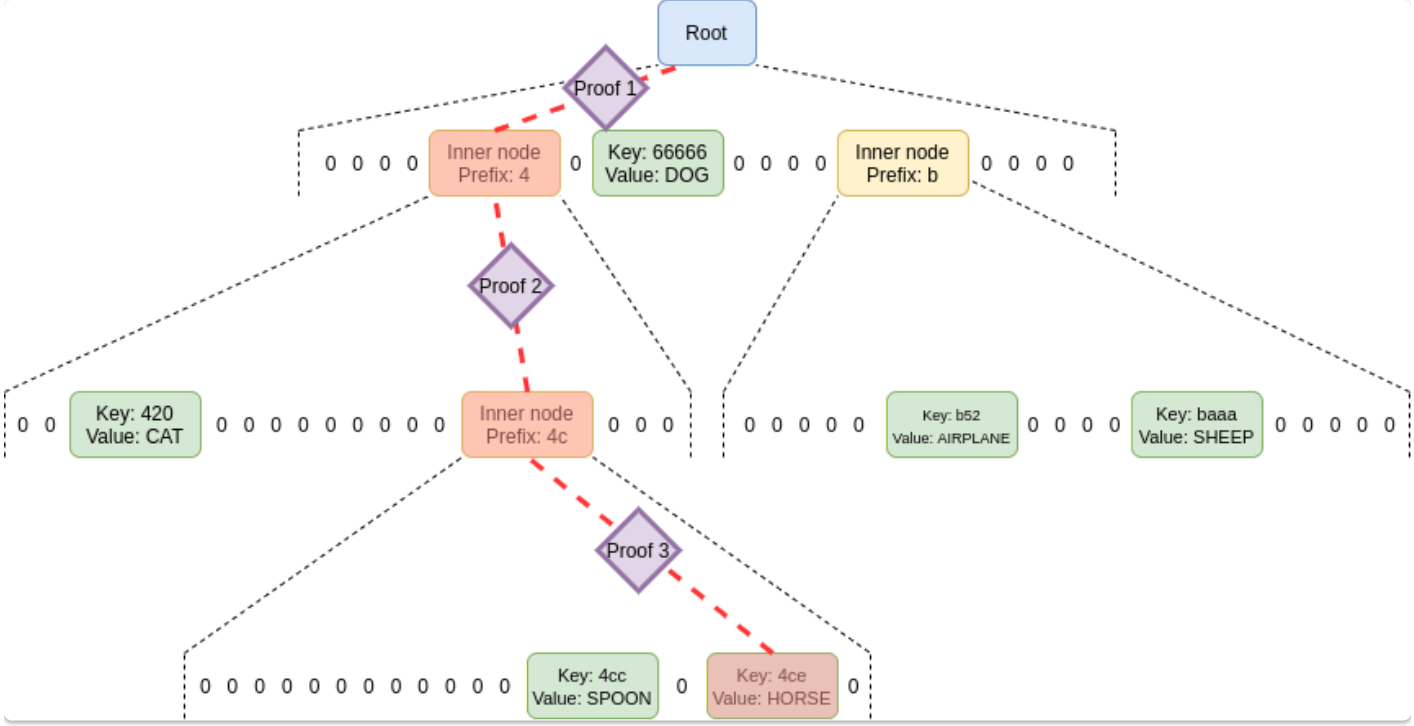
https://vitalik.ca/general/2021/06/18/verkle.html

See article
and Ethereum Cat Herders Videos

Like merkle trees, you can put a large amount of data into a Verkle tree, and make a short proof ("witness") of any single piece, or set of pieces, of that data that can be verified by someone who only has the root of the tree.
What Verkle trees provide, however, is that they are much more efficient in proof size. If a tree contains a billion pieces of data, making a proof in a traditional binary Merkle tree would require about 1 kilobyte, but in a Verkle tree the proof would be less than 150 bytes.
Verkle trees replace hash commitments with vector commitments or better still a polynomial commitment.
Polynomial commitments give us more flexibility that lets us improve efficiency, and the simplest and most efficient vector commitments available are polynomial commitments.

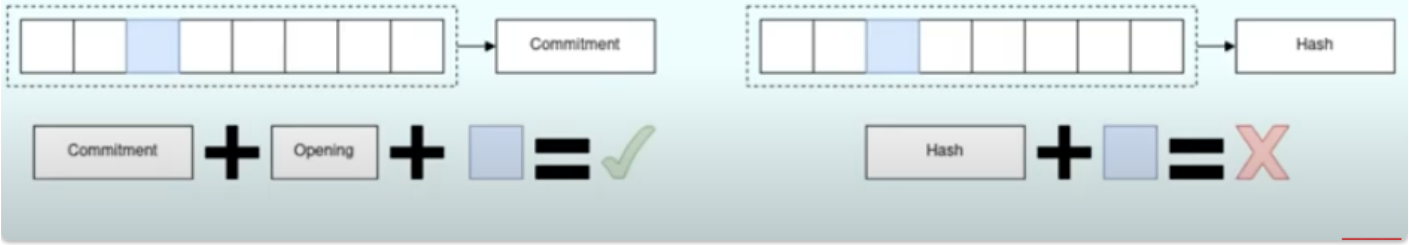
The number of nodes needed in a merkle proof is much greater than in a verkle proof





Vector commitments vs. Hash

- Vector commitments: existence of an “opening”, a small payload that allow for the verification of a portion of the source data without revealing it all.
- Hash : verifying a portion of the data = revealing the whole data.



