Async Await

AND MORE

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ALL CODE EXAMPLES

Cows

ALL CODE EXAMPLES

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Why Cows?

Glad you asked

Why Cows?

Glad you asked

- Never in a hurry ➜ Asynchrony

Why Cows?

Glad you asked

- Never in a hurry ➜ Asynchrony
- Lots of cows ➜ Concurrency

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- Never in a hurry ➜ Asynchrony
- Lots of cows ➜ Concurrency
- Emoji Rich Environment

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- Lots of cows ➜ Concurrency
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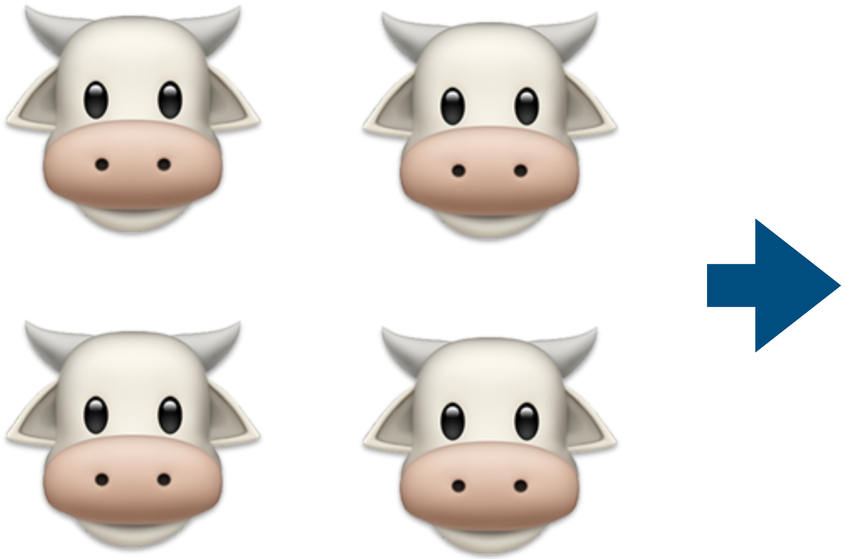

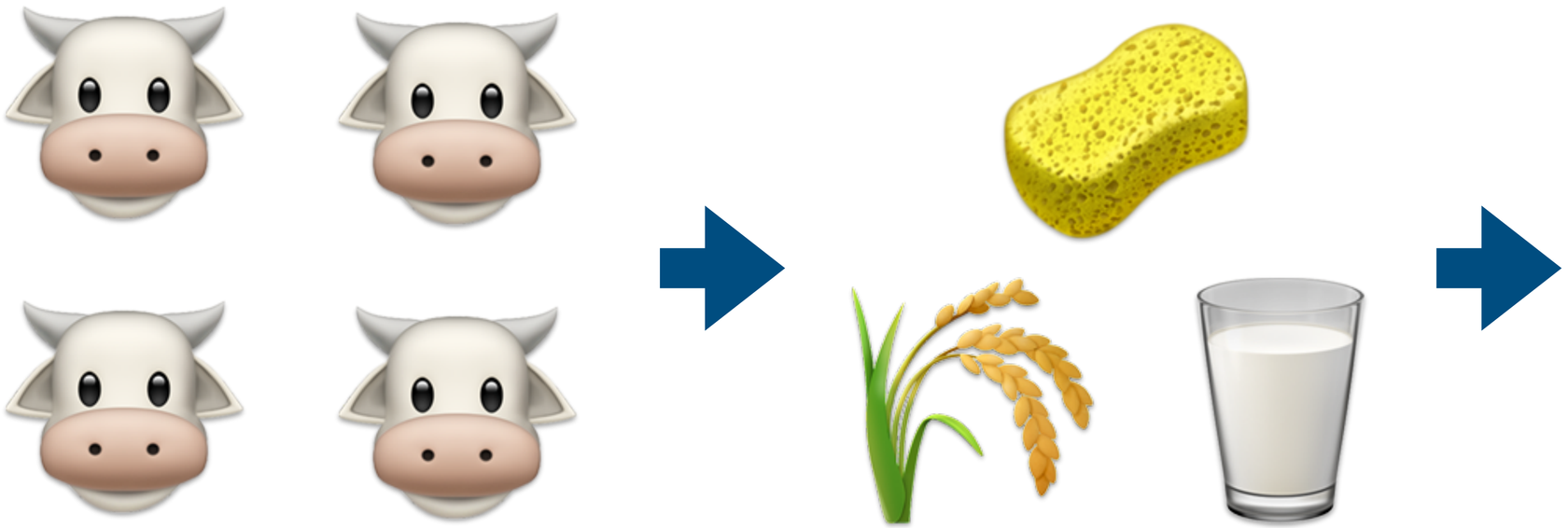

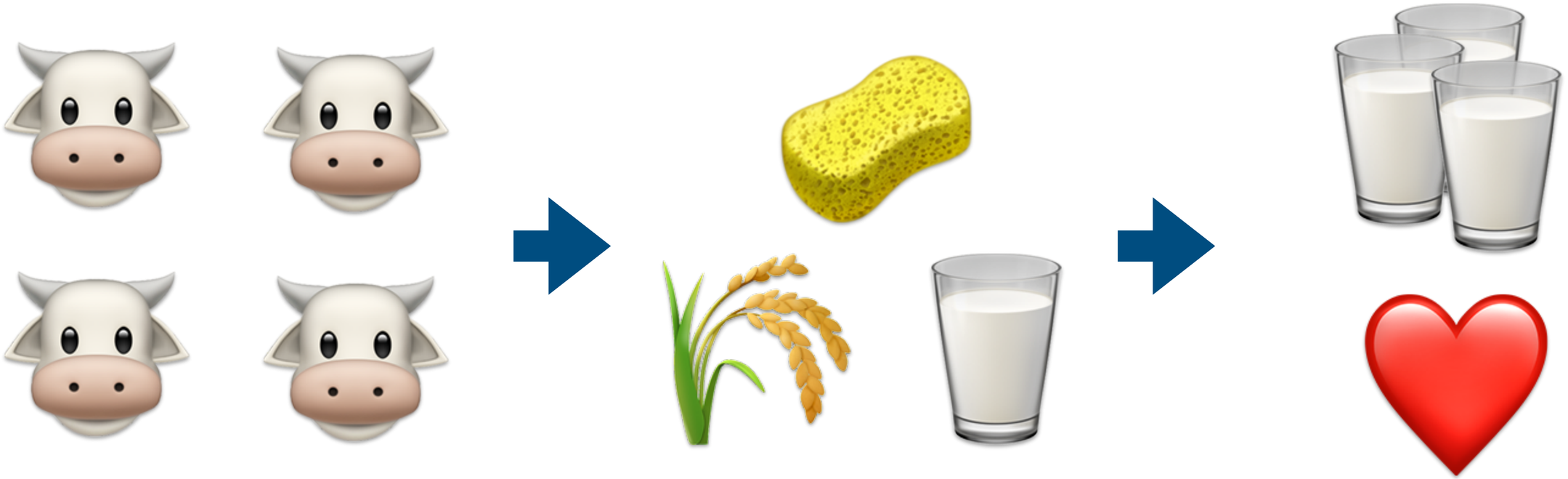

Coding for Asynchrony

with Async and Await

Asynchronous Programing Paradigms

A Farewell Tour

Completion Handlers

```
fetchCow { cow in
    feedCow(cow) { isFull in
        guard !isFull else {
            completion(.failure(CowError.unhappyCow))
            return
        }
        cow.collectMilk { milk in
            completion(.success(milk))
        }
    }
}
```

Completion Handlers

- Easy and simple to set up

```
fetchCow { cow in
    feedCow(cow) { isFull in
        guard !isFull else {
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Completion Handlers

- Easy and simple to set up
- Error prone

```
fetchCow { cow in
    feedCow(cow) { isFull in
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        }
        cow.collectMilk { milk in
            completion(.success(milk))
        }
    }
}
```

Completion Handlers

- Easy and simple to set up
- Error prone
- Hard to scale

```
fetchCow { cow in
    feedCow(cow) { isFull in
        guard !isFull else {
            completion(.failure(CowError.unhappyCow))
            return
        }
        cow.collectMilk { milk in
            completion(.success(milk))
        }
    }
}
```

Promises

```
fetchCow()
    .then { cow -> Promise<(Cow, Bool), CowError> in
        return feedCow(cow)
    }
    .map { (cow, isFull) -> Promise<Milk, CowError> in
        guard isFull else { return CowError.unhappyCow }
        return cow.collectMilk()
    }
    .then { milk in
        // do something with milk
    }
    .catch {
        // handle error
    }
```

Promises

- Chaining and transformations

```
fetchCow()
    .then { cow -> Promise<(Cow, Bool), CowError> in
        return feedCow(cow)
    }
    .map { (cow, isFull) -> Promise<Milk, CowError> in
        guard isFull else { return CowError.unhappyCow }
        return cow.collectMilk()
    }
    .then { milk in
        // do something with milk
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    .catch {
        // handle error
    }
```

Promises

- Chaining and transformations
- Poor local reasoning

```
fetchCow()
    .then { cow -> Promise<(Cow, Bool), CowError> in
        return feedCow(cow)
    }
    .map { (cow, isFull) -> Promise<Milk, CowError> in
        guard isFull else { return CowError.unhappyCow }
        return cow.collectMilk()
    }
    .then { milk in
        // do something with milk
    }
    .catch {
        // handle error
    }
```

Async & Await

```
func fetchCow() async -> Cow {
    // does asynchronous network fetch
}

...

let cow = await fetchCow()
let isClean = await washCow(cow)
let isFull = await feedCow(cow)
let milk = await cow.collectMilk()
```

Async & Await

- Mark asynchronous functions

```
func fetchCow() async -> Cow {
    // does asynchronous network fetch
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let cow = await fetchCow()
let isClean = await washCow(cow)
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Async & Await

- Mark asynchronous functions
- Function suspension

```
func fetchCow() async -> Cow {
    // does asynchronous network fetch
}

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let cow = await fetchCow()
let isClean = await washCow(cow)
let isFull = await feedCow(cow)
let milk = await cow.collectMilk()
```

Async & Await

- Mark asynchronous functions
- Function suspension
- Sequentially execution

```
func fetchCow() async -> Cow {
    // does asynchronous network fetch
}

...

let cow = await fetchCow()
let isClean = await washCow(cow)
let isFull = await feedCow(cow)
let milk = await cow.collectMilk()
```

Async/Await ❤️ Throws/Try

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
}

...

do {
    let cow = try await fetchCow()
    let isClean = await washCow(cow)
    let isFull = try await feedCow(cow)
    let milk = try await cow.collectMilk()
} catch let error {
    // handle error
}
```

Async/Await ❤️ Throws/Try

- Similar Paradigm

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
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do {
    let cow = try await fetchCow()
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Async/Await ❤️ Throws/Try

- Similar Paradigm
- Compiler enforcement

```
func fetchCow() async throws -> Cow {
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...

do {
    let cow = try await fetchCow()
    let isClean = await washCow(cow)
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    let milk = try await cow.collectMilk()
} catch let error {
    // handle error
}
```

Async/Await ❤️ Throws/Try

- Similar Paradigm
- Compiler enforcement
- `async` & `throws` are composable

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
}

...

do {
    let cow = try await fetchCow()
    let isClean = await washCow(cow)
    let isFull = try await feedCow(cow)
    let milk = try await cow.collectMilk()
} catch let error {
    // handle error
}
```

Ye Olden Days

```
fetchCow { result in
    switch result {
    case .success(let cow):
        feedCow(cow) { result in
            switch result {
            case .success(let isFull):
                // ...
            case .failure(let error):
                // ...
            }
        }
    case .failure(error):
        // ...
    }
}
```

Ye Olden Days

- Completion handler with Result

```
fetchCow { result in
    switch result {
    case .success(let cow):
        feedCow(cow) { result in
            switch result {
            case .success(let isFull):
                // ...
            case .failure(let error):
                // ...
            }
        }
    case .failure(error):
        // ...
    }
}
```

Ye Olden Days

- Completion handler with Result
- Error handling without `throws`

```
fetchCow { result in
    switch result {
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                // ...
            }
        }
    case .failure(error):
        // ...
    }
}
```

Ye Olden Days

- Completion handler with Result
- Error handling without `throws`
- Pyramid of doom @2x

```
fetchCow { result in
    switch result {
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        feedCow(cow) { result in
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            }
        }
    case .failure(error):
        // ...
    }
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```


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Completion Handlers with Result

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fetchCow { result in
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            }
        }
    case .failure(error):
        // ...
    }
}
```

Completion Handlers with Result

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fetchCow { result in
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                // ...
            case .failure(let error):
                // ...
            }
        }
    case .failure(error):
        // ...
    }
}
```

async/await with try/catch

```
do {
    let cow = try await fetchCow()
    let isClean = await washCow(cow)
    let isFull = try await feedCow(cow)
    let milk = try await cow.collectMilk()
} catch let error {
    // handle error
}
```

Function Suspension

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
}

...

do {
    // checkpoint A
    let cow = try await fetchCow()
    // checkpoint B
} catch let error {
    // ...
}
```

Function Suspension

- No future, promise, or handle

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
}

...

do {
    // checkpoint A
    let cow = try await fetchCow()
    // checkpoint B
} catch let error {
    // ...
}
```

Function Suspension

- No future, promise, or handle
- Return actual value

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
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do {
    // checkpoint A
    let cow = try await fetchCow()
    // checkpoint B
} catch let error {
    // ...
}
```

Function Suspension

- No future, promise, or handle
- Return actual value
- Nothing to work with synchronously

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
}

...

do {
    // checkpoint A
    let cow = try await fetchCow()
    // checkpoint B
} catch let error {
    // ...
}
```

Function Suspension

- No future, promise, or handle
- Return actual value
- Nothing to work with synchronously
- Non-blocking

```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
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do {
    // checkpoint A
    let cow = try await fetchCow()
    // checkpoint B
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Function Suspension

- No future, promise, or handle
- Return actual value
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do {
    // checkpoint A
    let cow = try await fetchCow()
    // checkpoint B
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Function Suspension

- No future, promise, or handle
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    let cow = try await fetchCow()
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Function Suspension

- No future, promise, or handle
- Return actual value
- Nothing to work with synchronously
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```
func fetchCow() async throws -> Cow {
    // does asynchronous network fetch
}

...

do {
    // checkpoint A
    let cow = try await fetchCow()
➜   // checkpoint B
} catch let error {
    // ...
}
```

Async Everywhere

Async Everywhere

- Functions

Async Everywhere

- Functions
- Property getters

Async Everywhere

- Functions
- Property getters
- Initializers

Async Everywhere

- Functions
- Property getters
- Initializers

Parallel Processing

with Structured Concurrency

Structured Concurrency

Structured Concurrency

- Structured Programming
  - if / else
  - for / while loops
  - functions

Structured Concurrency

- Structured Programming
  - if / else
  - for / while loops
  - functions
- Structured Programming with an understanding of concurrency

What does this mean for me writing Swift apps?

What does this mean for me writing Swift apps?

Concurrent and asynchronous code that looks and feels *normal*.

Async Let

