Proofs and Hints

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Logistics

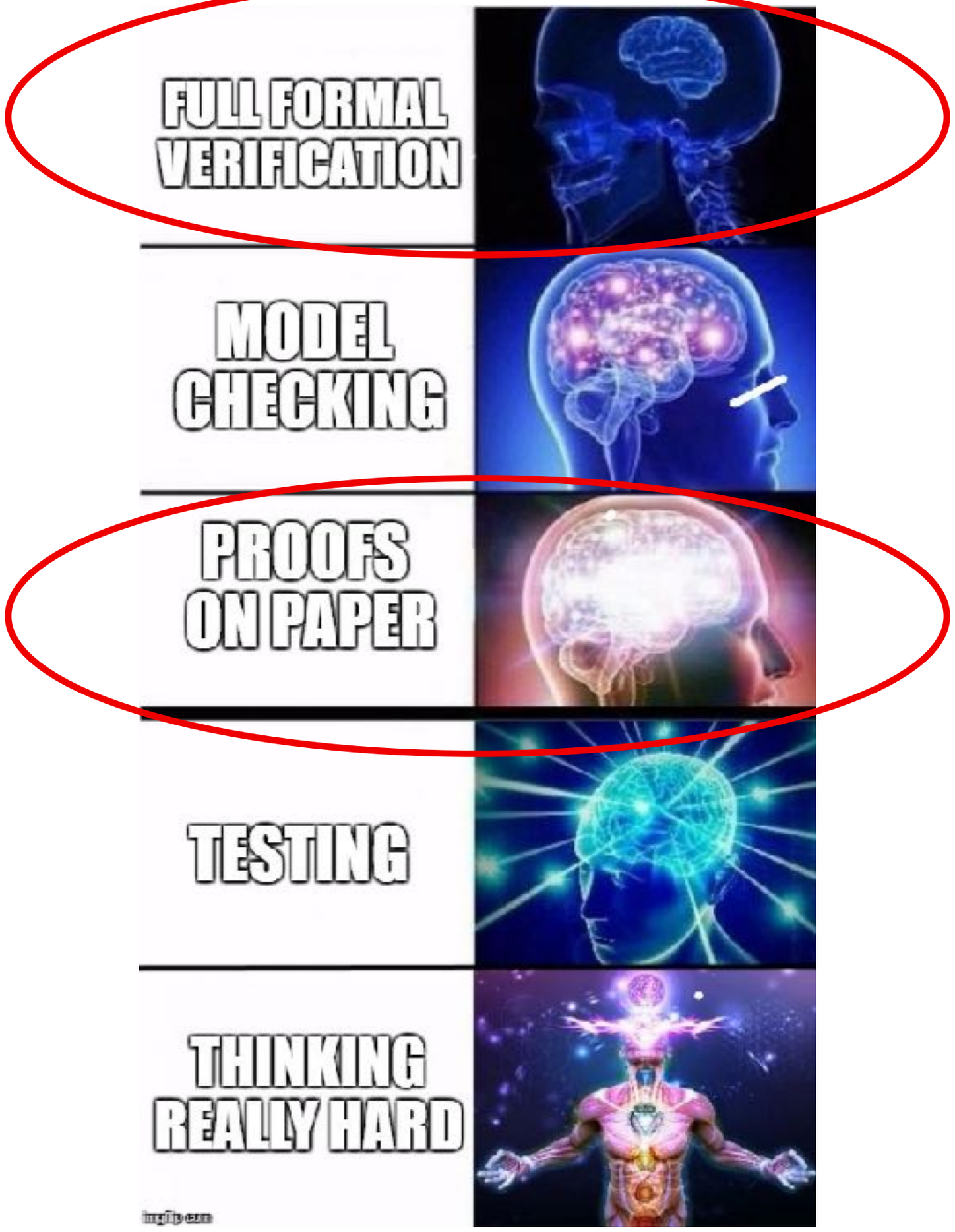
Last class!

