



Feeling the

Local-First

Elephant

A Roadmap, Hidden Gems, and New Puzzles from the Field

Feeling the Local-First Elephant



Blind monks examining an elephant, Hanabusa Itchō (1652–1724)

Feeling the Local-First Elephant



Blind monks examining an elephant, Hanabusa Itchō (1652-1724)

Feeling the Local-First Elephant

Brooklyn Zelenka @expede

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- ◆ Cofounder & CTO at Fission Codes 
- ◆ <https://fission.codes>
- ◆ Est. 2019 to do LoFi, secure, user-owned browser apps
- ◆ Now mainly focused on edge & LoFi computing
- ◆ PLs and DS are my jam 🙌
- ◆ Thrilled to be here! Had to cut sooo many slides 



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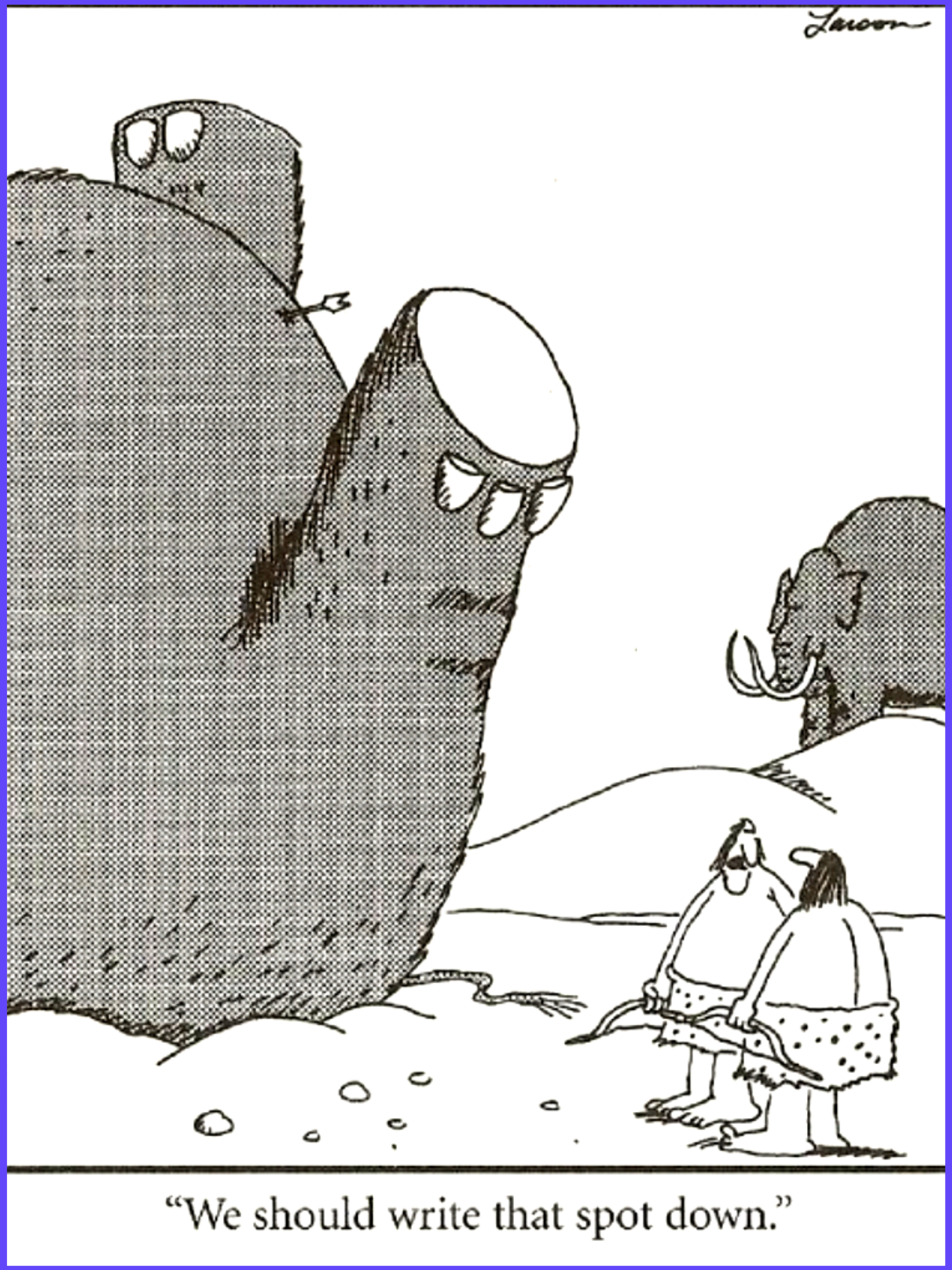
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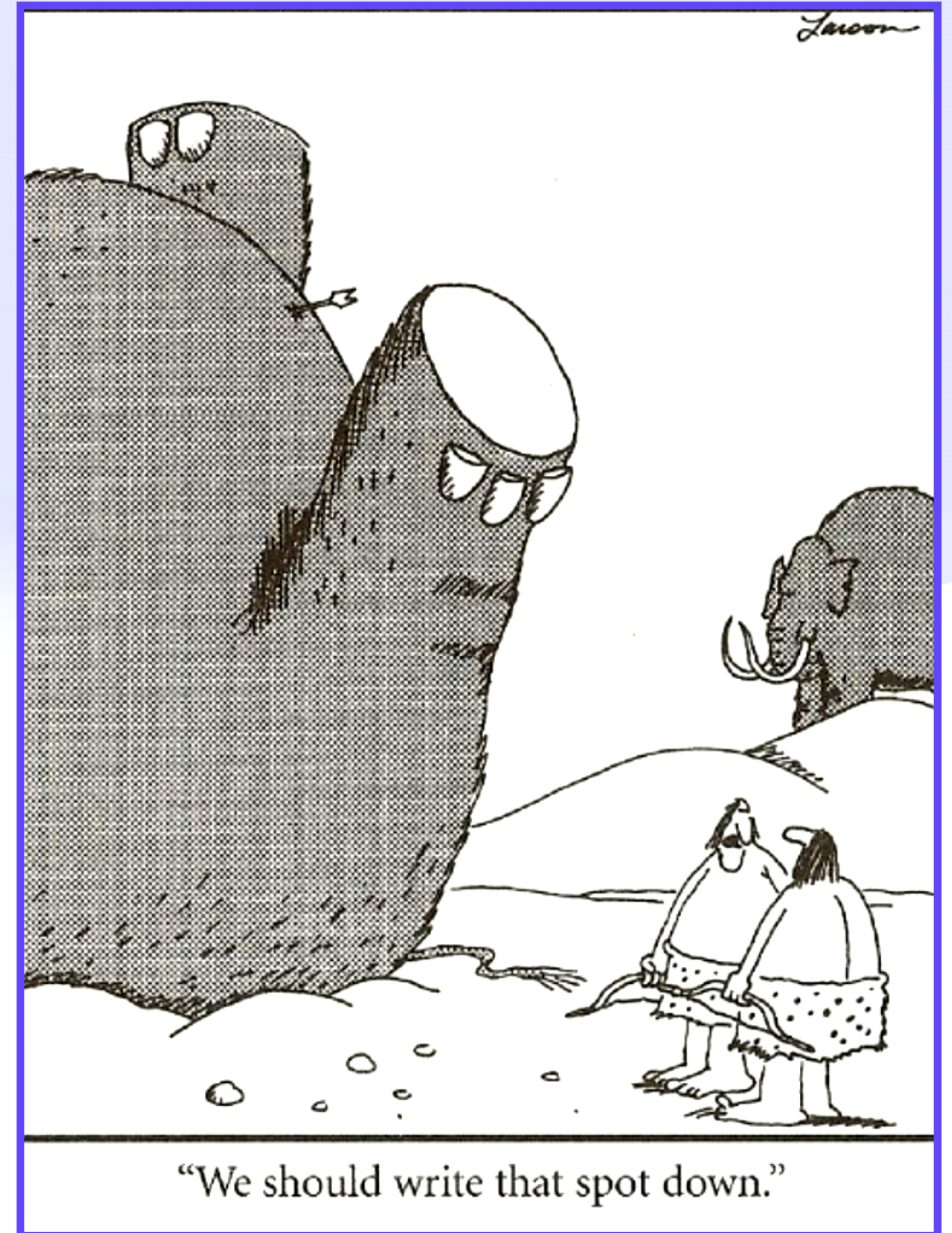
Feeling the Local-First Elephant
Topics



The Far Side, Gary Larson

Feeling the Local-First Elephant *Topics*

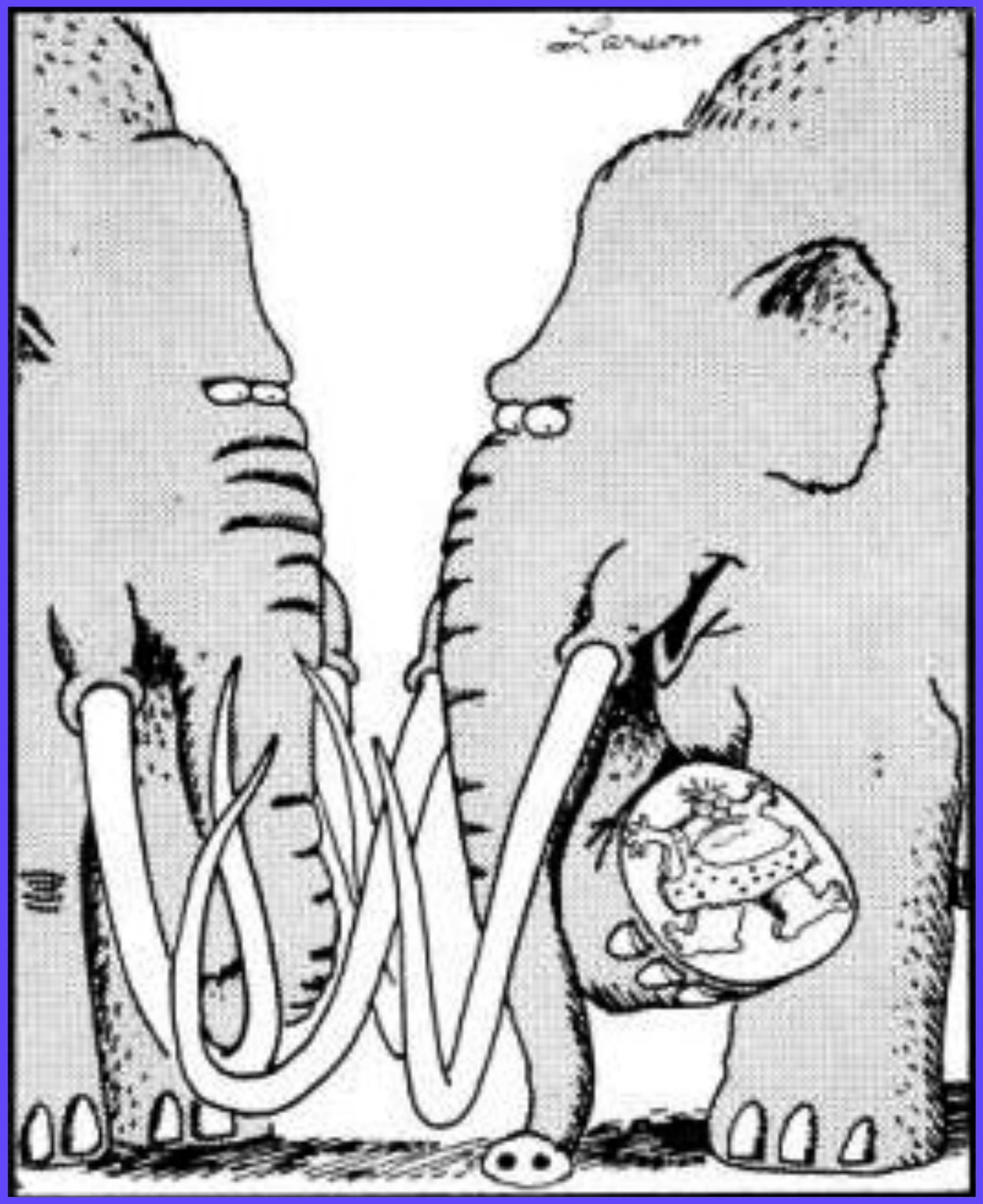
- ◆ **Taking stock:** state of the union
- ◆ **Looking back:** an experience report (YMMV)
 - ◆ Took a breath-first approach
 - ◆ Surprising things I've seen along the way
 - ◆ Point to things that I don't hear much about in LoFi
- ◆ **Mainly looking forward:** pointing at the next chapter



The Far Side, Gary Larson

Feeling the Local-First Elephant Up

Six Blind Elephants 🐘



Gary Larson, The Far Side

Knee of the (Bell) Curve

🎵 The Times They Are a-Changin' 📈

Knee of the (Bell) Curve

Picking Up Steam

Knee of the (Bell) Curve

Picking Up Steam



VIDEO: ARDHIRA PUTRA

GREGORY BARBER BACKCHANNEL AUG 3, 2023 6:00 AM

The Cloud Is a Prison. Can the Local-First Software Movement Set Us Free?

Knee of the (Bell) Curve

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Knee of the (Bell) Curve

Picking Up Steam

A new breed of apps.

Local-first

A fully local database provides an instant-on app experience, especially when combined with PWA or hybrid app architecture.

Unabashedly local-first software

Local-First

Set `clientPersistence: true` and data is also stored on the client, providing instant ("local-first") startup, navigation, and offline support.



The best way to local-first

Local-first sync for Postgres from the inventors of CRDTs

VIDEO: ARDHIRA PUTRA

GREGORY BARBER BACKCHANNEL AUG 3, 2023 6:00 AM

The Cloud Is a Prison. Can the Local-First Software Movement Set Us Free?



Knee of the (Bell) Curve

In the Wild 🦁

Knee of the (Bell) Curve

In the Wild 🦁



Knee of the (Bell) Curve

Livin' On the Edge

Knee of the (Bell) Curve

Livin' On the Edge

- ◆ Exciting times — in both senses 🎢



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- ◆ Lots of low hanging fruit!



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 - ◆ No LoFi LAMP... yet



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- ◆ No hand holding



Knee of the (Bell) Curve

New Constrains = New Design Space

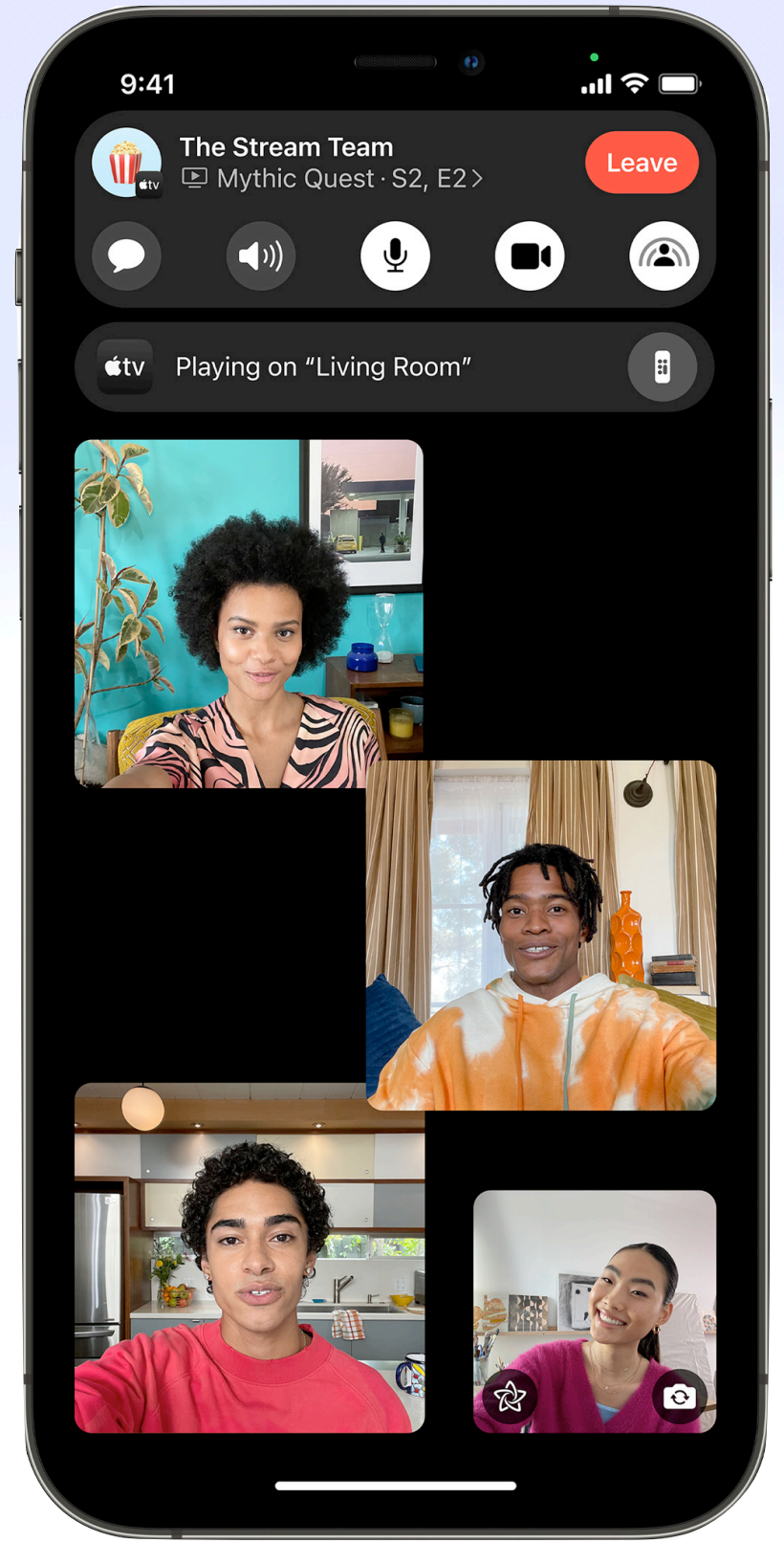
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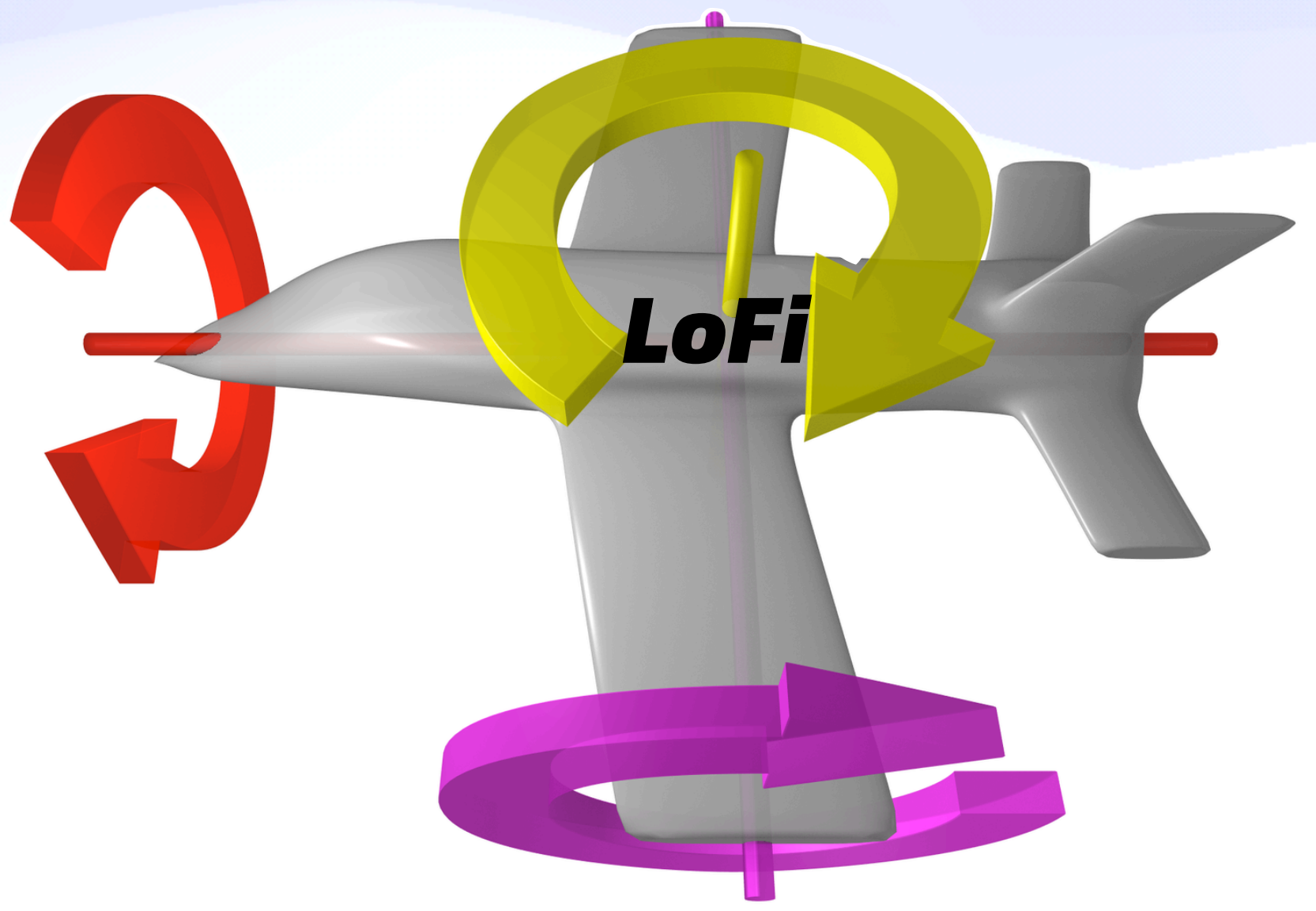
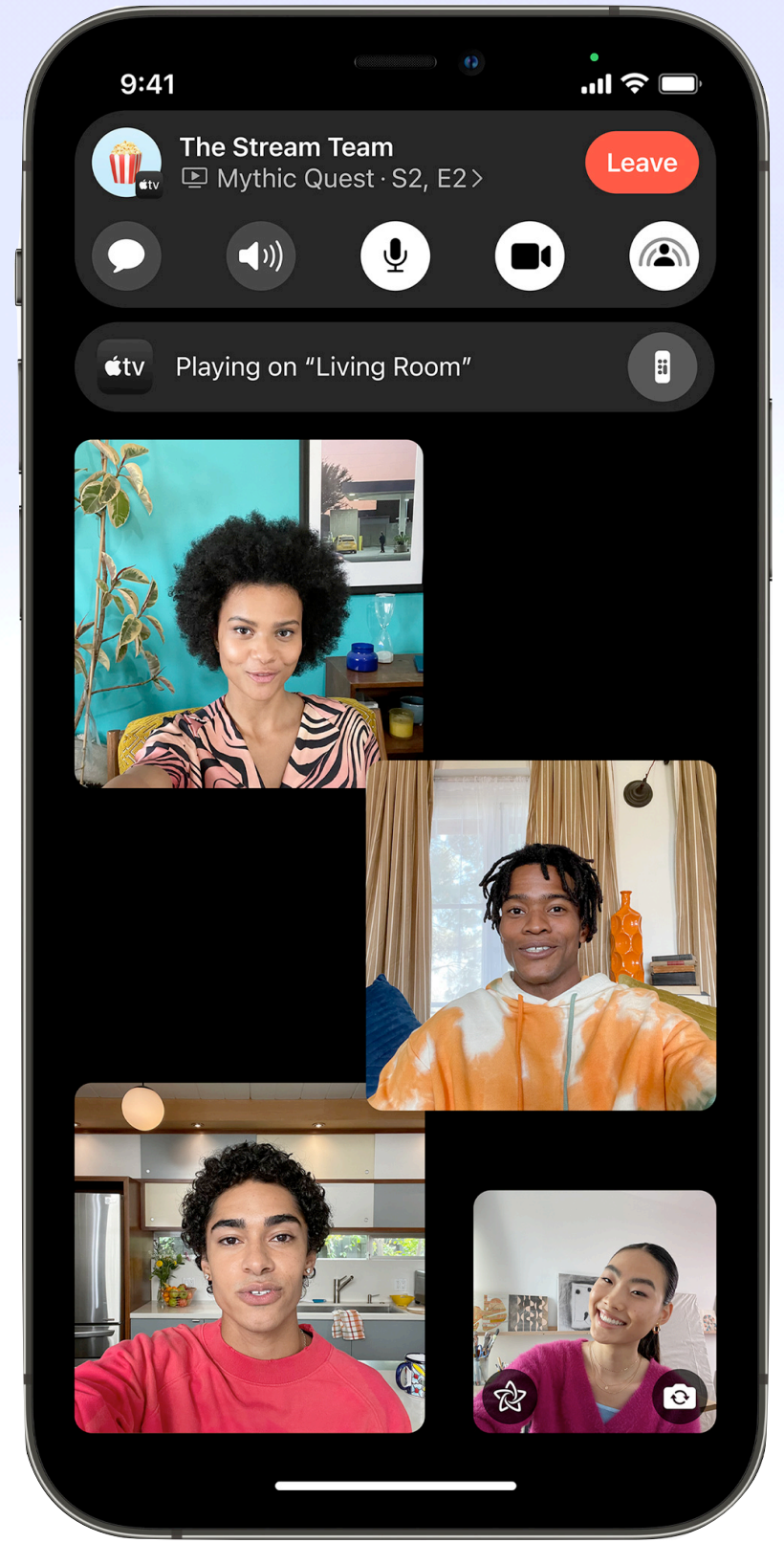
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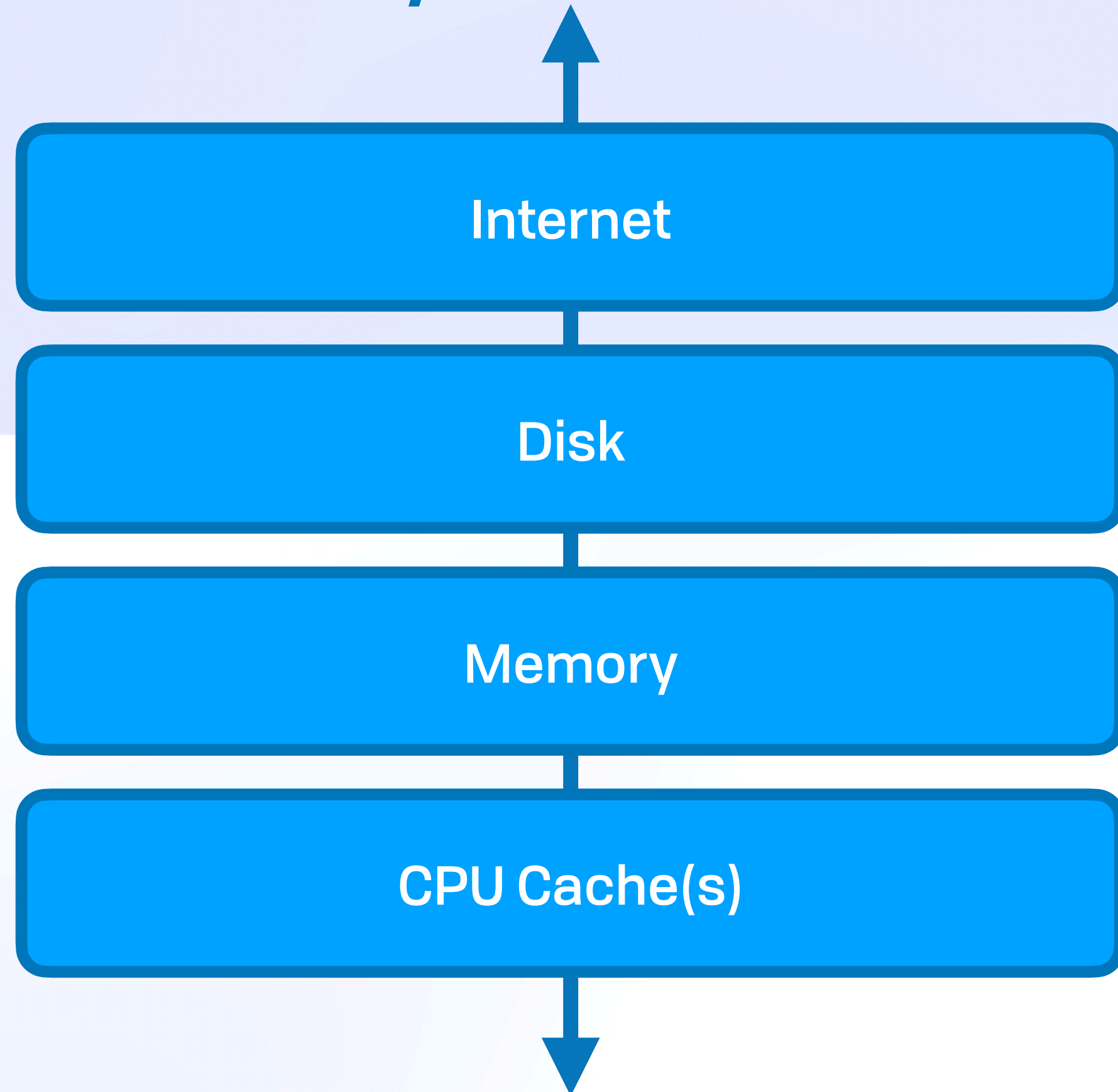
New Metaphors

Layered Cache

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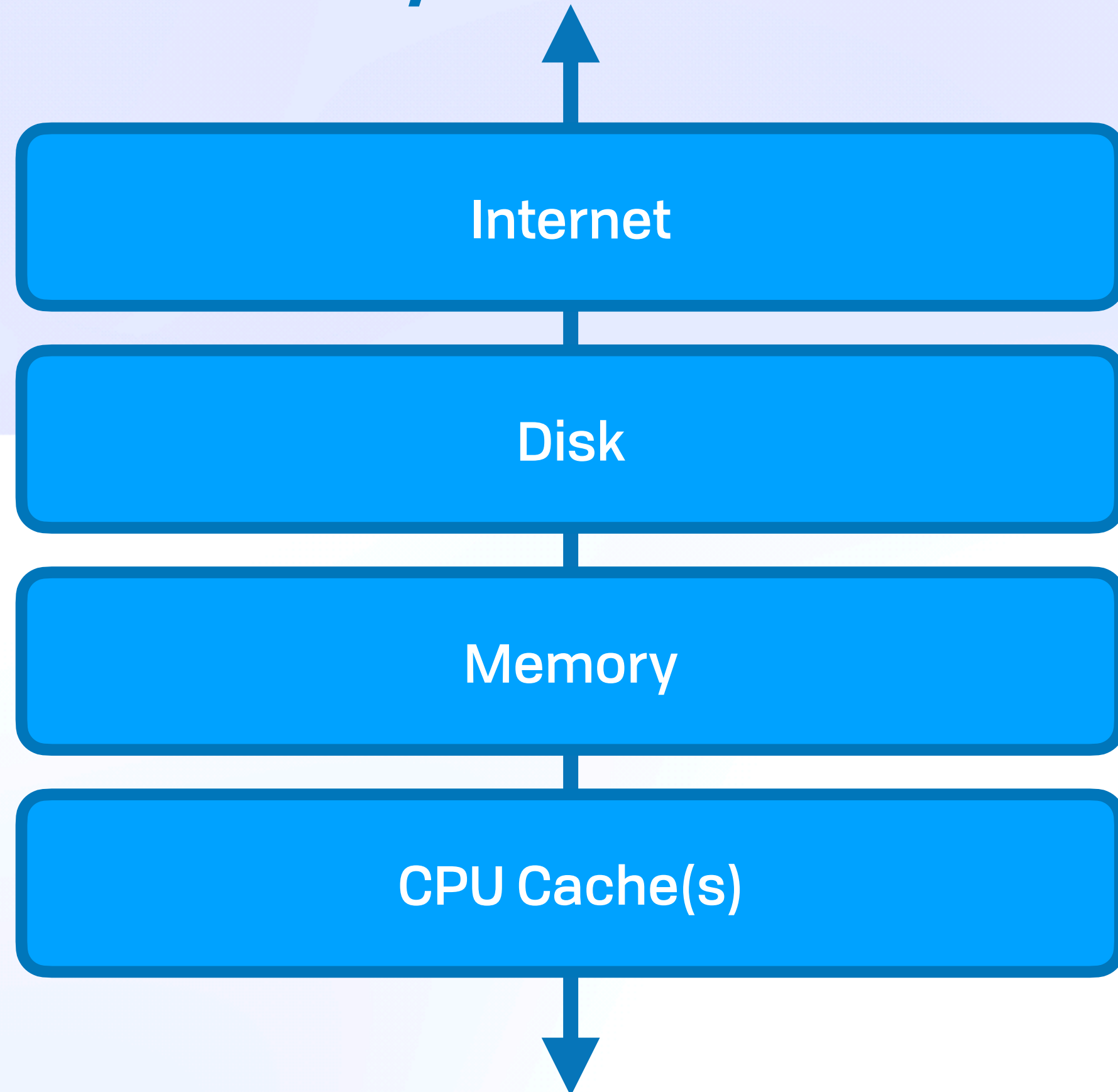
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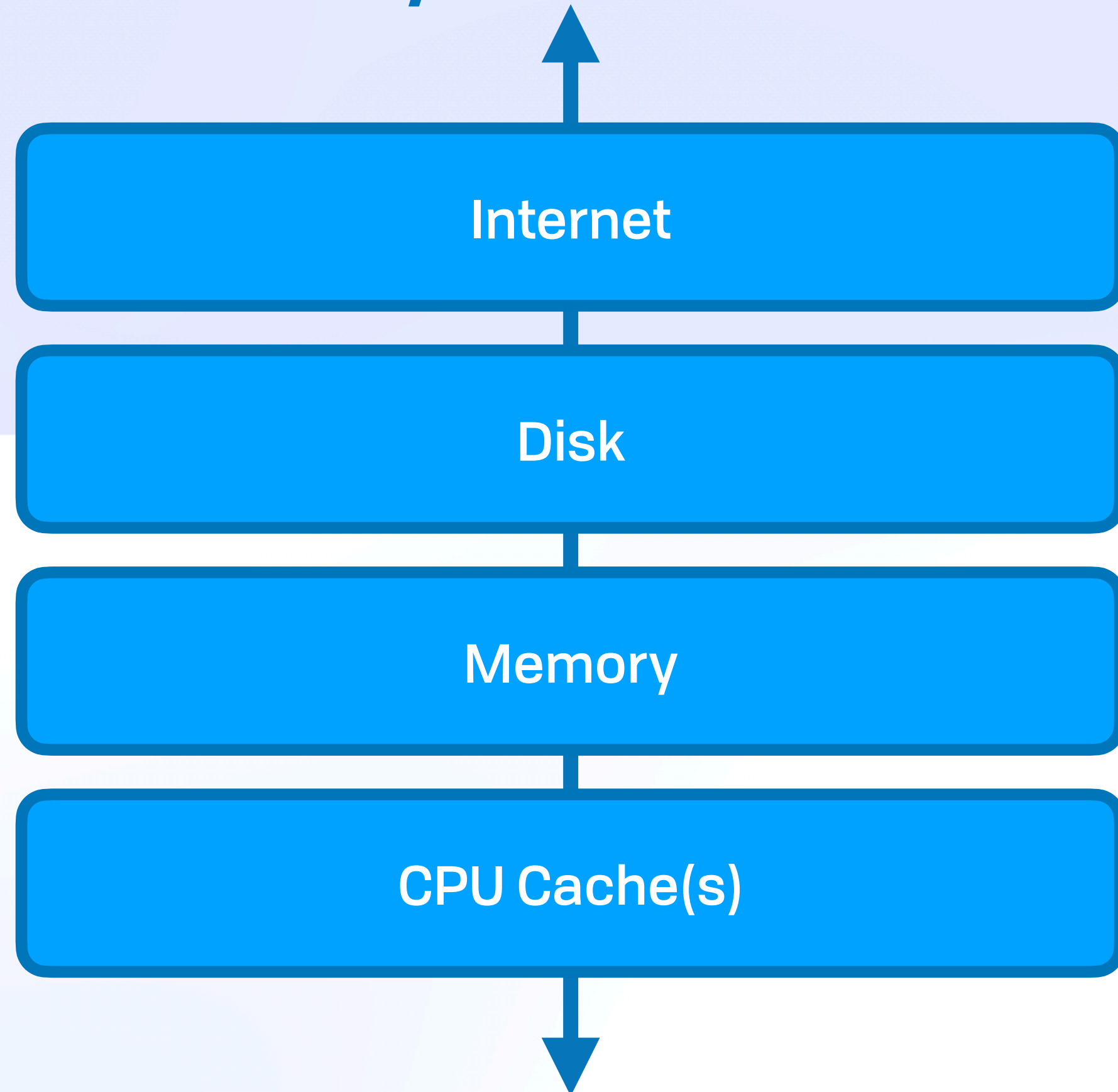


Cellular / P2P

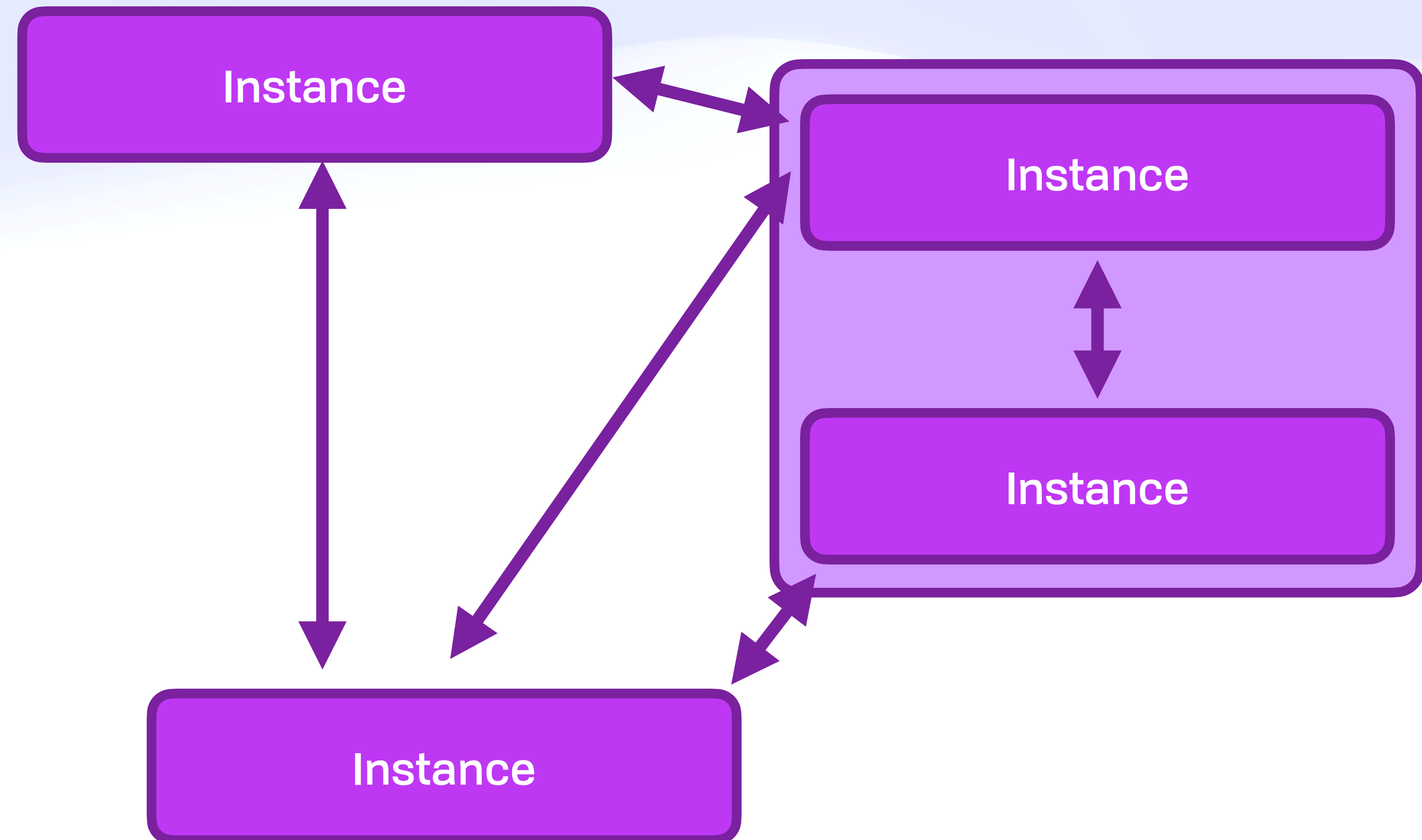
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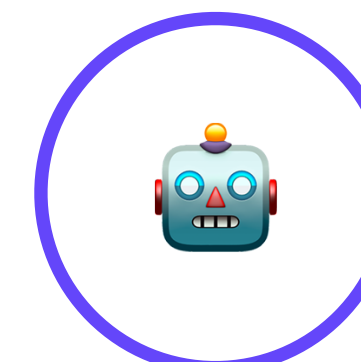
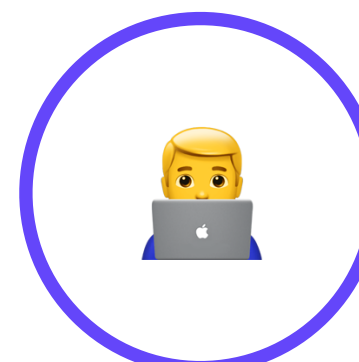
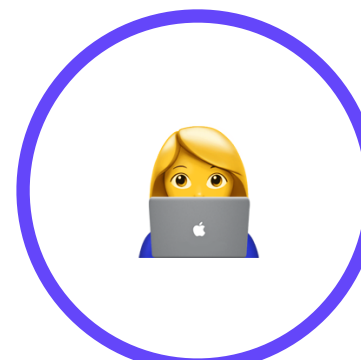
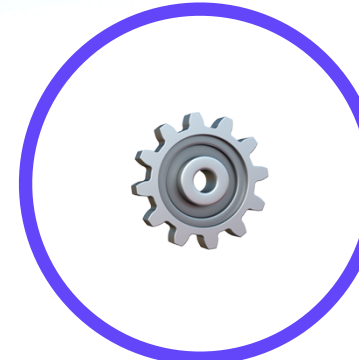
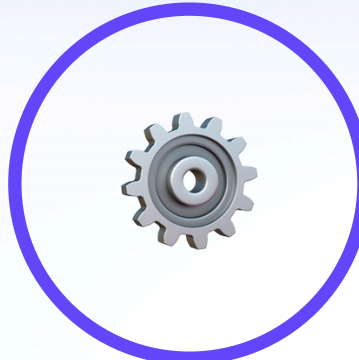
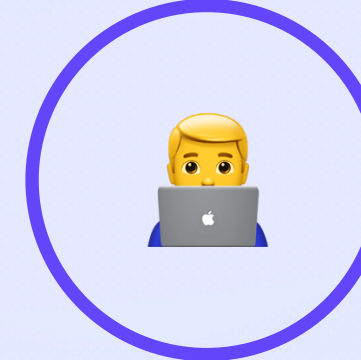
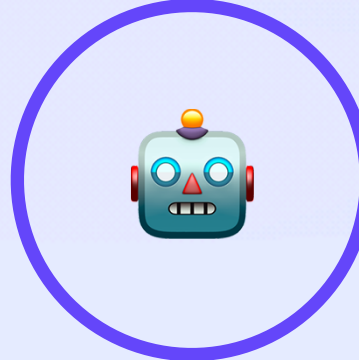


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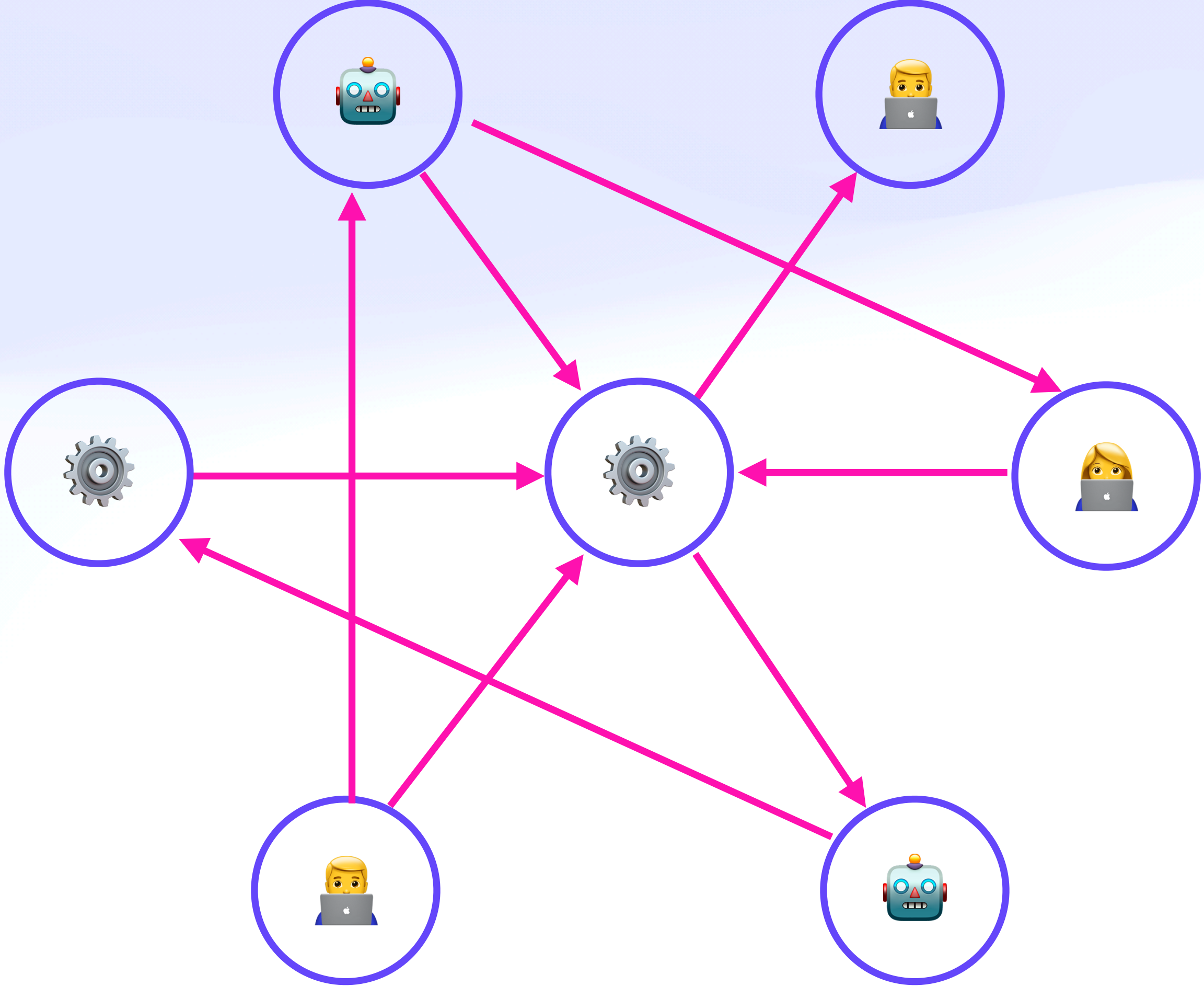
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Disorderly Programming



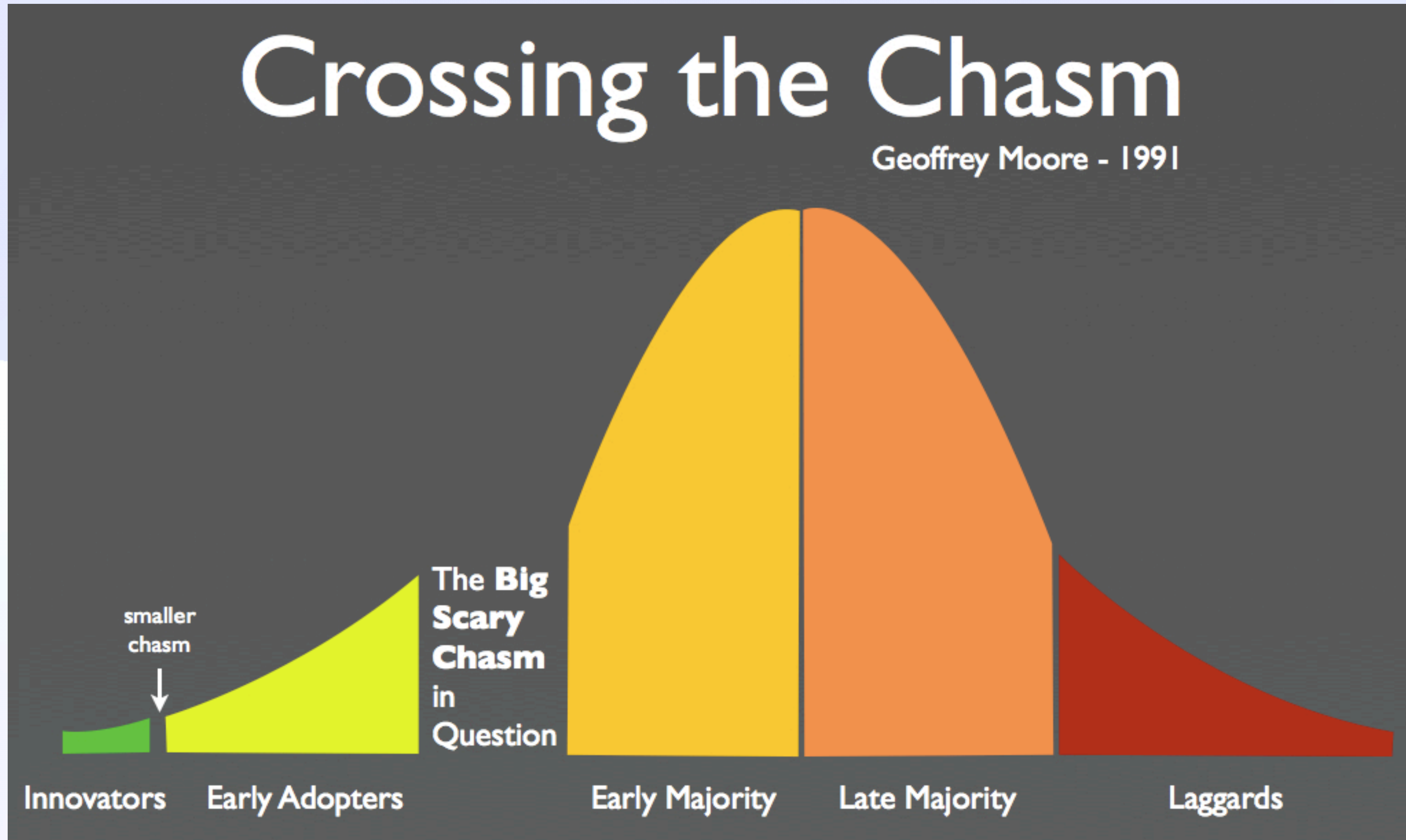
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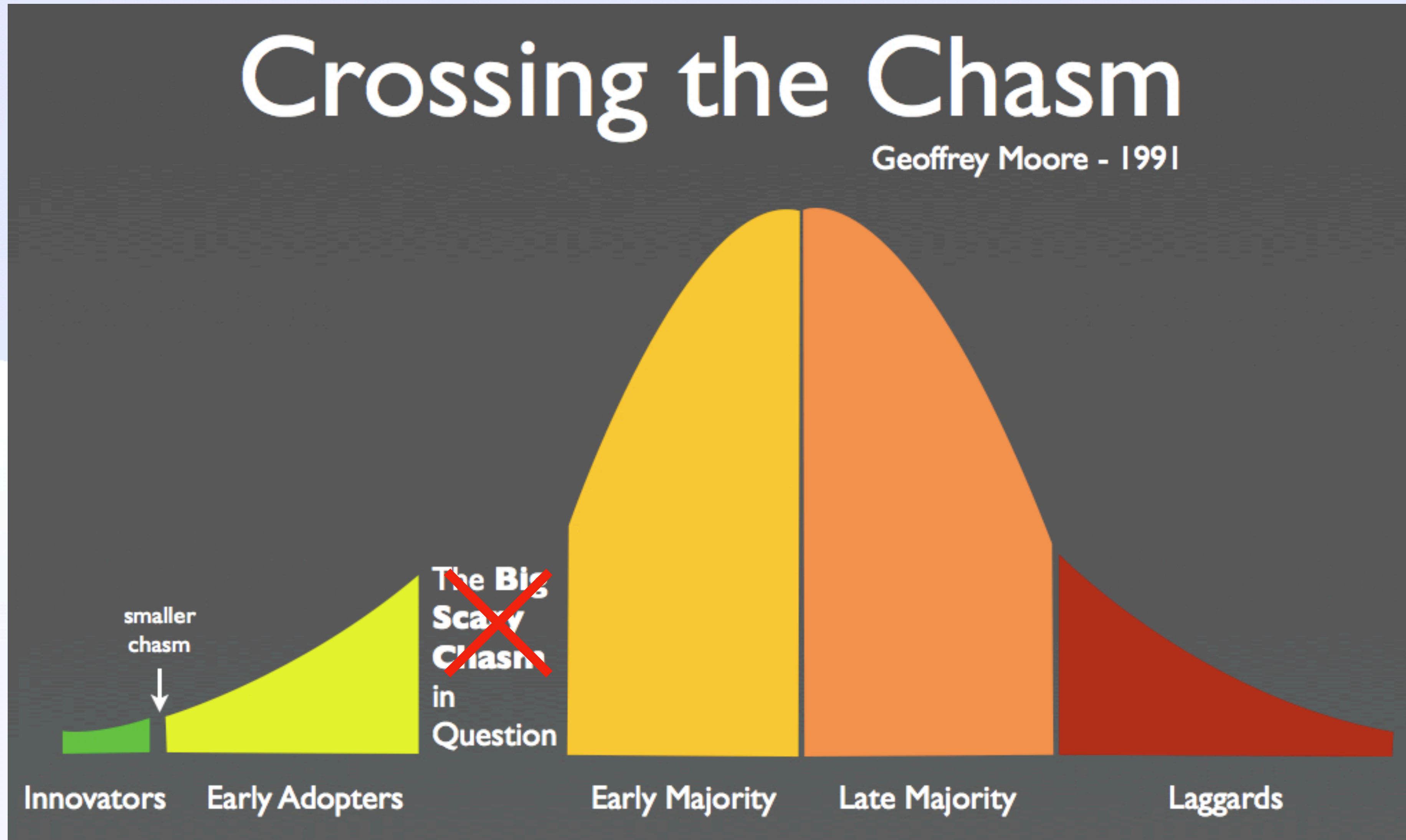
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Know Your Audience