```
func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
    async let isFull = feedCow(cow)
    async let milk = cow.collectMilk()

    // execution continues

    guard try await isFull,
        try await isClean else {
        throw FarmError.unhappyCow
    }
    return try await milk
}
```

Async Let

- Run in parallel

```
func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
    async let isFull = feedCow(cow)
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```

Async Let

- Run in parallel
- `await` when needed

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func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
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    // execution continues

    guard try await isFull,
        try await isClean else {
        throw FarmError.unhappyCow
    }
    return try await milk
}
```

Async Let

- Run in parallel
- `await` when needed
- Observe errors on `await`

```
func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
    async let isFull = feedCow(cow)
    async let milk = cow.collectMilk()

    // execution continues

    guard try await isFull,
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}
```

Task

Foundational unit in running concurrent code

Task

Foundational unit in running concurrent code

- Run in the background

Task

Foundational unit in running concurrent code

- Run in the background
- Support Asynchrony
  - Running, Suspended, or Cancelled
  - All async work is done in Tasks

Task

Foundational unit in running concurrent code

- Run in the background
- Support Asynchrony
  - Running, Suspended, or Cancelled
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Task

Foundational unit in running concurrent code

- Run in the background
- Support Asynchrony
  - Running, Suspended, or Cancelled
  - All async work is done in Tasks
- Run in parallel
- Non-atomic

Async Let + Tasks

```
func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
    async let isFull = feedCow(cow)
    async let milk = cow.collectMilk()

    // execution continues

    guard try await isFull,
        try await isClean else {
        throw FarmError.unhappyCow
    }
    return try await milk
}
```

Async Let + Tasks

- Creates new child task

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func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
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    async let milk = cow.collectMilk()

    // execution continues

    guard try await isFull,
        try await isClean else {
        throw FarmError.unhappyCow
    }
    return try await milk
}
```

Async Let + Tasks

- Creates new child task
- Tasks run in parallel if/when possible

```
func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
    async let isFull = feedCow(cow)
    async let milk = cow.collectMilk()

    // execution continues

    guard try await isFull,
        try await isClean else {
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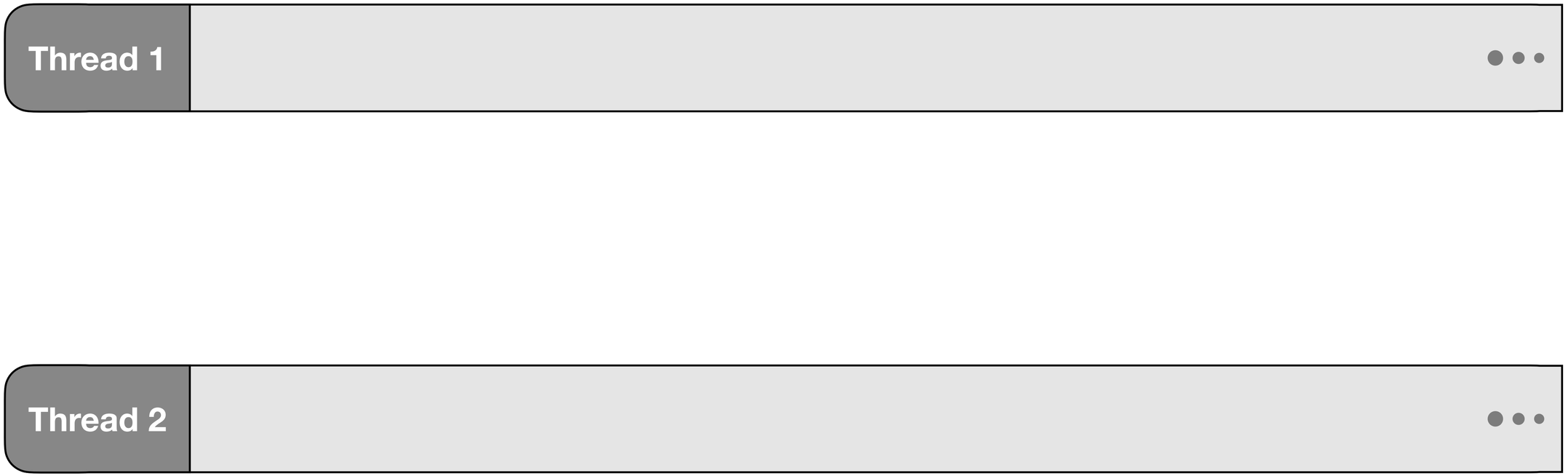
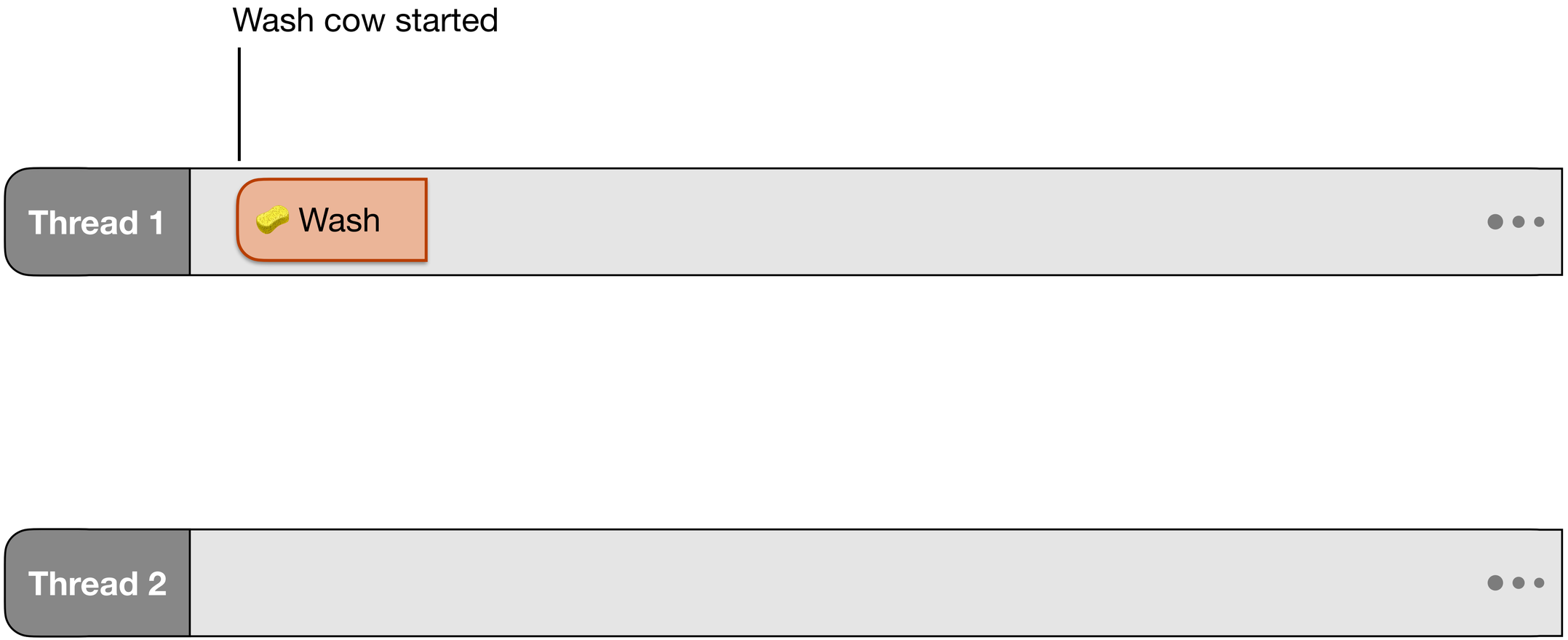
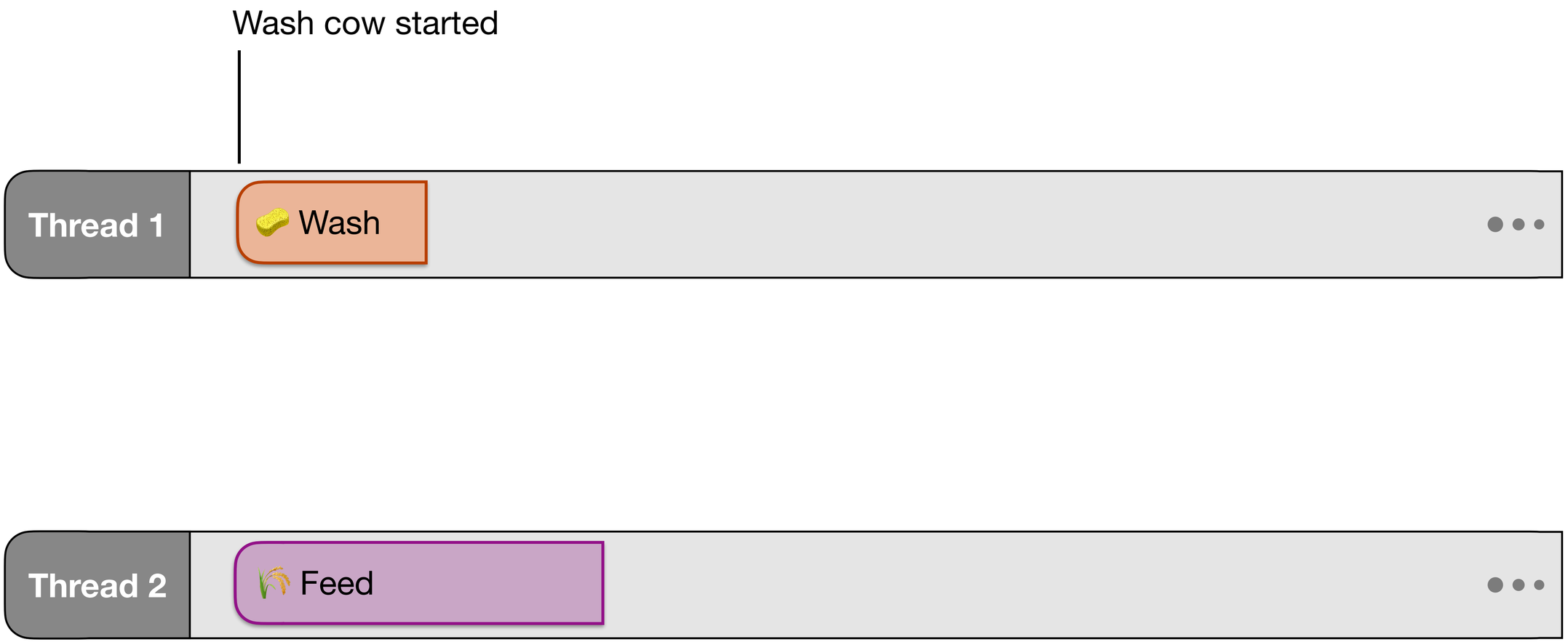
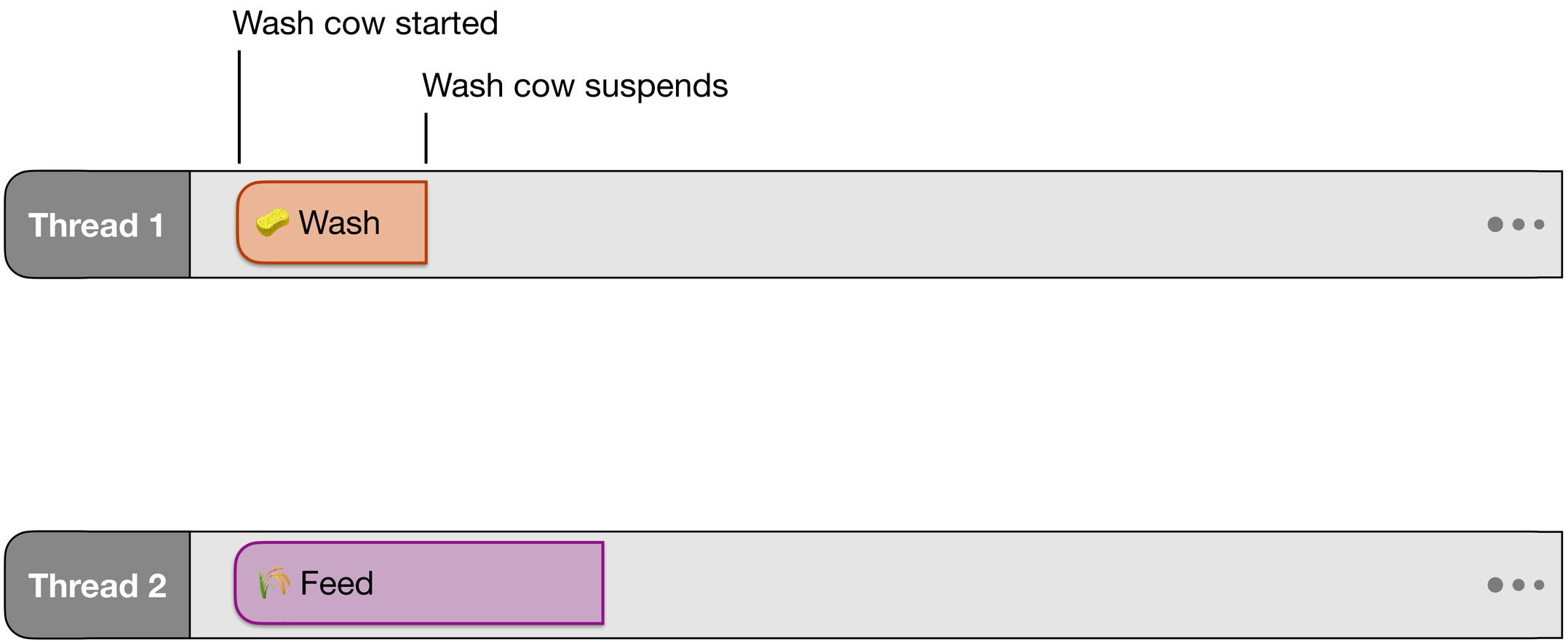
    return try await milk
}
```