PS5 clarification

No regular OH next week

- Doug, Wednesday 3:30-4:30, CSE 314

- And, by appointment

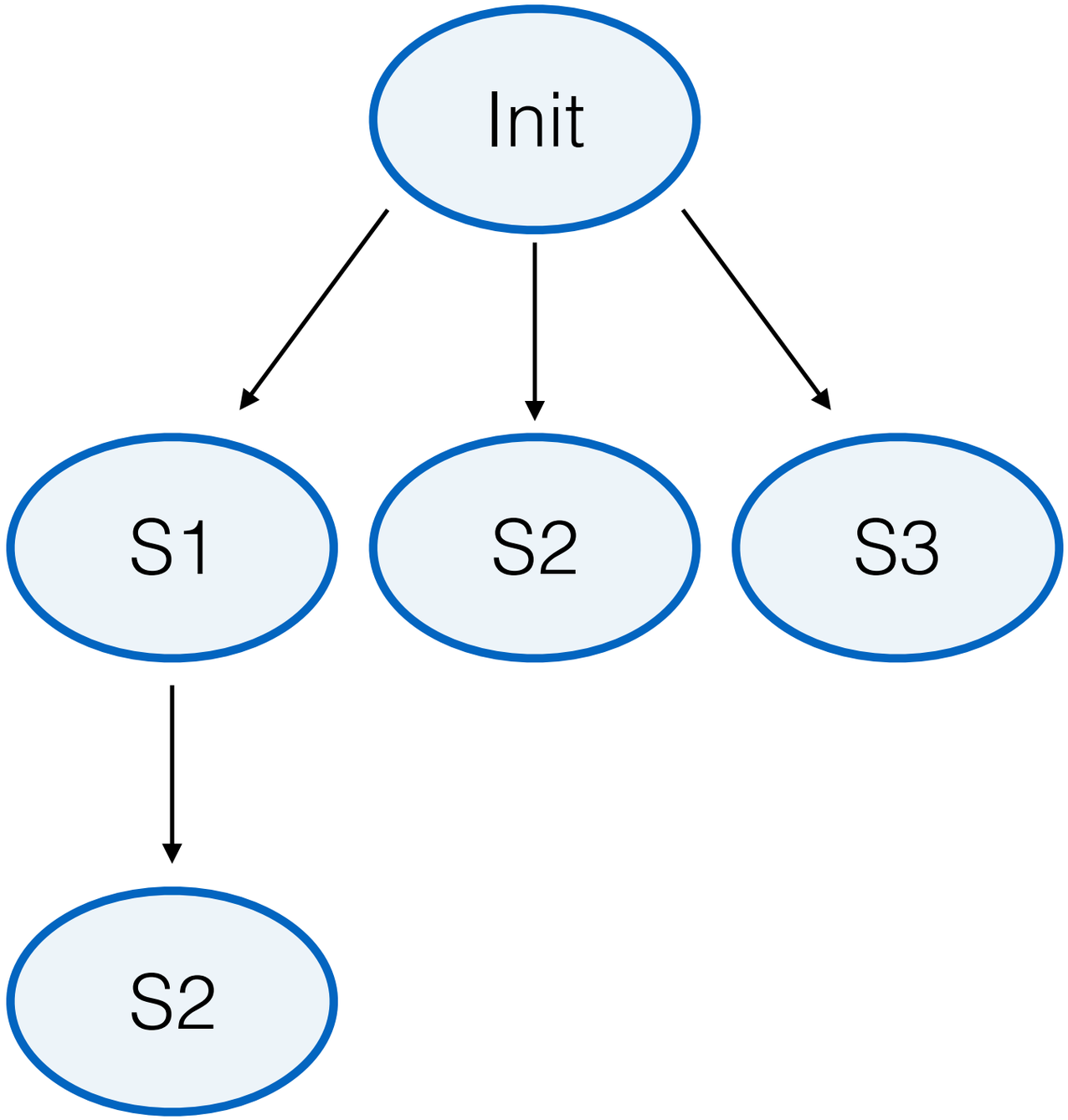

FULL FORMAL VERIFICATION
MODEL CHECKING
PROOFS ON PAPER
TESTING
THINKING REALLY HARD

Distributed systems correctness

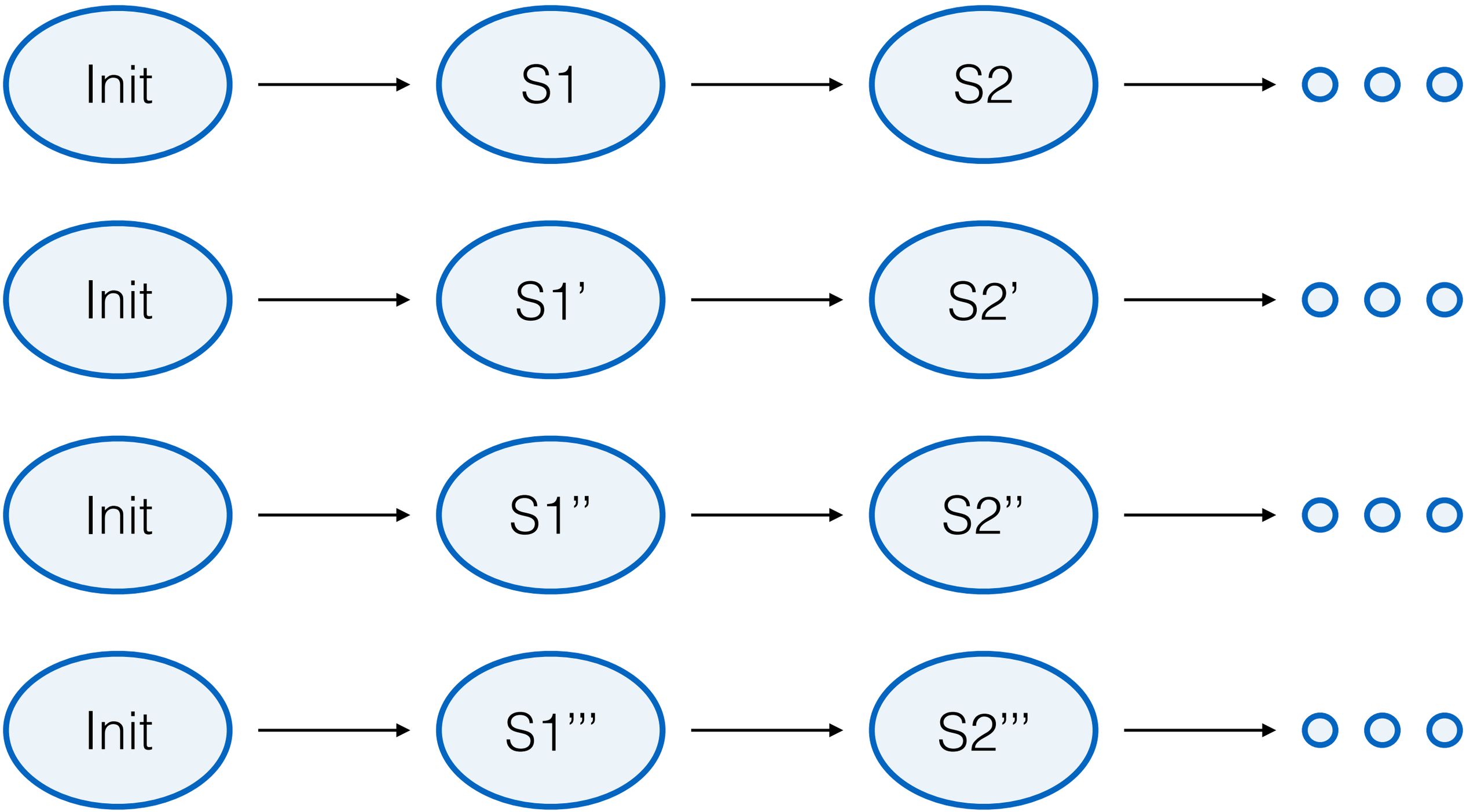
A distributed system is a collection of behaviors

- Sequences of states
- Potentially infinite
- Non-deterministic

Distributed systems correctness



Distributed systems correctness



Safety and liveness

Safety

- The system never does bad stuff
- Property of any prefix of any sequence

Liveness

- The system sometimes does good stuff
- Property of any (infinite?) postfix of any sequence

