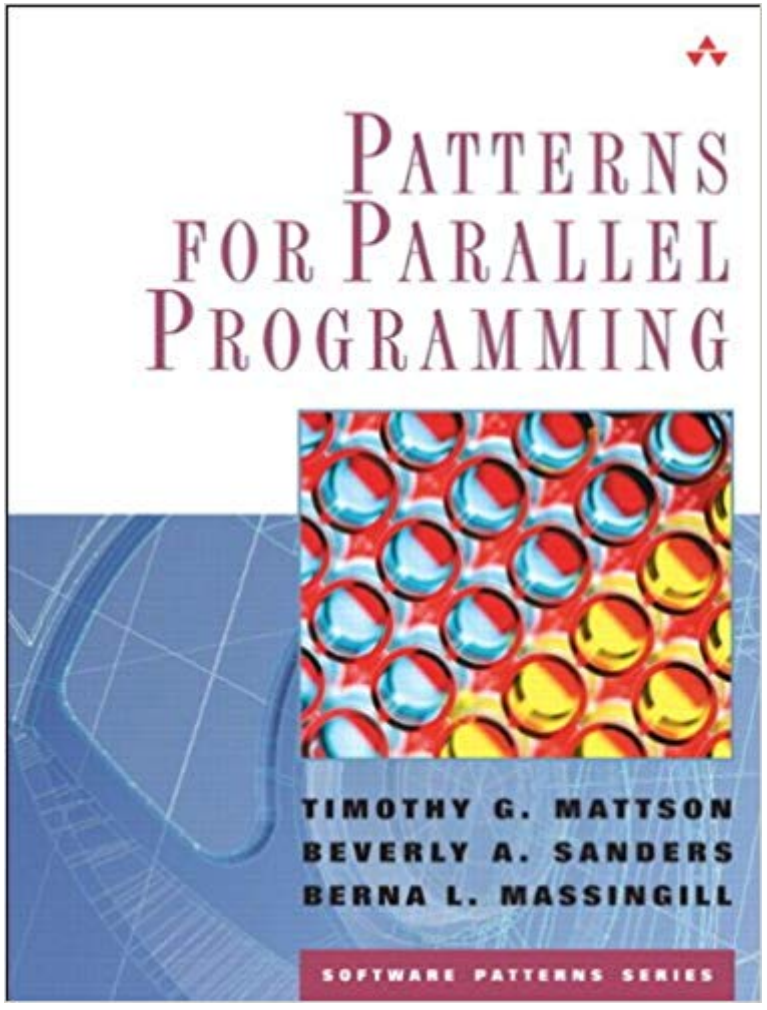
Comparing Common Concurrency Patterns

in Elixir and Erlang

A Pattern Language for Parallel Application Programming

Berna L. Massingill, Timothy G. Mattson, Beverly A. Sanders


PATTERNS
FOR PARALLEL
PROGRAMMING
TIMOTHY G. MATTSON
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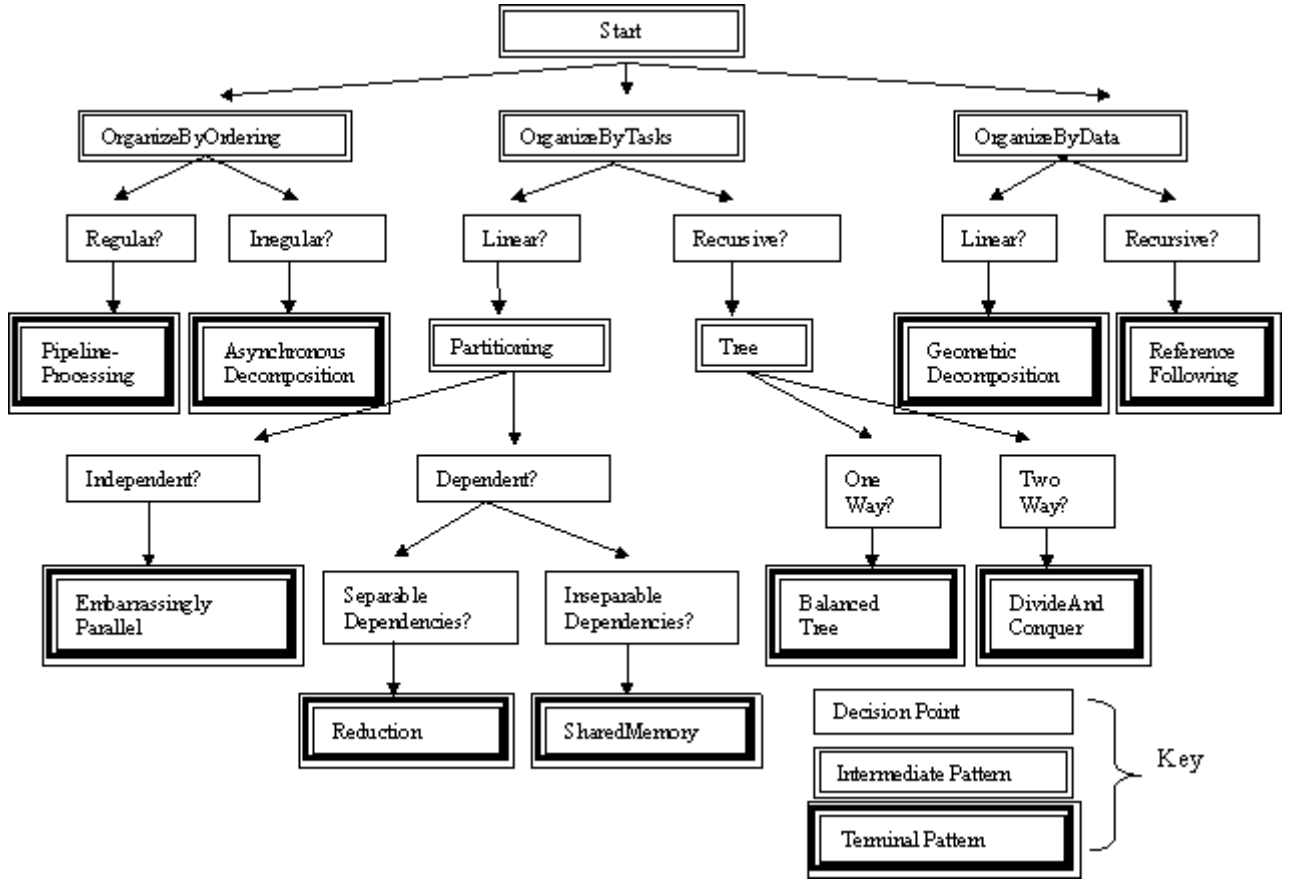
Start
OrganizeByOrdering
OrganizeByTasks
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Regular?
Irregular?
Linear?
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Pipeline-Processing
Asynchronous Decomposition
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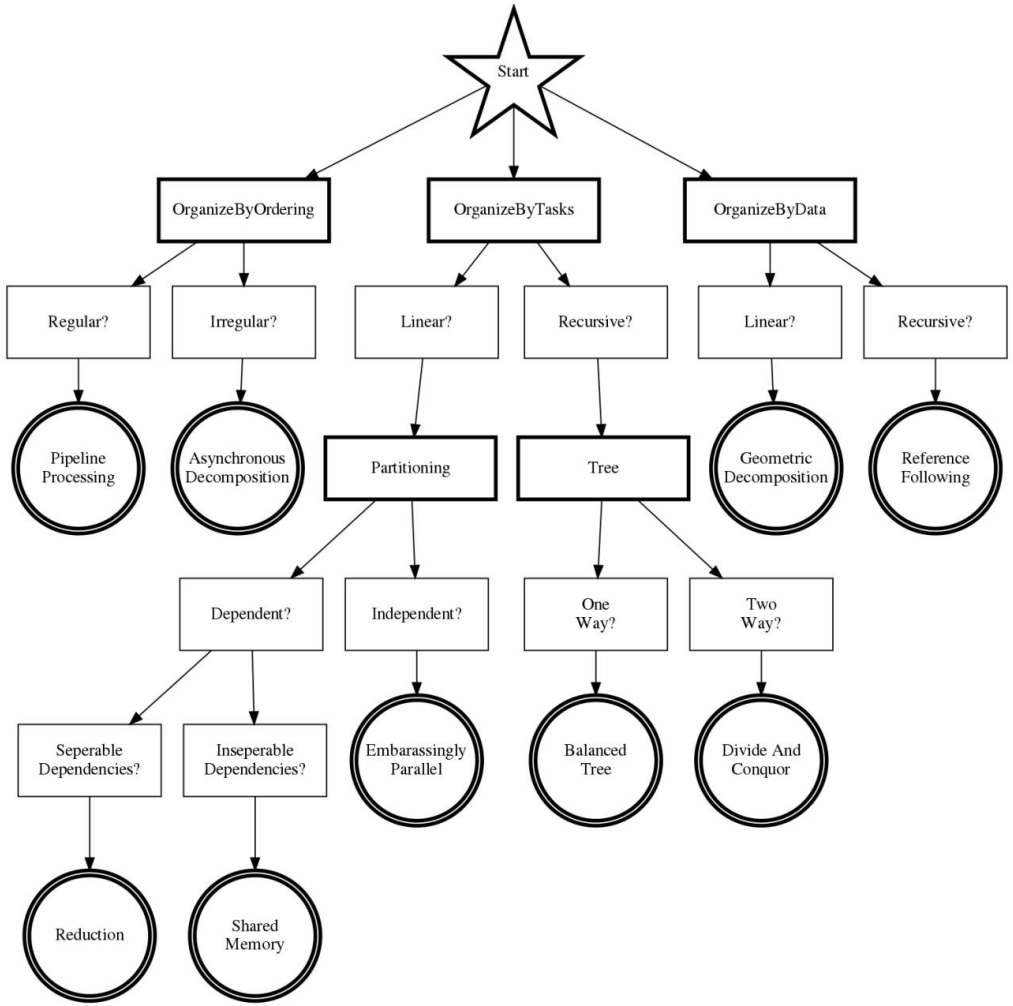
Two Way?
Embarrassingly Parallel
Separable Dependencies?
Inseparable Dependencies?
Balanced Tree
DivideAnd Conquer
Reduction
SharedMemory
Decision Point
Intermediate Pattern
