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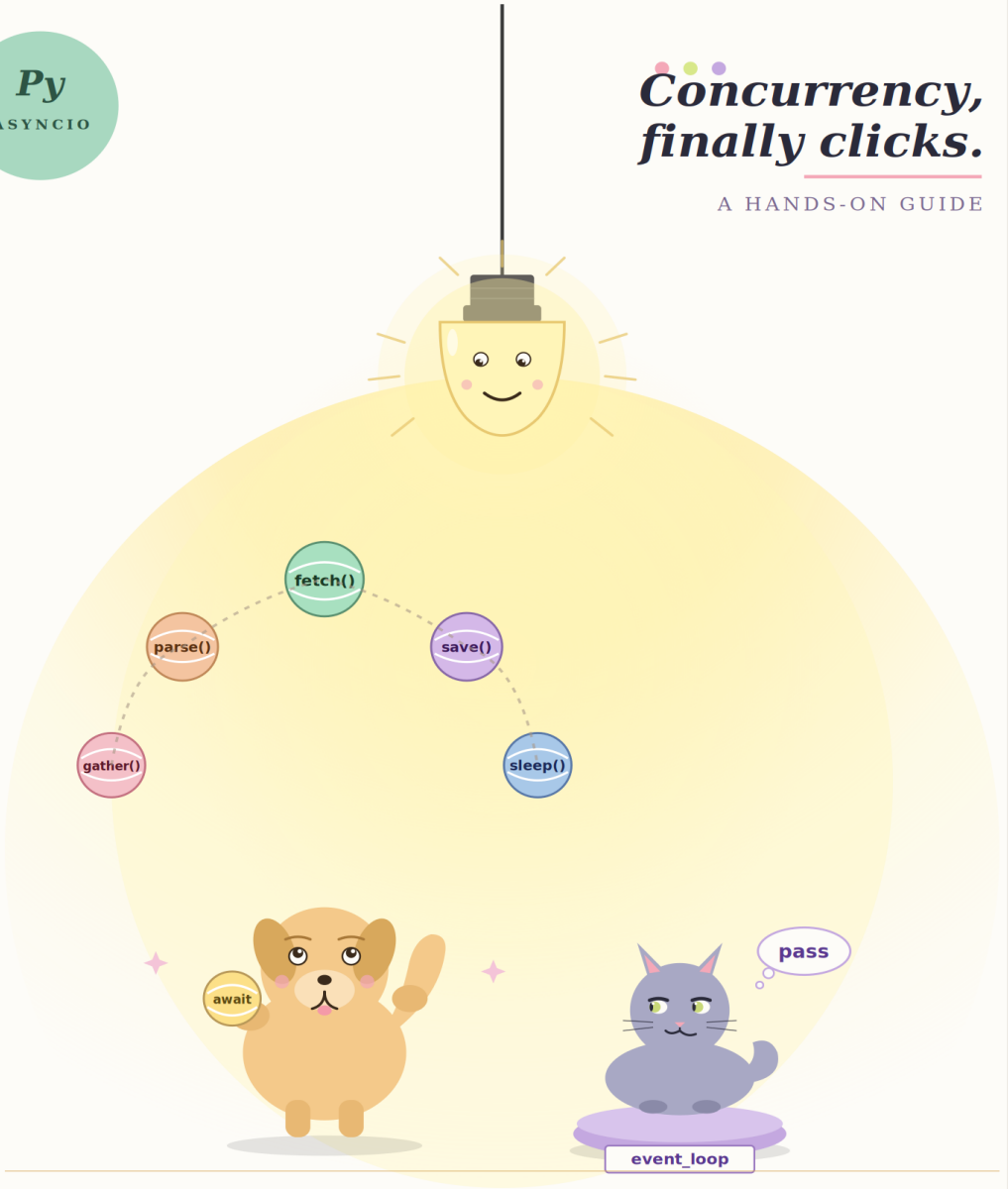
A HANDS-ON GUIDE



asyncio from groundup

A working mental model for python asyncio

RITESH MODI
Head of AI, MarketOnce
Ex-Microsoft Principal Engineer

FIRST EDITION
2026

asyncio from ground up

A working Mental Model for Python asyncio

Ritesh Modi

This book is available at https://leanpub.com/asyncio

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Contents

Getting Started

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Writing in Markua

Writing in Markua is easy! You can learn most of what you need to know with just a few examples.

To make *italic text* you surround it with single asterisks. To make **bold text** you surround it with double asterisks.

Section One

You can start new sections by starting a line with two # signs and a space, and then typing your section title.

Sub-Section One

You can start new sub-sections by starting a line with three # signs and a space, and then typing your sub-section title.

