Lecture 07-1: Web Data Pipelines

DATA 503: Fundamentals of Data Engineering

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This lecture covers building data engineering pipelines from web data. We start with web scraping using the Web Scraper Chrome extension, scrape vinyl record data from Discogs, then deploy a full pipeline using Docker on Railway: database setup, data ingestion, transformation, dashboards, API bridge, and developer portal.

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1 Part 1: Web Scraping with Web Scraper

1.1 What is Web Scraping?

Web scraping is the process of automatically extracting data from websites. Instead of manually copying and pasting, we write (or configure) tools to do it for us.

Why? Because life is too short to copy 10,000 rows by hand. Your fingers will thank you.

1.1.1 Use Cases for Web Scraping

- Price monitoring (e-commerce, travel)
- Research data collection (academic datasets)
- Job posting aggregation
- Social media analysis
- Building datasets that do not exist as downloads

1.1.2 The Ethics and Legality Disclaimer

Before you go scraping the entire internet:

- Check the site's `robots.txt` file (e.g., `https://example.com/robots.txt`)
- Respect rate limits – do not hammer servers
- Check Terms of Service
- Do not scrape personal/private data
- When in doubt, ask. Or just do not do it.

We are responsible data engineers, not chaos agents.

1.2 Web Scraper Chrome Extension

1.2.1 What is Web Scraper?

Web Scraper is a free Chrome/Firefox extension that lets you scrape websites without writing code. It uses a point-and-click interface to define what data to extract.

Think of it as "I can not code a spider, but I can click on things."

Install it from:

- Chrome Web Store
- Firefox Add-ons

After installation, restart your browser (or just use new tabs).

1.2.2 Accessing Web Scraper

1. Open Chrome DevTools (`F12` or `Cmd+Opt+I` on Mac)
2. Look for the **Web Scraper** tab in DevTools
3. If you do not see it, you may need to click the `>>` arrows to find it

That is where all the magic happens.

1.2.3 Key Terminology: Sitemap

A **Sitemap** is your scraping project. It defines:

- **Start URL(s)** – where the scraping begins
- **Selectors** – what data to extract and how to navigate
- The overall structure of your scrape

Think of it like a treasure map, except the treasure is data and X marks the CSS selector.

