How to Bootstrap a Research Project

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PLMW @ POPL 2019

About myself

MSc Saint Petersburg State University, 2008

PhD KU Leuven, 2008-2012

Currently Associate Professor (tenure-track) at Yale-NUS College & NUS

Previously Lecturer at University College London
Postdoc at IMDEA Software Institute
Software Engineer at JetBrains

Anxiety

Why do a PhD?

Why do a PhD?

Challenge

Not this kind of Challenge…

SECTION A (80 Marks)

[10×3]

Question 1

(i) Find the matrix X for which:

$$\begin{bmatrix} 5 & 4 \\ 1 & 1 \end{bmatrix} X = \begin{bmatrix} 1 & -2 \\ 1 & 3 \end{bmatrix}$$

(ii) Solve for x, if:

$$\tan(\cos^{-1}x) = \frac{2}{\sqrt{5}}$$

(iii) Prove that the line $2x - 3y = 9$ touches the conics $y^2 = -8x$. Also, find the point of contact.

(iv) Using L'Hospital's Rule, evaluate:

$$\lim_{x \to 0} \left(\frac{1}{x^2} - \frac{\cot x}{x}\right)$$

(v) Evaluate: $\int tan^3 x \, dx$

(vi) Using properties of definite integrals, evaluate:

$$\int_0^{\pi/2} \frac{\sin x - \cos x}{1 + \sin x \cos x} \, dx$$

(vii) The two lines of regressions are $x + 2y - 5 = 0$ and $2x + 3y - 8 = 0$ and the variance of x is 12. Find the variance of y and the coefficient of correlation.

(viii) Express $\frac{2+i}{(1+i)(1-2i)}$ in the form of $a + ib$. Find its modulus and argument.

More like this kind of Challenge

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Millennium Problems

Yang–Mills and Mass Gap

Experiment and computer simulations suggest the existence of a "mass gap" in the solution to the quantum versions of the Yang-Mills equations. But no proof of this property is known.

Riemann Hypothesis

The prime number theorem determines the average distribution of the primes. The Riemann hypothesis tells us about the deviation from the average. Formulated in Riemann's 1859 paper, it asserts that all the 'non-obvious' zeros of the zeta function are complex numbers with real part 1/2.

P vs NP Problem

If it is easy to check that a solution to a problem is correct, is it also easy to solve the problem? This is the essence of the P vs NP question. Typical of the NP problems is that of the Hamiltonian Path Problem: given N cities to visit, how can one do this without visiting a city twice? If you give me a solution, I can easily check that it is correct. But I cannot so easily find a solution.

Navier–Stokes Equation

This is the equation which governs the flow of fluids such as water and air. However, there is no proof for the most basic questions one can ask: do solutions exist, and are they unique? Why ask for a proof? Because a proof gives not only certitude, but also understanding.

Hodge Conjecture

The answer to this conjecture determines how much of the topology of the solution set of a system of algebraic equations can be defined in terms of further algebraic equations. The Hodge conjecture is known in certain special cases, e.g., when the solution set has dimension less than four. But in dimension four it is unknown.

http://www.claymath.org/millennium-problems

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Challenge

Accepted to POPL

paper.pdf

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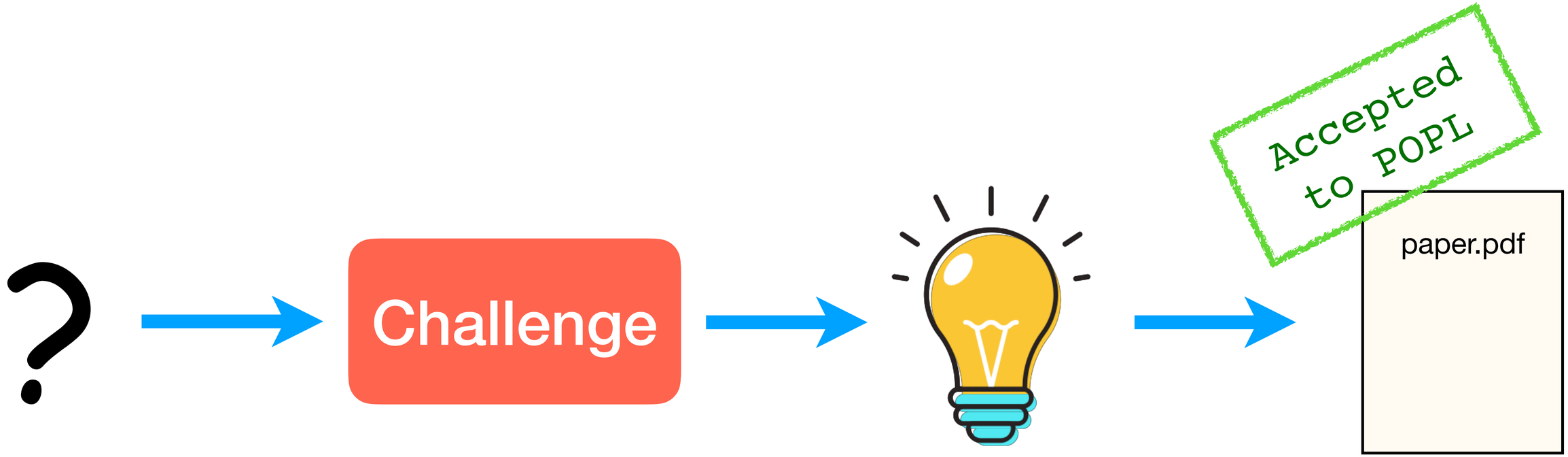
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Challenge
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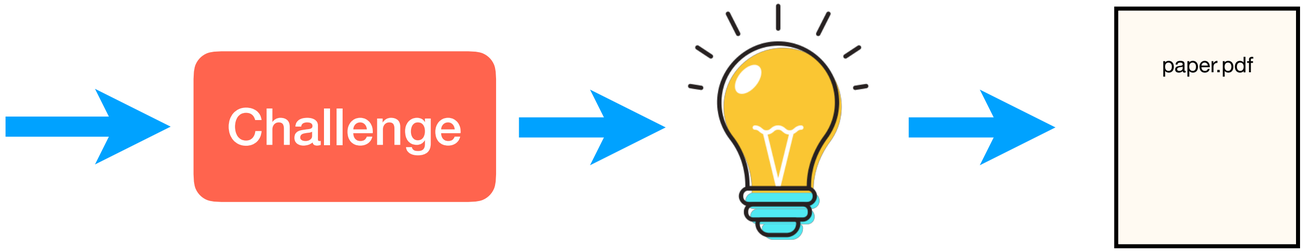
What is “?”



When did it go wrong?

- Need to find your own project
- Lost interest in a given project
- Got scooped
- Writer’s Block

Research Limbo

- Is what I’m about to do relevant?
- What if it won’t work?
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Limbo game art copyright: Playdead ApS

You know what to do

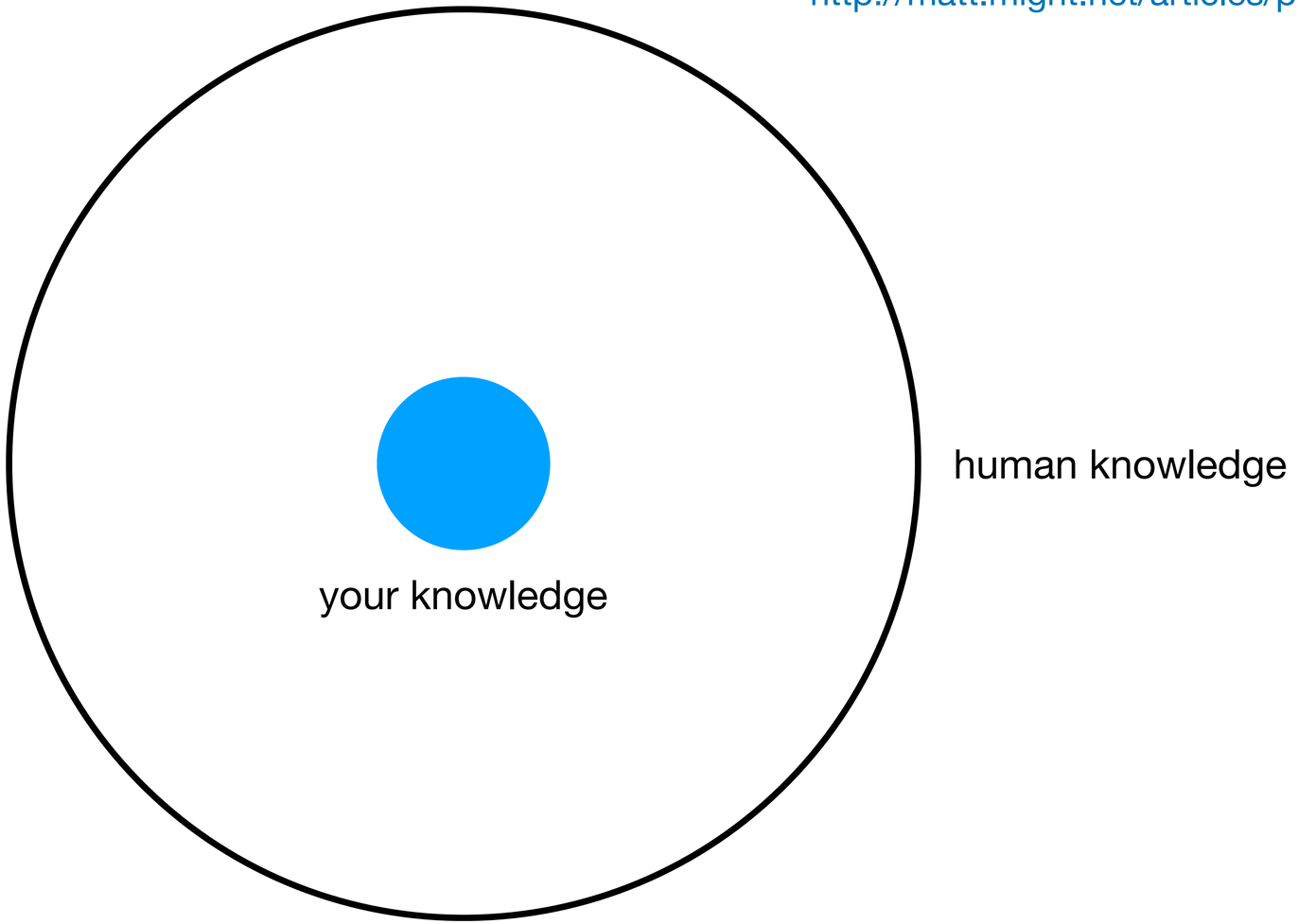
Blame Others

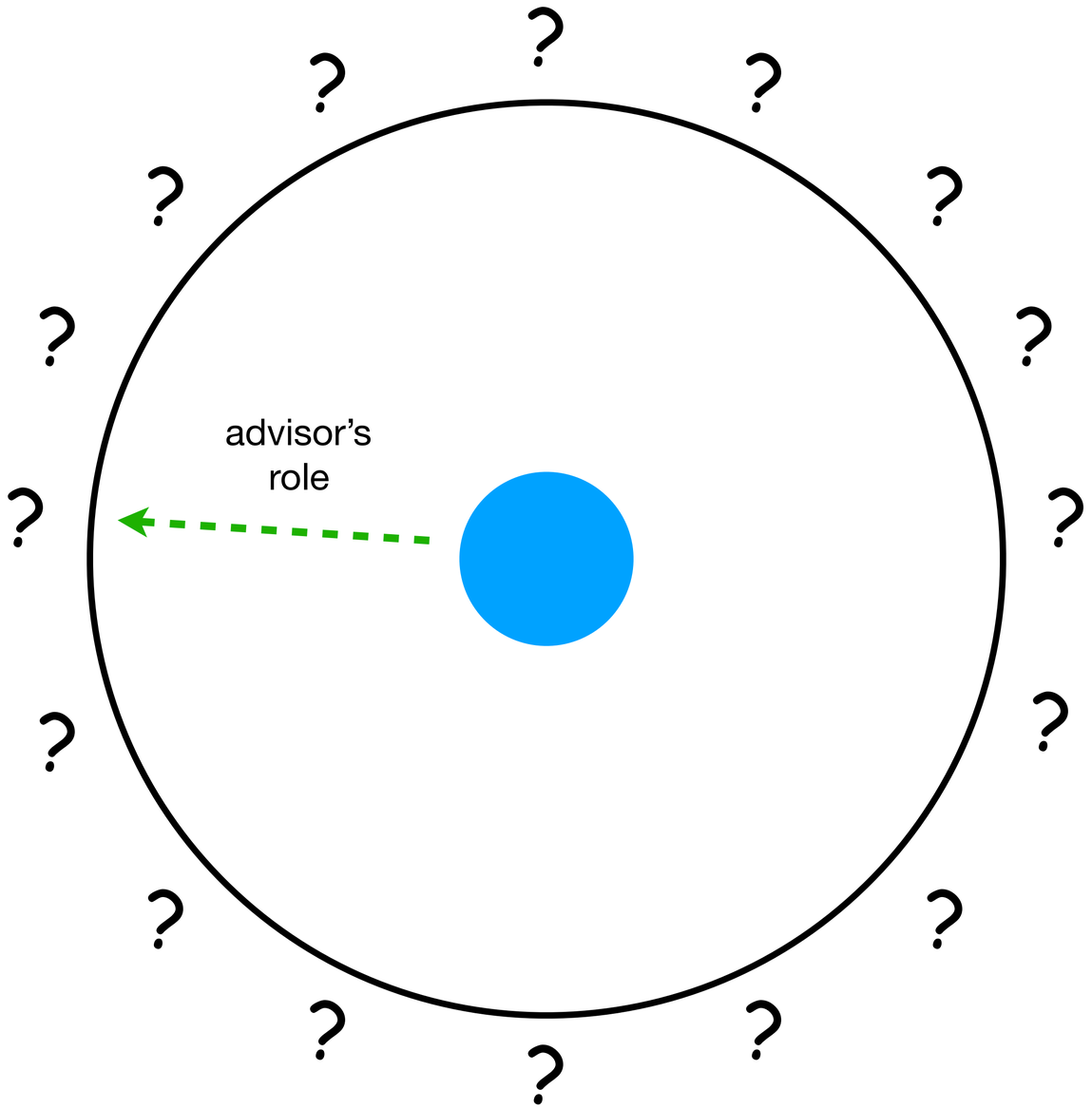
- your advisor
- your research environment
- your officemates
- your parents
- the pizza delivery guys