Thread 1
Thread 2


Wash cow started
Thread 1
Wash
Thread 2


Wash cow started
Thread 1
Wash
Thread 2
Feed


Wash cow started
Wash cow suspends
Thread 1
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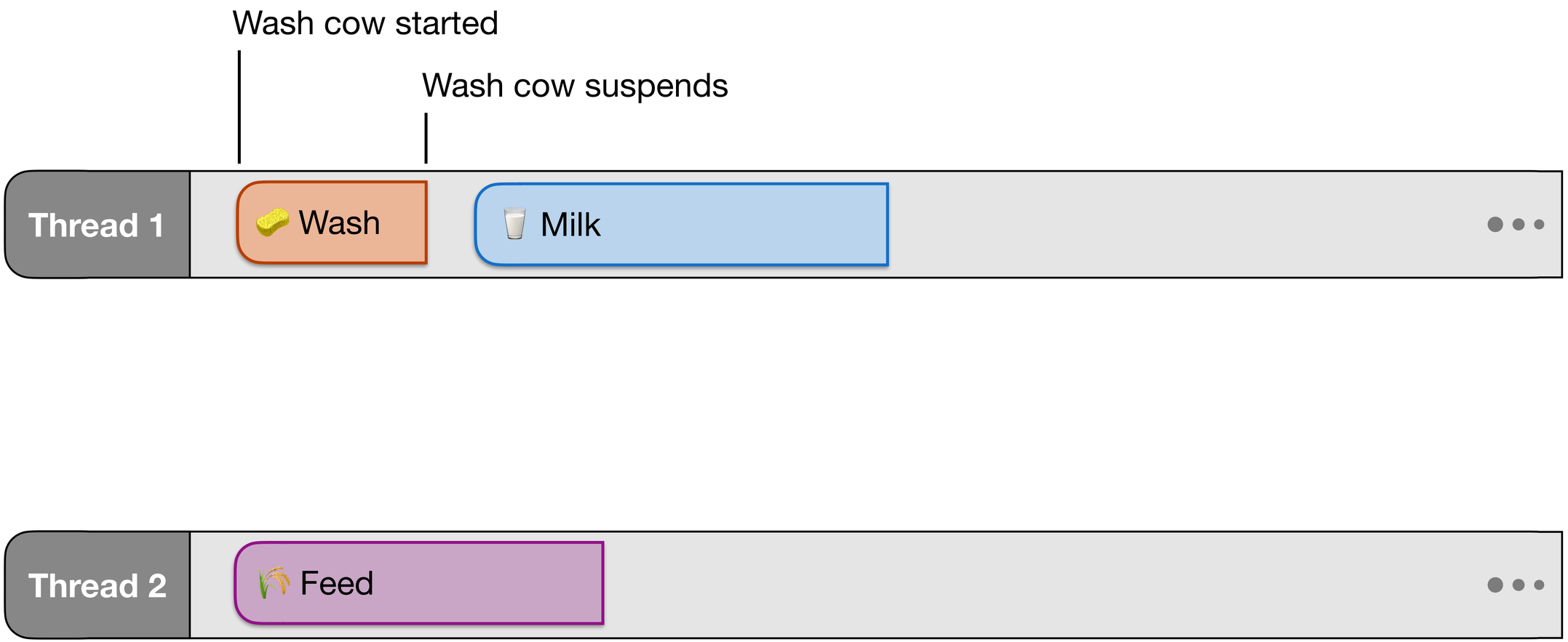
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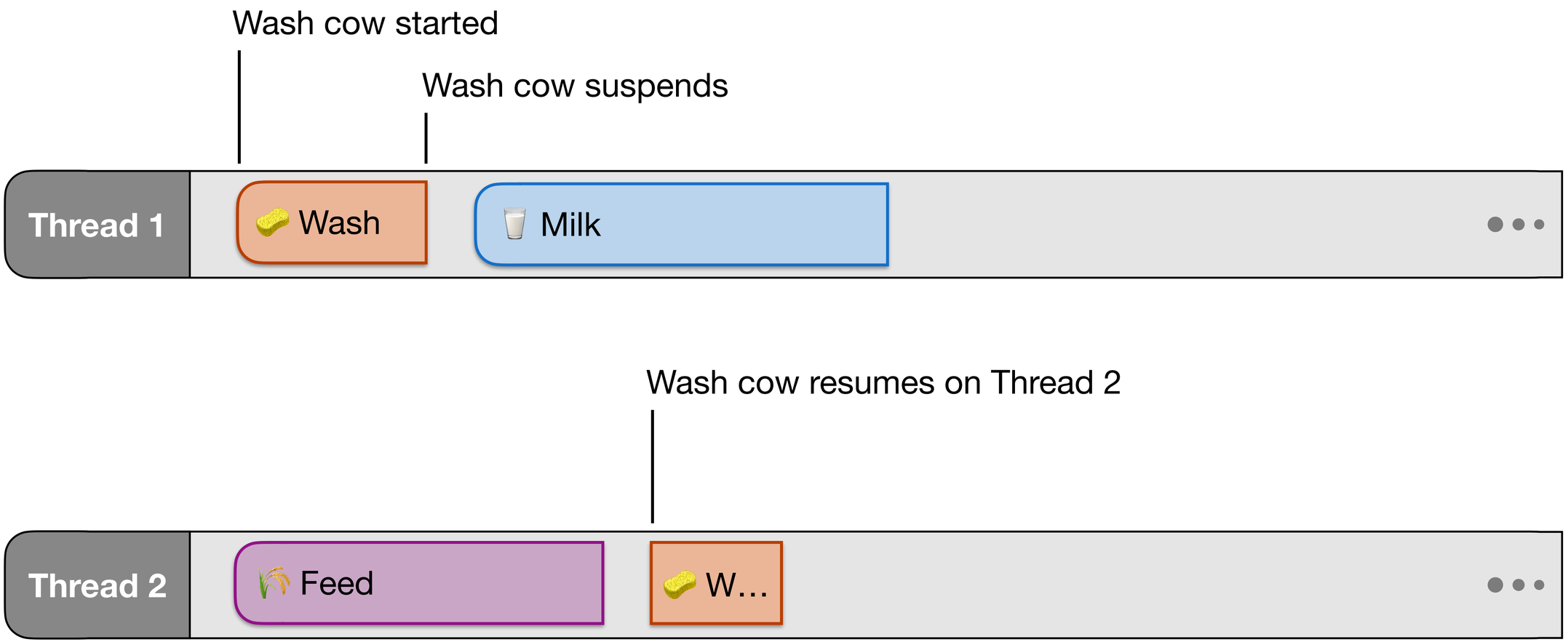
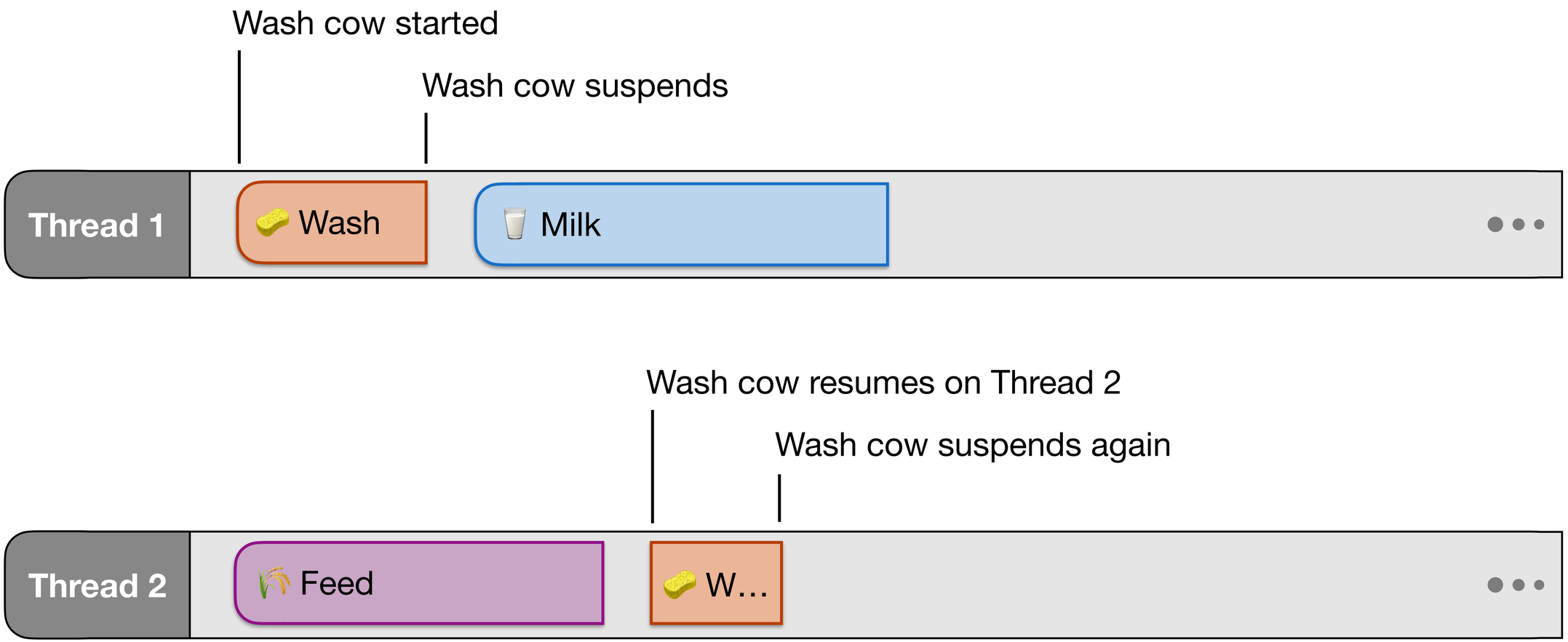