Proof sizes

Merkle

Leaf data +
15 sibling
32 bytes each
for each level (~7)

= ~3.5MB for 1K leaves

Verkle

Leaf data +
commitment + value + index
32 + 32 + 1 bytes
for ~4 levels
+ small constant-size data

= ~ 150K for 1K leaves

ZKP Bridges

With succinct proofs, zkBridge not only guarantees strong security without external assumptions, but also significantly reduces on-chain verification cost. zkBridge provides a modular design supporting a base layer with a standard API for smart contracts on one chain to obtain verified block headers from another chain using snarks. By separating the bridge base layer from application-specific logic, zkBridge makes it easy to enable additional applications on top of the bridge, including message passing, token transfer, etc..

Audit

A number of auditing companies are active in this space
Peckshield, Chainsecurity, Open Zeppelin
Nethermind are building their audit team, and have created tools and guidelines.
Consensys Dilligence have announced a partnership with Starkware for auditing Cairo contracts.

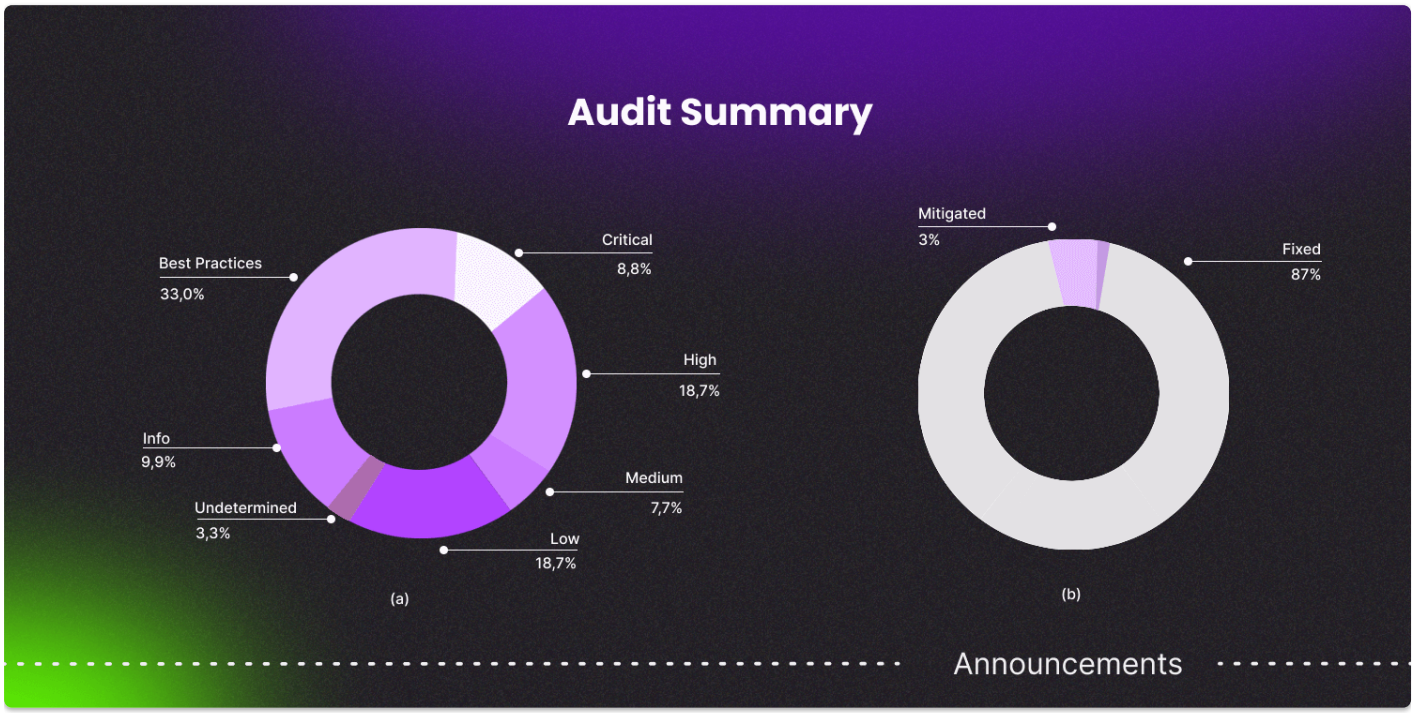
Security Guidelines

See this article from ctrlc03 an internal auditor and developer within the EF's PSE team.

This article also gives some vulnerabilities in cairo.