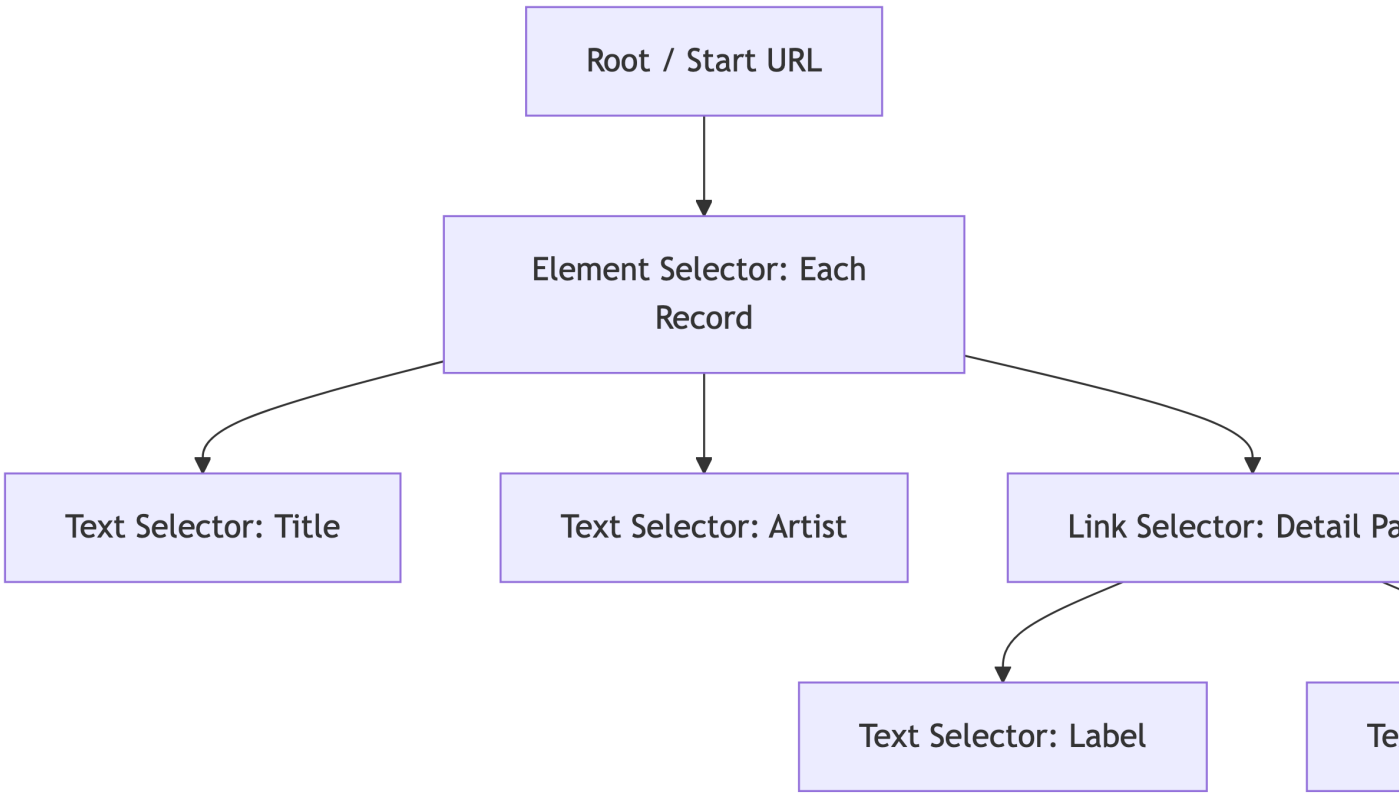
1.2.4 Key Terminology: Selectors

Selectors are the building blocks of your sitemap. Web Scraper has three types:

Category	Purpose	Examples
Data extraction	Pull data from elements	Text, Link, Image, Table, HTML
Link navigation	Follow links to other pages	Link selector
Element grouping	Group related data together	Element selector, Element click

1.2.5 Key Terminology: Selector Tree

Selectors are organized in a **tree structure**. The scraper executes them top-down:



Parent selectors define scope. Child selectors extract data within that scope.

1.2.6 Key Terminology: Multiple Records

When a selector has **Multiple** checked, it means:

- "There are many of these on the page"
- The scraper will iterate through all matching elements
- Each match becomes a separate data row

For example: a product listing page has 25 items. The Element selector with Multiple checked will find all 25.

1.2.7 The Select Tool

Web Scraper's point-and-click tool:

1. Click **Select** in the selector creation interface
2. **Yellow** highlight = element that will be selected on click

3. **Red** highlight = already selected element
4. Click again to deselect

Keyboard shortcuts (after clicking Select):

Key	Action
`P`	Expand to parent element
`C`	Narrow to child element
`S`	Select without clicking (for dynamic elements)
`Shift`	Select multiple element groups

1.2.8 Element Preview and Data Preview

Always use these before running a scrape:

- **Element Preview** – highlights which elements on the page match your selector (visual check)
- **Data Preview** – shows the actual data that will be extracted (sanity check)

If the preview looks wrong, the scrape will be wrong. Trust the preview.

1.2.9 Pagination with Range URLs

Instead of clicking "Next" 100 times, use **range URLs**:

Pattern	Generates
`https://example.com/page/[1-3]`	`/page/1`, `/page/2`, `/page/3`
`https://example.com/page/[001-100]`	`/page/001`, `/page/002`, … (zero-padded)
`https://example.com/page/[0-100:10]`	`/page/0`, `/page/10`, `/page/20`, …

This is how we handle multi-page scrapes without link selectors for pagination.