Wash cow started
Wash cow suspends
Thread 1
Wash
Milk
Wash cow resumes on Thread 2
Thread 2
Feed
W…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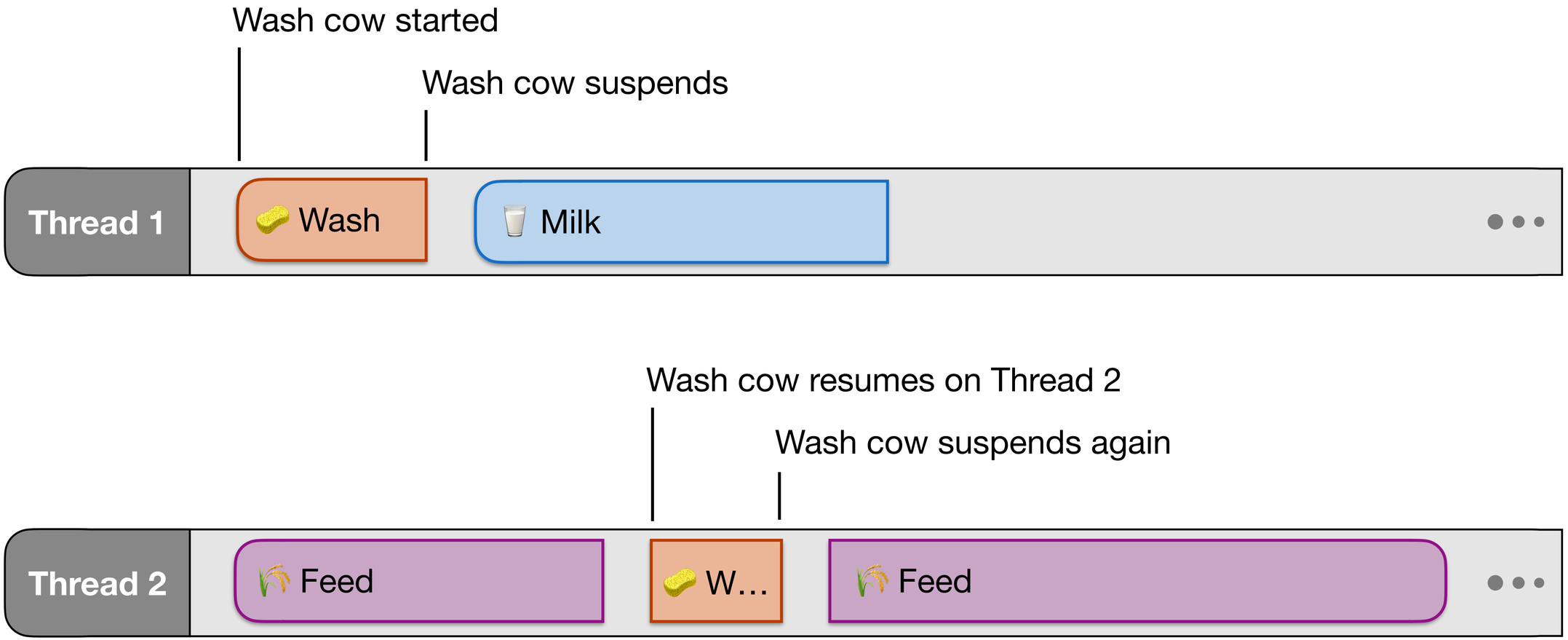
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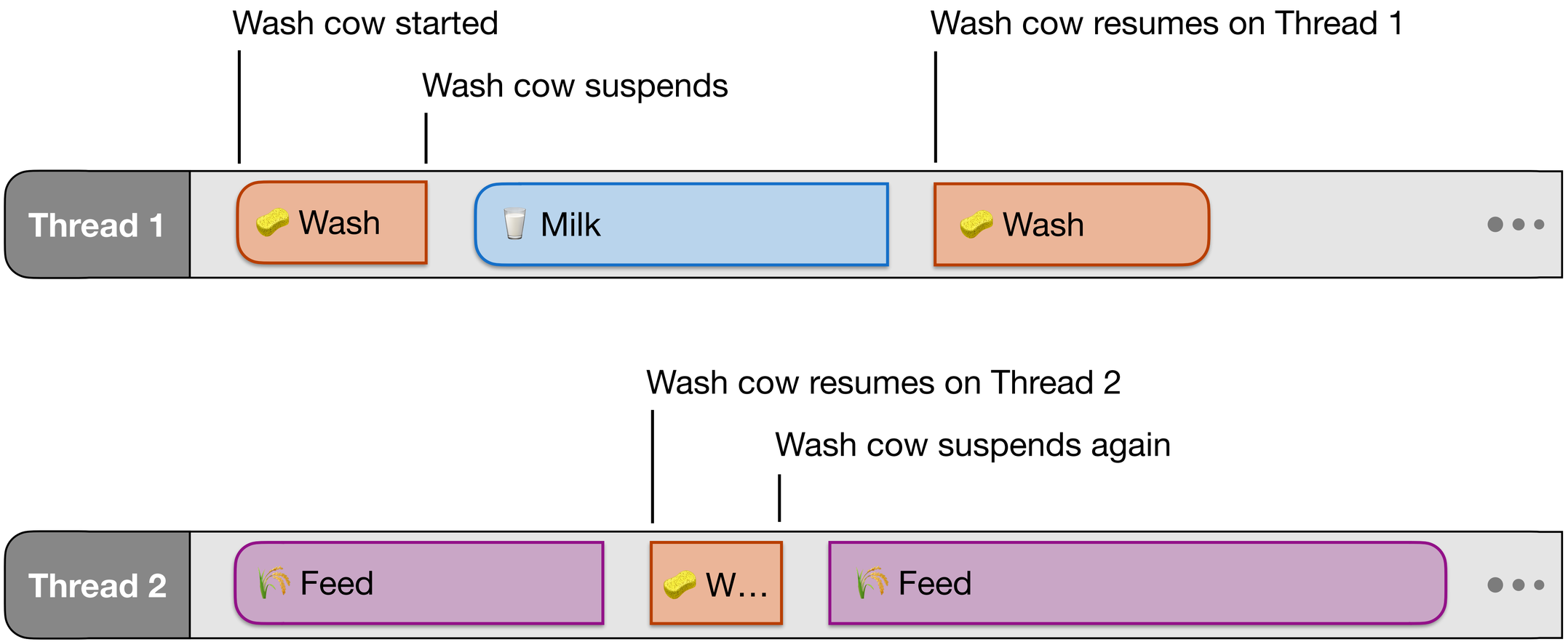
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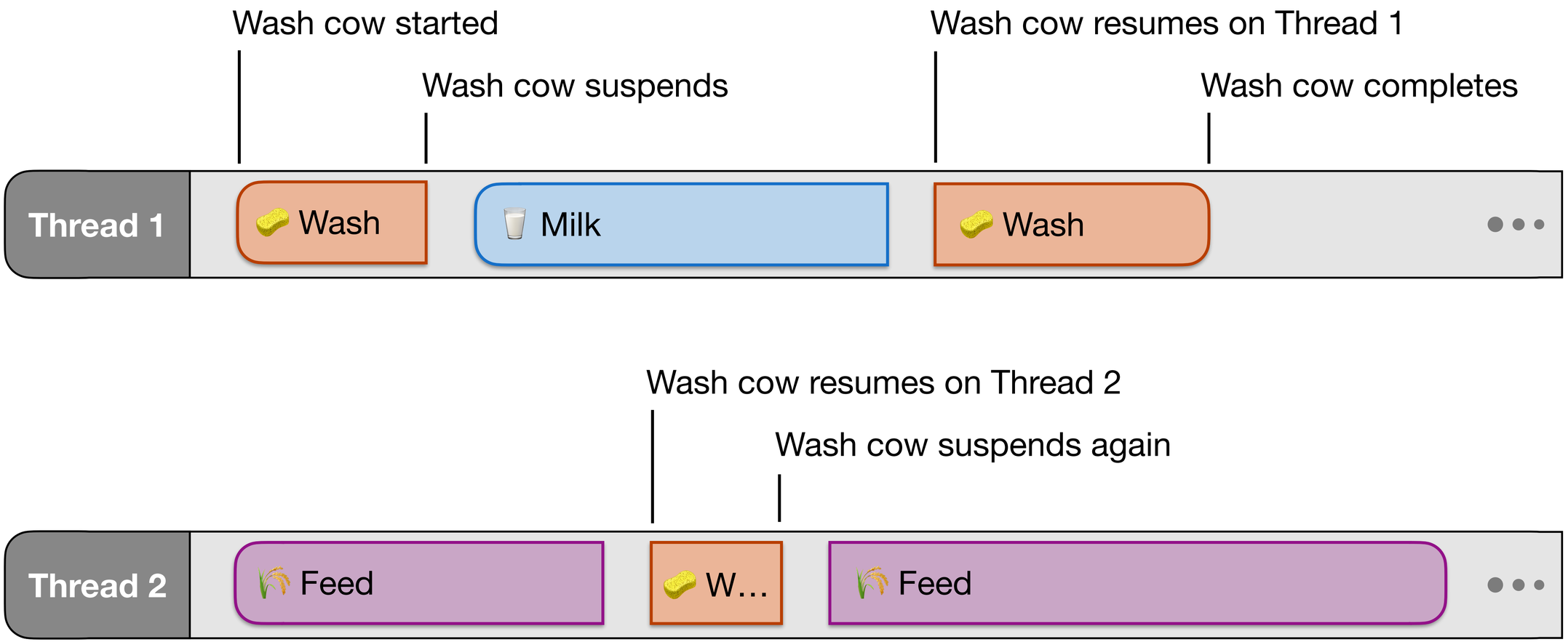
Wash cow started
Wash cow suspends
Wash cow resumes on Thread 1
Wash cow completes
Thread 1
Wash
Milk
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Wash cow resumes on Thread 2
Wash cow suspends again
Thread 2
Feed
W…
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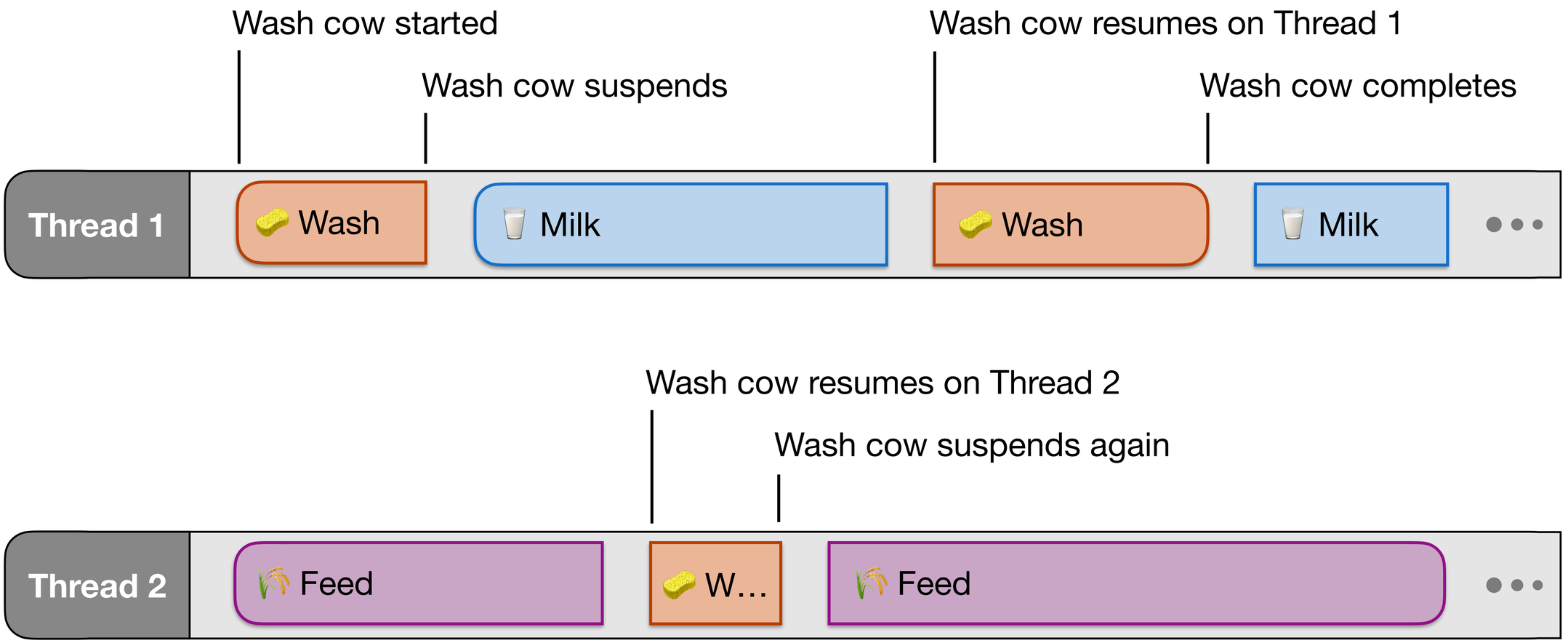
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Thread 1
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Milk
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Milk
Wash cow resumes on Thread 2
Wash cow suspends again
Thread 2
Feed
W…
Feed

Task Tree

Task Tree

- Tasks can have child tasks

Task Tree

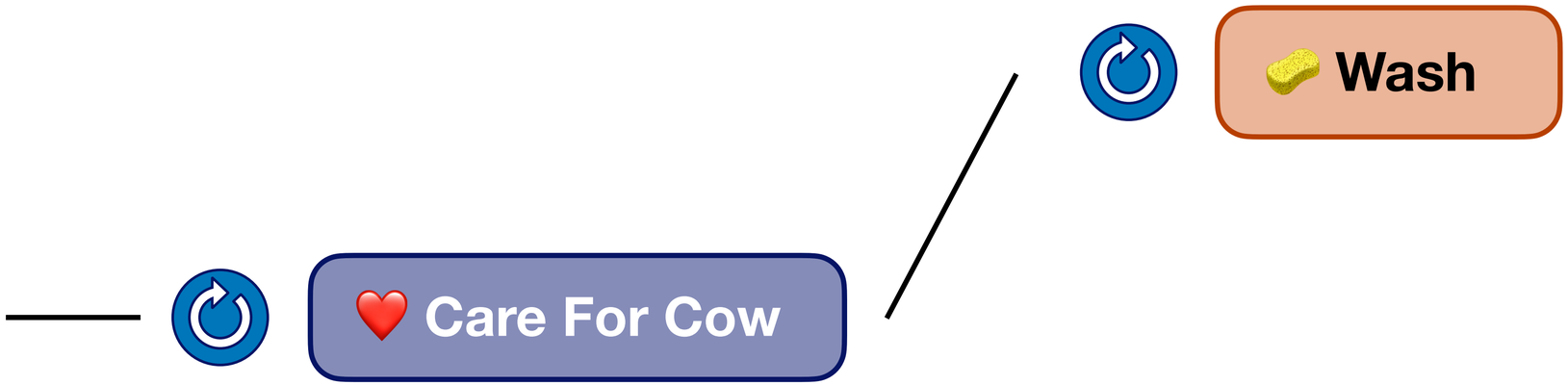
- Tasks can have child tasks
- Child tasks inherit properties of their parent task

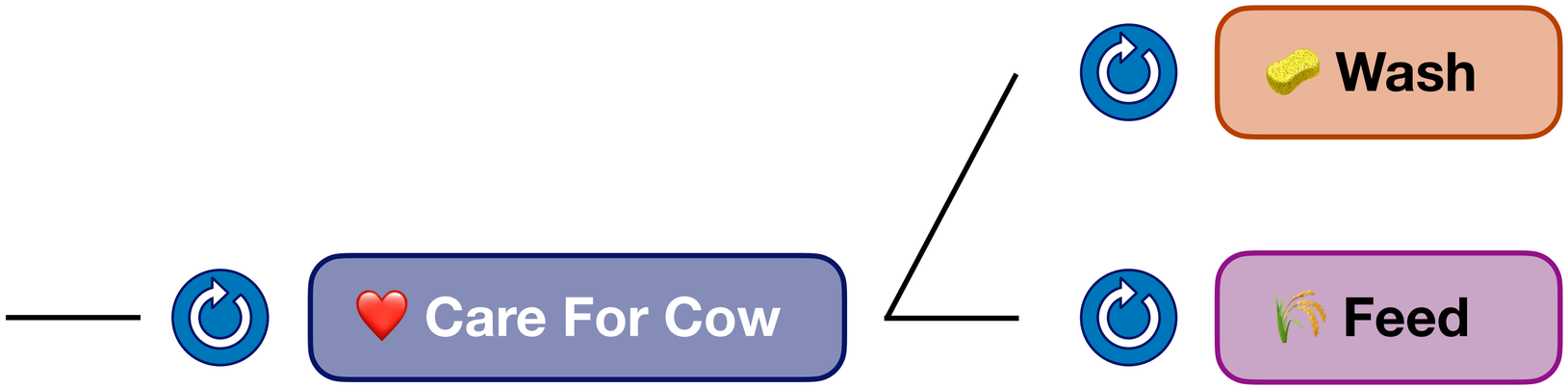
Task Tree

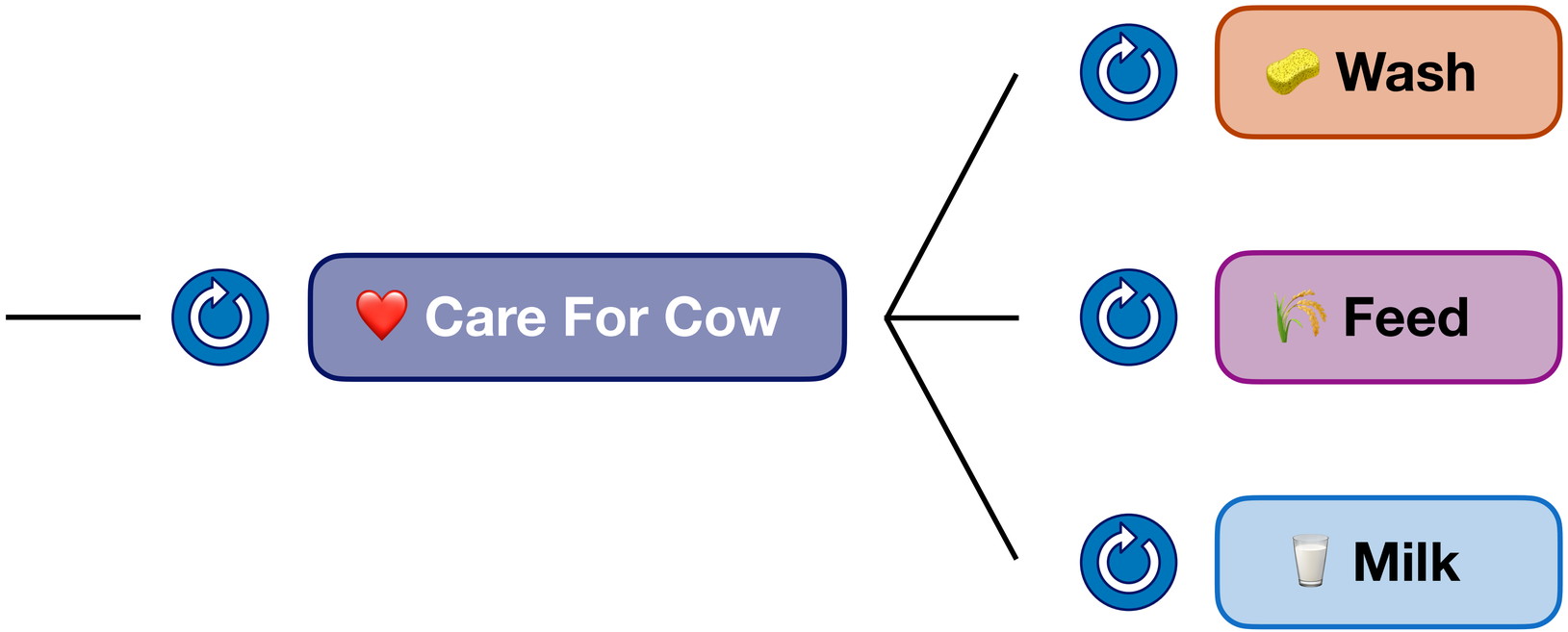
- Tasks can have child tasks
- Child tasks inherit properties of their parent task
- Child tasks cannot outlive their parent task