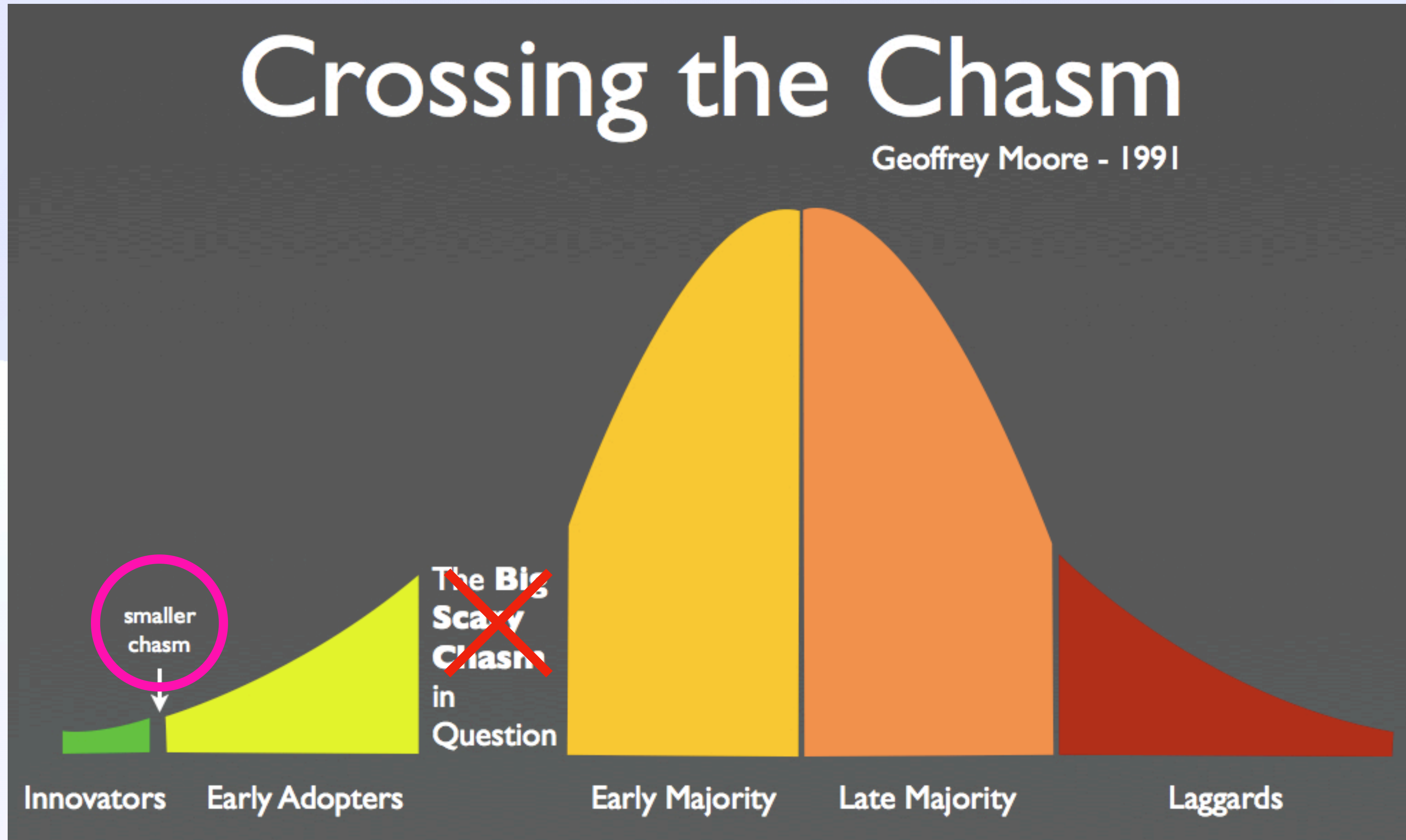
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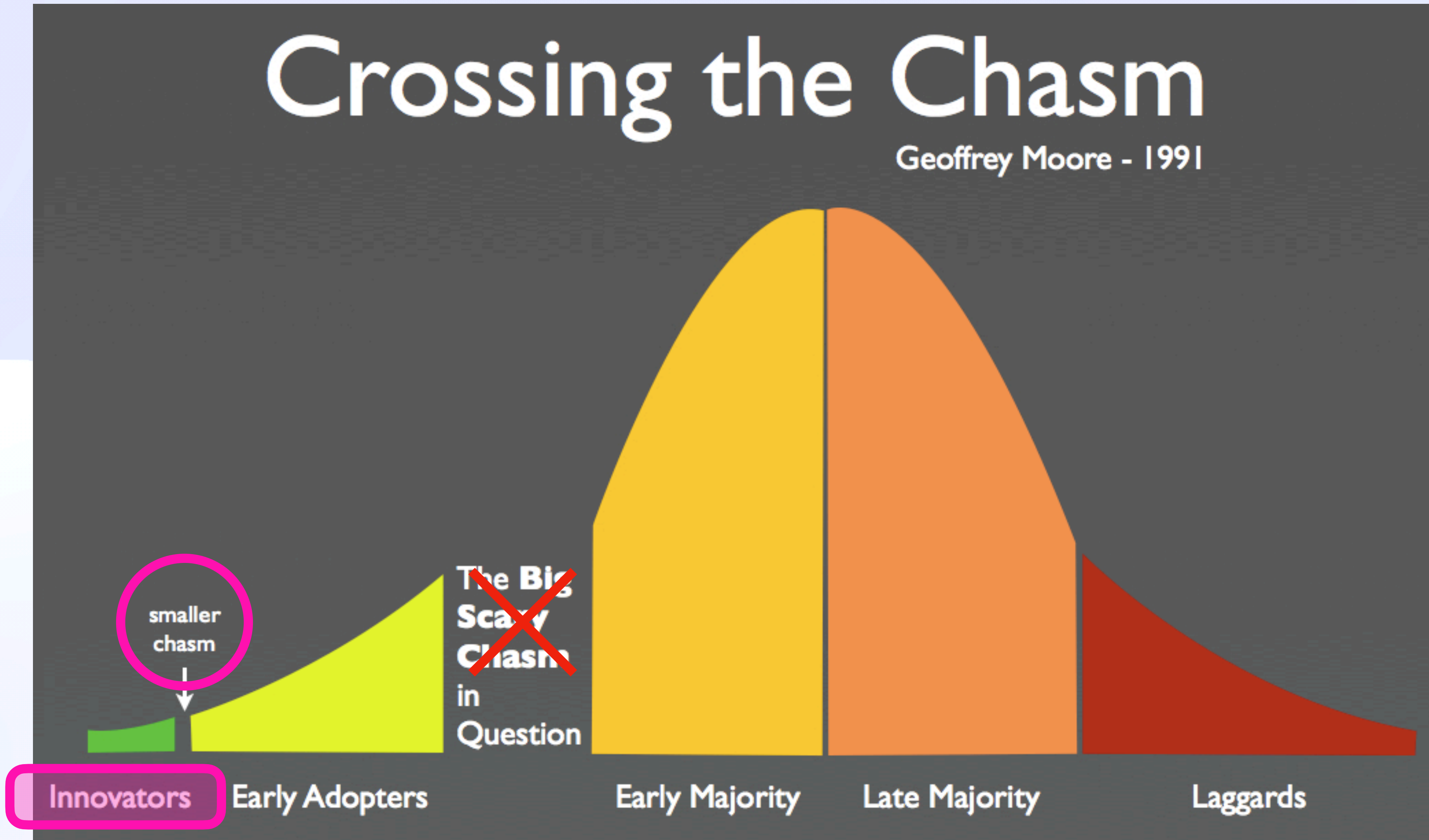
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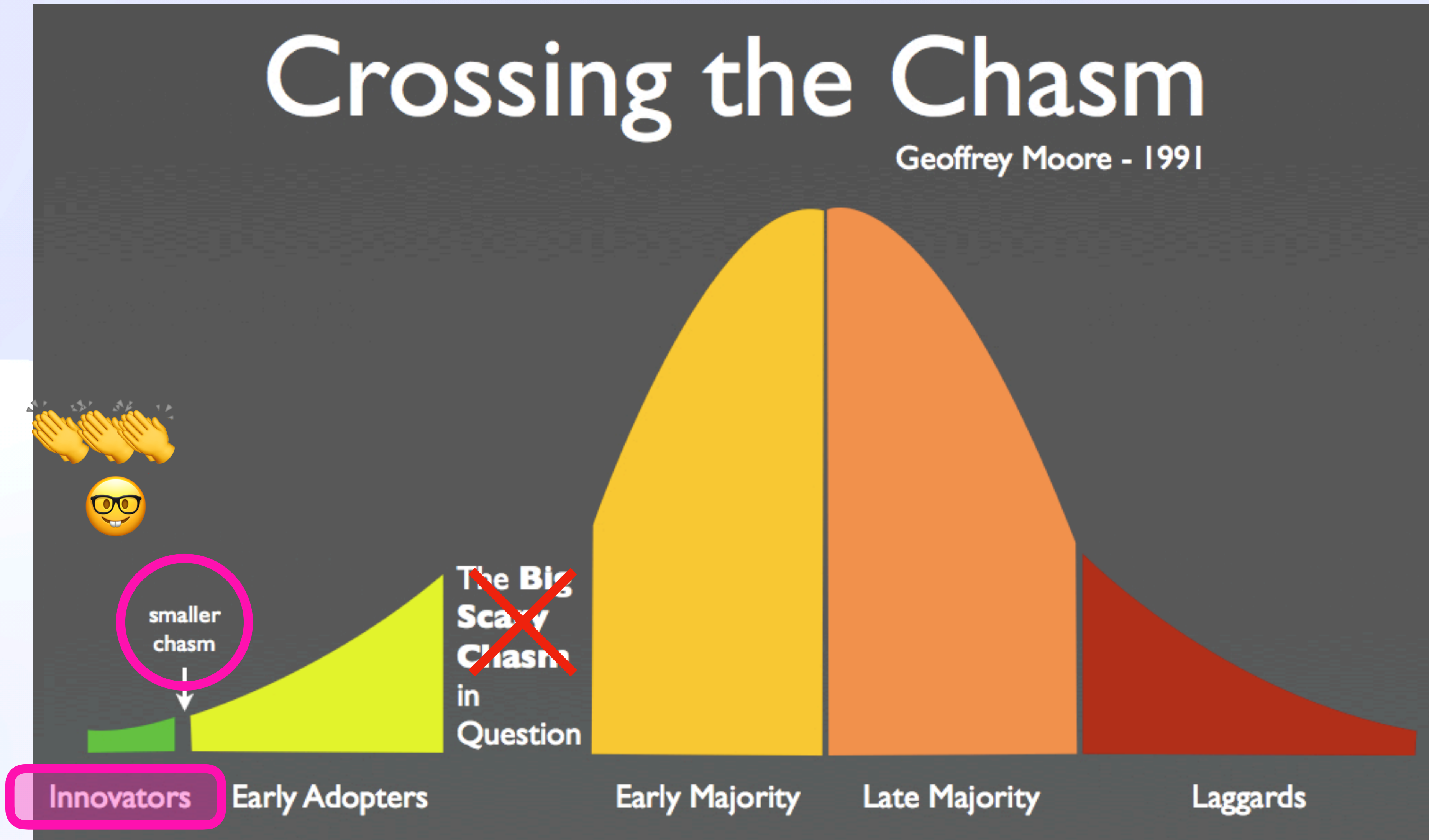
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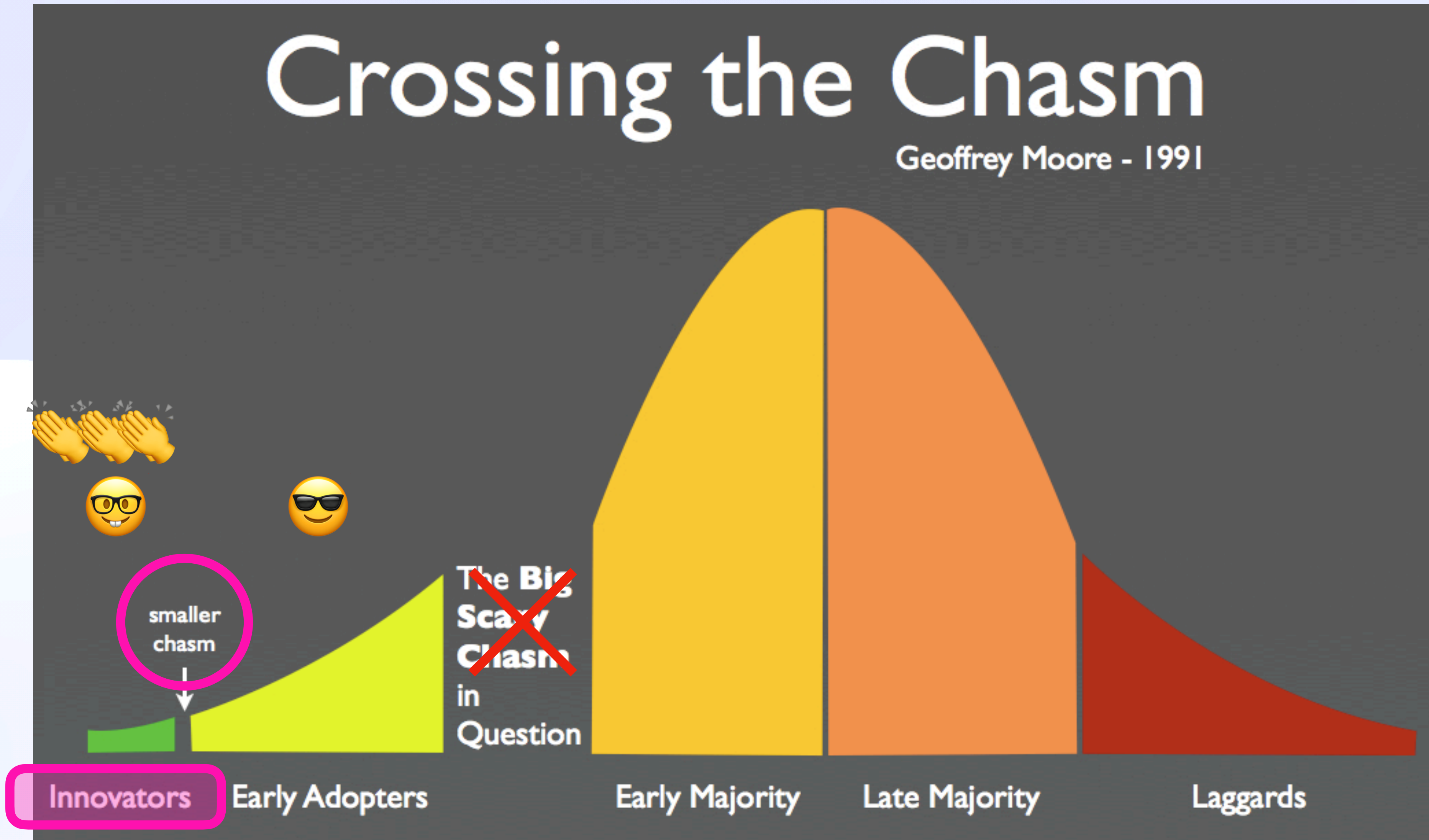
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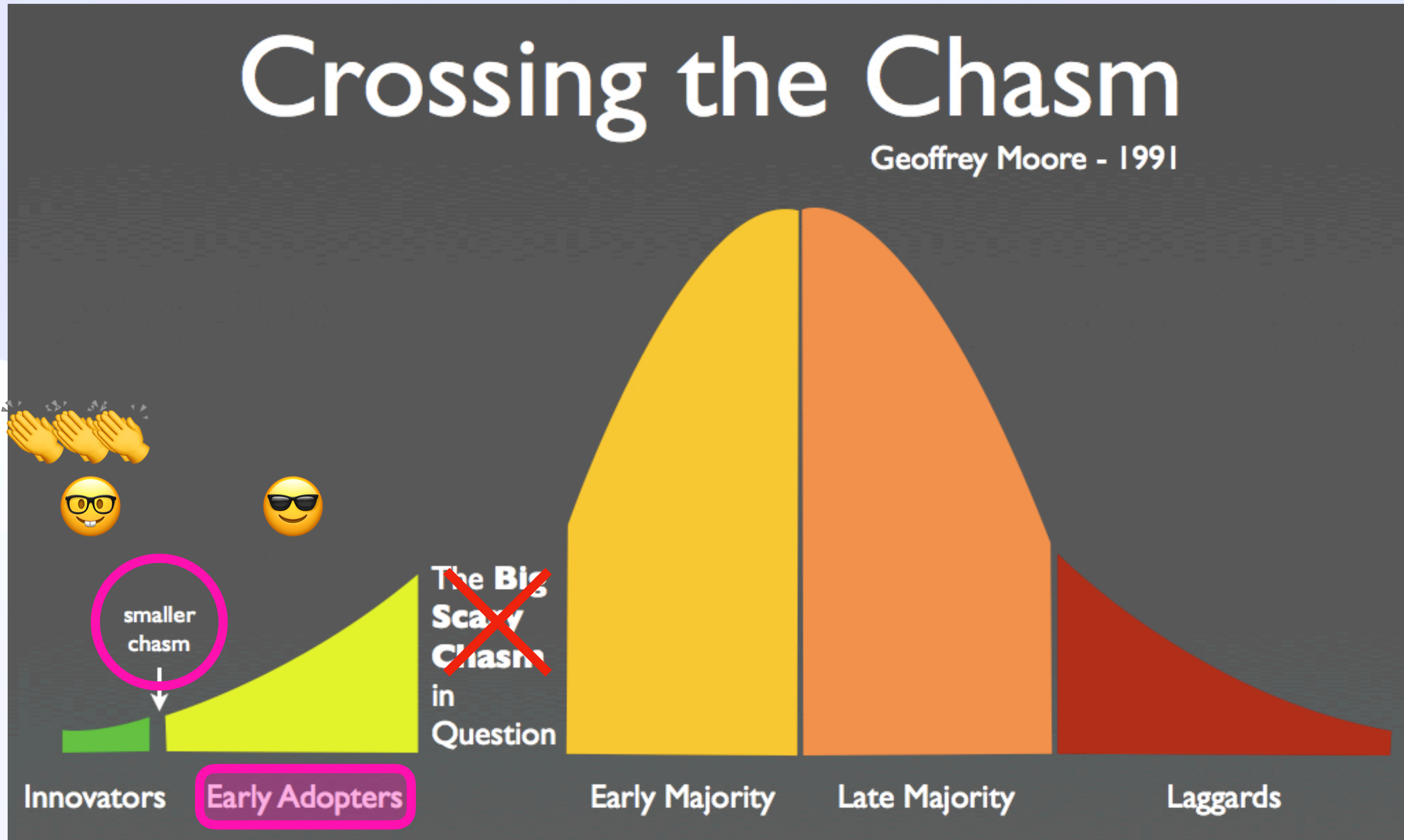
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Knee of the (Bell) Curve

The Great Spiral 🛠️

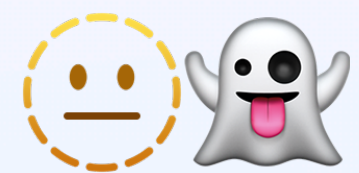
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Invention

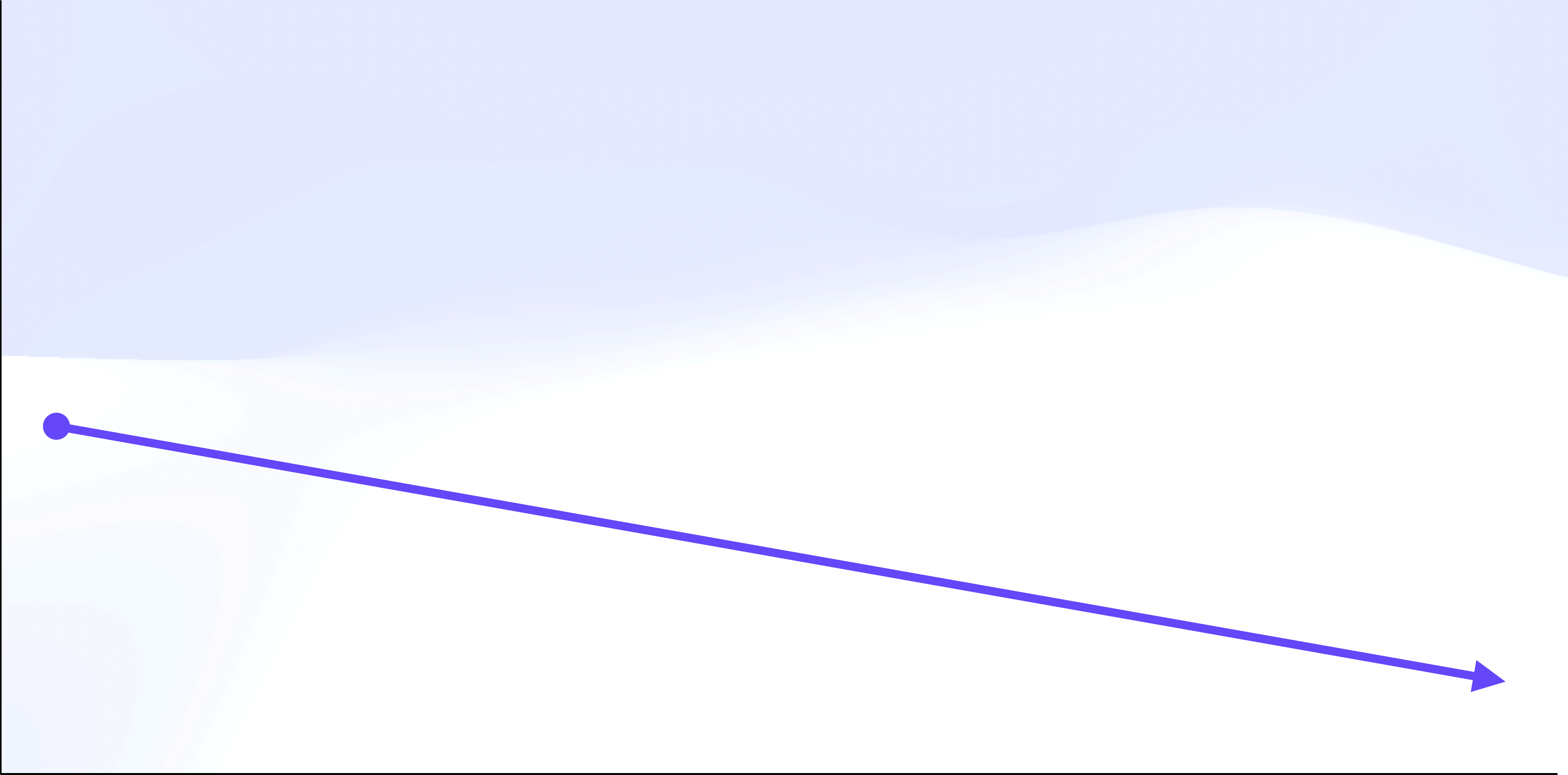
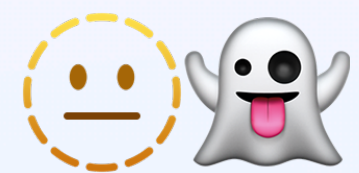
Custom

Off-the-Shelf

Utility

Knee of the (Bell) Curve

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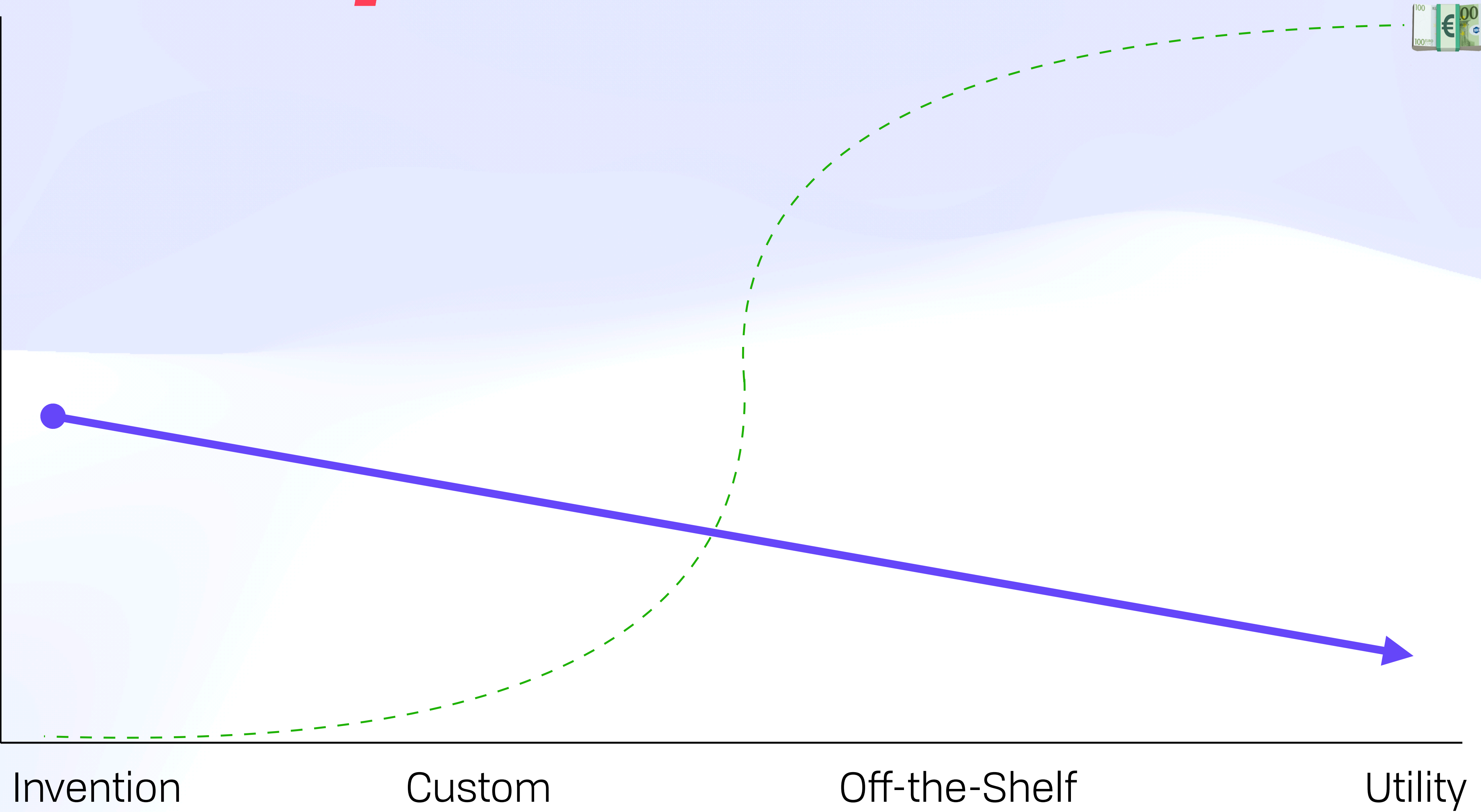
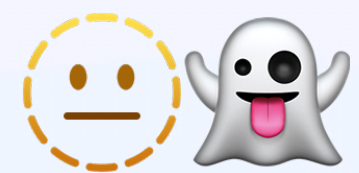
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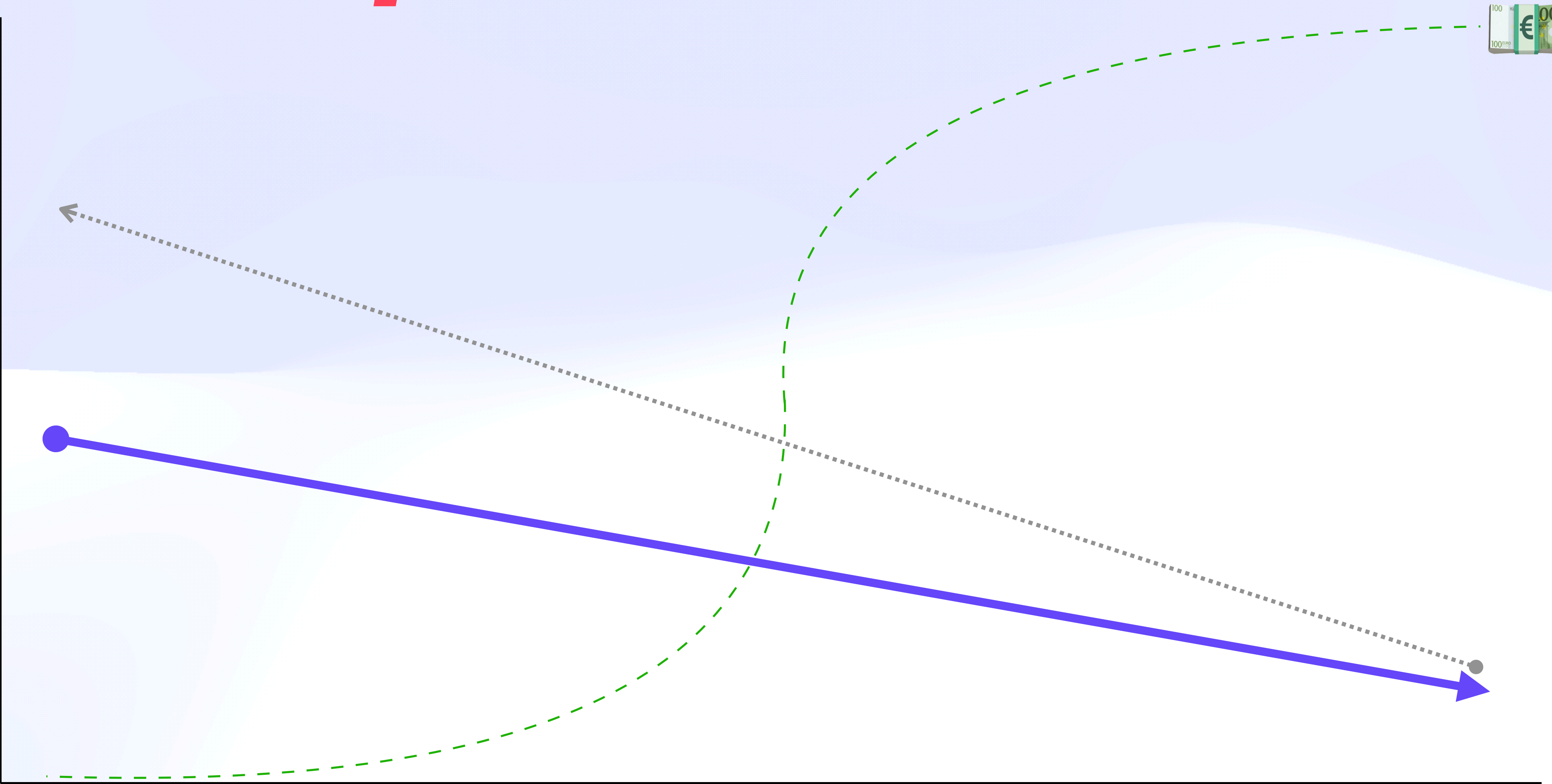
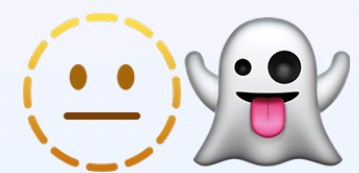
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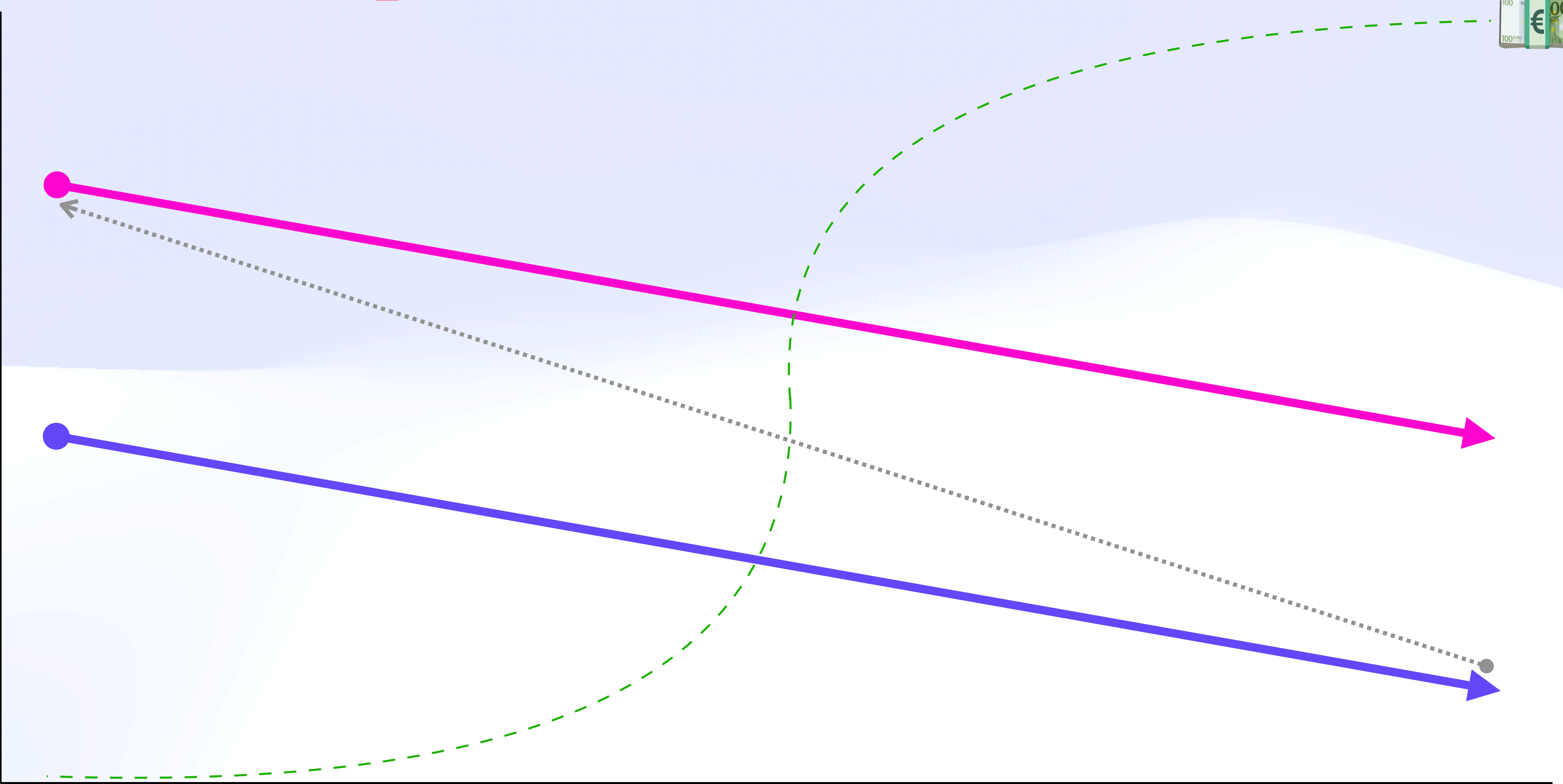
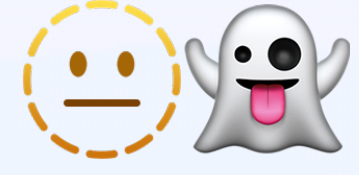
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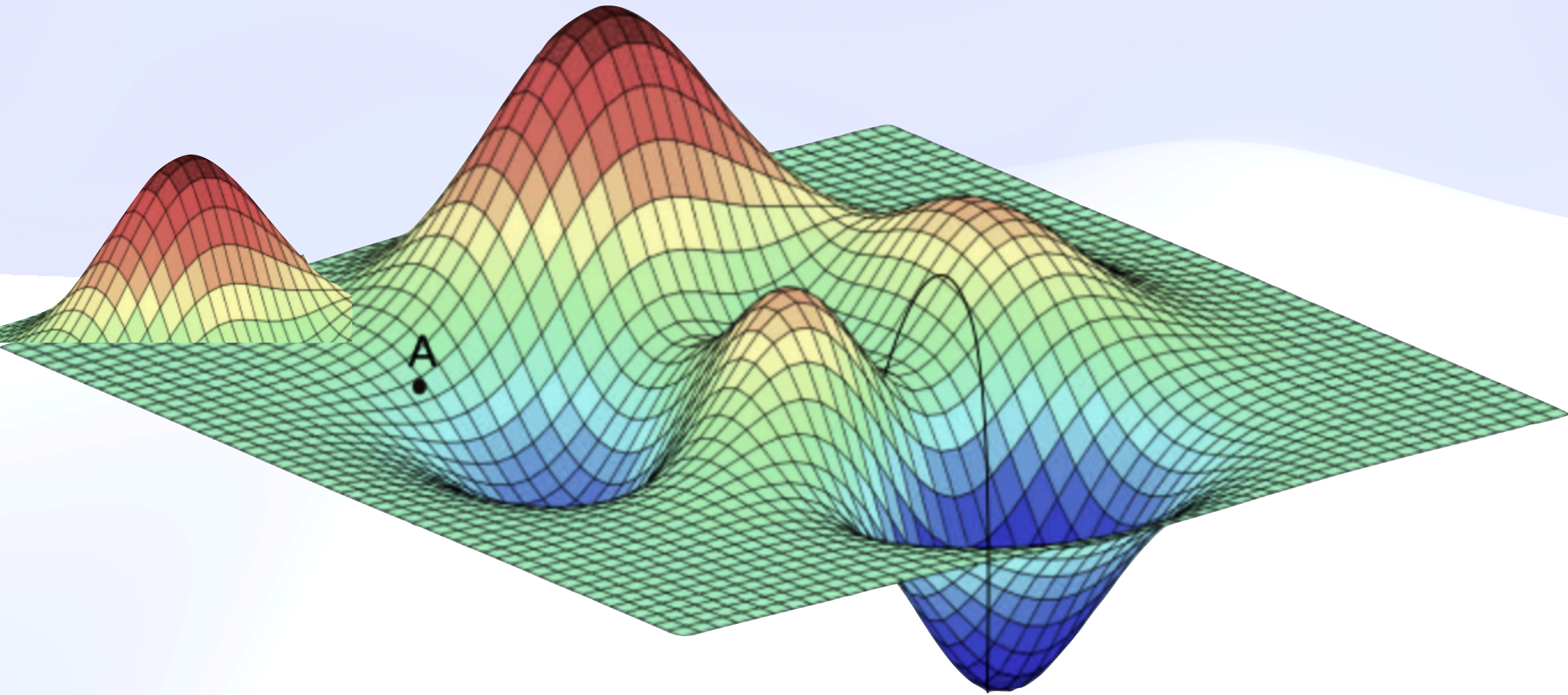


Knee of the (Bell) Curve

Random Walk

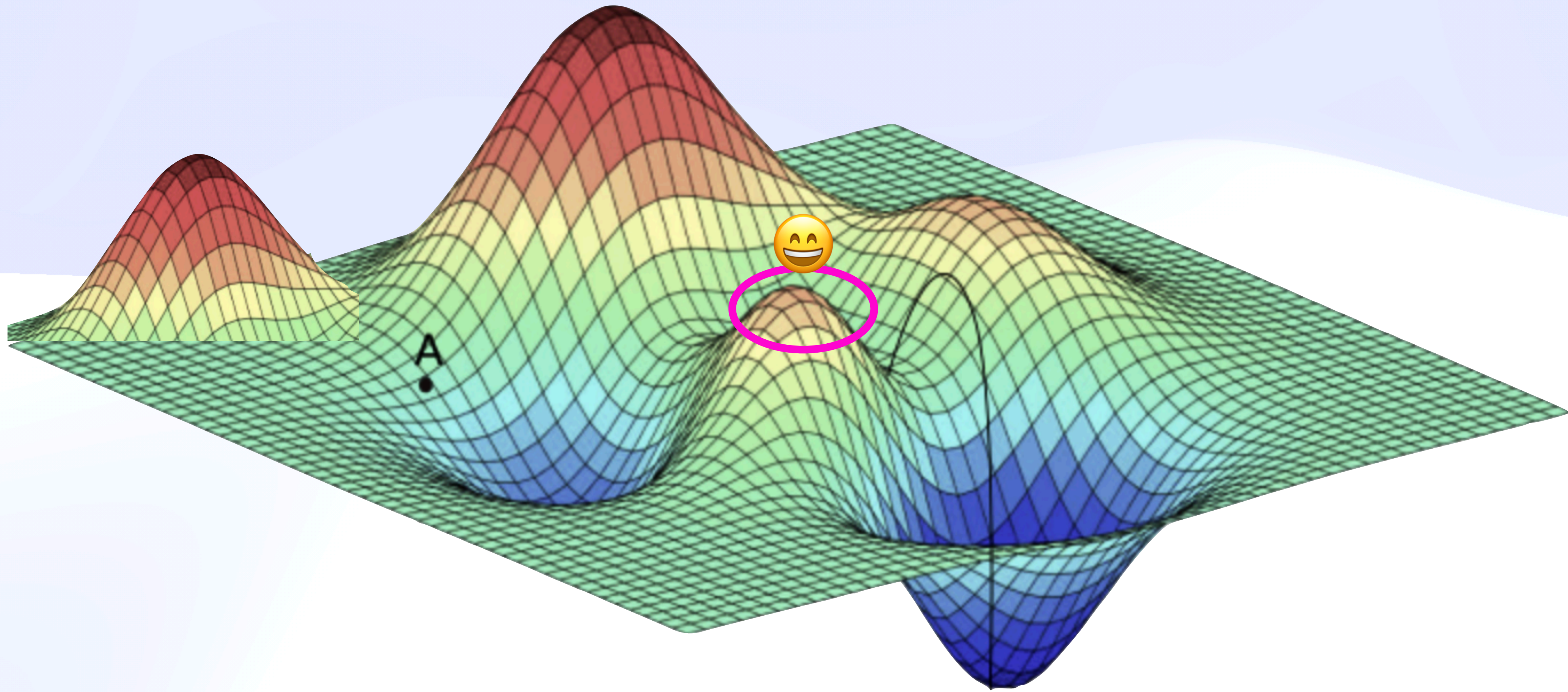
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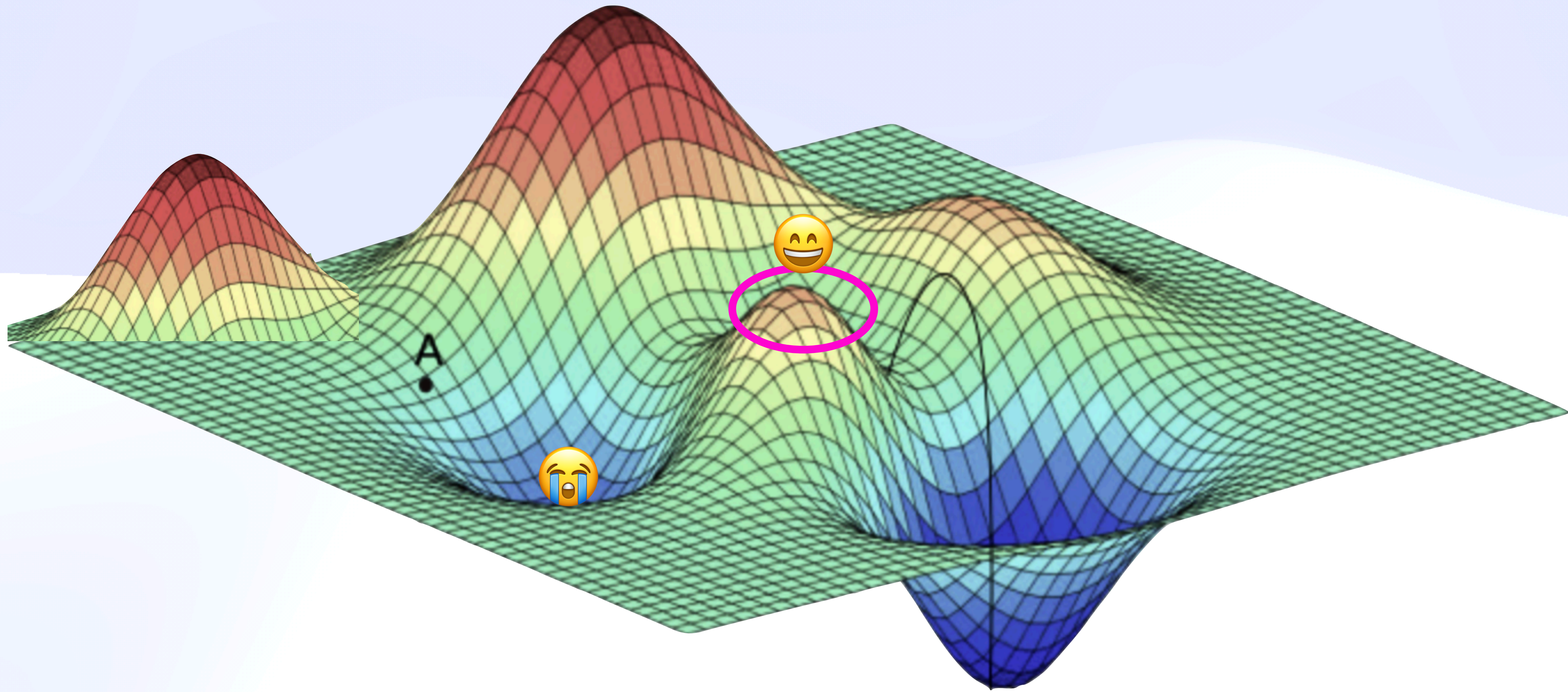
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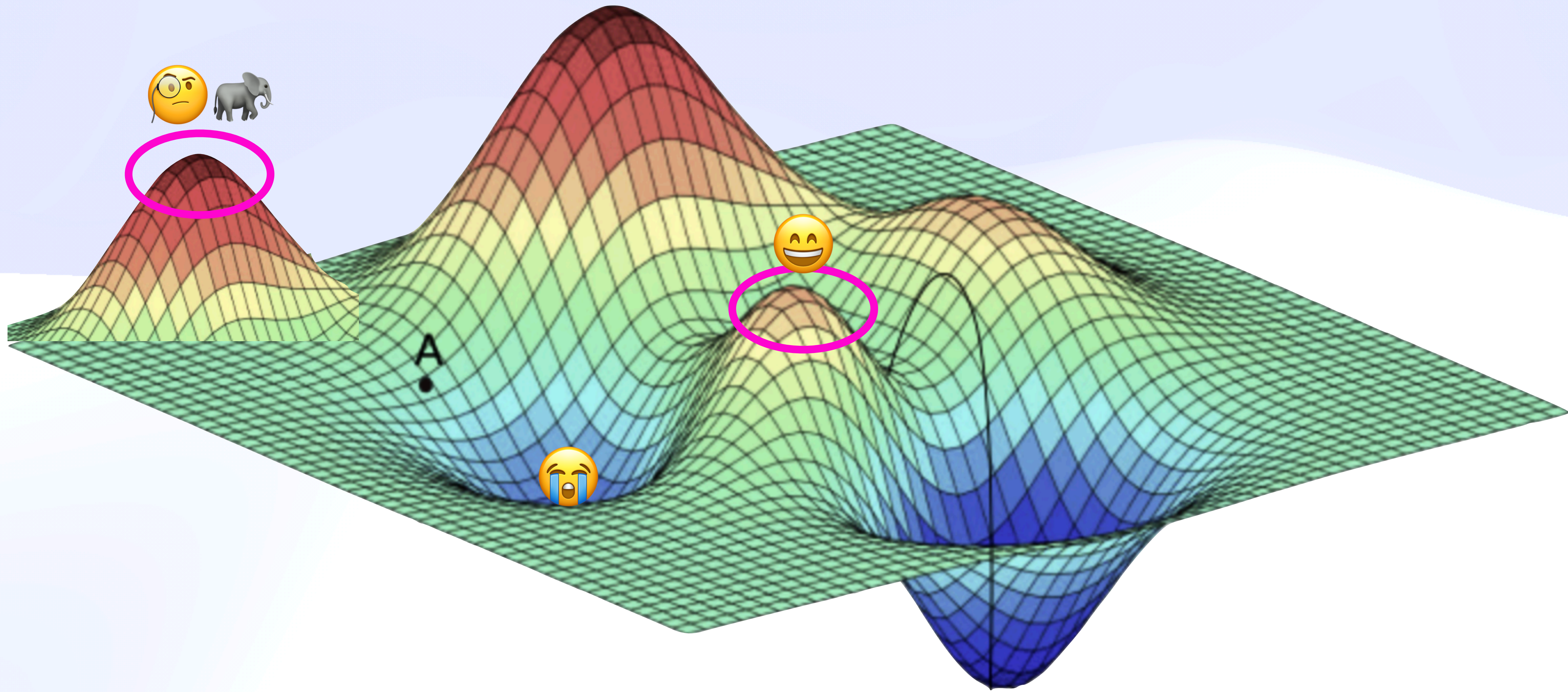
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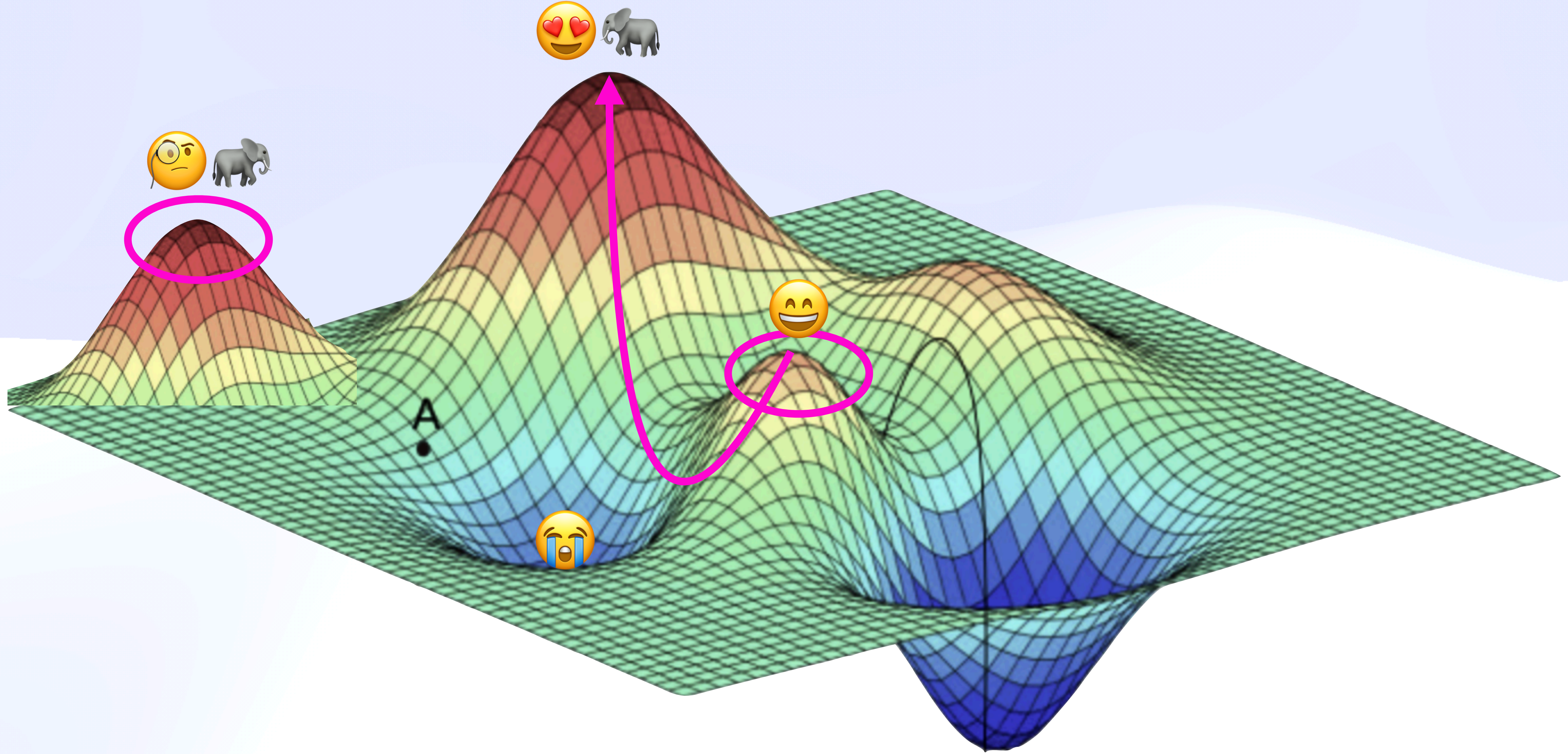
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What Even is "Local-First"?