Including a Chapter in the Sample Book

At the top of this file, you will also see a line at the top:

```
1  {sample: true}
```

Leanpub has the ability to make a sample book, which interested readers can download or read online. If you add this line above a chapter heading, then when you publish your book, this chapter will be included in a separate sample book for these interested readers.

Links

You can add web links easily.

Here's a link to the Leanpub homepage.

Images

You can add an image to your book in a similar way.

First, add the image to the “Resources” folder for your book. You will find the “Resources” folder under the “Manuscript” menu to the left.

If you look in your book’s “Resources” folder right now, you will see that there is an example image there with the file name “palm-trees.jpg”. Here’s how you can add this image to your book:

If you want to add a figure title, you put it in quotes:

Figure 1. Palm Trees

If you want to add descriptive alt text, which is good for accessibility, you put it between the square brackets:

Figure 2. Palm Trees

You can also set the alt text and/or the figure title in an attribute list:

Figure 3. Palm Trees

Finally, if no title is provided, and the `alt-title` document setting is the default of `all`, the alt text will be used as the figure title instead of as alt text.

Figure 4. Palm Trees

You can set the important document settings at Settings > Generation Settings.

Lists

Numbered Lists

You make a numbered list like this:

1. kale
2. carrot
3. ginger

Bulleted Lists

You make a bulleted list like this:

- kale

- carrot
- ginger

Definition Lists

You can even have definition lists!

term 1
: definition 1a

: definition 1b

term 2
: definition 2

Page Breaks

We don't recommend that you manually break pages, since that is brittle and can lead to unexpected formatting if you edit text earlier in your chapter and forget about the manual page breaks. But if you really want to add a page break, you use the `{pagebreak}` directive on a line by itself, with blank lines above it and below it.

Code Samples

You can add code samples really easily. Code can be in separate files (a "local" resource) or in the manuscript itself (an "inline" resource).

Local Code Samples

Here's a local code resource:

Figure 5. Hello World in Ruby

```ruby
require 'time'

# This is just some pointless code so you can see the syntax highlighting...
def display_info
  pi = Math::PI.round(10)
  time_last_year = (Time.now - 365 * 24 * 60 * 60).getlocal("-08:00")
  formatted_time = time_last_year.strftime("%Y-%m-%d %H:%M:%S")
  puts "Pi to 10 decimal places: #{pi}"
  puts "The time 1 year ago in Pacific Time: #{formatted_time}"
end
```

Inline Code Samples

Inline code samples can either be spans or figures.

A span looks like `puts "hello world"` this.

A figure looks like this:

```ruby
require 'time'

# This is just some pointless code so you can see the syntax highlighting...
def display_info
  pi = Math::PI.round(10)
  time_last_year = (Time.now - 365 * 24 * 60 * 60).getlocal("-08:00")
  formatted_time = time_last_year.strftime("%Y-%m-%d %H:%M:%S")
  puts "Pi to 10 decimal places: #{pi}"
  puts "The time 1 year ago in Pacific Time: #{formatted_time}"
end
```

You can also add a figure title using the title attribute:

Figure 6. Hello World in Ruby

```ruby
require 'time'

# This is just some pointless code so you can see the syntax highlighting...
def display_info
  pi = Math::PI.round(10)
  time_last_year = (Time.now - 365 * 24 * 60 * 60).getlocal("-08:00")
  formatted_time = time_last_year.strftime("%Y-%m-%d %H:%M:%S")
  puts "Pi to 10 decimal places: #{pi}"
  puts "The time 1 year ago in Pacific Time: #{formatted_time}"
end
```

Tables

You can insert tables easily inline, using the GitHub Flavored Markdown (GFM) table syntax:

Header 1	Header 2
Content 1	Content 2
Content 3	Content 4 Can be Different Length

Tables work best for numeric tabular data involving a small number of columns containing small numbers:

Central Bank	Rate
JPY	-0.10%
EUR	0.00%
USD	0.00%
CAD	0.25%

Definition lists are preferred to tables for most use cases, since reading a large table with many columns is terrible on phones and since typing text in a table quickly gets annoying.

Math

You can easily insert math equations inline using either spans or figures.

Here's one of the kinematic equations $d = v_i t + \frac{1}{2}at^2$ inserted as a span inside a sentence.

Here's some math inserted as a figure.

$$\left|\sum_{i=1}^{n} a_i b_i\right| \le \left(\sum_{i=1}^{n} a_i^2\right)^{1/2} \left(\sum_{i=1}^{n} b_i^2\right)^{1/2}$$

Figure 7. Something Involving Sums

Headings

Markua supports both of Markdown's heading styles.

The preferred style, called atx headers, has the following meaning in Markua:

```
{class: part}
# Part

This is a paragraph.

# Chapter

This is a paragraph.

## Section

This is a paragraph.

### Sub-section

This is a paragraph.

#### Sub-sub-section

This is a paragraph.

##### Sub-sub-sub-section

```

```
This is a paragraph.

###### Sub-sub-sub-sub-section

This is a paragraph.
```

Note the use of three backticks in the above example, to treat the Markua like inline code (instead of actually like headers).