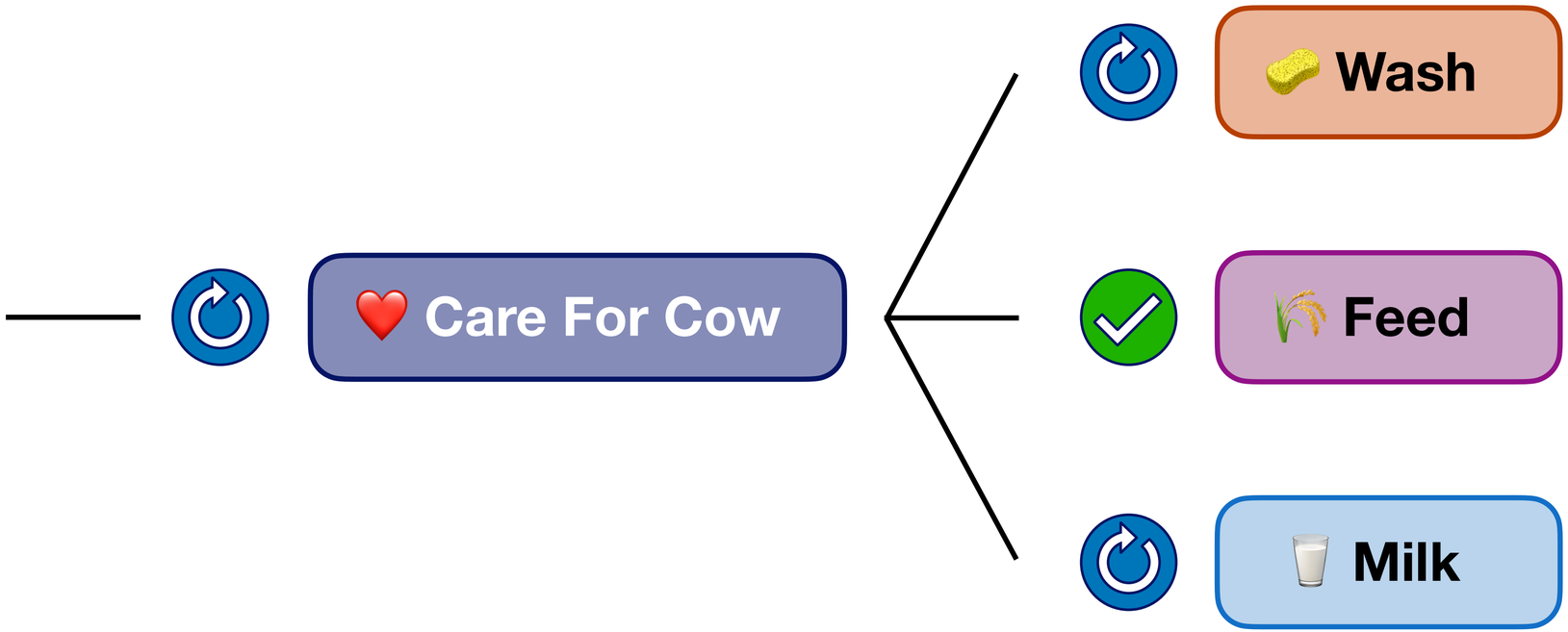
Structured Concurrency > Task > Completion


❤️ Care For Cow


Wash
Care For Cow


❤️ Care For Cow
🧽 Wash
🌾 Feed


❤️ Care For Cow
🧽 Wash
🌾 Feed
🥛 Milk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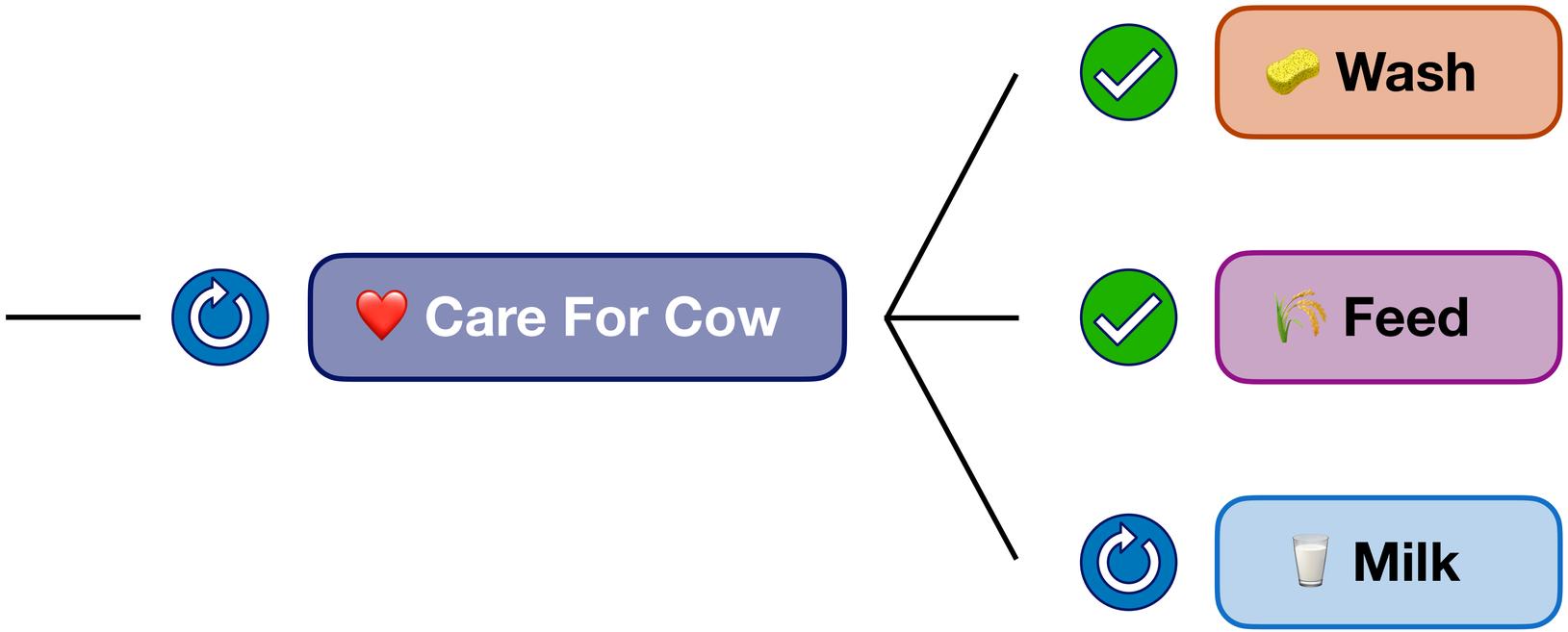
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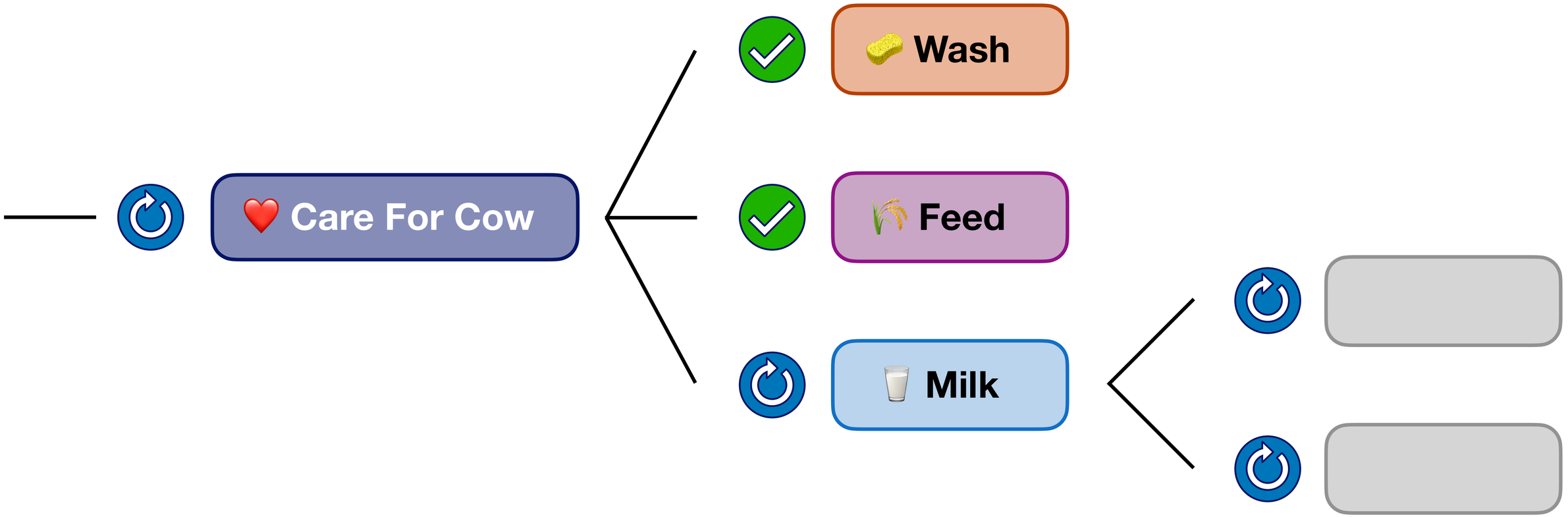
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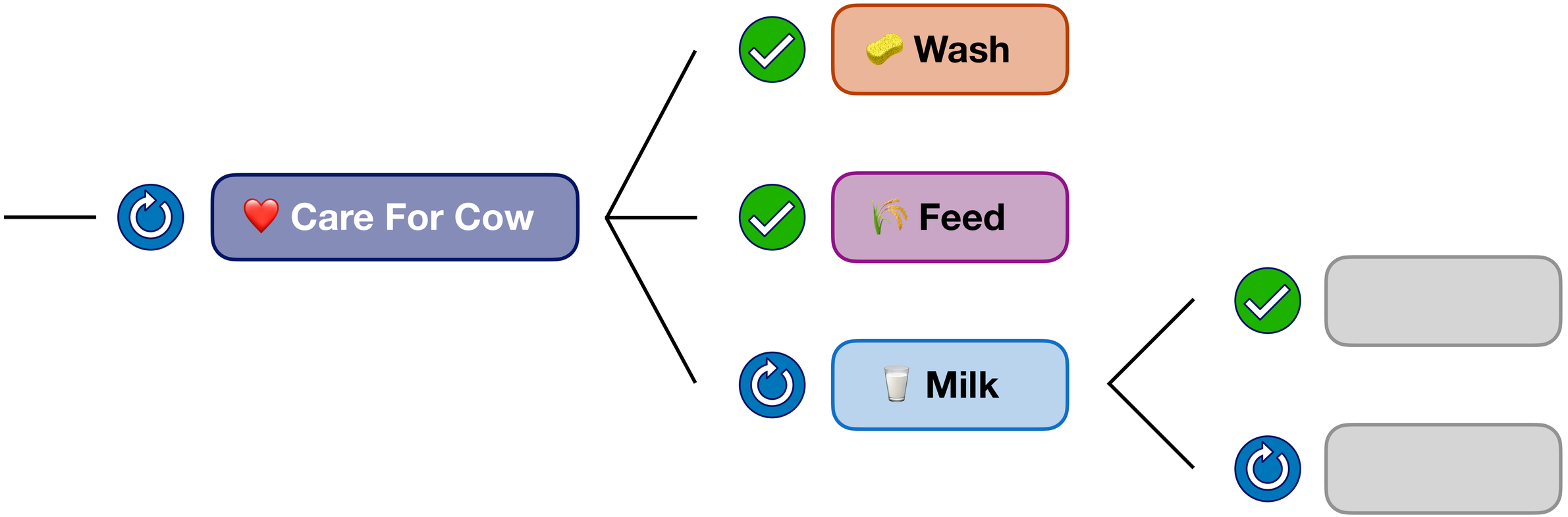
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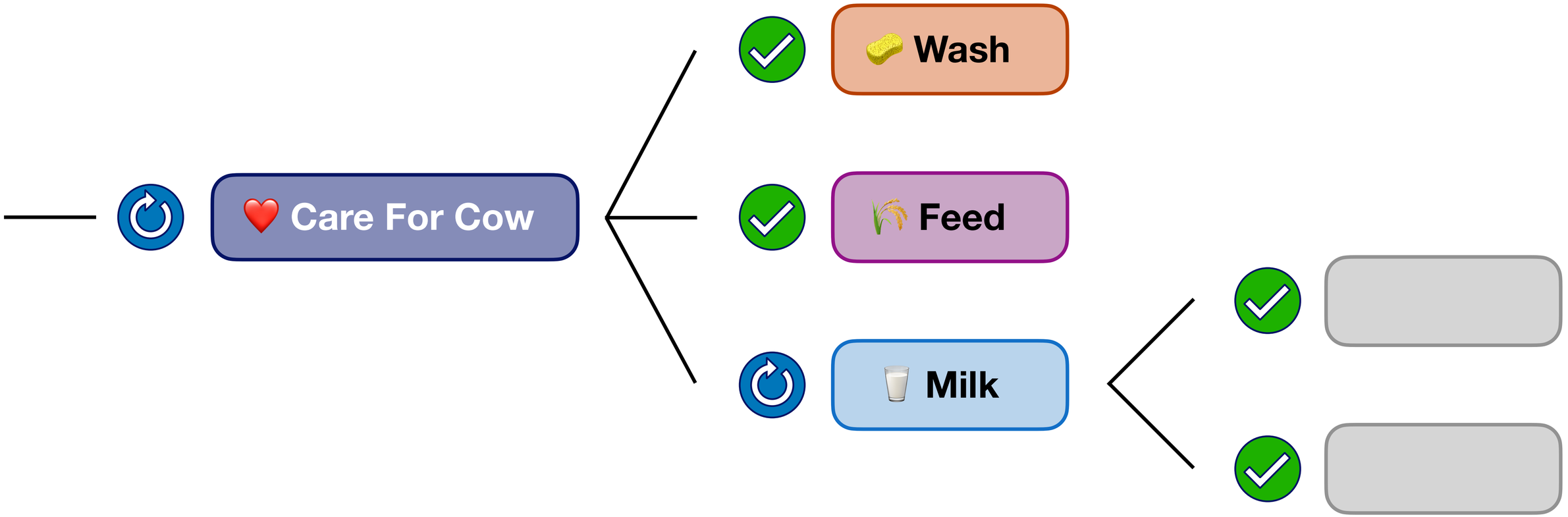
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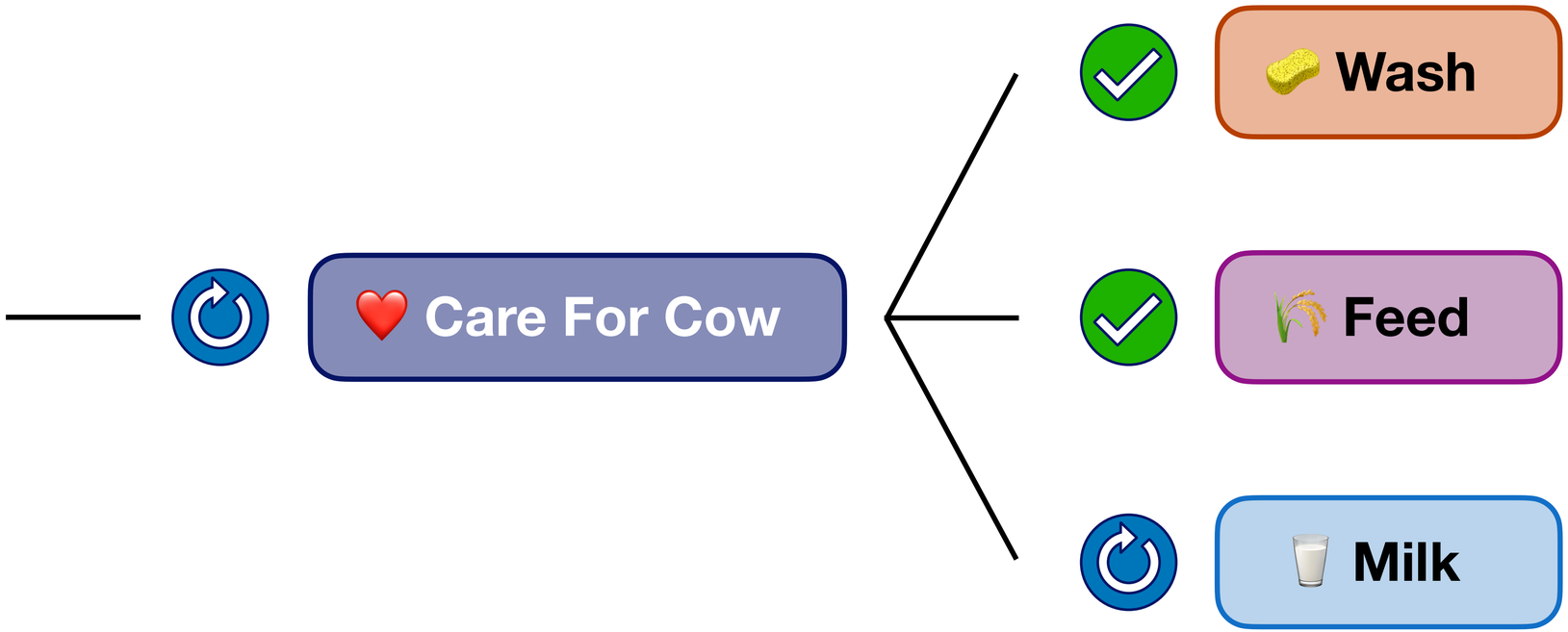
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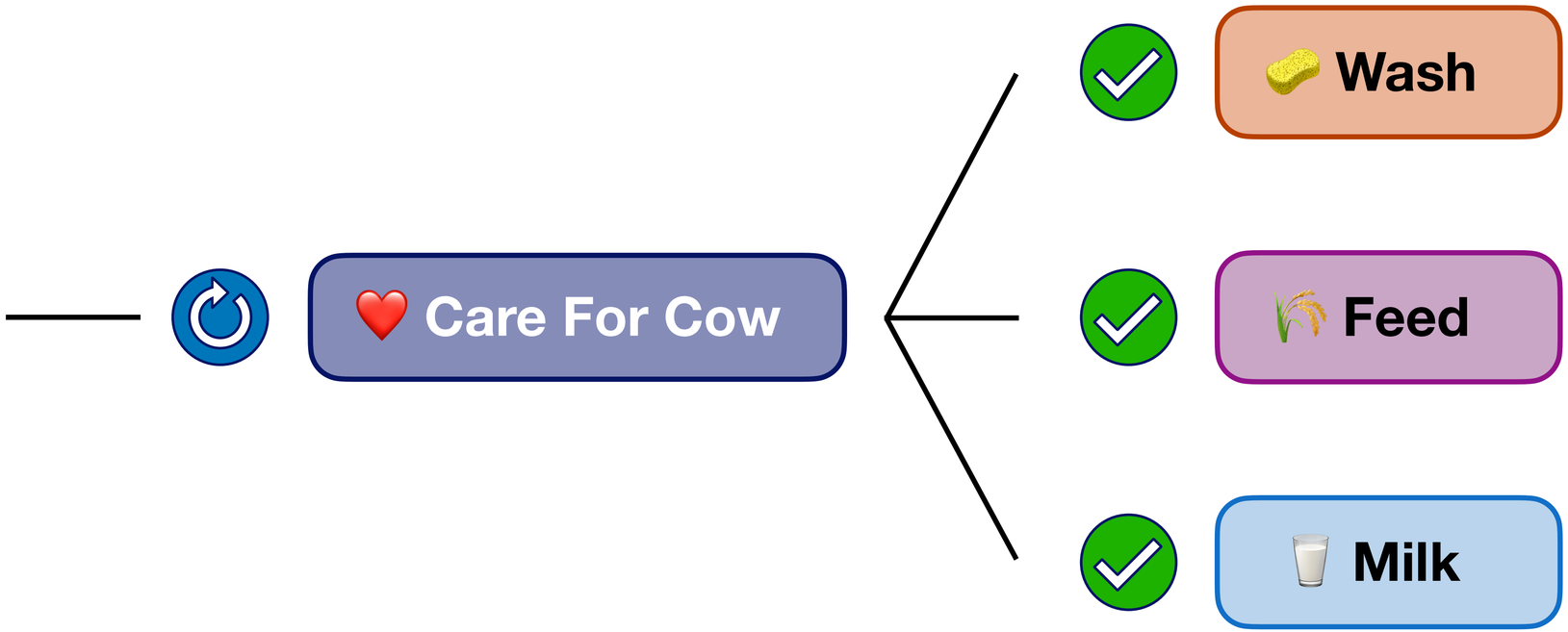
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❤️ Care For Cow