Convenience, Idealism, and Movement Building



What Even is "Local-First"?

Computing is Personal Again

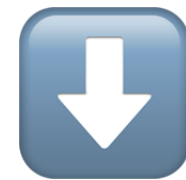
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Computing is Personal Again

Desktop: Personal Computing



Cloud: Impersonal Computing



LoFi: Interpersonal Computing

*Or: Postmodern

What Even is "Local-First"?

Slicing the Problem

Seven ideals for local-first software

1. No spinners: your work at your fingertips
2. Your work is not trapped on one device
3. The network is optional
4. Seamless collaboration with your colleagues
5. The Long Now
6. Security and privacy by default
7. You retain ultimate ownership and control

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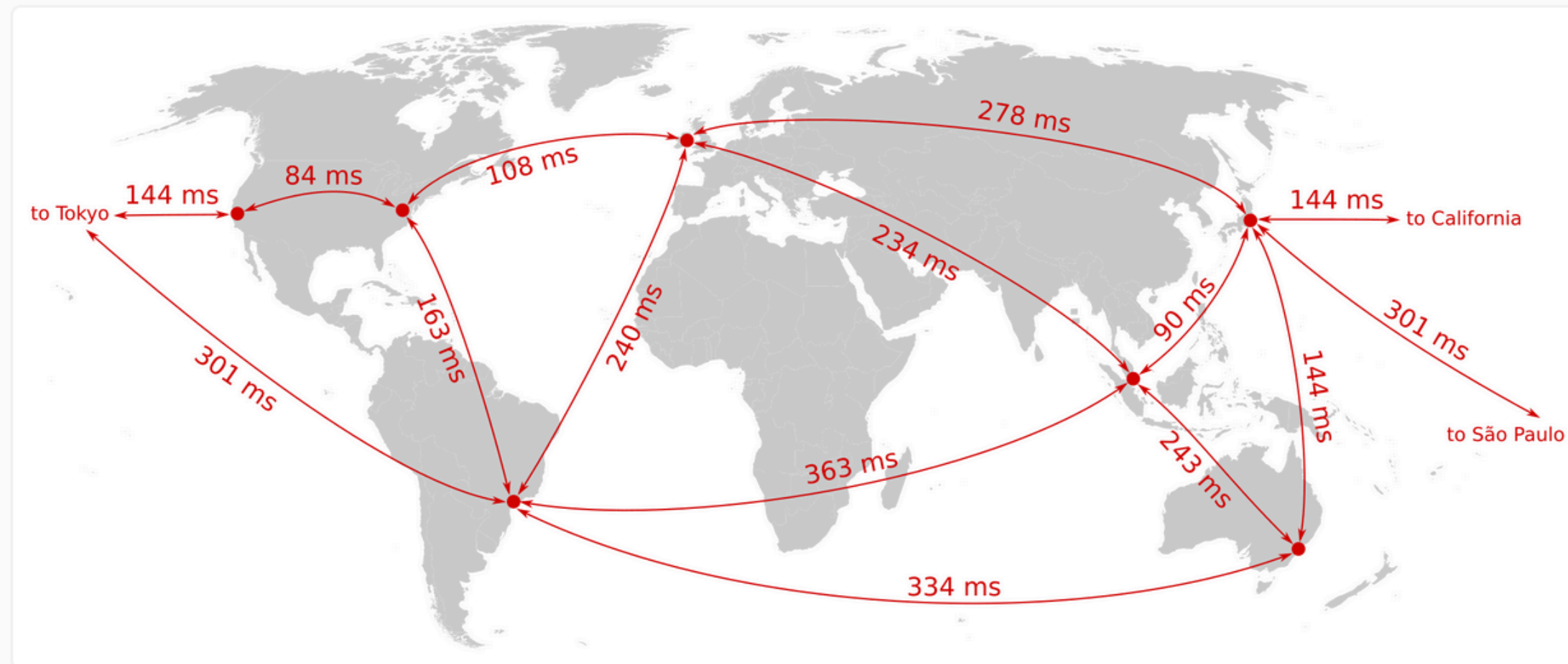
Inevitable

What Even is "Local-First"?

Inevitable

1. No spinners: your work at your fingertips

Much of today's software feels slower than previous generations of software. Even though CPUs have become ever faster, there is often a perceptible delay between some user input (e.g. clicking a button, or hitting a key) and the corresponding result appearing on the display. In previous work we measured the performance of modern software and analyzed why these delays occur.

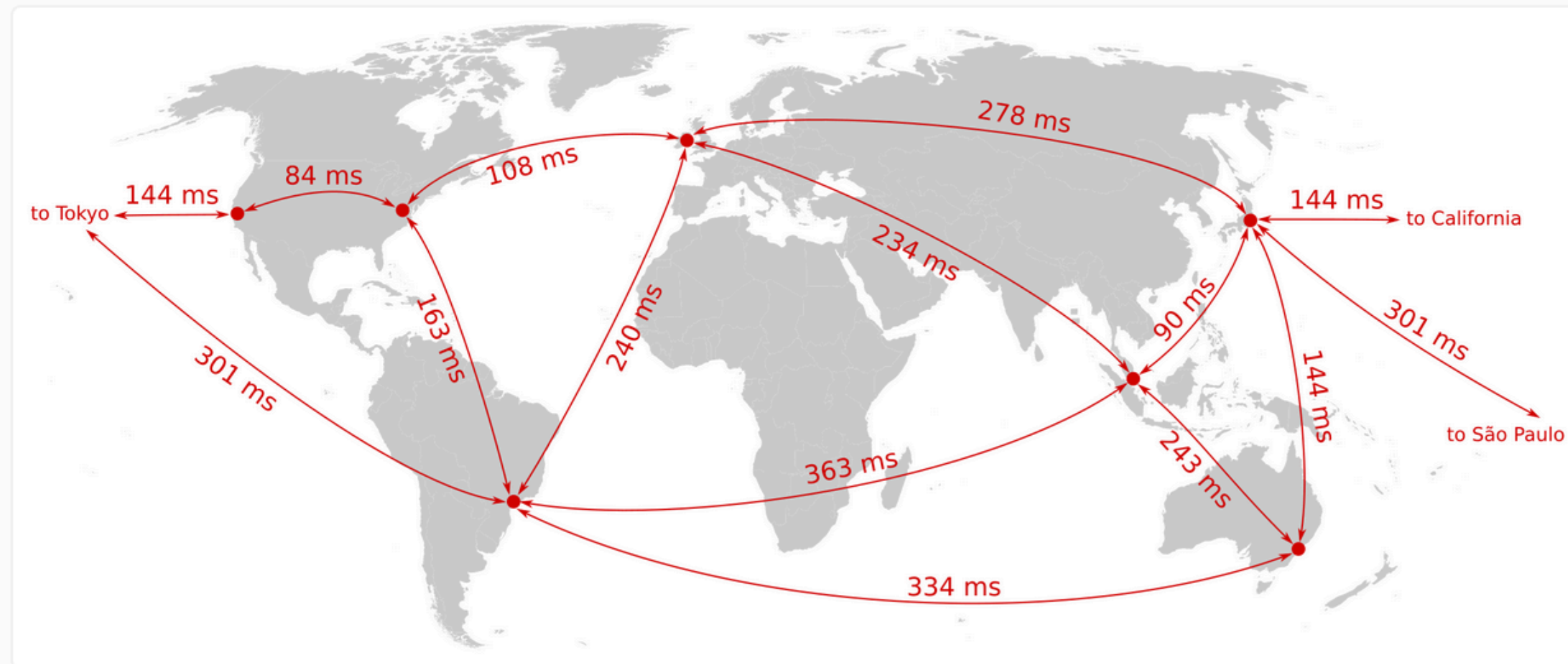


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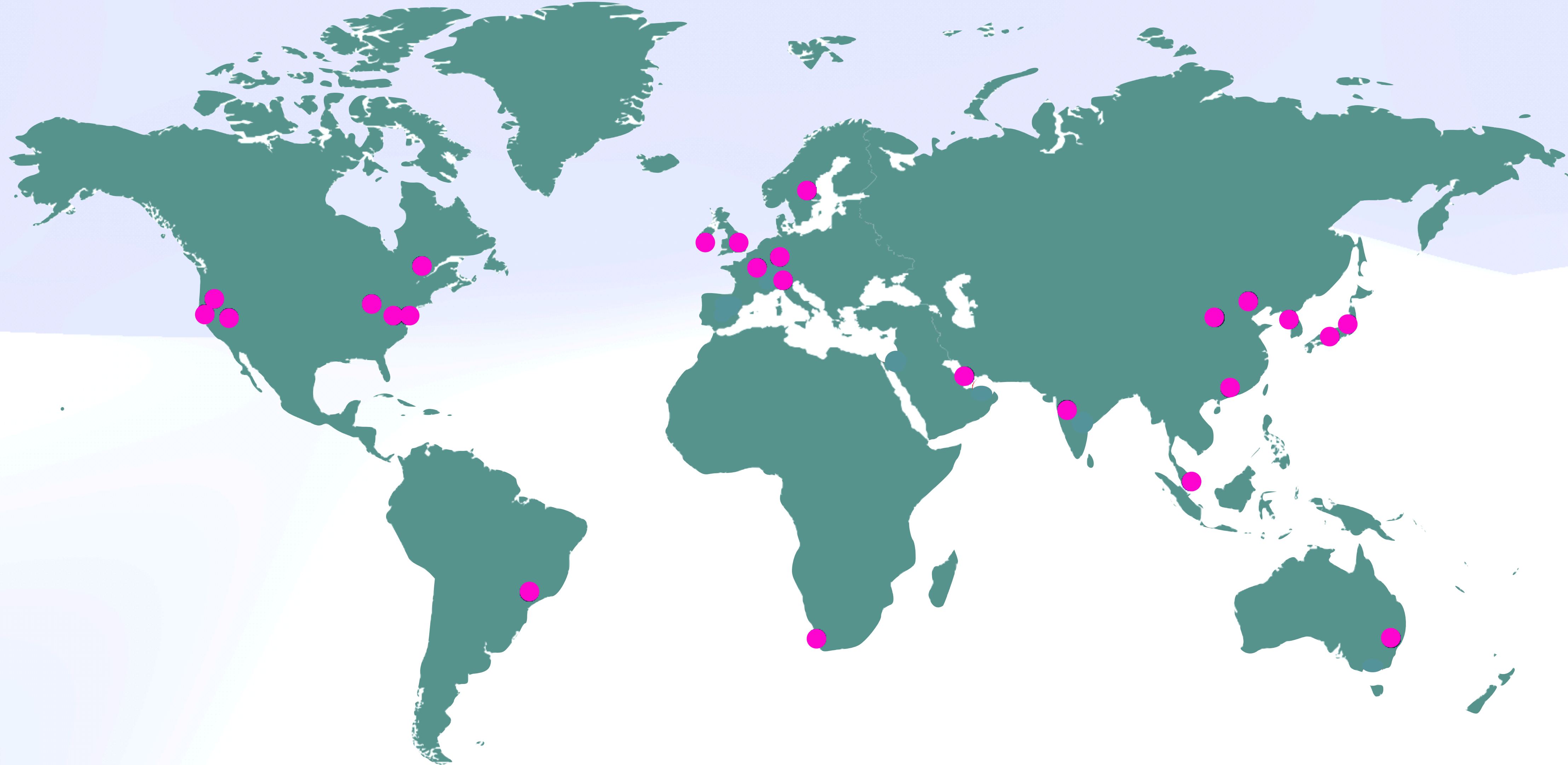
New York is not getting any closer to Tokyo [...]

The latency barrier [...] will increasingly dominate

— Mark Miller, Robust Composition

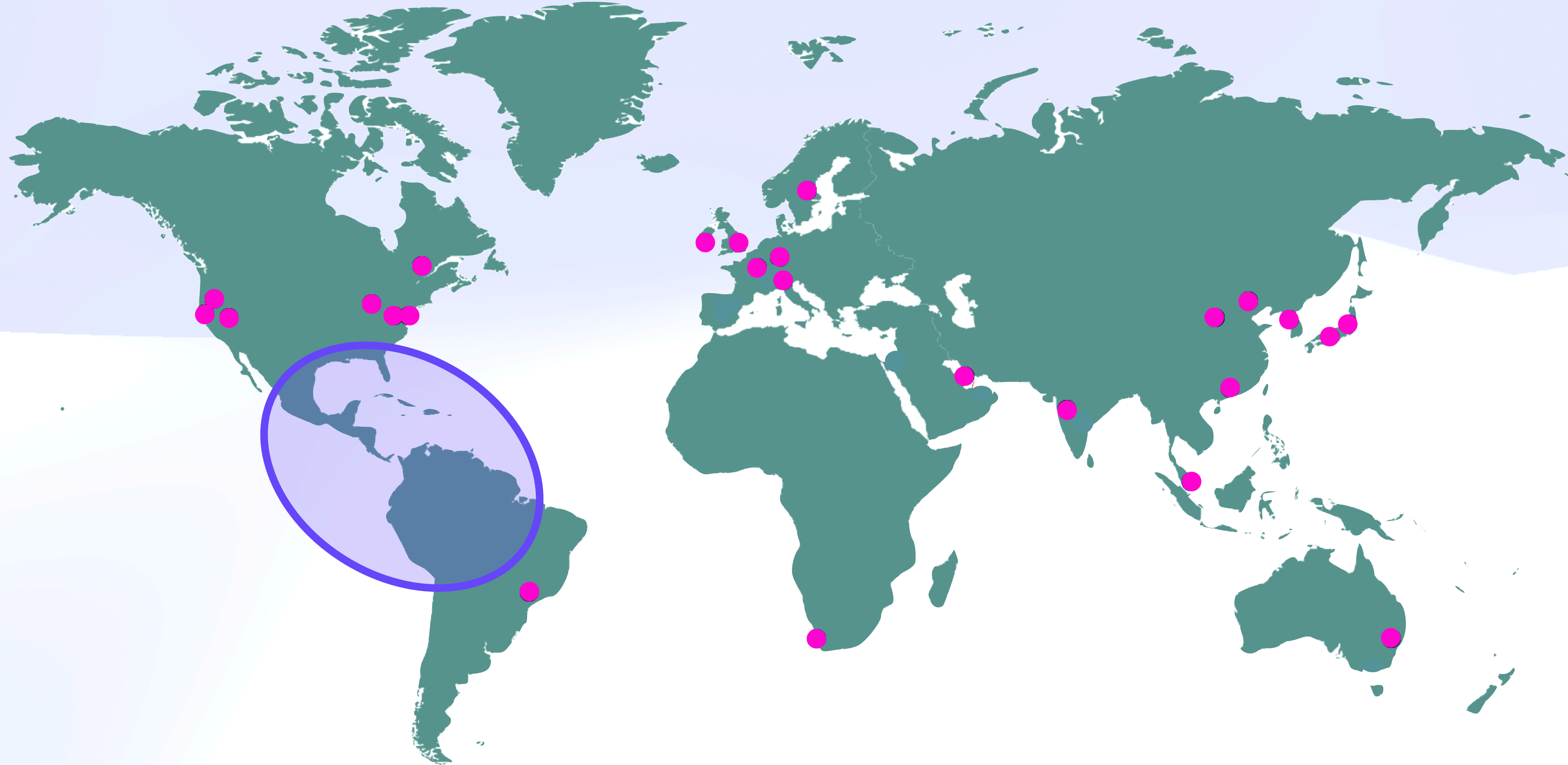
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Users vs Cloud Infra



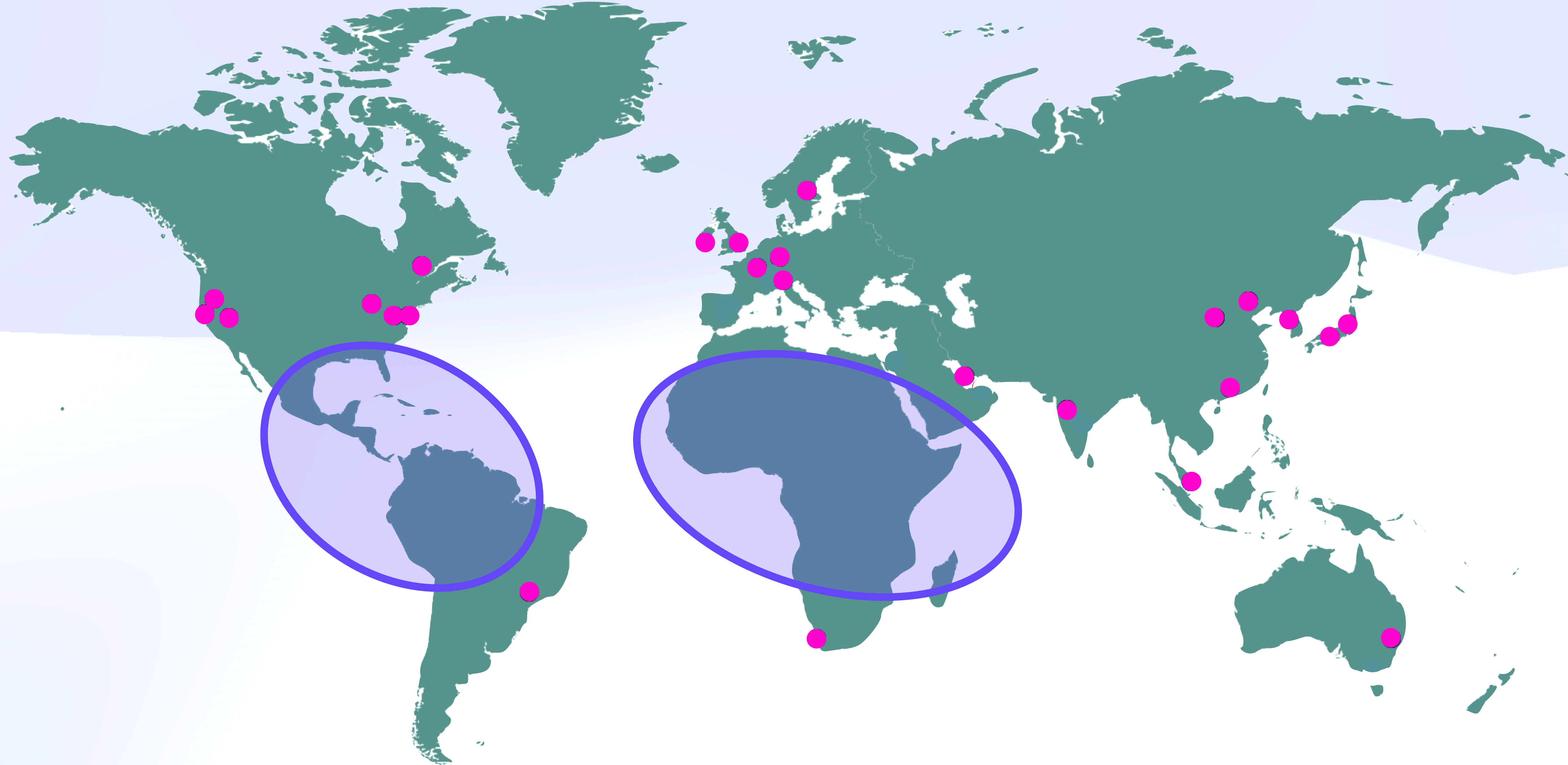
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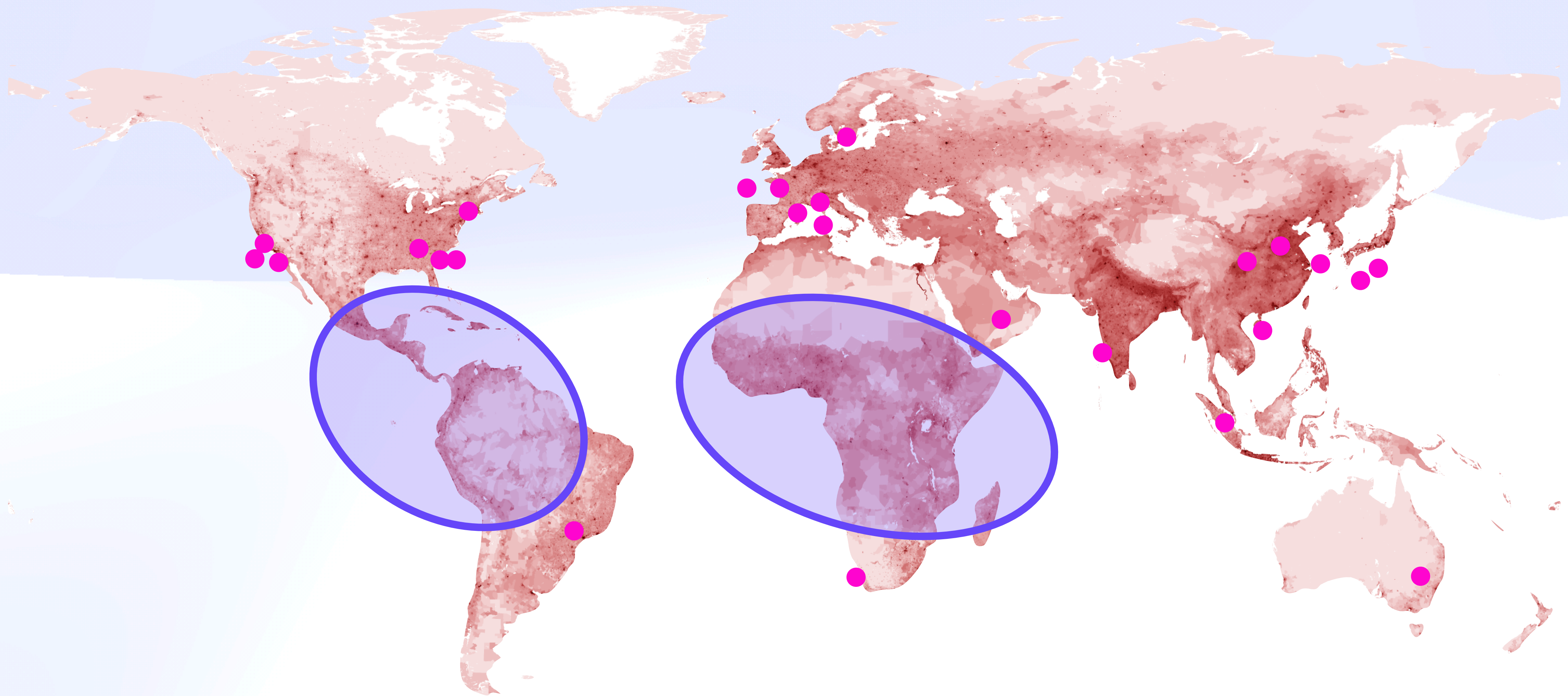
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What Even is "Local-First"?

Out of the Cloud Tarpit 

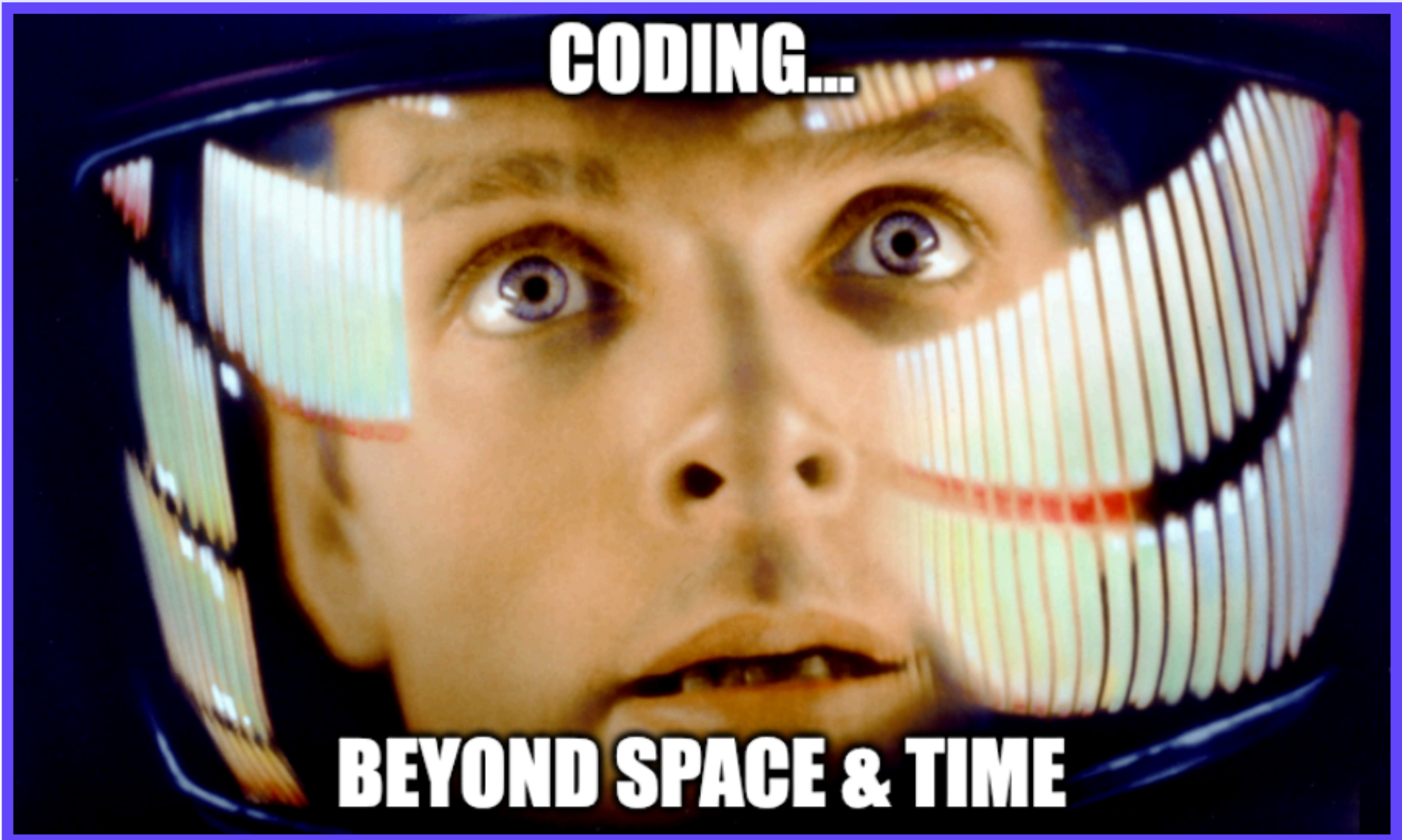
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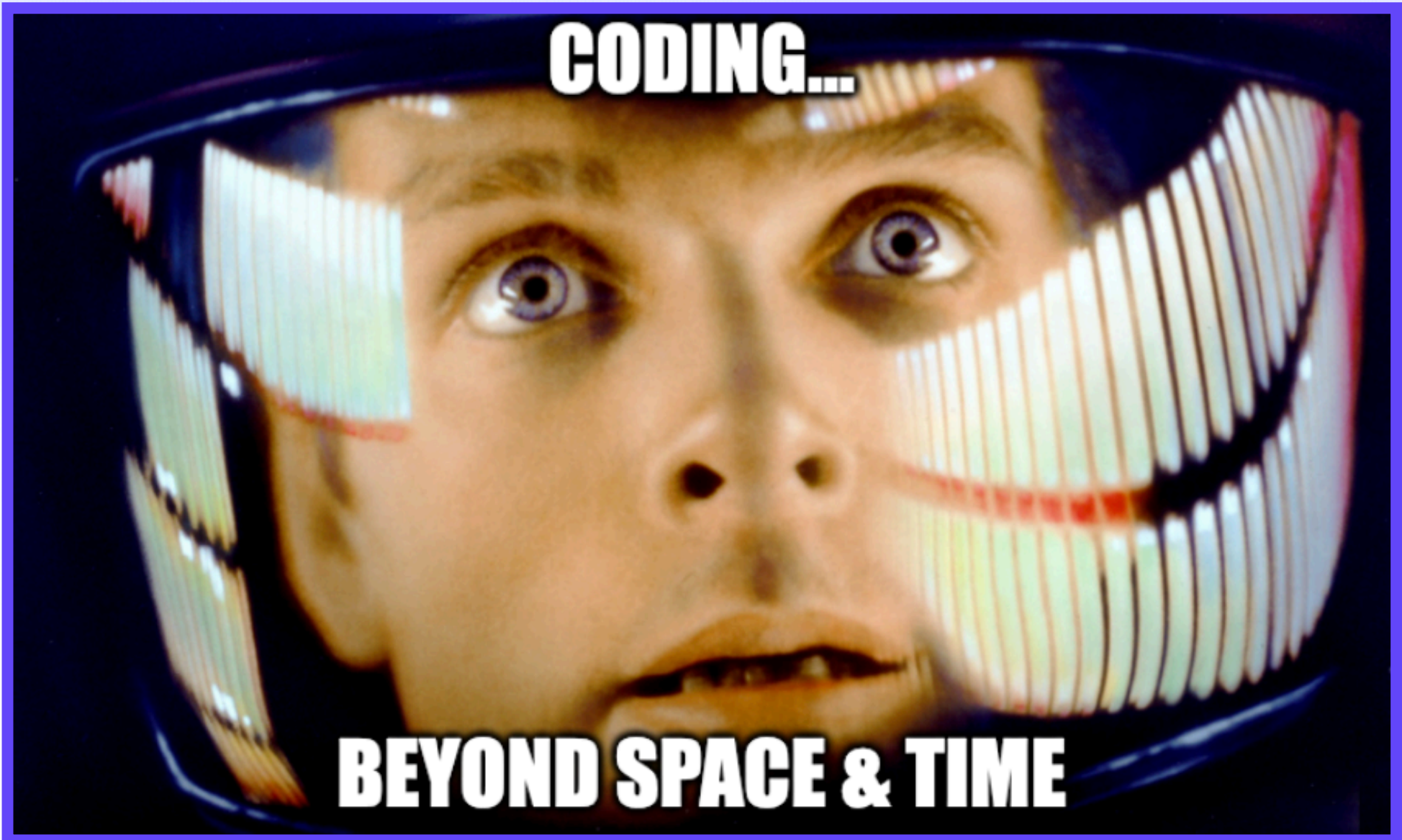
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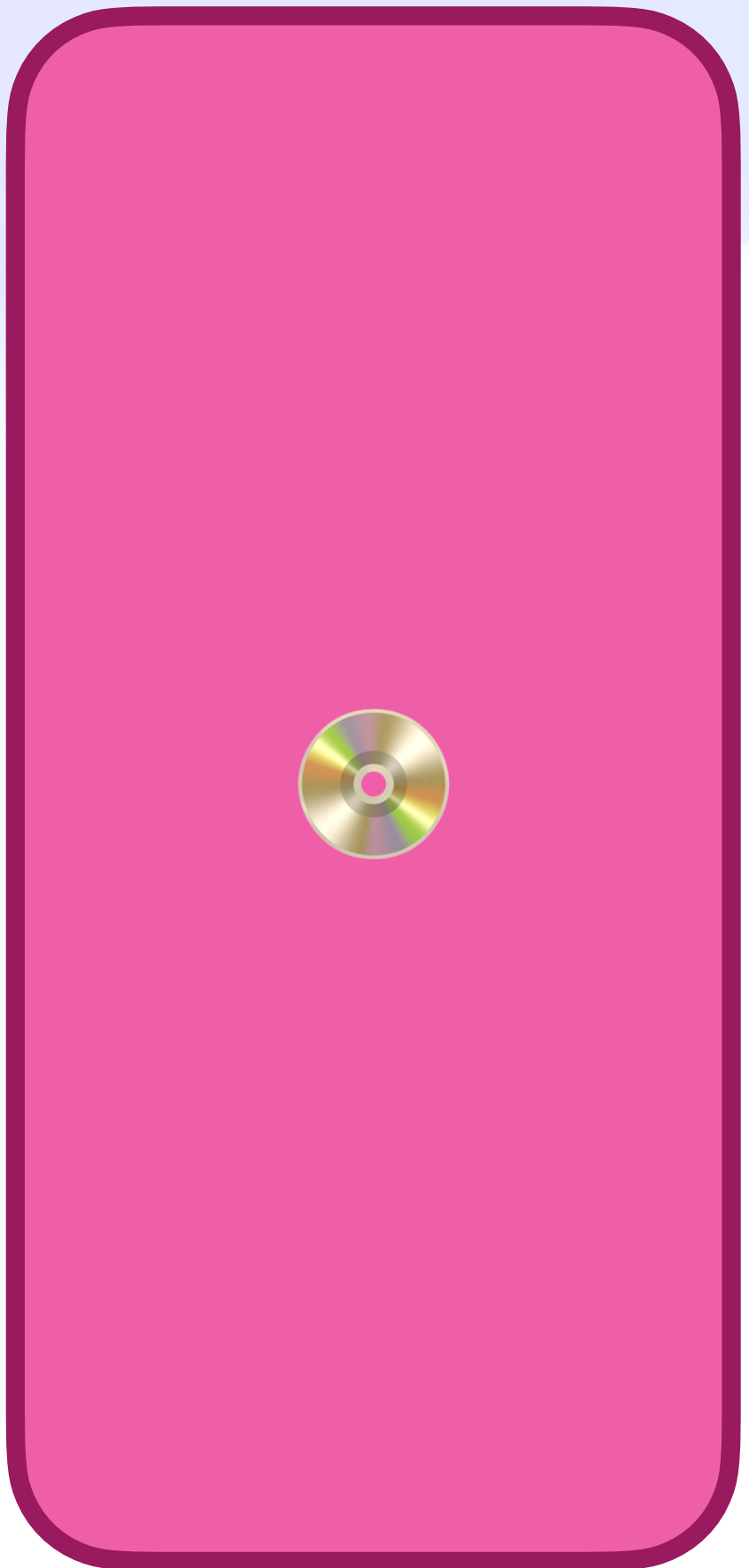
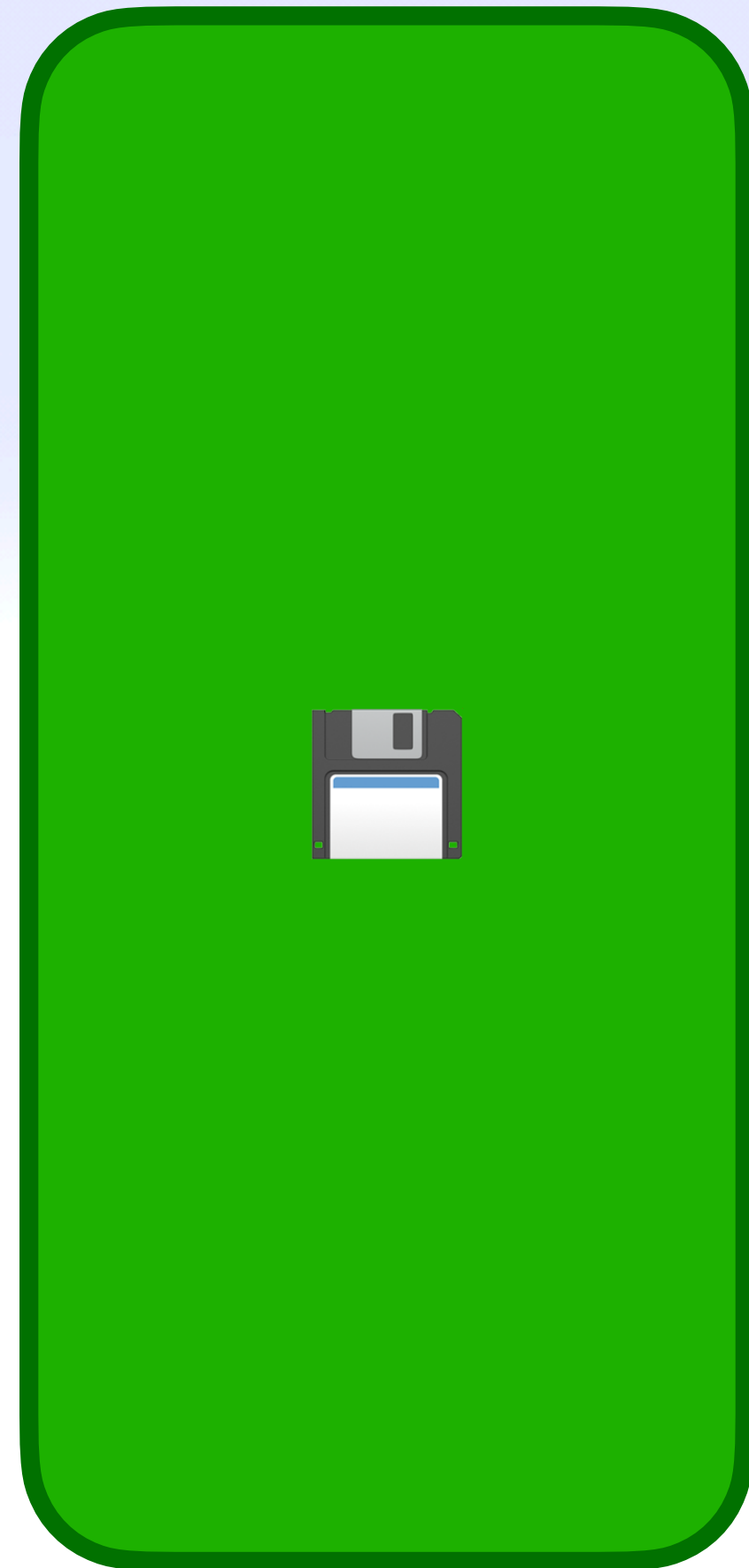
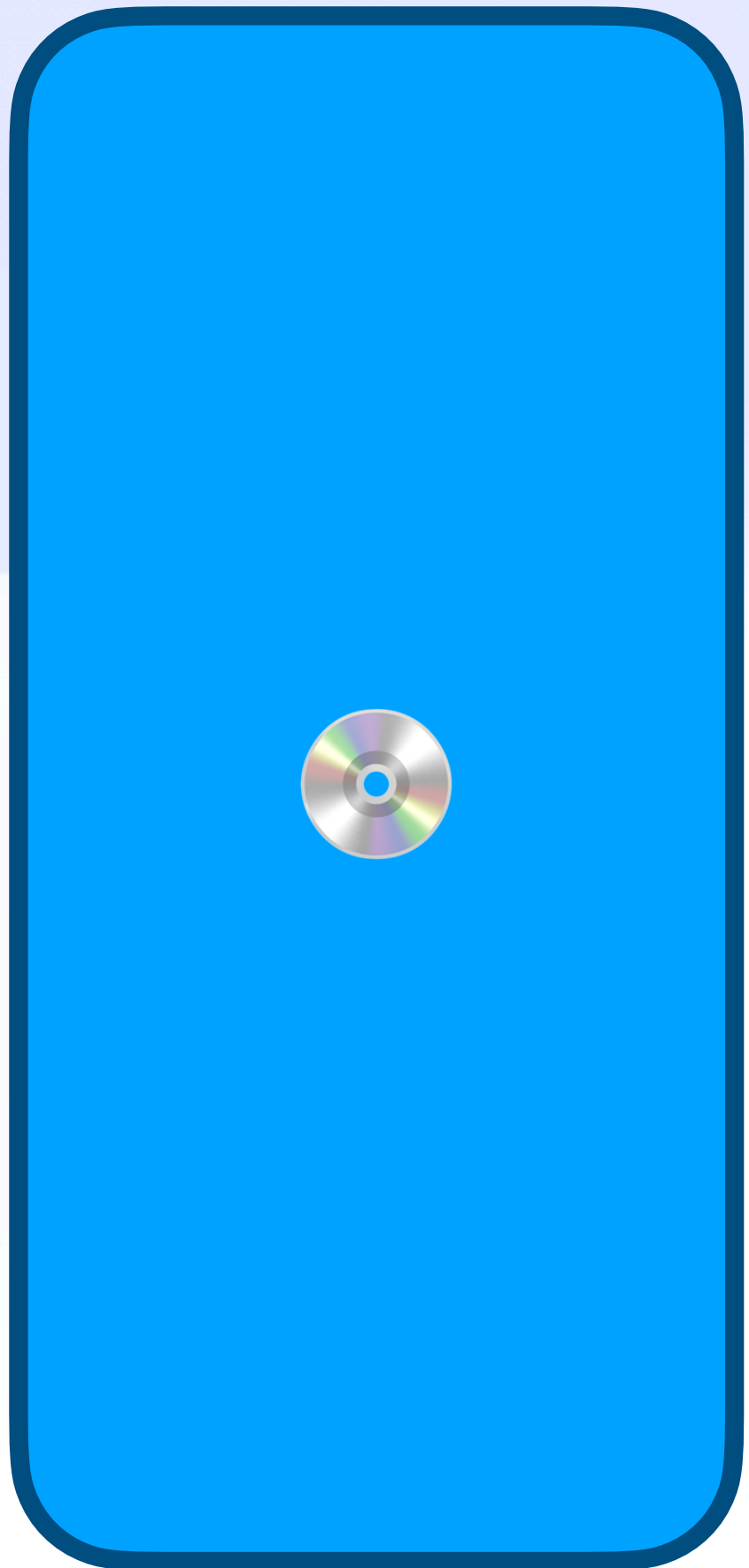


What Even is "Local-First"?

Federate Data, Not Apps

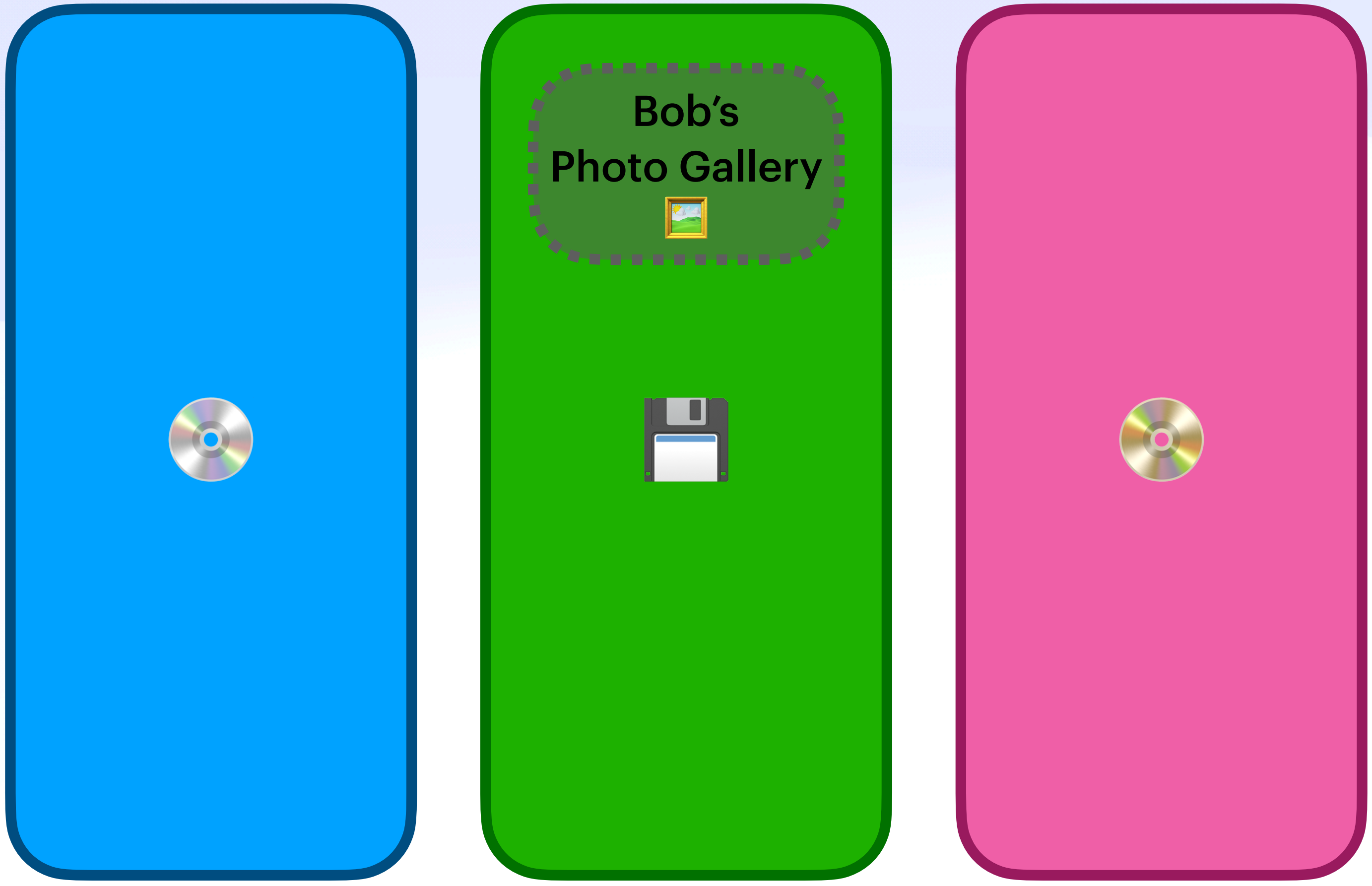
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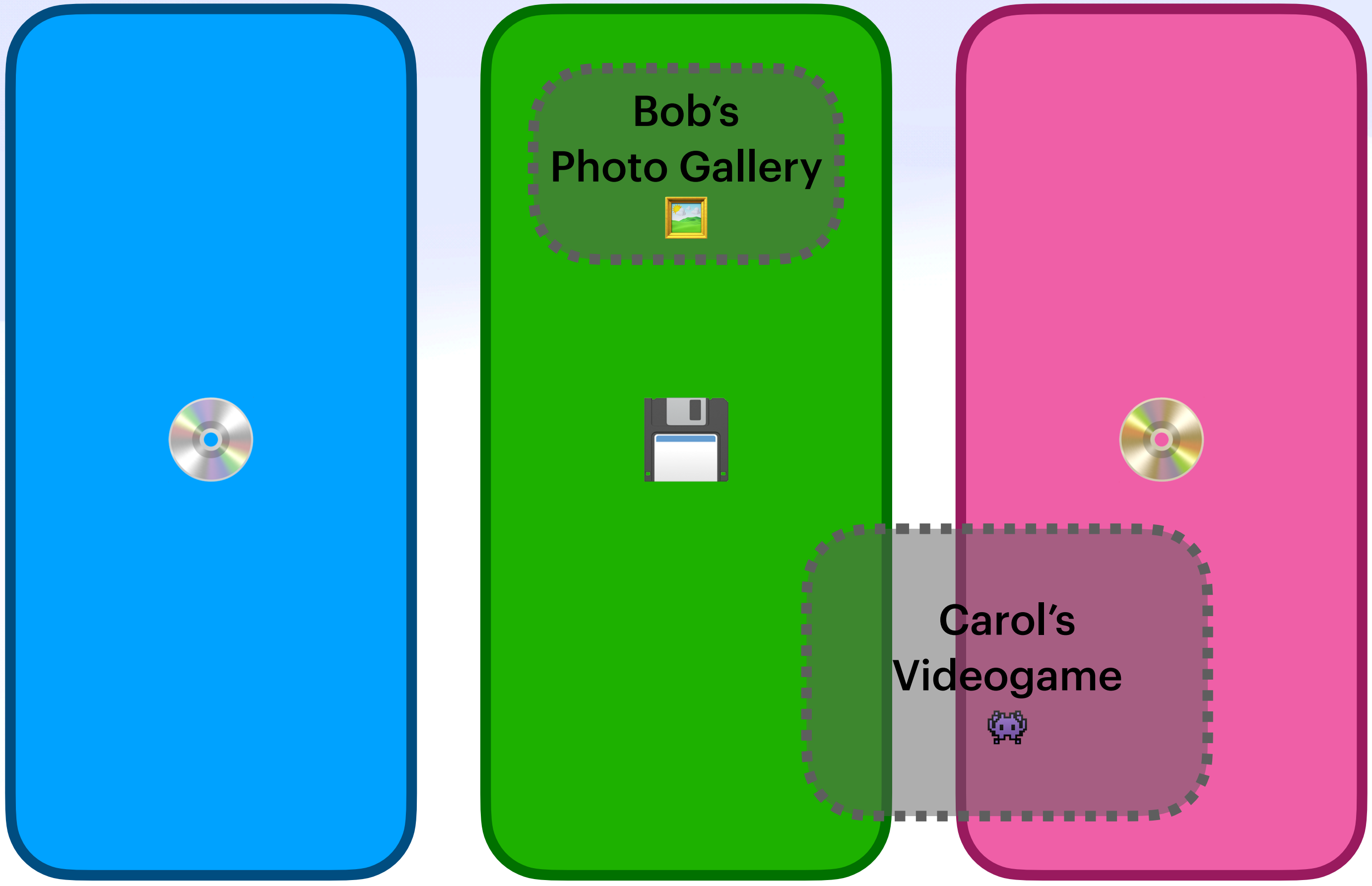
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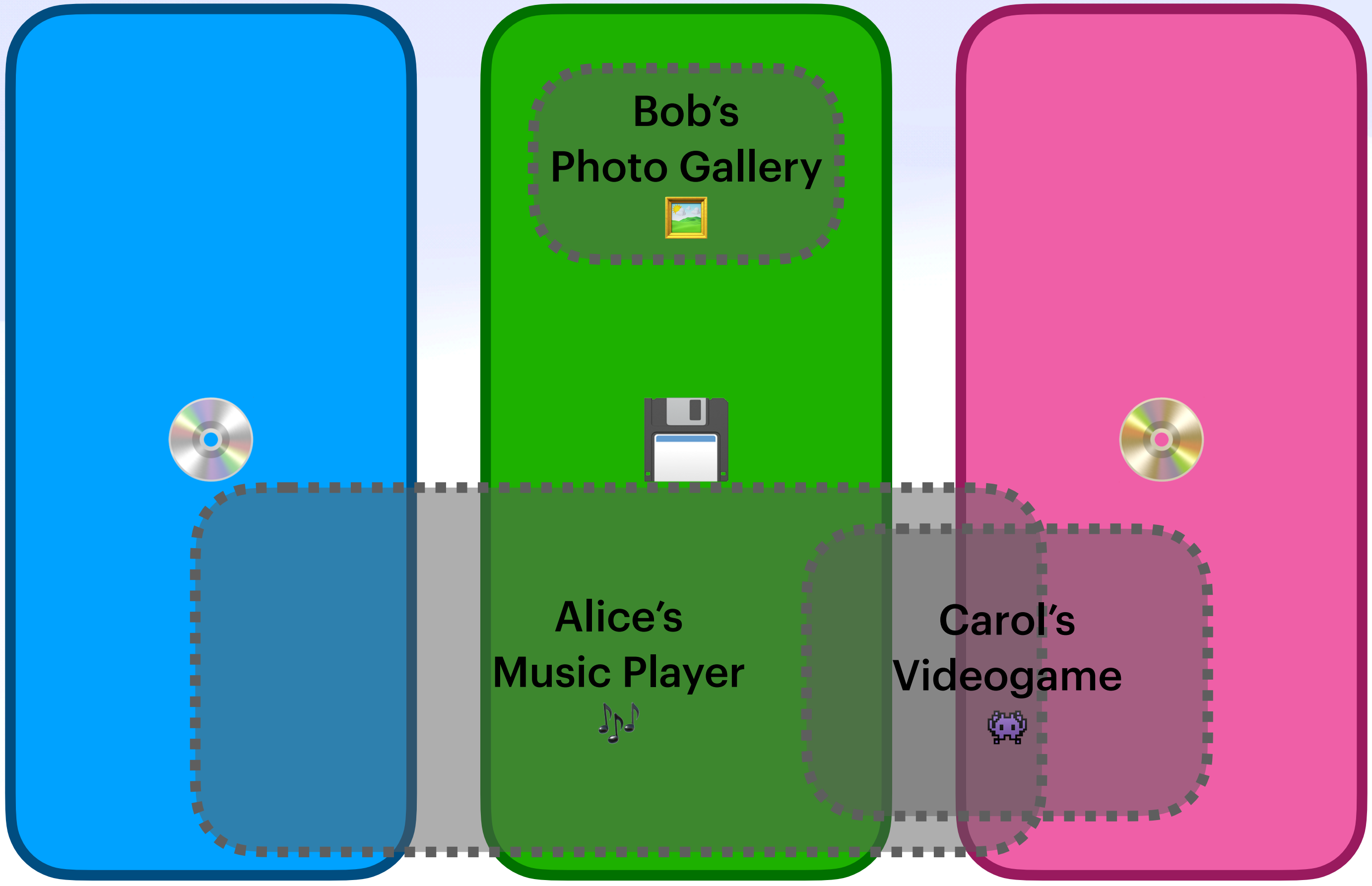
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What Even is "Local-First"?