The other style of headers, called Setext headers, has the following headings:

```
{class: part}
Part
====

This is a paragraph.

Chapter
=======

This is a paragraph.

Section
-------

This is a paragraph.
```

Setext headers look nice, but only if you're only using chapters and sections. If you want to add sub-sections (or lower), you'll be using atx headers for at least some of your headers. My advice is to just use atx headers all the time. (The `{class: part}` attribute list on a chapter header to make a part header does actually work with Setext headers, but it's really ugly.)

Note that while it is confusing and ugly to mix and match using atx and Setext headers for chapters and sections in the same document, you can do it. However, please don't.

Block quotes, Asides and Blurbs

> Block quotes are really easy too.
>
> —Peter Armstrong, *Markua Spec*

> Asides are useful for longer text.
>
> But typing them like this isn't fun.

> Asides can be written this way, since adding a bunch of A> stuff at the beginning of each line can get annoying with longer asides.

Blurbs are useful

Blurbs are useful

There are many types of blurbs, which will be familiar to you if you've ever read a computer programming book.

This is a discussion.

You can also specify them this way:

This is a discussion

This is an error.

This is information.

This is a question. (Not a question in a Markua course; those are done differently!)

This is a tip.

This is a warning.

This is an exercise. (Not an exercise in a Markua course; those are done differently!)

Good luck, have fun!

If you've read this far, you're definitely the right type of person to be here!

Our last piece of advice is simple: once you have a couple chapters completed, publish your book in-progress!

This approach is called Lean Publishing. It's why Leanpub is called Leanpub.

If you want to learn more about Lean Publishing, read this or watch this.

Asyncio from ground up

A Working Mental Model for Python asyncio

Ritesh Modi

Asyncio from ground up: A Working Mental Model for Python asyncio

First Edition

First printing: 2026

For everyone who closed three asyncio tutorials in a row and thought it was their fault.

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Concurrency, Parallelism, and the GIL

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.2 The blocking patterns to learn to recognize

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11.3 The single most useful tool: asyncio's debug mode

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.5 *Optional*: Testing TaskGroup error propagation

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12.6 Event loop fixture scope

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Chapter recap

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A.1 Python versions and what they buy you

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A.2 The packages the book uses

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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Glossary

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1.1 The first version of `news.py`

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1.3 The cost grows with the list

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1.4 The same shape, one layer down

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1.5 The question that drives the rest of the book

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Concurrency, Parallelism, and the GIL

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2.1 What a thread is, briefly

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2.2 The threaded version of `news.py`

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2.3 Threading the TCP probes

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2.4 Why the speedup actually works (and the GIL story you have heard wrong)

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2.6 The two scales the book cares about

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The Loop, From Scratch

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3.1 A queue of jobs

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3.2 A loop that runs the next ready job

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3.3 Two senses of “ready”, and the generator that gives us pause

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3.4 The loop sleeps when nothing is ready

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3.5 Connecting the toy loop to `news.py`

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3.5.1 Common mistakes you will make at least once

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Coroutines, Without the Magic

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4.1 Generators, the original coroutine

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4.2 yield as a pause point, one more time

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4.3 The toy loop

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4.4 What async def returns

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Polite driver `for x in gen():` (no `for`; the loop handles it)

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4.5 Coroutines are not running until the loop runs them

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4.5.1 Two coroutines yielding back and forth

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4.5.2 Common mistakes you will make at least once

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Optional: how the bridge works

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5.2 What await does at a call site

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5.4 The first real asyncio `news.py`

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await Yields, Suspends, and Resumes

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6.1 What await does

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6.2 What is saved across the pause

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6.3 How the loop wakes the coroutine back up

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6.4 A Task is a coroutine that the loop is driving

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6.5 *For the curious*: *coro.send(value)* and the bytecode

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6.6 *For the curious*: selectors and the operating system

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6.7 Watching news.py yield and resume

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asyncio.run, create_task, gather

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7.1 asyncio.run as the starting line

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7.2 What asyncio.run does

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7.3 await coro is sequential; create_task(coro) is concurrent

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7.4 asyncio.gather for “run these together”

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7.5 The fast `news.py`

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7.6 Concurrent TCP probes

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The Time Toolbox

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8.1 asyncio.sleep yields; time.sleep blocks

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8.2 wait_for for a deadline around an awaitable

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8.3 asyncio.timeout() as a context manager (Python 3.11+)

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8.4 asyncio.shield to protect from cancellation

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8.5 `asyncio.wait` vs `asyncio.gather`

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async for, async with, Async Iteration and Resource Management