❤️ Care For Cow

Async Let + Task Scoping

```
func careForCow(_ cow: Cow) async throws
-> Milk {
    async let isClean = washCow(cow)
    async let isFull = feedCow(cow)
    async let milk = cow.collectMilk()

    return try await milk
    // implicit cancellation of `isClean`
    // implicit cancellation of `isFull`
    // implicit await of `isClean`
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}
```

Async Let + Task Scoping

- Async let variable binding

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Async Let + Task Scoping

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- Child task lifetime

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- Un-awaited tasks will be implicitly cancelled and awaited

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Async Let + Task Scoping

- Async let variable binding
- Child task lifetime
- Un-awaited tasks will be implicitly cancelled and awaited

- Structured Concurrency 👍

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    // implicit cancellation of `isClean`
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    // implicit await of `isFull`
}
```

Task Cancellation

```
func washCow(_ cow: Cow) async throws -> Bool {
    // checkpoint 1
    try Task.checkCancellation()
    try await rinse(cow)

    // checkpoint 2
    guard !Task.isCancelled else {
        try await dry(cow)
        throw CancellationError()
    }

    // checkpoint 3
    try await scrub(cow)
    try await rinse(cow)
    try await dry(cow)
    return true
}
```

Task Cancellation

- Cancellation propagation

```
func washCow(_ cow: Cow) async throws -> Bool {
    // checkpoint 1
    try Task.checkCancellation()
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```

Task Cancellation

- Cancellation propagation
- Cooperative Cancellation
  - Check for cancellation
  - Clean up if needed

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    return true
}
```

Task Cancellation

- Cancellation propagation
- Cooperative Cancellation
  - Check for cancellation
  - Clean up if needed
- Exiting from cancelled task

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func washCow(_ cow: Cow) async throws -> Bool {
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}
```

Task Group

```
func careForCows(_ cows: [Cow]) async throws
-> Milk {
    return try await withThrowingTaskGroup(
        of: Milk.self,
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        for cow in cows {
            group.addTask {
                return try await careForCow(cow)
            }
        }

        var collectedMilk = Milk(gallons: 0)
        for try await milk in group {
            collectedMilk += milk
        }
        return collectedMilk
    }
}
```

Task Group

- Dynamic amount of concurrency

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Task Group

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  - Fetching a list of images
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Task Group

- Dynamic amount of concurrency
  - Fetching a list of images
  - Processing a list of files
  - … list of async ➜ Task Group
- Throwing & non-throwing variant

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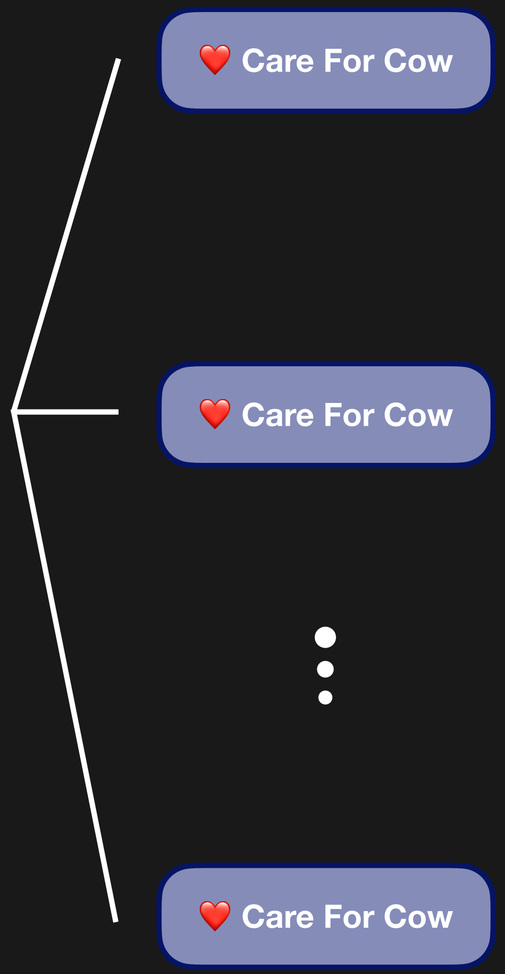

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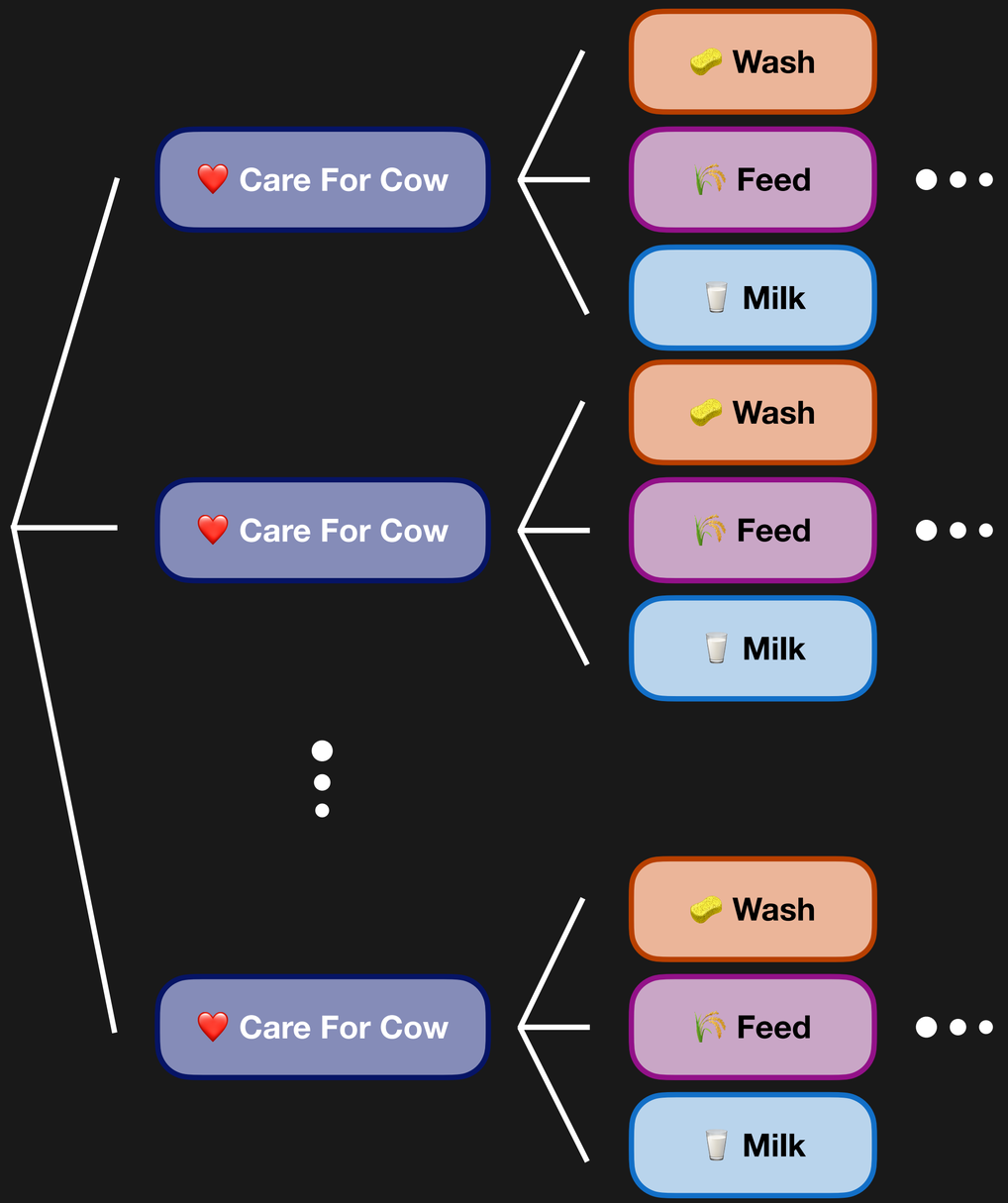

Structured Concurrency

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- Single task with `async let`

Structured Concurrency

- Single task with `async let`
- List of tasks with `TaskGroup`

Structured Concurrency

- Single task with `async let`
- List of tasks with `TaskGroup`
- Task lifetime and scoping

Unstructured Tasks

Break The Rules!

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- Task without a parent

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- Flexibility & Management

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Unstructured Tasks

Break The Rules!