Terminal Pattern
Key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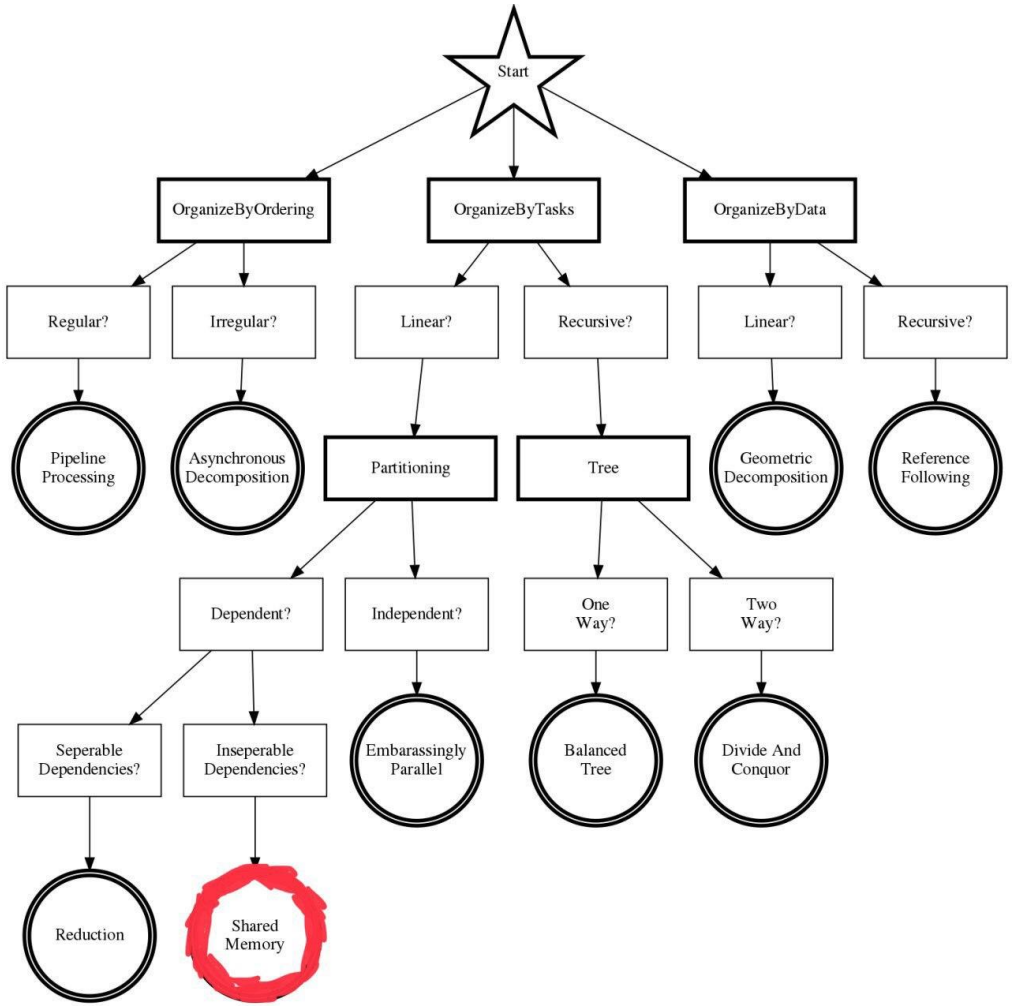
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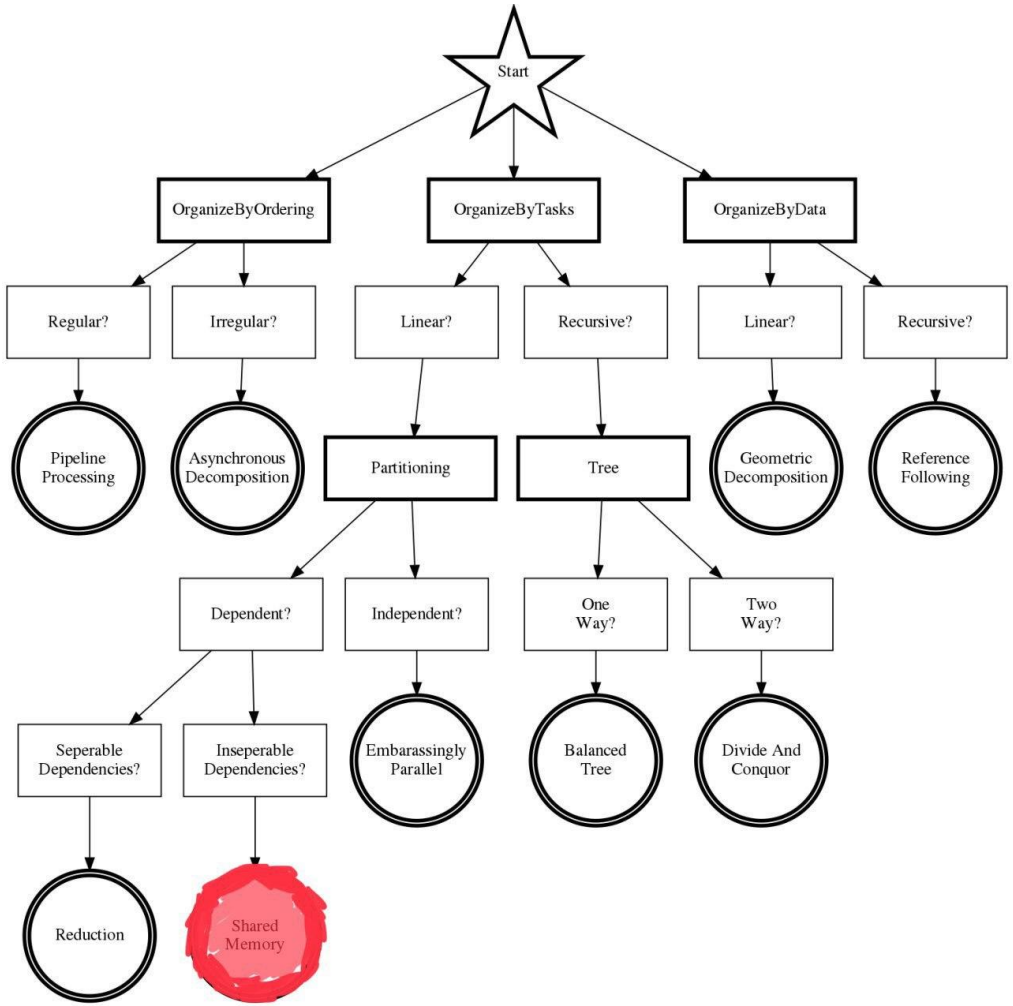
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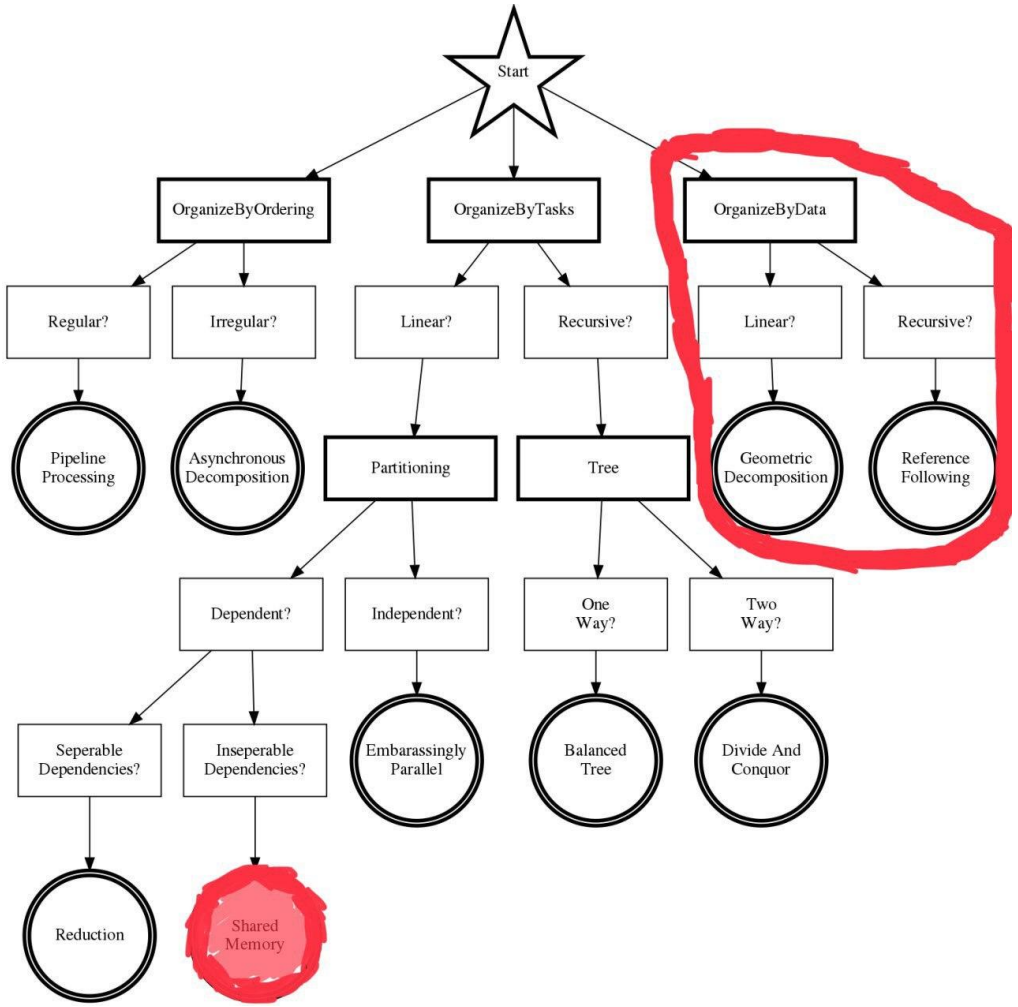
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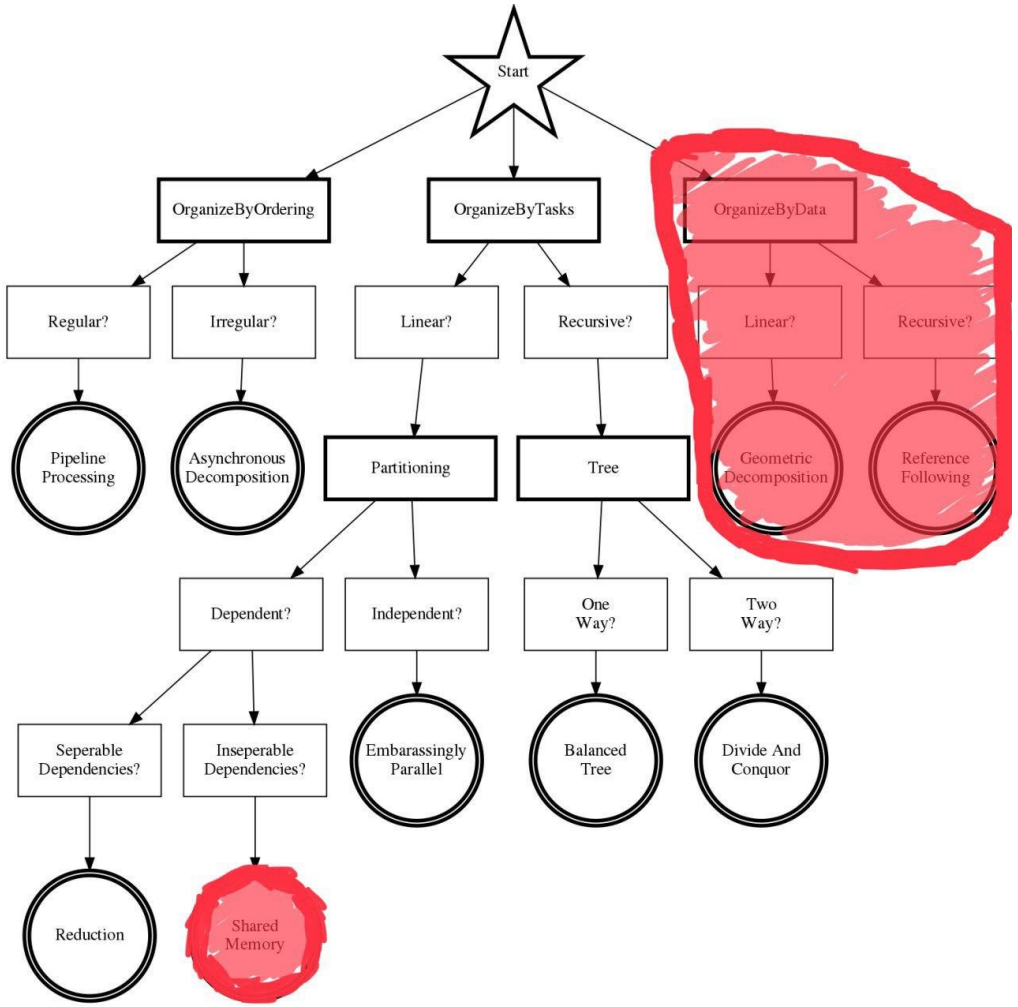
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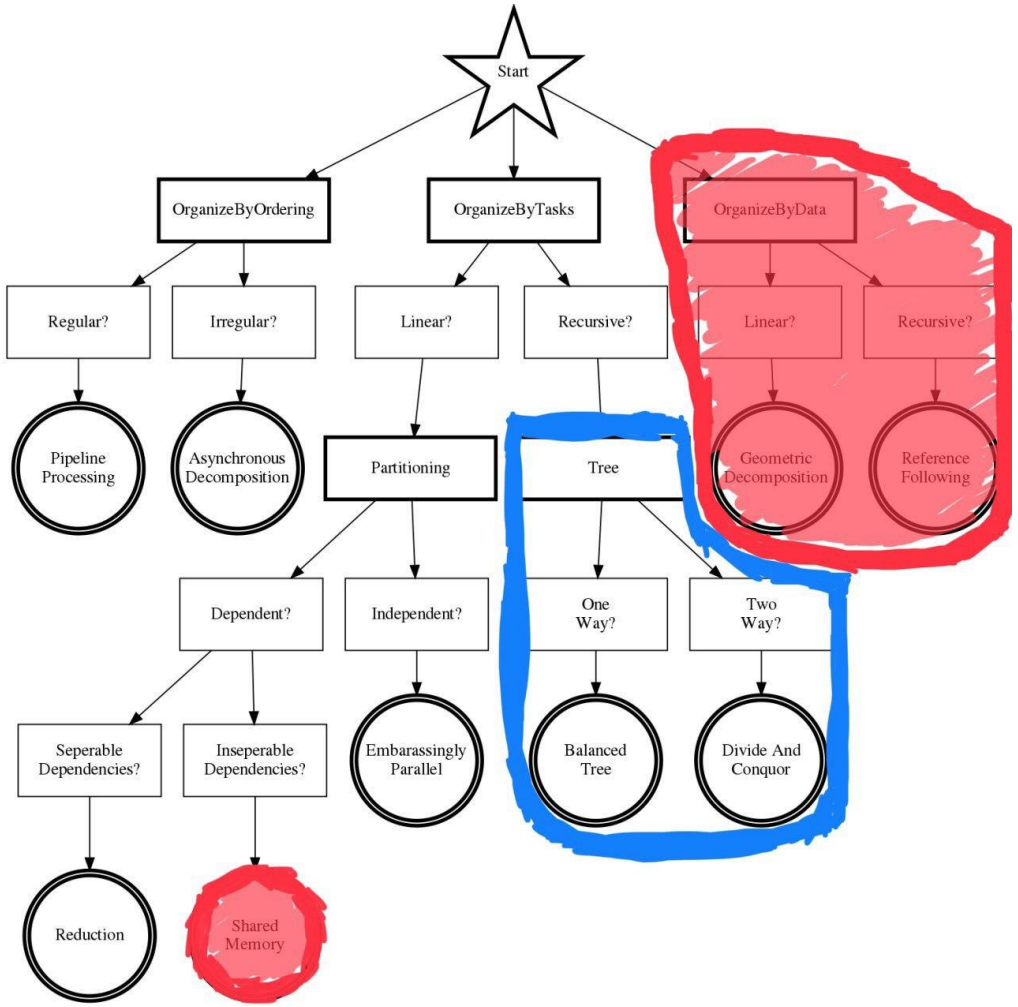
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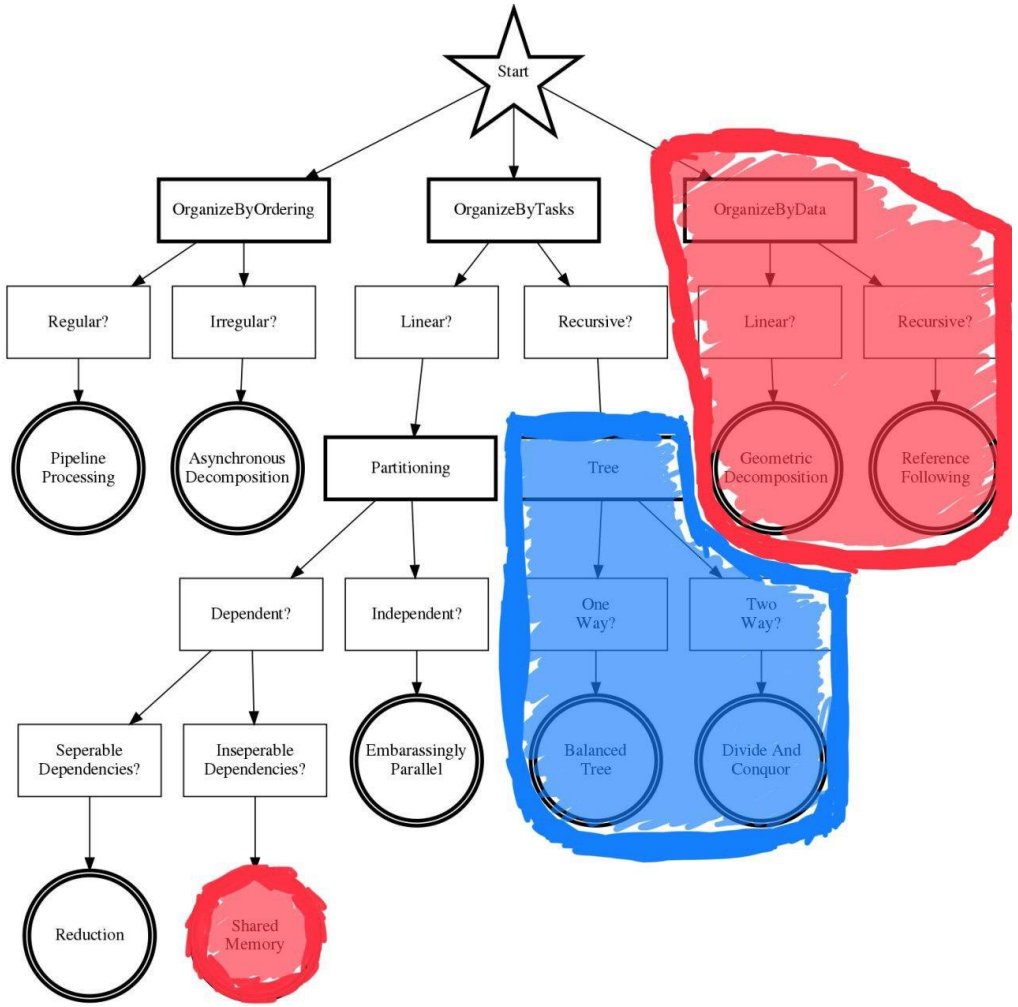
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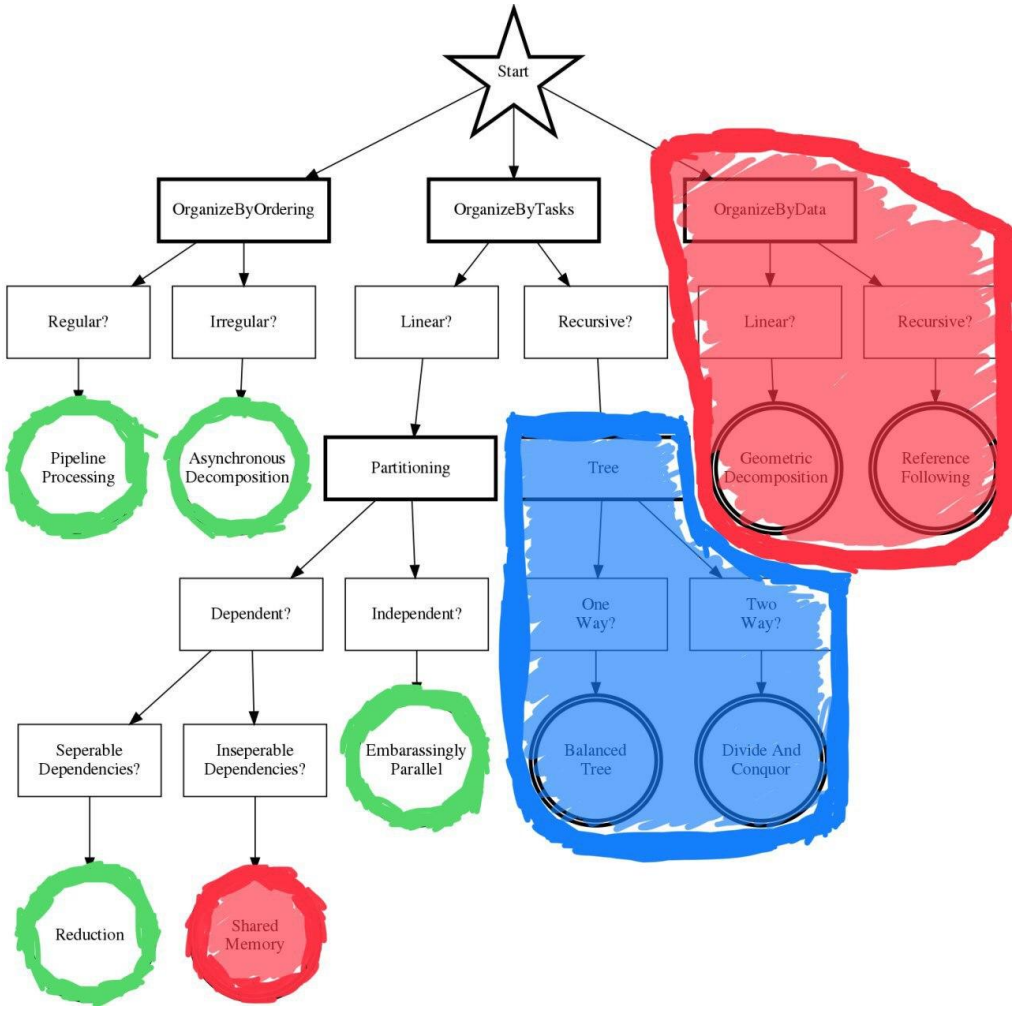
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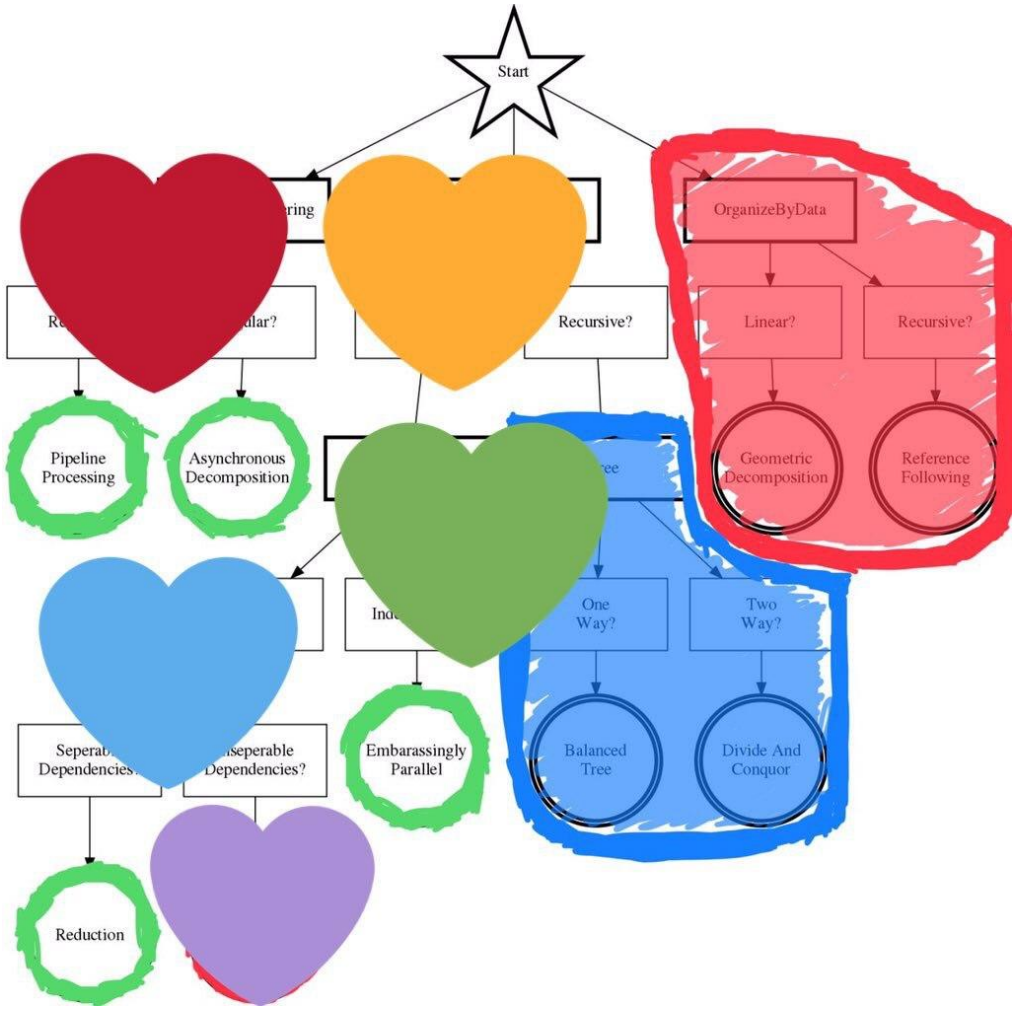
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Benchee Reduction