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9.1 async for and the iterator protocol

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9.2 Async generators

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9.2.1 Cleanup when iteration stops short

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9.4 async with and the context-manager protocol

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9.4.1 Multiple `async with` and `AsyncExitStack`

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9.5 Writing your own async context manager

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9.6 The streaming `news.py`

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9.6.1 Two more async-generator pitfalls

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Tasks, TaskGroups, Cancellation, Exception Groups, and contextvars

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10.1 `Task` is the loop's unit of work; the coroutine is just the recipe

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10.2 asyncio.TaskGroup: structured concurrency by construction

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10.4 The bare-except trap

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10.5 ExceptionGroup and except*

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10.6 Re-raising CancelledError after cleanup

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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`asyncio.Event`: one coroutine signals, others wait

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`asyncio.Queue`: pass items between coroutines

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10.9 Capping concurrency with `Semaphore`: 50 sites, 10 in flight

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10.10 contextvars for task-scoped state

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10.11 Producer-consumer with `asyncio.Queue`

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What Goes Wrong, and How to Find It

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.5 *Optional*: Testing TaskGroup error propagation

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Chapter recap

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A.2 The packages the book uses

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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The Blocking Function

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1.1 The first version of `news.py`

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1.3 The cost grows with the list

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1.4 The same shape, one layer down

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1.5 The question that drives the rest of the book

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Concurrency, Parallelism, and the GIL

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2.1 What a thread is, briefly

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2.2 The threaded version of `news.py`

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2.3 Threading the TCP probes

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2.4 Why the speedup actually works (and the GIL story you have heard wrong)

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2.6 The two scales the book cares about

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3.1 A queue of jobs

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3.2 A loop that runs the next ready job

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3.3 Two senses of “ready”, and the generator that gives us pause

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3.4 The loop sleeps when nothing is ready

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3.5 Connecting the toy loop to `news.py`

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3.5.1 Common mistakes you will make at least once

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Coroutines, Without the Magic

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4.1 Generators, the original coroutine

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4.2 yield as a pause point, one more time

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4.3 The toy loop

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4.4 What async def returns

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Polite driver `for x in gen():` (no `for`; the loop handles it)

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4.5 Coroutines are not running until the loop runs them

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4.5.1 Two coroutines yielding back and forth

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4.5.2 Common mistakes you will make at least once

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Optional: how the bridge works

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5.2 What await does at a call site

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5.4 The first real asyncio `news.py`

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await Yields, Suspends, and Resumes

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6.1 What await does

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6.2 What is saved across the pause

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6.3 How the loop wakes the coroutine back up

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6.4 A Task is a coroutine that the loop is driving

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6.5 *For the curious*: *coro.send(value)* and the bytecode

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6.6 *For the curious*: selectors and the operating system

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6.7 Watching news.py yield and resume

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asyncio.run, create_task, gather

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7.1 asyncio.run as the starting line

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7.2 What asyncio.run does

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7.3 await coro is sequential; create_task(coro) is concurrent

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7.4 asyncio.gather for “run these together”

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7.5 The fast `news.py`

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7.6 Concurrent TCP probes

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8.1 asyncio.sleep yields; time.sleep blocks

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8.2 wait_for for a deadline around an awaitable

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8.3 asyncio.timeout() as a context manager (Python 3.11+)

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8.4 asyncio.shield to protect from cancellation

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8.5 `asyncio.wait` vs `asyncio.gather`

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8.6 asyncio.as_completed for results as they arrive

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async for, async with, Async Iteration and Resource Management

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9.1 async for and the iterator protocol

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9.2.1 Cleanup when iteration stops short

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9.3.1 Async comprehensions

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9.4 async with and the context-manager protocol

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9.4.1 Multiple `async with` and `AsyncExitStack`

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9.5 Writing your own async context manager

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9.6 The streaming `news.py`

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9.6.1 Two more async-generator pitfalls

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Tasks, TaskGroups, Cancellation, Exception Groups, and contextvars

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10.1 `Task` is the loop's unit of work; the coroutine is just the recipe

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10.2 asyncio.TaskGroup: structured concurrency by construction

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10.3 Cancellation: `task.cancel()` and `CancelledError` at the next `await`

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10.4 The bare-except trap

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10.5 ExceptionGroup and except*

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10.6 Re-raising CancelledError after cleanup

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10.7 Canceling a TCP probe

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10.8 Synchronization primitives

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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`asyncio.Event`: one coroutine signals, others wait

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`asyncio.Queue`: pass items between coroutines

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10.9 Capping concurrency with `Semaphore`: 50 sites, 10 in flight

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10.10 contextvars for task-scoped state

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10.11 Producer-consumer with `asyncio.Queue`

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What Goes Wrong, and How to Find It

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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Testing async code