Example audits of cairo contracts

ZKX - overview of audit



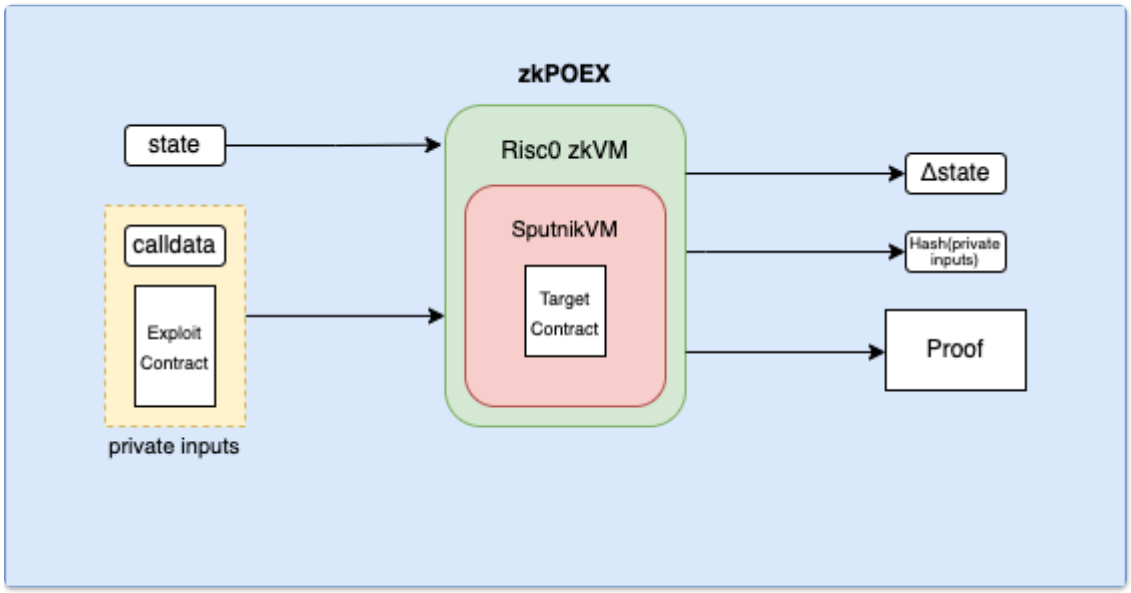
Maker DAO - Chain Security Report

Static Analysis

Armana Repo

Using ZKPs to verify exploits

See the recent project from ETHDenver



Technologies Used

The project utilises the following technologies:

- Risc0: A General Purpose Zero-Knowledge VM that allows to prove and verify any computation. The RISC Zero ZKVM is a verifiable computer that works like a real embedded RISC-V microprocessor, enabling programmers to write ZK proofs like they write any other code.
- SputnikVM: A high-performance, modular virtual machine for executing Ethereum smart contracts.

Circuit / QAP process in PLONK

What the prover and verifier can calculate ahead of time

The program-specific polynomials that the prover and verifier need to compute ahead of time are:

$Q_L(x), Q_R(x), Q_O(x), Q_M(x), Q_C(x)$, which together represent the gates in the circuit
(note that $Q_C(x)$ encodes public inputs, so it may need to be computed or modified at runtime)

The "permutation polynomials" $\sigma_a(x), \sigma_b(x)$ and $\sigma_c(x)$, which encode the copy constraints between the a, b,and c wires

Given a program P, you convert it into a circuit, and generate a set of equations that look like this:
Each equation is of the following form (L = left, R = right, O = output, M = multiplication, C = constant):
and a_i, b_i are the wire values
Each Q value is a constant; the constants in each equation (and the number of equations) will be different for each program.

$$(Q_{L_i})a_i + (Q_{R_i})b_i + (Q_{O_i})c_i + (Q_{M_i})a_i b_i + Q_{C_i} = 0$$

You then convert this set of equations into a single polynomial equation:

$$Q_L(x)a(x) + Q_R(x)b(x) + Q_O(x)c(x) + Q_M(x)a(x)b(x) + Q_C(x) = 0$$

You also generate from the circuit a list of copy constraints. From these copy constraints you generate the three polynomials representing the permuted wire indices:
$\sigma_a(x), \sigma_b(x), \sigma_c(x)$

To generate a proof, you compute the values of all the wires and convert them into three polynomials:
$a(x), b(x), c(x)$
You also compute six "coordinate pair accumulator" polynomials as part of the permutation-check argument.

Finally you compute the cofactors $H_i(x)$

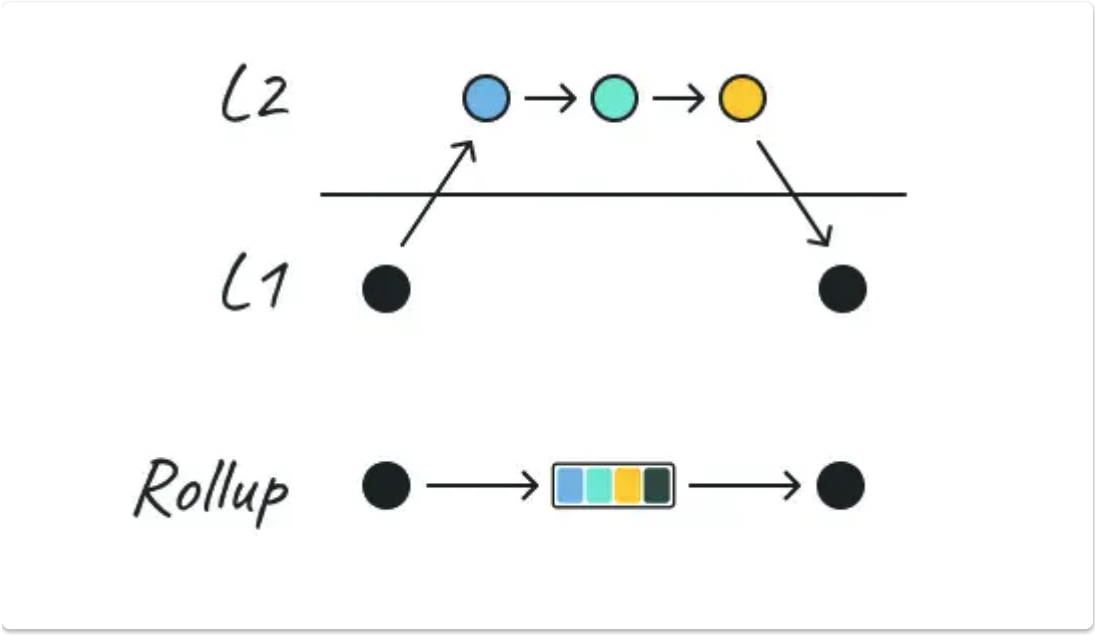
There is a set of equations between the polynomials that need to be checked; you can do this by making commitments to the polynomials, opening them at some random z (along with proofs that the openings are correct), and running the equations on these evaluations instead of the original polynomials.
The proof itself is just a few commitments and openings and can be checked with a few equations.