Solving Lamport's Problem

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Solving Lamport's Problem

A distributed system is one in which the failure of a computer you didn't even know existed can ***render your own computer unusable***

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Solving Lamport's Problem

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...by this definition,

LoFi isn't a distributed system 🤔

— Martin Kleppmann

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A Litmus Test 

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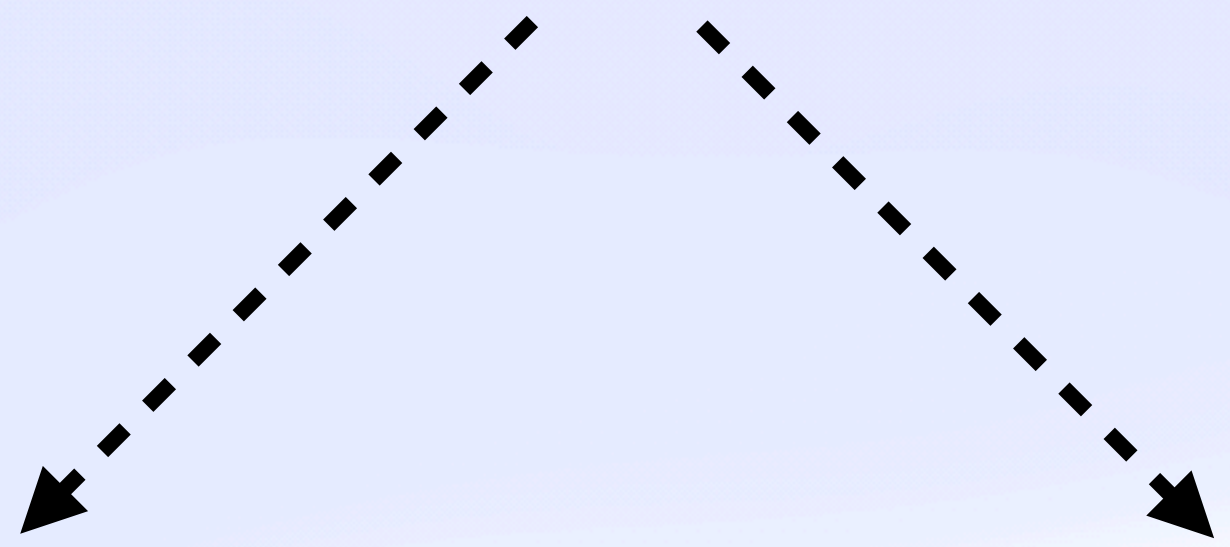
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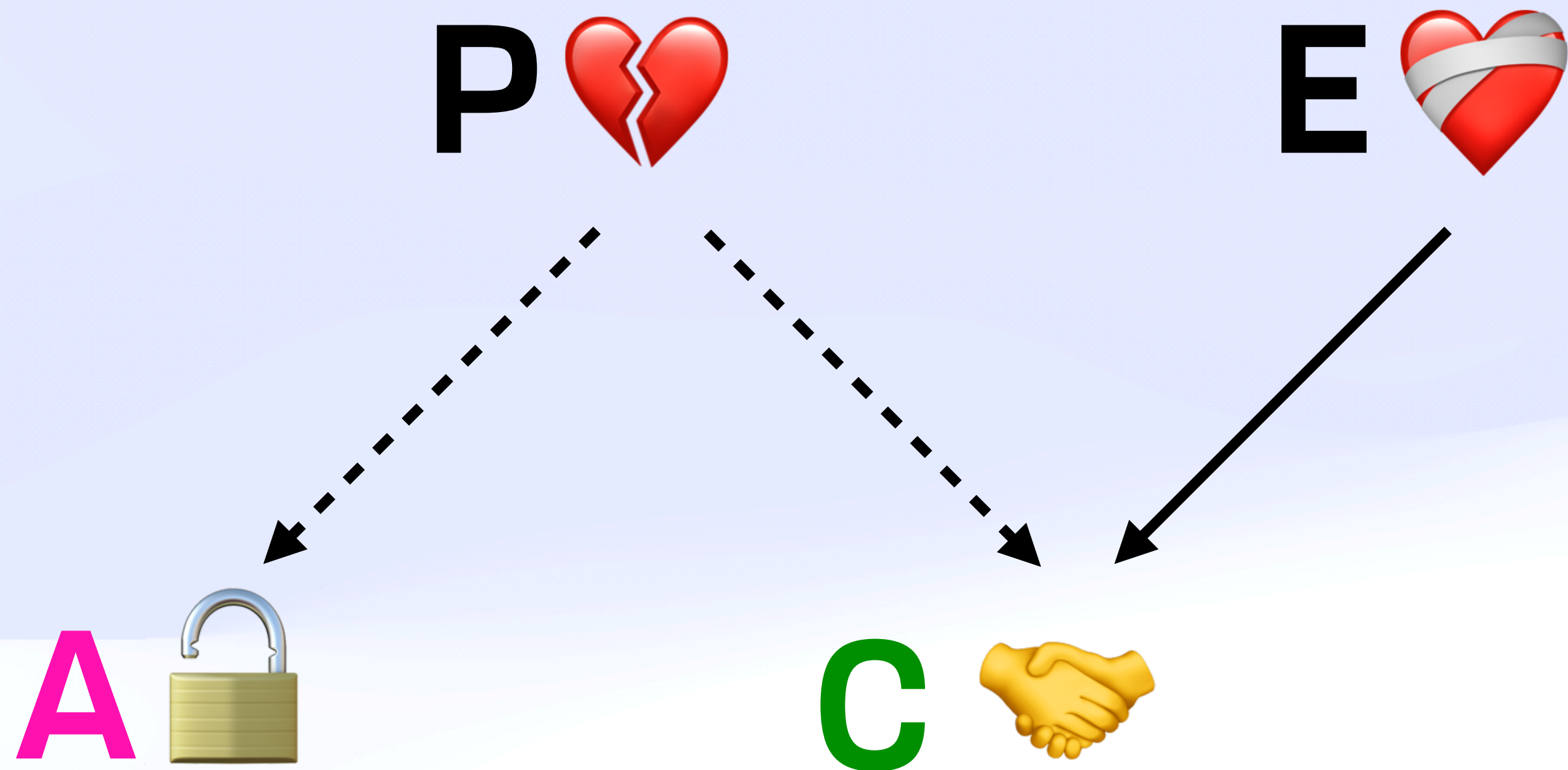
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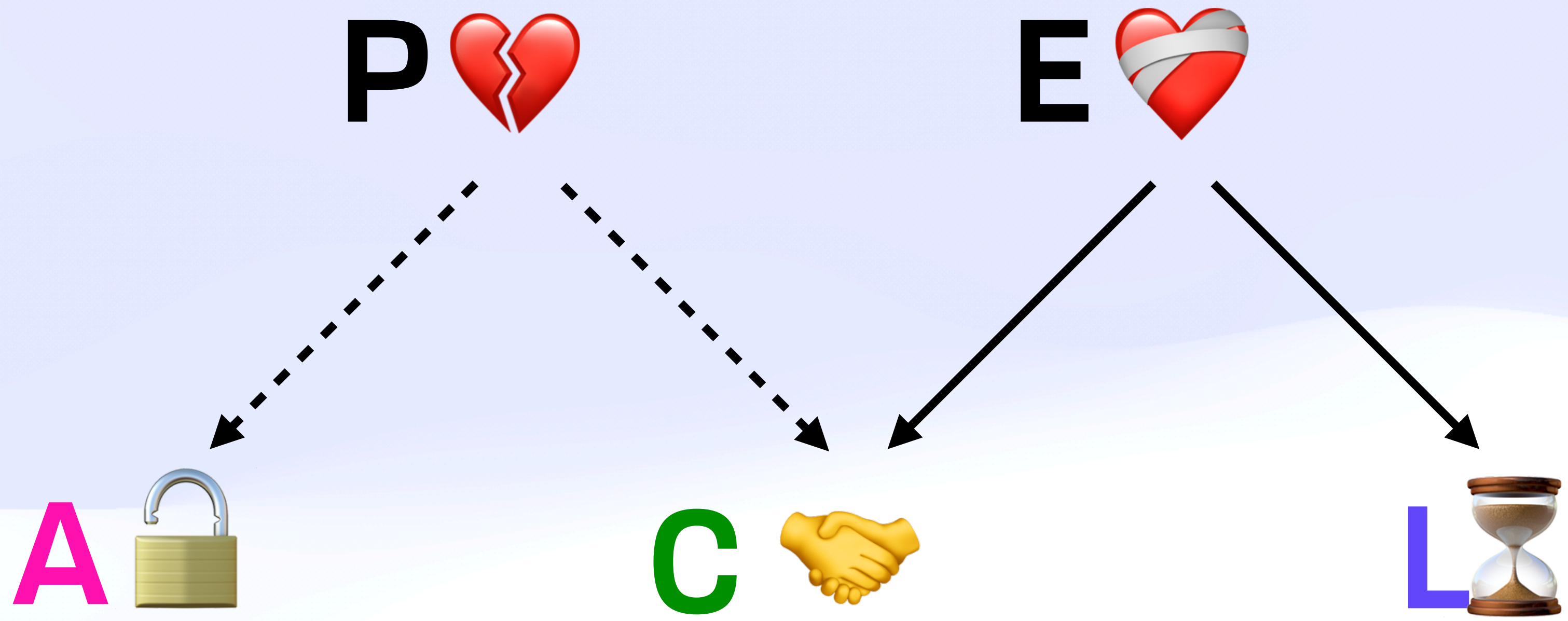
A 

C 

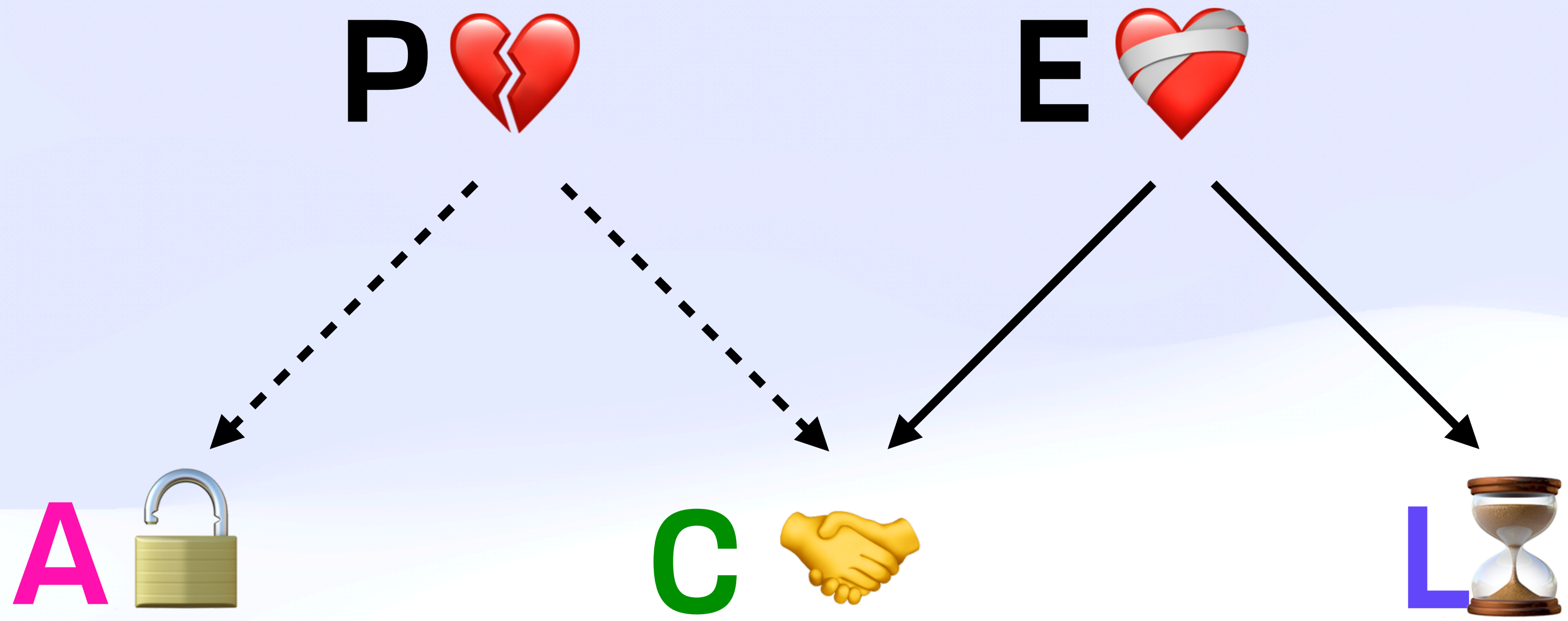
What Even is "Local-First"?



What Even is "Local-First"?

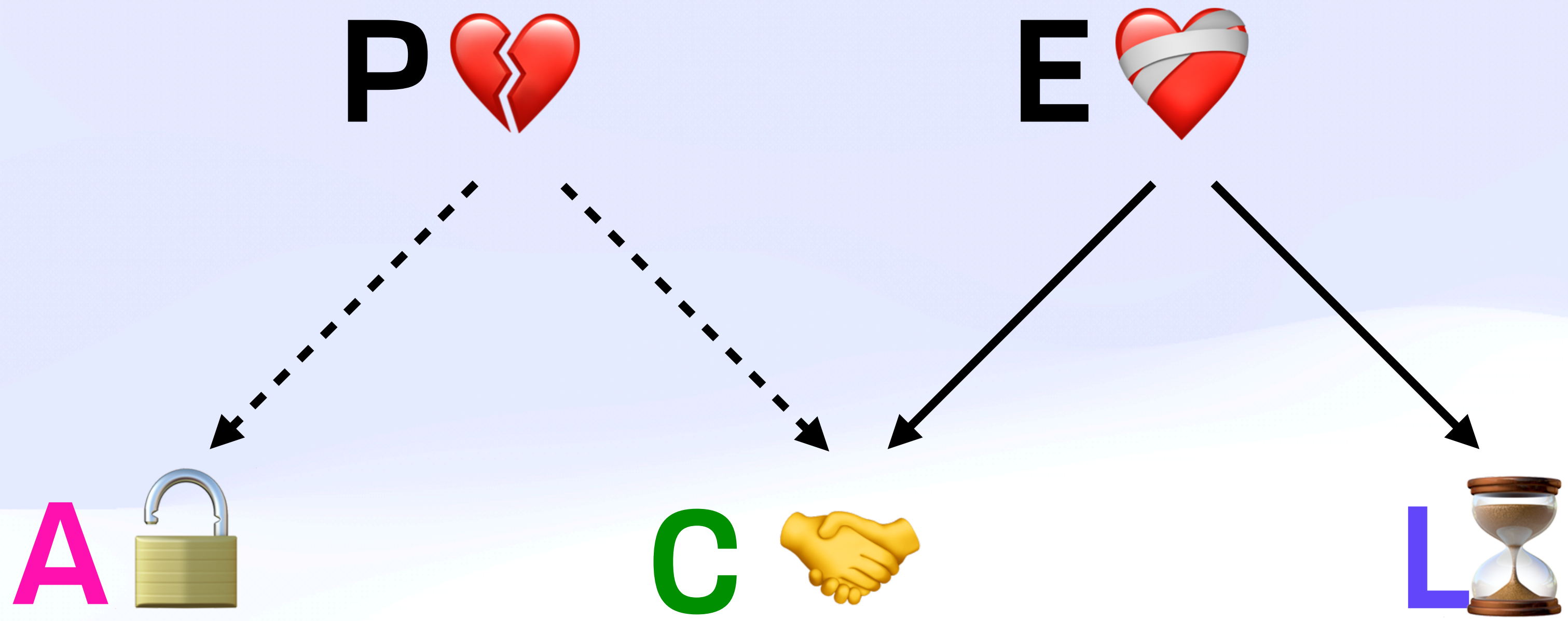







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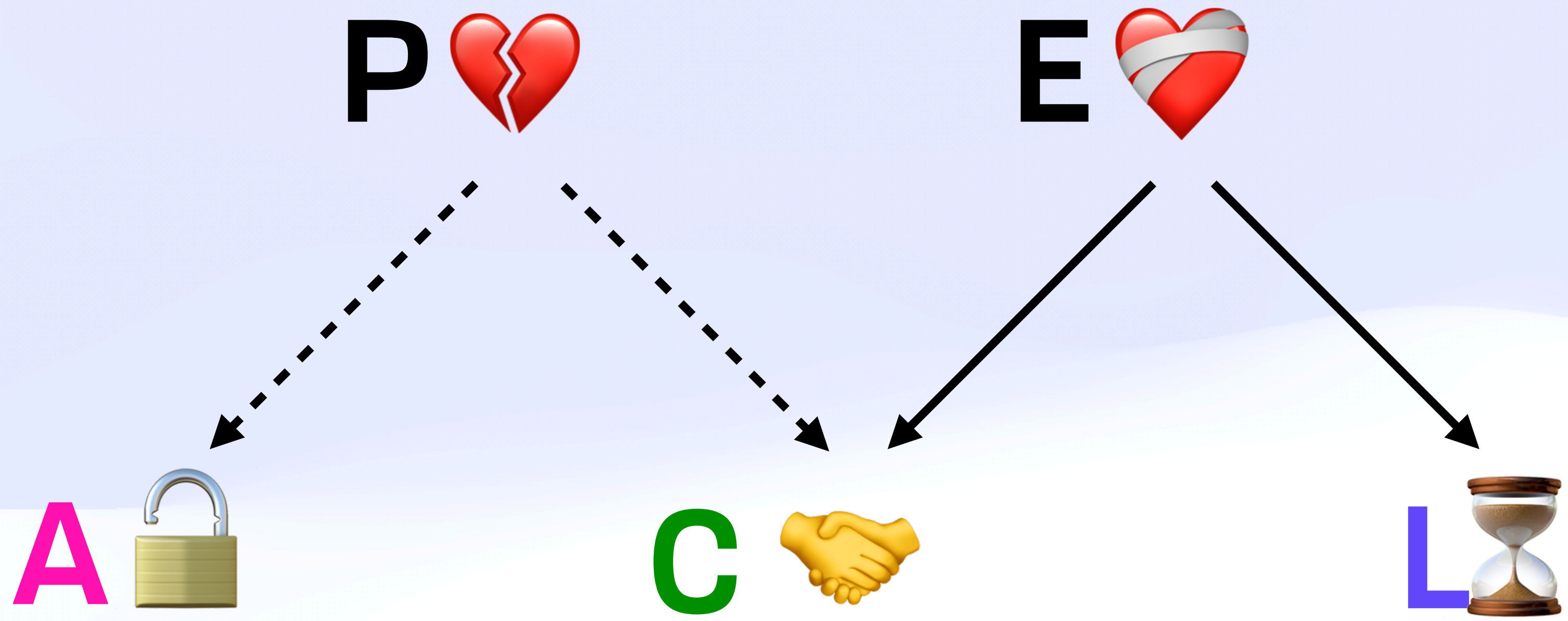
 Automerge **PA/EL**   




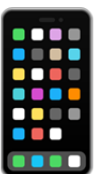



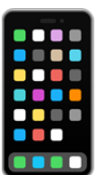




What Even is "Local-First"?



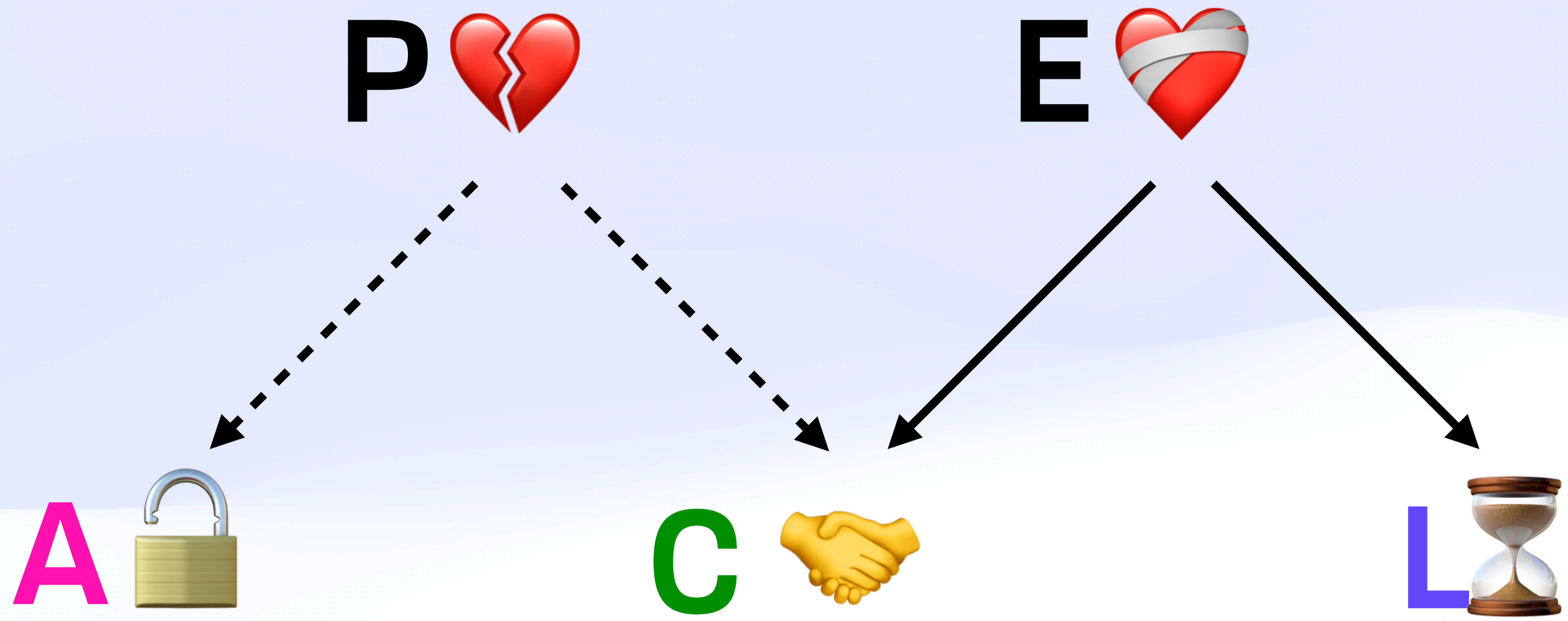
-  Automerge **PA/EL**   
-  electric **PA/EL**   


What Even is "Local-First"?



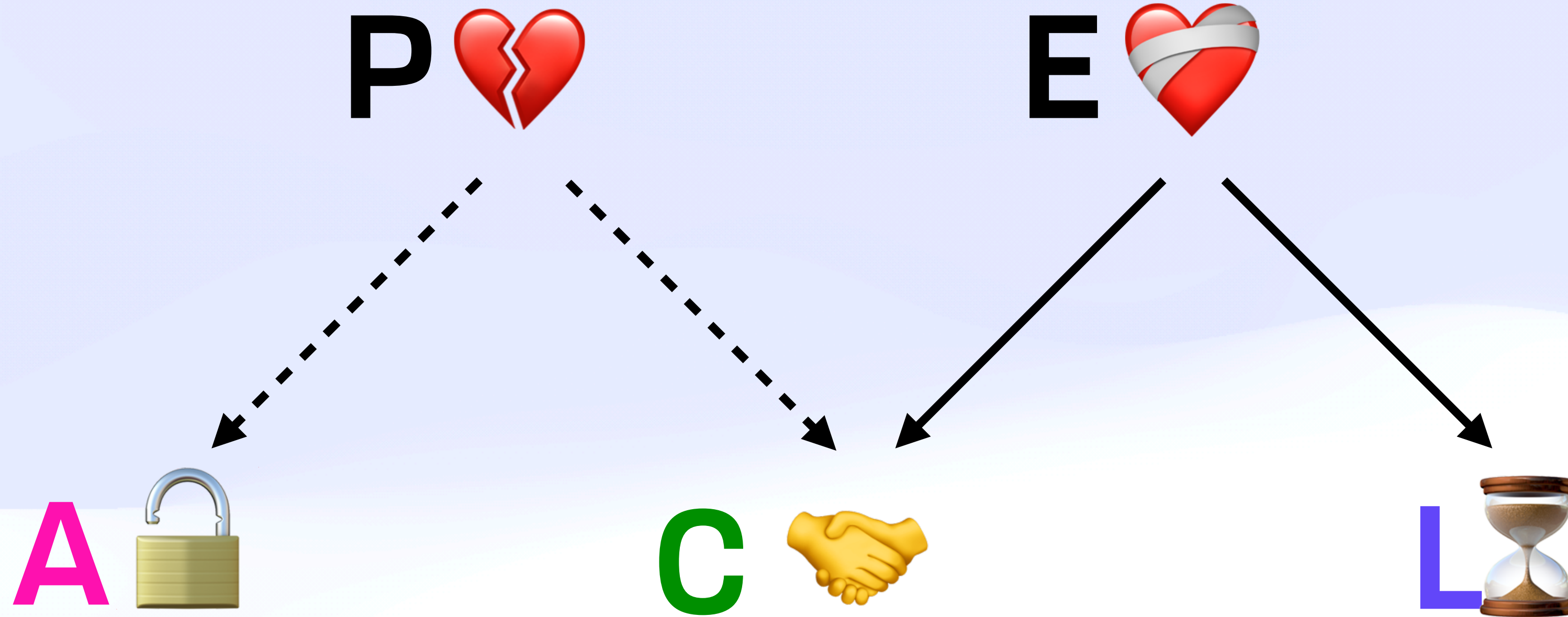
-  Automerge **PA/EL**   
-  electric **PA/EL**   
-  **PA/EL**   

















What Even is "Local-First"?



Automerge	PA/EL			
electric	PA/EL			
	PA/EL			
 OT (REDACTED)	PA/EC			

What Even is "Local-First"?



 Automerge	PA/EL			
 electric	PA/EL			
	PA/EL			
 OT (REDACTED)	PA/EC			

The bottom row of the table is circled with a red dashed line. To the right of this circle is a purple devil emoji and a grey building icon.

"the failure of a computer you didn't even know existed"

What Even is "Local-First"?

Embracing Reality! 

What Even is "Local-First"?

Embracing Reality!





Fallacies

1. The network is reliable
2. Latency is zero
3. Bandwidth is infinite
4. The network is secure
5. Topology doesn't change
6. There is one administrator
7. Transport cost is zero
8. The network is homogeneous

What Even is "Local-First"?

Embracing Reality!

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Embracing Reality! 

What Even is "Local-First"?

Embracing Reality! 

LoFi Fallacies


1. Everyone is online
2. Pull (manual) is a safe
3. Local-first doesn't suffer Tesler's Law
4. All programs are weakly consistent
5. Encryption-at-rest is secure forever
6. LoFi can avoid capture 

What Even is "Local-First"?

Embracing Reality! 

(Or: mistakes I personally have made)

LoFi Fallacies


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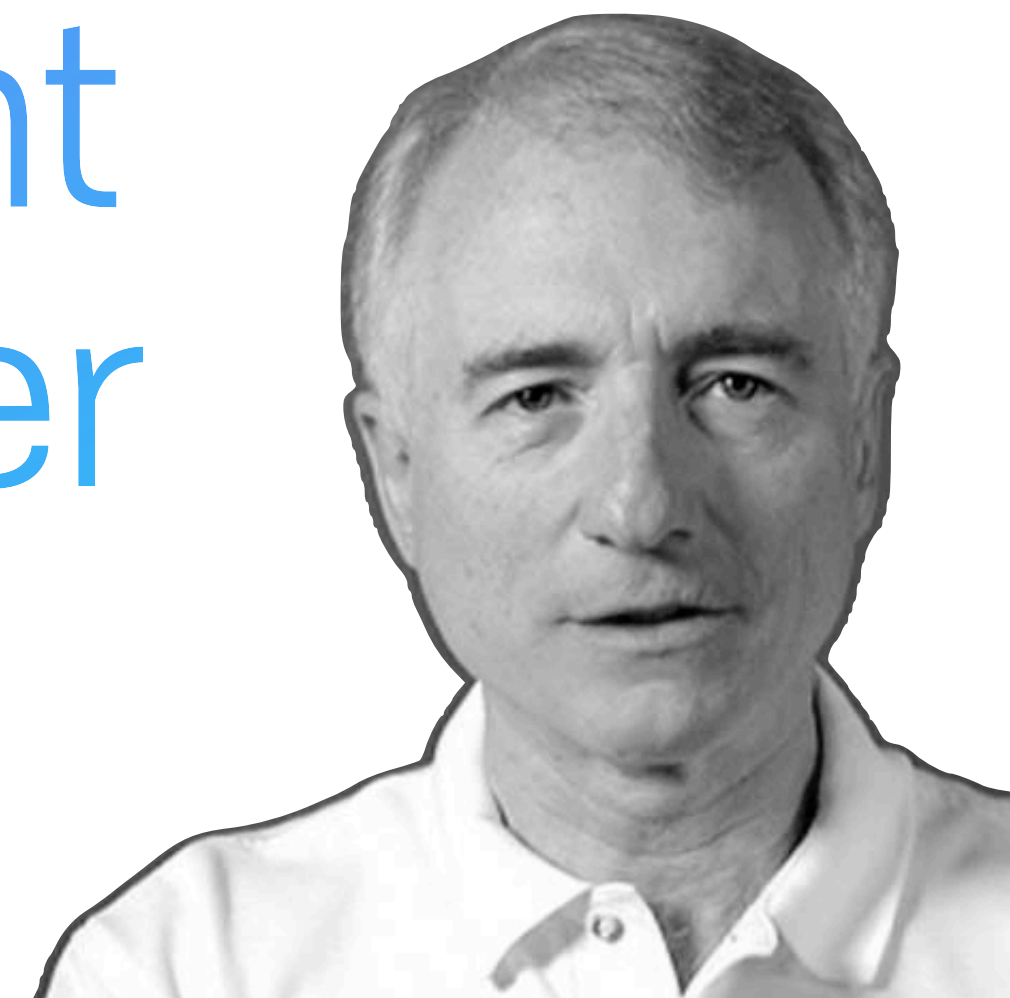
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From the Field



Celebrating *not quite* 5 years of LoFi

From the Field

Simplify. Simplify. Simplify.

From the Field

Simplify. Simplify. Simplify.

Users 

Developer 

From the Field

Simplify. Simplify. Simplify.

Users 

Browser 

REST / JSON-RPC / GraphQL 

Server 

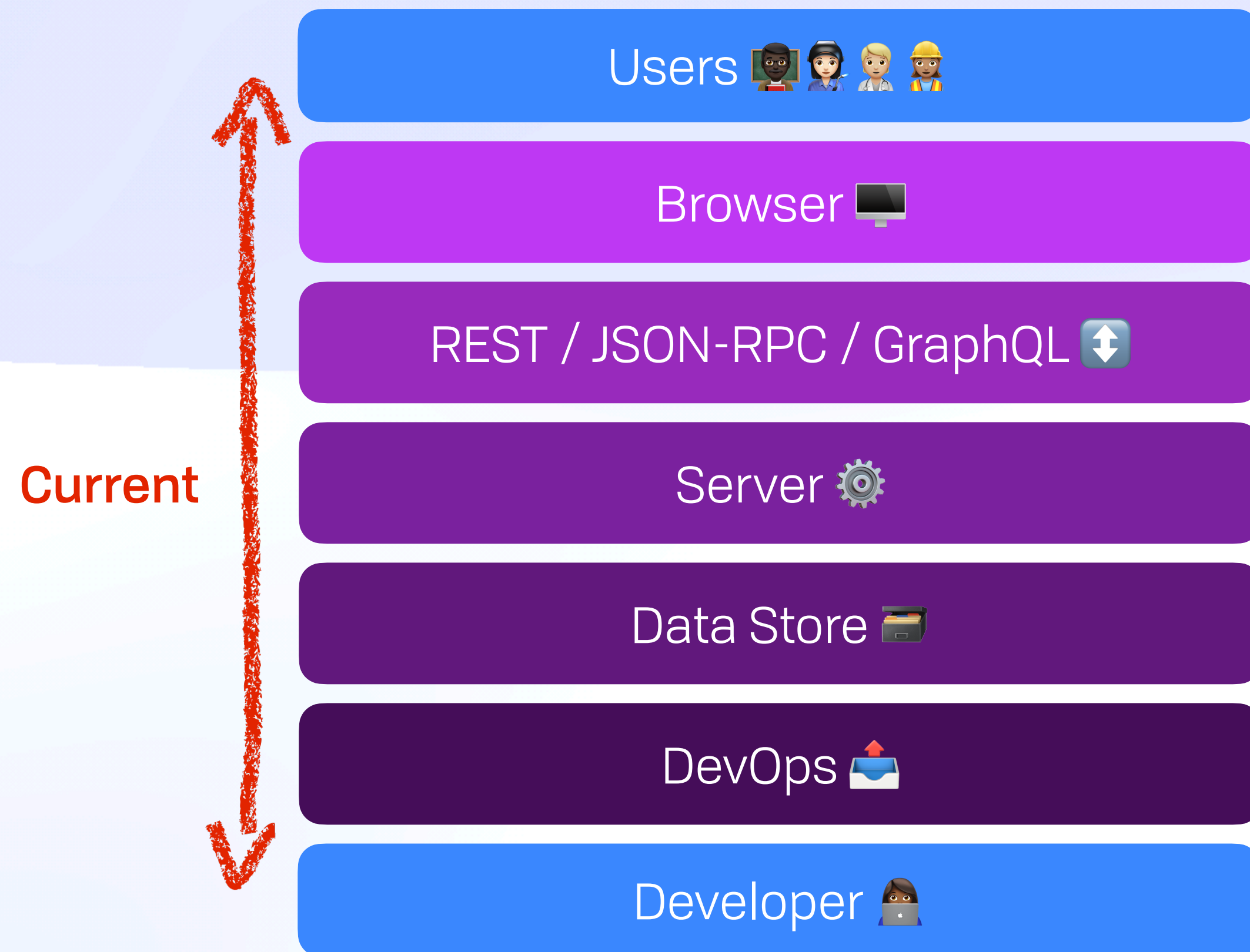
Data Store 

DevOps 

Developer 

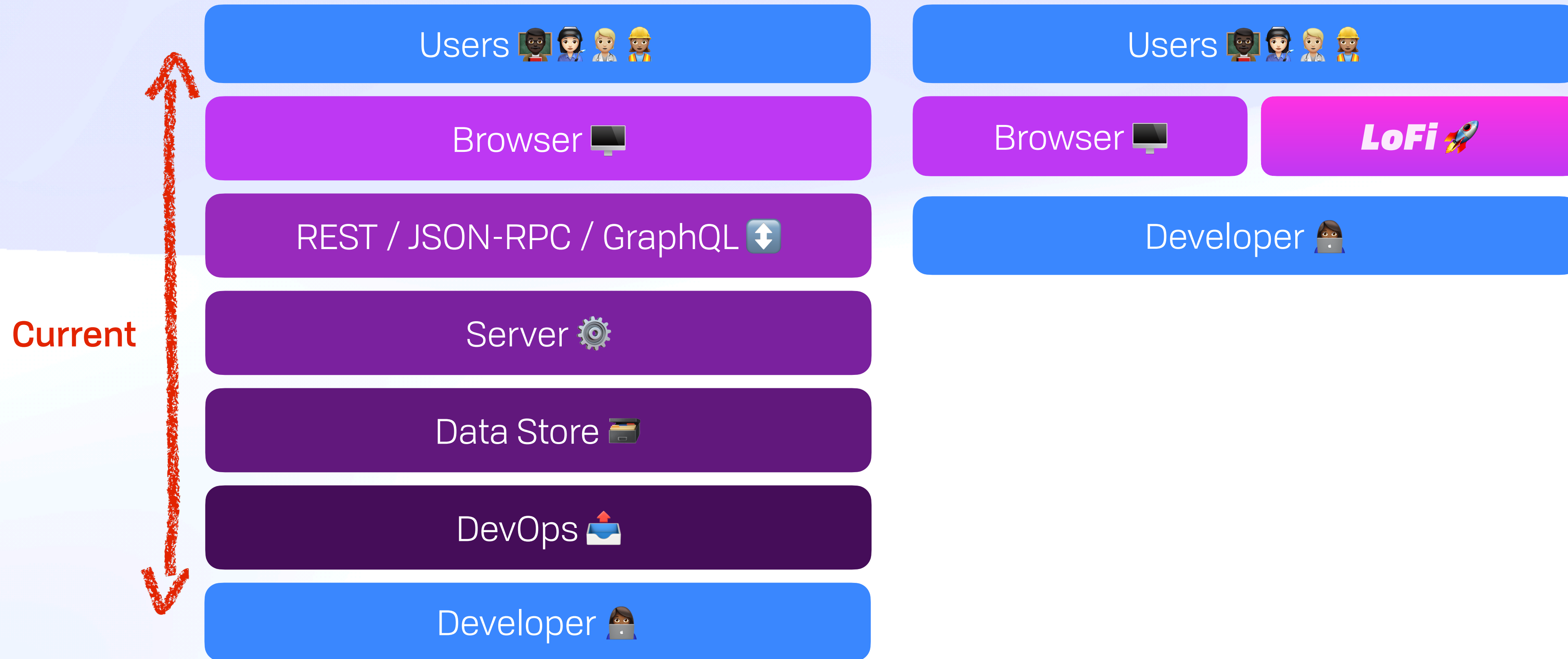
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Simplify. Simplify. Simplify.