Escaping Research Limbo

Big Picture

Matt Might. *The illustrated guide to a Ph.D.*
http://matt.might.net/articles/phd-school-in-pictures/

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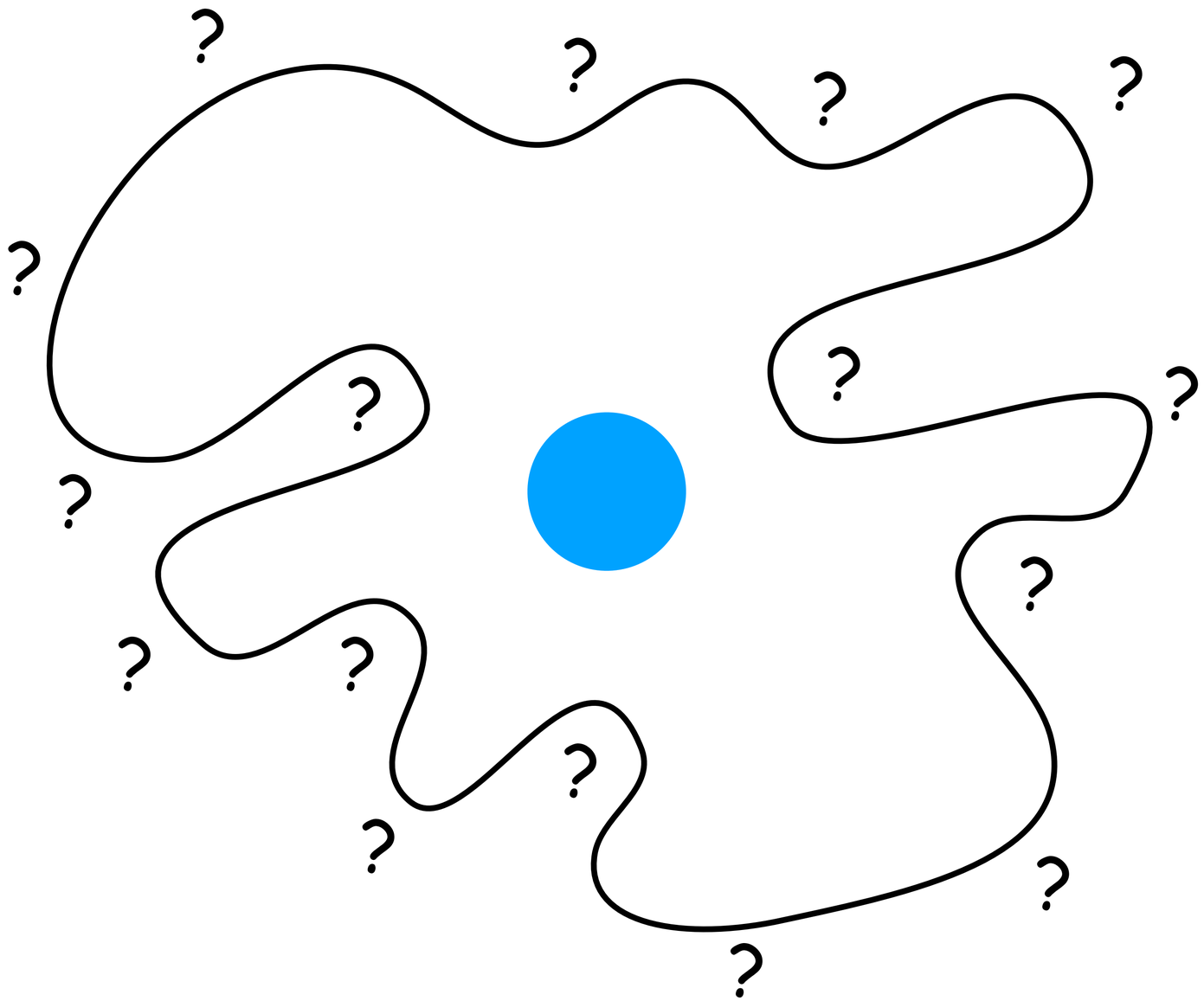
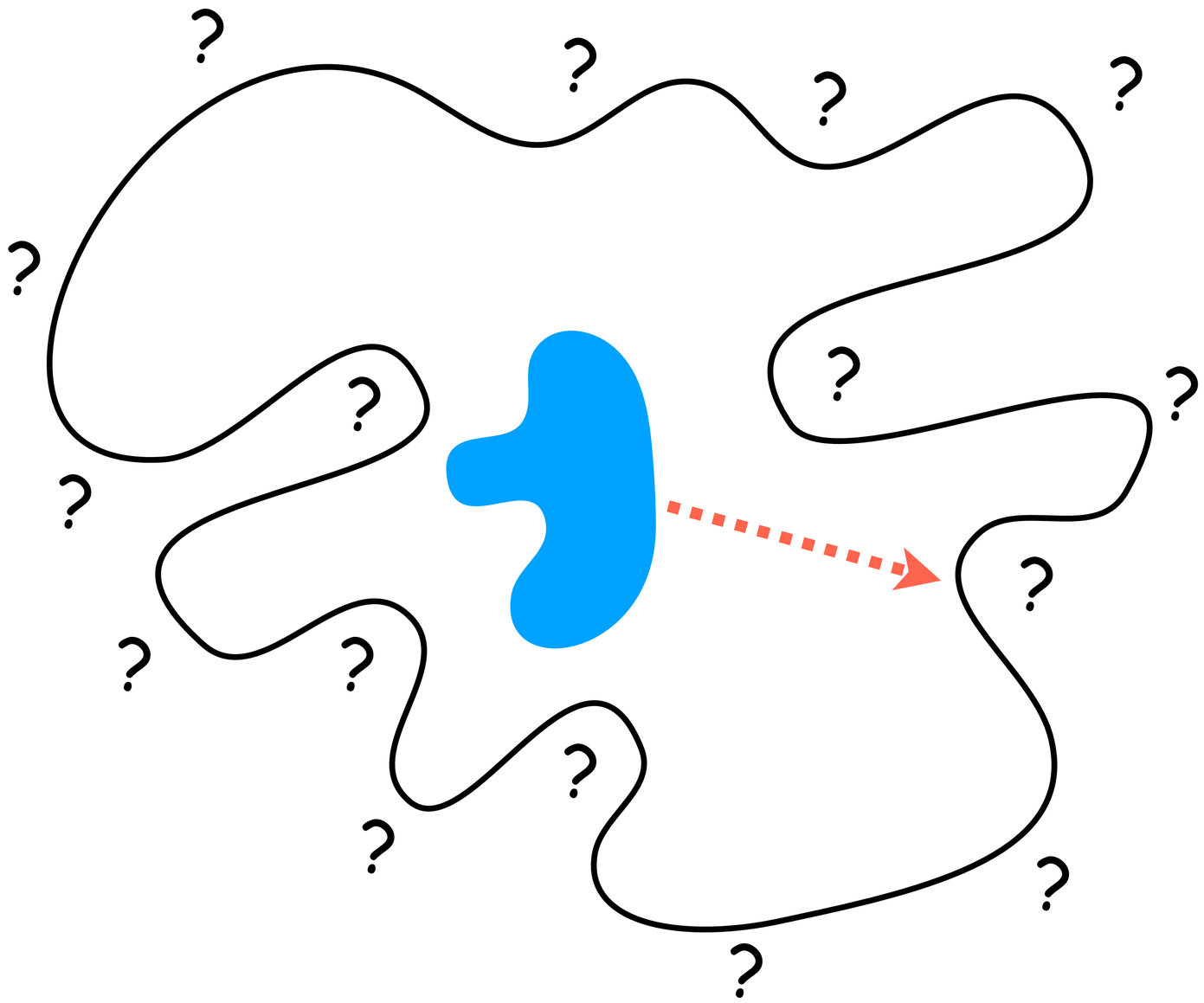
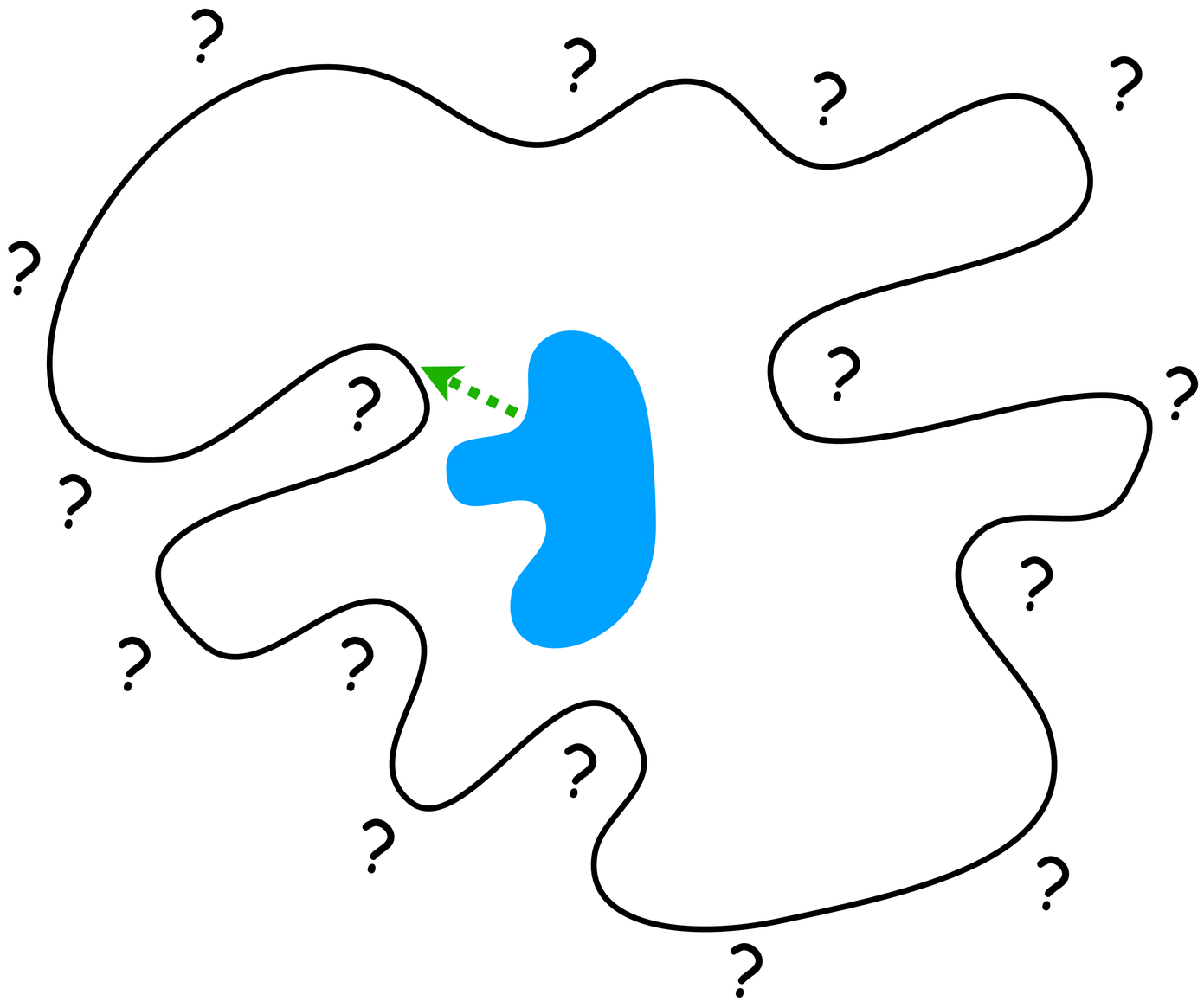
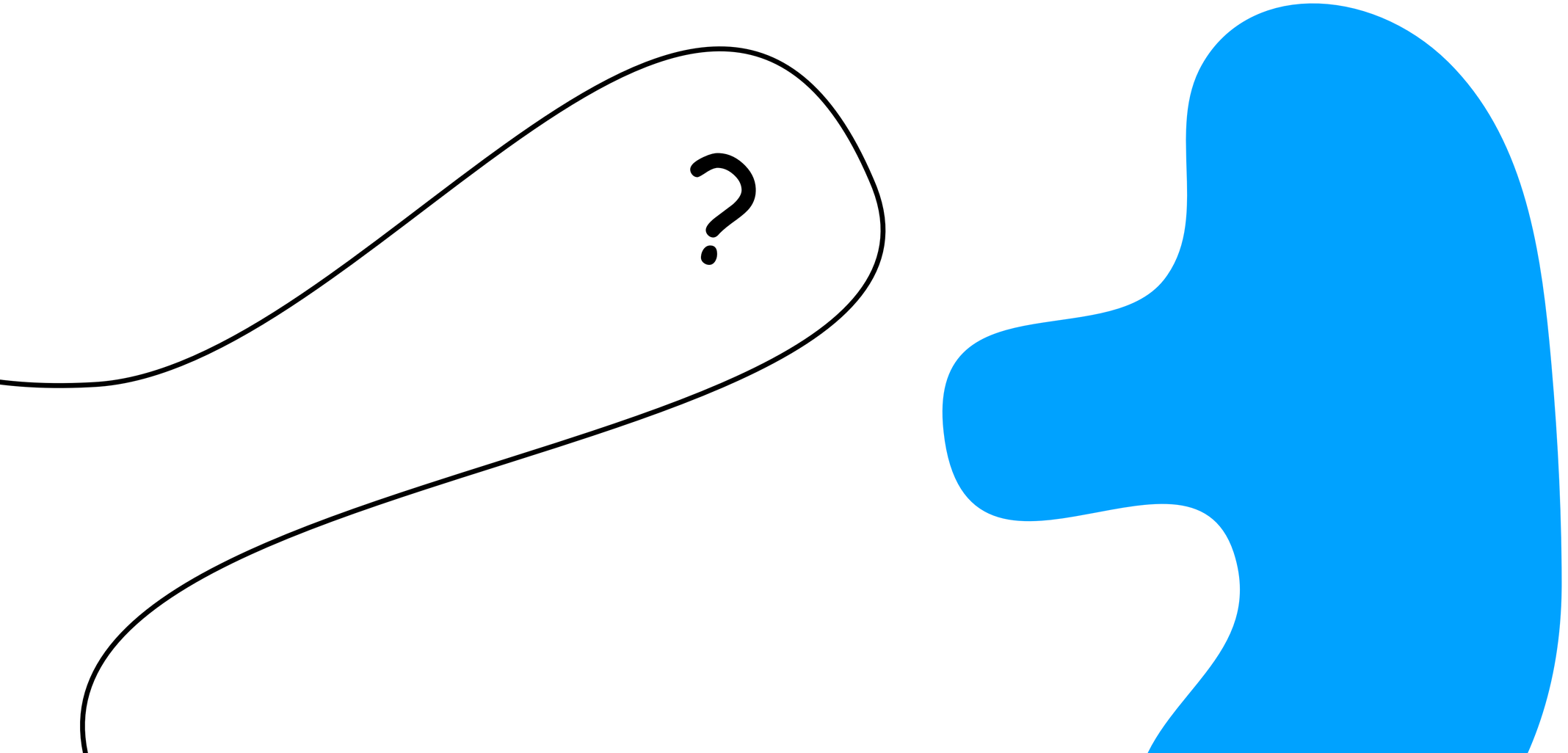
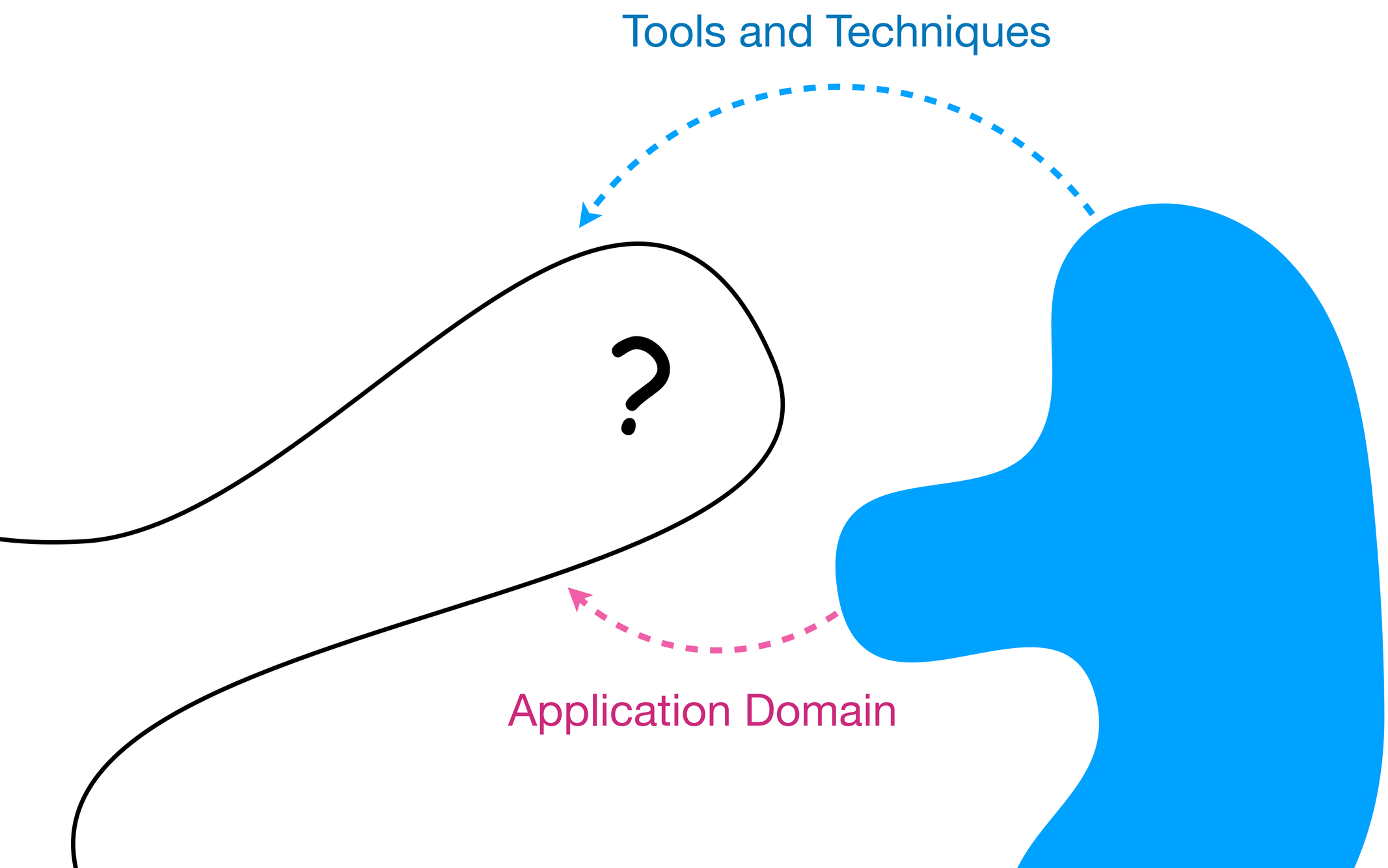
advisor's
role