- Task without a parent
- Flexibility & Management
- Inherit properties from the originating context
- Starting async work from a non-async context
- `Task { ... }`
- `Task.Handle`

```
class ViewController: UIViewController {

    var cowManager: CowManager
    var fetchCowsReportHandle: Task.Handle<Void, Never>? = nil

    @objc func fetchButtonPressed() {
        fetchCowsReportHandle = Task {
            await cowManager.fetchReport()
        }
    }

    @objc func cancelButtonPressed() {
        fetchCowsReportHandle?.cancel()
    }
}
```

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Detached Tasks

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Detached Tasks

- Most control, most overhead
- Nearly identical to unstructured tasks
  - Do not inherit any properties from originating context
- `Task.detached`
- analytics, logging, and ephemeral data storage

Shared Mutable State

with Actors

Actors > Data Races

```
class CowHerd {
    var name: String = "untitled herd"

    func fetchCow(_ id: Int) -> Cow { ... }
}

...

var herd = CowHerd()

Task {
    herd.name = "legen-dairy"
    print("task 1, herd name: \(herd.name)")
}

Task {
    herd.name = "moo-riffic"
    print("task 2, herd name: \(herd.name)")
}
```

Data Races

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Data Races

- Concurrent read and write

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Data Races

- Concurrent read and write
- Easy to introduce

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Data Races

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- Hard to track down

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```

Data Races

- Concurrent read and write
- Easy to introduce
- Hard to track down

Reference to captured var 'herd' in concurrently-executing code

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    var name: String = "untitled herd"

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...

var herd = CowHerd()

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```

Actors

New entity that safely provides access to shared mutable state

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- Protect access to mutable state

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- Protect access to mutable state
- Actor isolation

Actors

New entity that safely provides access to shared mutable state

- Protect access to mutable state
- Actor isolation
- Serialization mechanism

```
actor CowHerd {
    var name: String = "untitled herd"
}

...

var herd = CowHerd()

Task {
    herd.name = "deja moo"
    print("task 1, herd name: \(herd.name)")
}
```

```swift
actor CowHerd {
    var name: String = "untitled herd"
}

...

var herd = CowHerd()

Task {
    herd.name = "deja moo"
    print("task 1, herd name: \(herd.name)")
}
```

```
actor CowHerd {
    var name: String = "untitled herd"
}

...

var herd = CowHerd()

Task {
    herd.name = "deja moo"
    print("task 1, herd name: \(herd.name)")
}
```

Actor-isolated property ‘name' can not be mutated from a non-isolated context

```
actor CowHerd {
    var name: String = "untitled herd"

    func setName(_ name: String) {
        self.name = name
    }
}

...

var herd = CowHerd()

Task {
    herd.setName("deja moo")
    print("task 1, herd name: \(herd.name)")
}
```

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actor CowHerd {
    var name: String = "untitled herd"

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        self.name = name
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var herd = CowHerd()

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...

var herd = CowHerd()

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}
```

Expression is 'async' but is not marked with 'await'

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actor CowHerd {
    var name: String = "untitled herd"

    func setName(_ name: String) {
        self.name = name
    }
}

...

var herd = CowHerd()

Task {
    await herd.setName("deja moo")
    print("task 1, herd name: \(await herd.name)")
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```
actor CowHerd {
    var name: String = "untitled herd"

    func setName(_ name: String) {
        self.name = name
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✅

Actor

Isolated

- Mutable Properties
- Functions

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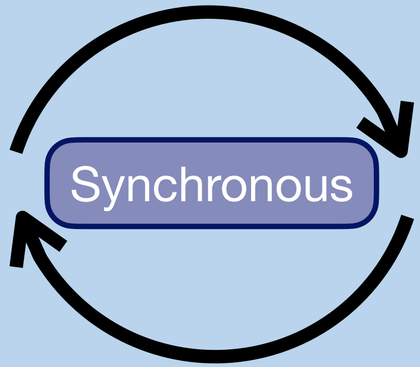

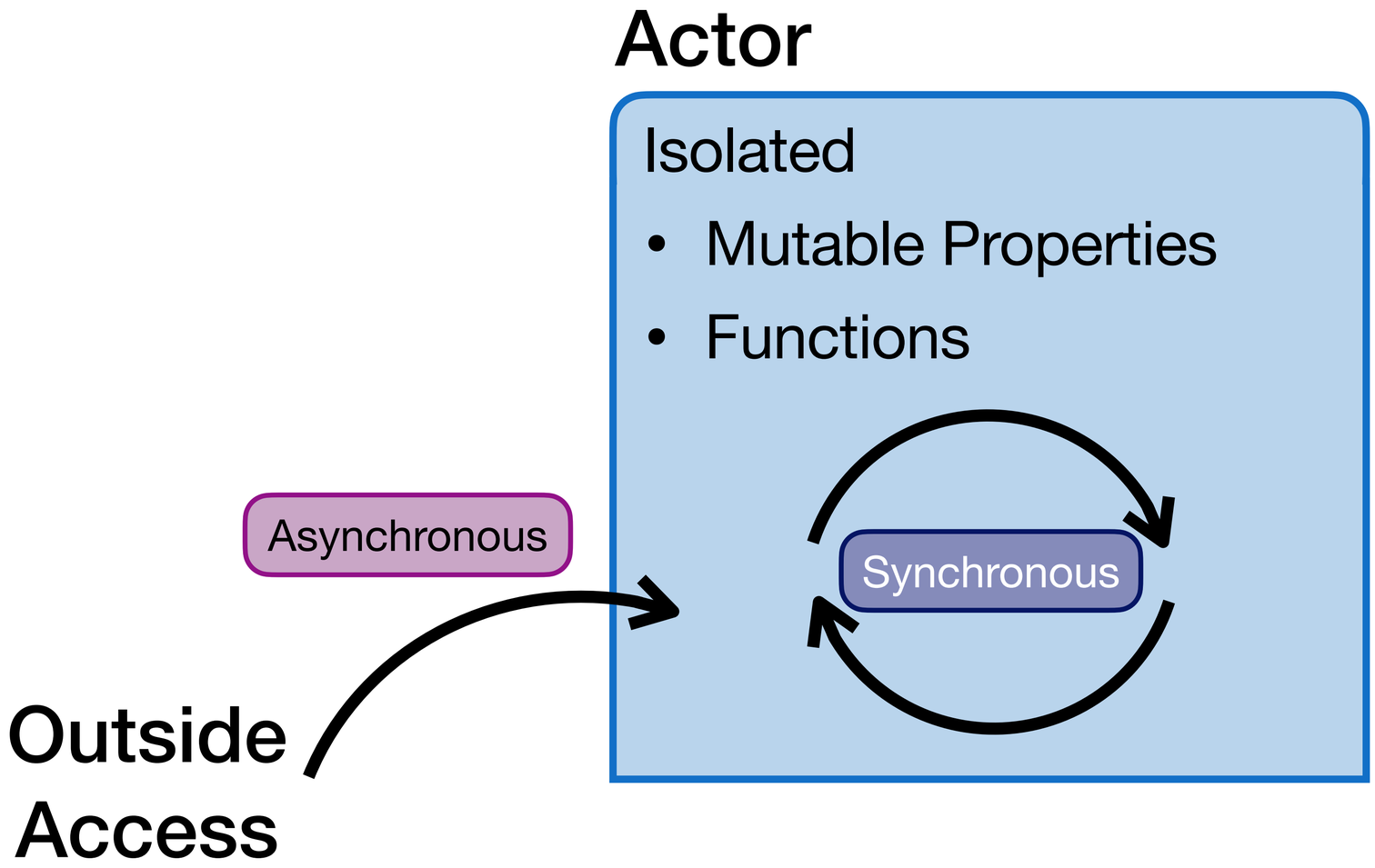
Actor
Isolated
• Mutable Properties
• Functions
Synchronous
Asynchronous
Outside
Access

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actor CowHerd {
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extension CowHerd {
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        print("MOOOOO")
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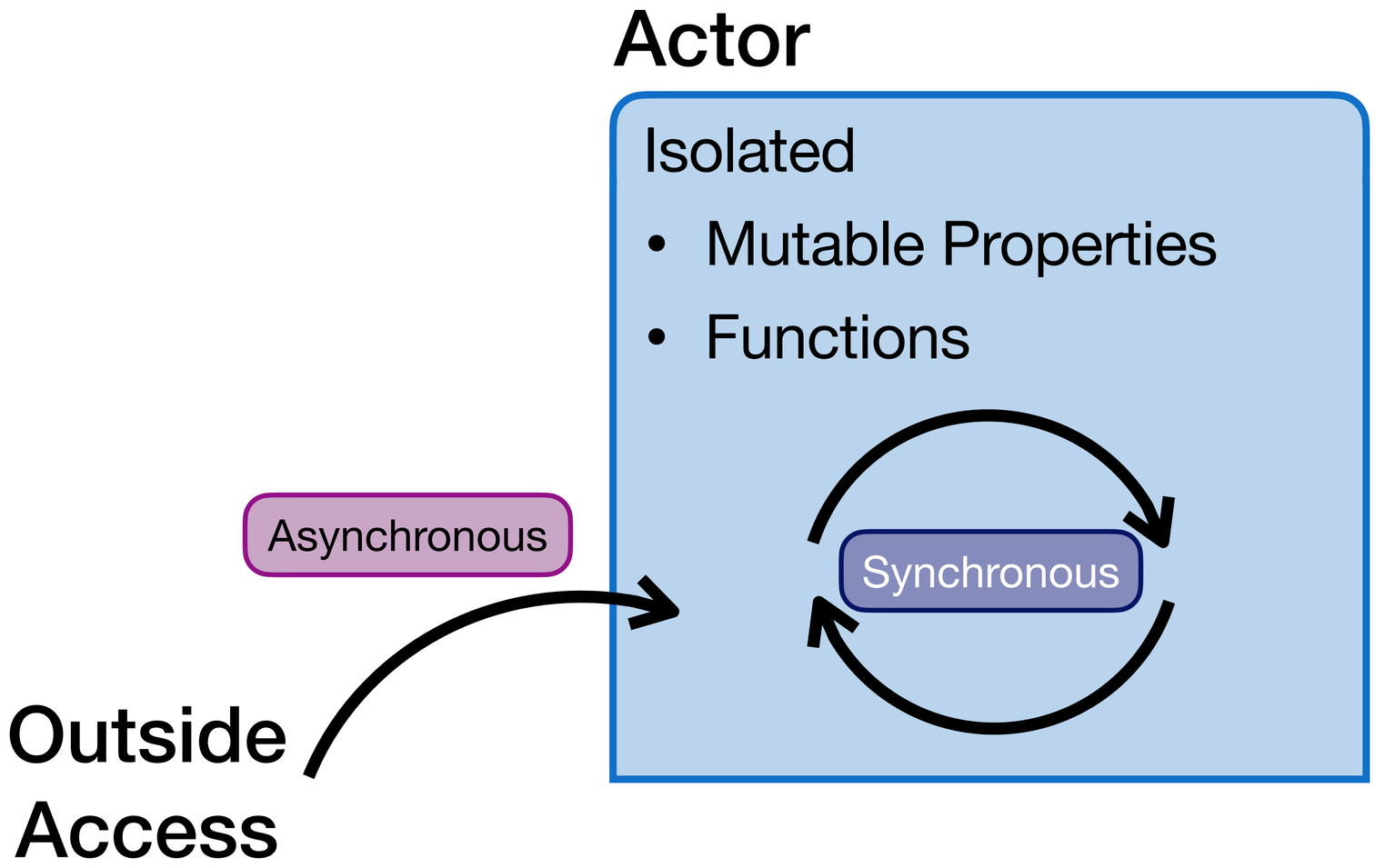
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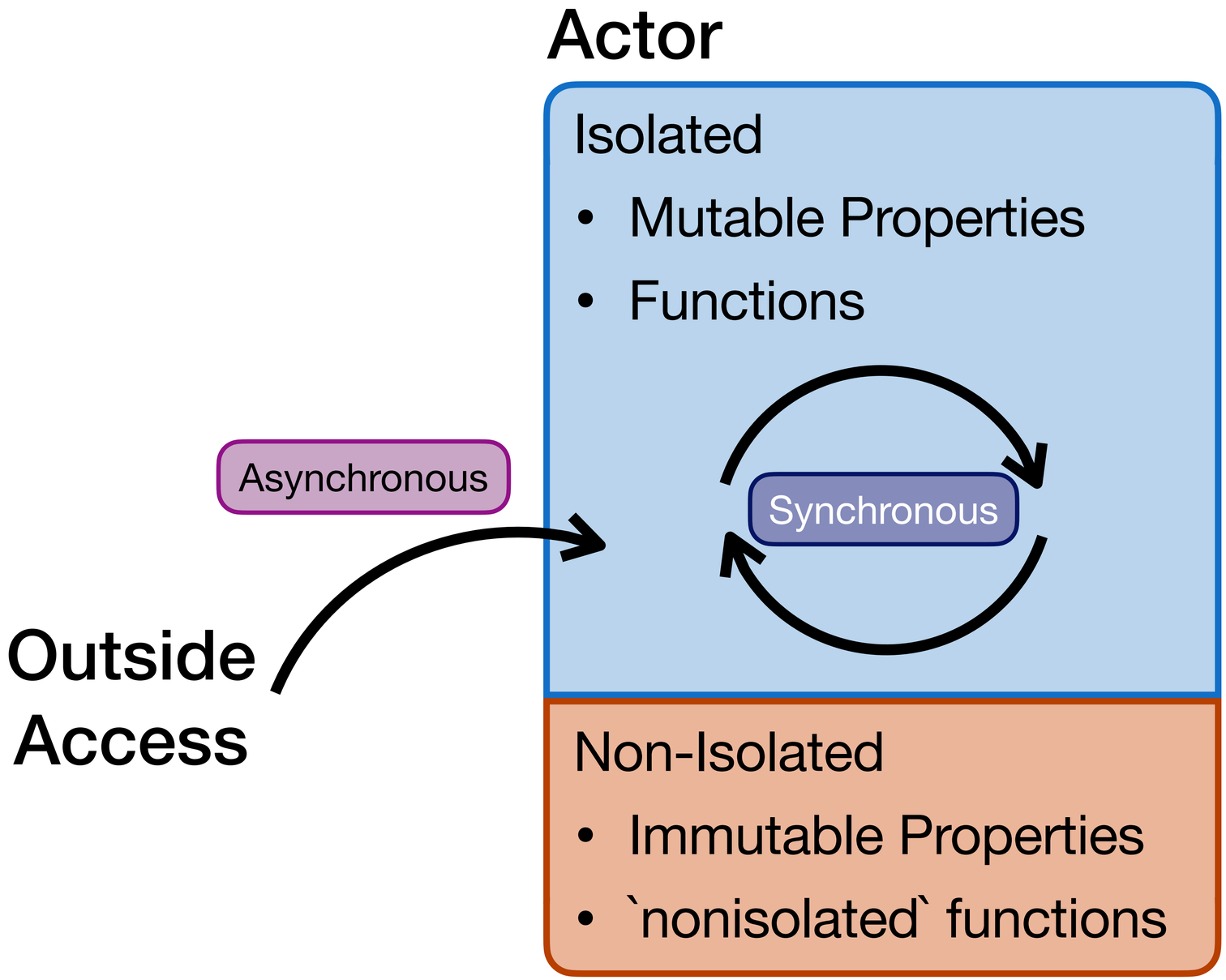
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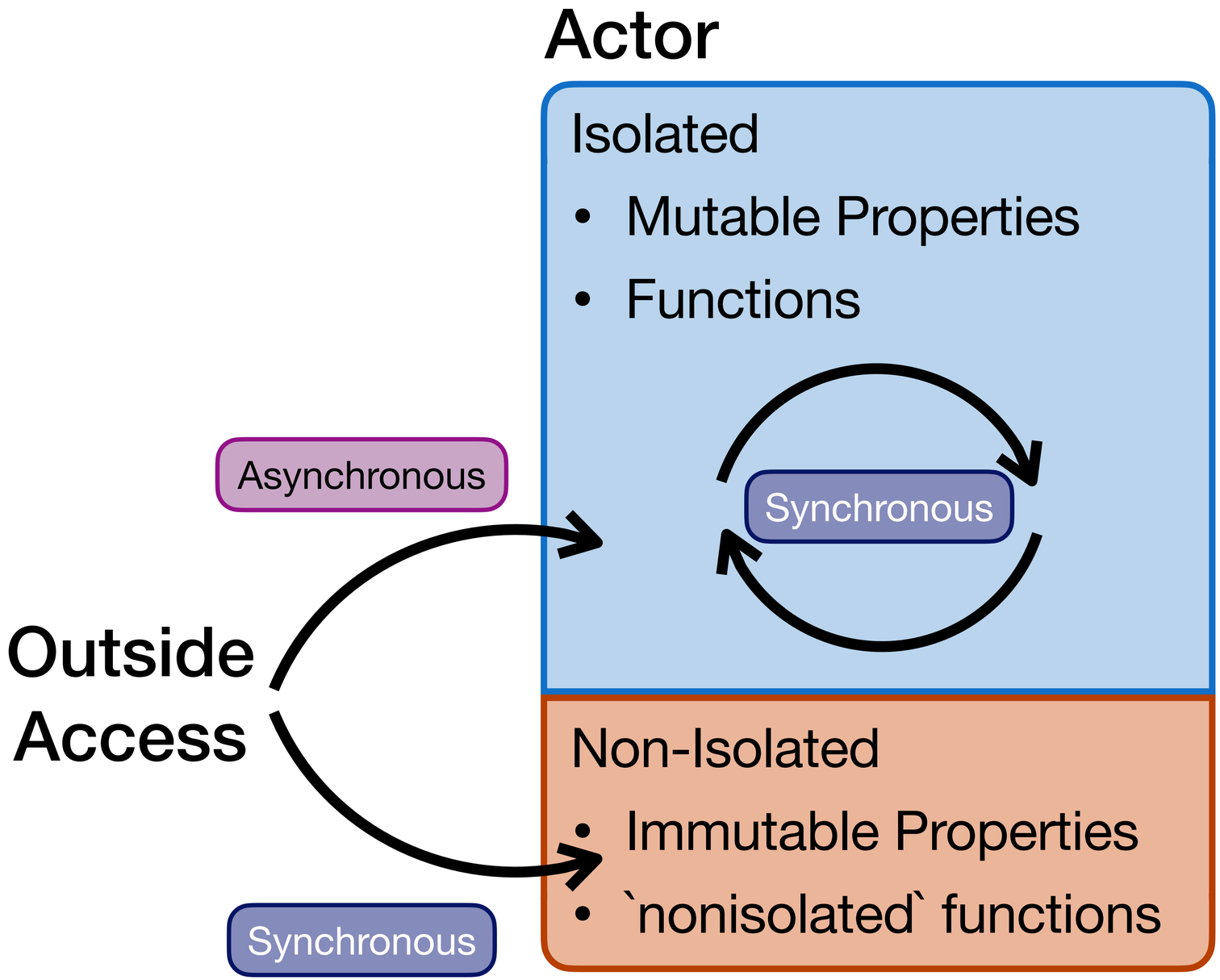
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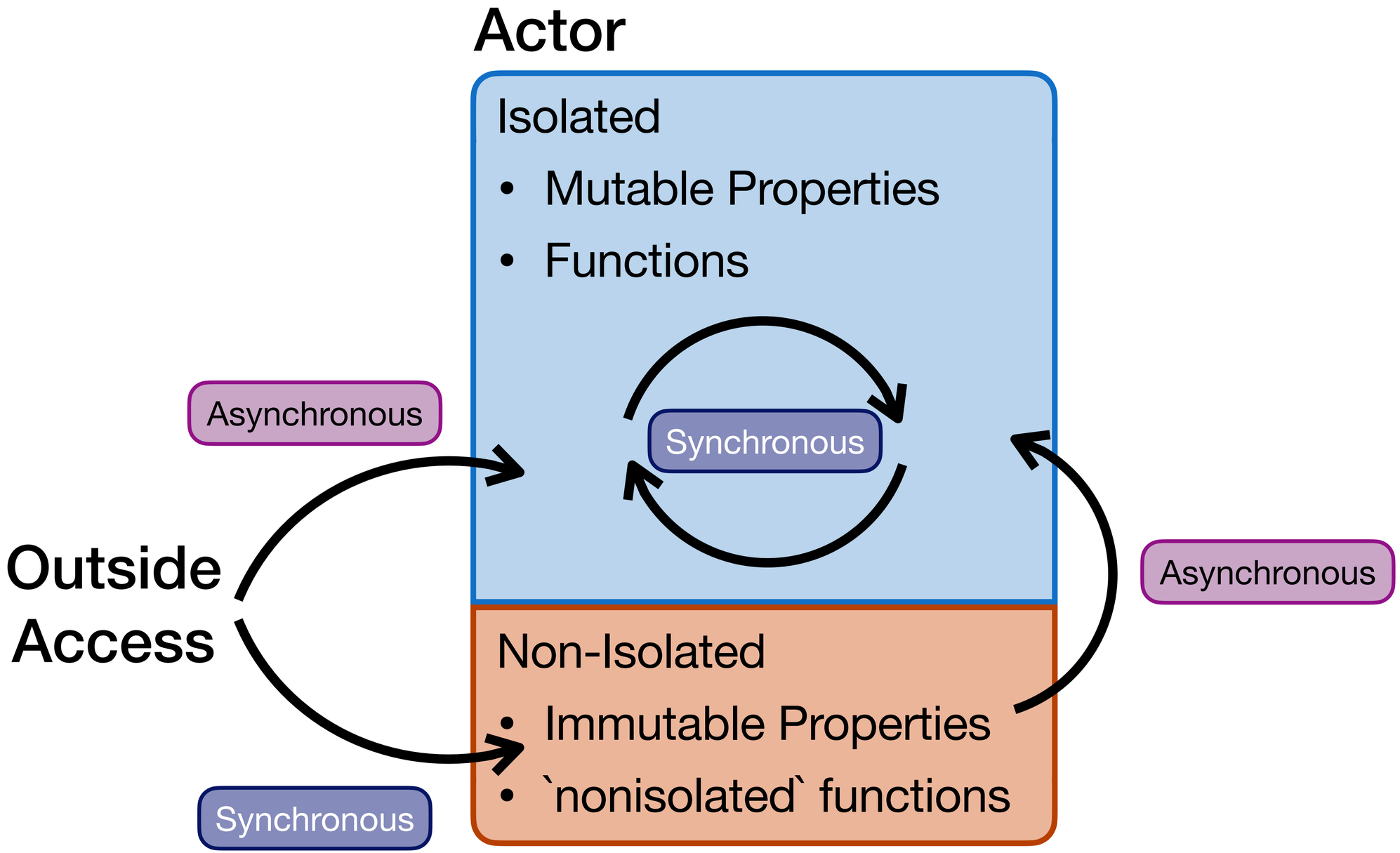
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Actor Continued…

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- Threading

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- Threading
  - Implicit background threading with `await`

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    - MainActor
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- Create multiple instances of an actor
- Logical controllers, managers, and data stores.

MainActor