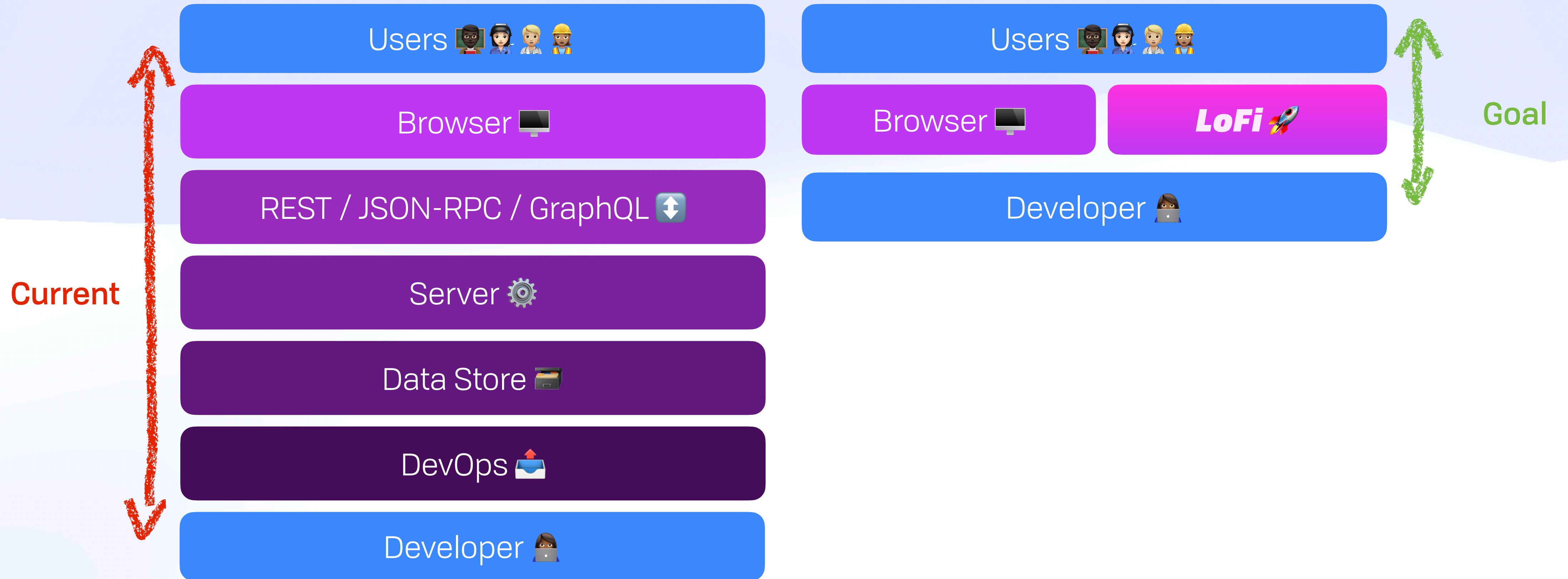
From the Field

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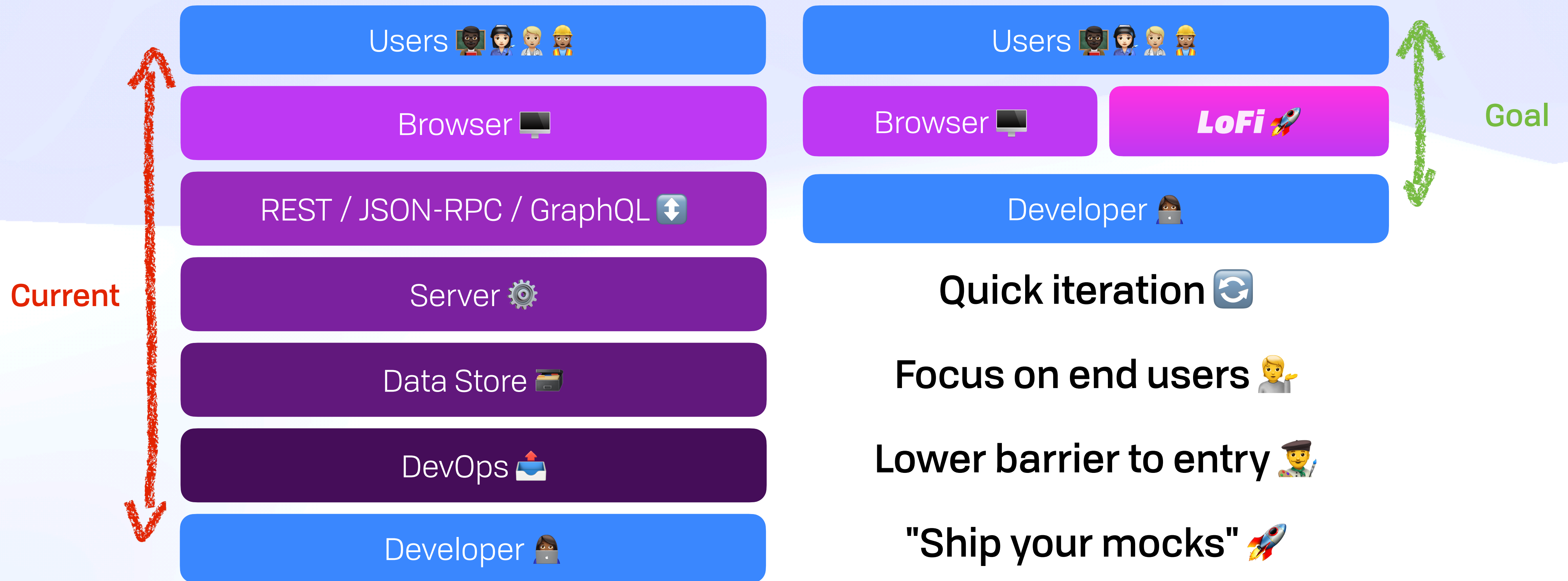
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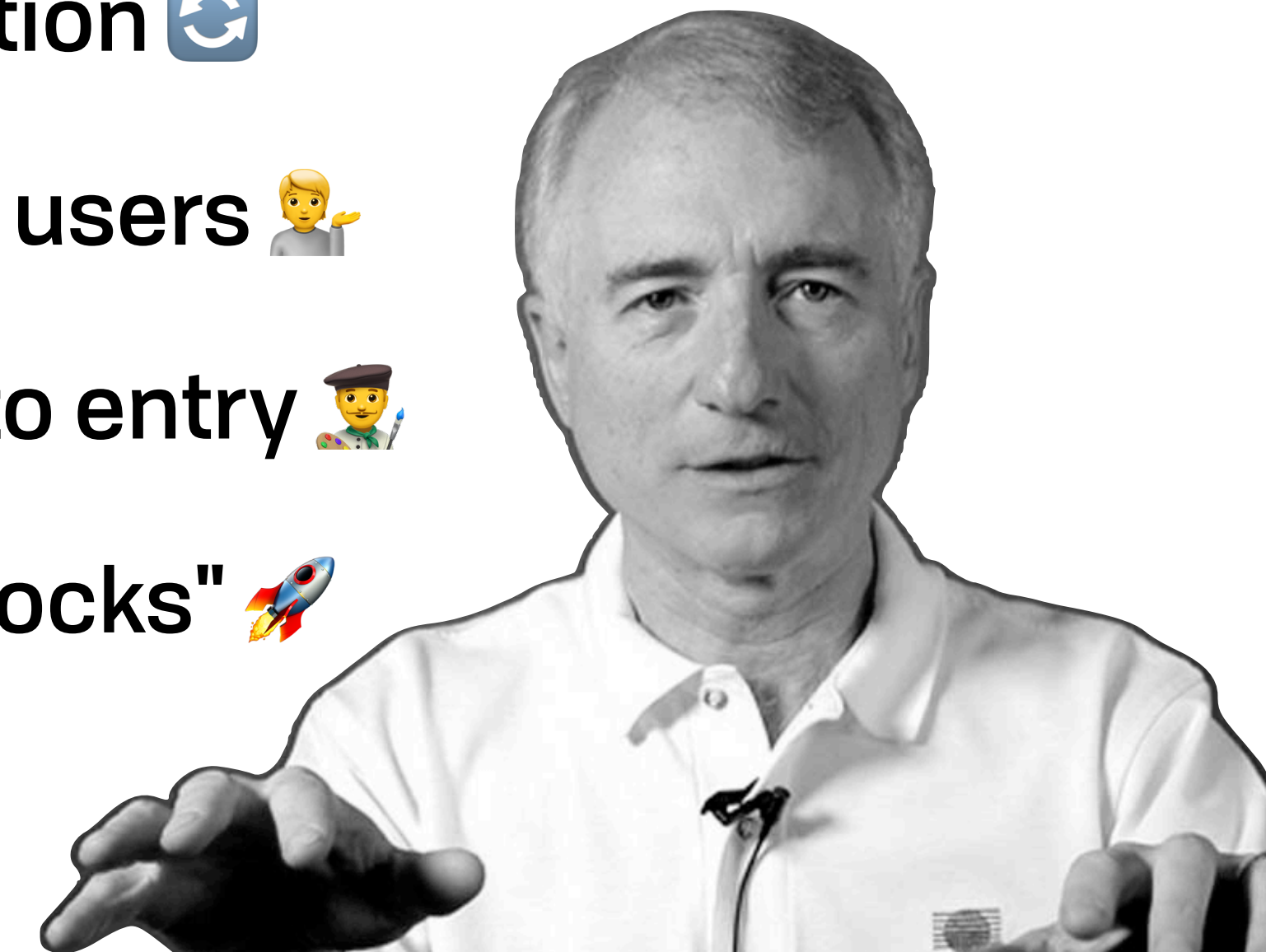
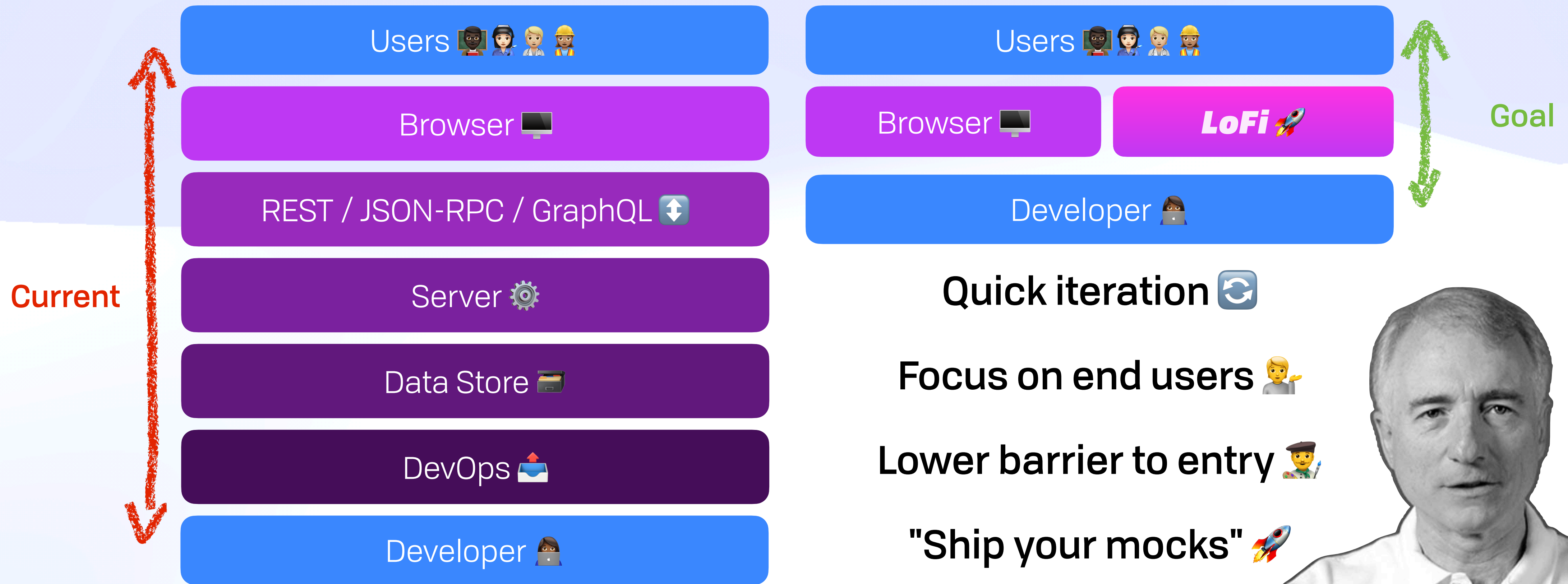
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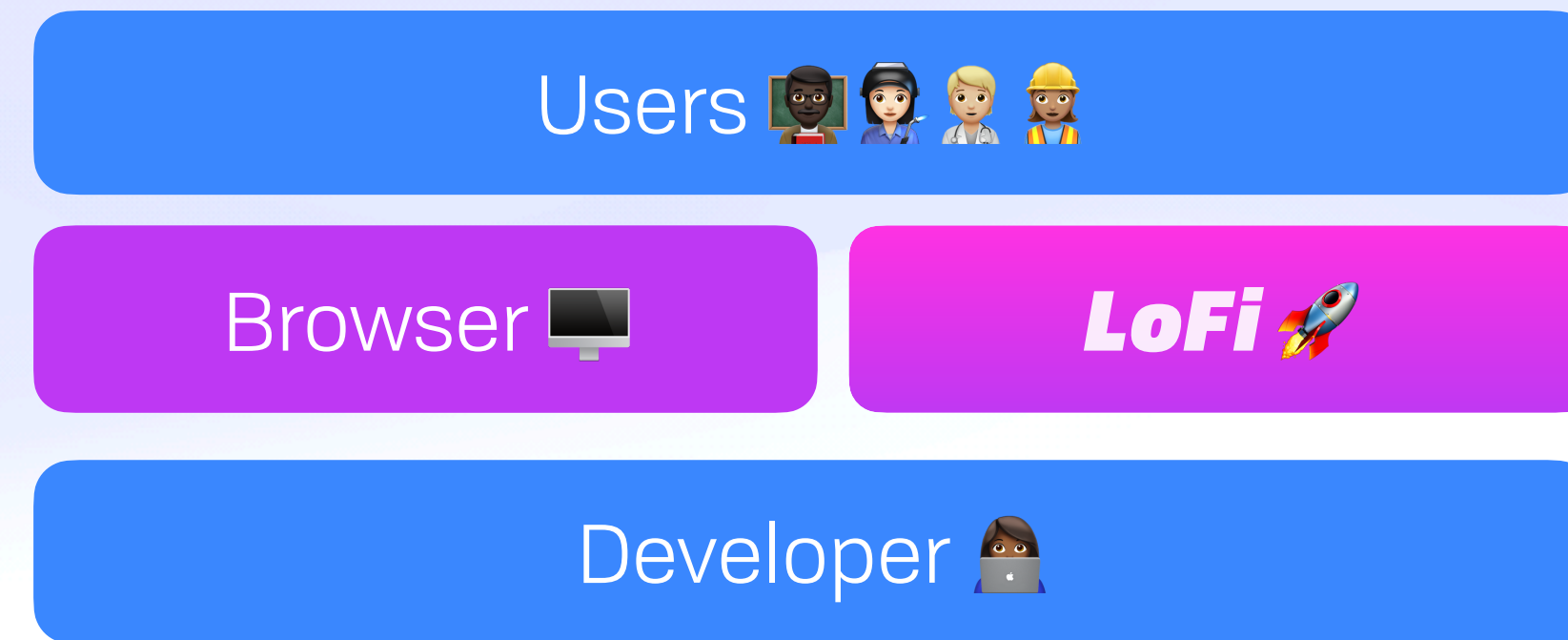
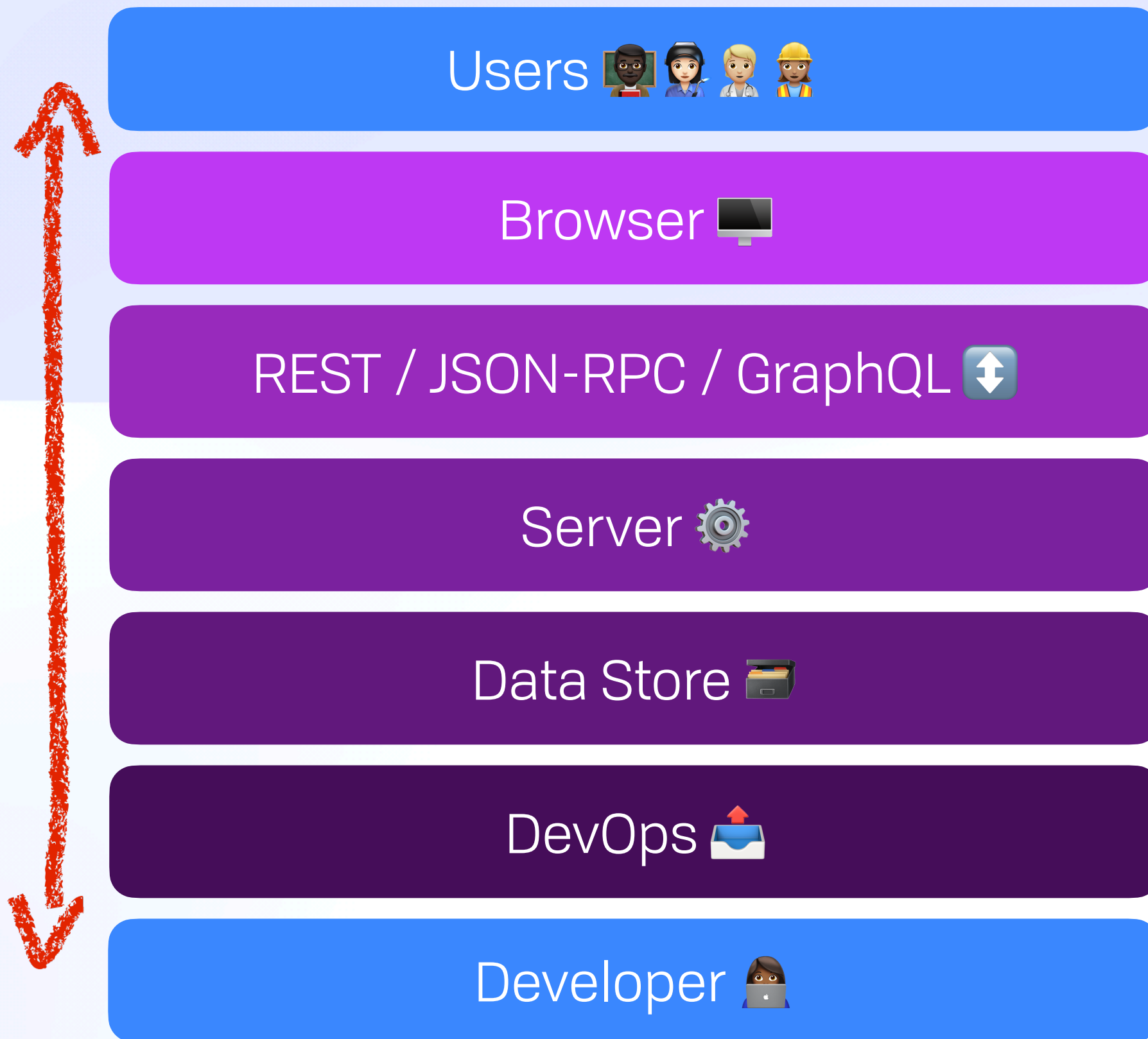
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From the Field

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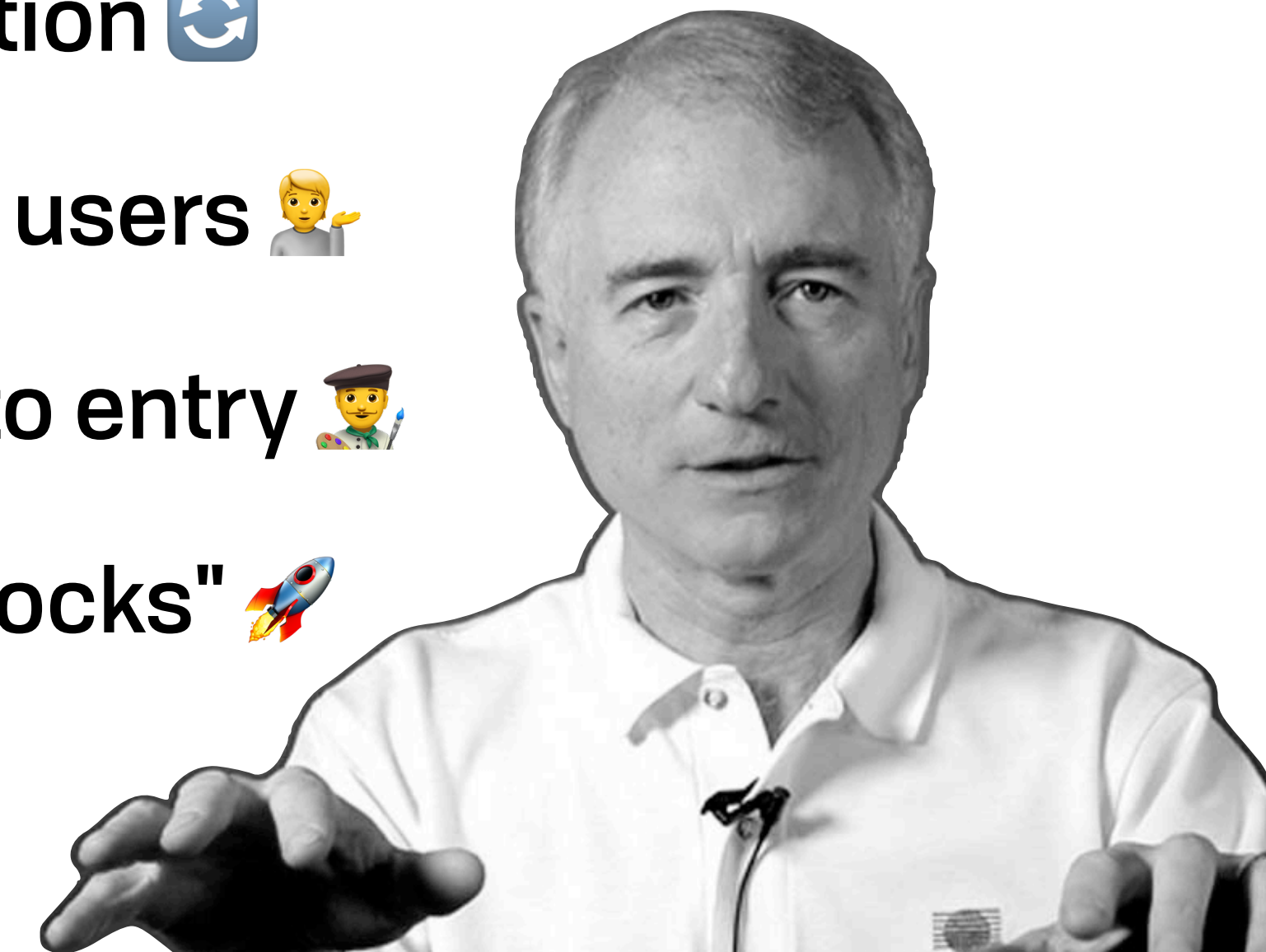


Quick iteration 🔄

Focus on end users 🧑

Lower barrier to entry 🧑

"Ship your mocks" 🚀



From the Field

Simplify. Simplify. Simplify.



From the Field

Simplify. Simplify. Simplify.

...how hard could it be? 🙄



App

Dev's App
Business Logic & View

Distributed Compute

Portable Compute
Interplanetary Virtual Machine (IPVM)

Broadcast

Collaboration, Chat, Instant Sync
Soft Realtime Store

Global: Aggregation, Forms, Feeds
Gossip Broadcast

Offline & Async Sharing
Exchange Store

(Un)structured Store
Rhizome (Postmodern) Database

Data Store

Secure Blob Storage
WebNative File System

Network

Selective Sync
CAR Pool, Datalog Selectors

Auth & ID

Command/Mutation Control
UCAN

Networking
DNS, IPFS, QUIC, Wireguard, Matrix

Read/Query Control
Dark Forest / Cryptree

Identity
PKI / did:key

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From the Field

Questions From Day One

From the Field

Questions From Day One

- ◆ Access control when I'm not online for each request?
- ◆ How to tie into existing (non-LoFi) services?
- ◆ Want access get more compute resources
 - ◆ e.g. GPU, email newsletters, secrets management
 - ◆ ...but going "full cloud" feels like a loss
- ◆ Read-optimisation / incremental view maintenance
- ◆ Selective replication
- ◆ Observability tools

From the Field

Reusable Hub Tools Can Be Magic ✨

From the Field

Reusable Hub Tools Can Be Magic ✨

The screenshot shows a file explorer interface for 'expede-strange-loop'. The left sidebar lists a directory 'strange-loop' and three files: 'cat', 'pwl', and 'rs-ucan-mascot'. The main area shows a video thumbnail of two chalkboards on easels. The left chalkboard has the text 'PAPERS WE LOVE' and a list of speakers: 9:50 - Zeeshan Akhori, 10:00 - M. Charity, 11:00 - Deirdre Connolly, and 12:00 - [unclear]. The right chalkboard has a schedule: 1:10p - Jason Hockman, 2:10p - Santosh NAGARAKatte, 3:00p - BREAK, 3:20p - Madeline Endres, 4:20p - Zach Tellman, and 5:10p - CLOSING. The interface includes a 'FISSION DRIVE' logo and 'Add / Create' and 'Copy Link' buttons.

From the Field

Layers  ***Prior Understanding***

From the Field

Layers **Prior Understanding**

Data 

From the Field

Layers 🧅 *Prior Understanding*

Compute 🗑️

Data 📁

From the Field

Layers 🧅 *Prior Understanding*

Auth 🧑

Compute ⚙️

Data 💾

From the Field

Layers 🧅 *Prior Understanding*

Auth

Compute 🗑️

Data 📀

From the Field

Layers 🍰 **Upside Down Cake**

Compute 

Data 

Auth

From the Field

Layers 🍰 *Upside Down Cake*

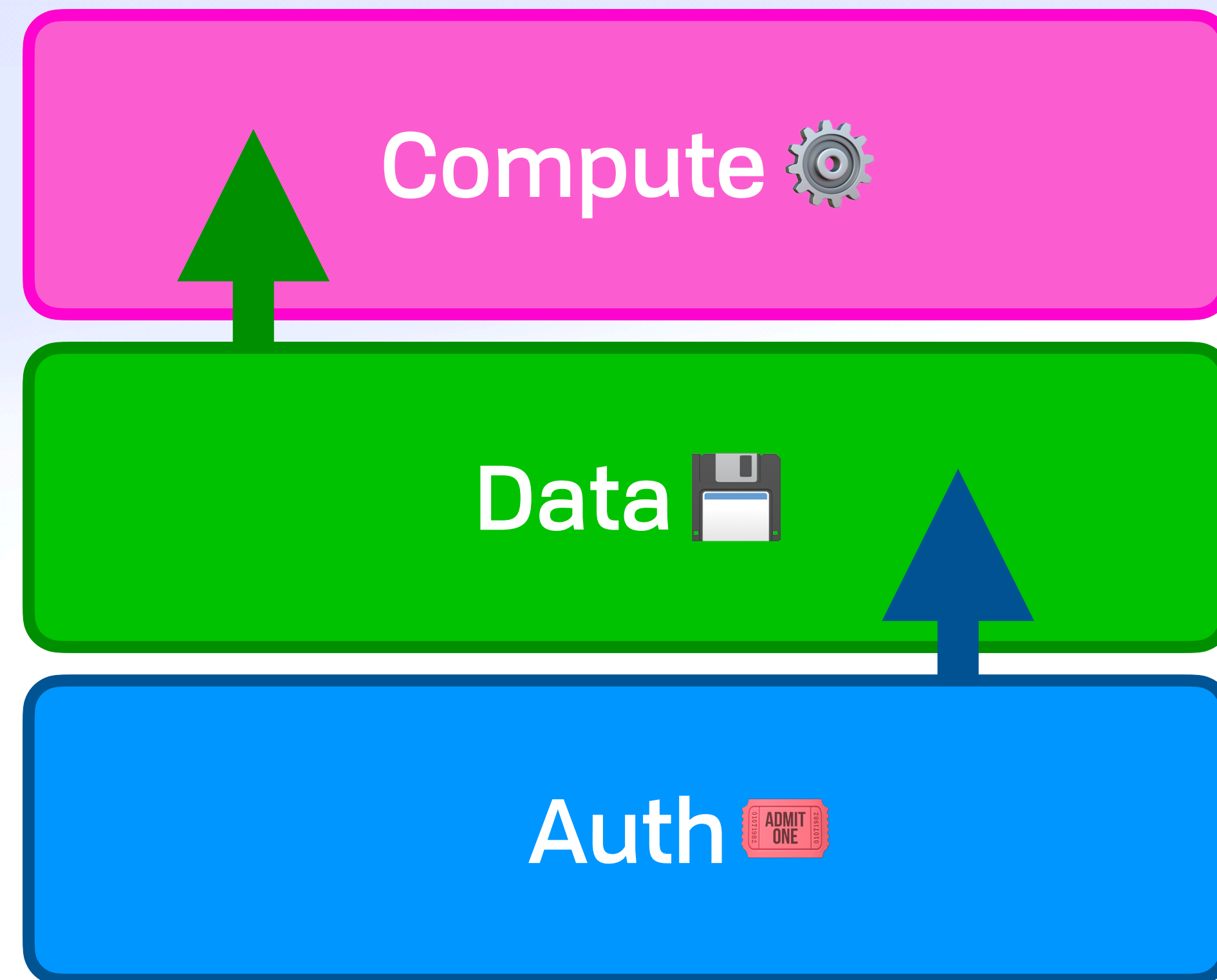
Compute 

Data 

Auth 

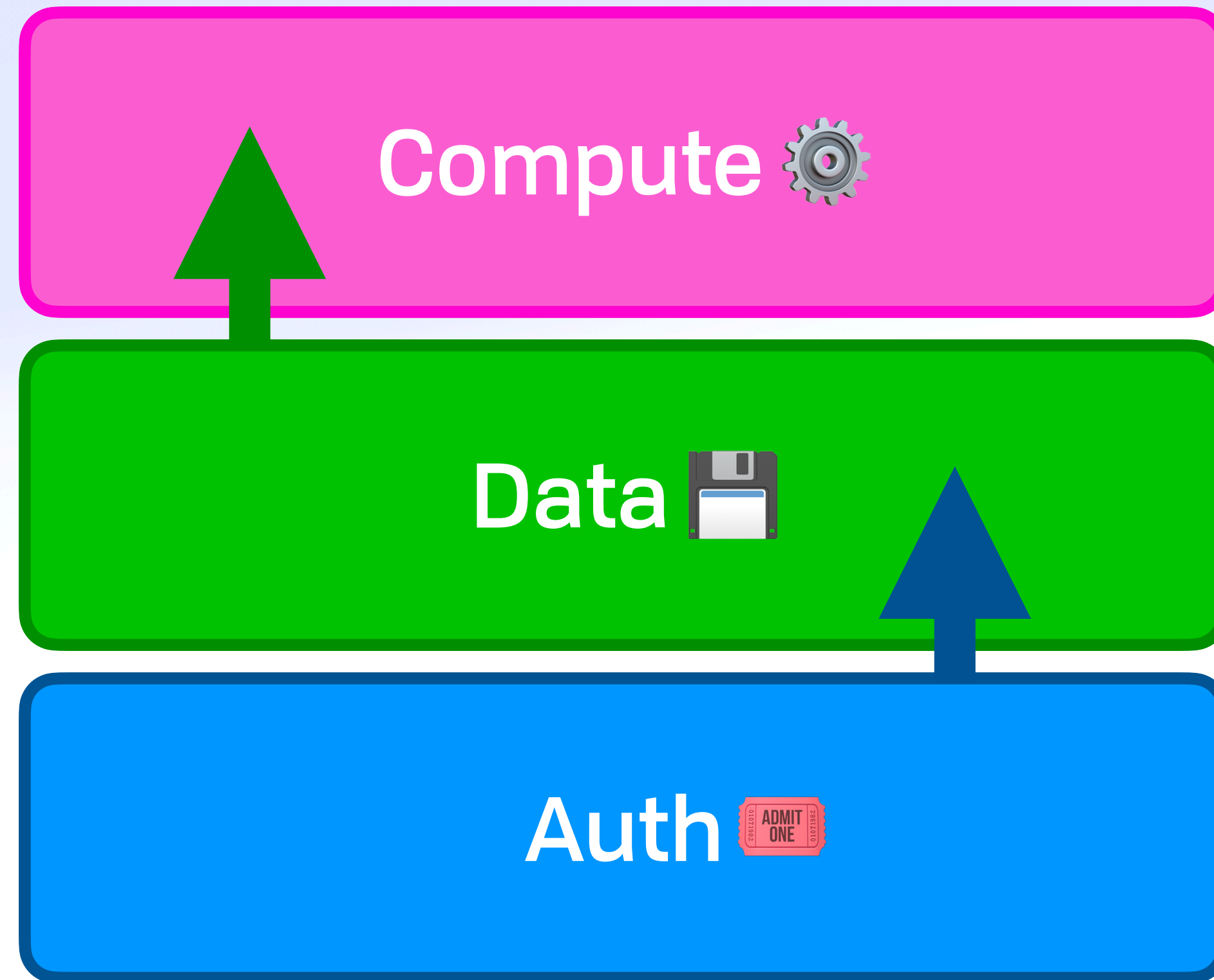
From the Field

Layers 🍰 *Upside Down Cake*



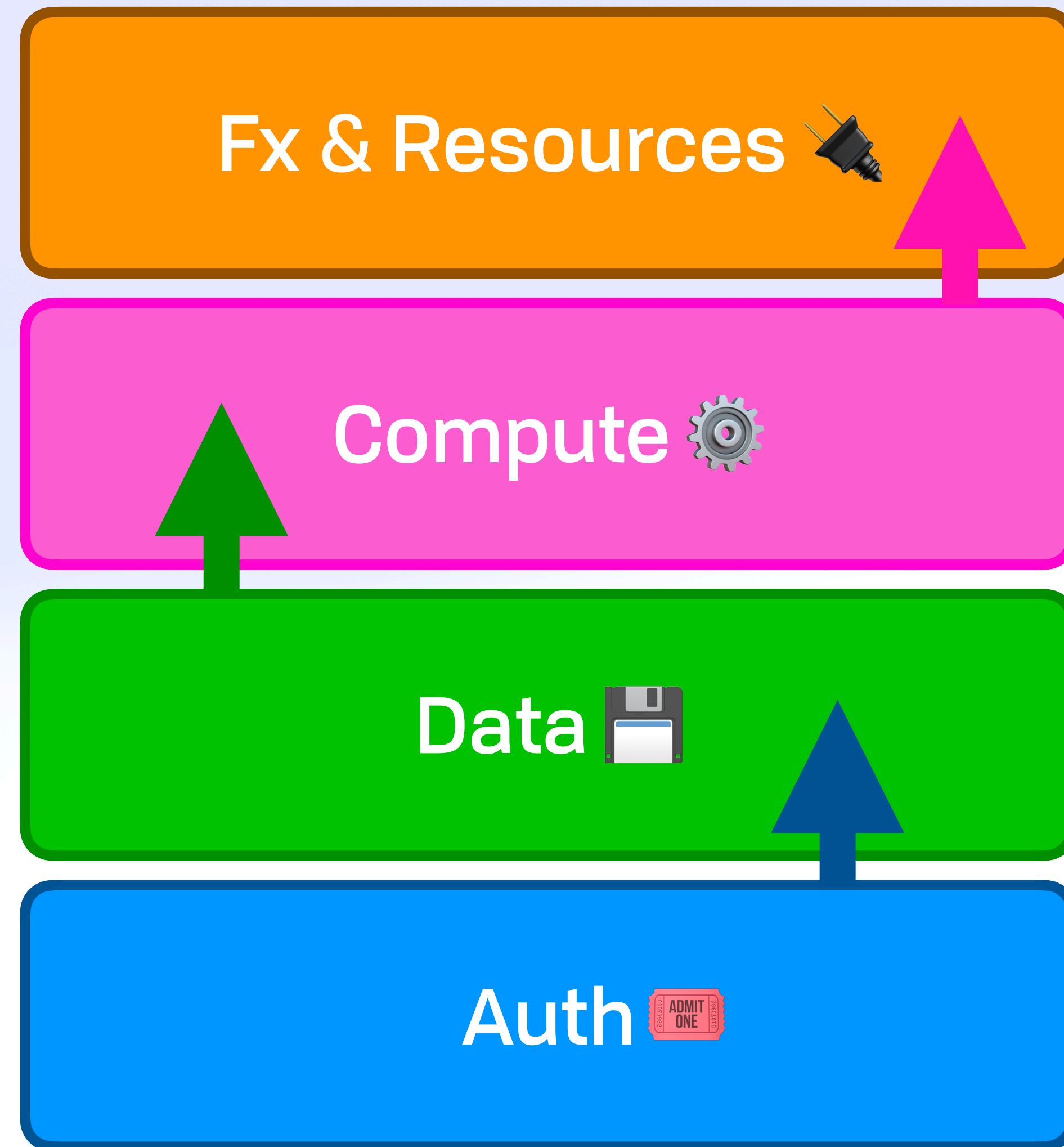
From the Field

Layers 🙄



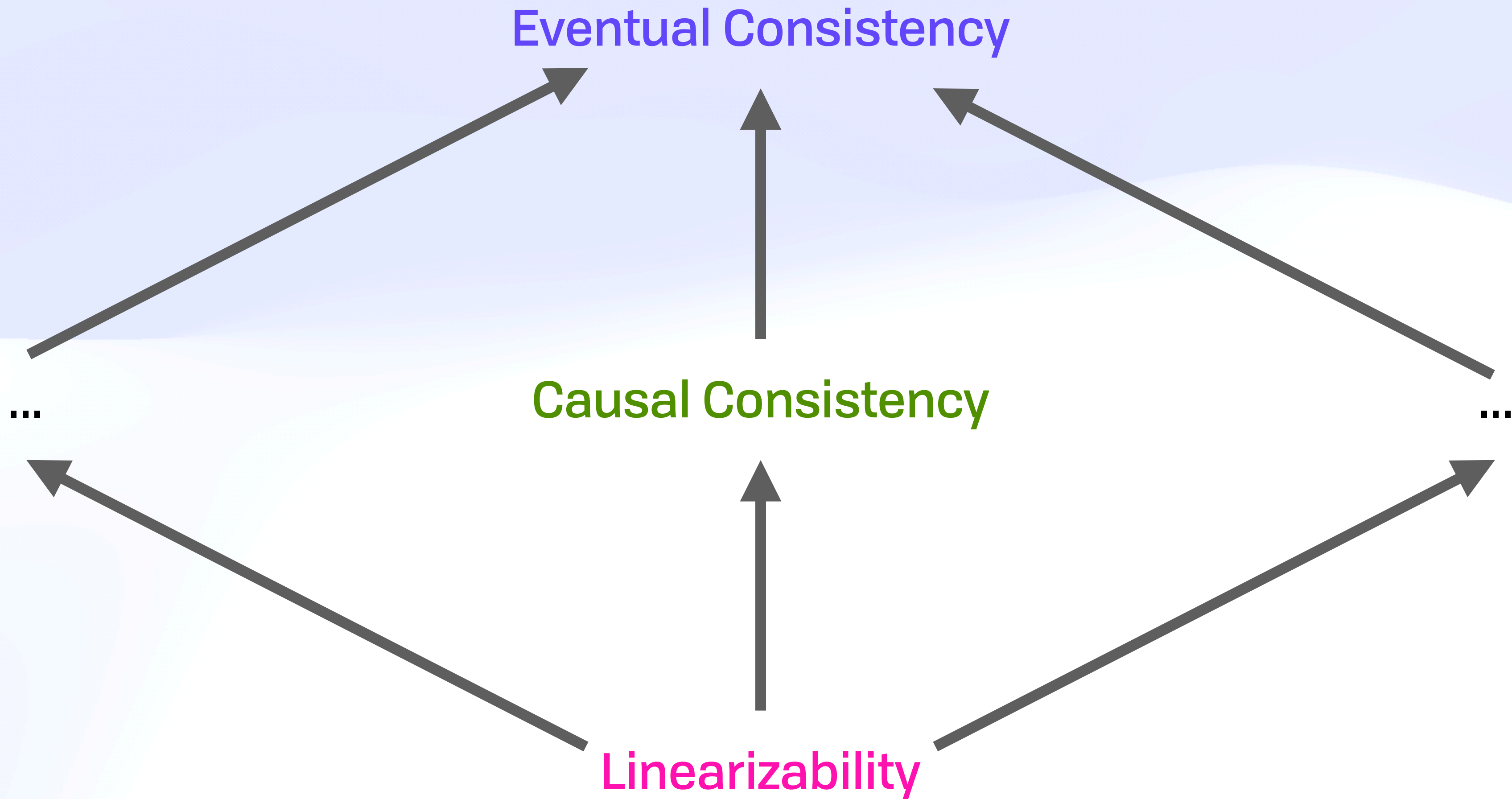
From the Field

Layers 🙄



From the Field

Plays Well With Others



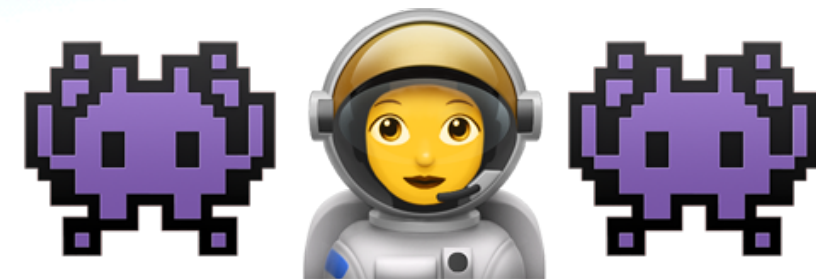
From the Field

Keeping CALM 🧘

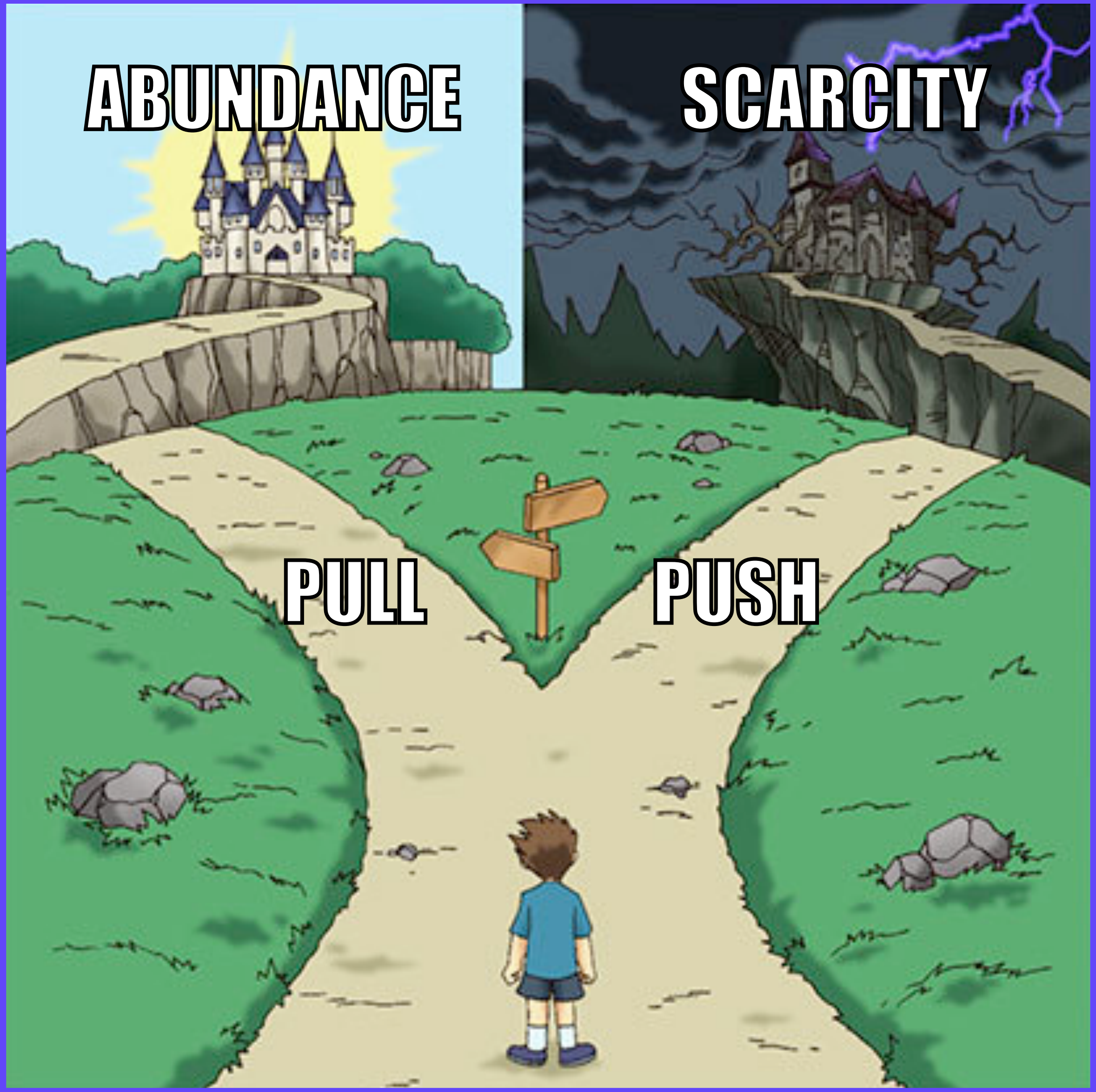
A problem has a **consistent, coordination-free** distributed implementation if and only if it is **monotonic**.

— CALM Theorem

LoFi Authorisation Space



LoFi Authorisation Space



LoFi Authorisation Space

LoFi Authorisation Space

Cryptography is a tool for turning
lots of different problems into
key management problems

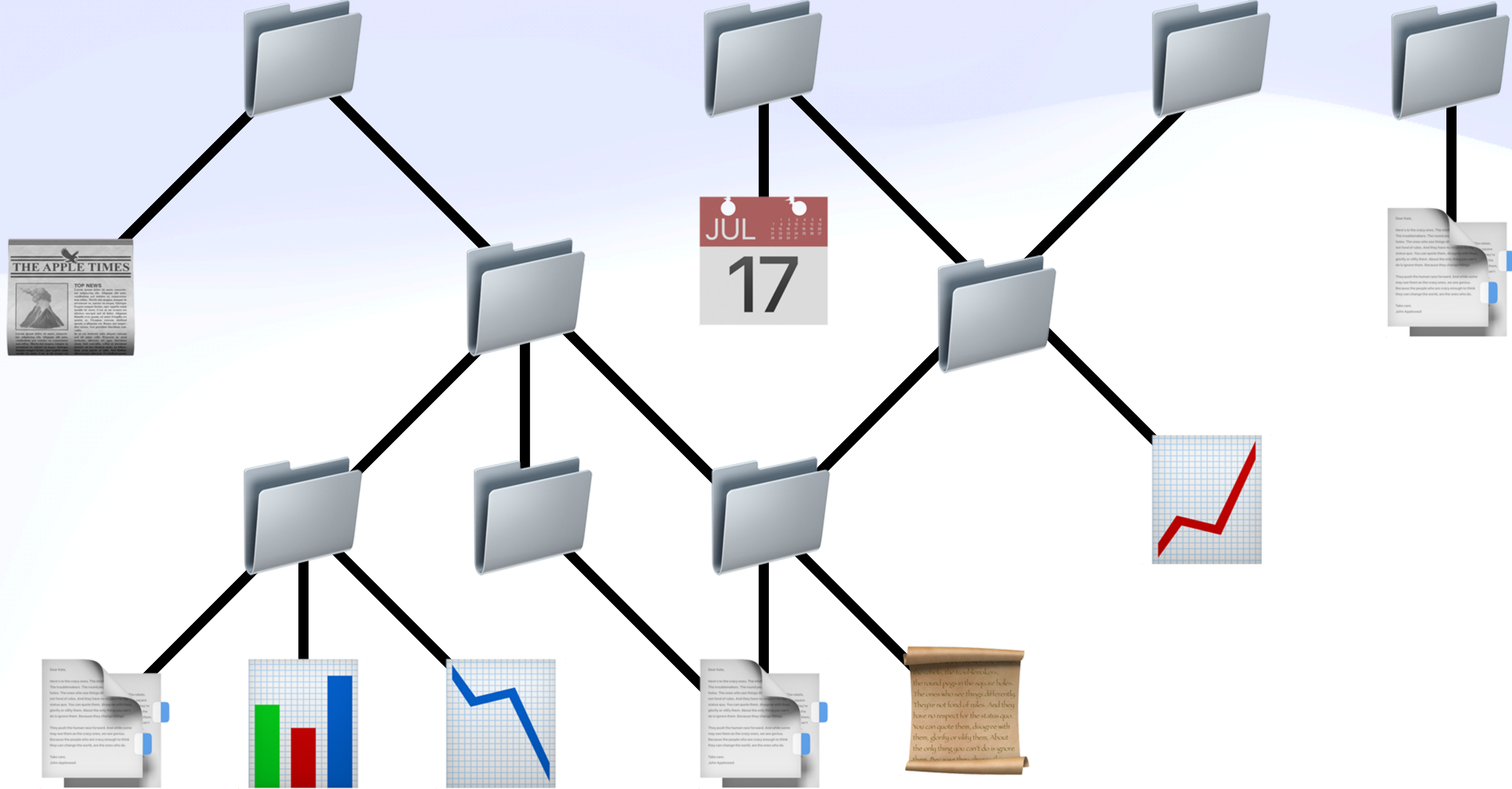
Dr. Lea Kissner, Global Lead of Privacy Technologies at Google

LoFi Authorisation Space

Beyond All-Or-Nothing

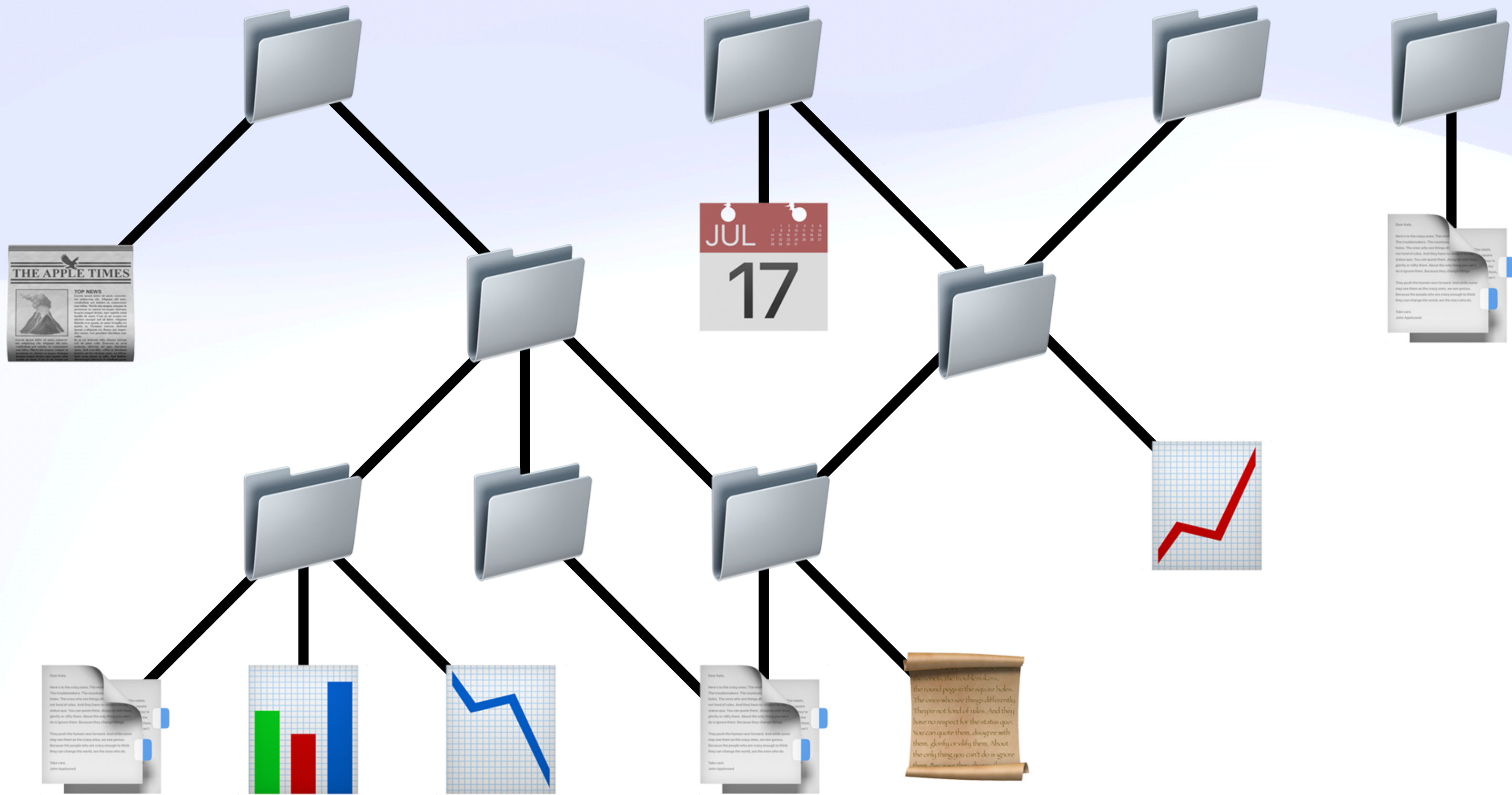
LoFi Authorisation Space

Beyond All-Or-Nothing



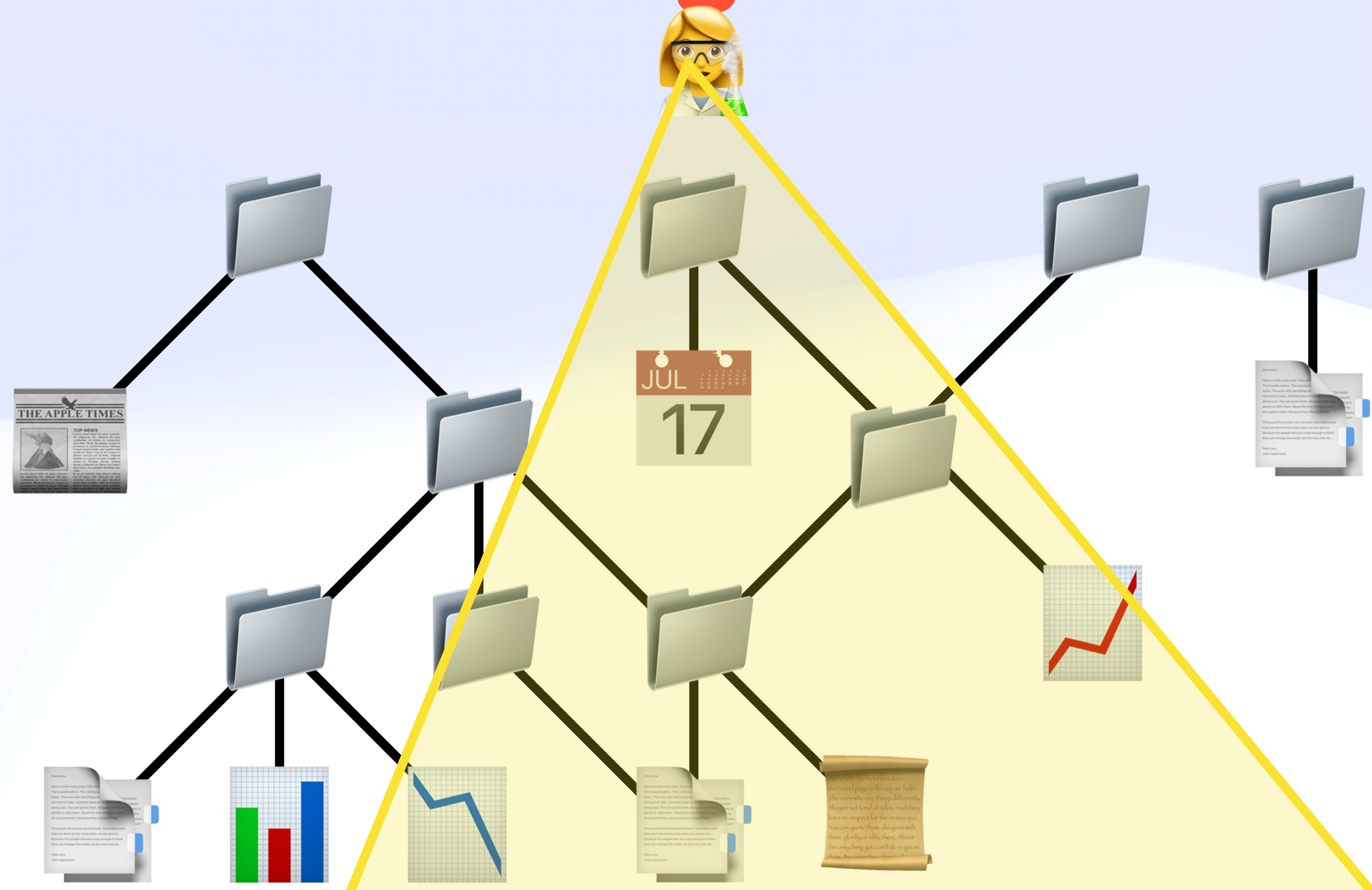
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Beyond All-Or-Nothing