Benchee

ExUnit

Reduction

Asynchronous

Decomposition

Benchee	Reduction
ExUnit	Asynchronous Decomposition
GenStage	Pipeline Processing

Embarrassingly Parallel

Embarrassingly Parallel

```
def send_emails(emails) do # serial
  Enum.map(emails, fn email ->
    send_email(email)
  end)
end
```

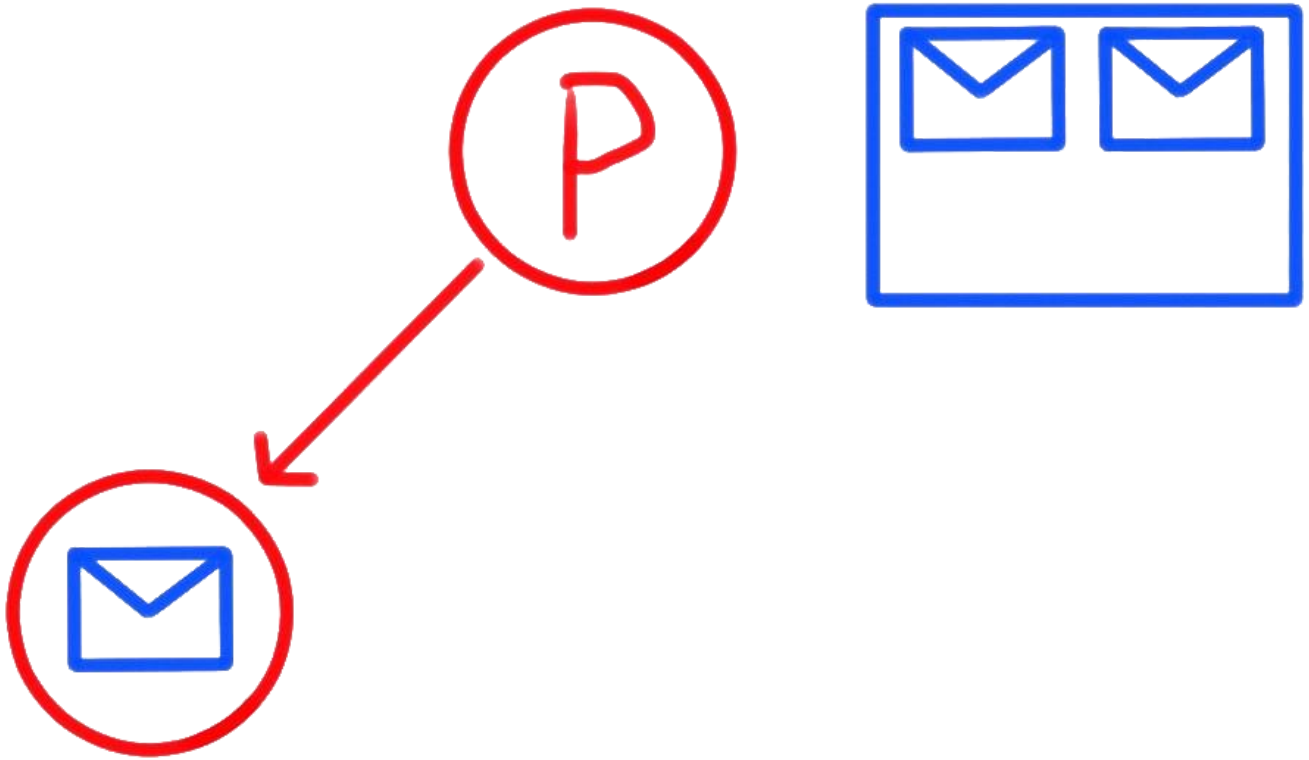
Embarrassingly Parallel

```
def send_emails(emails) do # serial
  Enum.map(emails, fn email ->
    send_email(email)
  end)
end

def send_emails(emails) do # parallel
  Enum.map(emails, fn email ->
    spawn(fn -> send_email(email) end)
  end)
end
```

Embarrassingly Parallel

```elixir
def send_emails(emails) do # serial
  Enum.map(emails, fn email ->
    send_email(email)
  end)
end

def send_emails(emails) do # parallel
  Enum.map(emails, fn email ->
    spawn(fn -> send_email(email) end)
  end)
end
```


P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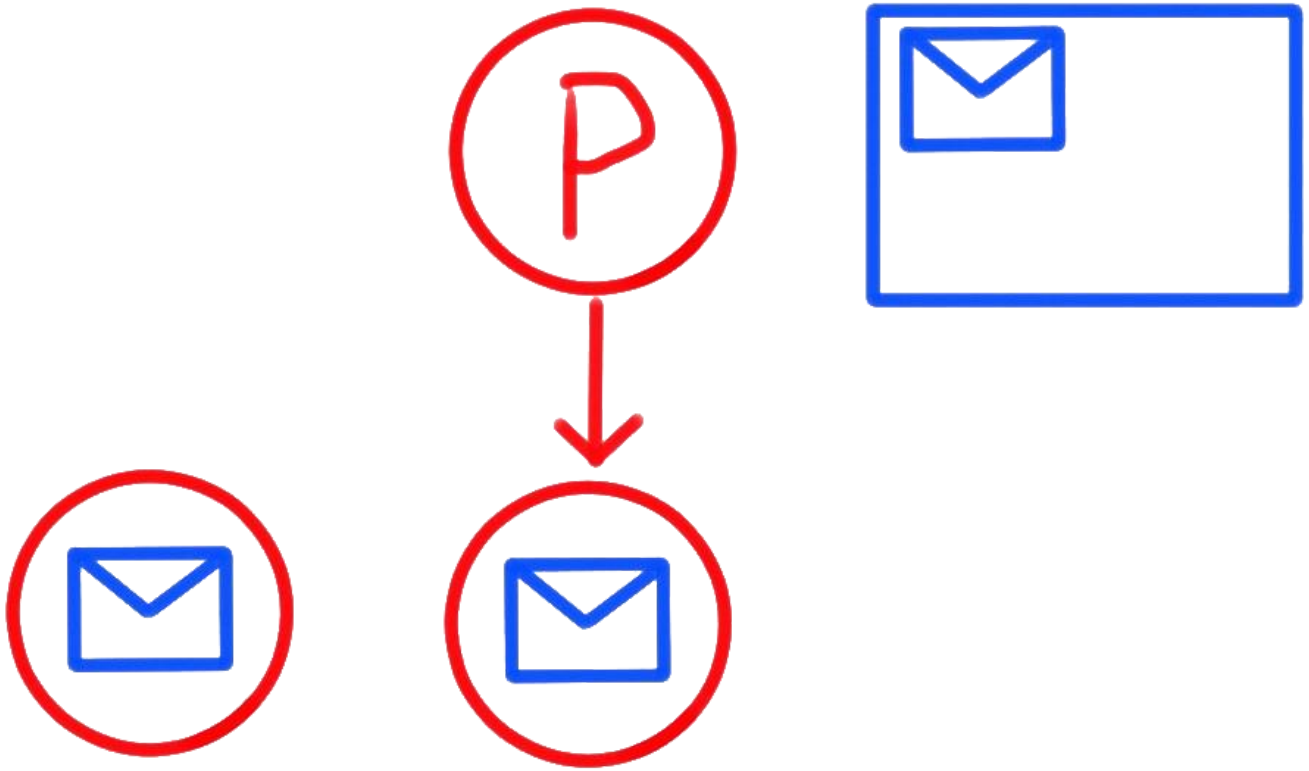
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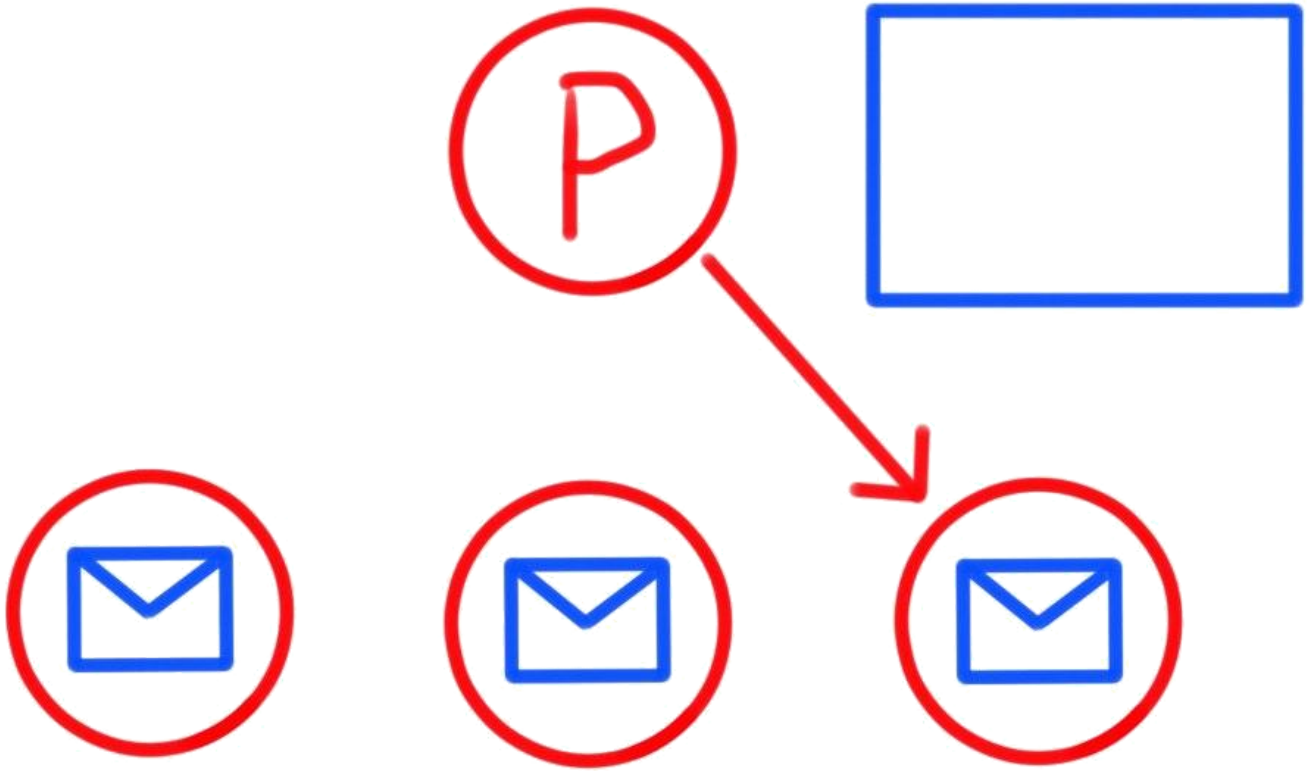
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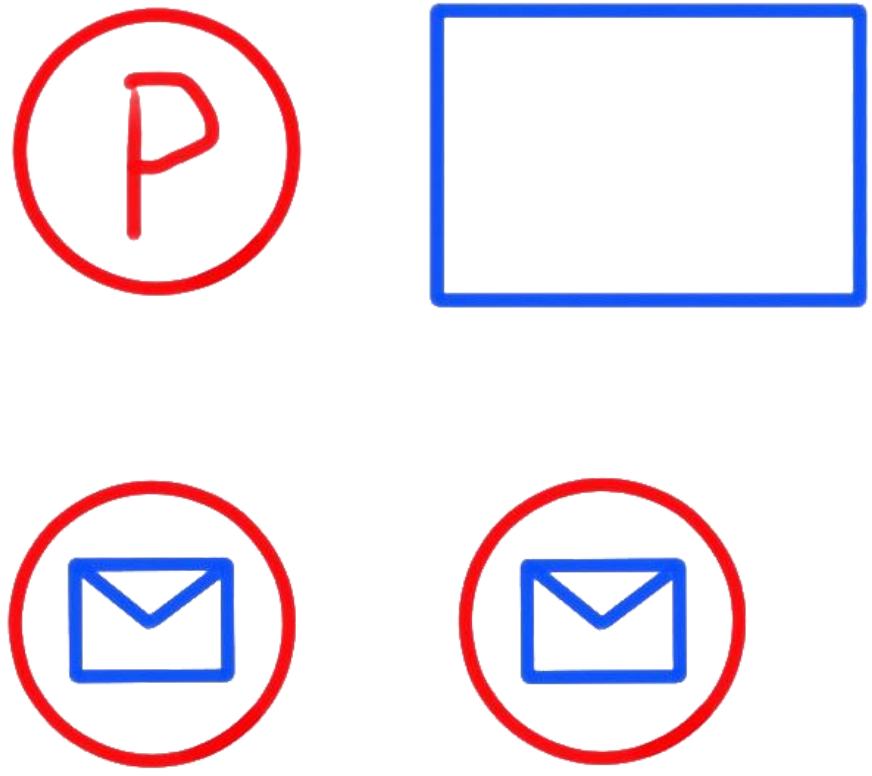
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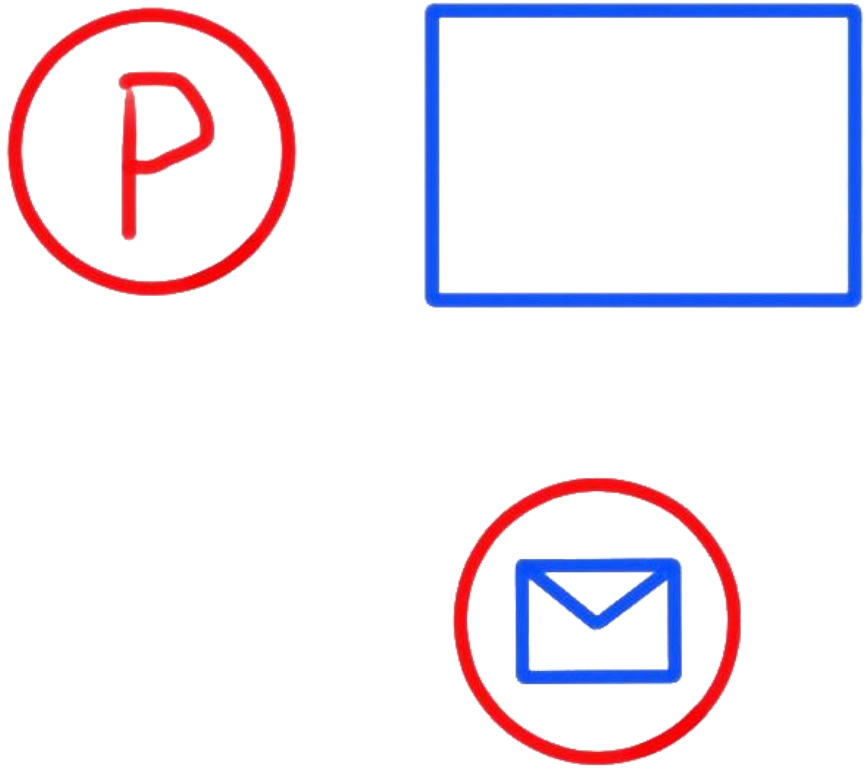