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.4 Testing cancellation

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12.5 *Optional*: Testing TaskGroup error propagation

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12.6 Event loop fixture scope

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Chapter recap

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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1.1 The first version of `news.py`

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1.3 The cost grows with the list

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1.4 The same shape, one layer down

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1.5 The question that drives the rest of the book

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Concurrency, Parallelism, and the GIL

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2.1 What a thread is, briefly

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2.2 The threaded version of `news.py`

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2.3 Threading the TCP probes

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2.4 Why the speedup actually works (and the GIL story you have heard wrong)

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3.1 A queue of jobs

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3.2 A loop that runs the next ready job

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3.3 Two senses of “ready”, and the generator that gives us pause

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3.4 The loop sleeps when nothing is ready

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3.5 Connecting the toy loop to `news.py`

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3.5.1 Common mistakes you will make at least once

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Coroutines, Without the Magic

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4.1 Generators, the original coroutine

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4.2 yield as a pause point, one more time

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4.3 The toy loop

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4.4 What async def returns

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Polite driver `for x in gen():` (no `for`; the loop handles it)

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4.5 Coroutines are not running until the loop runs them

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4.5.1 Two coroutines yielding back and forth

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Optional: how the bridge works

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5.2 What await does at a call site

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await Yields, Suspends, and Resumes

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6.1 What await does

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6.2 What is saved across the pause

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6.5 *For the curious*: *coro.send(value)* and the bytecode

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6.6 *For the curious*: selectors and the operating system

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6.7 Watching news.py yield and resume

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asyncio.run, create_task, gather

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7.4 asyncio.gather for “run these together”

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7.5 The fast `news.py`

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8.1 asyncio.sleep yields; time.sleep blocks

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8.2 wait_for for a deadline around an awaitable

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8.3 asyncio.timeout() as a context manager (Python 3.11+)

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8.4 asyncio.shield to protect from cancellation

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async for, async with, Async Iteration and Resource Management

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9.2.1 Cleanup when iteration stops short

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9.3 `async for` over `aiohttp` response bodies

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9.3.1 Async comprehensions

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9.4 async with and the context-manager protocol

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9.4.1 Multiple `async with` and `AsyncExitStack`

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9.5 Writing your own async context manager

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9.6 The streaming `news.py`

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9.6.1 Two more async-generator pitfalls

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Tasks, TaskGroups, Cancellation, Exception Groups, and contextvars

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10.1 `Task` is the loop's unit of work; the coroutine is just the recipe

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10.2 asyncio.TaskGroup: structured concurrency by construction

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10.3 Cancellation: `task.cancel()` and `CancelledError` at the next `await`

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10.4 The bare-except trap

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10.5 ExceptionGroup and except*

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10.6 Re-raising CancelledError after cleanup

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10.7 Canceling a TCP probe

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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`asyncio.Event`: one coroutine signals, others wait

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`asyncio.Queue`: pass items between coroutines

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10.9 Capping concurrency with `Semaphore`: 50 sites, 10 in flight

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10.10 contextvars for task-scoped state

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10.11 Producer-consumer with `asyncio.Queue`

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What Goes Wrong, and How to Find It

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.5 *Optional*: Testing TaskGroup error propagation

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12.6 Event loop fixture scope

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Chapter recap

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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1.1 The first version of `news.py`

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1.3 The cost grows with the list

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1.4 The same shape, one layer down

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1.5 The question that drives the rest of the book

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Concurrency, Parallelism, and the GIL

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2.1 What a thread is, briefly

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2.2 The threaded version of `news.py`

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2.3 Threading the TCP probes

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2.4 Why the speedup actually works (and the GIL story you have heard wrong)

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2.6 The two scales the book cares about

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The Loop, From Scratch

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3.1 A queue of jobs

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3.2 A loop that runs the next ready job

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3.3 Two senses of “ready”, and the generator that gives us pause

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3.4 The loop sleeps when nothing is ready

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3.5 Connecting the toy loop to `news.py`

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3.5.1 Common mistakes you will make at least once

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Coroutines, Without the Magic

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4.1 Generators, the original coroutine

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4.2 yield as a pause point, one more time

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4.3 The toy loop

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4.4 What async def returns

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Polite driver `for x in gen():` (no `for`; the loop handles it)

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4.5 Coroutines are not running until the loop runs them

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4.5.1 Two coroutines yielding back and forth

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4.5.2 Common mistakes you will make at least once

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Optional: how the bridge works

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async and await

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5.1 What async does to a function definition

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5.2 What await does at a call site

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5.3 What can be awaited, and what cannot

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6.1 What await does

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6.2 What is saved across the pause

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6.3 How the loop wakes the coroutine back up

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6.5 *For the curious*: *coro.send(value)* and the bytecode

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6.6 *For the curious*: selectors and the operating system