Current directions

L2 implementations

- Starknet
- ZKSync
- Polygon
- Aztec
  Also inter L2 communication - Mangata

see article



ZkML

- More projects - Giza / EZKL
- Hardware

Research

- Folding schemes
- Collaborative SNARKS
- Trusted setups : Join ceremony for RLN

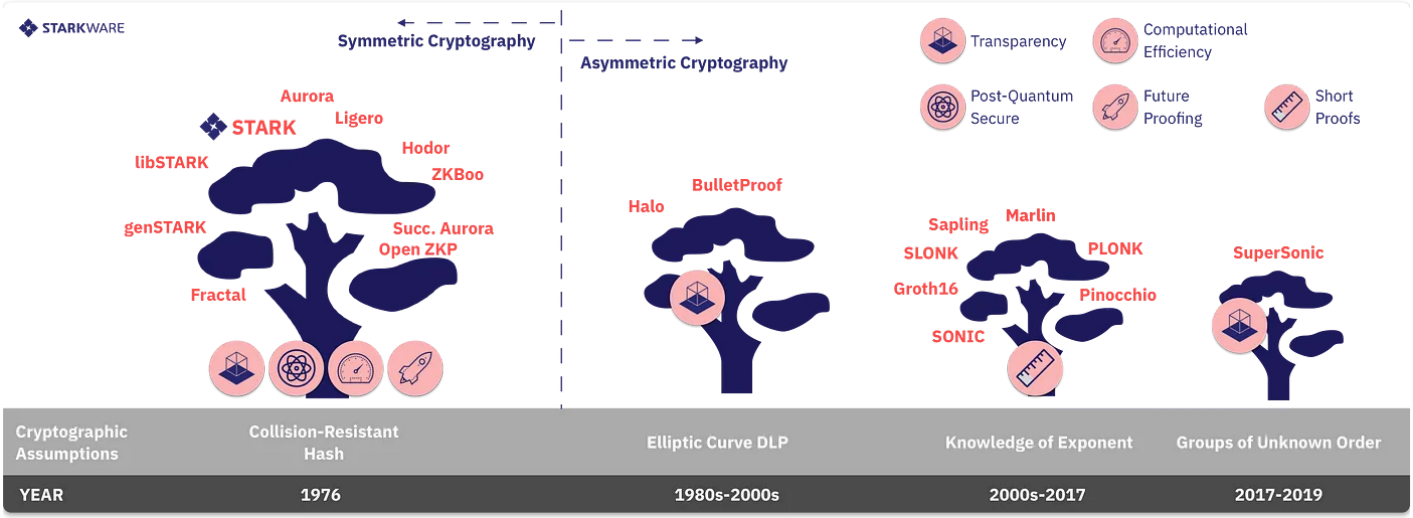
Useful talks from Devcon

ZKP Workshop video
Zk Application showcase video
The KZG Ceremony video
zkEVM Technical details video
Vampire SNARK from Nethermind video
Shielded Voting and Threshold encryption video
Self Sovereign Identity video
Are your ZKPs correct ? video
ZKP Performance video
Proving execution in zkEVM video
ZKP Introduction video
Autonomous Worlds workshop video