1.3 Demo: Scraping Discogs

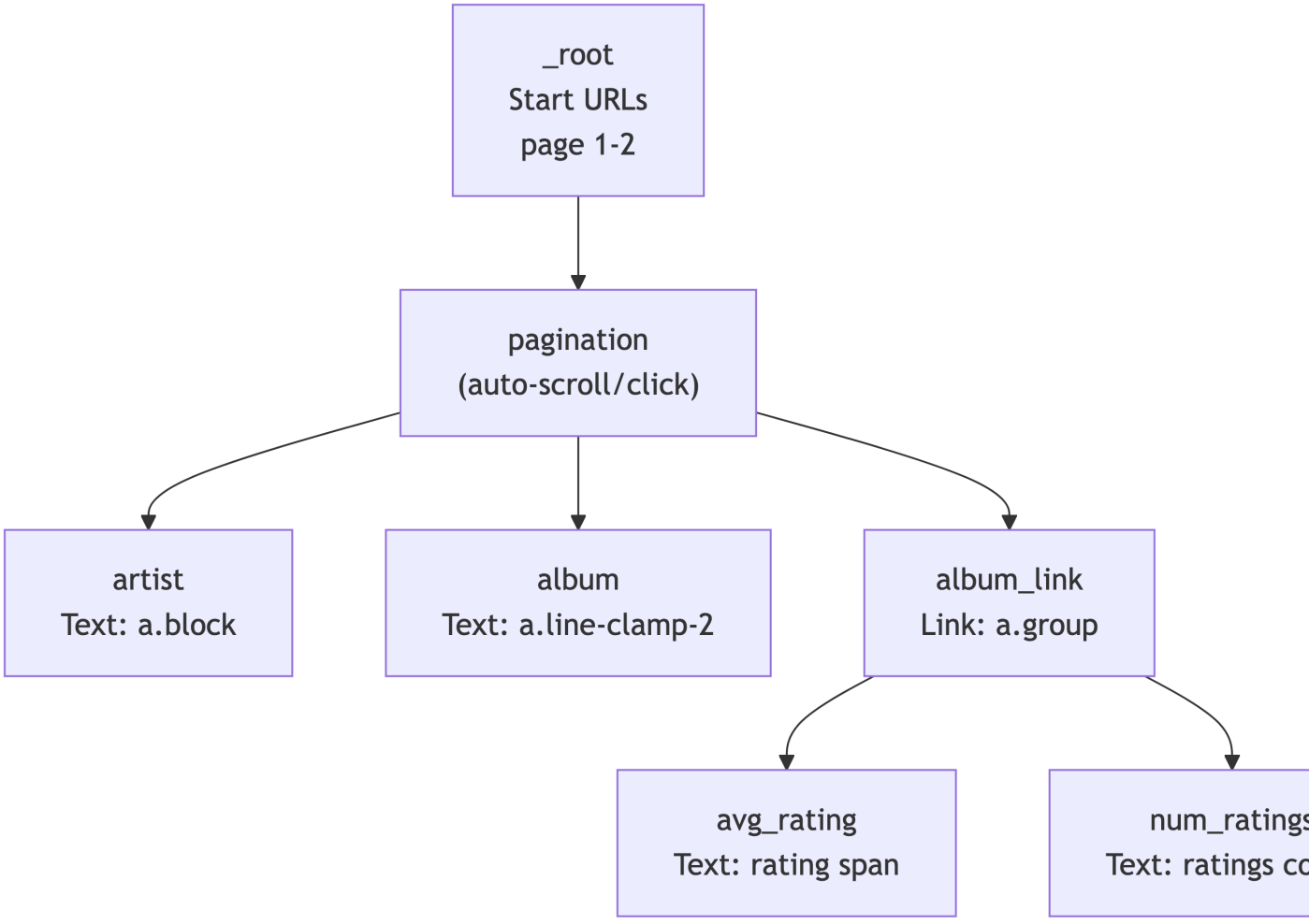
1.3.1 Our Target: Discogs Most Collected Releases

We are going to scrape the Most Collected Releases from Discogs – the world's largest music database.

We want: **artist name**, **album title**, and then we will **follow the link** to each album's detail page to grab the **average rating** and **number of ratings**. This is a two-level scrape.

1.3.2 The Sitemap Structure

Our scrape has two levels: the search results page and each album's detail page:



The **pagination** selector handles navigating through search result pages. Under it, we extract text (artist, album) and follow links (album_link) to detail pages where we grab ratings.

1.3.3 Step 1: Create a New Sitemap

1. Open DevTools (`F12` or `Cmd+Opt+I`) and go to the **Web Scraper** tab
2. Click **Create new sitemap** > **Create Sitemap**
3. **Sitemap name**: `discogs5`
4. **Start URL**: `https://www.discogs.com/search?sort=have%2Cdesc&type=release&page=[1-2]`

We use `[1-2]` to scrape the first 2 pages (~50 results). You can increase this later, but start small when testing.

1.3.4 Step 2: Add the Pagination Selector

This handles scrolling or clicking through search results on each page:

1. Make sure you are at the **_root** level of selectors
2. Click **Add new selector**
3. **ID**: `pagination`
4. **Type**: Pagination
5. **Selector**: Click **Select**, then find and click one of the page navigation arrows/buttons at the bottom of the search results. The CSS selector should resolve to something like `.hidden .cursor-pointer.justify-center span`
6. **Pagination type**: Auto (the scraper will keep clicking "next" until there are no more pages)
7. Click **Save selector**

Why Pagination instead of Element? The Pagination selector both groups the repeating data on the page AND handles navigating to subsequent pages. It is doing double duty.