Tools and Techniques
?
Application Domain

Tools and Techniques

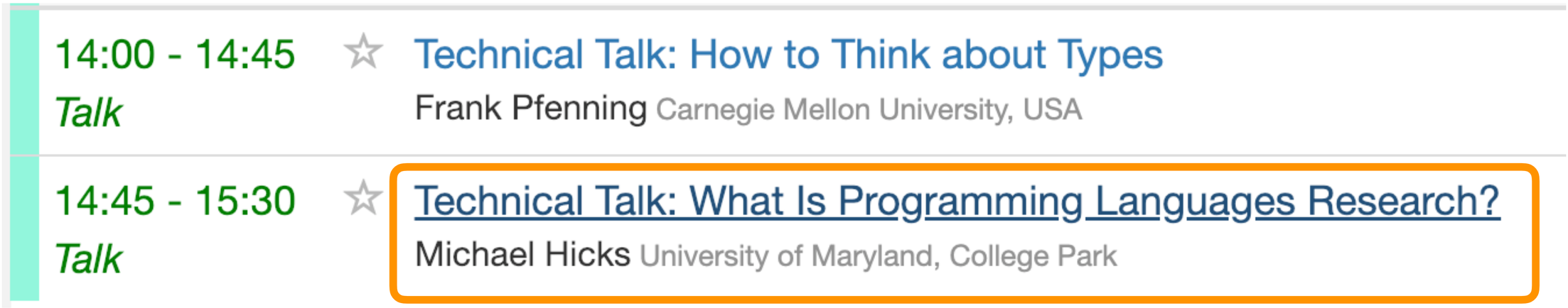
- Type Theory
- Semantics
- Abstract Interpretation
- SMT and Model Checking
- Logics and Proof Assistants
- Program Synthesis, *etc*

Application Domain

- Machine Learning
- Security and Privacy
- Quantum Computation
- Processor Architecture
- Resource Consumption
- Web, *etc*