Done!

Embarrassingly Parallel

- Eagerly evaluated, linear input

Embarrassingly Parallel

- Eagerly evaluated, linear input
- No communication with parent

Embarrassingly Parallel

- Eagerly evaluated, linear input
- No communication with parent
- No communication with siblings

Embarrassingly Parallel

- Eagerly evaluated, linear input
- No communication with parent
- No communication with siblings
- No shared dependencies between siblings

Reduction

Reduction

```elixir
defmodule Parallel do
  def map(collection, func) do
    refs =
      Enum.map(collection, fn element ->
        Task.async(fn -> func.(element) end)
      end)

    Enum.map(refs, fn ref ->
      Task.await(ref, :infinity))
    end)
  end
end
```

Reduction

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defmodule Parallel do
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end
```

Basic async & await

```
def async(func) do
  ref = make_ref()
  me = self()
  spawn(fn -> send(me, {ref, func()}) end)
  ref
end
```

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def async(func) do
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def await(ref, timeout \\ :infinity) do
  receive do
    {^ref, value} -> value
    after timeout -> {:error, :timeout}
  end
end
```

Basic async & await

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  ref
end


def await(ref, timeout \\ :infinity) do
  receive do
    {^ref, value} -> value
    after timeout -> {:error, :timeout}
  end
end
```

```
me = self()

fun = fn seconds ->
  Process.sleep(seconds * 1000)    # Simulate some expensive work
  send(me, Time.utc_now().second)
end
```

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me = self()

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end


Time.utc_now().second              #=> 48
```

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Time.utc_now().second              #=> 48


Parallel.map([1, 2, 3, 1], fun)    #=> [49, 50, 51, 49]
```

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me = self()

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  Process.sleep(seconds * 1000)    # Simulate some expensive work
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Time.utc_now().second              #=> 48


Parallel.map([1, 2, 3, 1], fun)    #=> [49, 50, 51, 49]


Time.utc_now().second              #=> 51
```

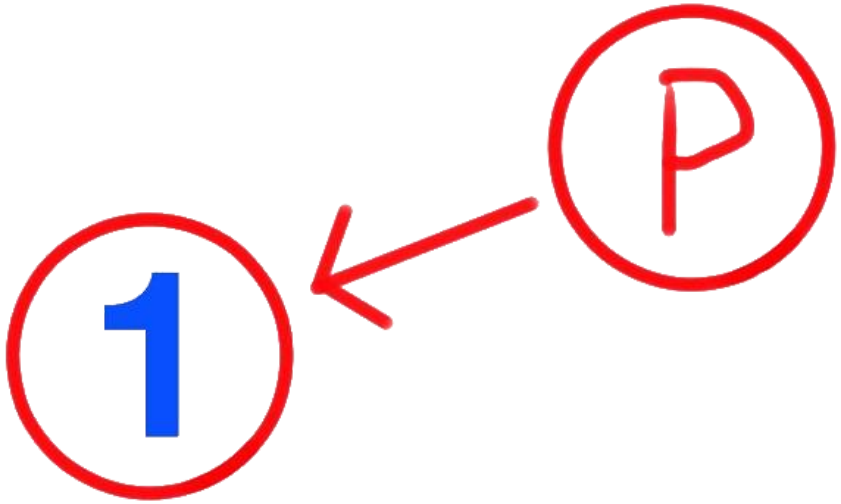
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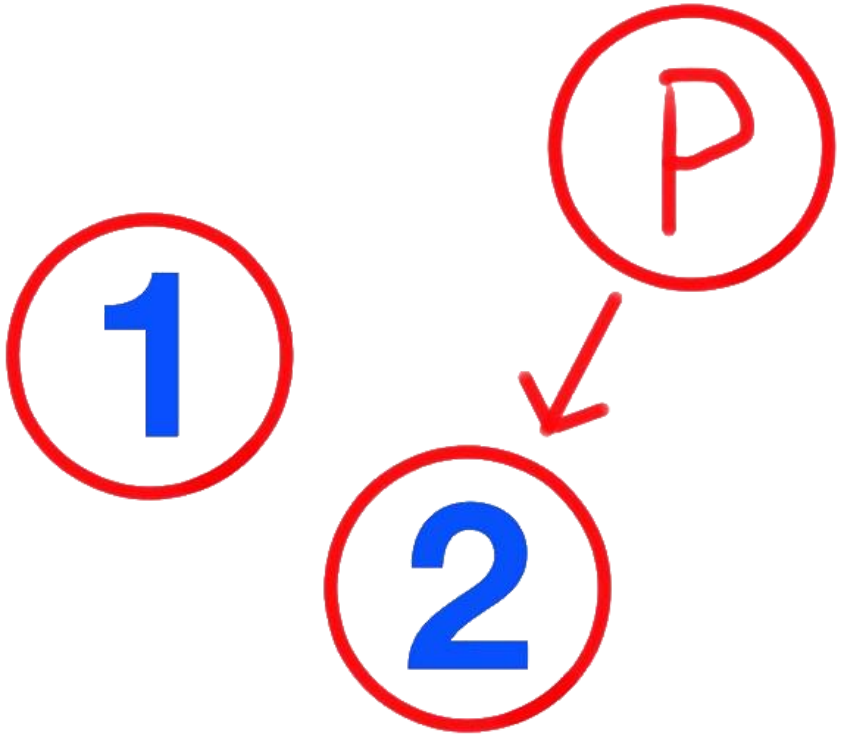
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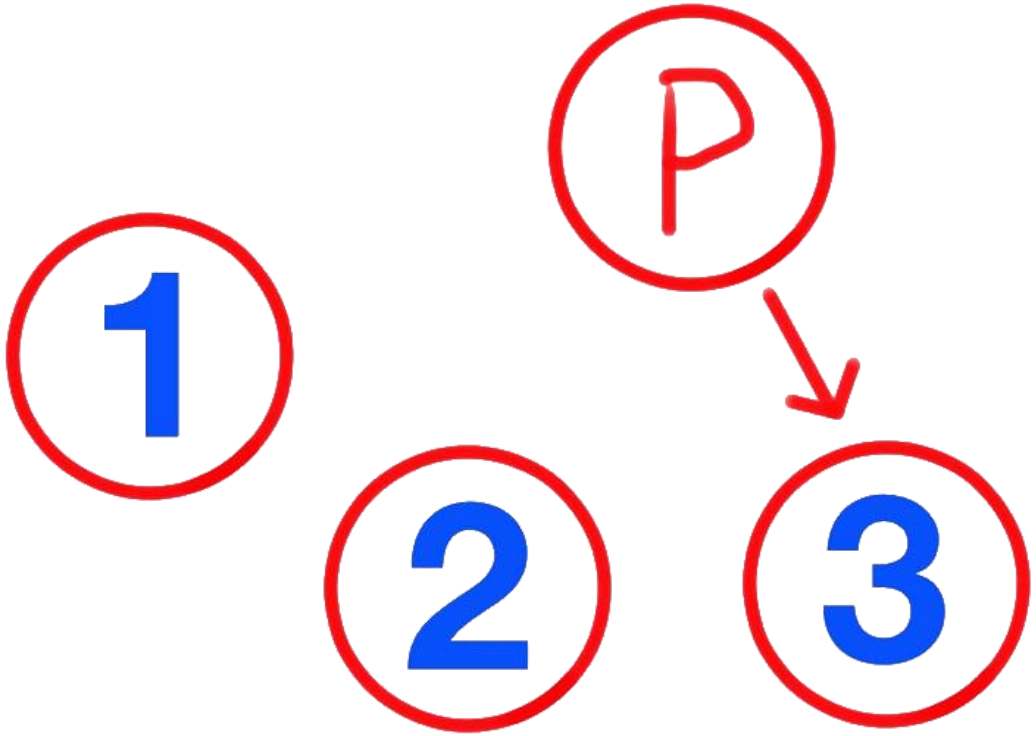
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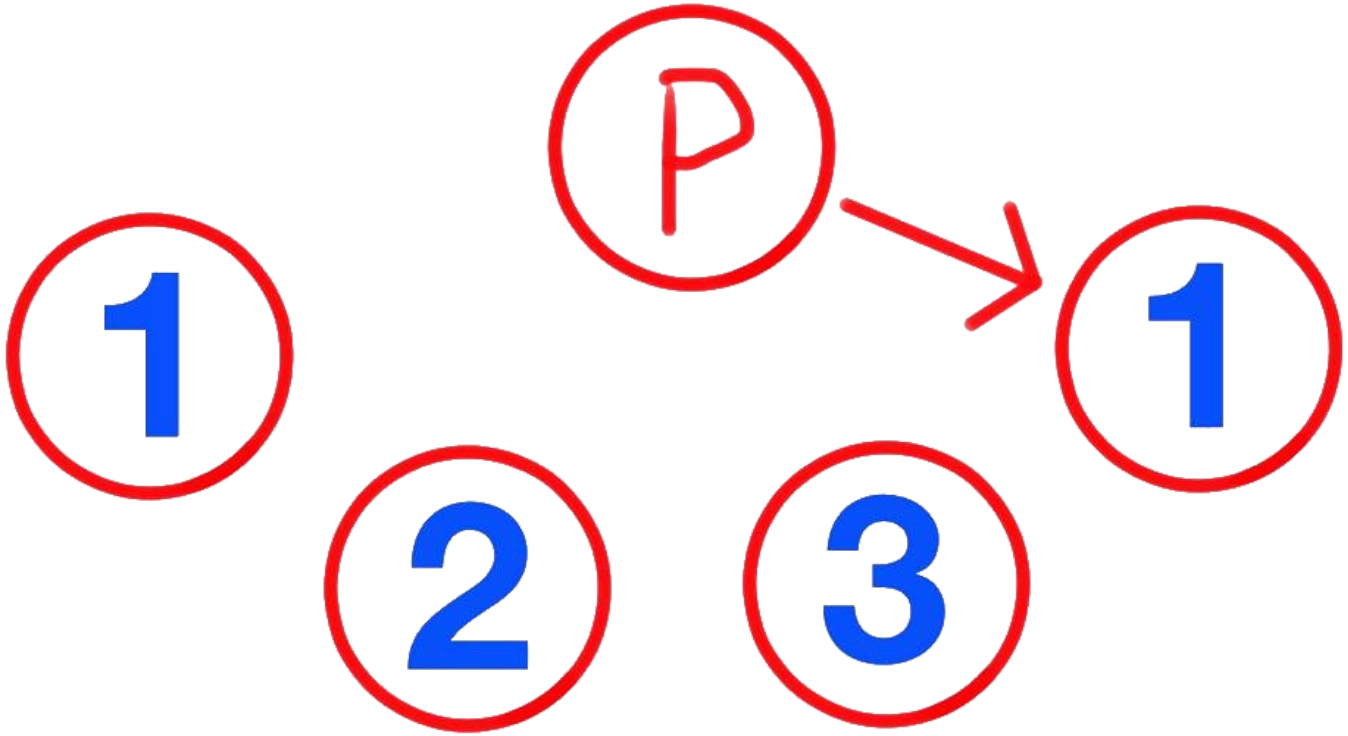
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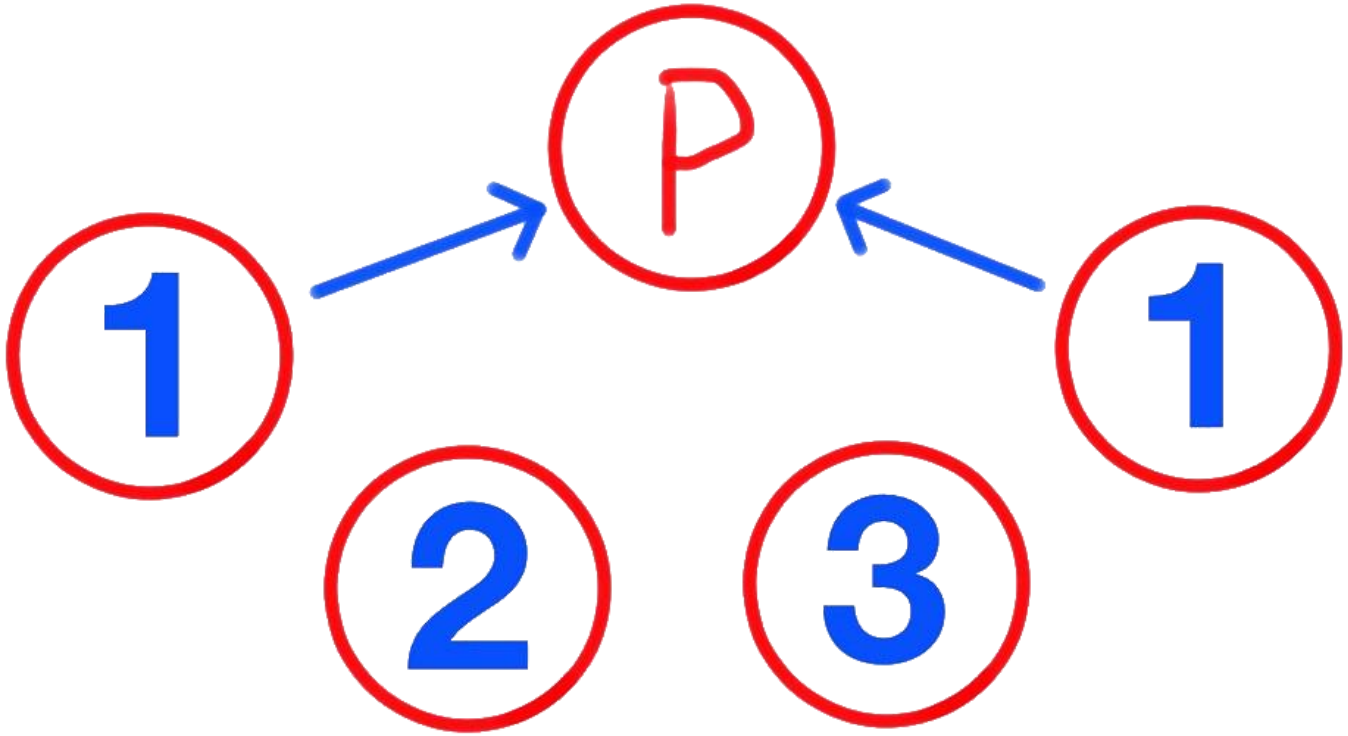
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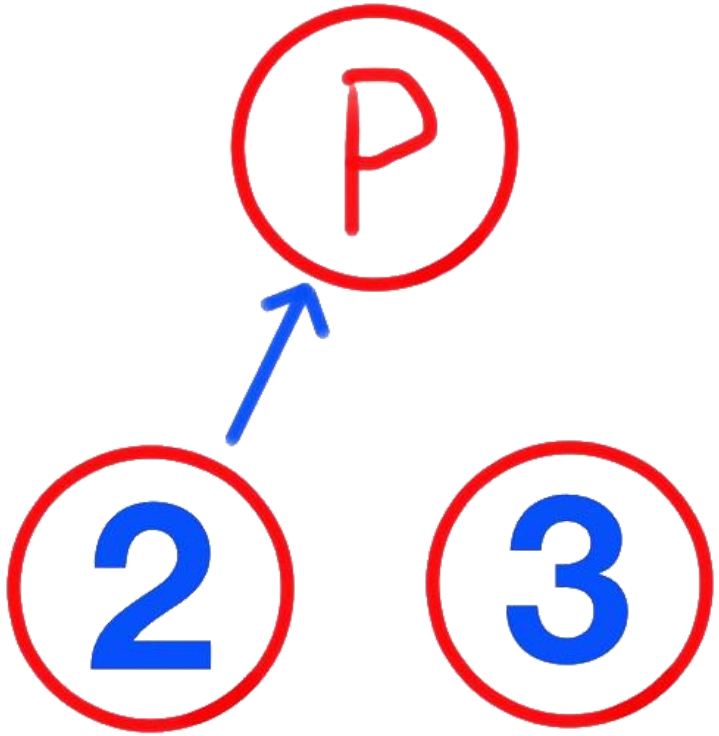
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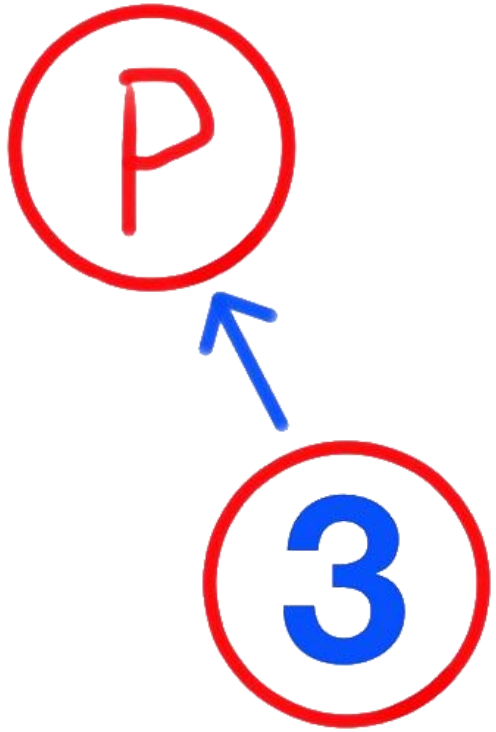
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3