1.3.5 Step 3: Add the Artist Text Selector

Navigate **into** the `pagination` selector (click on it), then:

1. Click **Add new selector**
2. **ID**: `artist`
3. **Type**: Text
4. **Selector**: Click **Select**, then click an artist name in the search results. The CSS selector should be `a.block`
5. Leave **Multiple** unchecked (one artist per result card)

6. Click **Save selector**

Use **Data Preview** to verify it is grabbing artist names correctly.

1.3.6 Step 4: Add the Album Text Selector

Still inside the `pagination` selector:

1. Click **Add new selector**
2. **ID**: `album`
3. **Type**: Text
4. **Selector**: Click **Select**, then click an album title. The CSS selector should be `a.line-clamp-2`
5. Leave **Multiple** unchecked
6. Click **Save selector**

Data Preview should now show album titles alongside artists.

1.3.7 Step 5: Add the Album Link Selector

This is the key step – we need to follow the link to each album's detail page to get ratings:

1. Still inside `pagination`, click **Add new selector**
2. **ID**: `album_link`
3. **Type**: Link
4. **Selector**: Click **Select**, then click the album card/link area. The CSS selector should be `a.group`
5. Check **Multiple** (there are many album links per page)
6. **Link type**: linkFromHref
7. Click **Save selector**

This tells the scraper: "For each result on the page, follow this link to the detail page." The child selectors under `album_link` will extract data from those detail pages.

1.3.8 Step 6: Add Detail Page Selectors

Navigate **into** the `album_link` selector. Now we define what to extract from each album's detail page.

Average Rating:

1. Click **Add new selector**
2. **ID**: `avg_rating`

3. **Type**: Text
4. **Selector**: Navigate to any album detail page manually to build this selector. Find the average rating value. The CSS selector should be `.section_Odw8o div div ul:nth-of-type(1) span:nth-of-type(2)`
5. Click **Save selector**

Number of Ratings:

1. Click **Add new selector**
2. **ID**: `num_ratings`
3. **Type**: Text
4. **Selector**: Find the total number of ratings on the detail page. The CSS selector should be `#release-stats li:nth-of-type(4) a`
5. Click **Save selector**

1.3.9 The Complete Selector Tree

Your sitemap should now look like this:

Selector ID	Type	Parent	CSS Selector
`pagination`	Pagination	`_root`	`.hidden .cursor-pointer.justify-center span`
`artist`	Text	`pagination`	`a.block`
`album`	Text	`pagination`	`a.line-clamp-2`
`album_link`	Link	`pagination`	`a.group`
`avg_rating`	Text	`album_link`	`.section_Odw8o div div ul:nth-of-type(1) span:nth-of-type(2)`
`num_ratings`	Text	`album_link`	`#release-stats li:nth-of-type(4) a`

1.3.10 Importing the Sitemap Directly

If you prefer to skip building it manually, you can import the complete sitemap JSON:

1. Go to the **Web Scraper** tab in DevTools
2. Click **Create new sitemap** > **Import Sitemap**
3. Paste this JSON and click **Import**:

```
{
  "_id": "discogs5",
  "startUrl": [
    "https://www.discogs.com/search?sort=have%2Cdesc&type=release&page=[1-2]"
  ],
  "selectors": [
    {
      "id": "pagination",
      "paginationType": "auto",
      "parentSelectors": ["_root", "", "pagination"],
      "selector": ".hidden .cursor-pointer.justify-center span",
      "type": "SelectorPagination"
    },
    {
      "id": "artist",
      "multiple": false,
      "parentSelectors": ["pagination"],
      "selector": "a.block",
      "type": "SelectorText",
      "version": 2
    },
    {
      "id": "album",
      "multiple": false,
      "parentSelectors": ["pagination"],
      "selector": "a.line-clamp-2",
      "type": "SelectorText",
      "version": 2
    },
    {
      "id": "album_link",
      "linkType": "linkFromHref",
      "multiple": true,
      "parentSelectors": ["pagination"],
      "selector": "a.group",
      "type": "SelectorLink",
      "version": 2
    },
    {
      "id": "avg_rating",
      "multiple": false,
      "parentSelectors": ["album_link"],
      "selector": ".section_Odw8o div div ul:nth-of-type(1) span:nth-of-type(2)",
```

```
      "type": "SelectorText",
      "version": 2
    },
    {
      "id": "num_ratings",
      "multiple": false,
      "parentSelectors": ["album_link"],
      "selector": "#release-stats li:nth-of-type(4) a",
      "type": "SelectorText",
      "version": 2
    }
  ]
}
```

1.3.11 Step 7: Preview and Validate

Before running the full scrape, always check:

1. Click **Element preview** on each selector – are the correct elements highlighted?
2. Click **Data preview** on `artist` and `album` – do they show real artist/album names?
3. Navigate to a detail page manually and test `avg_rating` and `num_ratings` element previews there

If the preview looks wrong, the scrape will be wrong. Trust the preview.