One researcher's Technique
is
another researcher's Domain

One researcher's Technique is another researcher's Domain



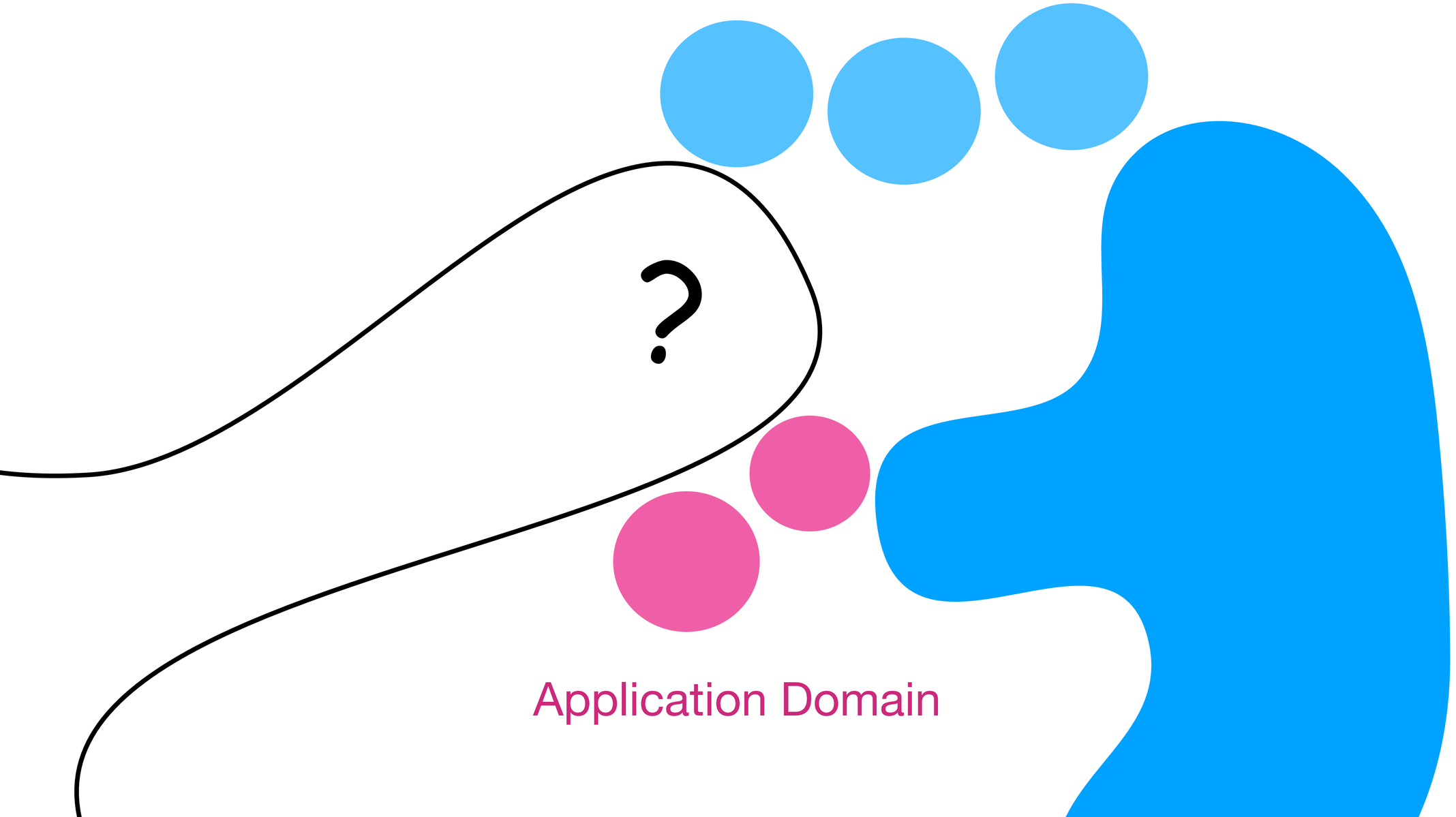
This year at POPL

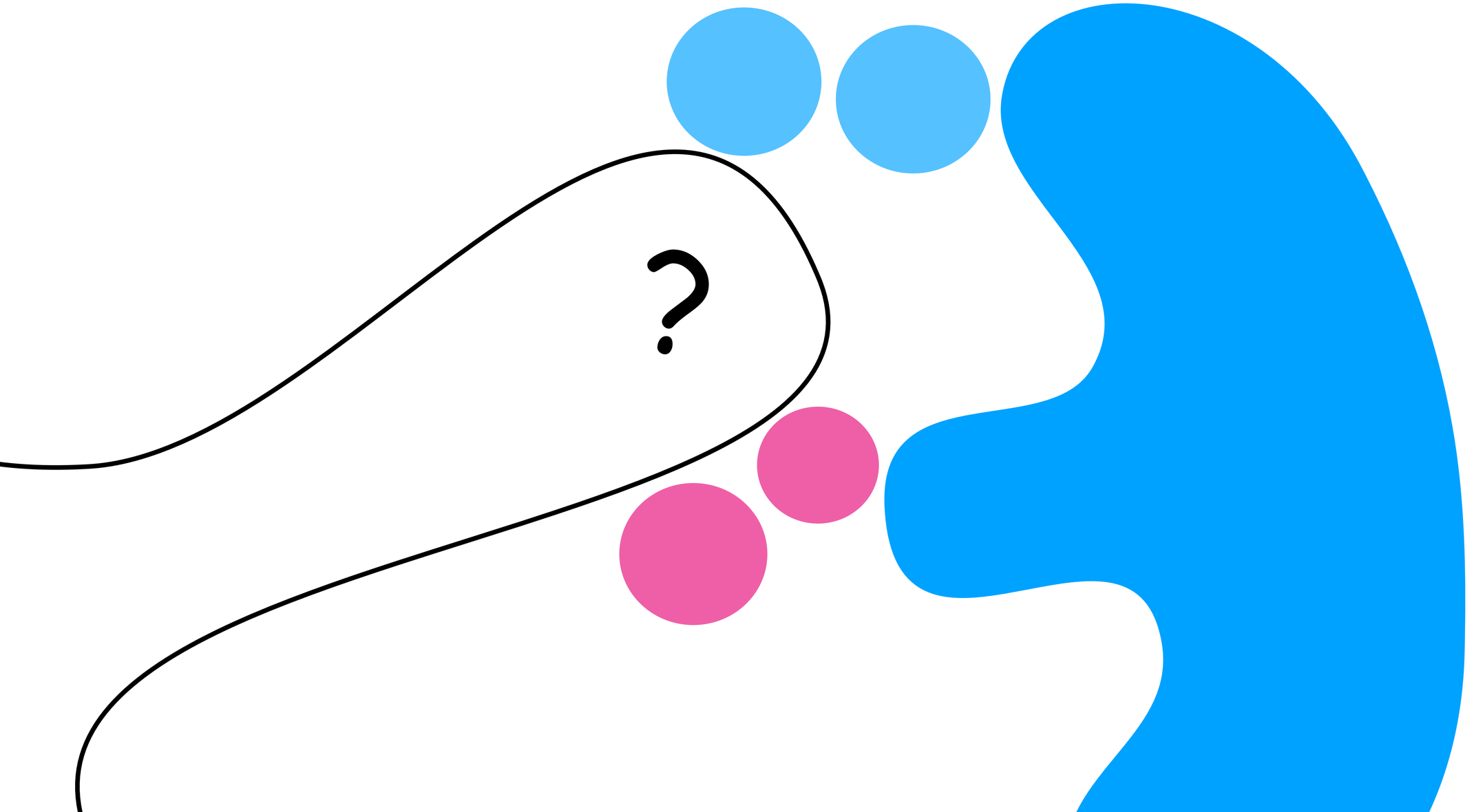
- Pretend Synchrony: Synchronous Verification of Asynchronous Distributed Programs
- A Separation Logic for Concurrent Randomized Programs
- Bayesian Synthesis of Probabilistic Programs for Automatic Data Modeling
- An Abstract Domain for Certifying Neural Networks
- Game Semantics for Quantum Programming
- Type-Driven Gradual Security with References
- ISA Semantics for ARMv8-A, RISC-V, and CHERI-MIPS
- JaVerT 2.0: Compositional Symbolic Execution for JavaScript
- LWeb: Information Flow Security for Multi-Tier Web Applications