Course Review

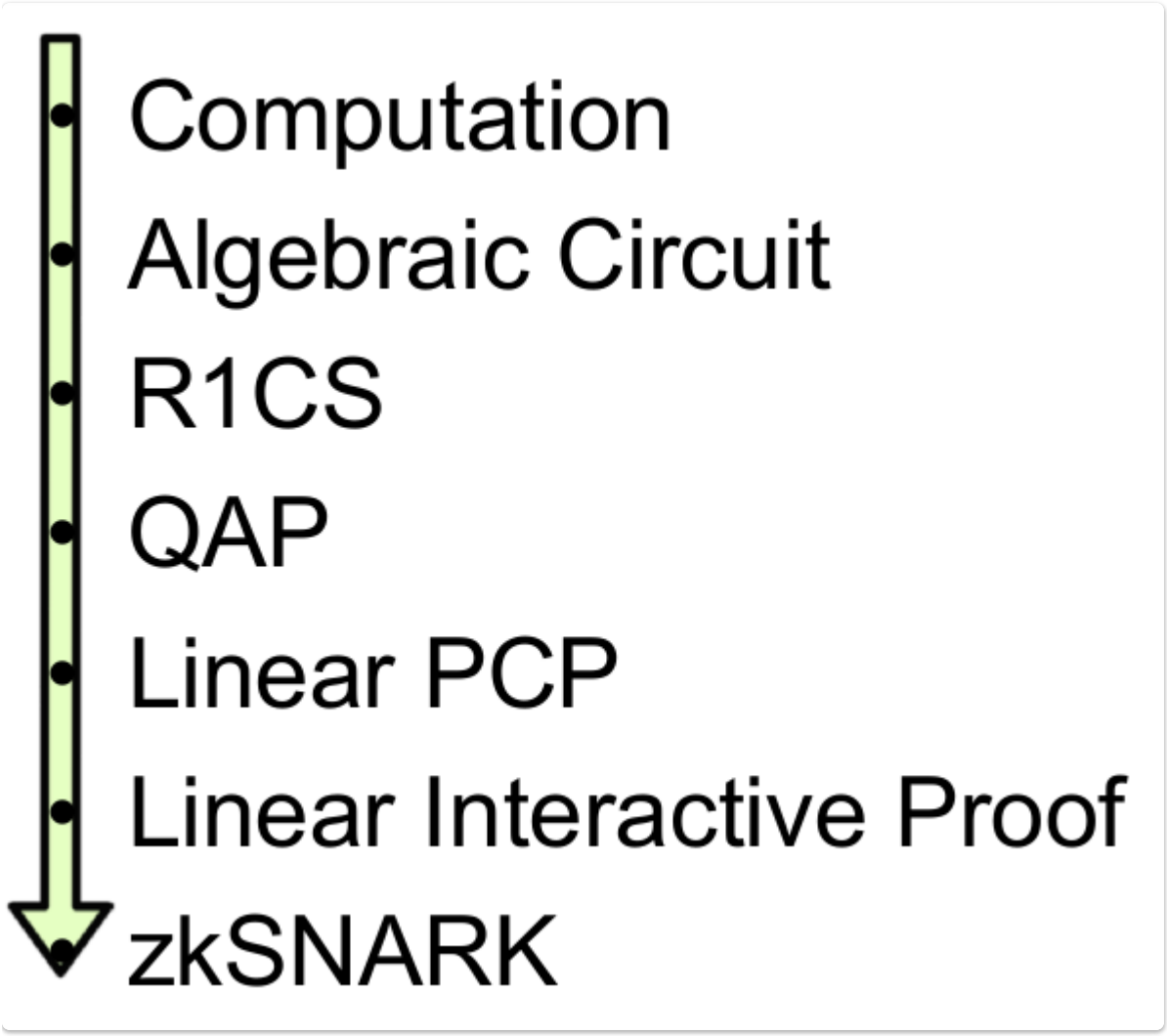
Lesson 1 & 2

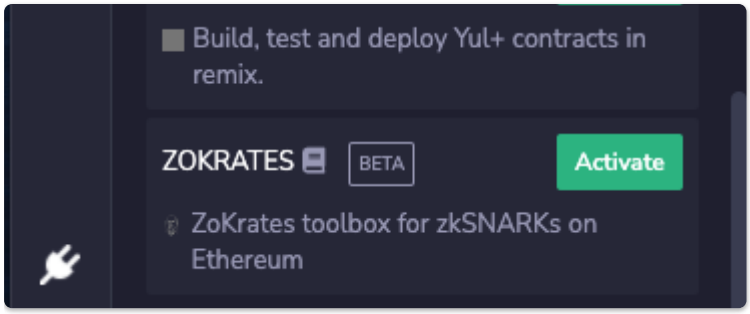
- Introductory maths & cryptography
- General ZKP theory



	SNARKs	STARKs	Bulletproofs
Algorithmic complexity: prover	O(N * log(N))	O(N * poly-log(N))	O(N * log(N))
Algorithmic complexity: verifier	~O(1)	O(poly-log(N))	O(N)
Communication complexity (proof size)	~O(1)	O(poly-log(N))	O(log(N))
- size estimate for 1 TX	Tx: 200 bytes, Key: 50 MB	45 kB	1.5 kb
- size estimate for 10.000 TX	Tx: 200 bytes, Key: 500 GB	135 kb	2.5 kb
Ethereum/EVM verification gas cost	~600k (Groth16)	~2.5M (estimate, no impl.)	N/A
Trusted setup required?	YES 😒	NO 😄	NO 😄
Post-quantum secure	NO 😒	YES 😄	NO 😒
Crypto assumptions	Strong 😒	Collision resistant hashes 😄	Discrete log 😏