Basic async & await

```
def async(func) do
  ref = make_ref()
  me = self()
  spawn(fn -> send(me, {ref, func()}) end)
  ref
end

def await(ref, timeout \\ :infinity) do
  receive do
    {^ref, value} -> value
    after timeout -> {:error, :timeout}
  end
end
```

Distributed Async & Await

```
def async(func, node \\ Node.self()) do
  ref = make_ref()
  me = self()
  Node.spawn(node, fn -> send(me, {ref, func()}) end)
  ref
end

def await(ref, timeout) do
  receive do
    {^ref, value} -> value
    after timeout -> {:error, :timeout}
  end
end
```

Reduction

- Eagerly evaluated, linear input

Reduction

- Eagerly evaluated, linear input
- Communication with parent allowed!

Reduction

- Eagerly evaluated, linear input
- Communication with parent allowed!
- No communication between children

Reduction

- Eagerly evaluated, linear input
- Communication with parent allowed!
- No communication between children
- No shared dependencies between children

Asynchronous Decomposition

Asynchronous Decomposition

```
def run() do
  # ...
end

def loop(:async) do
  # ...
end

def loop(:sync) do
  # ...
end

def run_module(mod) do
  # ...
end

def run_test(test) do
  # ...
end
```

Asynchronous Decomposition

```
def run() do
  EventManager.start()

  EventManager.suite_started()
  loop(:async)
  EventManager.suite_finished()

  results = EventManager.get_results()
  EventManger.stop()
  results
end
```

Asynchronous Decomposition

```
def loop(:async) do
  case wait_for_module(:async) do
    {:ok, mod} ->
      spawn(fn -> run_module(mod) end)
      loop(:async)

    {:error, :no_more_async_modules} ->
      loop(:sync)
  end
end
```

Asynchronous Decomposition

```elixir
def loop(:async) do
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Asynchronous Decomposition

```elixir
def loop(:async) do
  case wait_for_module(:async) do
    {:ok, mod} ->
      spawn(fn -> run_module(mod) end)   # non-blocking
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      loop(:sync)
  end
end

def loop(:sync) do
  case wait_for_module(:sync) do
    {:ok, mod} ->
      run_module(mod)
      loop(:sync)

    {:error, :no_more_modules} ->
      :ok
  end
end
```

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      loop(:sync)
  end
end

def loop(:sync) do
  case wait_for_module(:sync) do
    {:ok, mod} ->
      run_module(mod)
      loop(:sync)

    {:error, :no_more_modules} ->
      :ok
  end
end
```

Asynchronous Decomposition

```elixir
def loop(:async) do
  case wait_for_module(:async) do
    {:ok, mod} ->
      spawn(fn -> run_module(mod) end)   # non-blocking
      loop(:async)

    {:error, :no_more_async_modules} ->
      loop(:sync)
  end
end

def loop(:sync) do
  case wait_for_module(:sync) do
    {:ok, mod} ->
      run_module(mod)                    # blocking
      loop(:sync)

    {:error, :no_more_modules} ->
      :ok
  end
end
```

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def loop(:async) do
  case wait_for_module(:async) do
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      loop(:sync)
  end
end

def loop(:sync) do
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def loop(:sync) do
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    {:ok, mod} ->
      run_module(mod)                    # blocking
      loop(:sync)

    {:error, :no_more_modules} ->
      :ok
  end
end
```

Asynchronous Decomposition

```elixir
def run_module(mod) do
  EventManager.module_started(mod)

  mod
  |> get_tests()
  |> Enum.map(&run_test/1)

  EventManager.module_finished(mod)
end
```

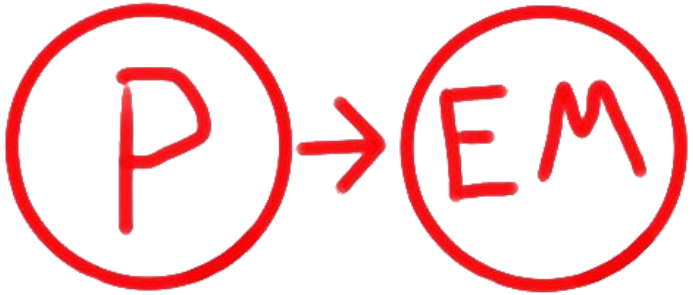
Asynchronous Decomposition

```
def run_module(mod) do
  EventManager.module_started(mod)

  mod
  |> get_tests()
  |> Enum.map(&run_test/1)