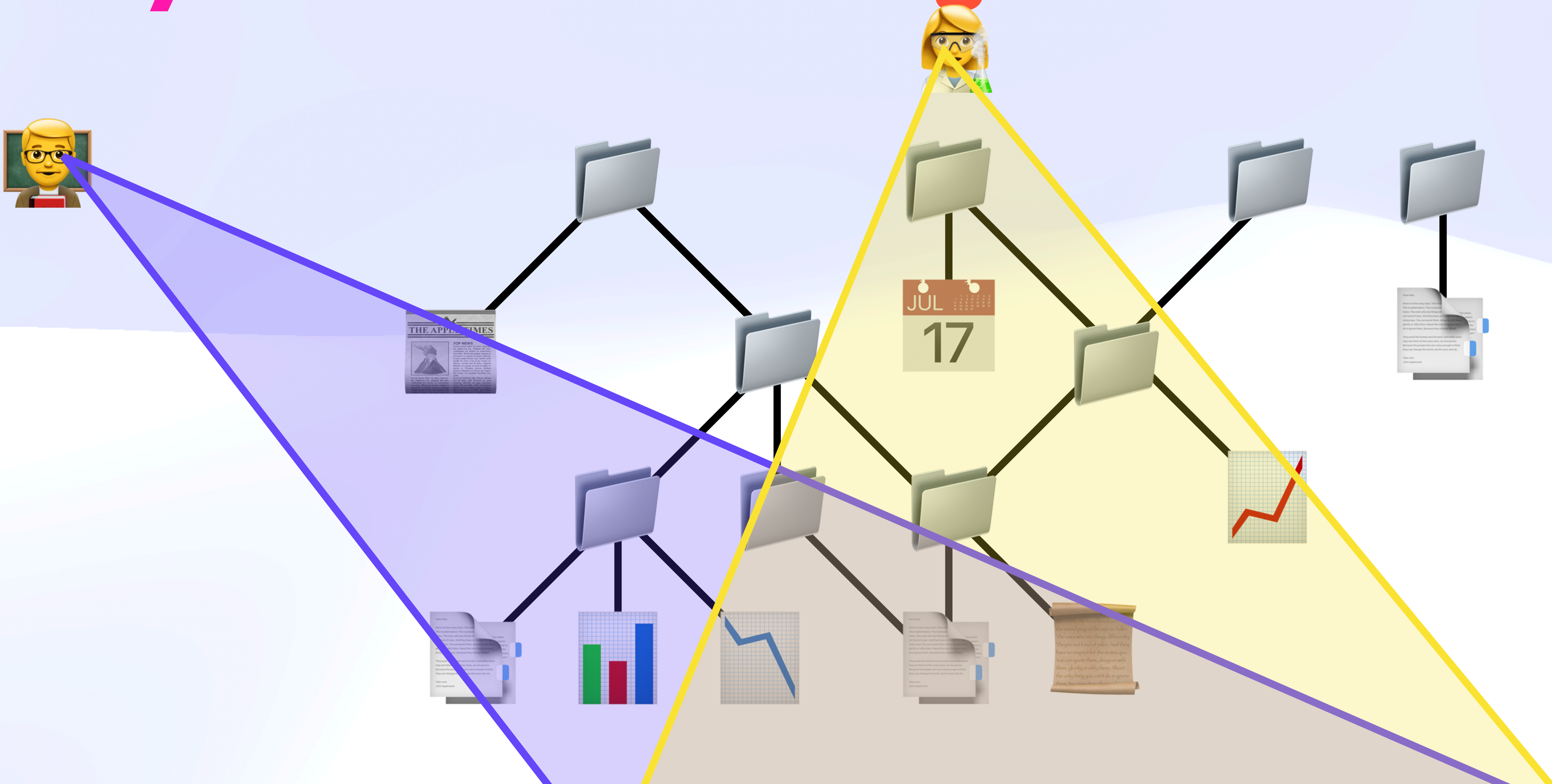
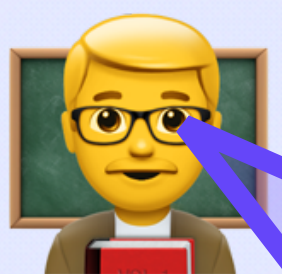
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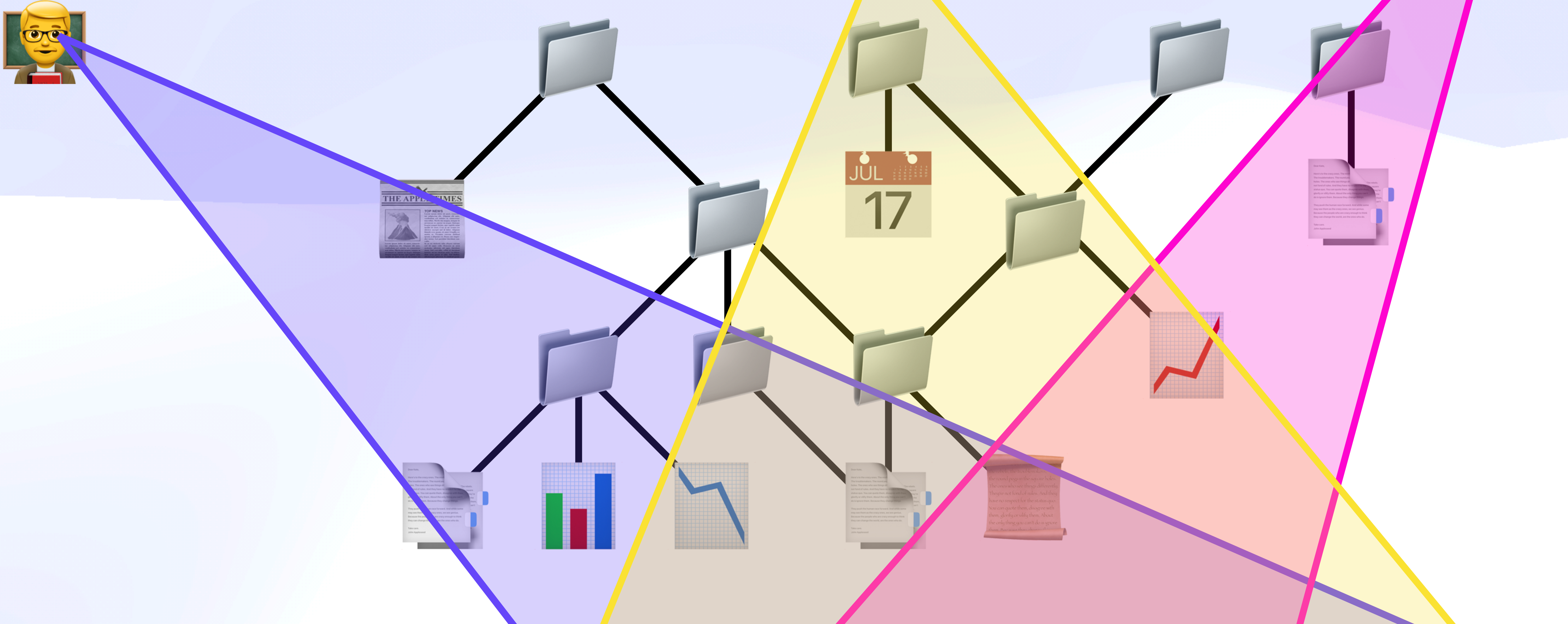
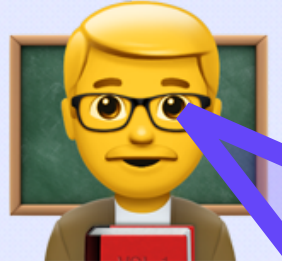
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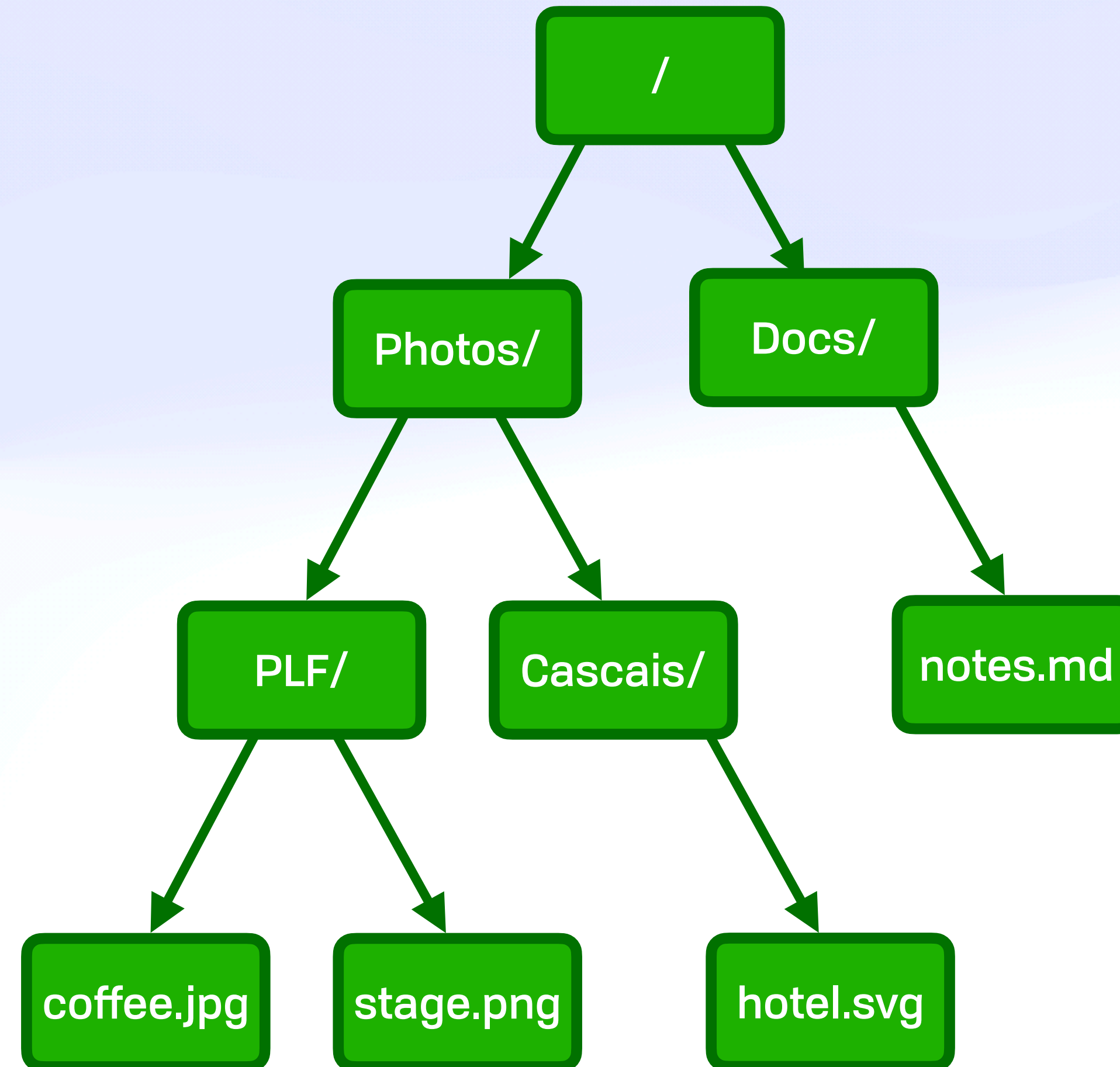
LoFi Authorisation Space

Beyond All-Or-Nothing



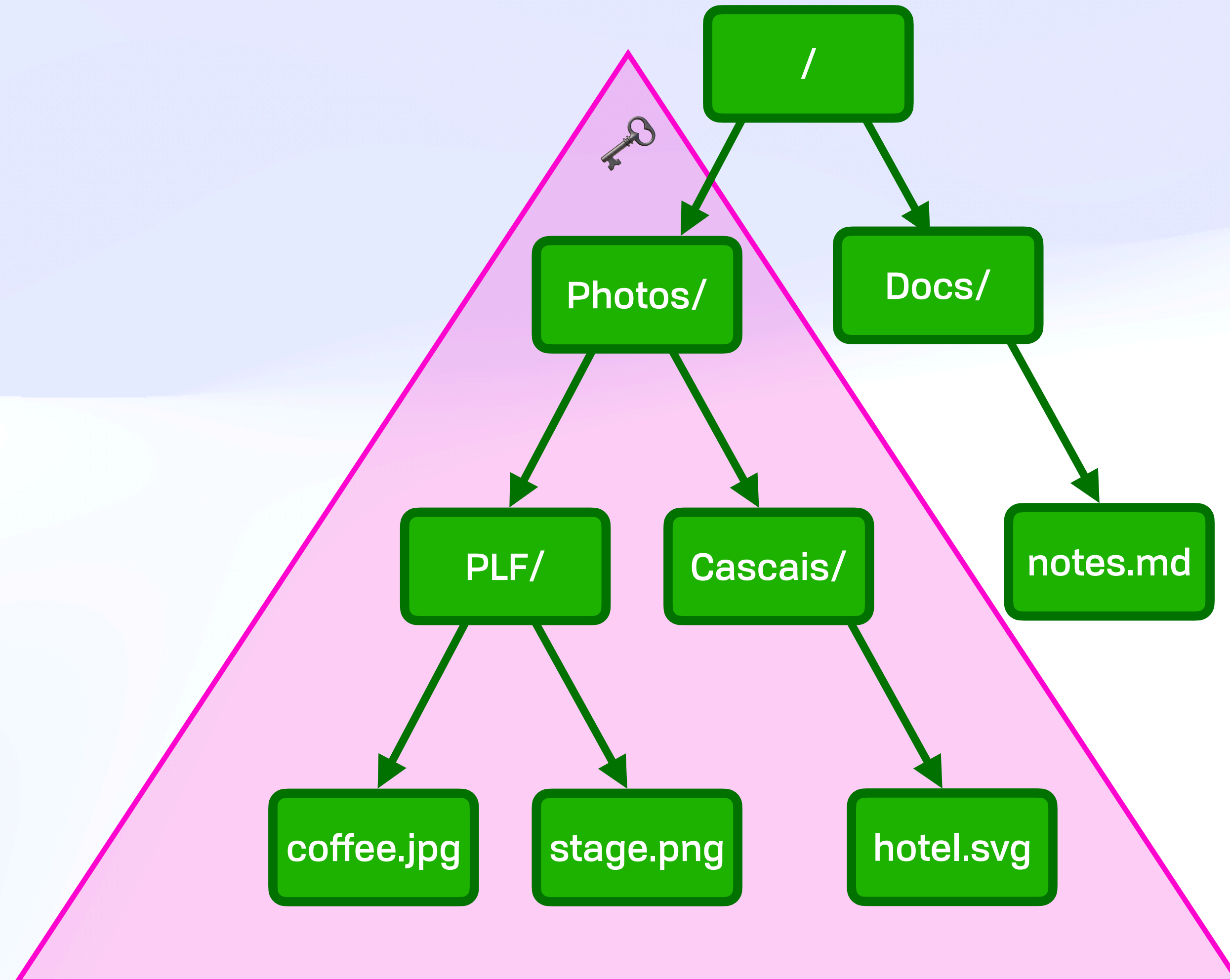
LoFi Authorisation Space

Offline Access Control



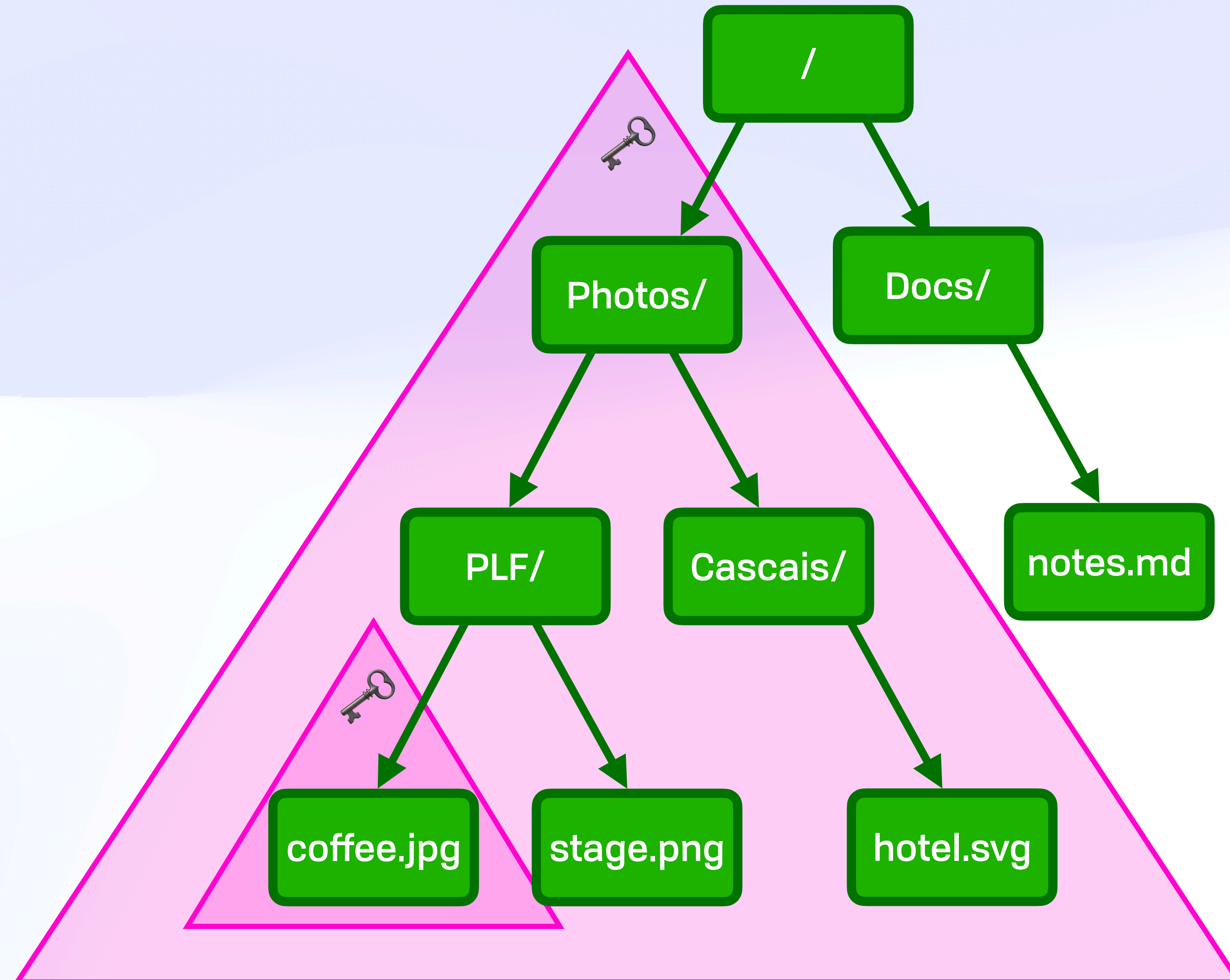
LoFi Authorisation Space

Offline Access Control



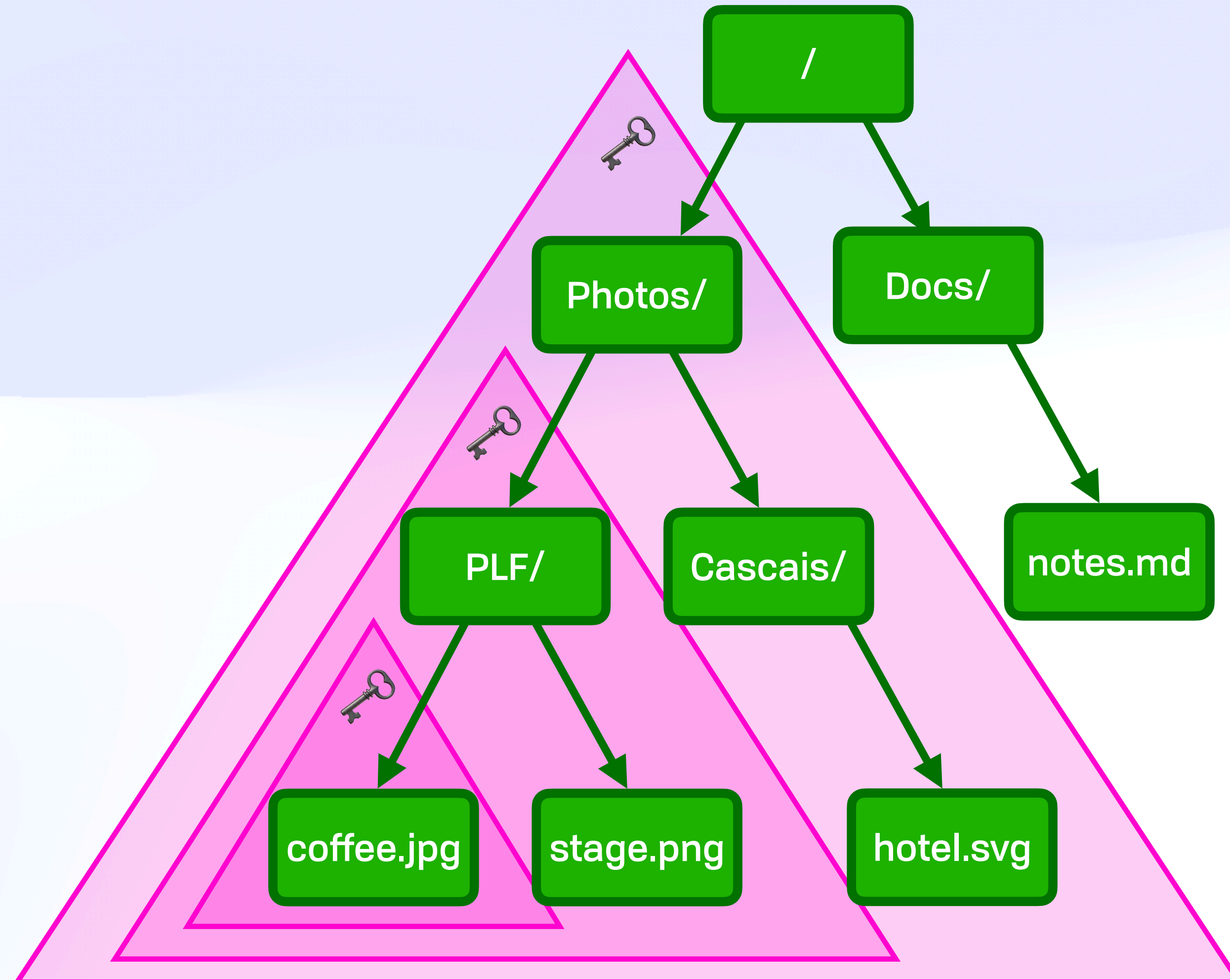
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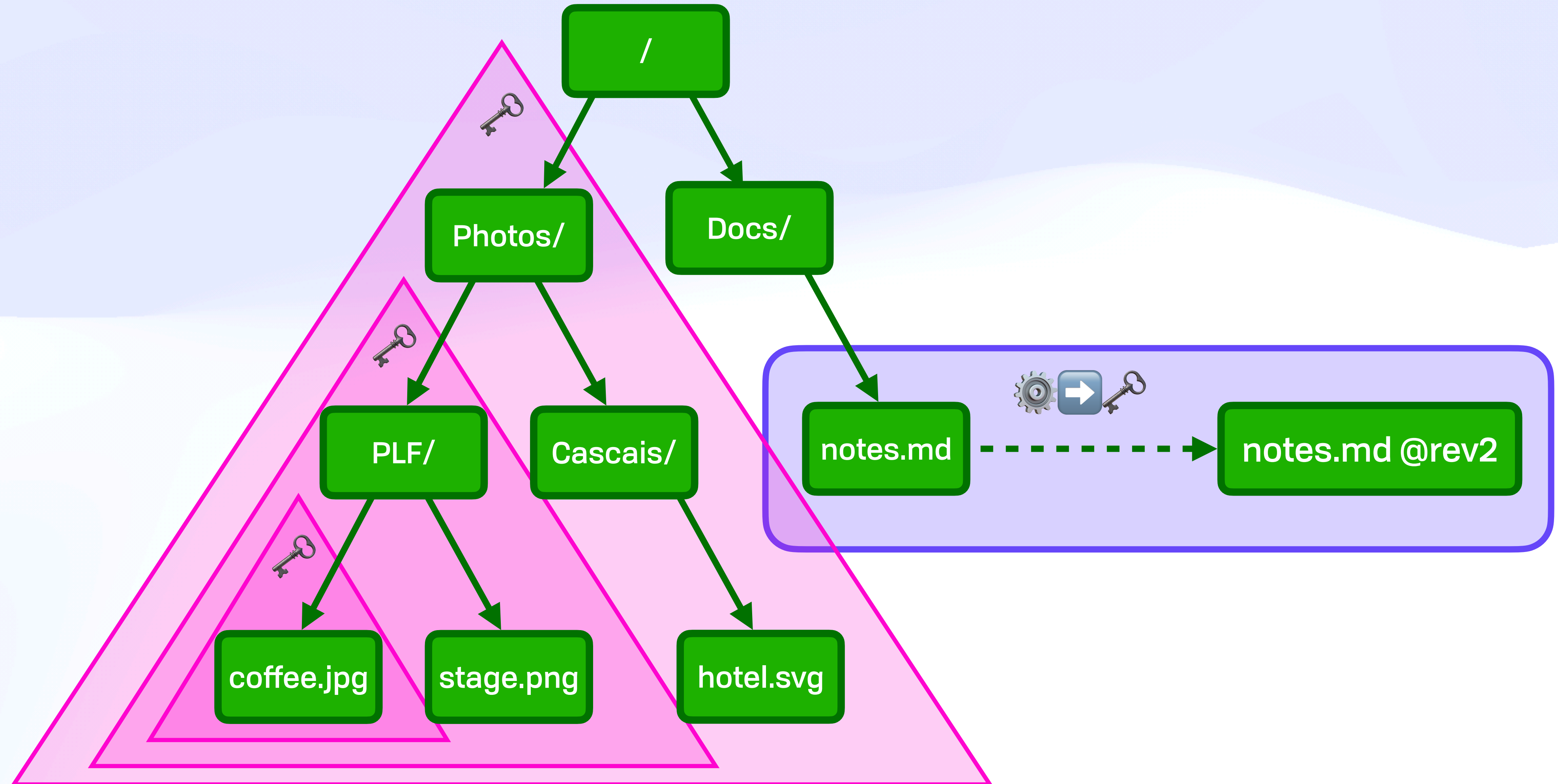
LoFi Authorisation Space

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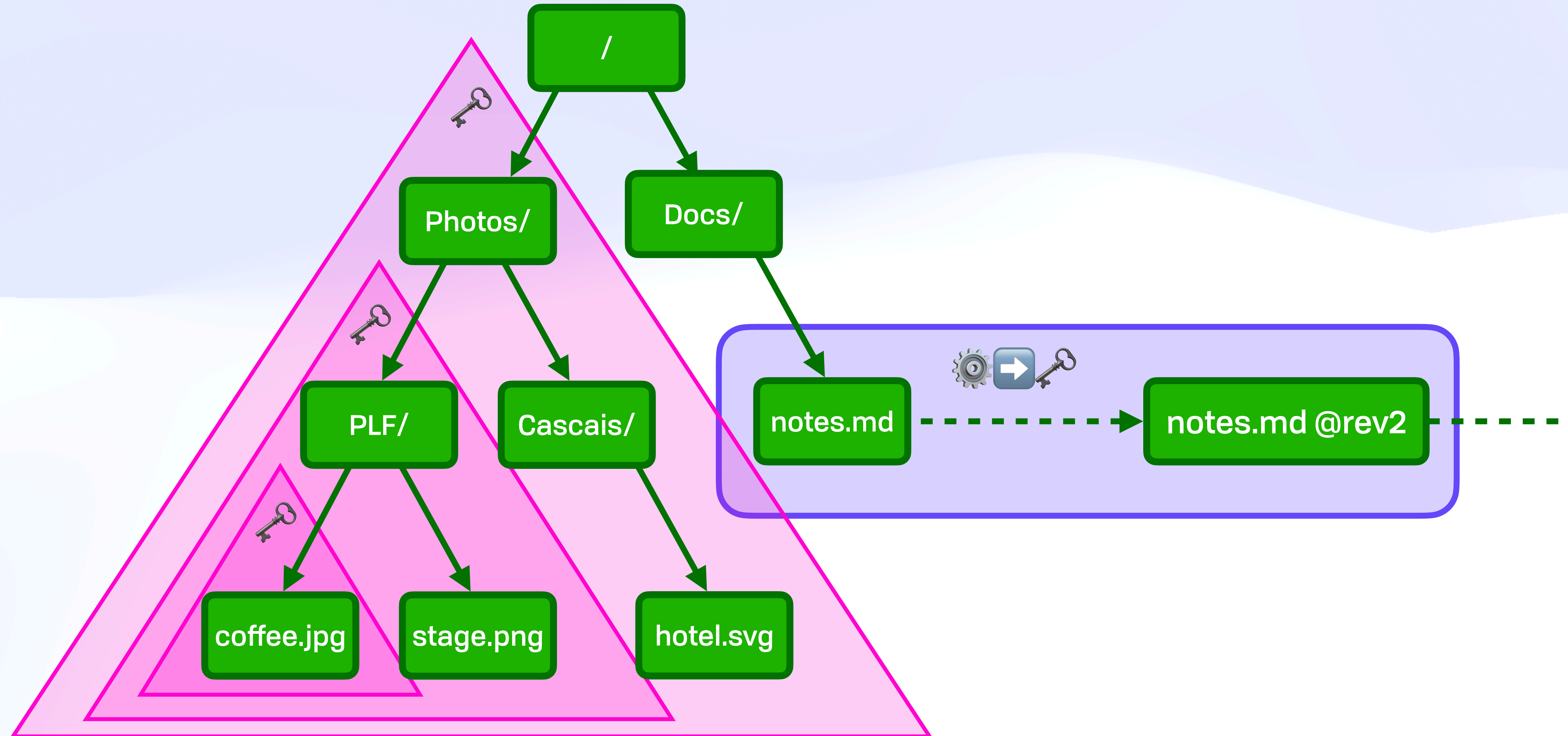
LoFi Authorisation Space

Offline Access Control



LoFi Authorisation Space

Offline Access Control



LoFi Authorisation Space

Cryptography is Not Always Enough

LoFi Authorisation Space

Cryptography is Not Always Enough

- Because it's done at write-time, all or nothing encryption is not enough
- Keep data off the network!

LoFi Authorisation Space

Auth Accidents Will Happen

LoFi Authorisation Space

Auth Accidents Will Happen

Byzantine Agent



LoFi Authorisation Space

Auth Accidents Will Happen

Byzantine Agent



Revocation (non-monotone)



LoFi Authorisation Space

Auth Provenance

👤 🖥️ 🌐

🌈 🐶
🍾 🍬 🧸

👤 📱 iOS

🌈 🐶
🧸

🌈
🍾 🧸

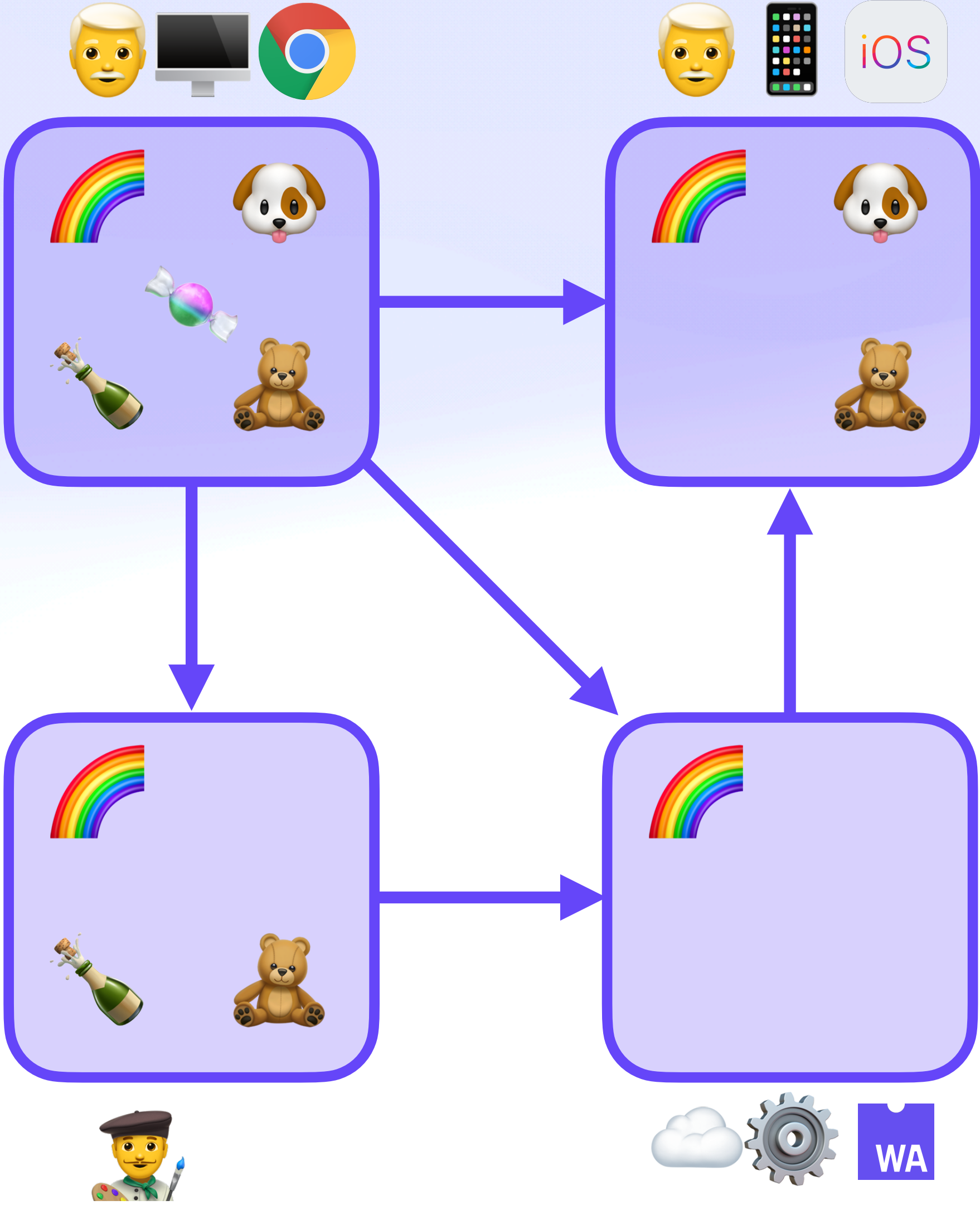
👨🎨

🌈

☁️ ⚙️ WA

LoFi Authorisation Space

Auth Provenance



LoFi Authorisation Space

Auth Provenance

- ✓ PA/EL
- ✓ Rooted authority
- ✓ Resource satisfiability
- ✓ EigenTrust

Brachthausen et al, Effects, Capabilities, and Boxes
Choudhury & Krishnaswami, Recovering Purity with Comonads and Capabilities
Bianchini et al, Coeffects for Sharing and Mutation
Johnathan Reiss, A Security Kernel Based on the Lambda Calculus
Mark Miller, Robust Composition

LoFi Authorisation Space

Auth Provenance

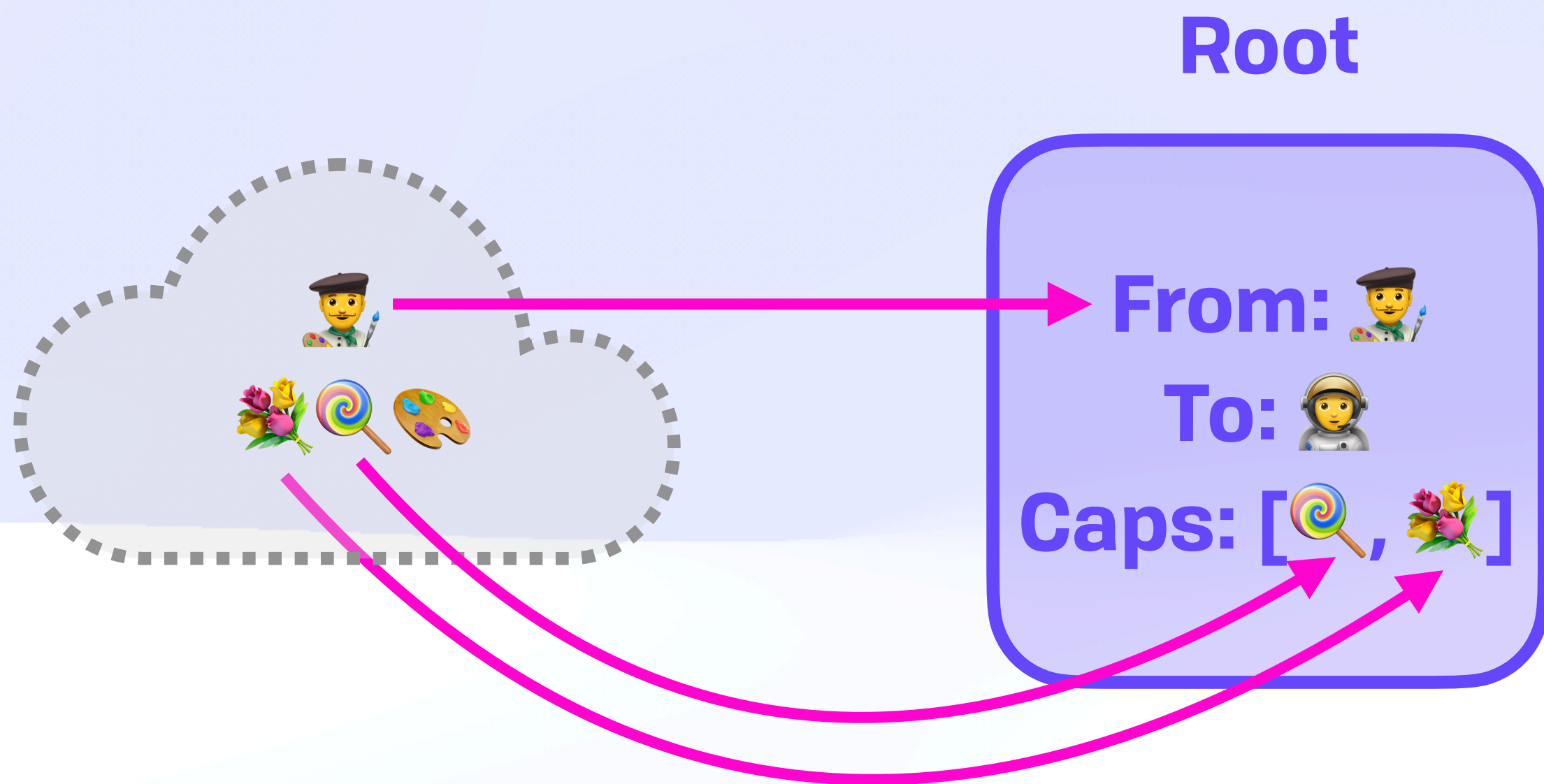


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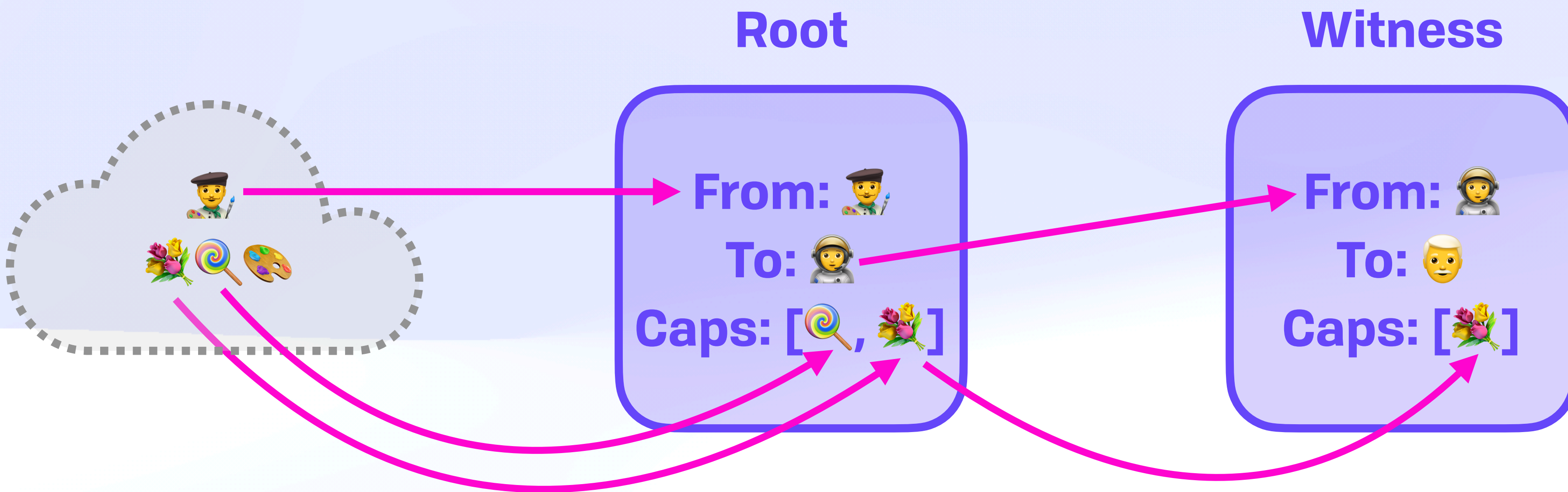
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LoFi Authorisation Space

Auth Provenance

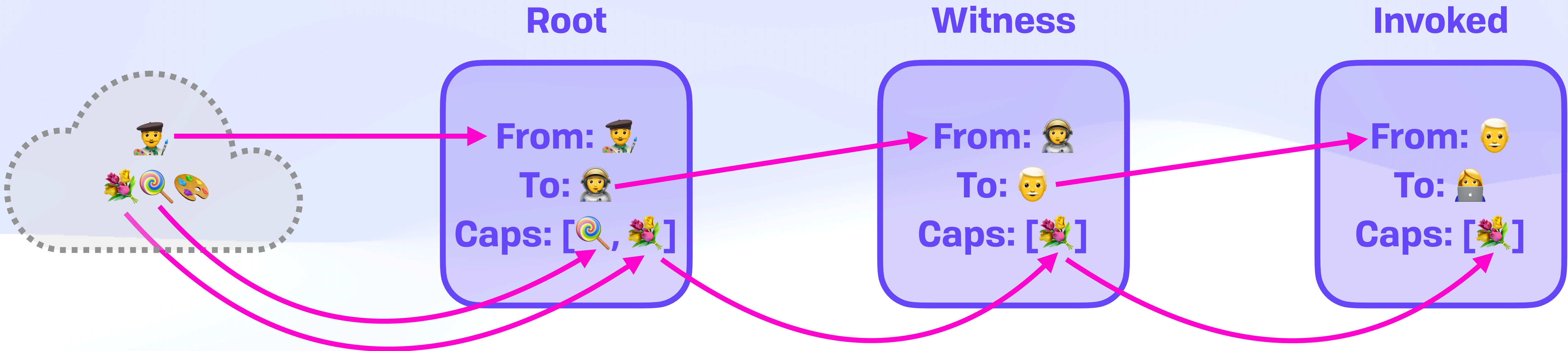


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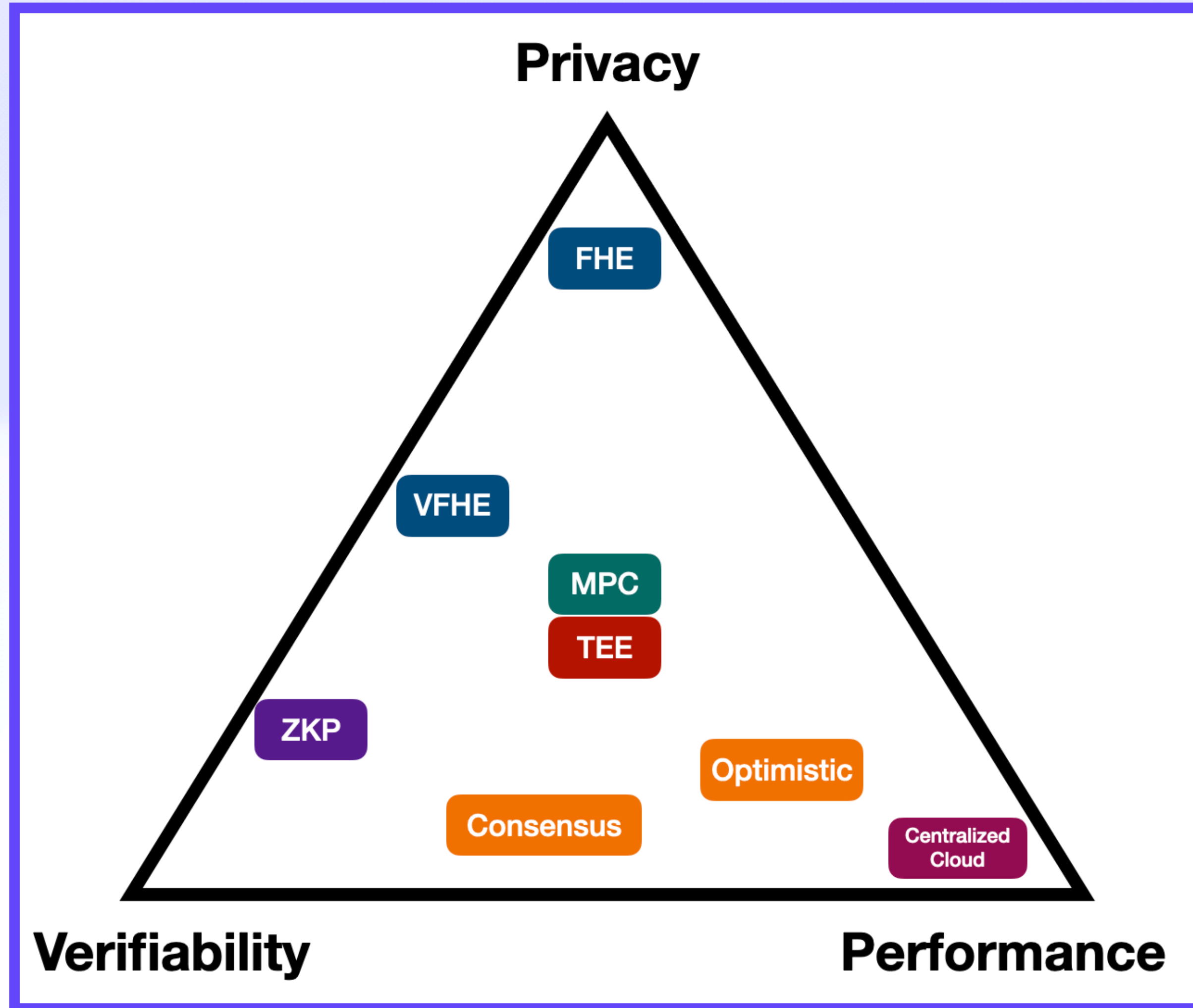


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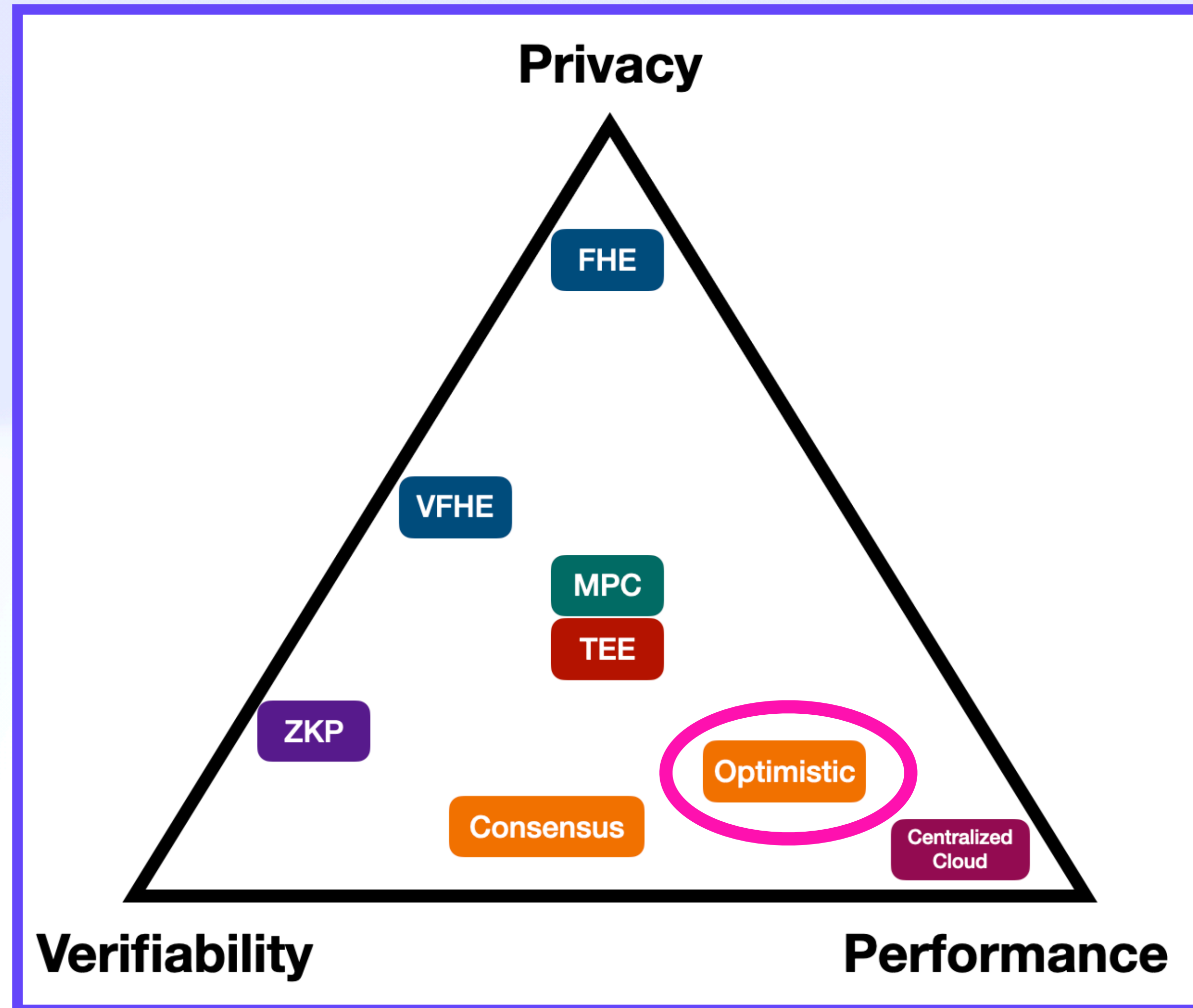
LoFi Authorisation Space

How to Trust Compute?



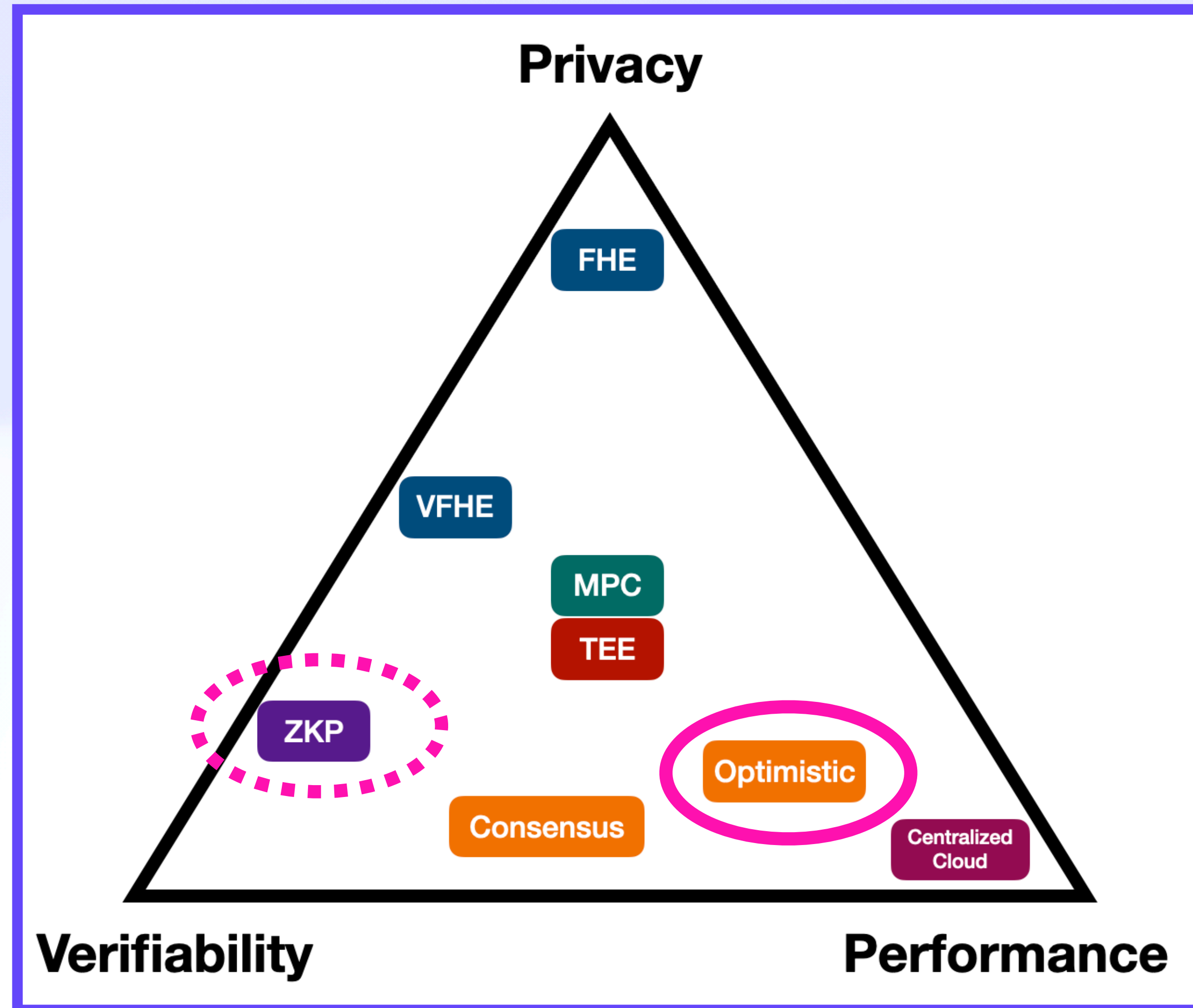
LoFi Authorisation Space

How to Trust Compute?