zkSNARKS





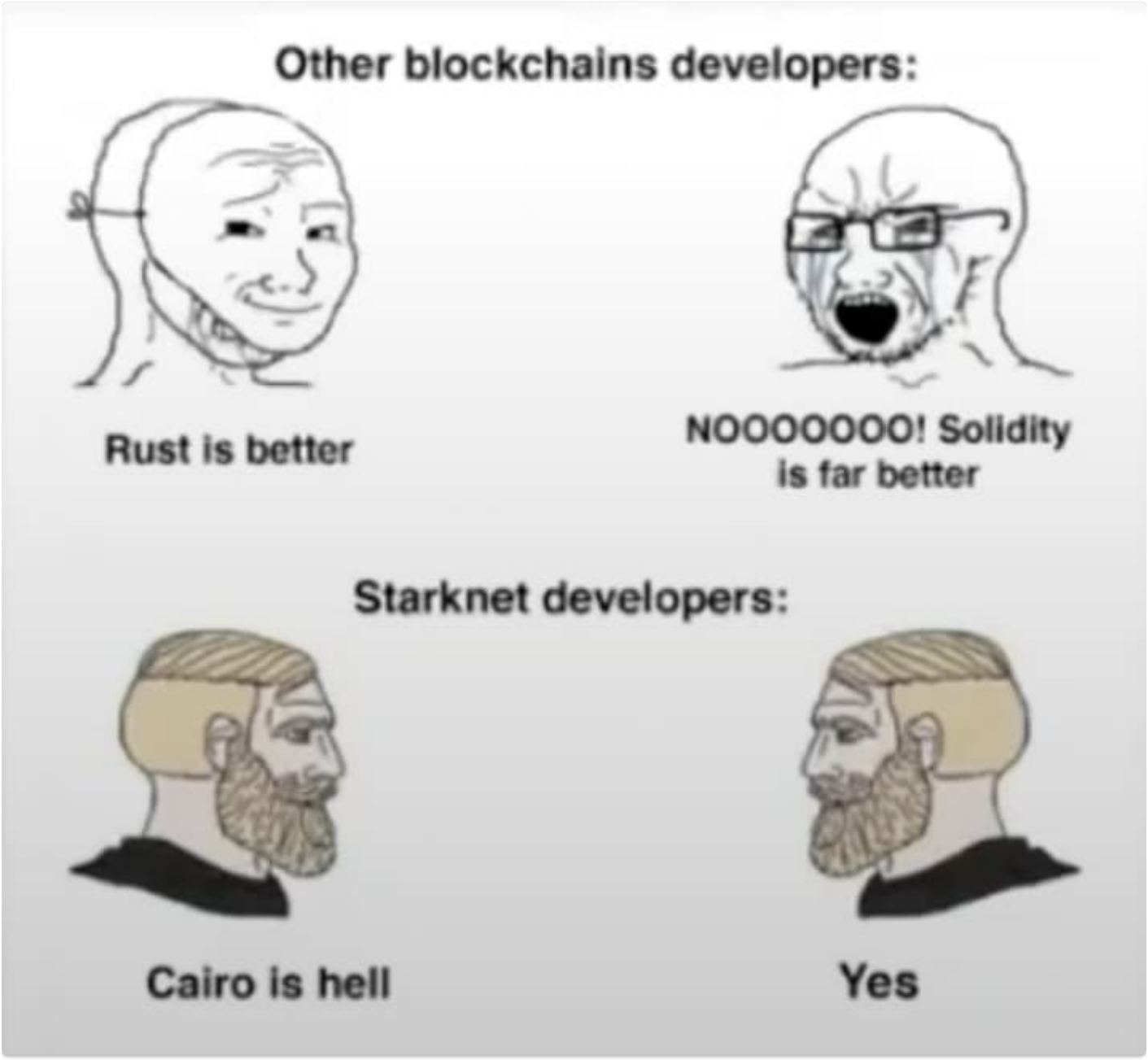
Lesson 3

- ZKP use cases / rollups

Lessons 4 - 5

- Starknet / Cairo / Warp

Cairo



Lesson 6

- Confidential tokens

Zcash is a privacy-protecting, digital currency built on strong science.