```
@MainActor
class View: UIView {
    ...

    func updateName(_ name: String) {
        ...
    }
}

...

Task {
    let name = await herd.name
    view.updateName(name)
    await view.updateName(name)
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MainActor

- Concrete actor implementation

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- Concrete actor implementation
- Represents the main thread

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    await view.updateName(name) ✅
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MainActor

- Concrete actor implementation
- Represents the main thread
- `@MainActor`

`DispatchQueue.main.async` 👋

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  - Function suspension
  - Error handling

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- **Ergonomics++**
  - Function suspension
  - Error handling
- **Compile time checks**
  - Async requires await
  - Actors and the MainActor
- **Local reasoning & scoping**
  - Easily visualize concurrent processing
  - Structured concurrency scoping

Recommendations

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- Use `try`/`catch` error handling

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- Convert modules at a time

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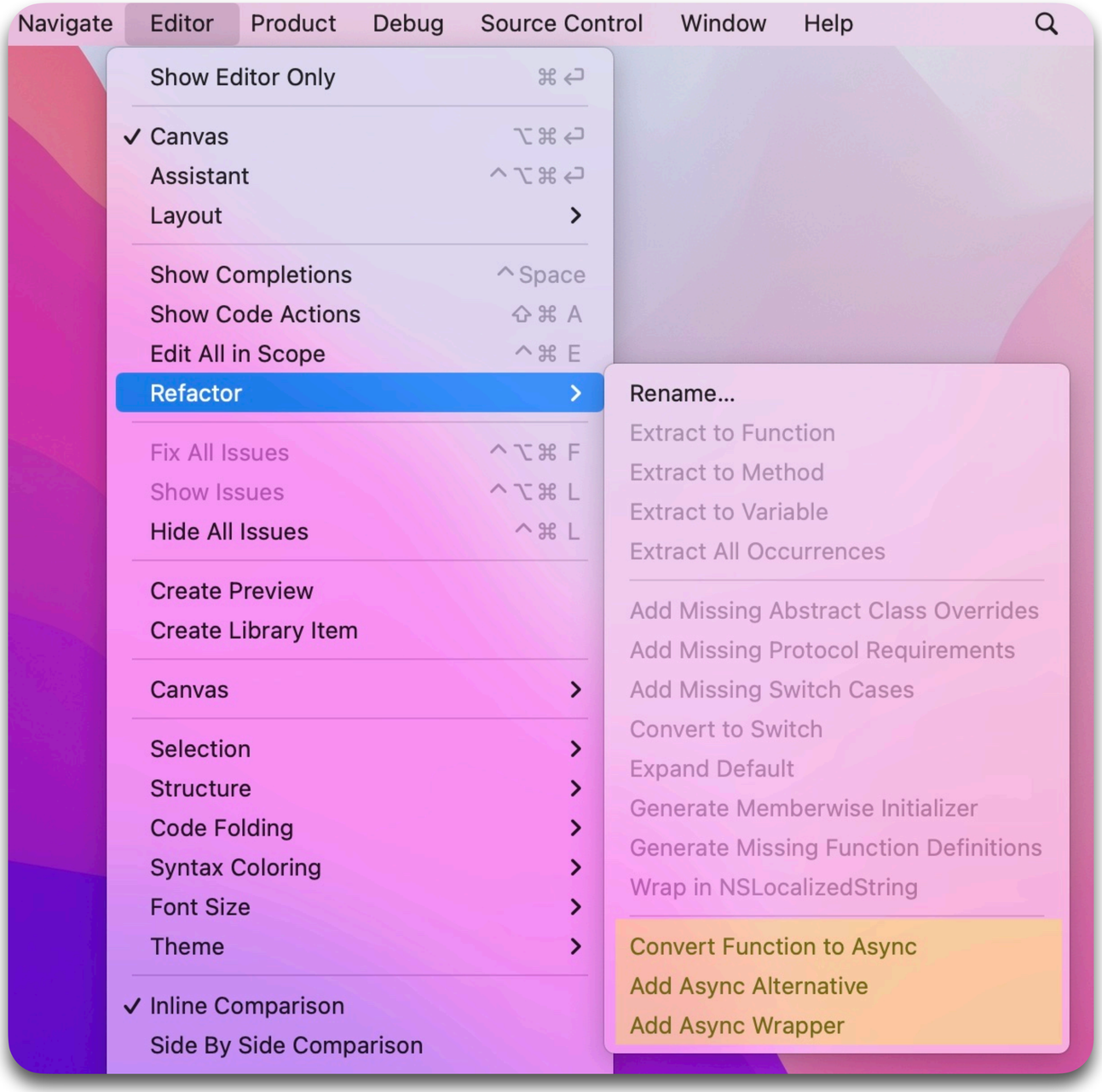
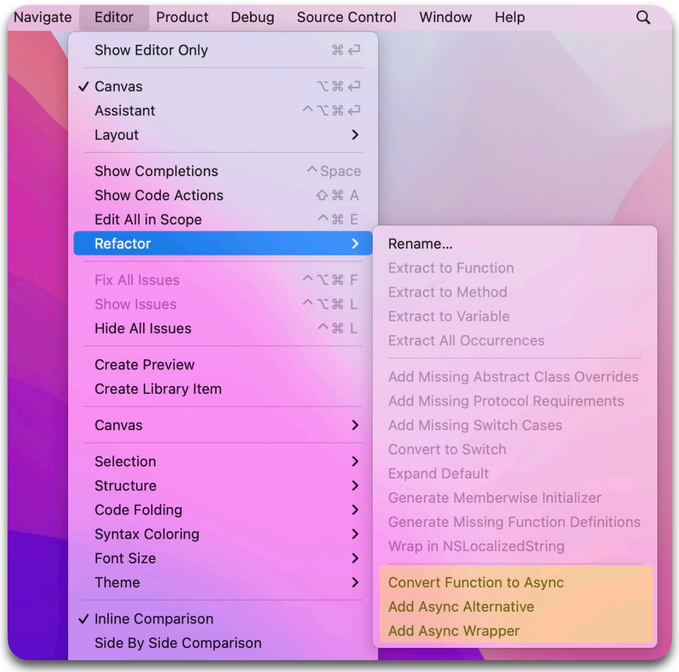
- Use `try`/`catch` error handling
- Convert modules at a time
- Create `async` shims for your APIs using Continuations
  - Utilize Xcode’s refactor tools


Navigate
Editor
Product
Debug
Source Control
Window
Help
Show Editor Only ⌘↩
Canvas ⌥⌘↩
Assistant ^⌥⌘↩
Layout
Show Completions ^Space
Show Code Actions ⇧⌘A
Edit All in Scope ^⌘E
Refactor
Fix All Issues ^⌥⌘F
Show Issues ^⌥⌘L
Hide All Issues ^⌘L
Create Preview
Create Library Item
Canvas
Selection
Structure
Code Folding
Syntax Coloring
Font Size
Theme
Inline Comparison
Side By Side Comparison
Rename...
Extract to Function
Extract to Method
Extract to Variable
Extract All Occurrences
Add Missing Abstract Class Overrides
Add Missing Protocol Requirements
Add Missing Switch Cases
Convert to Switch
Expand Default
Generate Memberwise Initializer
Generate Missing Function Definitions
Wrap in NSLocalizedString
Convert Function to Async
Add Async Alternative
Add Async Wrapper




```
func fetchCow(completion: (Result<Cow, Error>) -> Void) {
    // does asynchronous network fetch
}

func fetchCow() async throws -> Cow {
    return try await withCheckedThrowingContinuation {
        continuation in
        fetchCow() { result in
            continuation.resume(with: result)
        }
    }
}
```

Recommendations Cont…

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- Using thread locks

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- Using thread locks
- Marking everything with `async`
- Progress Updates