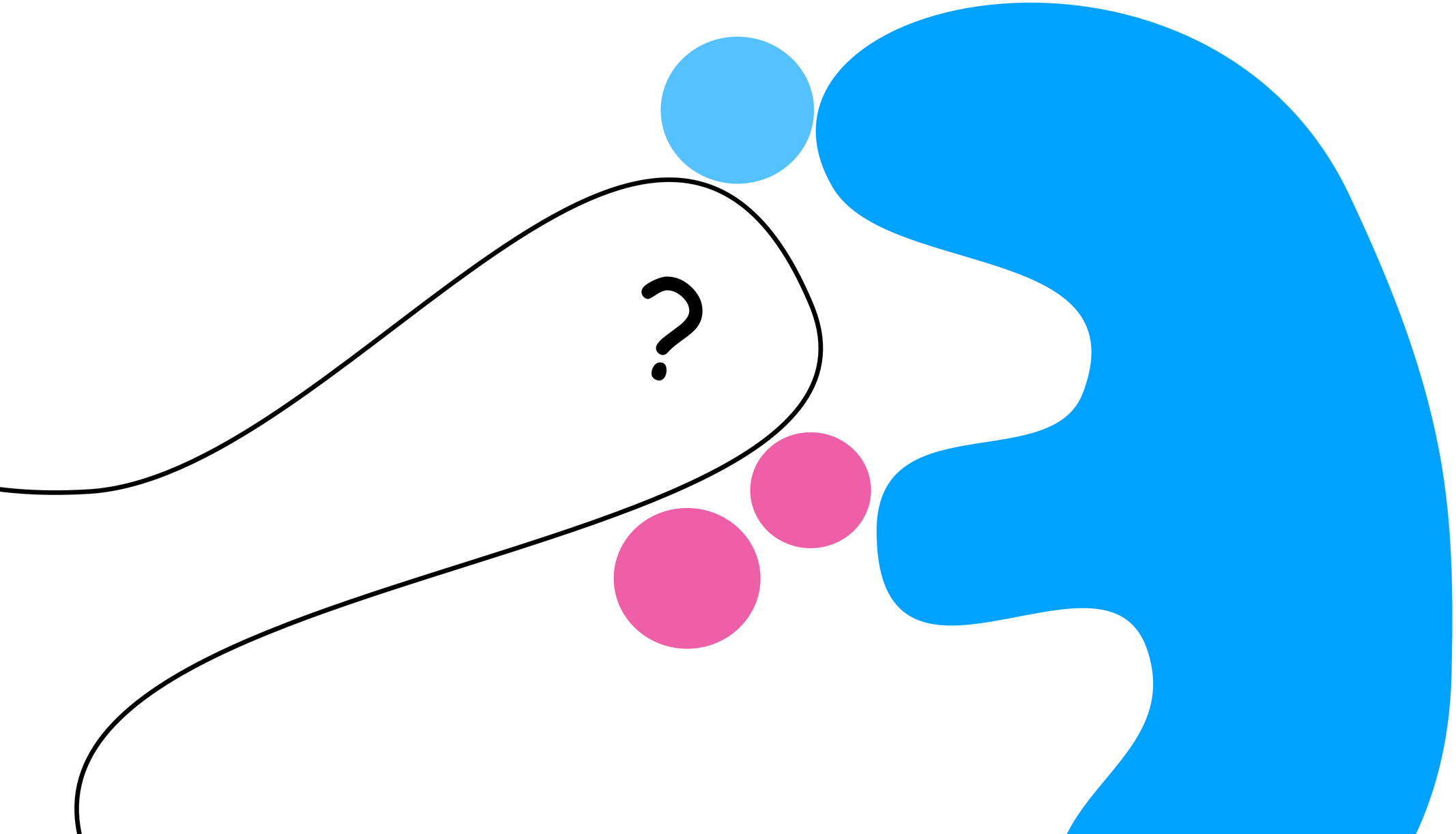
Escaping Research Limbo

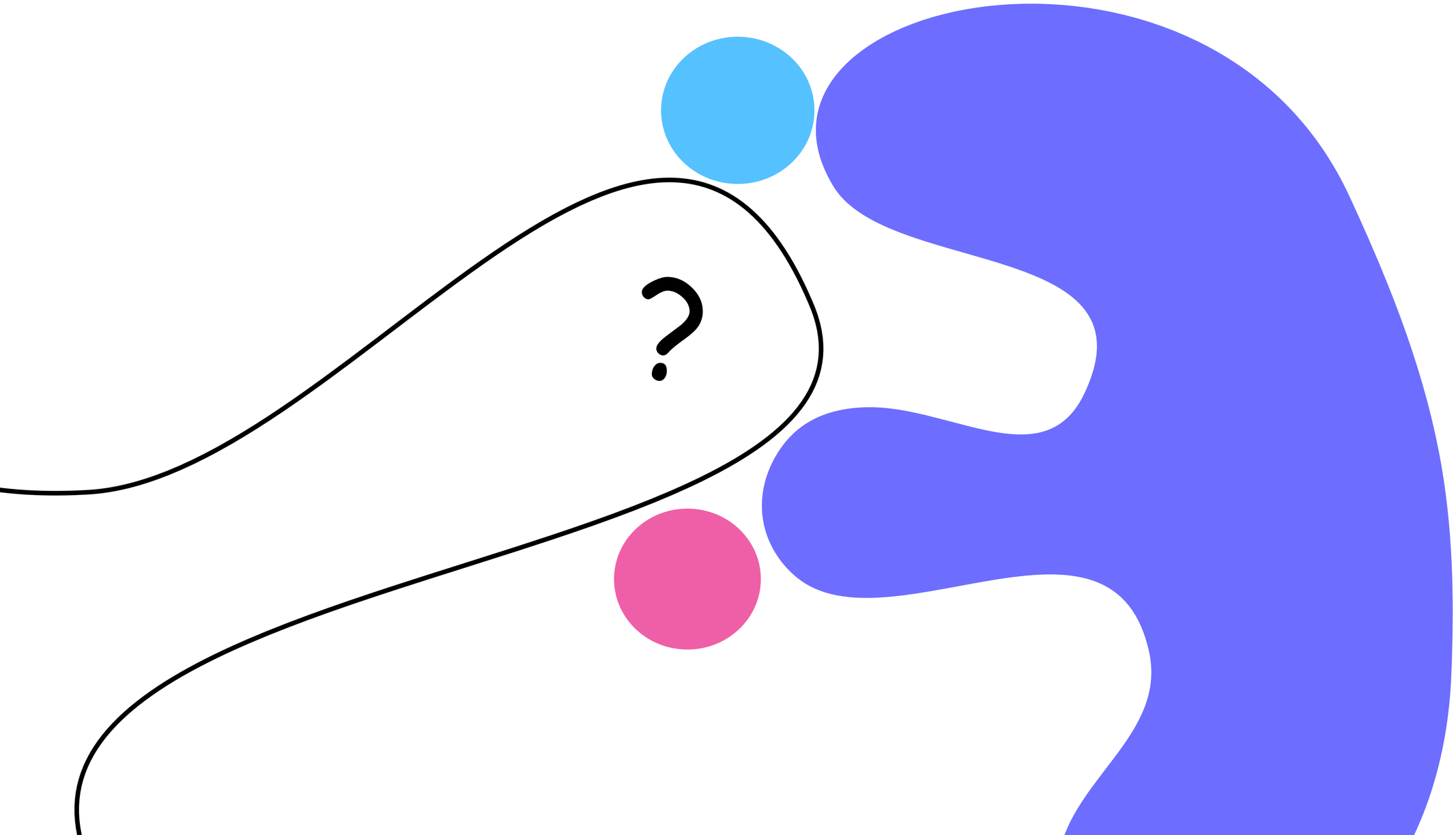
Step 1: Read

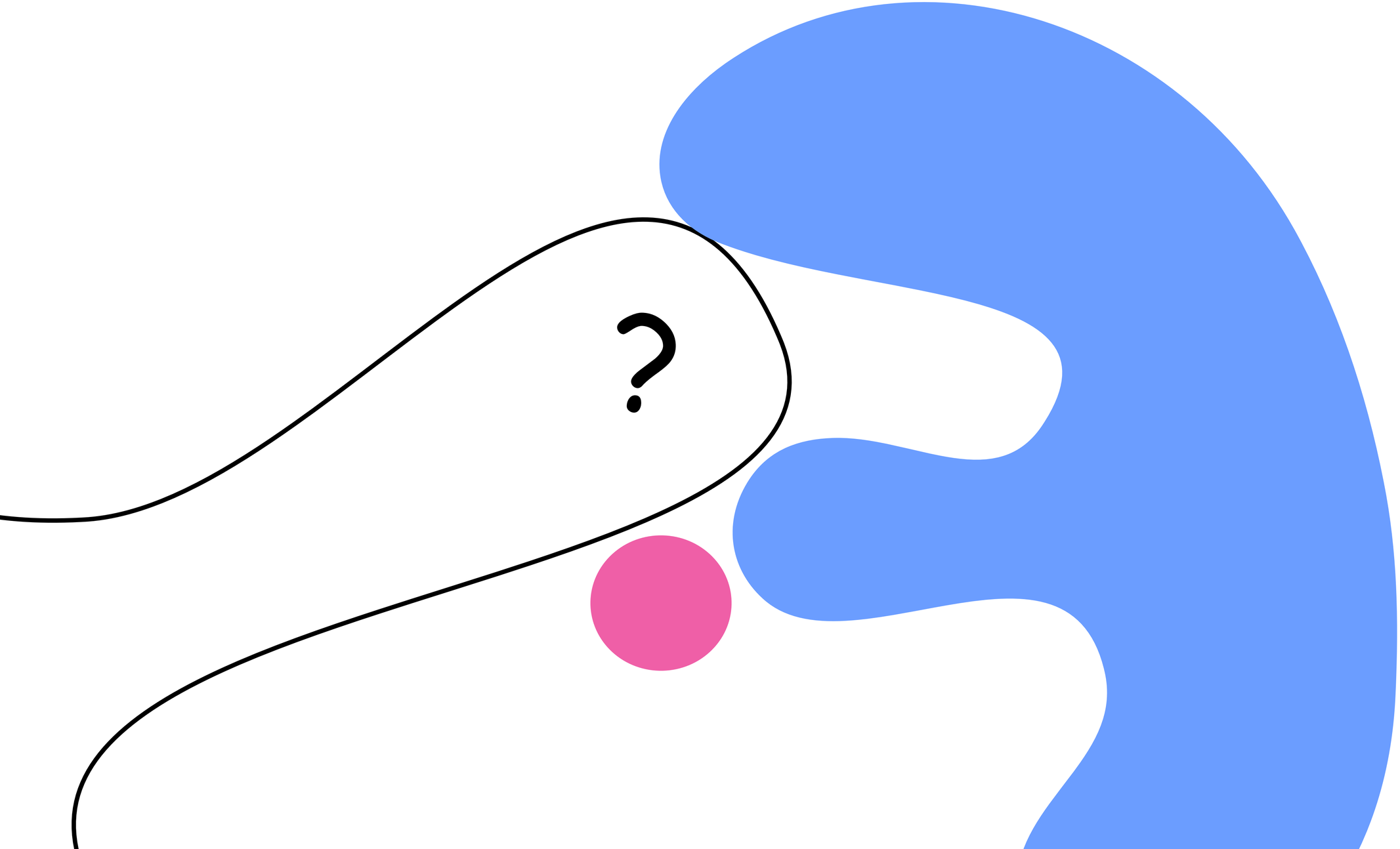
Tools and Techniques

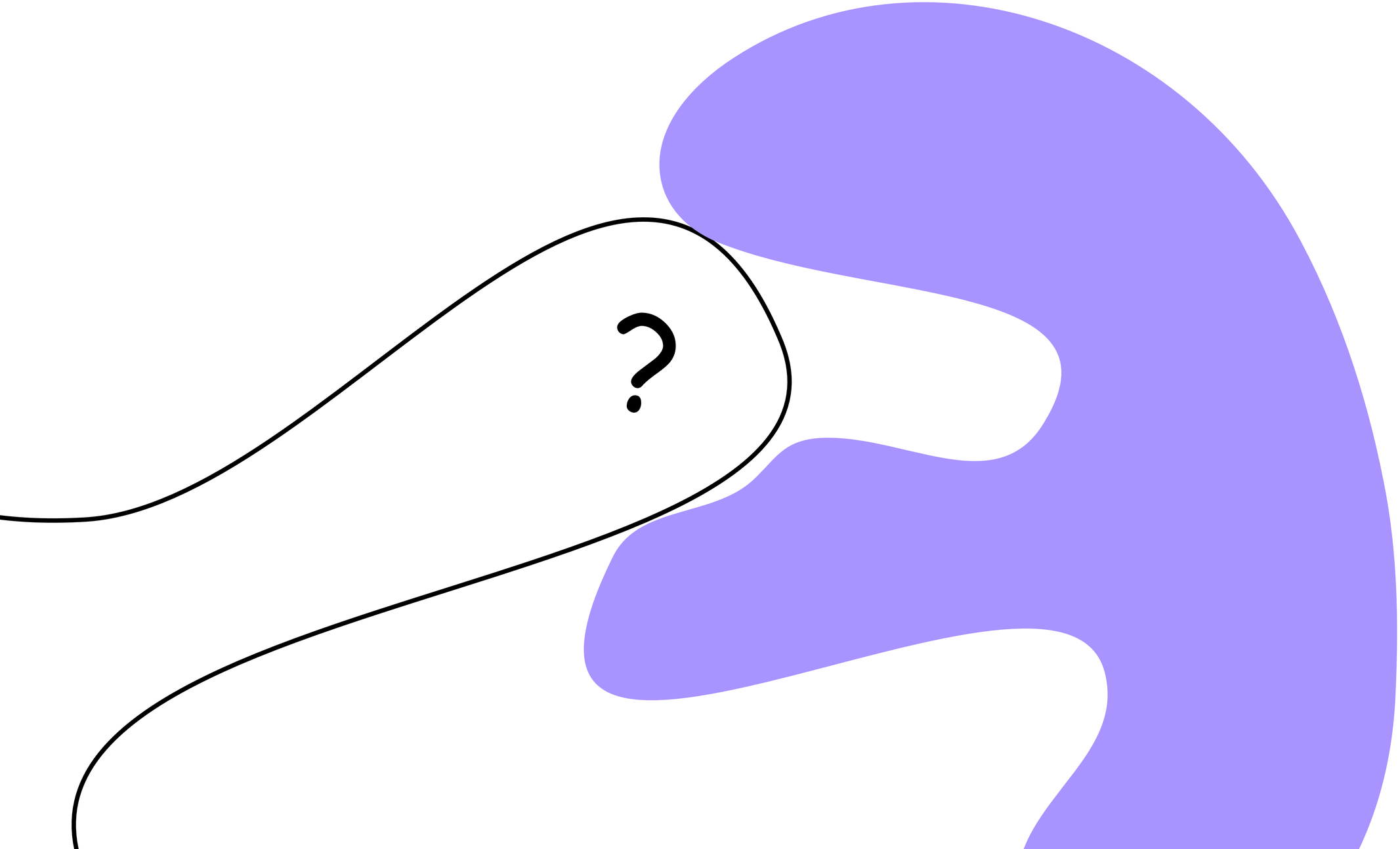












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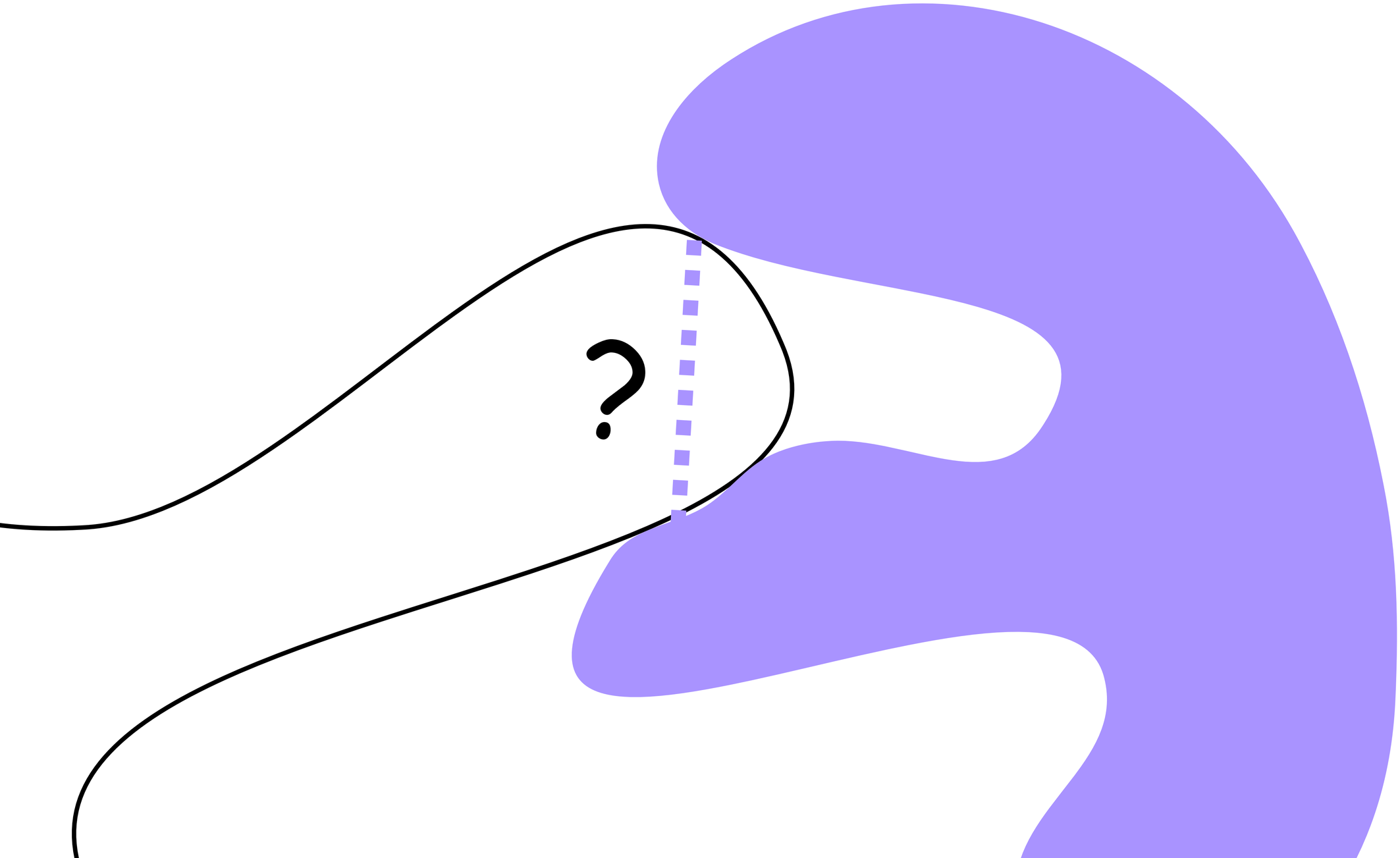


Finding the Path

There is no royal road to geometry.
Euclid

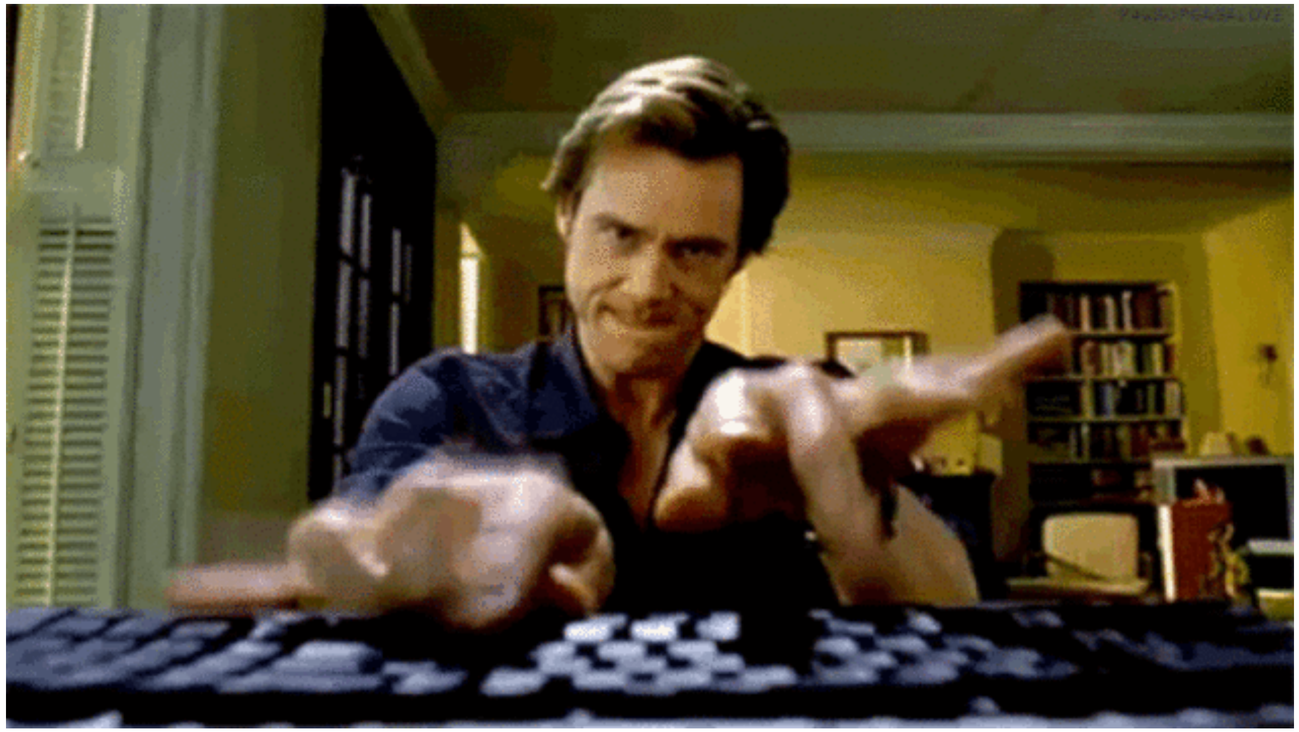
*Research is from "**search**".*
Aleks Nanevski

Move Fast and Break Things.