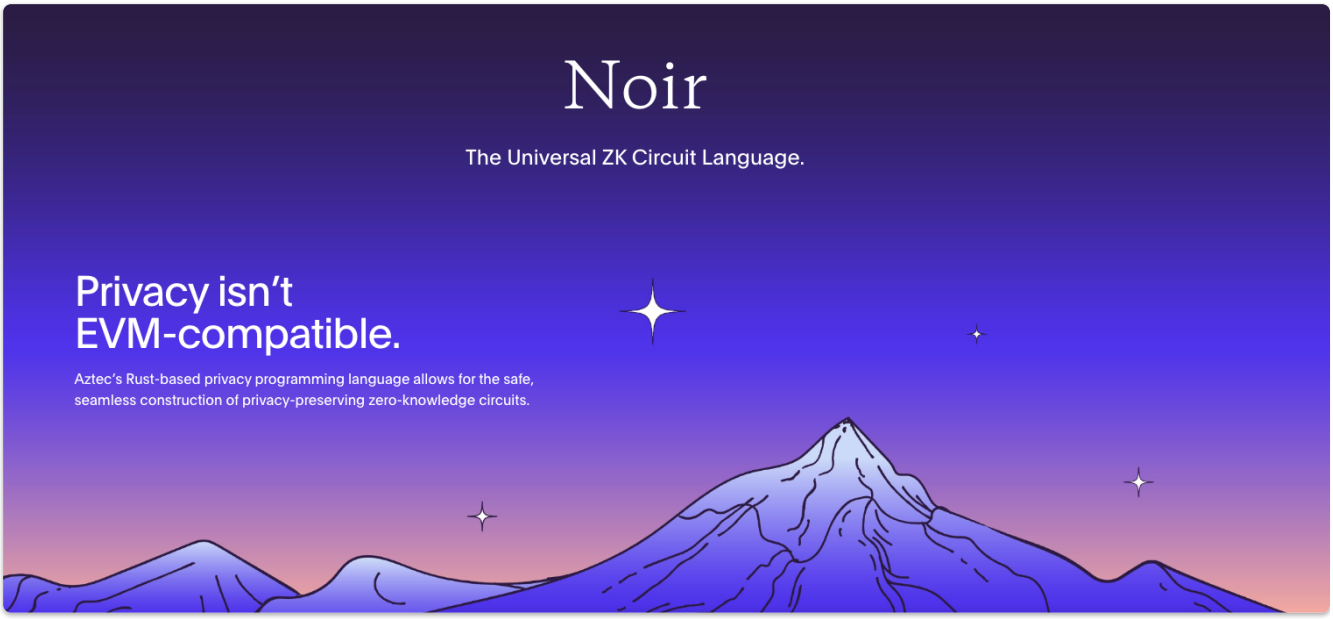
MONERO

Also Nightfall , ZKDai

AZTEC

Lesson 7

- Noir



Lesson 8

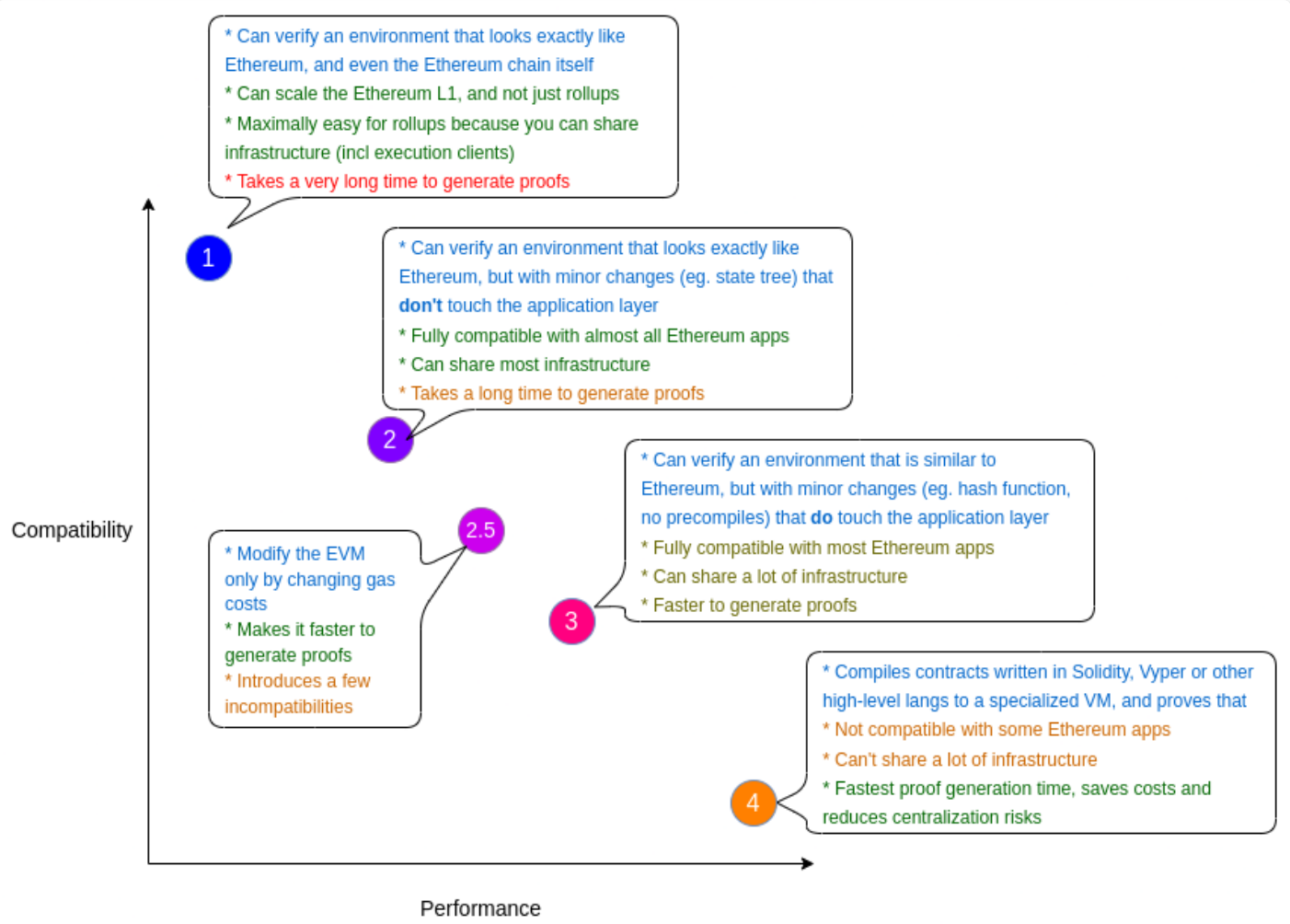
- Warp / Aztec

Lesson 9

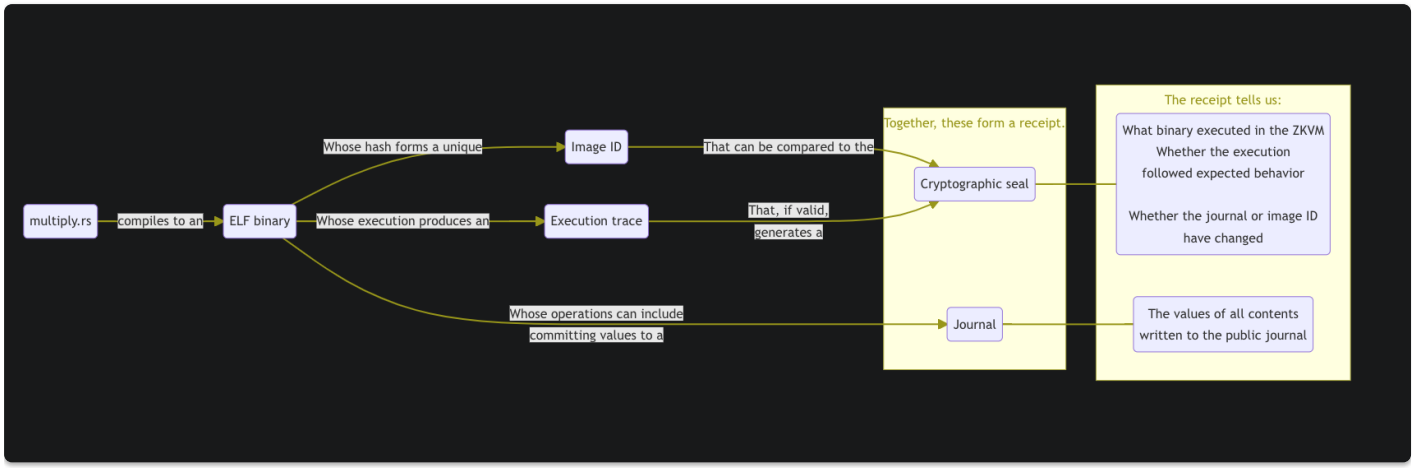
- Mina
- zkApps

Lesson 10

zkEVM solutions

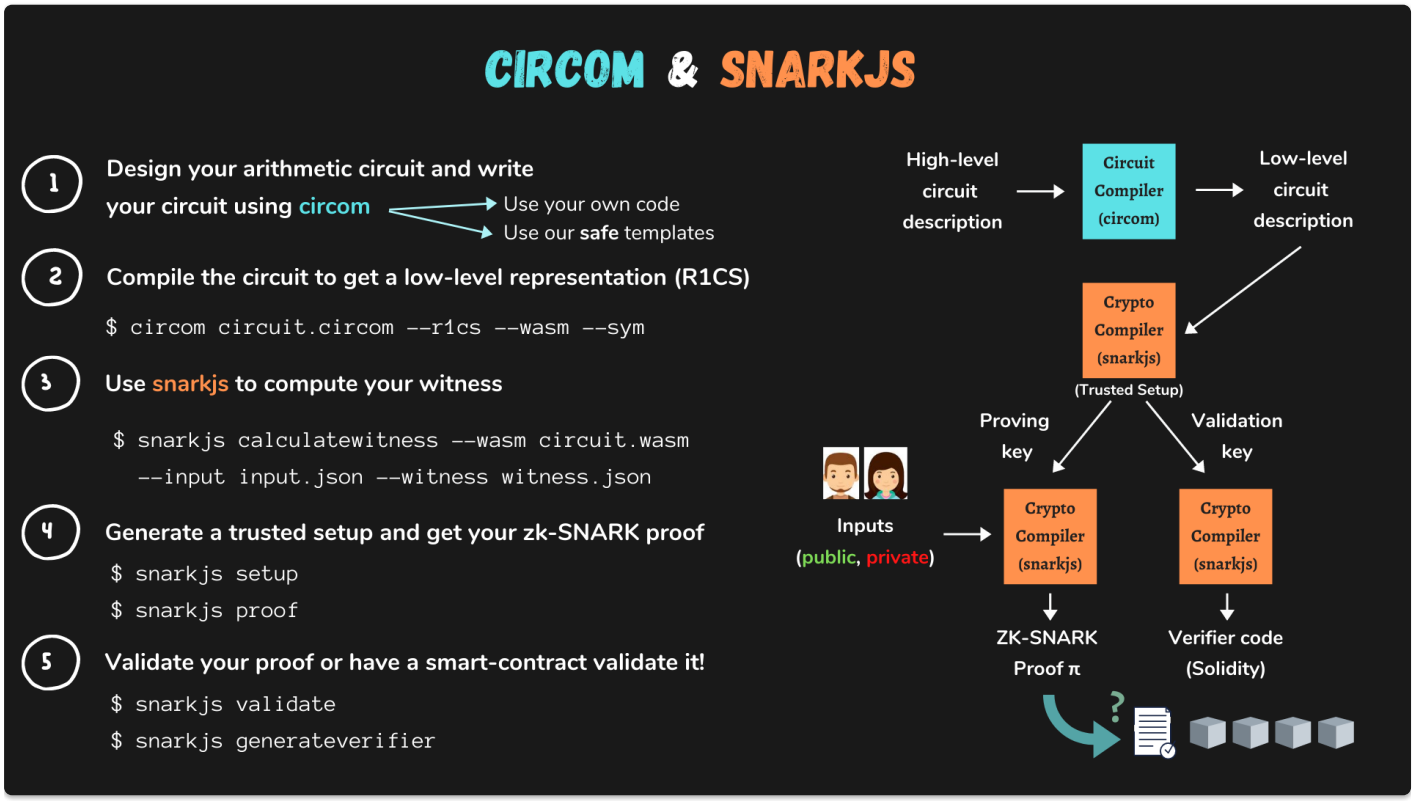


Lesson 11



- Risc zero
- PLONK

Lesson 12



- Circom
- SNARK theory

Lesson 13

- STARK theory

Lesson 14

- Alternative technologies

- Voting systems

Lesson 15

- Identity Solutions
- Oracles

Lesson 16

- Auditing / verification / trends

Developer Options

Writing zkp programs

Many languages are rust like

- Cairo
- Noir
- Leo (Aleo)
- Risc Zero

Others :

- Circom
- Snarky.JS (Mina)
- Lurk (Filecoin)
- Solidity (for zkEVM)
- Solidity + WARP -> Cairo

In addition to the DSL -> SNARK / STARK approach, there are other cryptographic techniques that could be useful, see the alternative techniques lesson.

There are many areas to get involved in

- L2 solutions
- Privacy / Identity projects
- ZK-ML
- zk Games
- Security / Auditing

At the protocol level

- STARKS
- SNARKS - PLONK derivatives
- zk VMs
- Recursive proofs

Hackathons and Builder Programs

Encode Hackathons
Mina zkIgnite
Aztec grants
Autonomous Worlds hackathon

Communities / Groups

Mina UK Meetup group
Starknet Meetup groups

Resources

Zero Knowledge Podcast
Starknet podcast
ZK Hack and ZK Study Club Videos
ZK Whiteboard sessions
Cairo mummies course
Berkley ZKP MOOC
Alex Pinto's Blog
Extropy Foundation collection