LoFi Authorisation Space

How to Trust Compute?



Program Locally First

$\Gamma \vdash x : \tau \rightarrow \text{Local } x : \text{LoFi } \tau$

Programming... Local-First

Programming... Local-First

Much of the pain in traditional distributed programming comes from this mismatch: programmers are expected to **bridge from an ordered programming model into a disordered reality** that executes their code.

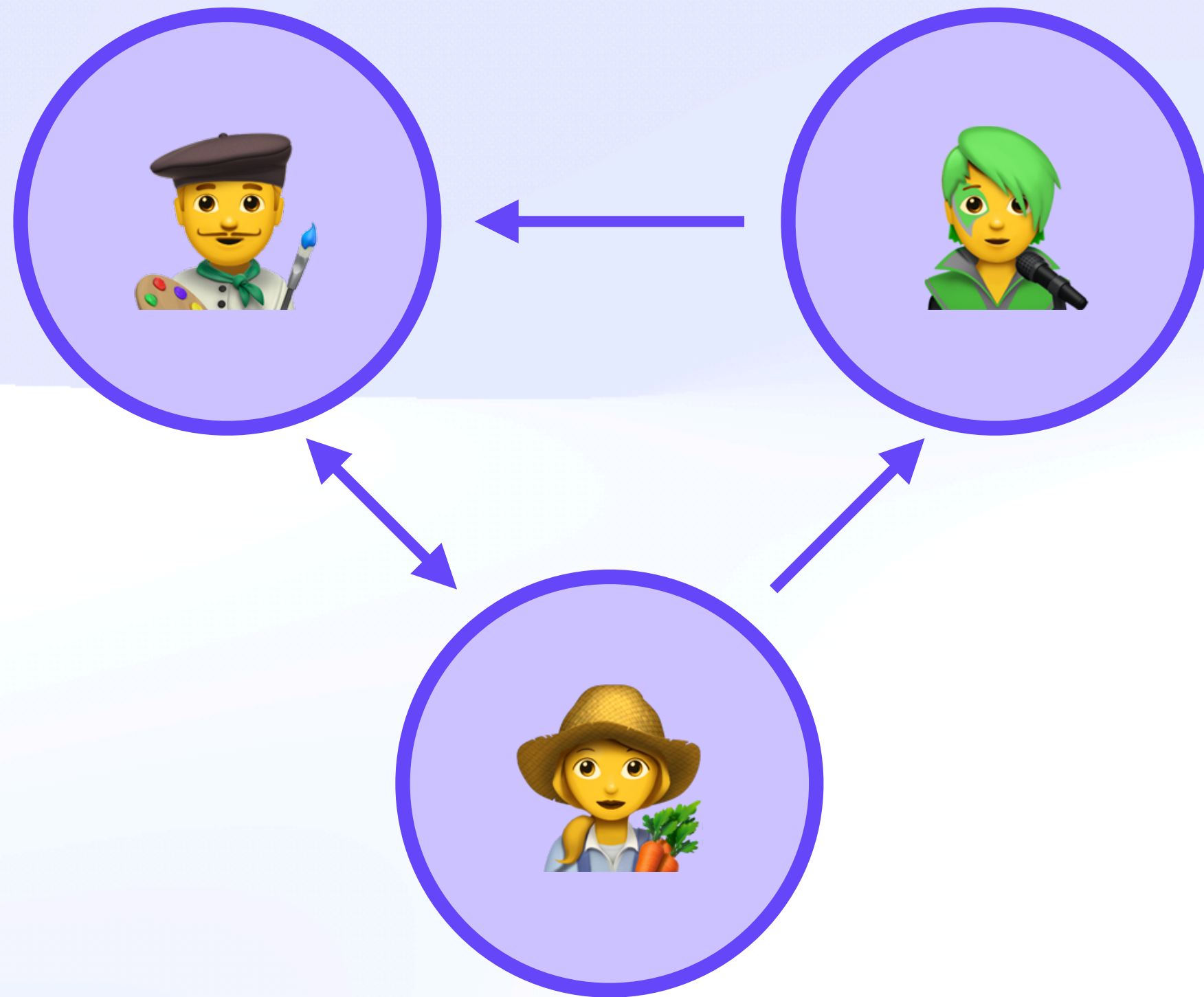
— BloomLang Website

Programming... Local-First

Semantics Non-Preservation

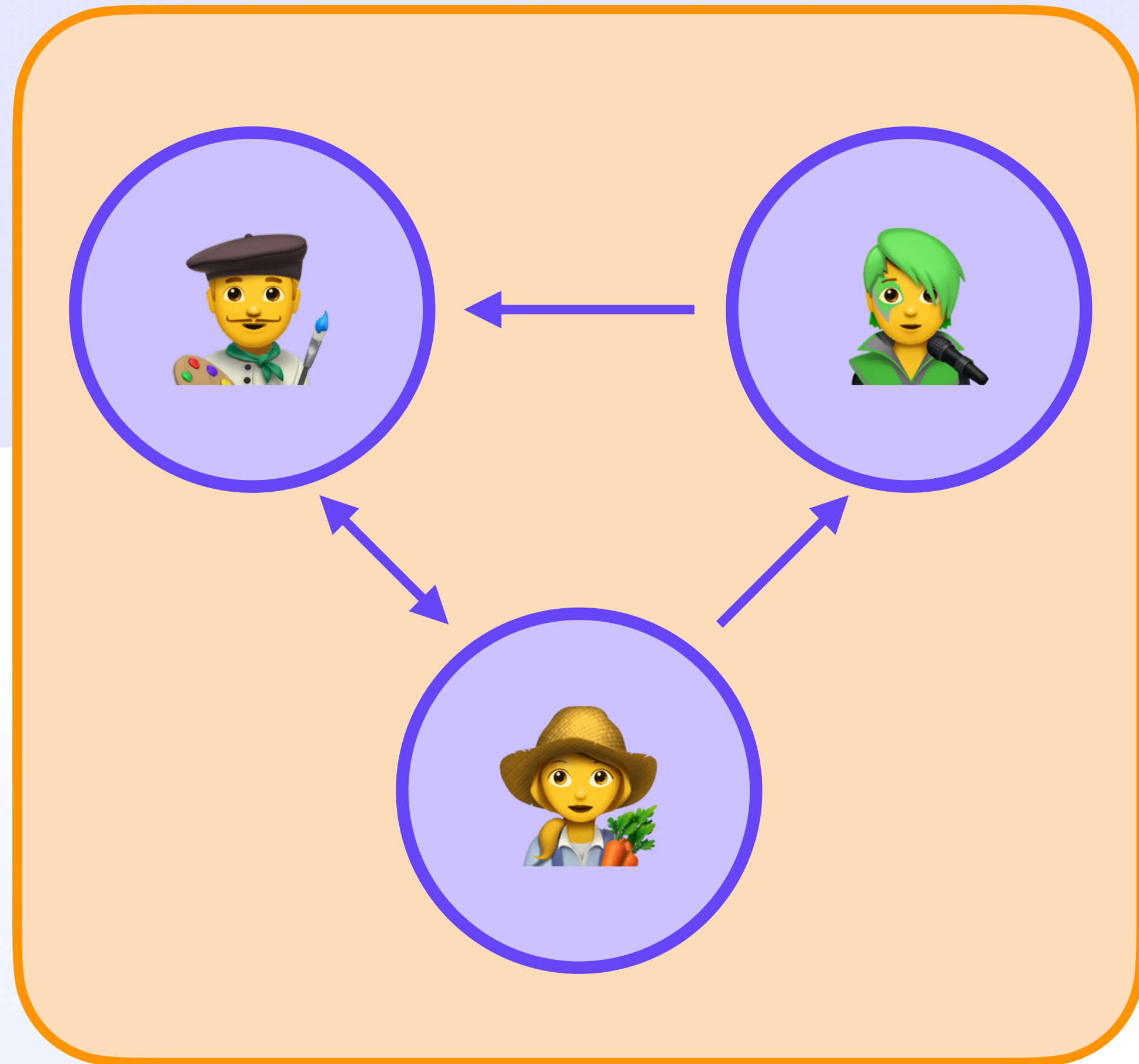
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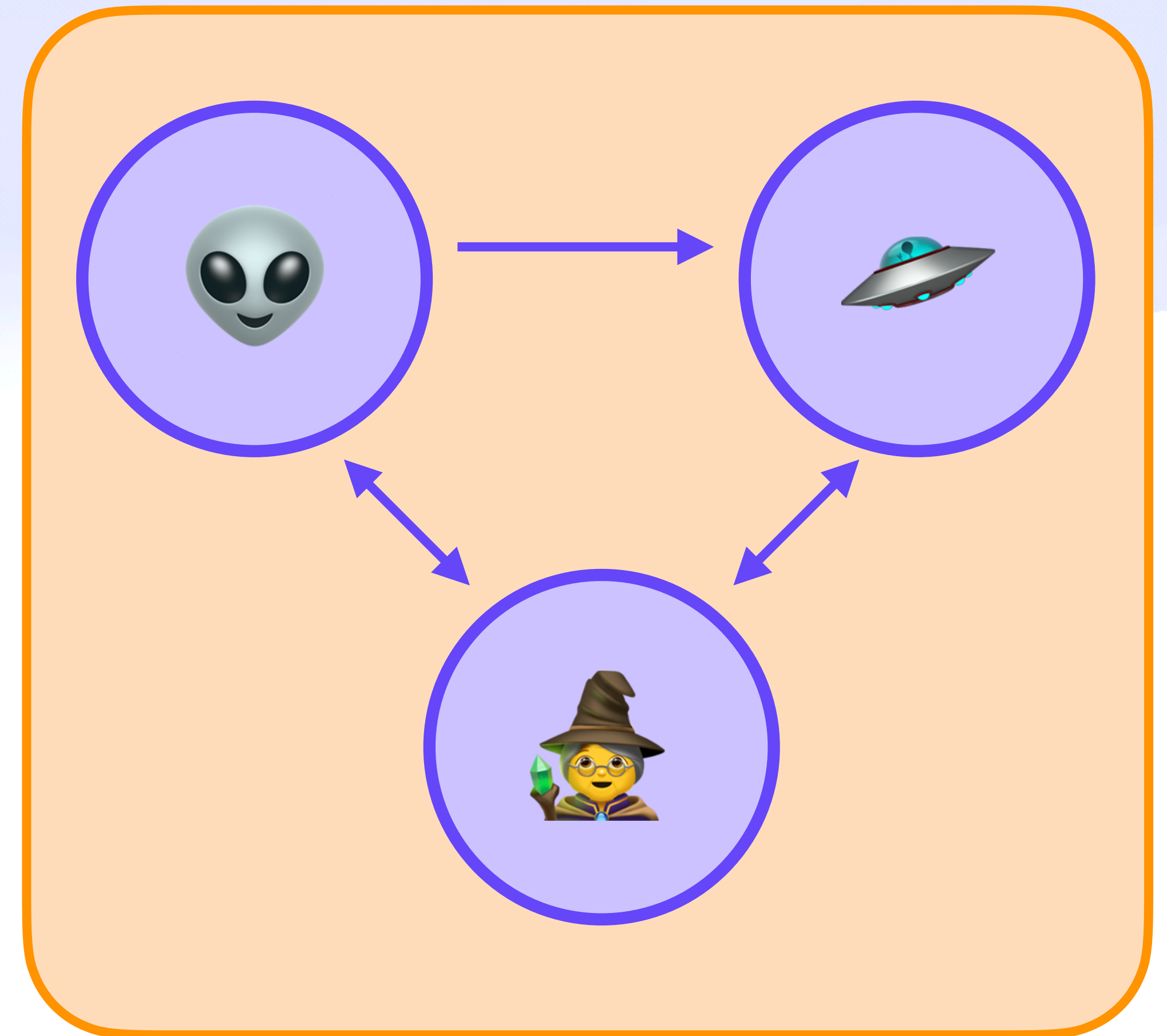
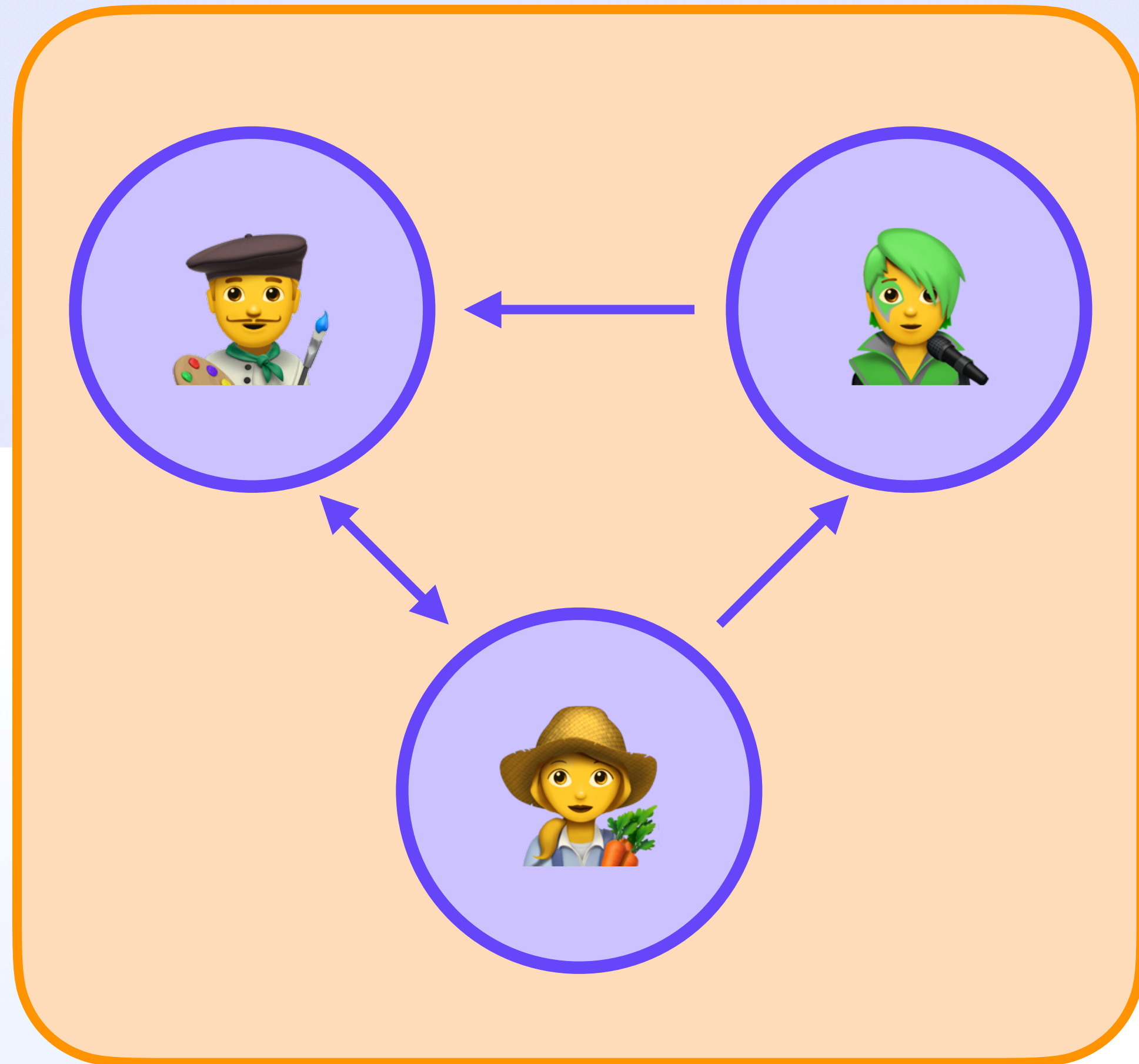
Programming... Local-First

Semantics Non-Preservation



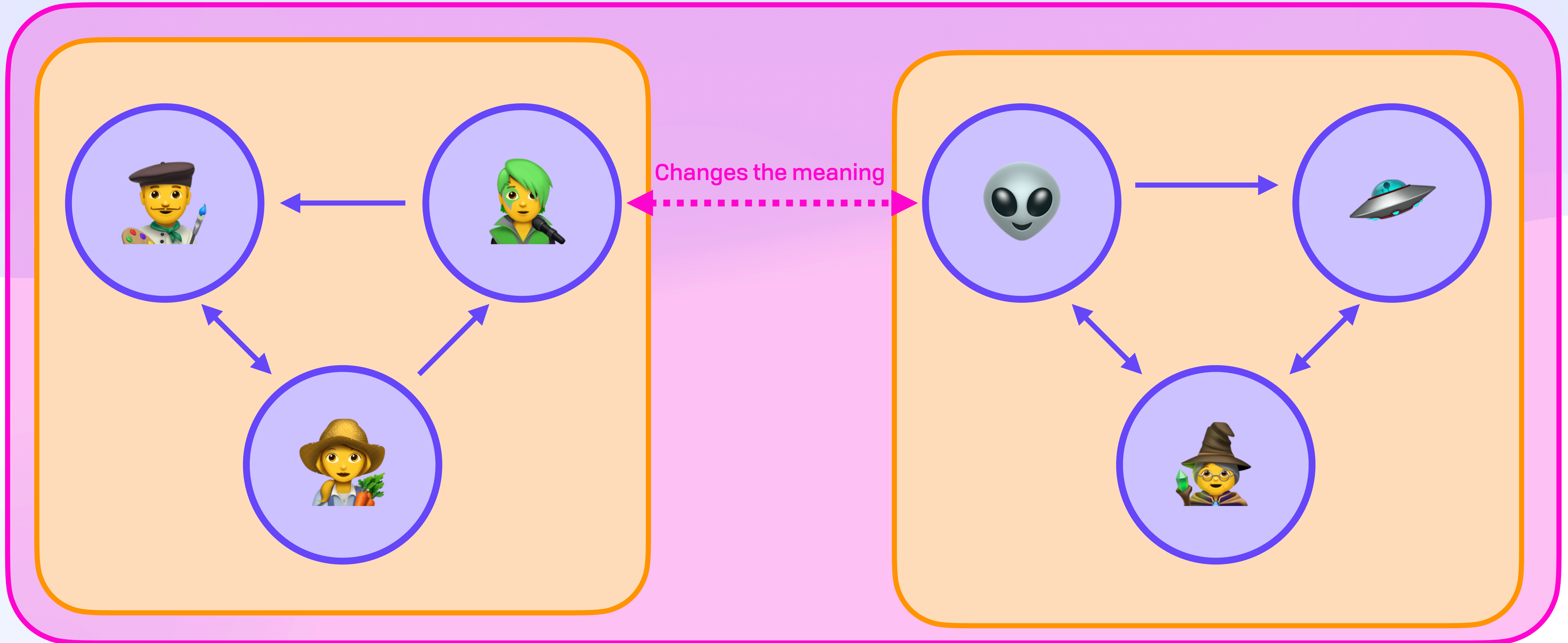
Programming... Local-First

Semantics Non-Preservation



Programming... Local-First

Semantics Non-Preservation



Programming... Local-First

Command! Query? Compute.

Mutation Effect Stream - - - - -

Query Effect Stream - - - - -

Pure Function Stream - - - - -

Base Event Stream —————

$t \rightarrow$

Programming... Local-First

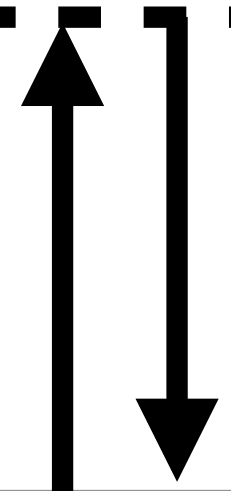
Command! Query? Compute.

Mutation Effect Stream - - - - -

Query Effect Stream - - - - -

Pure Function Stream - - - - -

Base Event Stream _____



$t \rightarrow$

Programming... Local-First

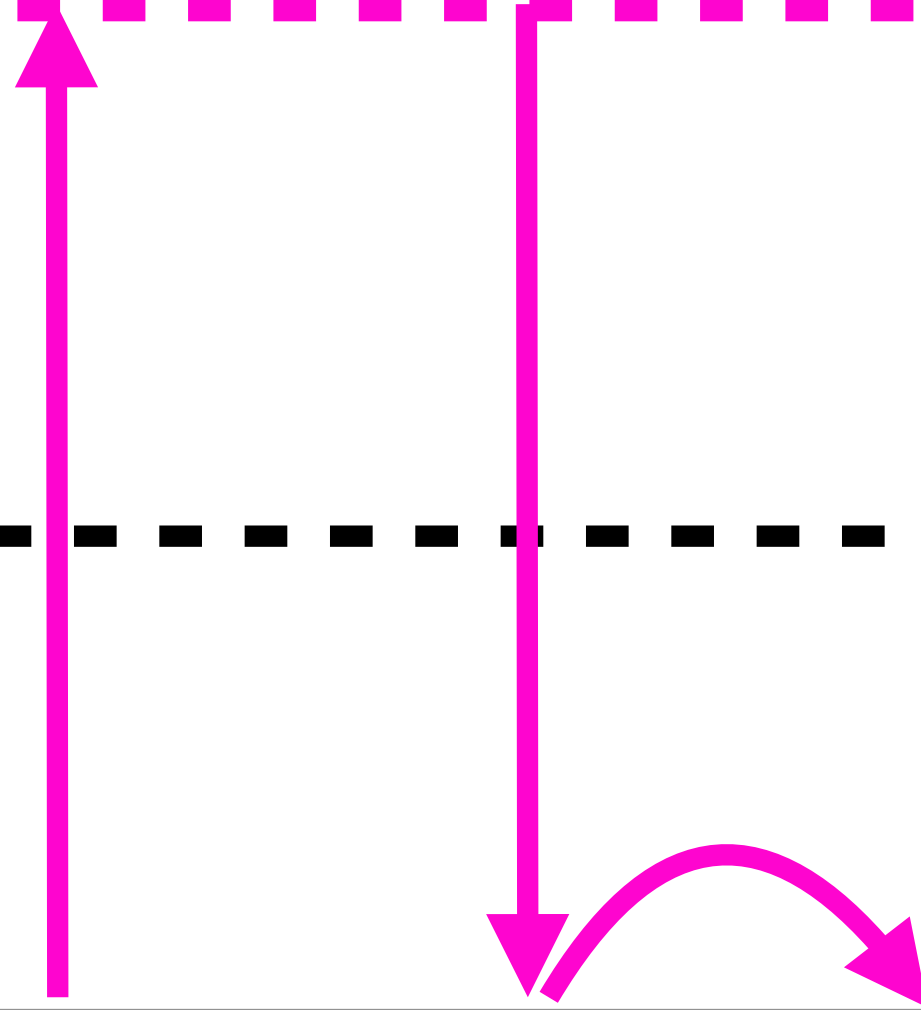
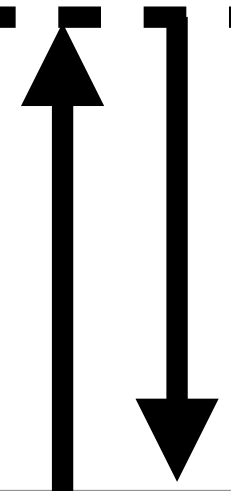
Command! Query? Compute.

Mutation Effect Stream - - - - -

Query Effect Stream - - - - -

Pure Function Stream - - - - -

Base Event Stream _____



$t \rightarrow$

Programming... Local-First

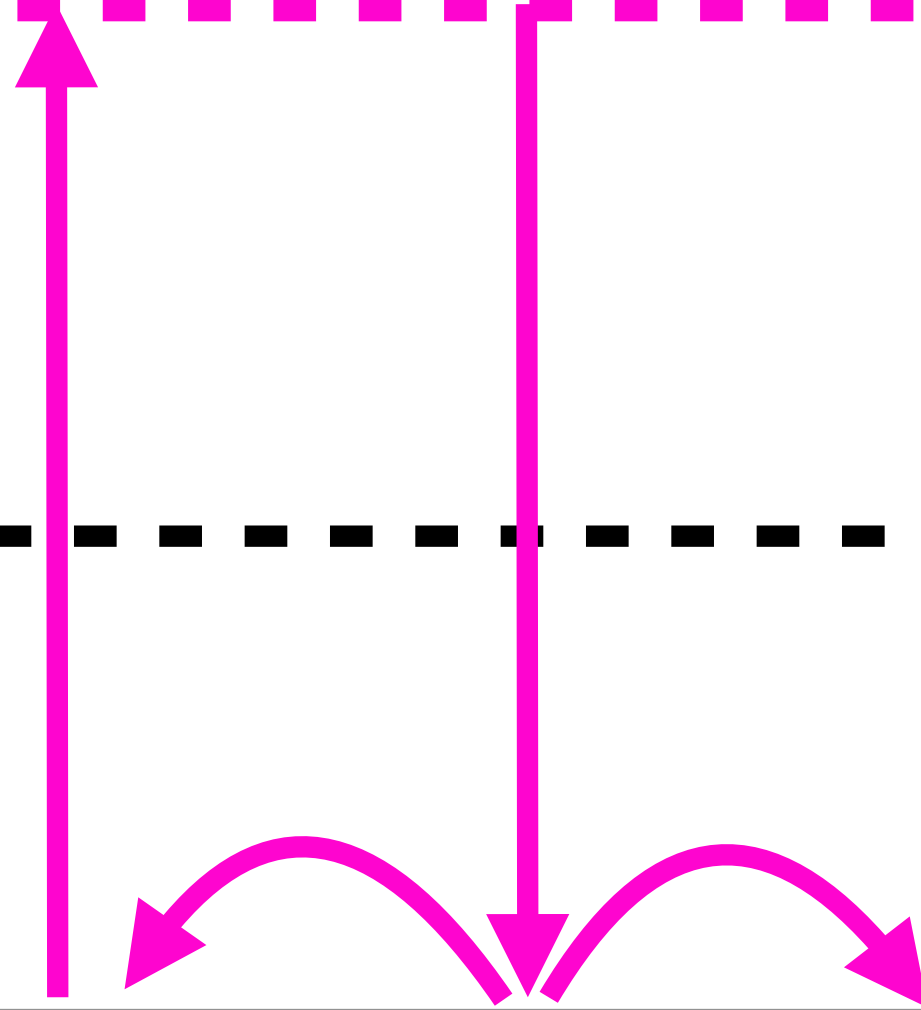
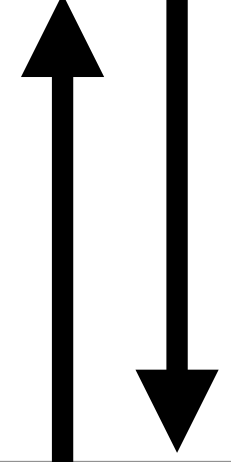
Command! Query? Compute.

Mutation Effect Stream - - - - -

Query Effect Stream - - - - -

Pure Function Stream - - - - -

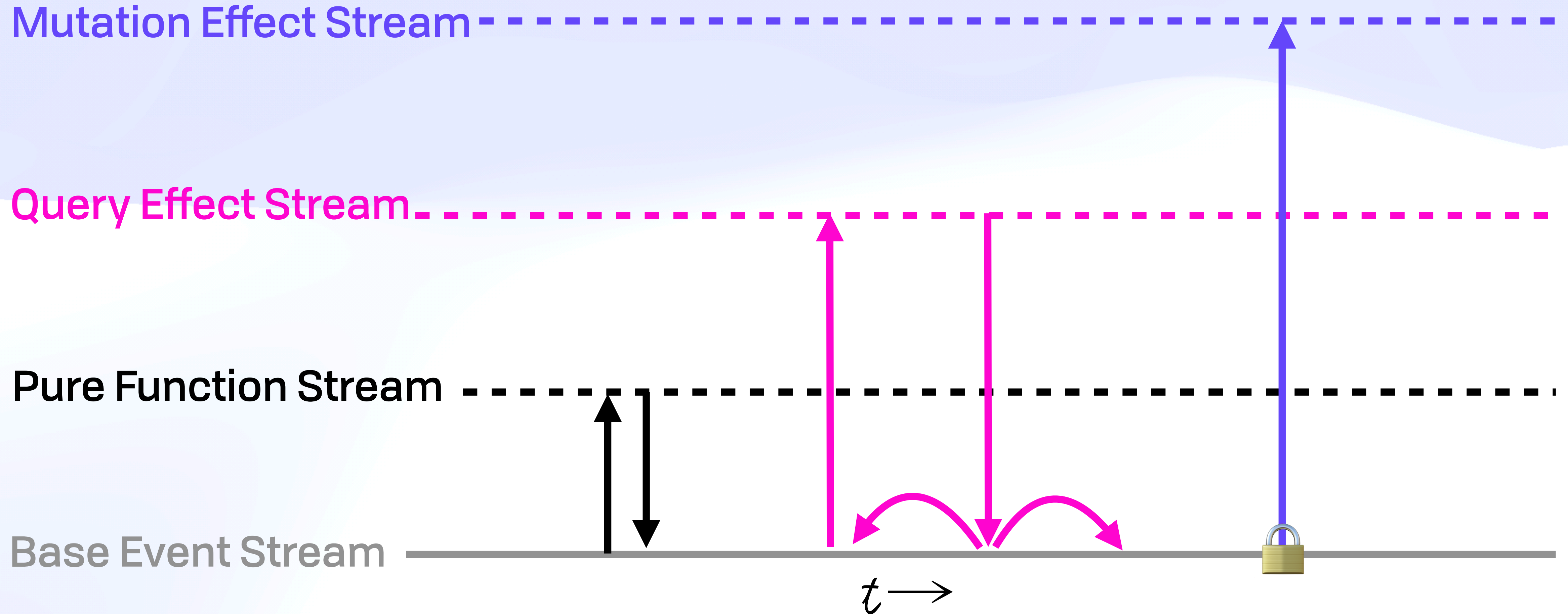
Base Event Stream _____



$t \rightarrow$

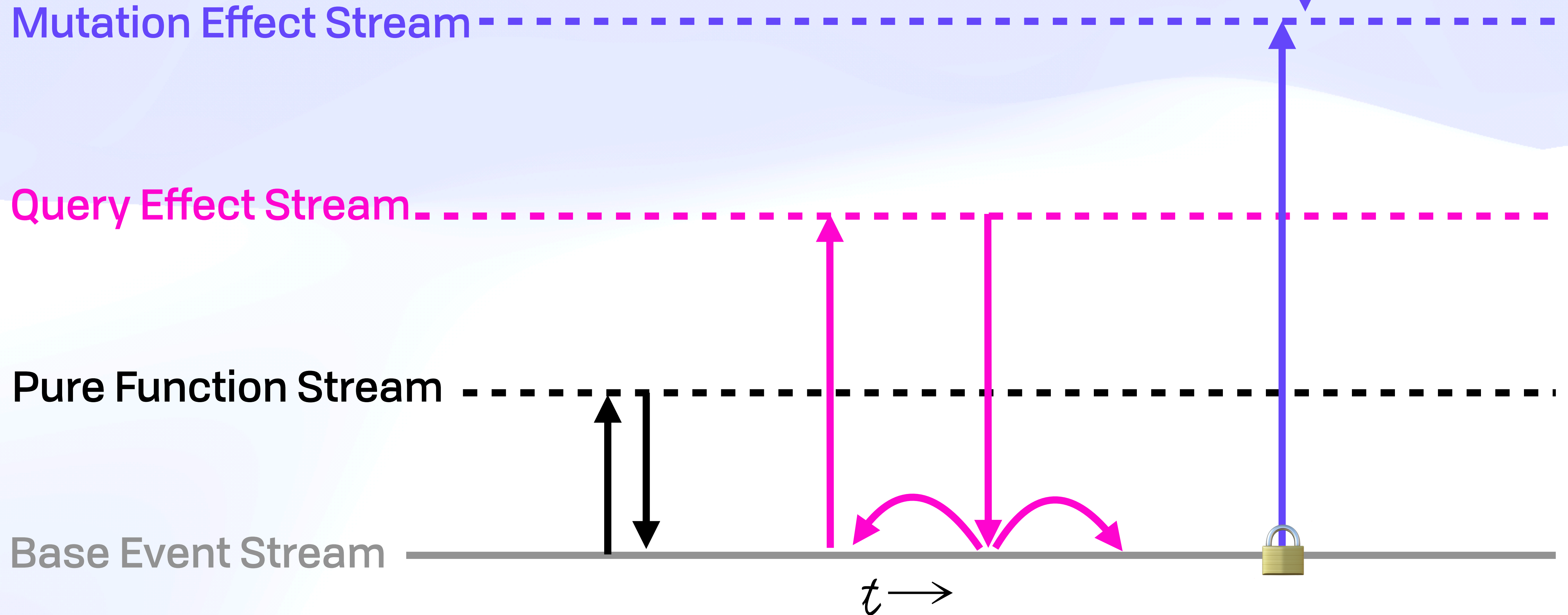
Programming... Local-First

Command! Query? Compute.



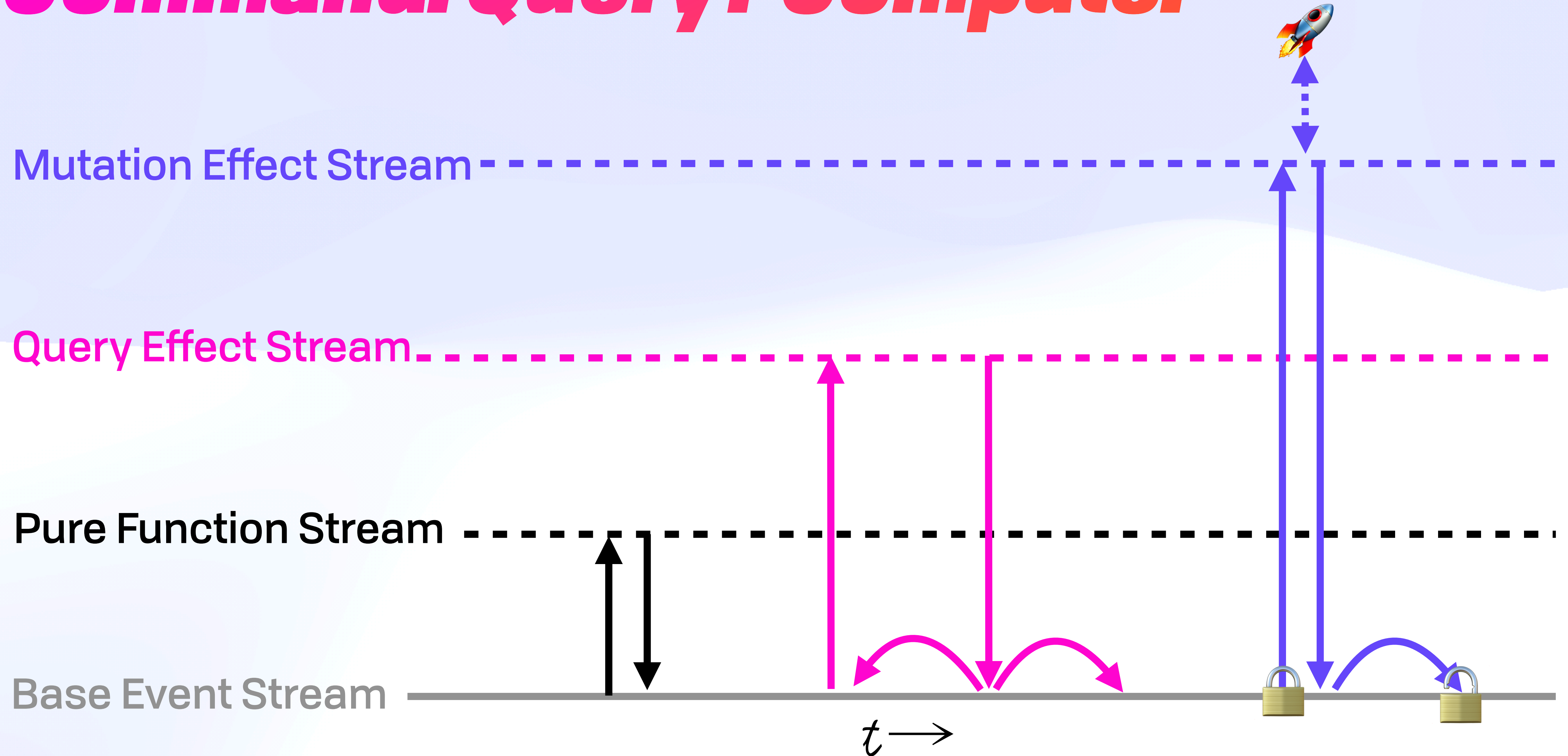
Programming... Local-First

Command! Query? Compute.



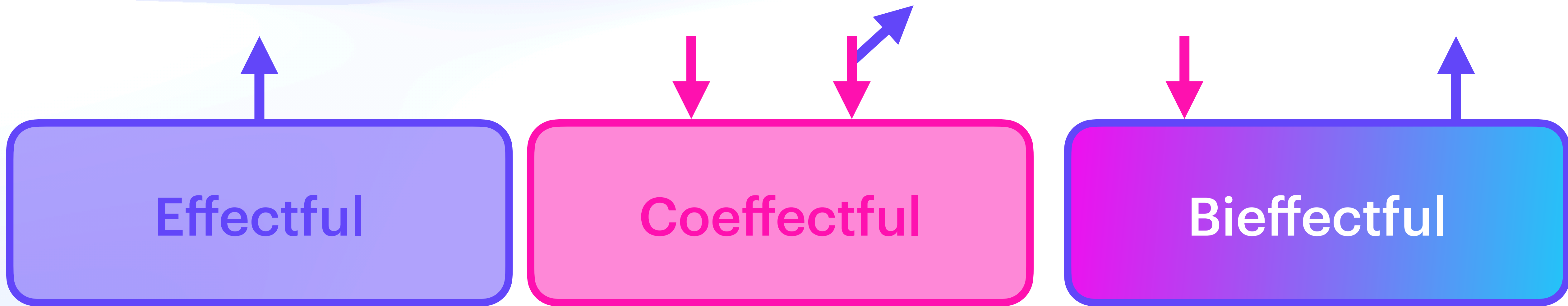
Programming... Local-First

Command! Query? Compute.



Programming... Local-First

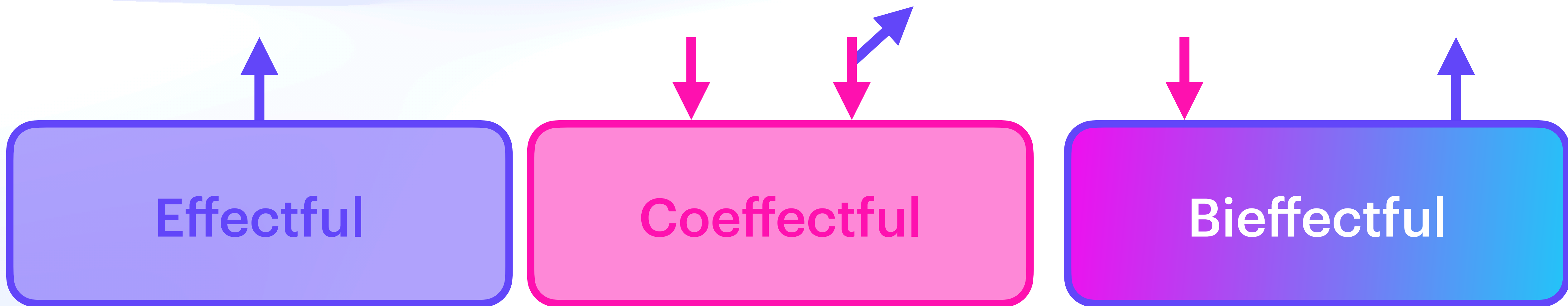
Coeffects 🤝 ***Caps***



Programming... Local-First

Coeffects 🤝 *Caps*

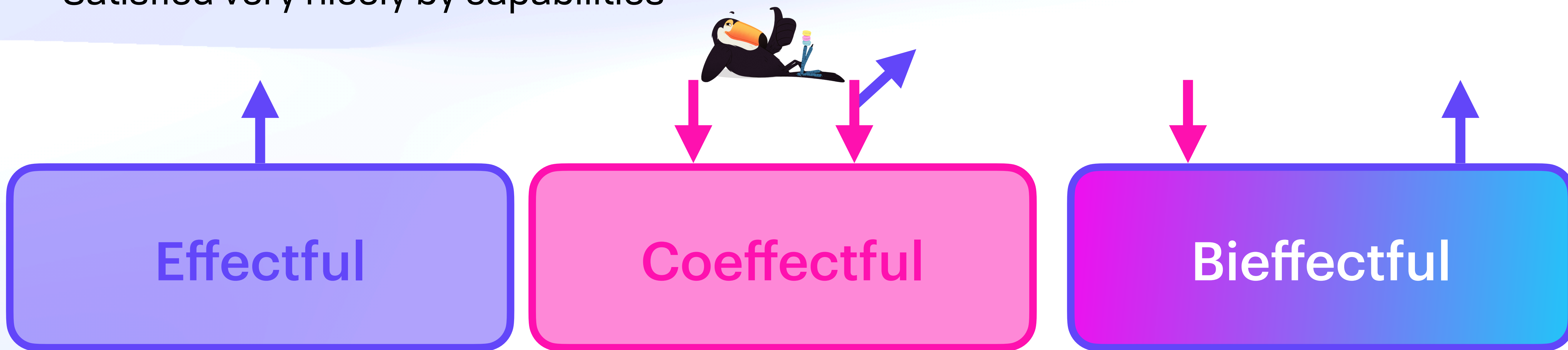
- ◆ Describes what a program requires from its environment
- ◆ Good at tracking resource requirements
- ◆ Satisfied very nicely by capabilities



Programming... Local-First

Coeffects 🤝 *Caps*

- ◆ Describes what a program requires from its environment
- ◆ Good at tracking resource requirements
- ◆ Satisfied very nicely by capabilities



Programming... Local-First

Better Together 🥜🍫

Programming... Local-First

Better Together 🥜🍫

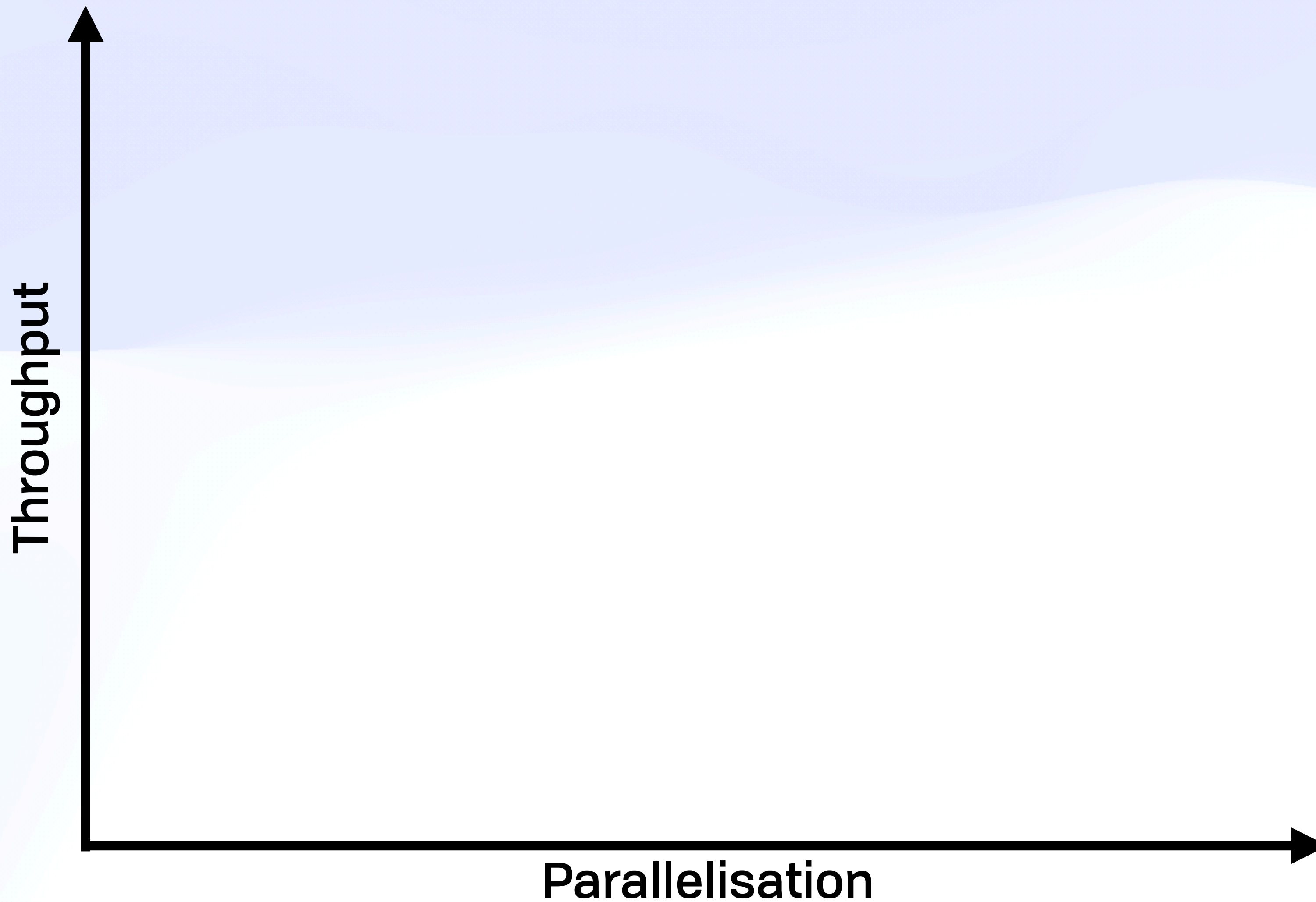
- ◆ Are there ways to lean into the computational advantages of LoFi?
- ◆ Blackboard computing, memoization, propagator state
- ◆ Collaborative indexing
- ◆ Autocodecs, lenses