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Proving safety properties

Safety properties are *invariants*: P is always true

- Mutual exclusion

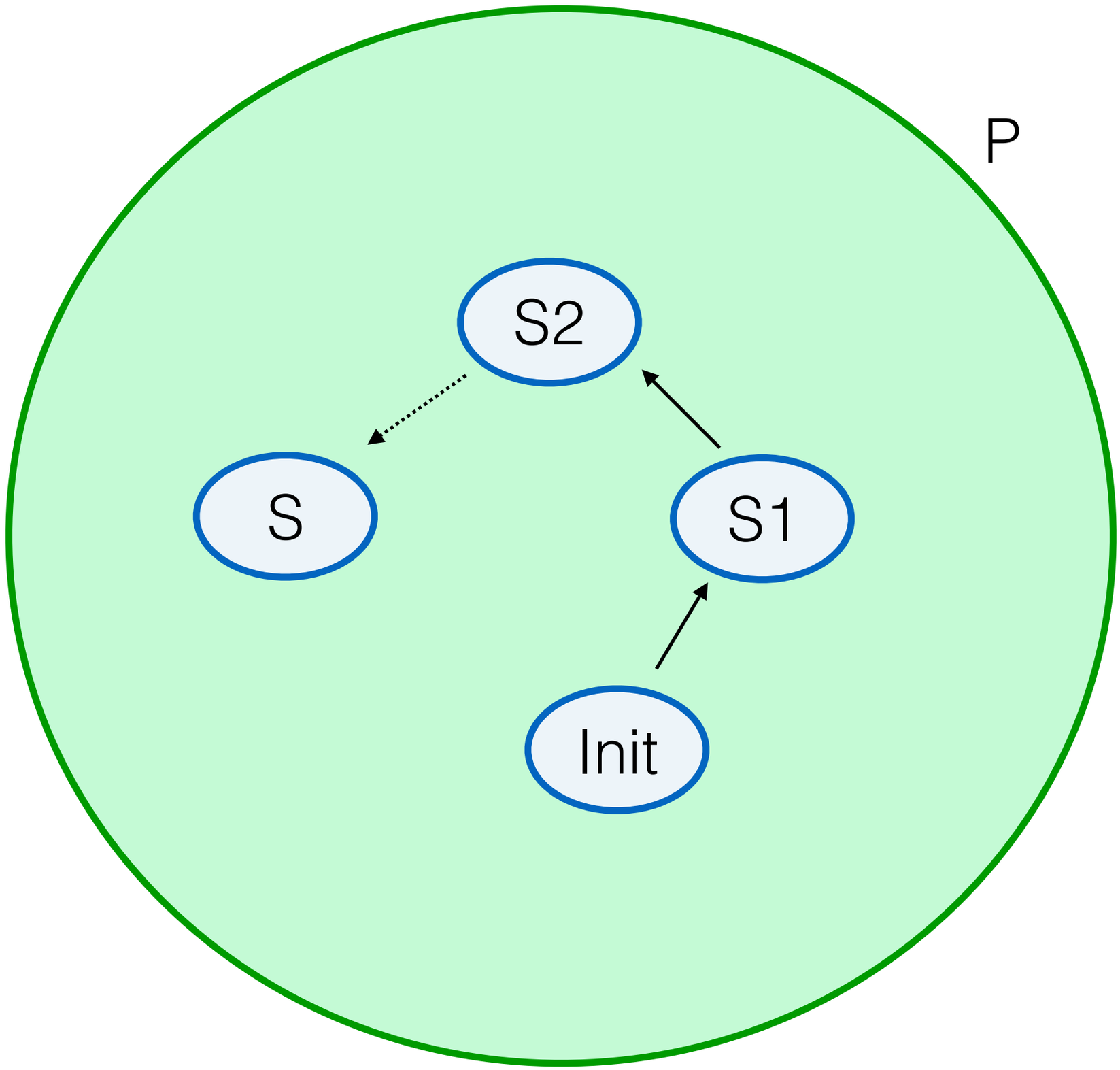
- Only one Multi-Paxos leader at a time

- If any two-phase commit node has aborted, none have committed

These properties must be true of any reachable state

- There are probably infinite reachable states!

Proving safety properties



Proving stuff about unbounded objects

One weird trick for proving things about all objects, even if there are an infinite number of them

Hint: how to prove something about all natural #’s?

Induction

Proving P for all natural #’s:

- Prove P(0)

- Prove that if P(n), P(n+1) for all n

Induction for safety properties

Proving P for all reachable states:

- Prove P(Init)

- Prove that if P(S) and S -> S’, then P(S’)

Proving mutual exclusion by induction

Does mutual exclusion hold in the start state?

How about the inductive step?