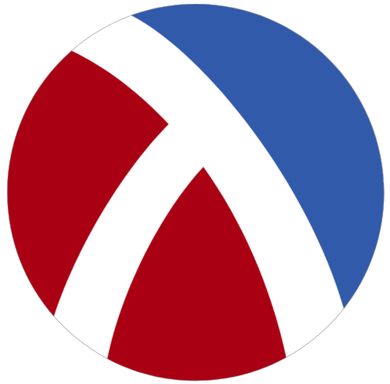
© facebook

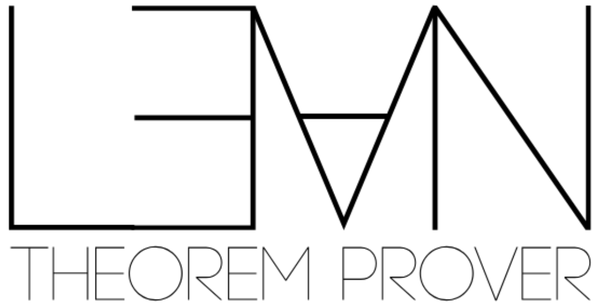
Escaping Research Limbo

Step 2: Hack



Pick your Favourite Tools





A typical POPL paper

- Introduction
- Overview
- Theory
- Mechanisation / Implementation
- Case Studies / Evaluation
- Related Work and Conclusion

A typical POPL paper

- Introduction
- Overview
- **Theory**
- **Mechanisation / Implementation**
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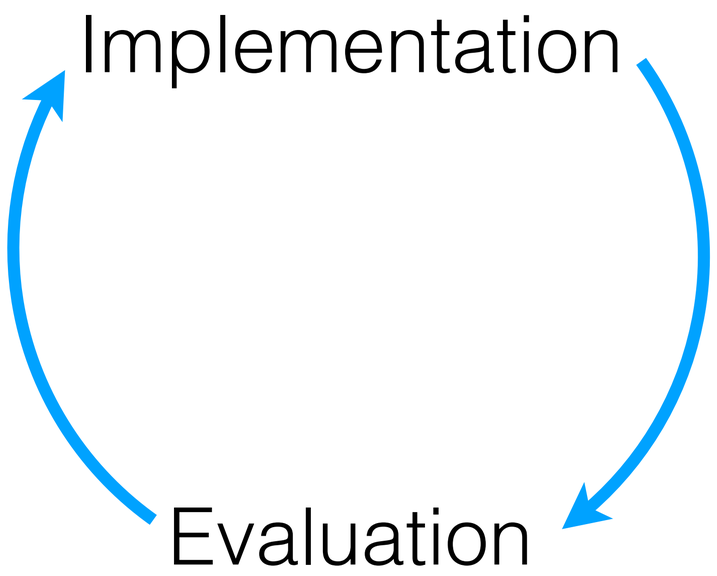
The Scientific Method

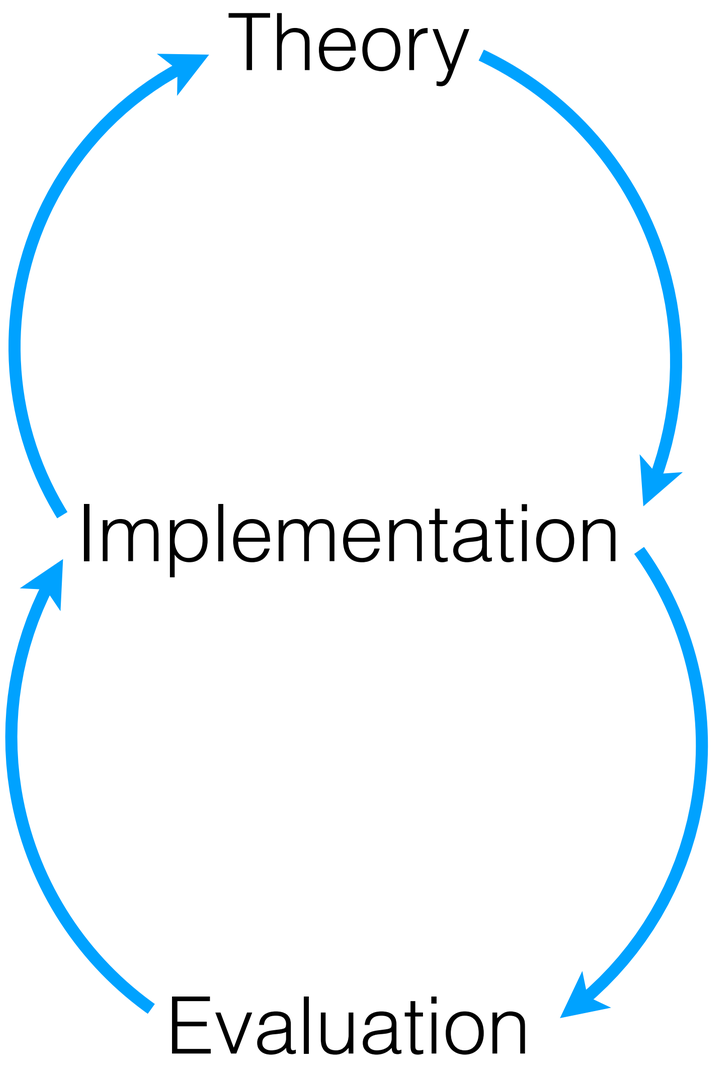
Theory

Implementation

Evaluation

Implementation


Implementation
Evaluation

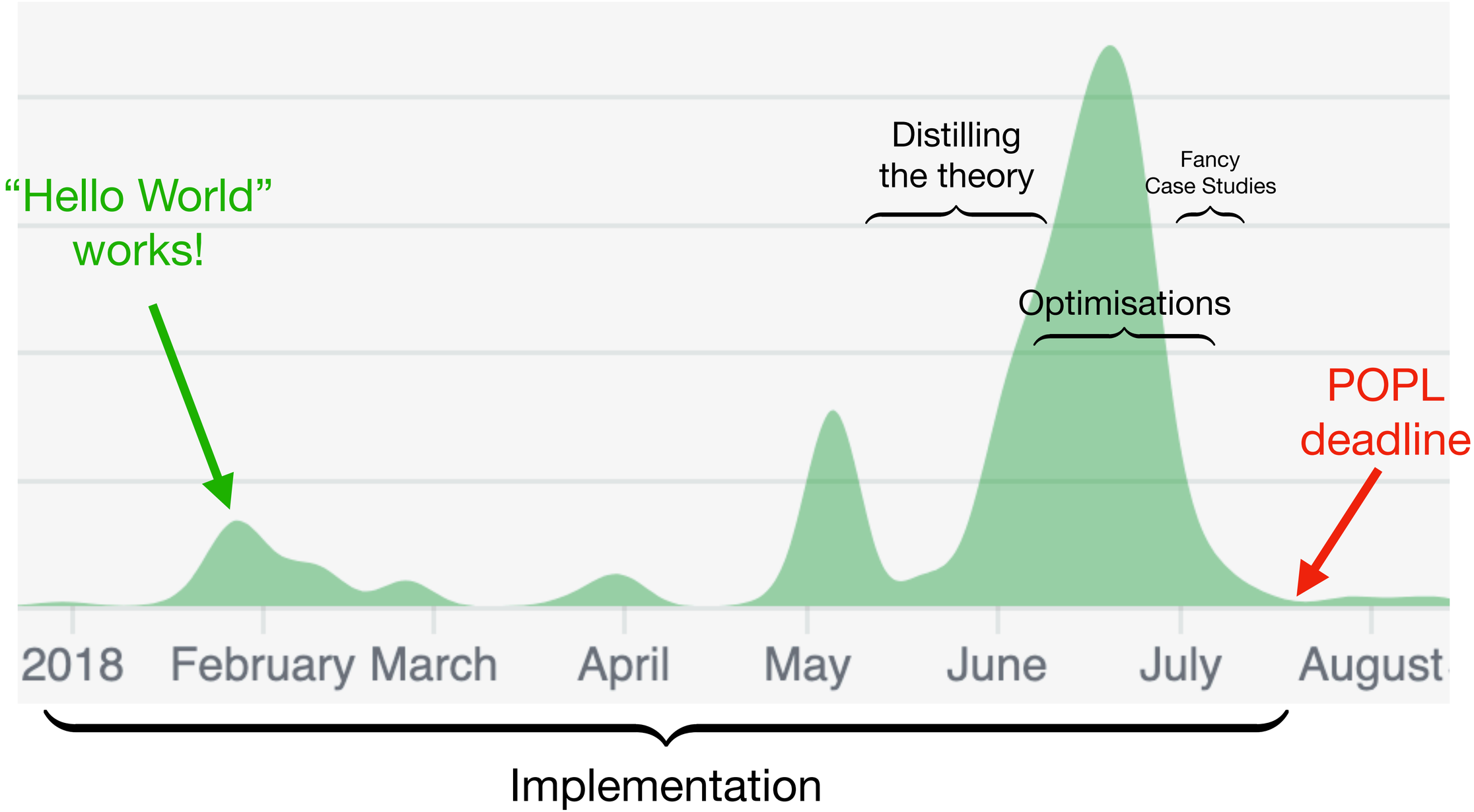

Theory
Implementation
Evaluation

Technique *Domain*

Structuring the Synthesis of Heap-Manipulating Programs

NADIA POLIKARPOVA, University of California, San Diego, USA
ILYA SERGEY, Yale-NUS College, Singapore and National University of Singapore, Singapore

This paper describes a deductive approach to synthesizing imperative programs with pointers from declarative specifications expressed in Separation Logic. Our synthesis algorithm takes as input a pair of assertions—


“Hello World”
works!
Distilling
the theory
Fancy
Case Studies
Optimisations
POPL
deadline
2018
February
March
April
May
June
July
August
Implementation