1.3.12 Step 8: Run the Scrape

1. Click **Scrape** in the Sitemap menu
2. Set **Request interval**: 2000ms (be polite to Discogs servers)
3. Set **Page load delay**: 2000ms
4. Click **Start scraping**

A popup window will open and start loading pages. It will visit each search results page, extract artist/album names, then follow each album link to grab ratings from the detail pages. Do not close the popup. Go get coffee – this is a two-level scrape so it takes longer than a single-page scrape.

1.3.13 Step 9: Export the Data

Once scraping is complete:

1. Click **Browse** to preview scraped data

2. Click **Export data as CSV**
3. Save the file – this is your raw dataset

Congratulations, you just built a two-level scraping pipeline with zero code. You scraped search results AND followed links to detail pages for extra data. Your future self who has to write Python scrapers will be jealous.

1.3.14 What We Scraped

Field	Source	Description
`artist`	Search results page	Artist or band name
`album`	Search results page	Album/release title
`album_link`	Search results page	URL to the album detail page
`avg_rating`	Album detail page	Average user rating (e.g., 4.21)
`num_ratings`	Album detail page	Total number of user ratings

This is our **raw data**. In a real pipeline, we would clean, transform, and load this into a database. Which is exactly what we are about to learn.

1.4 In-Class Exercise: Top Vinyl of the 2010s

1.4.1 Your Turn: Scrape the Top 200 Vinyl Releases of 2010-2020

Work individually or with a neighbor. You are going to build your own sitemap from scratch using what we just learned.

The Use Case: Discogs tracks which releases are the most collected by users worldwide. We want to find the most collected **vinyl** releases from the 2010s decade and pull rating data from each album's detail page.

1.4.2 The Search URL

Start with this base URL in your browser:

```
https://www.discogs.com/search?sort=have%2Cdesc&type=release&year1=2010&year2=2020&format_exa
```

This applies the following filters:

Filter	Value
Sort	Most Collected (have, descending)
Type	Release
Year Range	2010 to 2020
Format	Vinyl

Open this URL in Chrome and verify you see vinyl releases sorted by collector count.

1.4.3 Your Task

Build a Web Scraper sitemap that:

1. Paginates through the first **4 pages** of results (~100 releases)
2. Extracts the **artist name** and **album title** from each search result
3. **Follows the link** to each album's detail page
4. Extracts the **average rating** and **number of ratings** from the detail page

Bonus fields (if you finish early):

- Year and format info from the search results page
- "Have" count and "Want" count from the detail page

1.4.4 Hints

- Your sitemap structure should look very similar to the `discogs5` demo we just built
- Use a **Pagination** selector at the root level
- Use a **Link** selector to navigate to detail pages
- Use the **Select** tool and **Data Preview** to verify each selector before moving on
- If a CSS selector does not work, try using `P` (parent) or `C` (child) keys while the Select tool is active

1.4.5 Expected Output

When you export to CSV, each row should have:

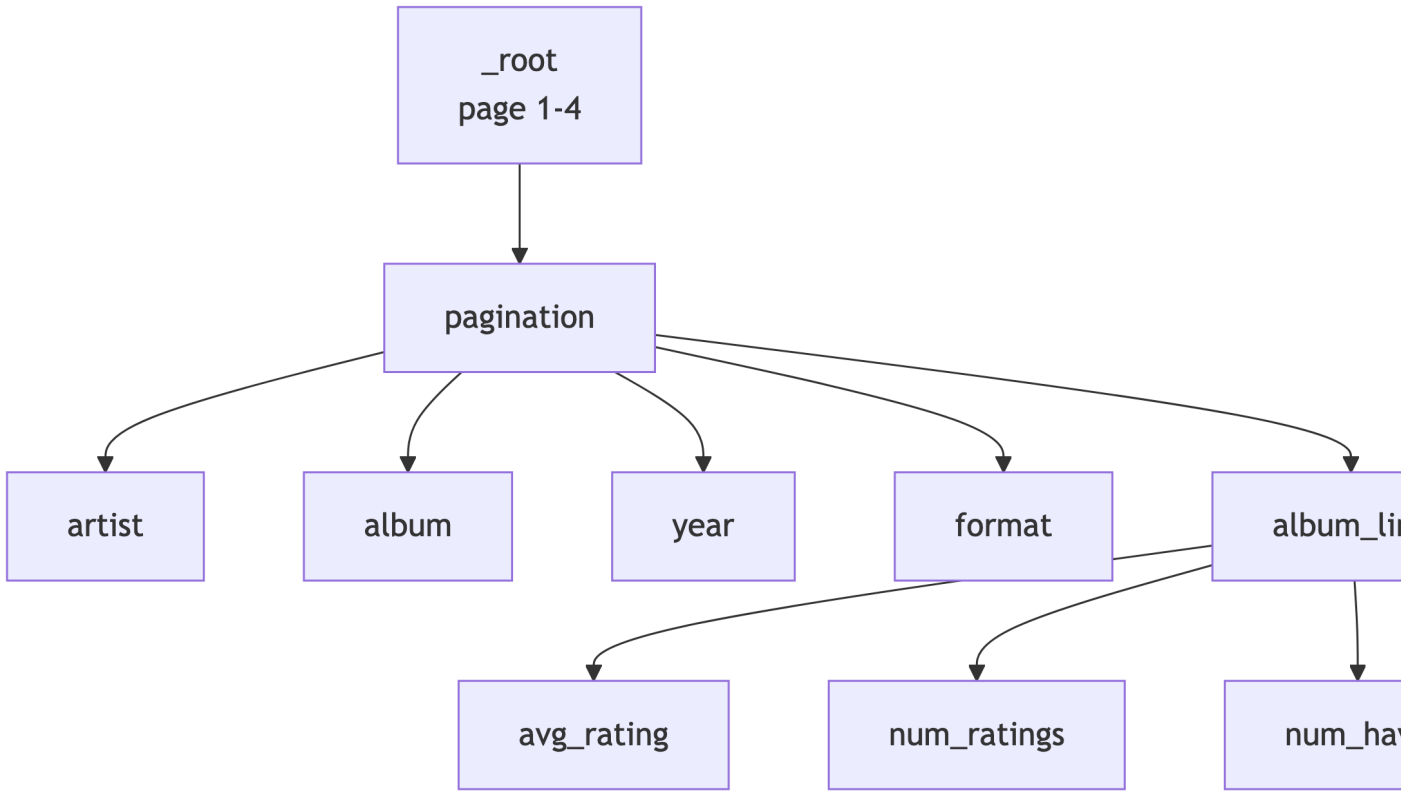
Column	Example Value
`artist`	Adele
`album`	21
`album_link`	https://www.discogs.com/release/…

Column	Example Value
`avg_rating`	4.18
`num_ratings`	1,247

You have **15 minutes**. When you are done (or stuck), we will compare sitemaps.

1.4.6 Solution: The Complete Sitemap

Here is a working sitemap for this exercise. You can import it via **Create new sitemap** > **Import Sitemap**:



The solution sitemap JSON is available as `top100_2010-2020.json` on the course site.

Selector ID	Type	Parent	CSS Selector
`pagination`	Pagination	`_root`	`.hidden .cursor-pointer.justify-center span`

Selector ID	Type	Parent	CSS Selector
artist	Text	pagination	a.block
album	Text	pagination	a.line-clamp-2
year	Text	pagination	span.block.text-xs
format	Text	pagination	p.text-xs.truncate
album_link	Link	pagination	a.group
avg_rating	Text	album_link	.section_Odw8o div div ul:nth-of-type(1) span:nth-of-type(2)
num_ratings	Text	album_link	#release-stats li:nth-of-type(4) a
num_have	Text	album_link	#release-stats li:nth-of-type(1) a
num_want	Text	album_link	#release-stats li:nth-of-type(2) a

2 Part 2: Docker and Deployment

2.1 What is Docker? (A Refresher)

2.1.1 The Problem Docker Solves

"It works on my machine." – Every developer, moments before disaster.

Docker packages your application and all its dependencies into a **container** – a lightweight, portable, isolated environment that runs the same everywhere.

2.1.2 Key Docker Concepts

Concept	What It Is	Analogy
Image	A blueprint/recipe for your container	A shipping manifest
Container	A running instance of an image	The actual shipping container
Registry	Where images are stored (Docker Hub)	The warehouse
Dockerfile	Instructions to build an image	The recipe card

2.1.3 Why Docker for Data Pipelines?

- **Reproducibility** – same environment everywhere
- **Isolation** – services do not interfere with each other
- **Scalability** – spin up more containers as needed
- **Deployment** – push an image, deploy anywhere
- **Scheduling** – run containers on a cron schedule (ingest every 5 min!)