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6.7 Watching news.py yield and resume

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asyncio.run, create_task, gather

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7.3 await coro is sequential; create_task(coro) is concurrent

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7.4 asyncio.gather for “run these together”

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8.2 wait_for for a deadline around an awaitable

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8.3 asyncio.timeout() as a context manager (Python 3.11+)

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8.4 asyncio.shield to protect from cancellation

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8.5 `asyncio.wait` vs `asyncio.gather`

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8.6 asyncio.as_completed for results as they arrive

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8.7 Timeouts and streaming

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async for, async with, Async Iteration and Resource Management

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9.1 async for and the iterator protocol

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9.2 Async generators

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9.2.1 Cleanup when iteration stops short

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9.3 `async for` over `aiohttp` response bodies

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9.3.1 Async comprehensions

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9.4 async with and the context-manager protocol

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9.4.1 Multiple `async with` and `AsyncExitStack`

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9.5 Writing your own async context manager

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9.6 The streaming `news.py`

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9.6.1 Two more async-generator pitfalls

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Tasks, TaskGroups, Cancellation, Exception Groups, and contextvars

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10.1 `Task` is the loop's unit of work; the coroutine is just the recipe

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10.2 asyncio.TaskGroup: structured concurrency by construction

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10.3 Cancellation: `task.cancel()` and `CancelledError` at the next `await`

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10.4 The bare-except trap

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10.5 ExceptionGroup and except*

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10.6 Re-raising CancelledError after cleanup

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10.7 Canceling a TCP probe

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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`asyncio.Event`: one coroutine signals, others wait

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`asyncio.Queue`: pass items between coroutines

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10.9 Capping concurrency with `Semaphore`: 50 sites, 10 in flight

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10.10 contextvars for task-scoped state

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10.11 Producer-consumer with `asyncio.Queue`

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What Goes Wrong, and How to Find It

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.2 The blocking patterns to learn to recognize

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11.3 The single most useful tool: asyncio's debug mode

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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Testing async code

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.4 Testing cancellation

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12.5 *Optional*: Testing TaskGroup error propagation

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12.6 Event loop fixture scope

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12.7 Testing timeouts without real time

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Chapter recap

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Appendix A: Setting up your environment

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A.1 Python versions and what they buy you

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A.2 The packages the book uses

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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From the Author

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The Blocking Function

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1.1 The first version of `news.py`

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1.2 What "blocking" actually means

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1.3 The cost grows with the list

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1.4 The same shape, one layer down

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1.5 The question that drives the rest of the book

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Concurrency, Parallelism, and the GIL

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2.1 What a thread is, briefly

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2.2 The threaded version of `news.py`

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2.3 Threading the TCP probes

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2.4 Why the speedup actually works (and the GIL story you have heard wrong)

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2.6 The two scales the book cares about

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2.7 Where the next chapter goes

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The Loop, From Scratch

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3.1 A queue of jobs

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3.2 A loop that runs the next ready job

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3.3 Two senses of “ready”, and the generator that gives us pause

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3.4 The loop sleeps when nothing is ready

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3.5 Connecting the toy loop to `news.py`

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3.5.1 Common mistakes you will make at least once

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Coroutines, Without the Magic

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4.1 Generators, the original coroutine

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4.2 yield as a pause point, one more time

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4.3 The toy loop

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4.4 What async def returns

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Polite driver `for x in gen():` (no `for`; the loop handles it)

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4.5 Coroutines are not running until the loop runs them

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4.5.1 Two coroutines yielding back and forth

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4.5.2 Common mistakes you will make at least once

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Optional: how the bridge works

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5.2 What await does at a call site

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5.3 What can be awaited, and what cannot

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5.4 The first real asyncio `news.py`

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6.1 What await does

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6.2 What is saved across the pause

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6.3 How the loop wakes the coroutine back up

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6.5 *For the curious*: *coro.send(value)* and the bytecode

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6.6 *For the curious*: selectors and the operating system

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6.7 Watching news.py yield and resume

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asyncio.run, create_task, gather

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7.1 asyncio.run as the starting line

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7.2 What asyncio.run does

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7.3 await coro is sequential; create_task(coro) is concurrent

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7.4 asyncio.gather for “run these together”

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7.5 The fast `news.py`

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7.6 Concurrent TCP probes

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7.7 The lost-task trap

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8.1 asyncio.sleep yields; time.sleep blocks

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8.2 wait_for for a deadline around an awaitable

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8.3 asyncio.timeout() as a context manager (Python 3.11+)

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8.4 asyncio.shield to protect from cancellation

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8.5 `asyncio.wait` vs `asyncio.gather`

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8.6 asyncio.as_completed for results as they arrive

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8.7 Timeouts and streaming

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async for, async with, Async Iteration and Resource Management