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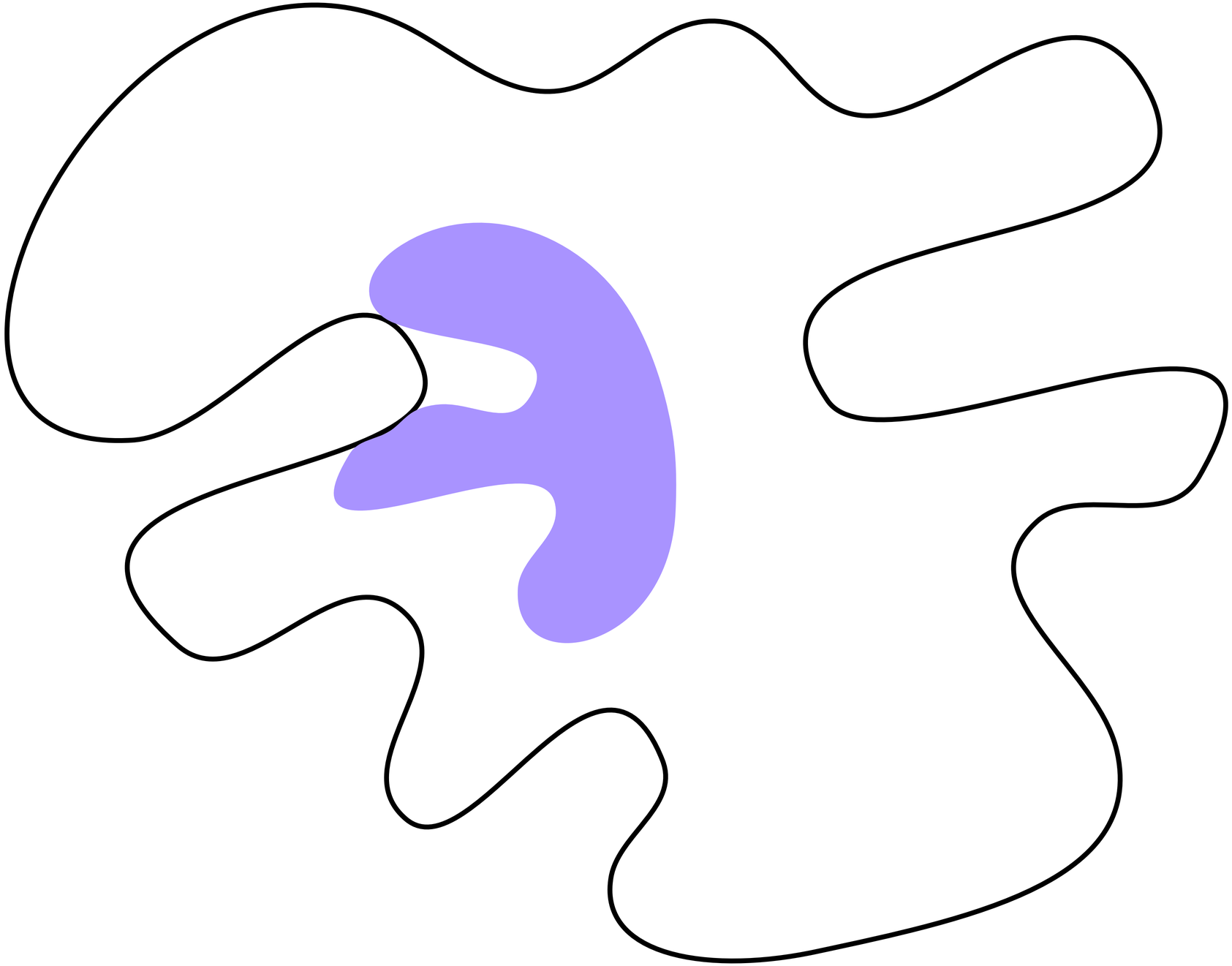
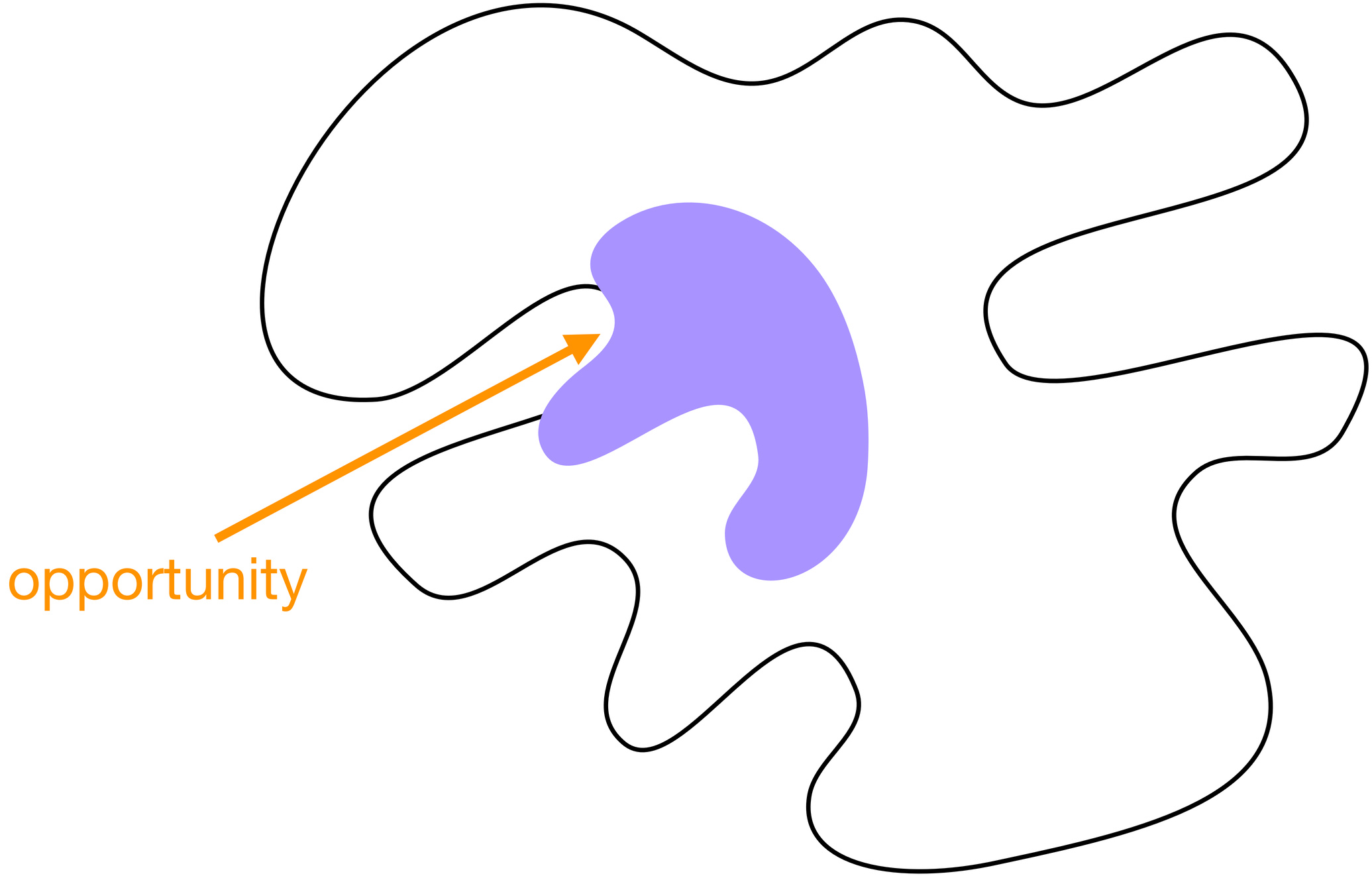
Escaping Research Limbo

Step 3: Look for Shortcomings




opportunity

The Virtue of PL Research

Implementation to
Solve a Domain Problem

too messy
too brittle
too inefficient

Can we make it better ?

A novel technique
for better implementations.

In praise of Incrementality

Bertrand Meyer. *One cheer for incremental research*
https://bertrandmeyer.com/2009/08/10/one-cheer-for-incremental-research/

Story One

"Can we make Static Analyses less complex?"

Abstracting Abstract Machines

David Van Horn *
Northeastern University
dvanhorn@ccs.neu.edu

Matthew Might
University of Utah
might@cs.utah.edu

ICFP'10

Can we make Static Analyses less complex?

too inefficient

Introspective Pushdown Analysis of Higher-Order Programs

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Matthew Might
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David Van Horn
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ICFP'12

lots of code duplication

Monadic Abstract Interpreters

PLDI'13

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Dave Clarke
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See **David Darais**' works for the follow-ups.

Story Two

"Can we unify existing Concurrency Logics?"

POPL'15

Iris: Monoids and Invariants as an Orthogonal Basis for Concurrent Reasoning

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Can we unify existing Concurrency Logics?

how do we use it?

ICFP'16

Higher-Order Ghost State

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Derek Dreyer
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proofs are difficult to manage

POPL'17

Interactive Proofs in Higher-Order Concurrent Separation Logic

Robbert Krebbers *
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amin.timany@cs.kuleuven.be

Lars Birkedal
Aarhus University, Denmark
birkedal@cs.au.dk

Standing on the Shoulders of Giants

16:30 - 17:30 ☆ **Panel: How to Do Great PL Research**

Talk

Vasco Vasconcelos LASIGE, Faculty of Sciences, University of Lisbon, Deepak Garg Max Planck Institute for Software Systems, Philippa Gardner Imperial College London, Atsushi Igarashi Kyoto University, Japan, Neelakantan R. Krishnaswami Computer Laboratory, University of Cambridge

Escaping Research Limbo

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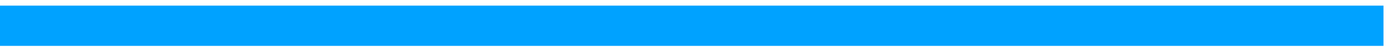
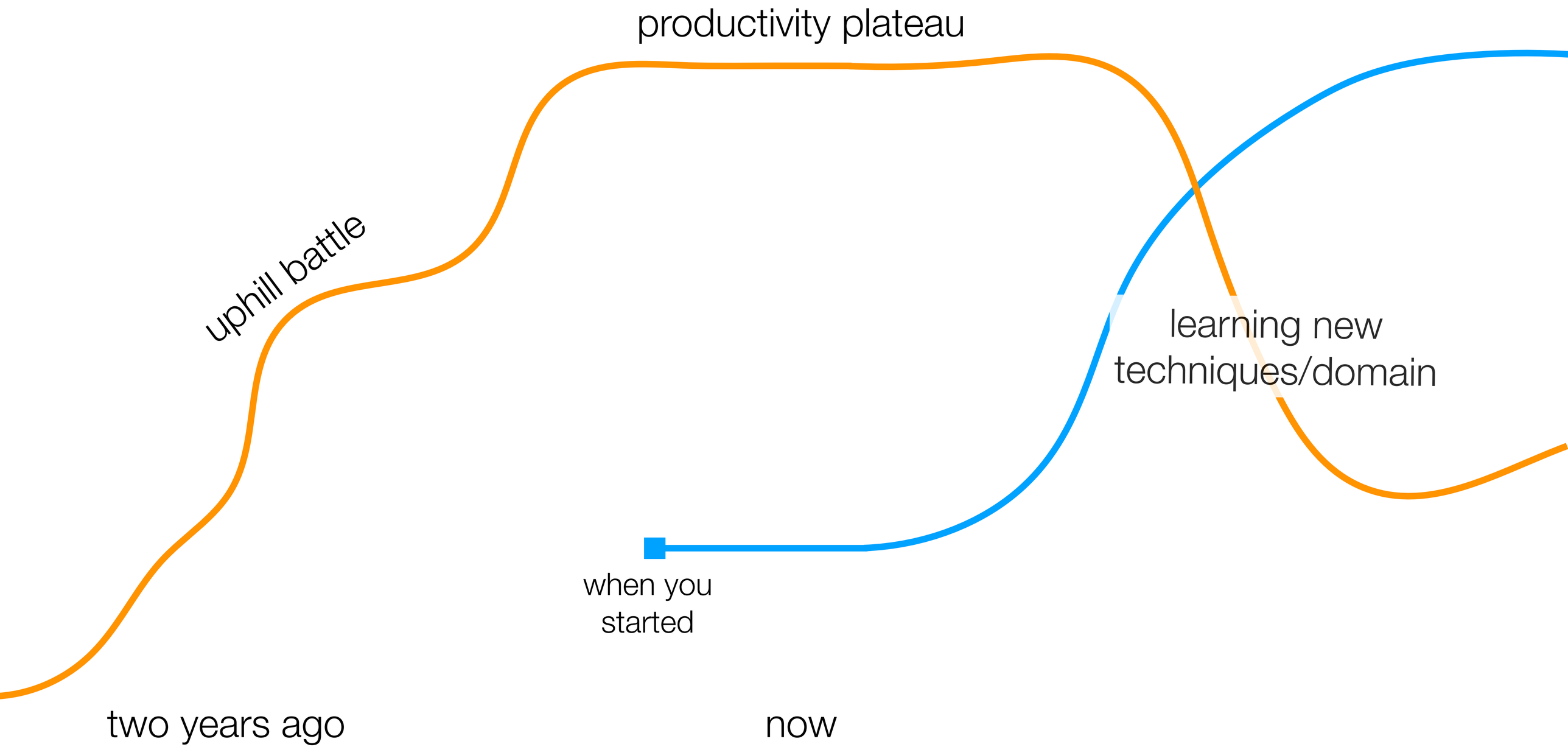
POPL CAV PLDI POPL again