Programming... Local-First

Better Together 🥜🍫

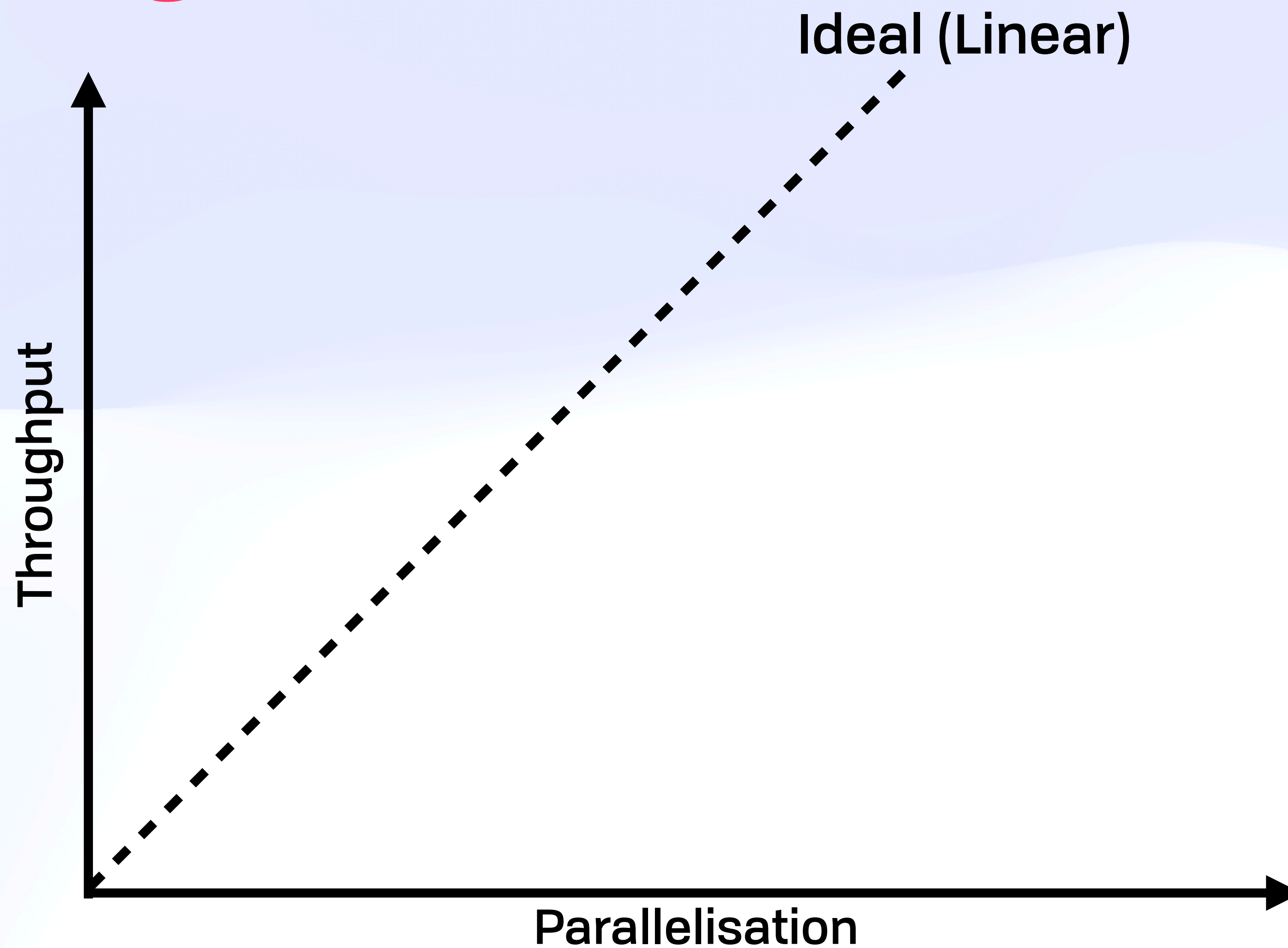
Programming... Local-First

Better Together 🥜🍫



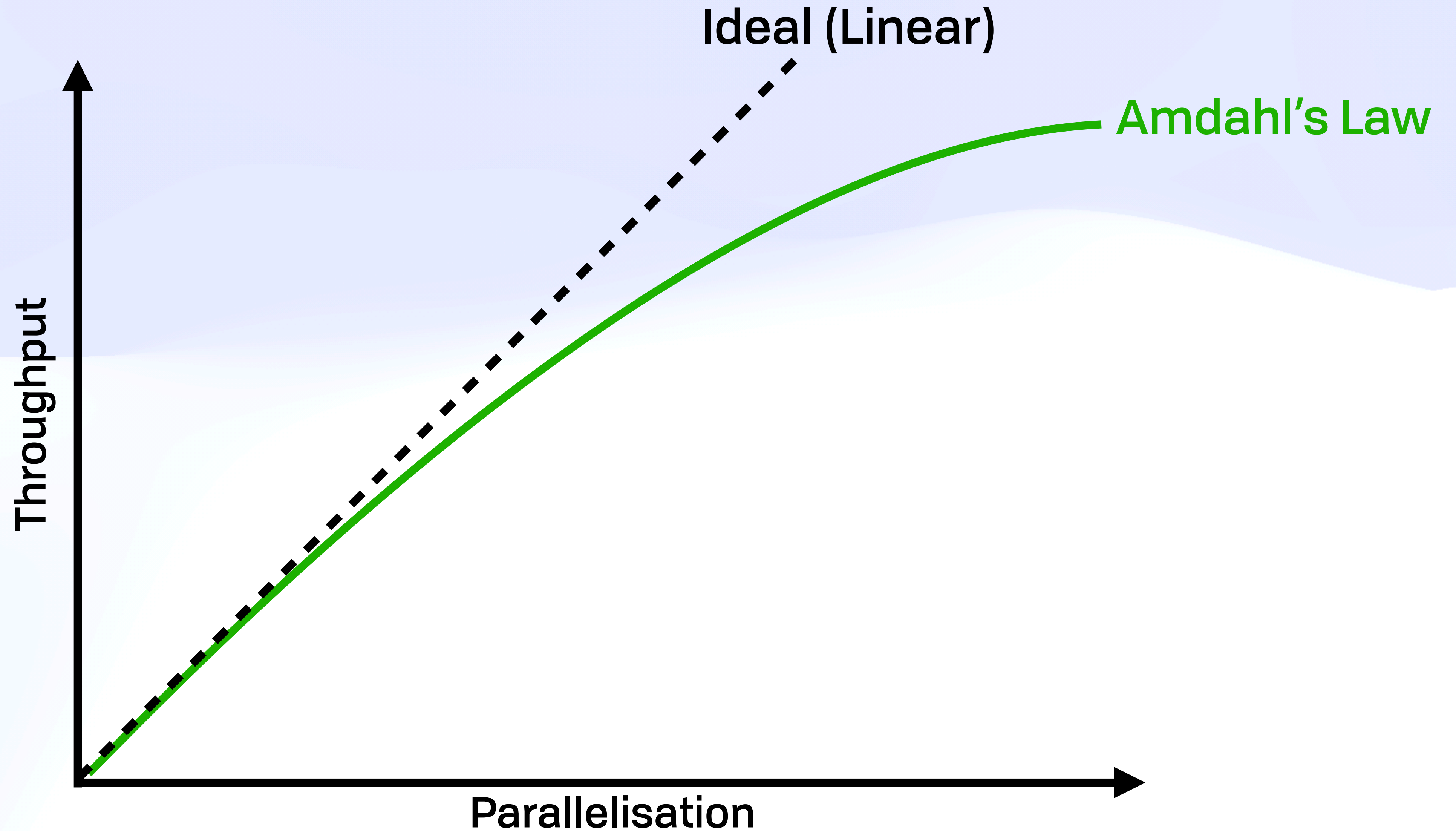
Programming... Local-First

Better Together 🥜🍫



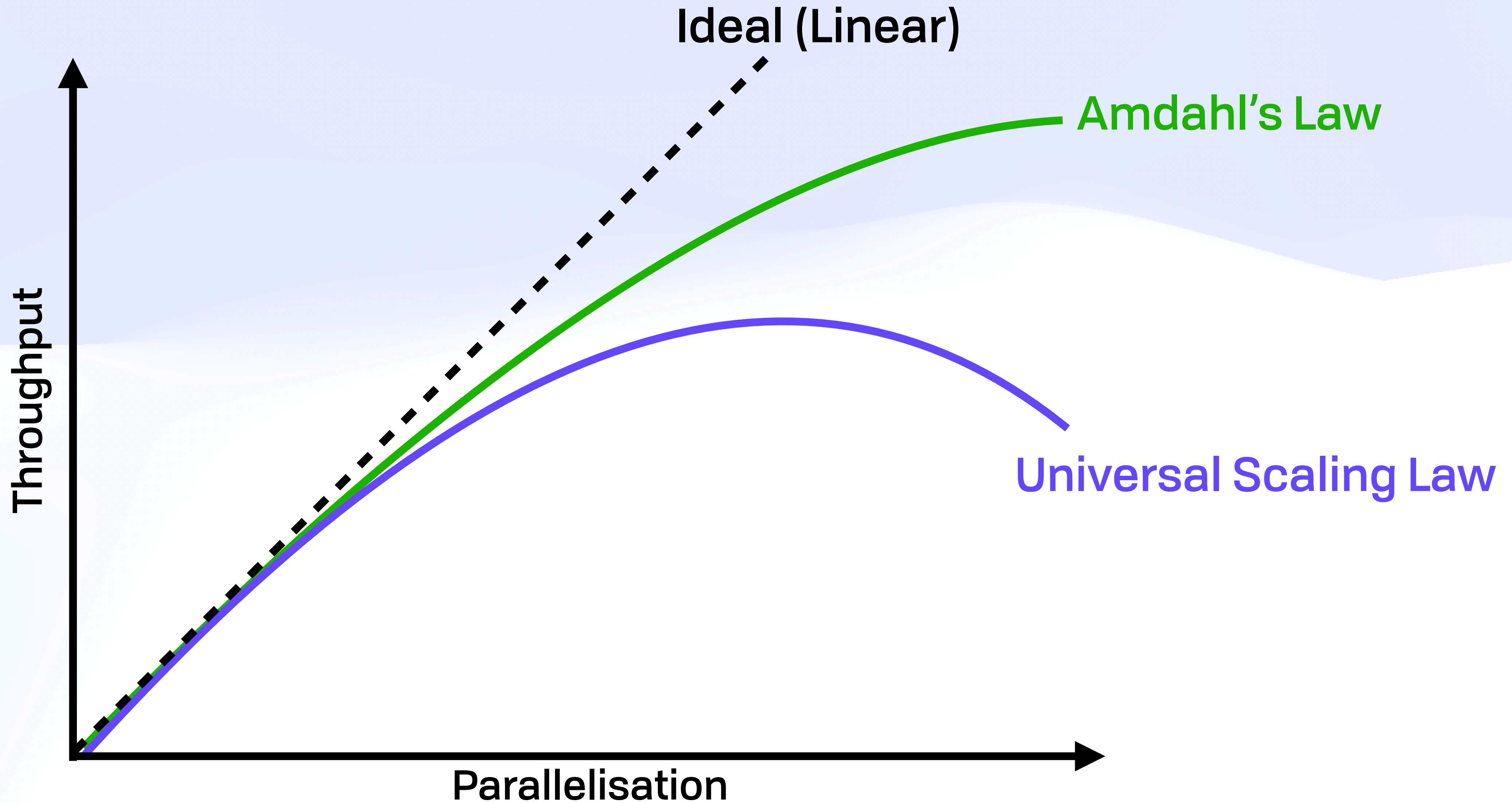
Programming... Local-First

Better Together 🥜🍫



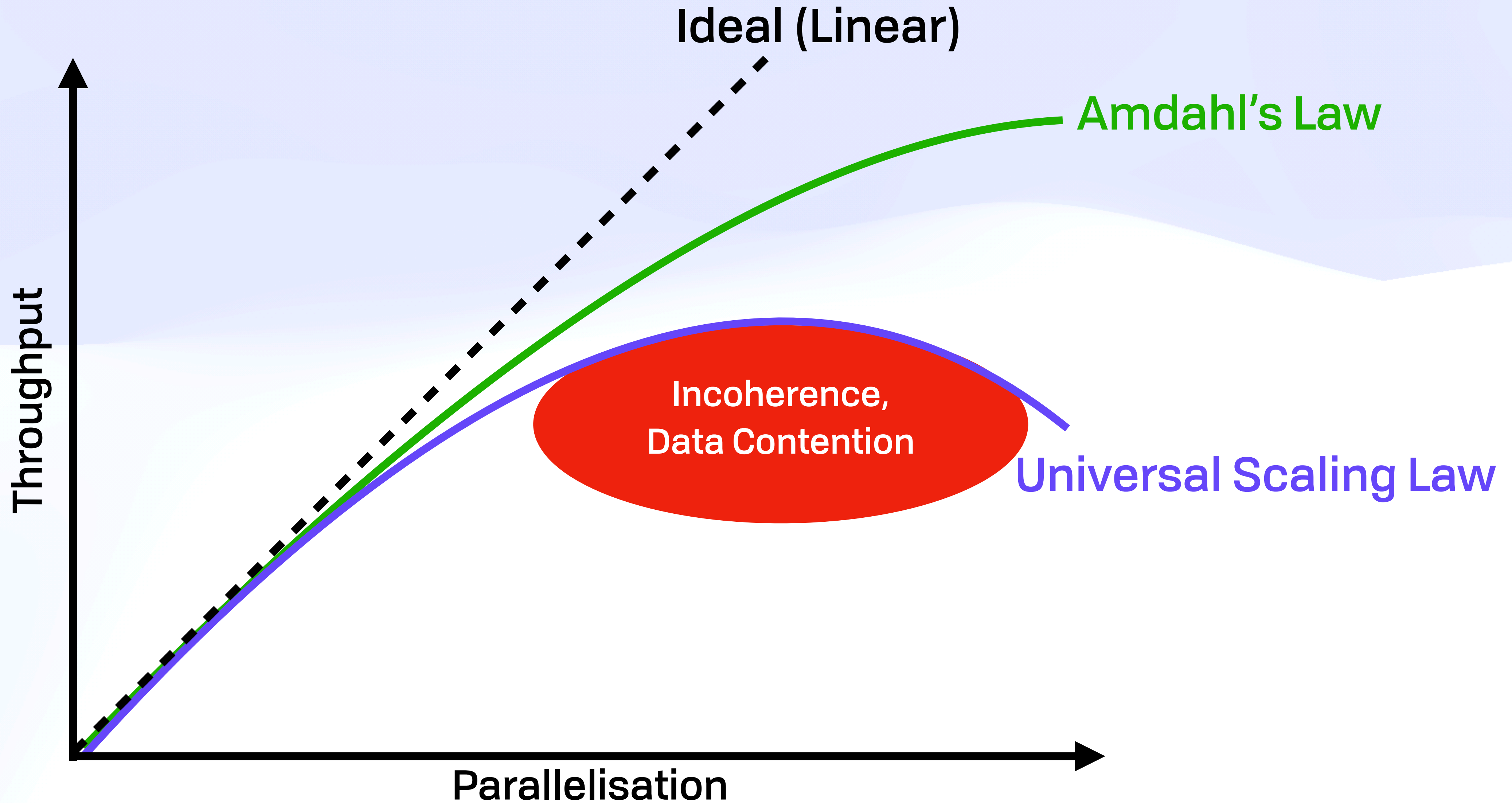
Programming... Local-First

Better Together 🥜🍫



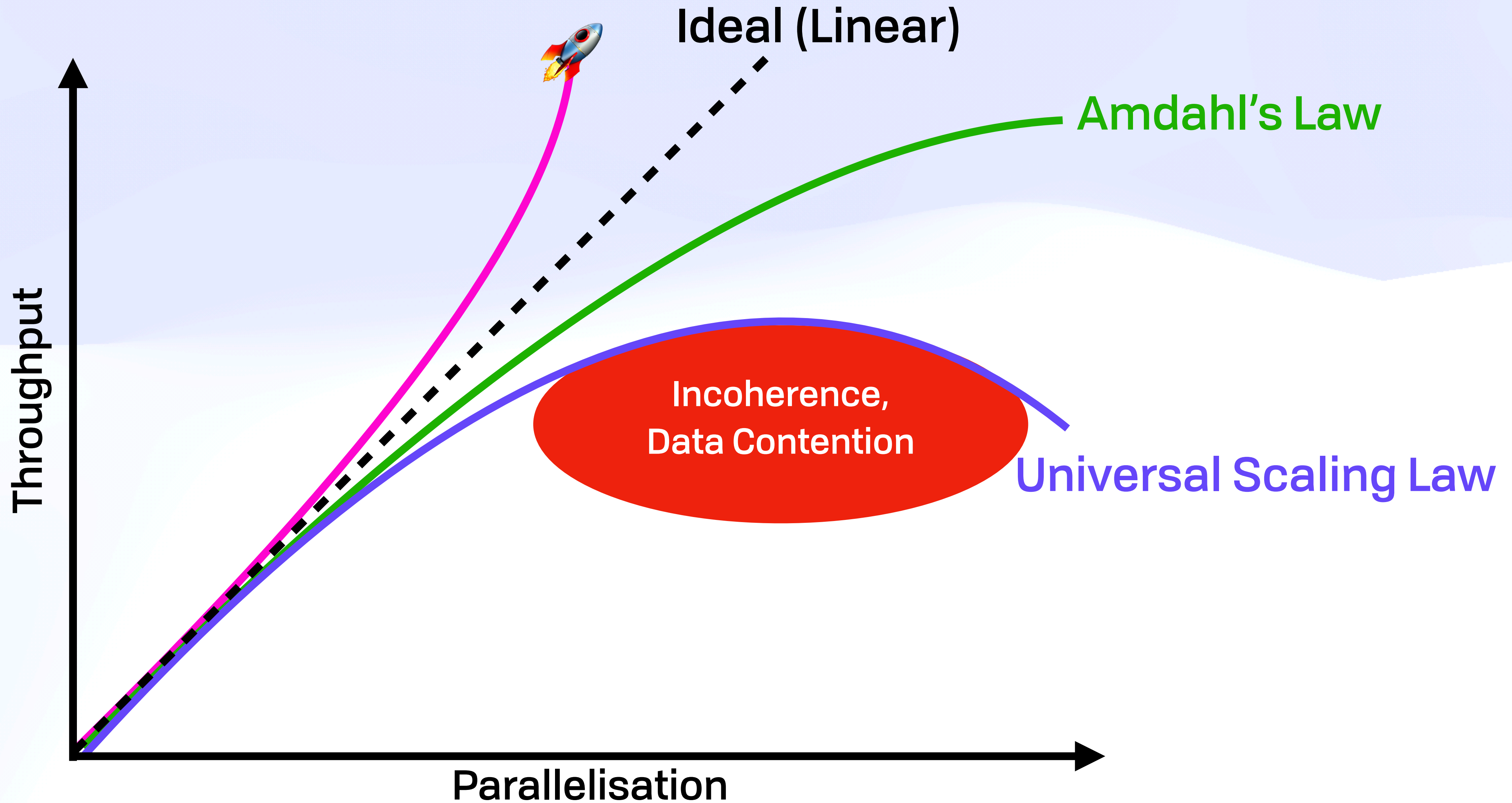
Programming... Local-First

Better Together 🥜🍫



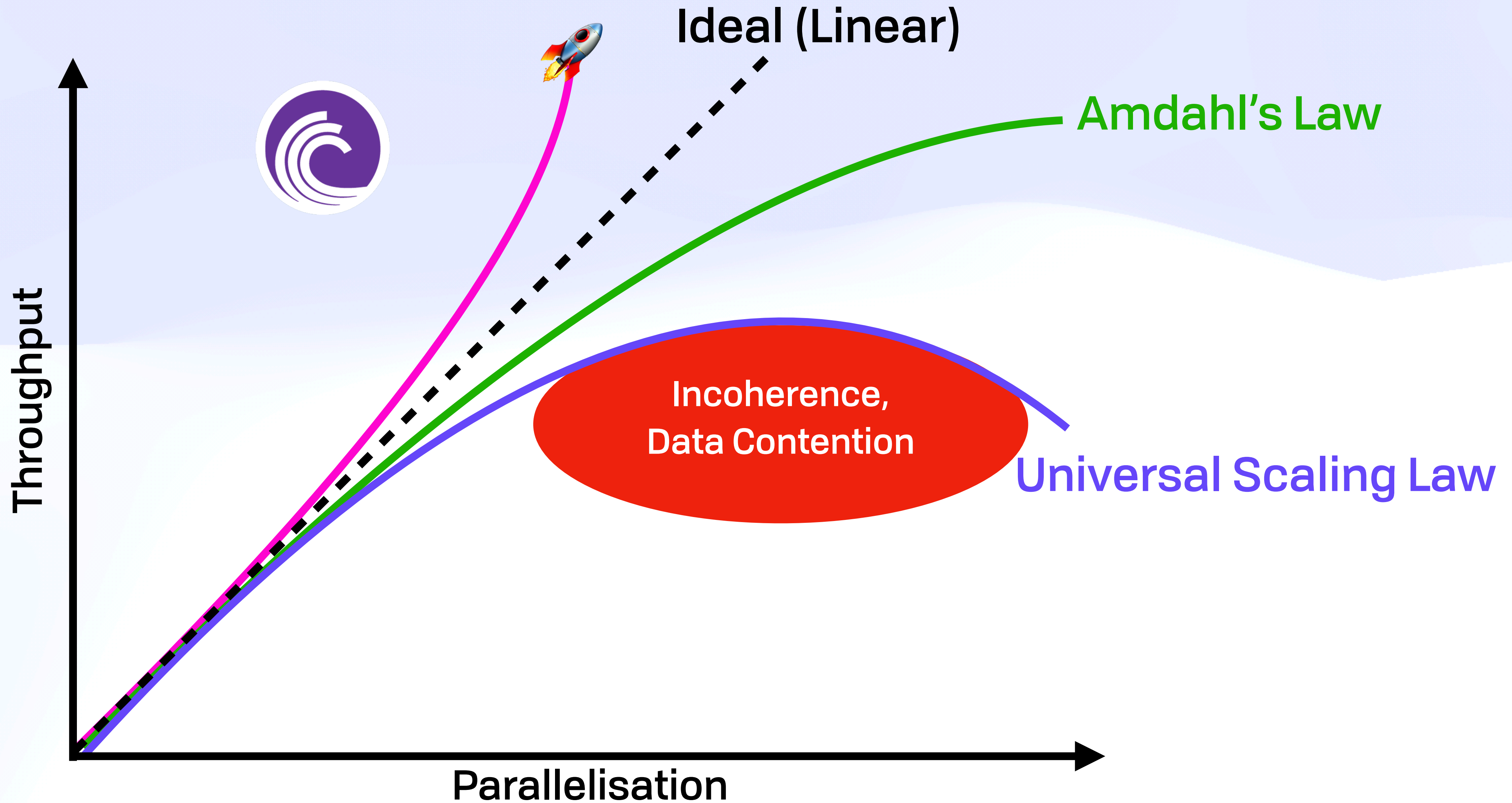
Programming... Local-First

Better Together 🥜🍫



Programming... Local-First

Better Together 🥜🍫



Programming... Local-First

Better Together 🥜🍫

Programming... Local-First

Better Together 🥜🍫

A programming language

influences the way that its users think

about programming; matching a language to a

methodology ***increases the likelihood that***

the methodology will be used

– Barbara Liskov et al, Abstraction Mechanisms in CLU

For Fun & Profit 🤑

Sustainable growth while avoiding capture

For Fun & Profit

The Path of LocalHub

For Fun & Profit

The Path of LocalHub



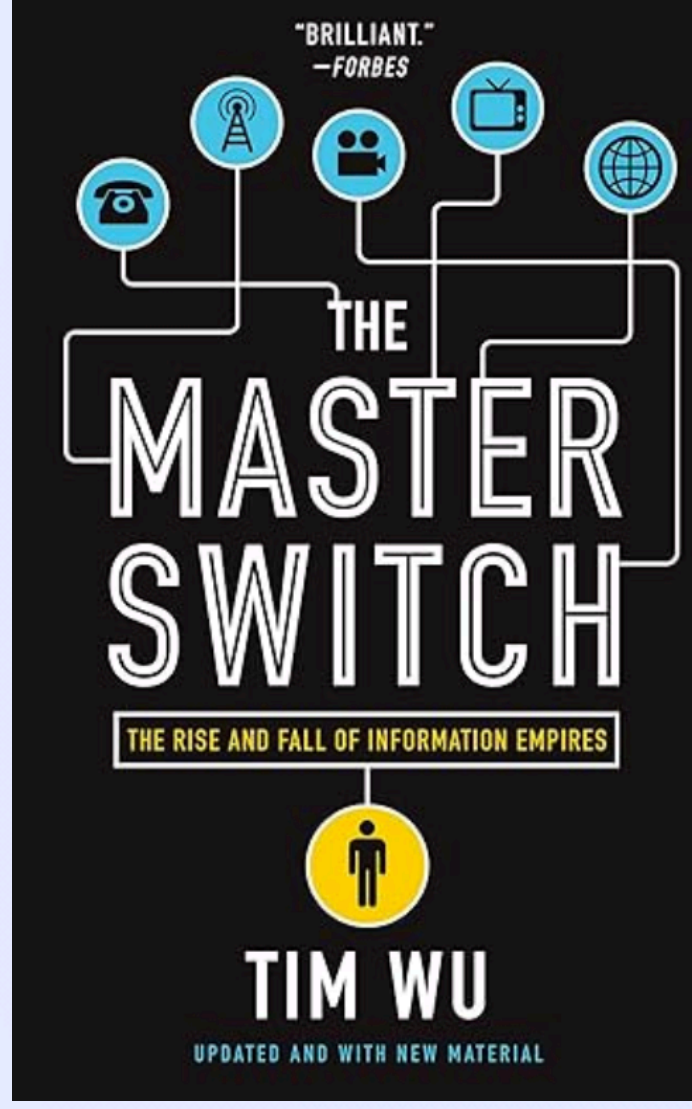
For Fun & Profit

The Path of LocalHub



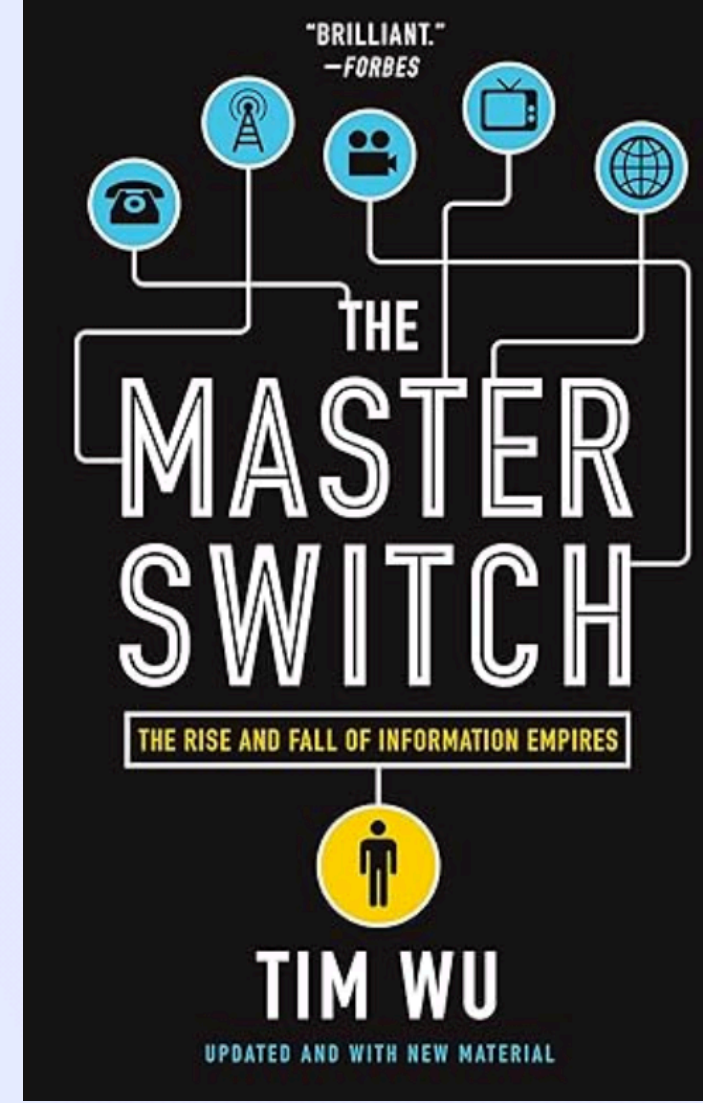
For Fun & Profit

The Path of LocalHub



For Fun & Profit

The Path of LocalHub



"Do it yourself, use store bought when you get busy"

For Fun & Profit

Not Losing Your Soul 

Sustainable & values aligned?

For Fun & Profit

Not Losing Your Soul 🧛‍♂️

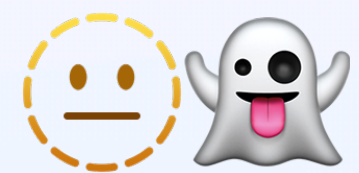
Sustainable & values aligned?

For Fun & Profit

Not Losing Your Soul 🧛



Sustainable & values aligned?



Invention

Custom

Off-the-Shelf

Utility

For Fun & Profit

Not Losing Your Soul 🧛‍♂️



Sustainable & values aligned?

Invention

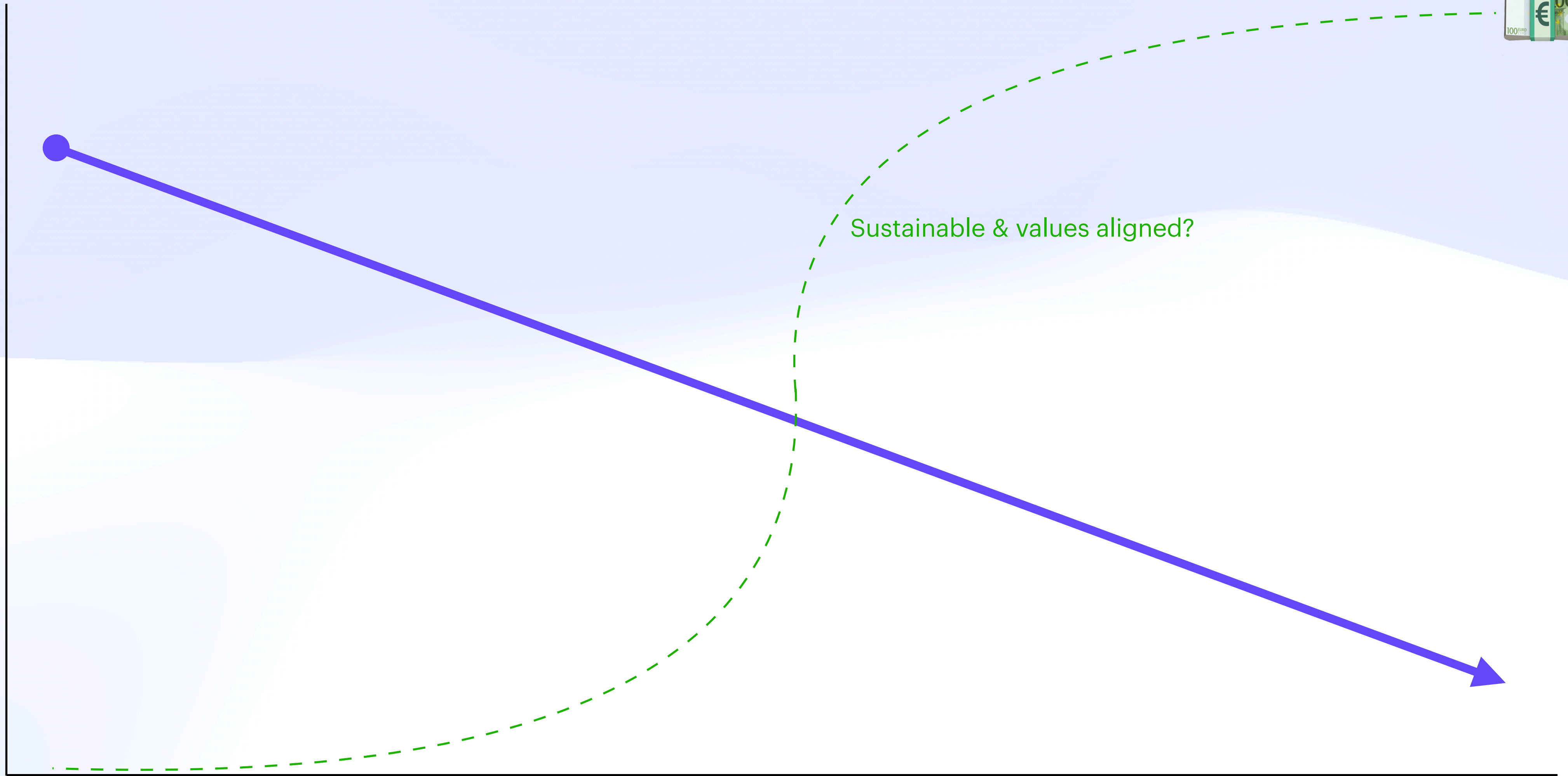
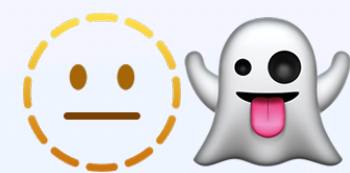
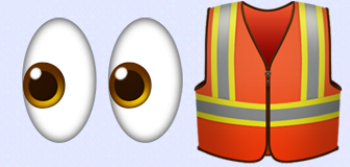
Custom

Off-the-Shelf

Utility

For Fun & Profit

Not Losing Your Soul 🧛‍♂️



Invention

Custom

Off-the-Shelf

Utility

For Fun & Profit

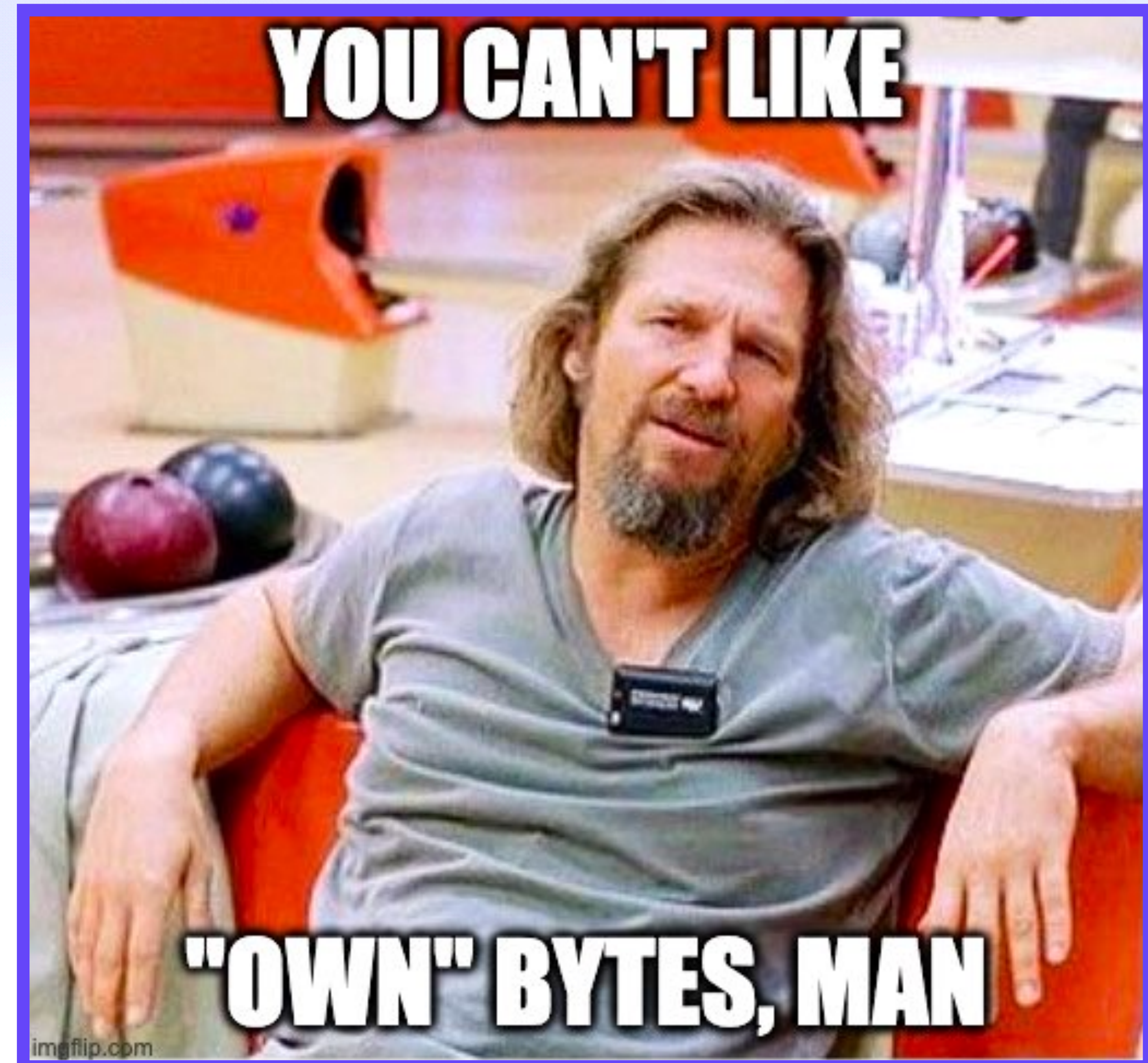
Eat Your Veggies 🥦



For Fun & Profit

User Agency for Great Good

- Empower users to participate (entry)
- Leave without loss (exit)
- Control access to your data (safety)
- Provide capacity to others (serve)



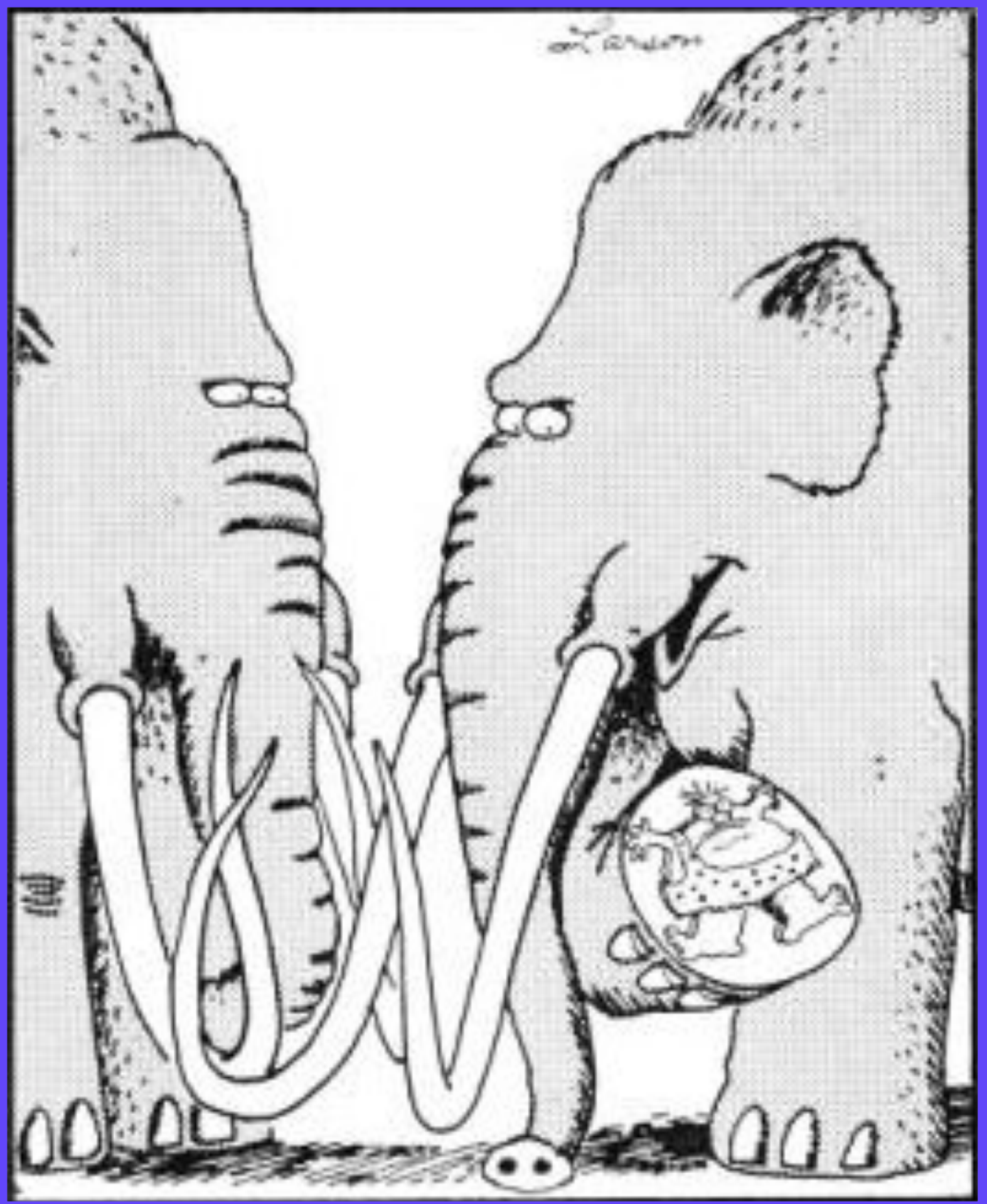
A Roadmap Wrap Up

Threading the Needle 

A Roadmap Wrap Up
Narratives

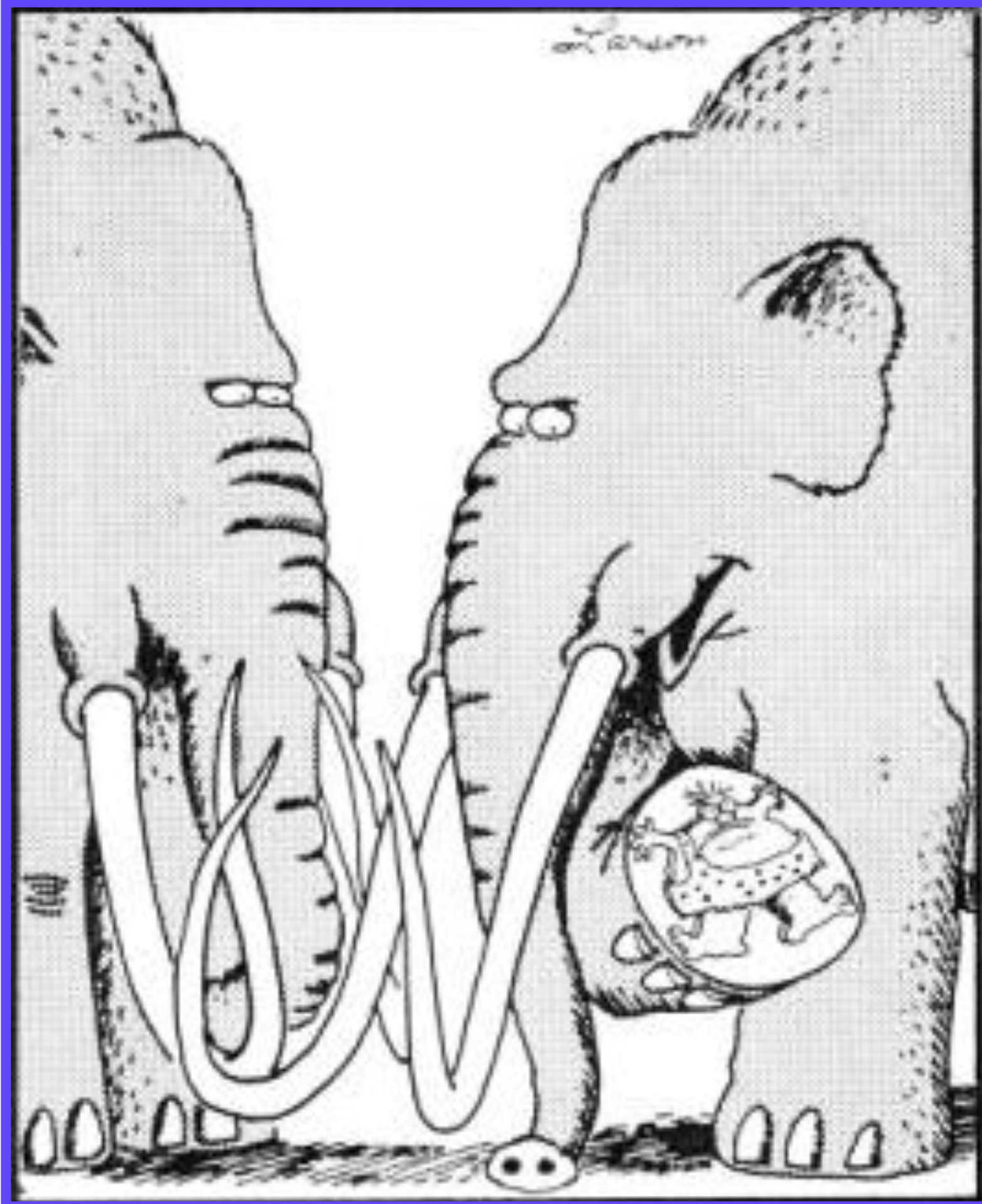
A Roadmap Wrap Up

Narratives



A Roadmap Wrap Up

Narratives



A Roadmap Wrap Up

Amazing Job So Far! 🏒

A Roadmap Wrap Up

Amazing Job So Far! 🏒



A Roadmap Wrap Up

Open Problems for the Next Era

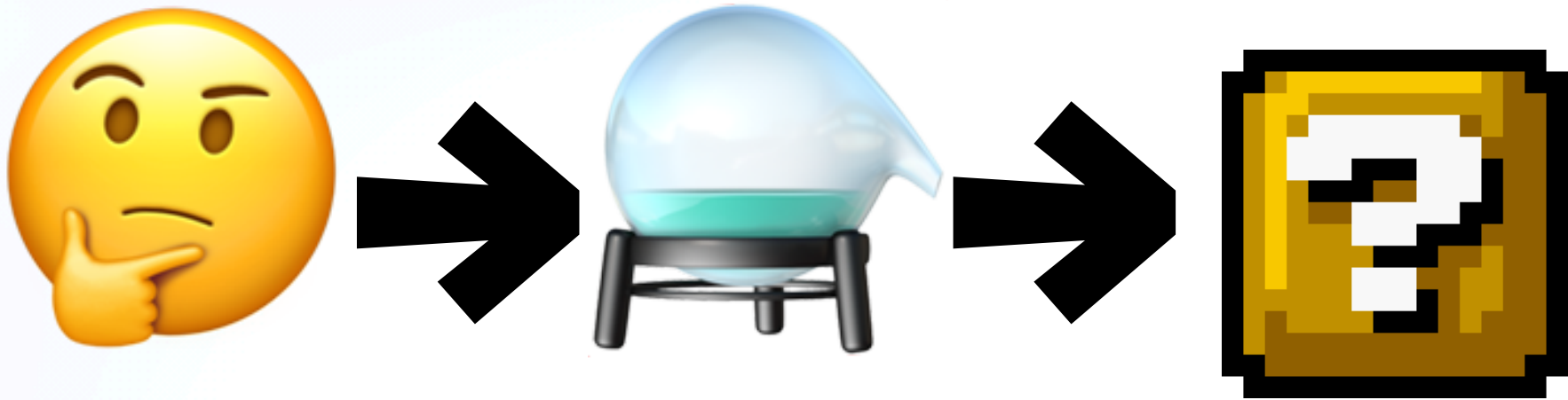
- Identity, trust, encryption
 - Lossless data interop
 - Remote resource access
- Networking: Tech that still works in 40 years?
 - Schemas: How to allow independent evolution?
 - Security & Privacy: Whom to trust?
 - Version Control: How to let users access and manage multiple versions?
 - Indexing & Queries: How to scale local-first to more than what fits in memory?
 - Decentralized Search: How to make non-replicated information accessible to everyone?
 - Portable Compute: How to replicate – distribute – application execution?
 - Code as (CRDT) Data: How to improve the collaborative coding experience?
 - Programming Models: How everything fits together, and the core question of this workshop.
- Extensible CRDT frameworks (flexible CRDTs)
 - Collaborative (verifiable?) computation — esp. computing indexes!
 - Retroactive data structures / reversible compute
 - Business models

A Roadmap Wrap Up

Go Find More Elephants!

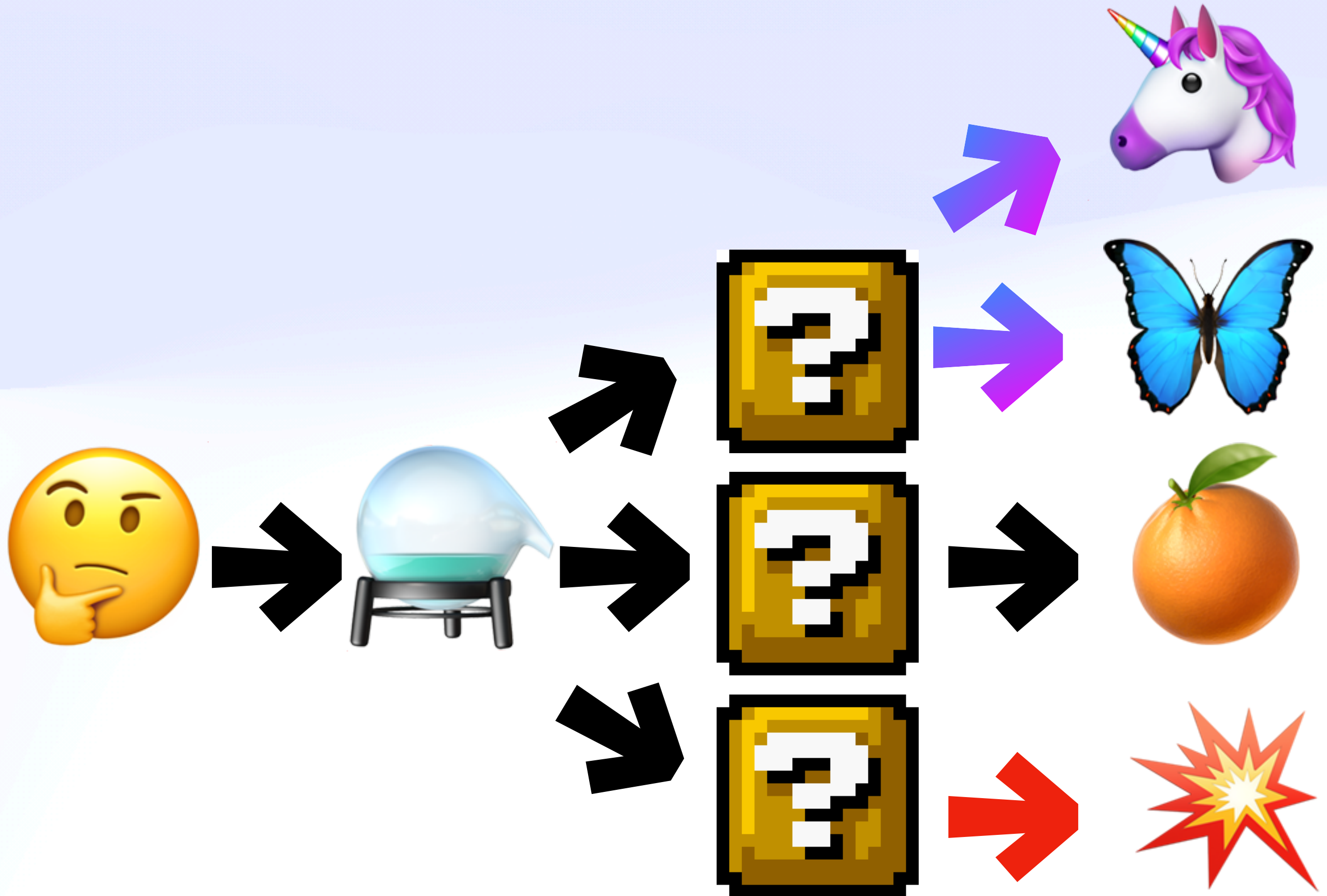
A Roadmap Wrap Up

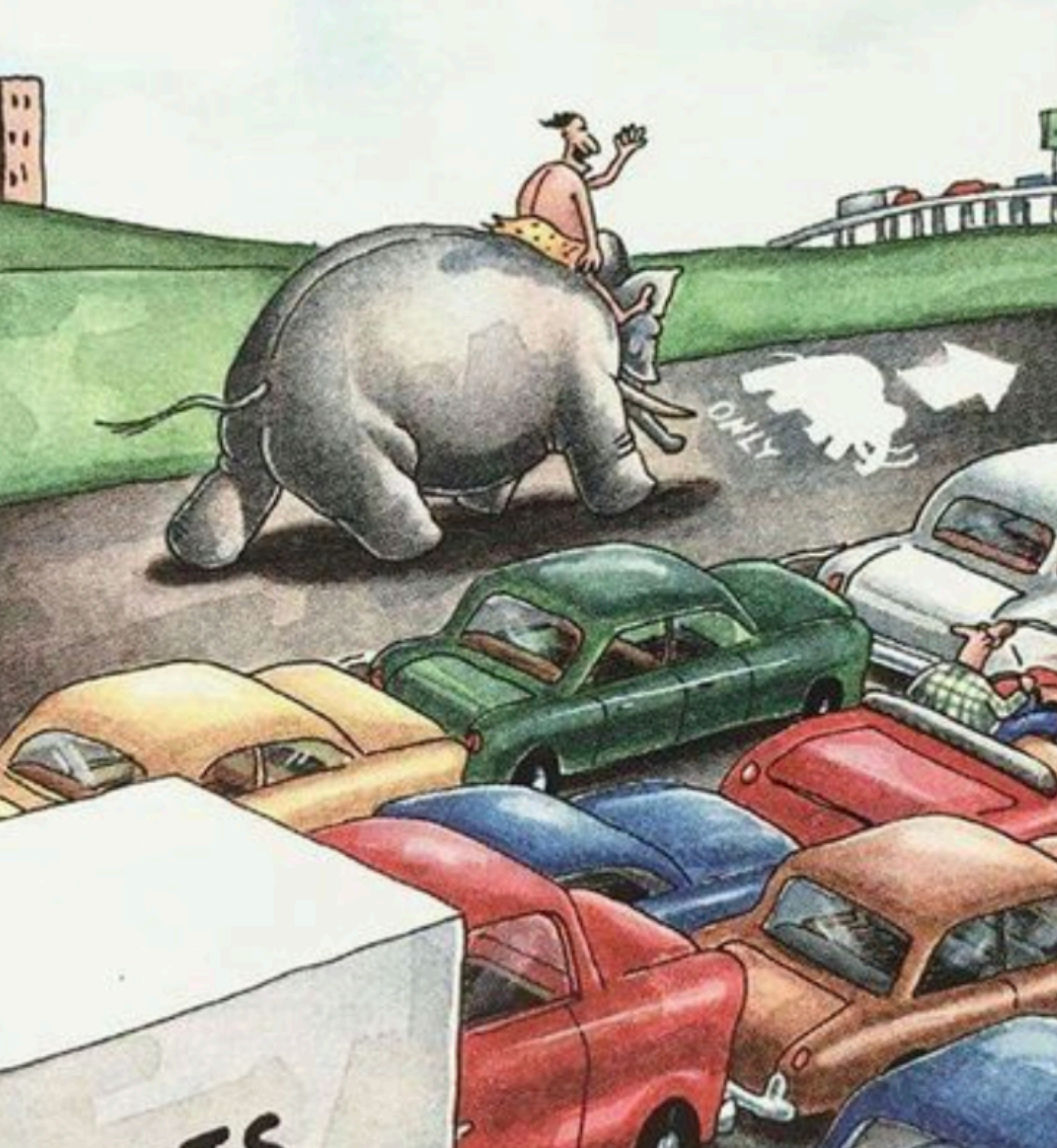
Go Find More Elephants!



A Roadmap Wrap Up

Go Find More Elephants!





Thank You, Cascais!



 <https://fission.codes>

 brooklyn@fission.codes

 [@expede@octodon.social](https://twitter.com/expede)

 bsky.app/profile/expede.wtf