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9.1 async for and the iterator protocol

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9.2 Async generators

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9.2.1 Cleanup when iteration stops short

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9.3 `async for` over `aiohttp` response bodies

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9.3.1 Async comprehensions

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9.4 async with and the context-manager protocol

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9.4.1 Multiple `async with` and `AsyncExitStack`

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9.5 Writing your own async context manager

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9.6 The streaming `news.py`

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9.6.1 Two more async-generator pitfalls

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Tasks, TaskGroups, Cancellation, Exception Groups, and contextvars

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10.1 `Task` is the loop's unit of work; the coroutine is just the recipe

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10.2 asyncio.TaskGroup: structured concurrency by construction

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10.3 Cancellation: `task.cancel()` and `CancelledError` at the next `await`

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10.4 The bare-except trap

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10.5 ExceptionGroup and except*

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10.6 Re-raising CancelledError after cleanup

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10.7 Canceling a TCP probe

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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`asyncio.Event`: one coroutine signals, others wait

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`asyncio.Queue`: pass items between coroutines

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10.9 Capping concurrency with `Semaphore`: 50 sites, 10 in flight

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10.10 contextvars for task-scoped state

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10.11 Producer-consumer with `asyncio.Queue`

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What Goes Wrong, and How to Find It

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.4 Testing cancellation

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12.5 *Optional*: Testing TaskGroup error propagation

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12.6 Event loop fixture scope

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12.7 Testing timeouts without real time

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Chapter recap

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Appendix A: Setting up your environment

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A.2 The packages the book uses

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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1.1 The first version of `news.py`

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1.3 The cost grows with the list

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1.4 The same shape, one layer down

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1.5 The question that drives the rest of the book

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2.1 What a thread is, briefly

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2.2 The threaded version of `news.py`

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2.3 Threading the TCP probes

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2.4 Why the speedup actually works (and the GIL story you have heard wrong)

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2.6 The two scales the book cares about

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2.7 Where the next chapter goes

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3.2 A loop that runs the next ready job

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3.3 Two senses of “ready”, and the generator that gives us pause

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3.4 The loop sleeps when nothing is ready

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3.5 Connecting the toy loop to `news.py`

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3.5.1 Common mistakes you will make at least once

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Coroutines, Without the Magic

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4.1 Generators, the original coroutine

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4.2 yield as a pause point, one more time

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4.3 The toy loop

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4.4 What async def returns

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Polite driver `for x in gen():` (no `for`; the loop handles it)

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4.5 Coroutines are not running until the loop runs them

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4.5.1 Two coroutines yielding back and forth

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Optional: how the bridge works

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5.2 What await does at a call site

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5.4 The first real asyncio `news.py`

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await Yields, Suspends, and Resumes

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6.1 What await does

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6.2 What is saved across the pause

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6.3 How the loop wakes the coroutine back up

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6.4 A Task is a coroutine that the loop is driving

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6.5 *For the curious*: *coro.send(value)* and the bytecode

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6.6 *For the curious*: selectors and the operating system

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6.7 Watching news.py yield and resume

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asyncio.run, create_task, gather

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7.1 asyncio.run as the starting line

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7.2 What asyncio.run does

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7.3 await coro is sequential; create_task(coro) is concurrent

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7.4 asyncio.gather for “run these together”

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7.5 The fast `news.py`

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7.6 Concurrent TCP probes

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7.7 The lost-task trap

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The Time Toolbox

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8.1 asyncio.sleep yields; time.sleep blocks

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8.2 wait_for for a deadline around an awaitable

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8.3 asyncio.timeout() as a context manager (Python 3.11+)

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8.4 asyncio.shield to protect from cancellation

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8.5 `asyncio.wait` vs `asyncio.gather`

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8.6 asyncio.as_completed for results as they arrive

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8.7 Timeouts and streaming

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async for, async with, Async Iteration and Resource Management

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9.1 async for and the iterator protocol

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9.2 Async generators

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9.2.1 Cleanup when iteration stops short

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9.3 `async for` over `aiohttp` response bodies

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9.3.1 Async comprehensions

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9.4 async with and the context-manager protocol

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9.4.1 Multiple `async with` and `AsyncExitStack`

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9.5 Writing your own async context manager

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9.6 The streaming `news.py`

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9.6.1 Two more async-generator pitfalls

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Tasks, TaskGroups, Cancellation, Exception Groups, and contextvars

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10.1 `Task` is the loop's unit of work; the coroutine is just the recipe

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10.2 asyncio.TaskGroup: structured concurrency by construction

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10.3 Cancellation: `task.cancel()` and `CancelledError` at the next `await`

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10.4 The bare-except trap

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10.5 ExceptionGroup and except*

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10.6 Re-raising CancelledError after cleanup