Proving mutual exclusion by induction

Often need to strengthen the induction hypothesis

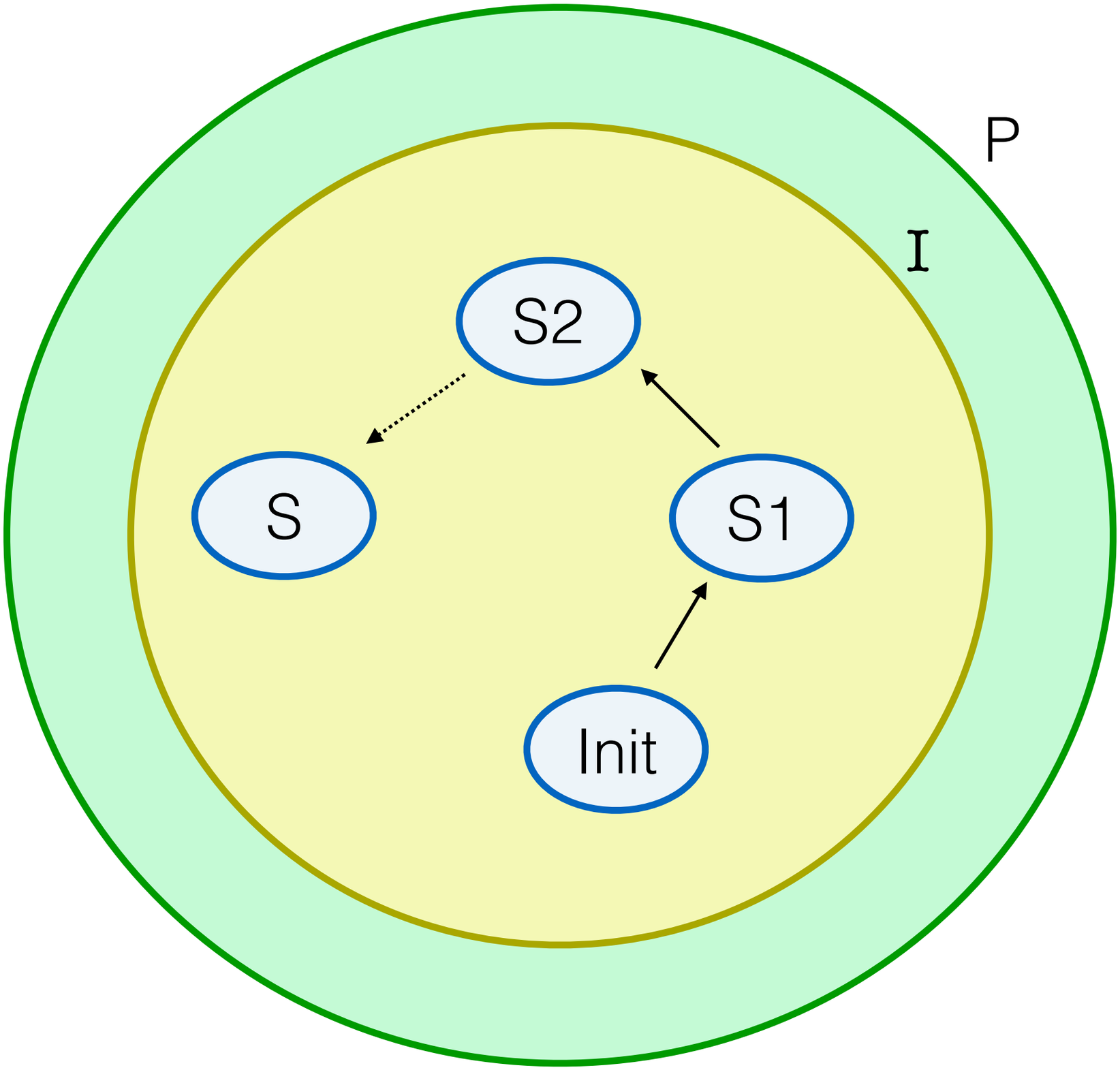
Need `I` such that:

- `I` -> P
- `I` is actually inductive

Examples of strengthening:

- Constrain network contents
- Further constrain state (matching between nodes)

Proving safety properties



Proving mutual exclusion by induction

Coming up with inductive invariants is hard!

- Requires really understanding how a system works
- Provably impossible to do automatically

Proving invariants inductive is doable

- Requires only “local” reasoning—single-step

Machine-checked proofs

Easy to get proofs about software wrong

- Math proofs: often (not always!) short, elegant
- Software proofs almost always long and boring

Idea: have machines check proofs!

- Machines can also help write the proofs
- For (way) more on this, take CSE 505

Hints for system design

Written in 1983

- Before I was born

- Year Tom graduated from college

Lampson: now researcher at MSR, MIT

- Turing award in 1992

- laser printers, two-phase commit, WYSIWYG, Ethernet, and the personal computer

This paper: some hints for building large systems

Why?	*Functionality* Does it work?	*Speed* Is it fast enough?	*Fault-tolerance* Does it keep working?
Where?			
Completeness	Separate normal and worst case	Shed load End-to-end Safety first	End-to-end
Interface	Do one thing well: Don't generalize Get it right Don't hide power Use procedure arguments Leave it to the client Keep basic interfaces stable Keep a place to stand	Make it fast Split resources Static analysis Dynamic translation	End-to-end Log updates Make actions atomic
Implementation	Plan to throw one away Keep secrets Use a good idea again Divide and conquer	Cache answers Use hints Use brute force Compute in background Batch processing	Make actions atomic Use hints

Figure 1: Summary of the slogans

Wrapping up

Thanks!!!