  EventManager.module_finished(mod)
end


def run_test(test) do
  EventManager.test_started(test)
  result = run(test)
  EventManager.test_finished(result)
end
```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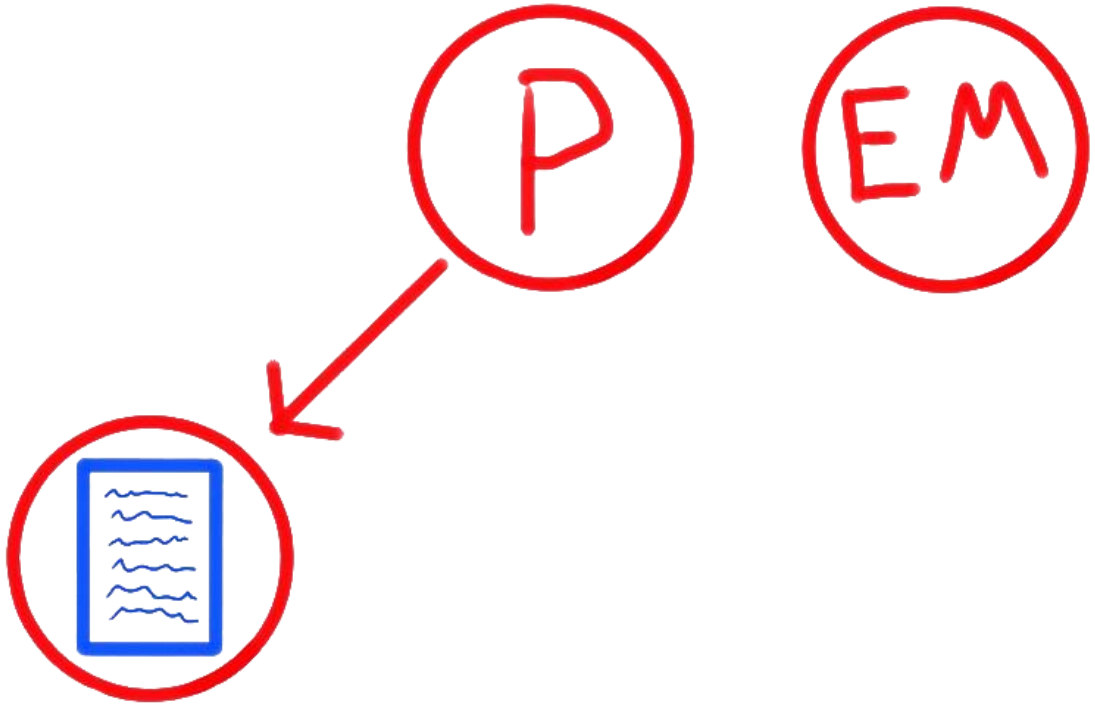
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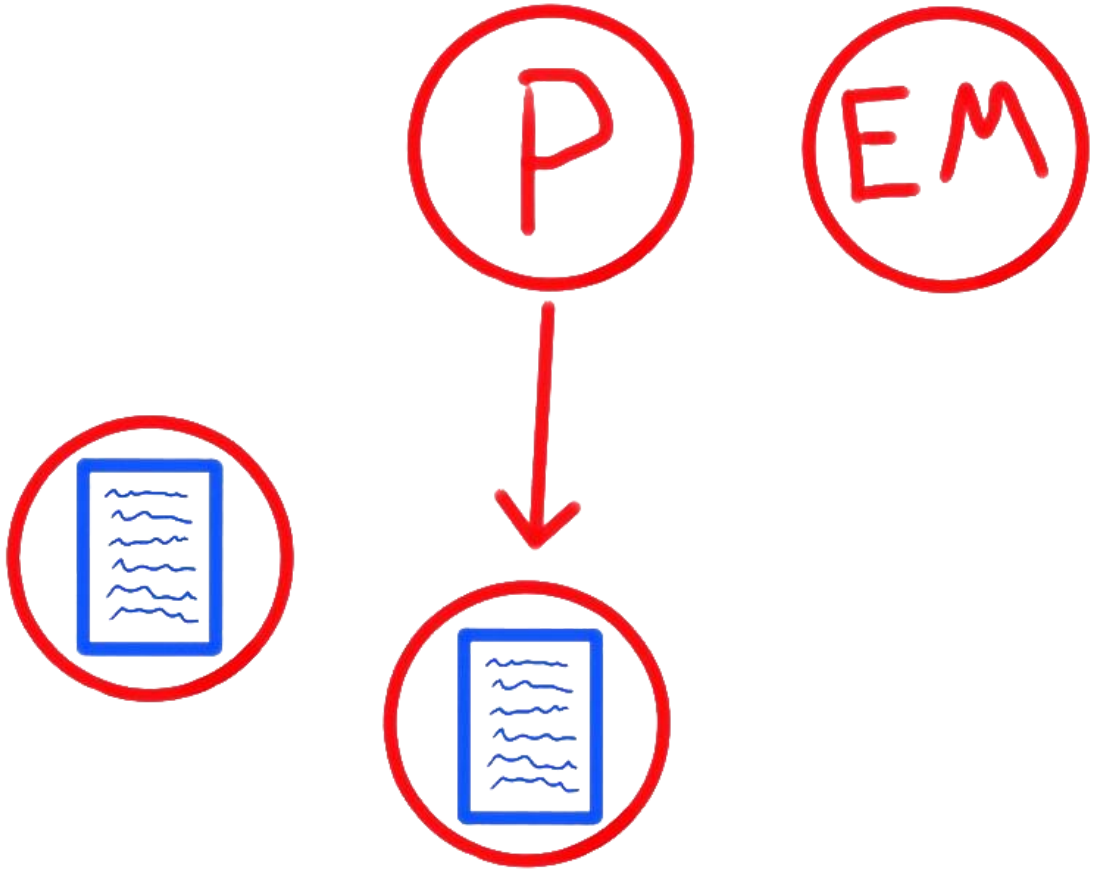
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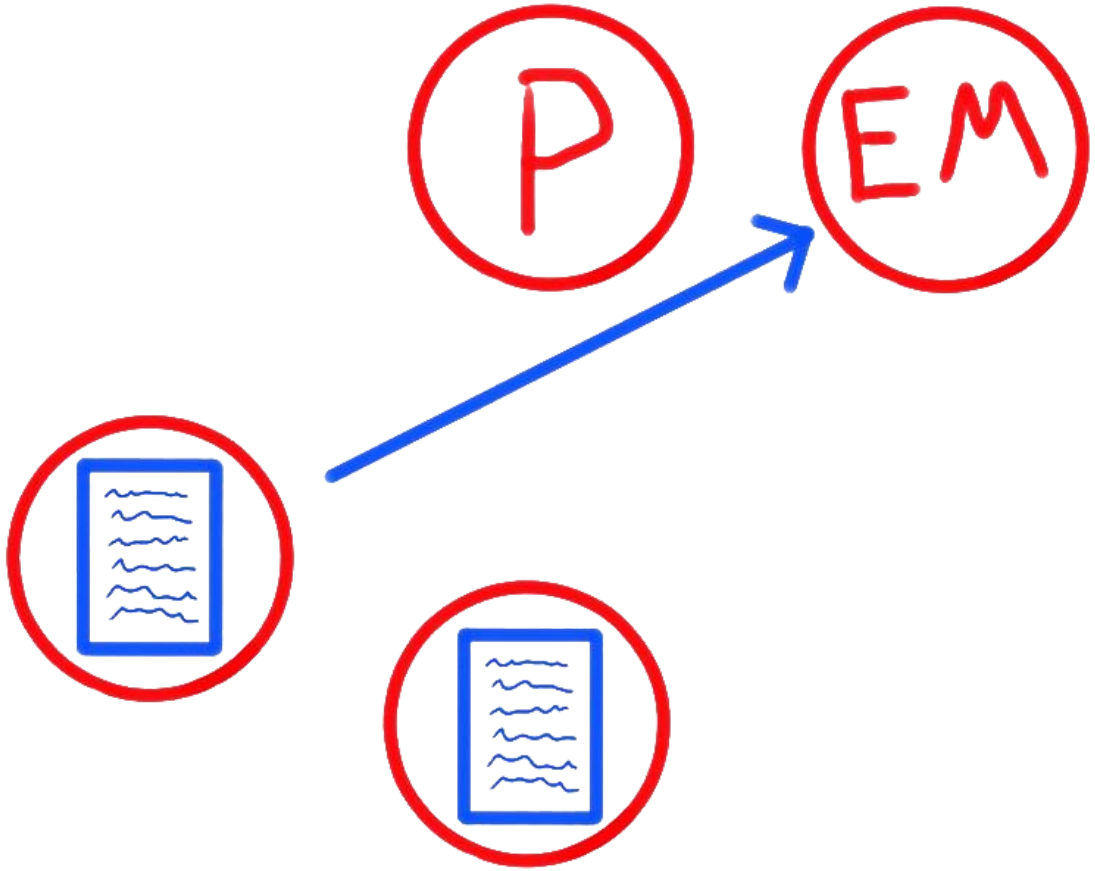
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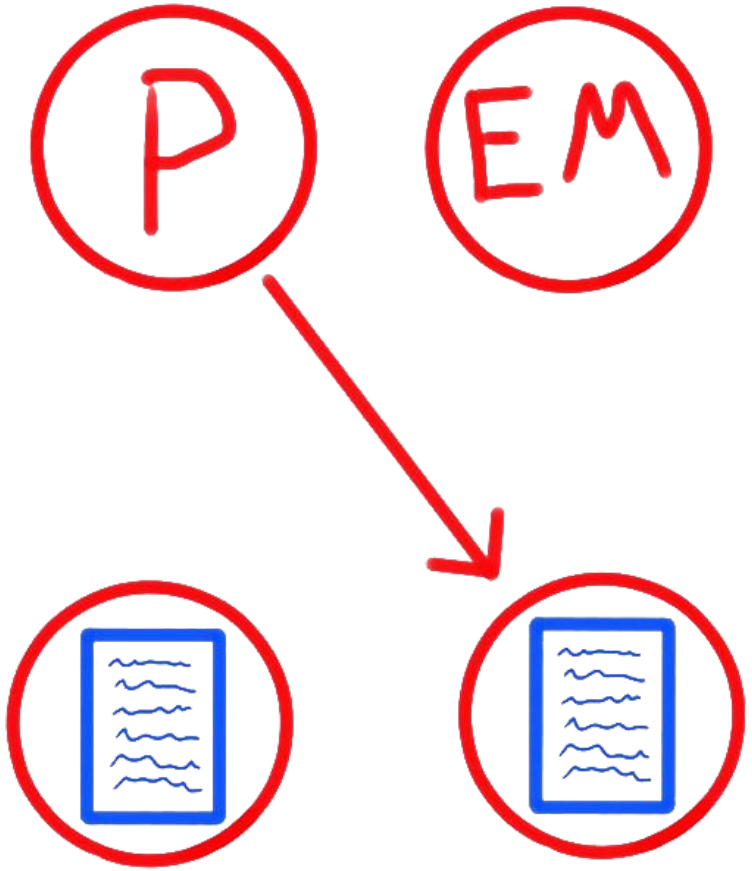
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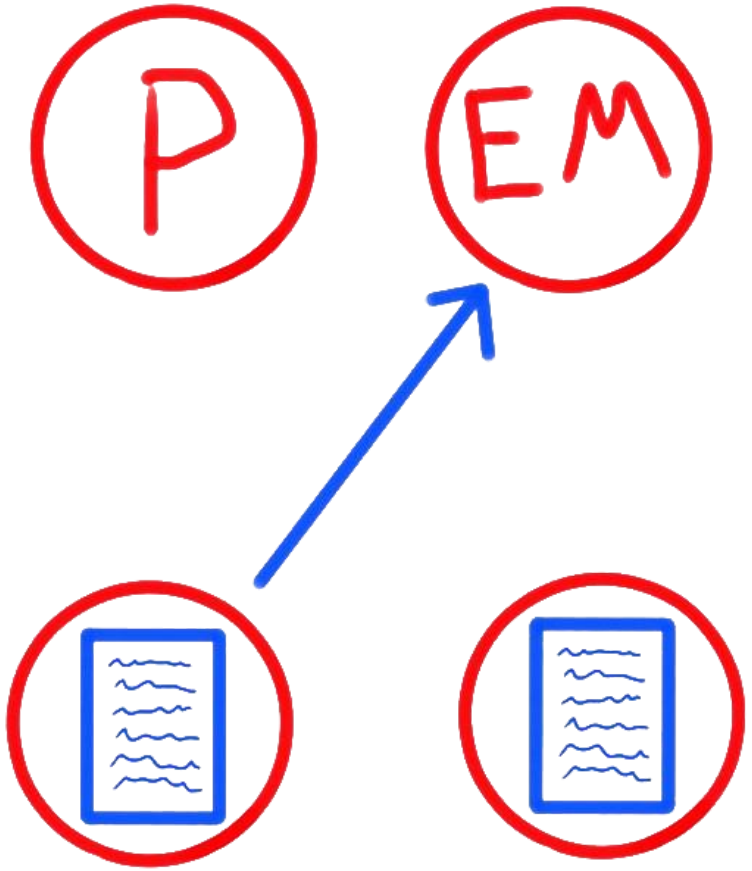
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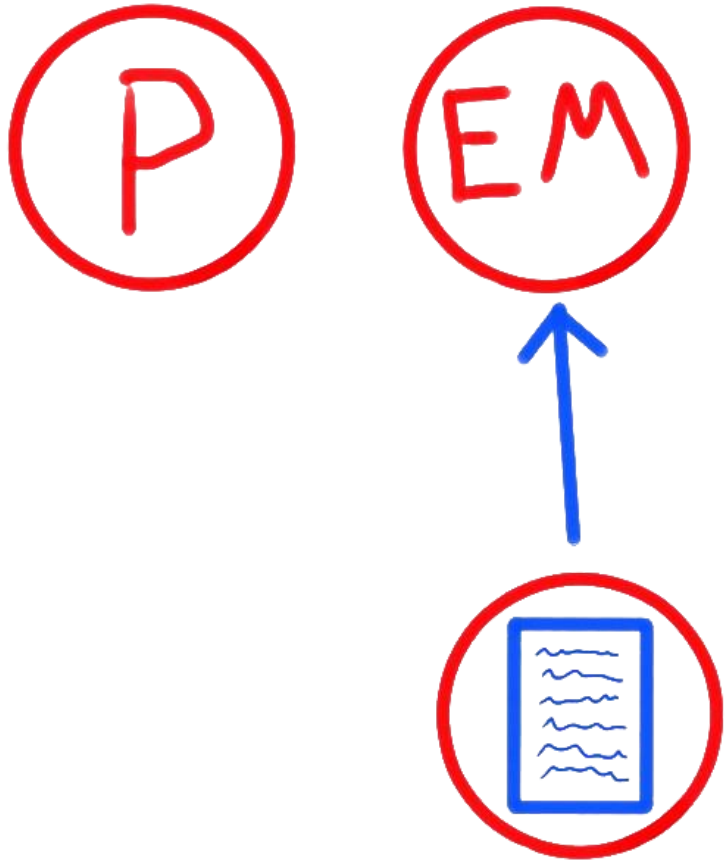
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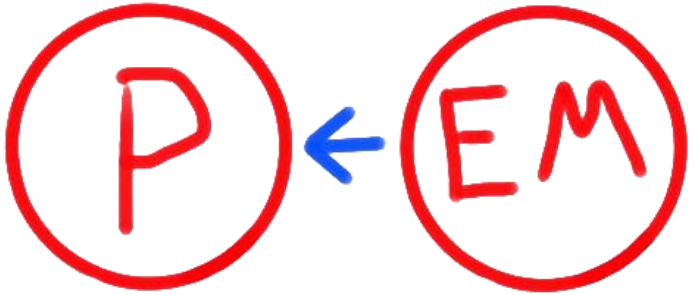
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Asynchronous Decomposition

- Lazily evaluated input of unknown size

Asynchronous Decomposition

- Lazily evaluated input of unknown size
- Communication with parent allowed

Asynchronous Decomposition

- Lazily evaluated input of unknown size
- Communication with parent allowed
- No communication between siblings

Asynchronous Decomposition

- Lazily evaluated input of unknown size
- Communication with parent allowed
- No communication between siblings
- No shared dependencies between siblings

ExUnit As Reduction

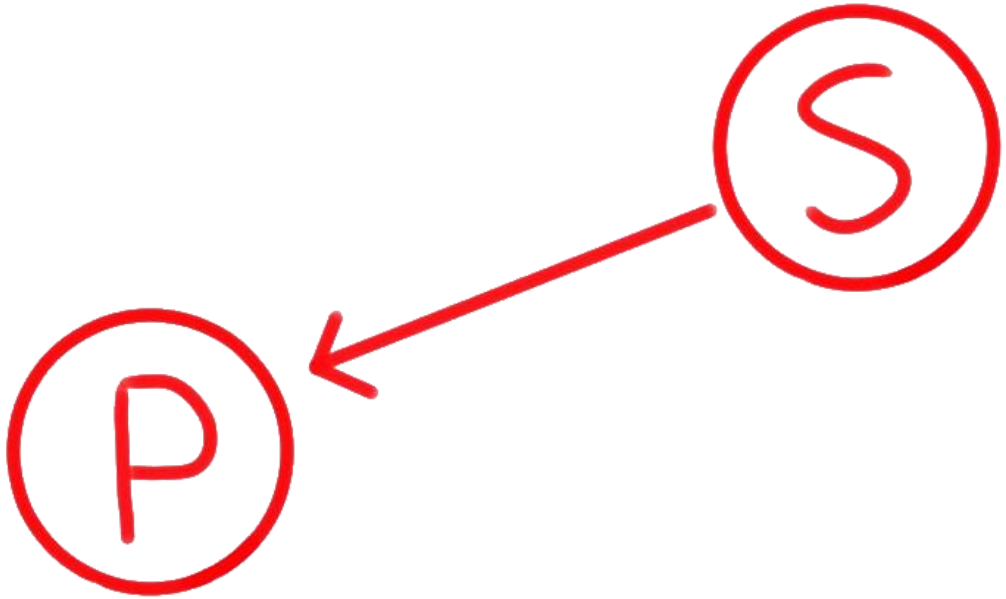
```
def run() do
  {sync_modules, async_modules} = load_modules()

  results =
    Parallel.map(async_modules, &run_module/1) ++
      Enum.map(sync_modules, &run_module/1)