Docker turns "how do I deploy this?" from a week-long saga into a one-liner.

2.1.4 Our Docker Image: `lucascordova/web2db`

We will use a pre-built Docker image called `lucascordova/web2db`.

This image:

- Fetches data from a URL (any API or web endpoint)
- Stores the raw JSON response in a PostgreSQL table
- Runs once per execution (designed for cron scheduling)

Environment variables control its behavior – no code changes needed:

Variable	Purpose
`SITE_URL`	The URL to fetch data from
`DATABASE_URL`	PostgreSQL connection string
`TABLE_NAME`	Which table to insert into
`DEBUG`	Enable verbose logging

3 Part 3: Pipeline Architecture

3.1 The Big Picture

3.1.1 Our Pipeline

We are building an end-to-end data engineering pipeline:

Seven services, one Railway project, zero hand-waving. Let us build each one.

4 Stage 1: Database Service Setup

4.1 Overview

4.1.1 The Central Knowledge Repository

In this pipeline, **Postgres** is the brain. Everything flows into it and everything reads from it.

It serves a dual role:

1. **Raw Data Storage** – capturing unstructured API responses as JSON blobs
2. **Structured Relational Modeling** – clean, normalized tables ready for querying

We will deploy it on Railway and connect using Beekeeper Studio.

4.2 Prerequisites

4.2.1 What You Need Before Starting

- A GitHub account
- A Railway account with **Hobby** tier access ($5 credit deposit with a credit card)
- Beekeeper Studio installed on your computer

Beekeeper Studio is an open-source desktop SQL client. It is like pgAdmin but prettier and less likely to make you cry.

4.3 Setting Up Postgres on Railway

4.3.1 Step 1: Create a New Railway Project

1. Log in at railway.app
2. Click **"New Project"**
3. Select **"Blank Project"**
4. Name your project (e.g., `discogs-pipeline`)

4.3.2 Step 2: Add a Postgres Database

1. In your project dashboard, click **"New"** to add a service
2. Choose **"Database"**, then click **"PostgreSQL"**
3. Railway will provision your database automatically

This database becomes the shared backend for all services in your pipeline.

4.3.3 Step 3: Get Your Connection URL

1. Click into the **Postgres** service
2. Open the **Variables** tab
3. Copy the `DATABASE_PUBLIC_URL`

It looks something like:

```
postgresql://postgres:<password>@<server>.proxy.rlwy.net:20848/railway
```

This is your golden ticket. Guard it like a secret.

4.4 Connecting with Beekeeper Studio

4.4.1 Step 4: Connect from Beekeeper

1. Open Beekeeper Studio and click **"New Connection"**
2. Choose **PostgreSQL**
3. Click **"Import from URL"**
4. Paste the `DATABASE_PUBLIC_URL`
5. Click **"Connect"**

You should see an empty database. That is expected – your ingestion services will fill it up shortly.

4.5 Creating Raw Storage Tables

4.5.1 Step 5: Create Tables for Raw JSON

Before ingestion can begin, we need tables to hold the raw API responses. These are append-only logs: full JSON payloads with timestamps.

```
CREATE TABLE flight_json_data (
    id SERIAL PRIMARY KEY,
    raw_json JSONB NOT NULL,
    timestamptz TIMESTAMPTZ NOT NULL DEFAULT NOW()
);

CREATE TABLE weather_json_data (
    id SERIAL PRIMARY KEY,
    raw_json JSONB NOT NULL,
    timestamptz TIMESTAMPTZ NOT NULL DEFAULT NOW()
);
```

Paste this SQL into Beekeeper Studio and execute it.

4.5.2 Why JSONB?

- `JSONB` stores JSON in a binary format – faster to query than `JSON`
- Supports indexing, containment operators (`@>`), and path queries (`->`, `->>`)
- Perfect for storing raw API responses where the schema might vary

We store the raw data first, ask questions later. This is the **ELT** pattern (Extract, Load, Transform) rather than ETL.

5 Stage 2: Data Ingestion with web2db

5.1 Flight Data Ingestion

5.1.1 Overview

The `web2db` service fetches data from a URL and stores the JSON response in Postgres. We will deploy it as a Docker container on Railway with a cron schedule.

First up: flight data from the OpenSky Network API.

5.1.2 Understanding the API URL

`https://opensky-network.org/api/states/all?lamin=45.08&lomin=-123.50&lamax=45.88&lomax=-122.00`

Parameter	Value	Meaning
`lamin`	45.08	Latitude minimum
`lamax`	45.88	Latitude maximum
`lomin`	-123.50	Longitude minimum
`lomax`	-122.00	Longitude maximum

This bounding box covers the **Portland metropolitan area** and surrounding airspace. We are basically watching planes fly over our heads. Legally.