your officemate now

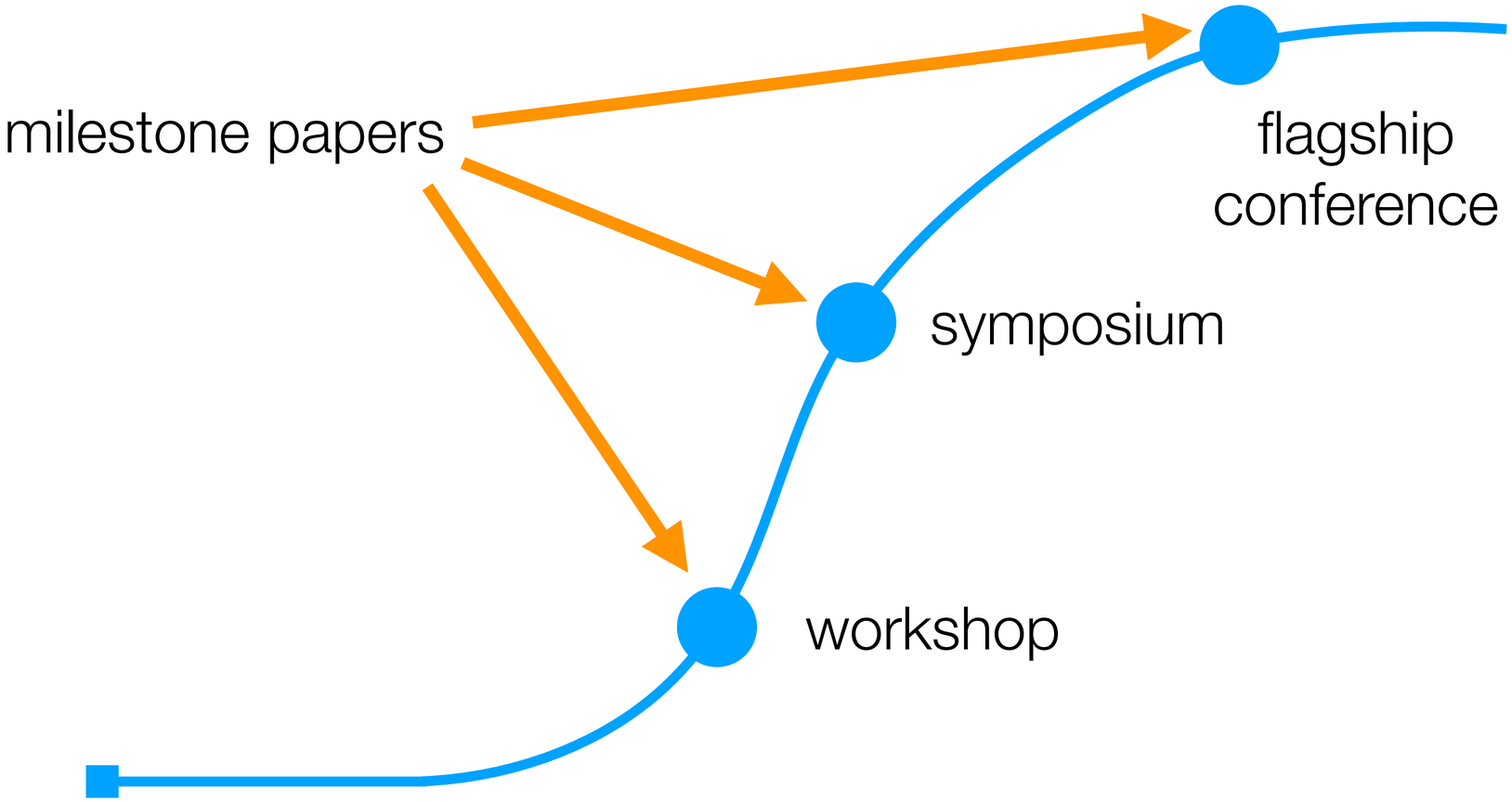


you now


productivity plateau
uphill battle
learning new
techniques/domain
when you
started
two years ago
now

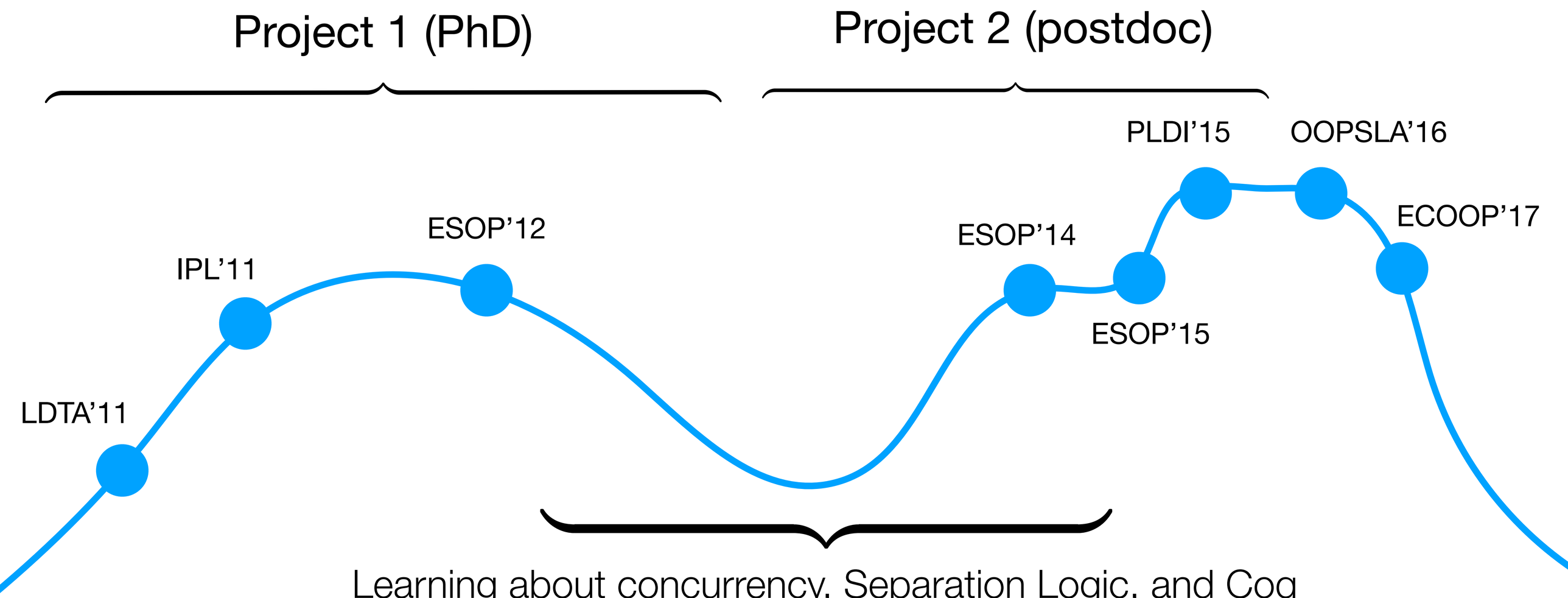
Escaping Research Limbo

Step 4: Document your results



My first Highs and Lows

Inspired by **Greg Morrisett's** *Highs and Lows of a Language Researcher. PLMW@POPL'16*



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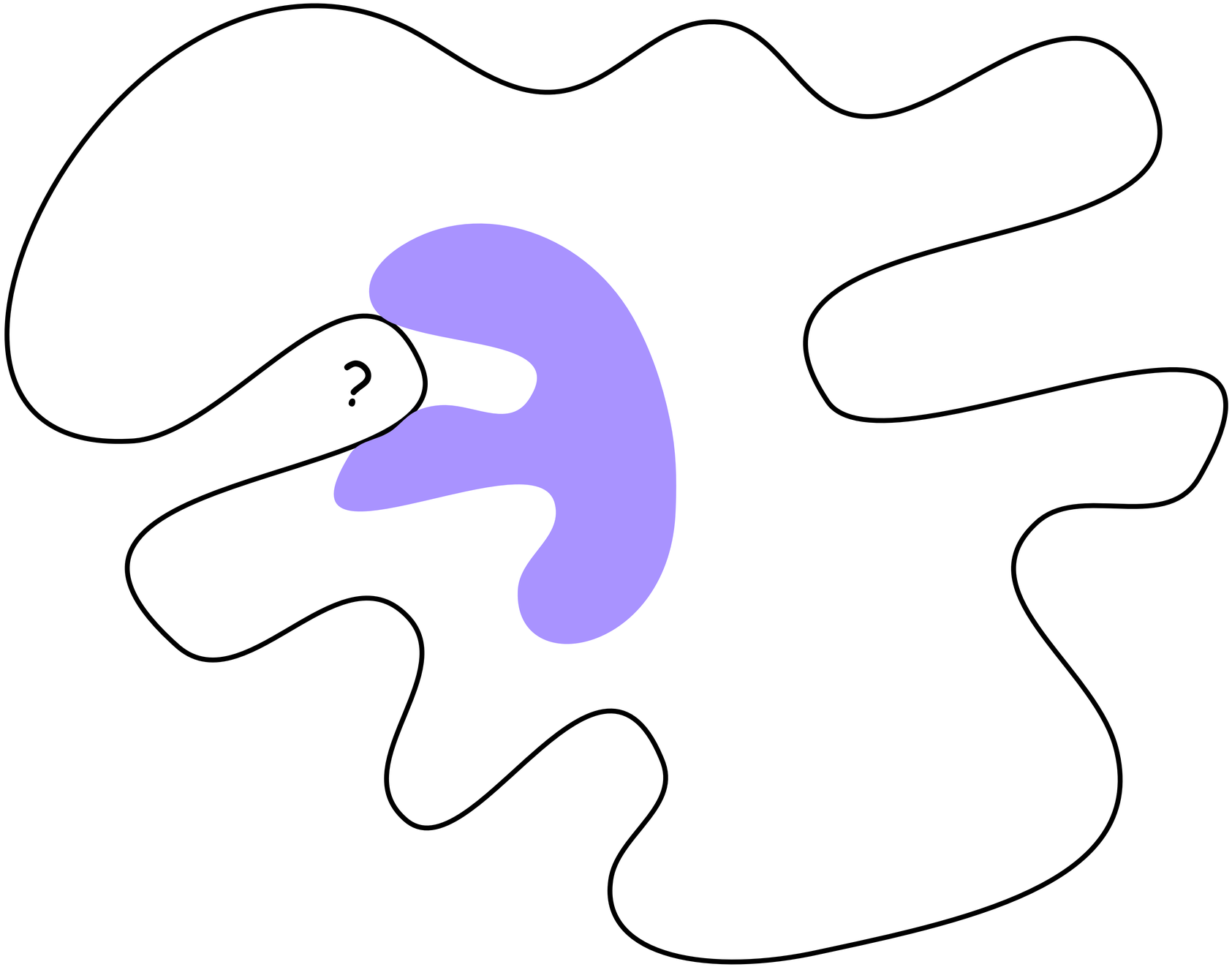
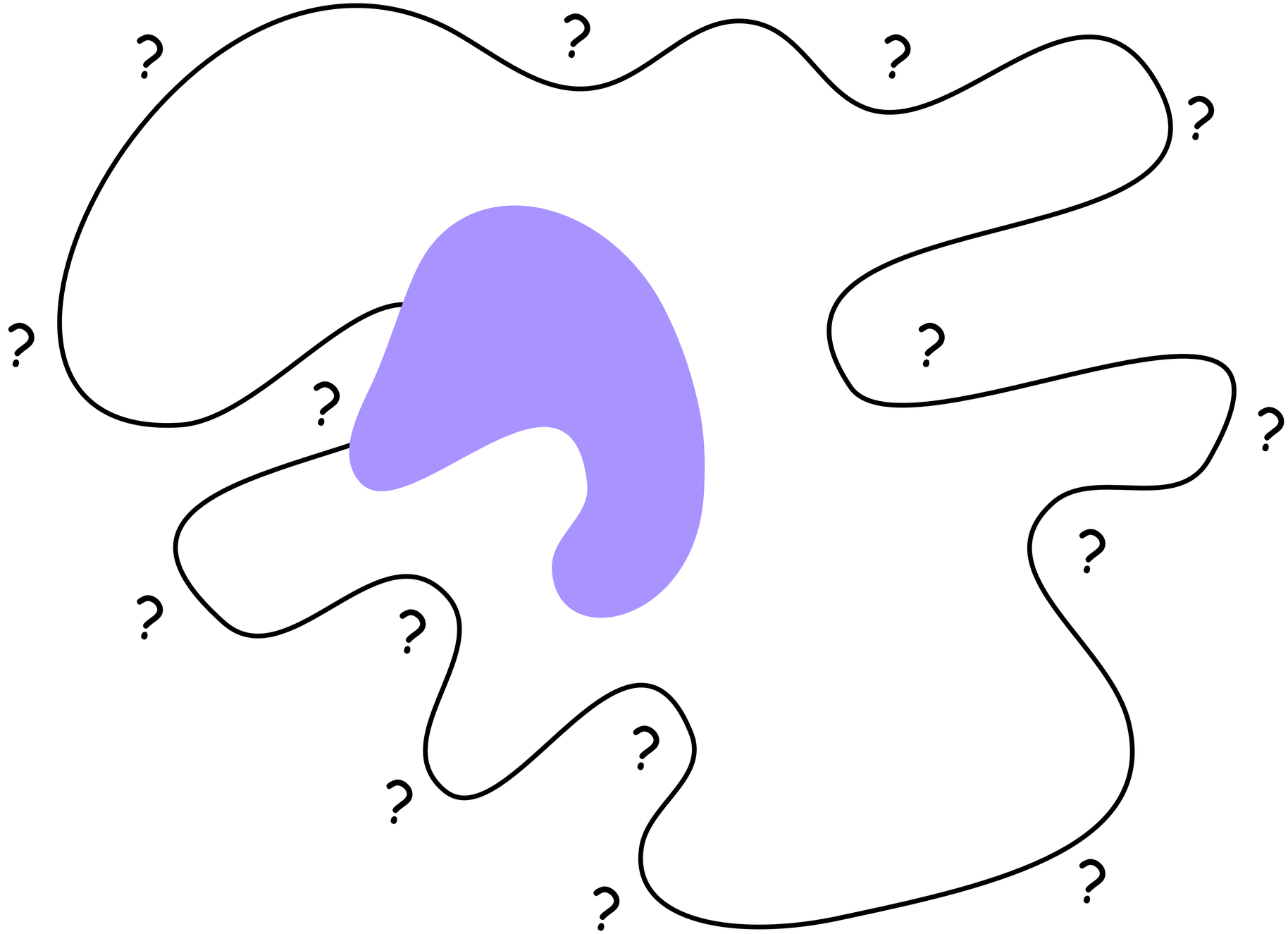
You have acquired skills

They are reusable





To Take Away

- Starting a new project is always scary!
- To escape the ***Research Limbo***:

  Read, Hack, Find shortcomings, Write

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Thank you and good luck!