  format_results(results)
end
```

Pipeline Processing


S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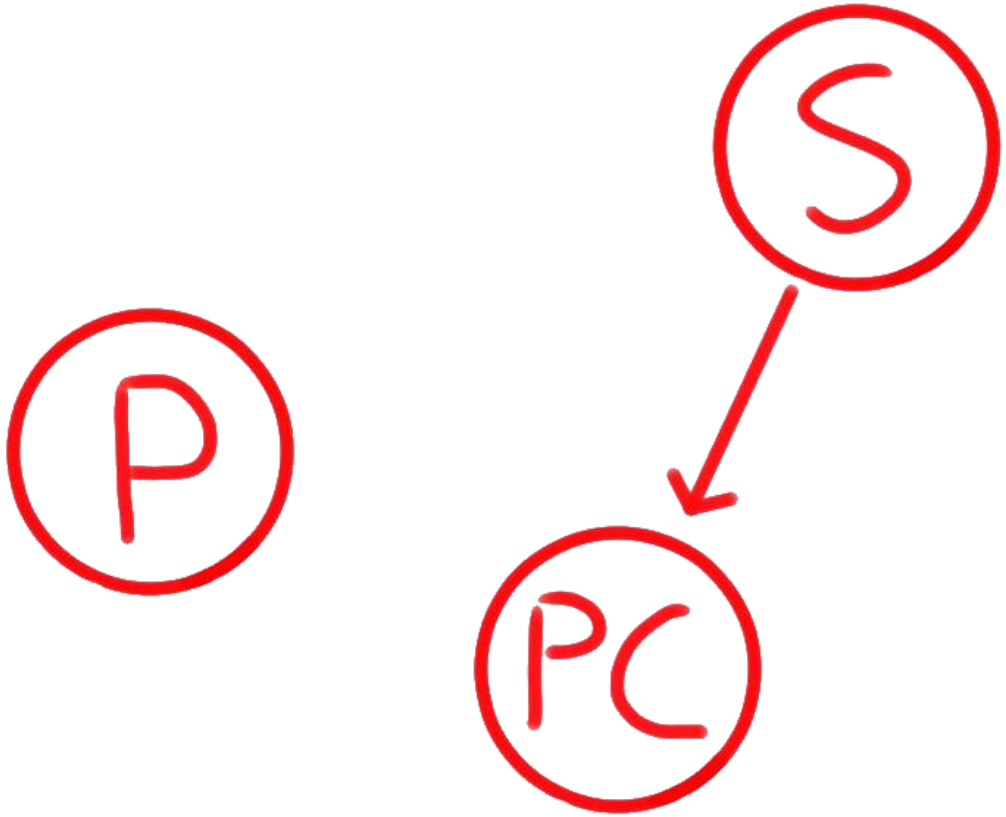
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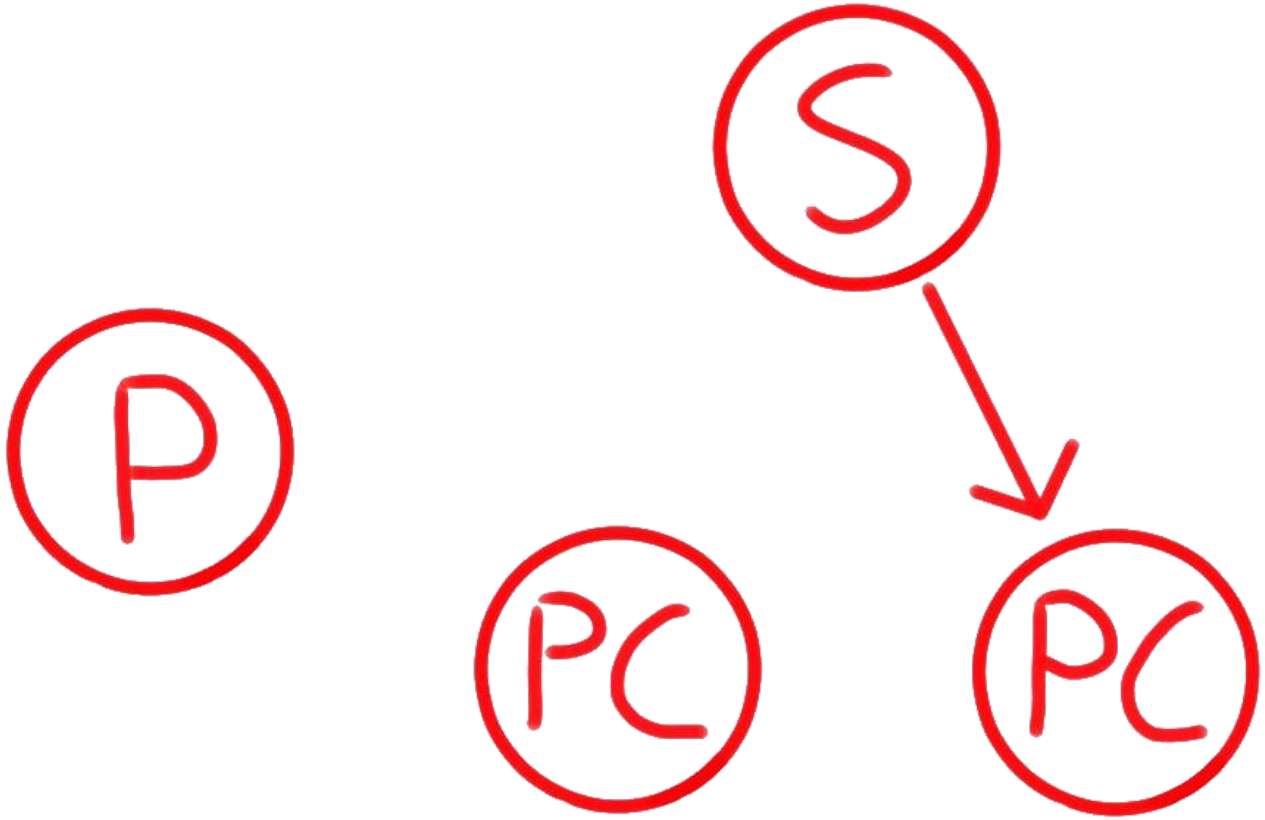
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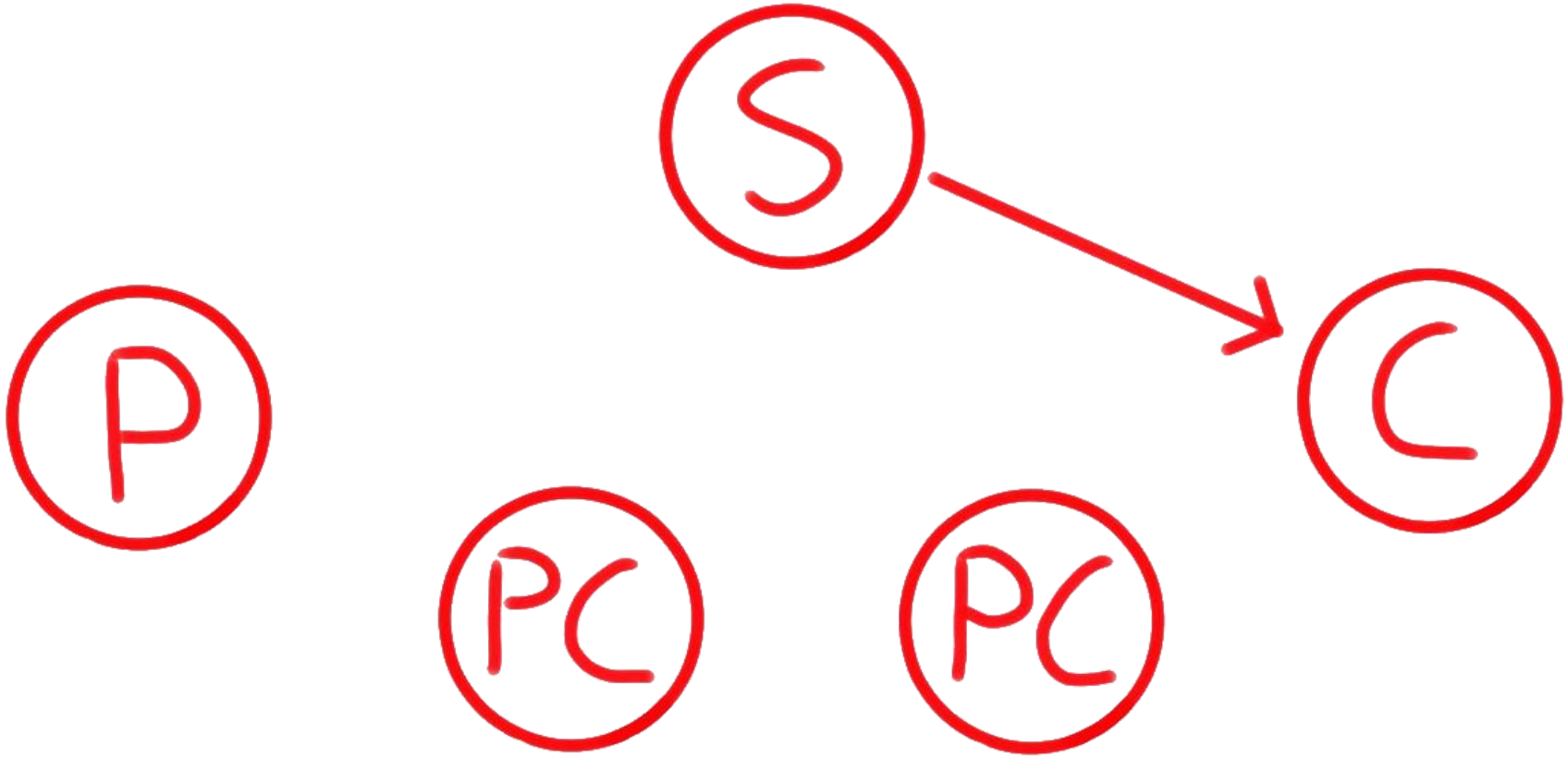
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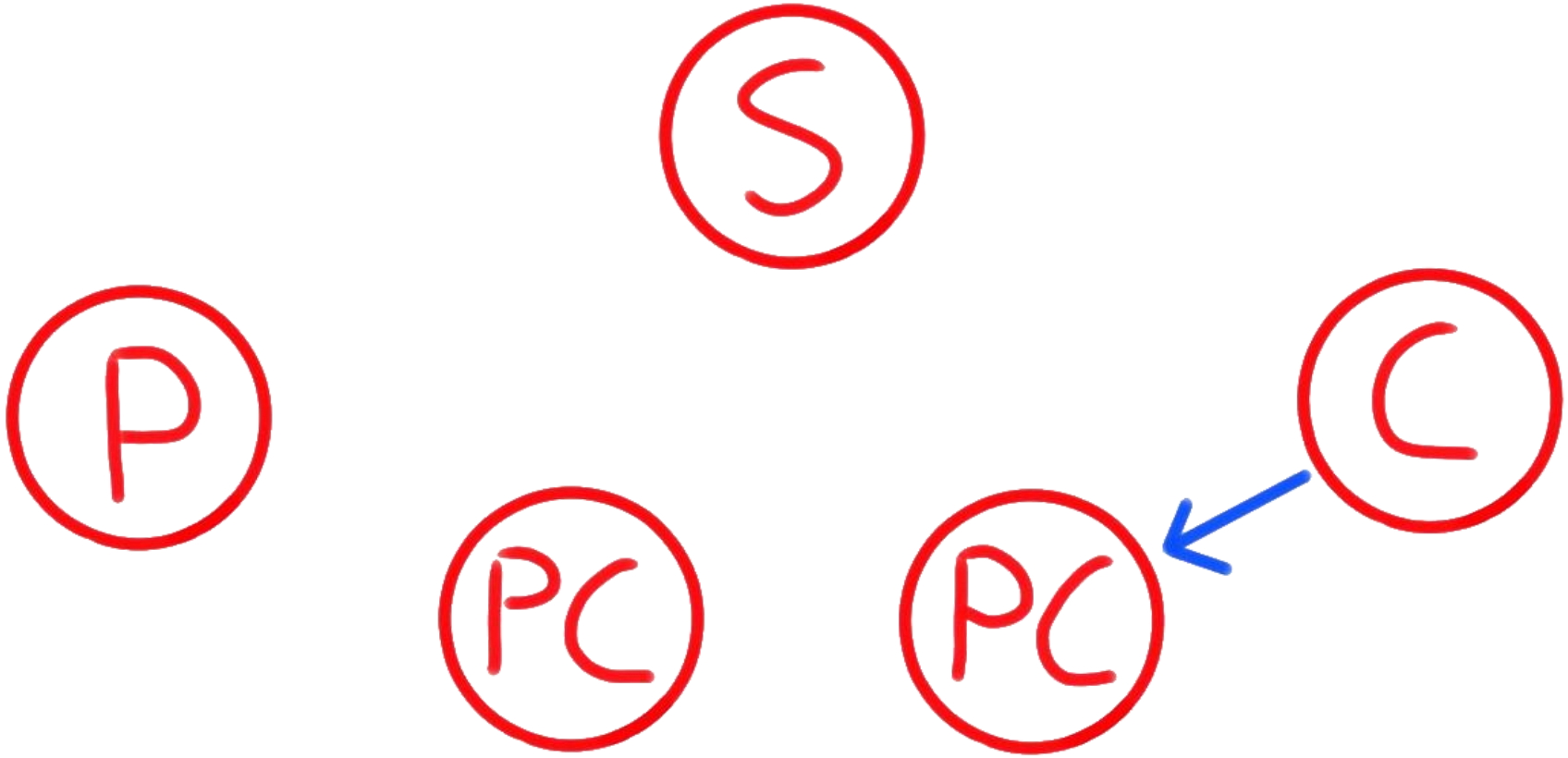
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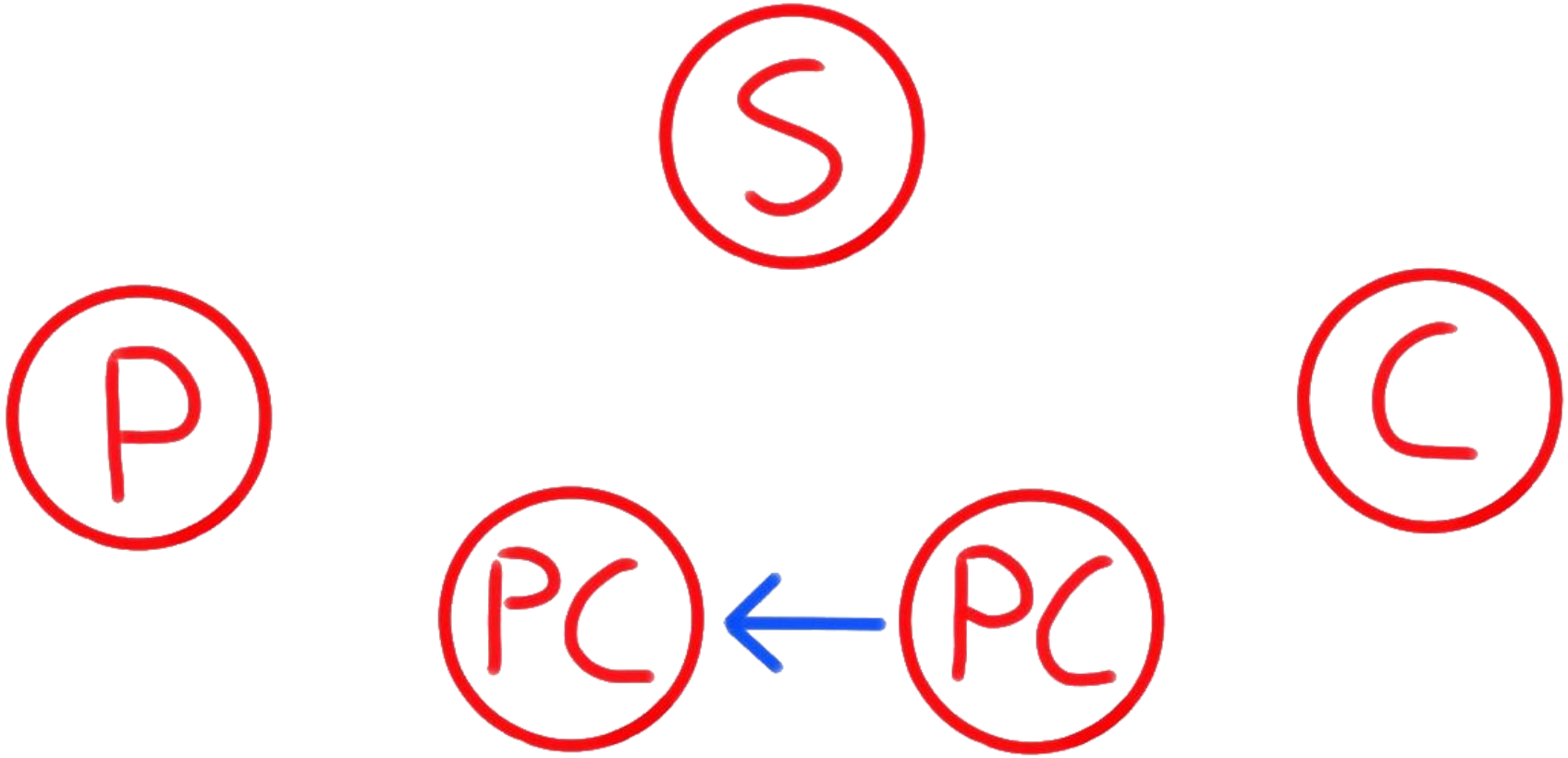
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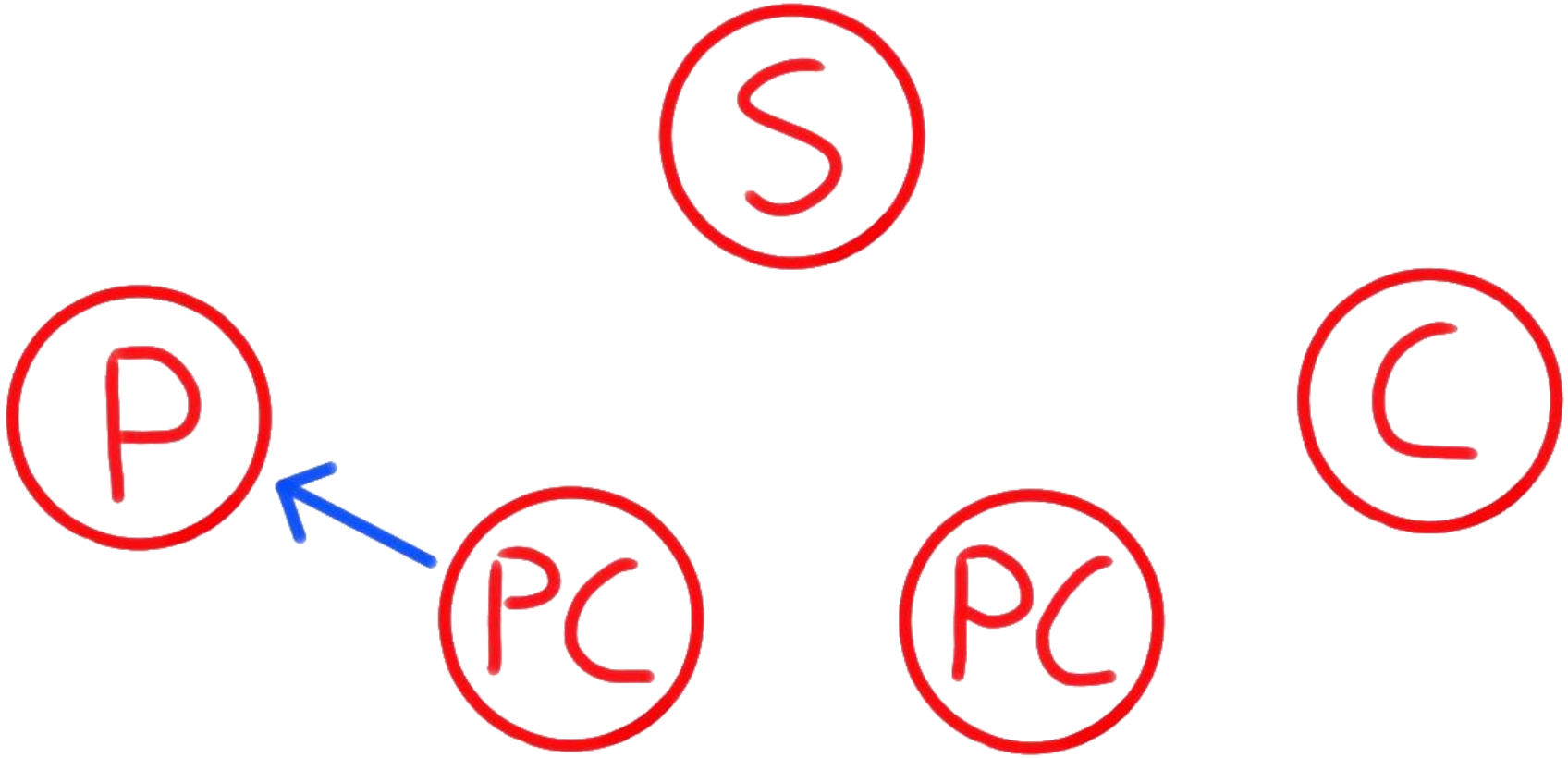
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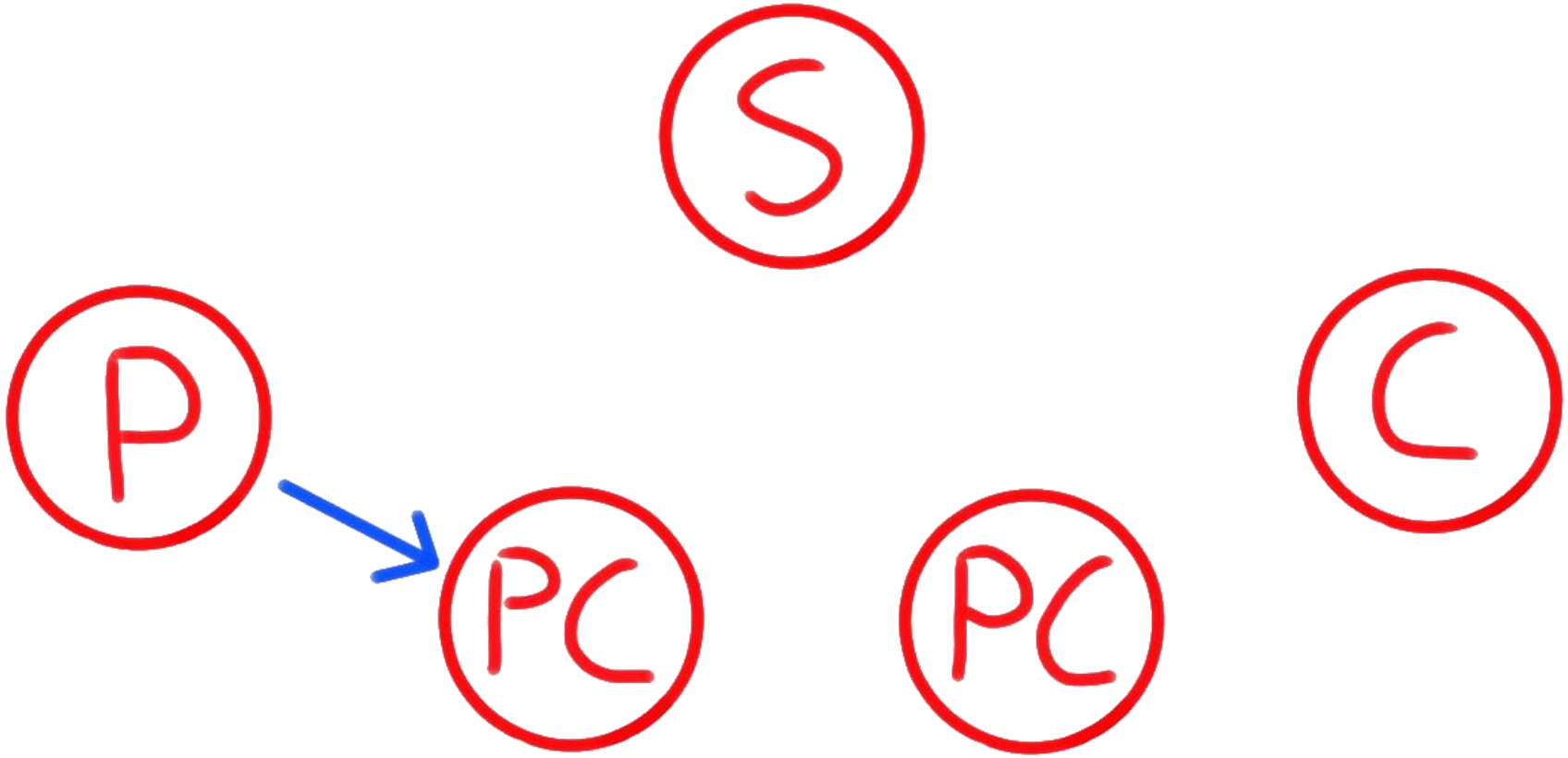
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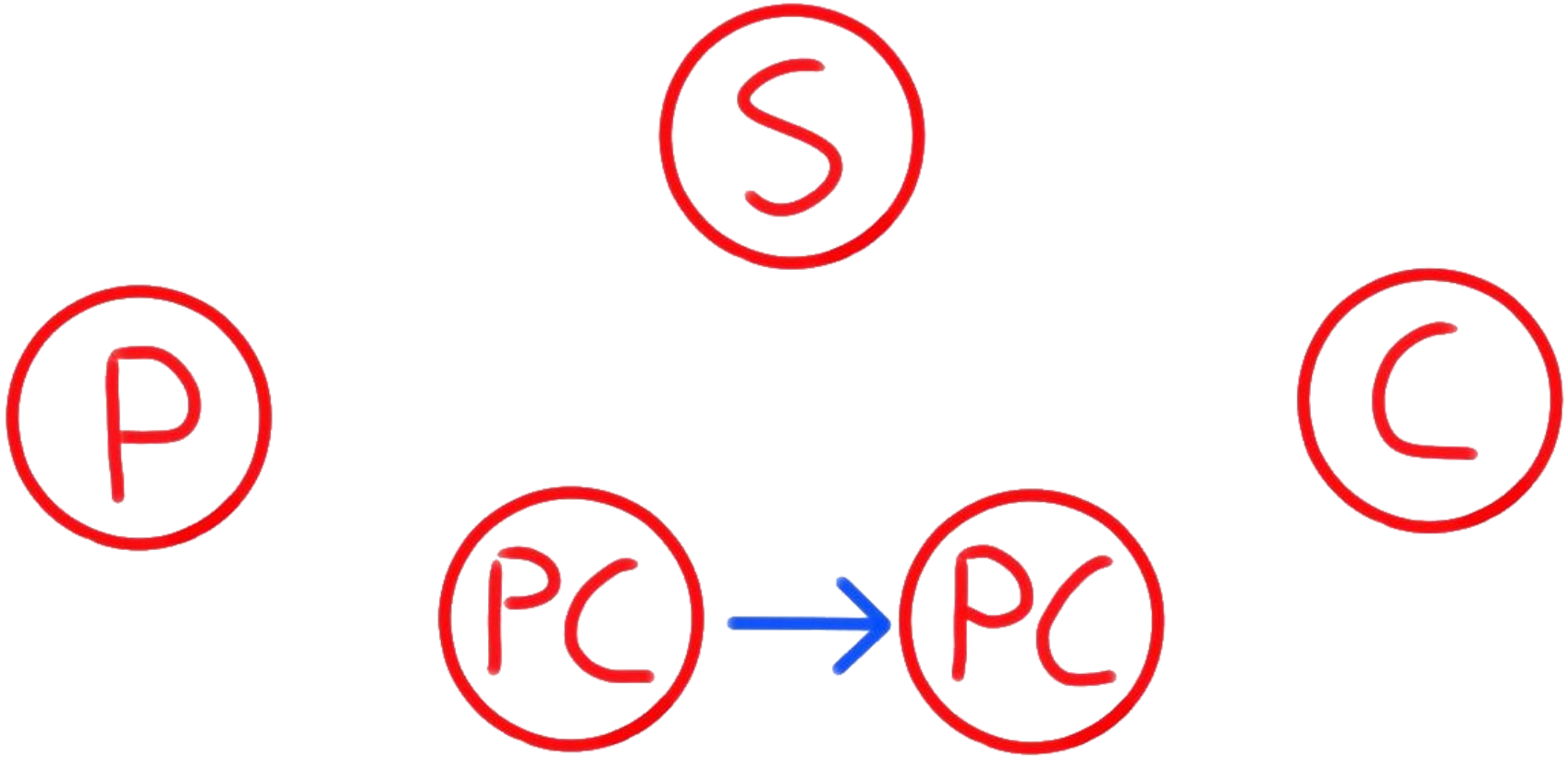