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10.7 Canceling a TCP probe

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10.8 Synchronization primitives

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asyncio.Lock: only one at a time

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`asyncio.Semaphore`: only N at a time

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`asyncio.Event`: one coroutine signals, others wait

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`asyncio.Queue`: pass items between coroutines

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10.9 Capping concurrency with `Semaphore`: 50 sites, 10 in flight

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10.10 contextvars for task-scoped state

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10.11 Producer-consumer with `asyncio.Queue`

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What Goes Wrong, and How to Find It

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11.1 The failure mode: one synchronous call freezes the whole loop

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11.2 The blocking patterns to learn to recognize

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11.3 The single most useful tool: asyncio's debug mode

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11.4 The four warnings the runtime emits

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11.5 asyncio.all_tasks() and task.get_stack()

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11.6 aiomonitor: a live REPL inside a running program

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11.7 Profiling that sees the loop correctly

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11.8 Logging task names

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11.9 pdb and async

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11.10 A guided debugging session on the broken `news.py`

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11.11 tcpcheck.py as a diagnostic tool

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Testing async code

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12.1 Your first async test

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12.2 The standard-library alternative

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12.3 What mocks are, and why async needs a different one

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12.4 Testing cancellation

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12.5 *Optional*: Testing TaskGroup error propagation

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12.6 Event loop fixture scope

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12.7 Testing timeouts without real time

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12.8 The most subtle async test bug

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12.9 When a test hangs

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12.10 The full test suite for the fetcher

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Where asyncio Ends: Executors, Graceful Shutdown

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13.1 Fixing the parser bug from Chapter 11

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13.2 The executor toolbox

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13.3 The decision tree

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Heavy CPU work that needs to scale across cores Use `multiprocessing` directly. asyncio is the wrong tool for that workload.

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13.4 Bridging from sync to async, and back

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13.5 Library design: expose async, do not hide it

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13.6 Graceful shutdown

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13.7 The final news.py

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Closing reflection

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Chapter recap

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Further reading

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Appendix A: Setting up your environment

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A.1 Python versions and what they buy you

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A.2 The packages the book uses

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A.3 The smallest runnable asyncio script

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A.4 Reading the running example as you go

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Appendix B: The asyncio API surface

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Functions

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`asyncio.wait_for(coro, timeout)` Wraps a single awaitable with a deadline; cancels the inner work and raises `TimeoutError` on expiry. 8

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Classes and protocols

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`ExceptionGroup` The exception type that holds multiple exceptions raised by sibling Tasks in a TaskGroup. Caught with `except*` (3.11+). 10

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Loop methods worth knowing

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`loop.set_default_executor(executor)` Replaces the loop's default executor. Useful when the default thread pool is too small for the workload. 13

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aiohttp API surface used in the book

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`response.text()` Awaitable that returns the full response body as a decoded string. 5

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Where to find the rest

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Appendix C: Troubleshooting guide

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C.1 Asyncio runtime warnings, what they mean and what to fix

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`RuntimeWarning: async generator 'X' was never closed` An async generator was garbage-collected mid-iteration without the consumer running it to completion or calling `aclose()`. Wrap resources held between `yield`s in `try/finally`. Call `aclose()` explicitly when you need cleanup at a specific moment. (Chapter 9, Section 9.2.1.)

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C.2 The script runs without errors but is no faster than synchronous

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Slow-callback warnings fire (`Executing <Task ...> took 0.234 seconds`) when running with `debug=True`. A coroutine ran for too long between `await`s, blocking the loop. Usually a CPU-bound function or a sync I/O call. Move the slow work to a thread pool with `asyncio.to_thread`. For CPU-bound work that needs cores, use a process pool via `loop.run_in_executor(ProcessPoolExecutor(), ...)`. (Chapter 11; Chapter 13.)

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C.3 The program hangs or never exits

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Ctrl+C does not interrupt the program. No signal handler installed; or a signal handler that schedules async work but `asyncio.run` is blocked elsewhere. Install signal handlers with `loop.add_signal_handler(sig, callback)`. Cancel the top-level Task in the callback. The TaskGroup propagates cancellation to children. (Chapter 13.)

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C.4 Common errors and what they mean

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`RuntimeError: Event loop is closed` (often during program shutdown) Code is trying to use the loop after `asyncio.run` returned and closed it. Common when a finalizer or `__del__` method tries to schedule async work. Move any async cleanup into the running coroutine's normal exit path (`finally` blocks, `__aexit__`). Do not rely on `__del__` or `atexit` for async cleanup.

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When the table does not have your symptom

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Appendix D: Further reading

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D.1 The asyncio source code

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D.2 The async library ecosystem

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D.3 The structured concurrency literature

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D.4 The PEPs that shaped asyncio

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D.5 Things this book did not cover, that you may want next

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Glossary

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