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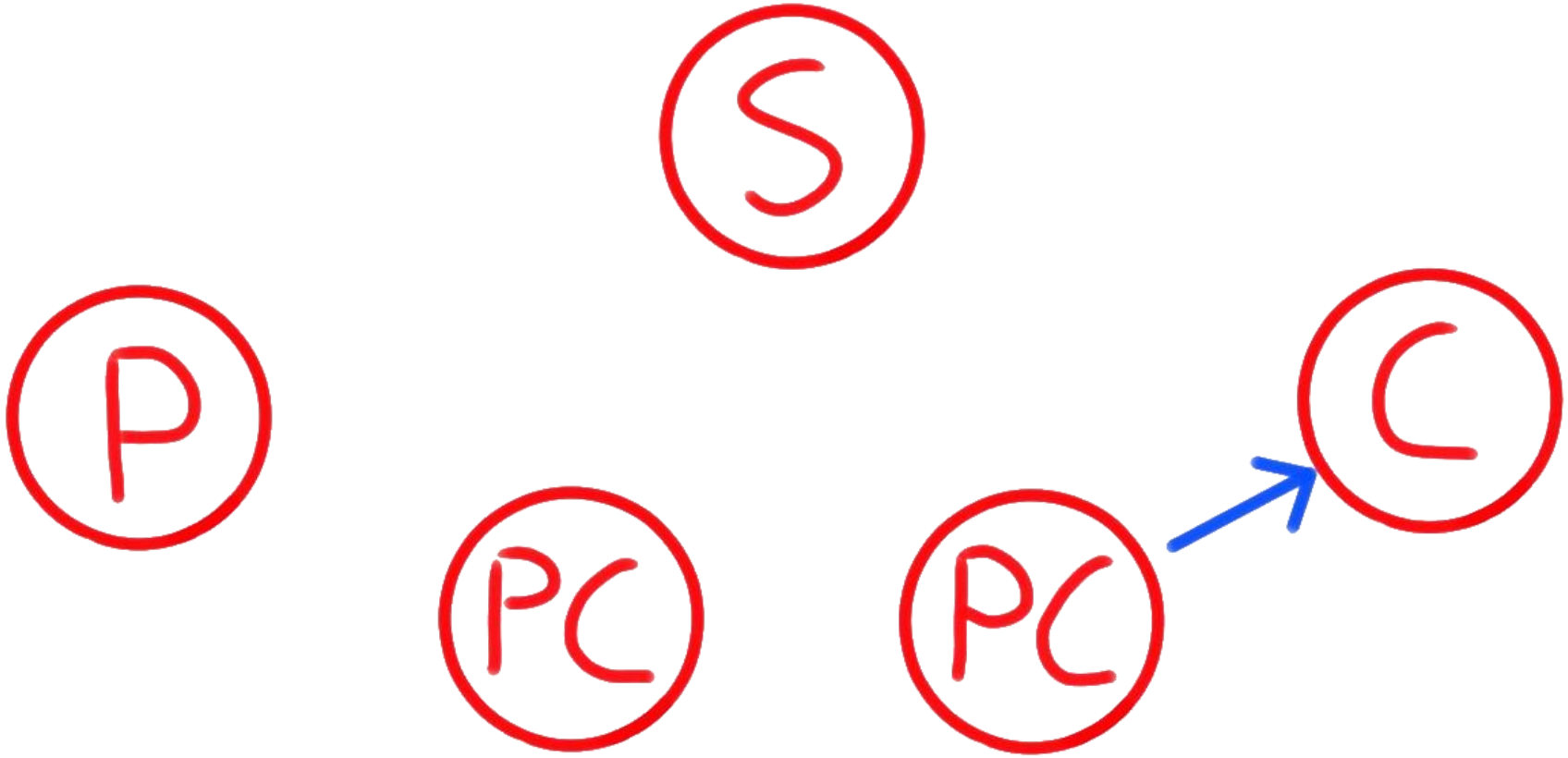
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Pipeline processing

- Lazily evaluated collection of unknown size

Pipeline processing

- Lazily evaluated collection of unknown size
- Communication with parent allowed (rare)

Pipeline processing

- Lazily evaluated collection of unknown size
- Communication with parent allowed (rare)
- Communication between sibilings allowed

Pipeline processing

- Lazily evaluated collection of unknown size
- Communication with parent allowed (rare)
- Communication between sibilings allowed
- Shared dependencies allowed (but require management)

Summary

Eager	No	No	No

Summary

Eager	No	No	No
Eager	Yes	No	No

Summary

Eager	No	No	No
Eager	Yes	No	No
Lazy	Yes	No	No

Summary

Eager	No	No	No
Eager	Yes	No	No
Lazy	Yes	No	No
Lazy	Yes	Yes	Yes


Sketch

Thank you!