5.1.3 Deploying the Flight Ingestion Service

1. In your Railway project, click **"New"** > **"Deploy from Docker Image"**
2. Enter the image name: `lucascordova/web2db`
3. Click **Deploy**

5.1.4 Configure Environment Variables

In the **Variables** tab, add:

Key	Value
`SITE_URL`	`https://opensky-network.org/api/states/all?lamin=45.08&lomin=-123.50&lamax=45.88&lomax=-122.00`
`DATABASE_URL`	`${{Postgres.DATABASE_PUBLIC_URL}}`
`TABLE_NAME`	`flight_json_data`
`DEBUG`	`TRUE`

Use Railway's variable picker to reference the Postgres service directly for `DATABASE_URL`.

5.1.5 Set Up Cron Scheduling

1. Go to the **Settings** tab
2. Scroll to **Triggers** > click **"New Trigger"**
3. Choose **Cron** and enter: `*/5 * * * *`

This runs the service every 5 minutes.

Cron format: `minute hour day month weekday`

`*/5` = "every 5 minutes"

Bookmark Crontab Guru – it will save your life when writing cron expressions.

5.1.6 Verify the Data

After a few minutes, check in Beekeeper Studio:

```
SELECT * FROM flight_json_data
ORDER BY timestamptz DESC
LIMIT 10;
```

If you see rows with timestamps and JSON blobs, you are golden.

Troubleshooting:

- Check **Deployments** tab for successful completion
- Check **Logs** tab for debug output
- Verify `SITE_URL` and `DATABASE_URL` for typos

5.2 Weather Data Ingestion

5.2.1 Overview

Same concept, different API. We are pulling weather data for Portland from Open-Meteo.

Parameter	Value	Meaning

5.2.2 The Weather API URL

```
https://api.open-meteo.com/v1/forecast?latitude=45.52&longitude=-122.68&current=temperature_
```

Parameter	Value	Meaning
`latitude`	45.52	Downtown Portland
`longitude`	-122.68	Downtown Portland
`current`	temperature, wind, weathercode	Current conditions

5.2.3 Deploy Weather Ingestion

Same steps as flights:

1. **"New"** > **"Deploy from Docker Image"** > `lucascordova/web2db`
2. Add environment variables:

Key	Value
`SITE_URL`	`https://api.open-meteo.com/v1/forecast?latitude=45.52&longitude=-122.68&current=temperature_2m,wind_speed_10m,weathercode`
`DATABASE_URL`	`${{Postgres.DATABASE_PUBLIC_URL}}`
`TABLE_NAME`	`weather_json_data`
`DEBUG`	`TRUE`

3. Set cron trigger: `*/5 * * * *`

5.2.4 Verify Weather Data

```
SELECT * FROM weather_json_data
ORDER BY timestamptz DESC
LIMIT 10;
```

You now have two data streams flowing into your database. You are officially a data engineer. Put it on your resume.

6 Stage 3: Data Transformation

6.1 Overview

6.1.1 From Raw to Structured

Raw JSON is great for storage but terrible for analysis. The transformation service:

1. Reads raw JSON from the ingestion tables
2. Extracts meaningful fields using PostgreSQL JSON functions
3. Inserts structured rows into normalized tables
4. Deletes processed raw data

This is the "T" in ETL (or the "T" in ELT, depending on your religion).

6.2 Understanding the JSON

6.2.1 Inspect Before You Transform

Always look at what you are working with:

```
SELECT raw_json
FROM flight_json_data
ORDER BY timestamptz DESC
LIMIT 1;
```

```
SELECT raw_json
FROM weather_json_data
ORDER BY timestamptz DESC
LIMIT 1;
```

OpenSky returns an array of arrays. Open-Meteo returns a nested object. Different APIs, different headaches.

6.3 Designing the Physical Schema

6.3.1 Structured Target Tables

```
CREATE TABLE flights (
    id SERIAL PRIMARY KEY,
    icao24 VARCHAR(10) NOT NULL,
    callsign VARCHAR(10),
```

```
    country VARCHAR(64),
    latitude DOUBLE PRECISION,
    longitude DOUBLE PRECISION,
    altitude_meters DOUBLE PRECISION,
    velocity_knots DOUBLE PRECISION,
    heading_degrees DOUBLE PRECISION,
    vertical_rate DOUBLE PRECISION,
    timestamp TIMESTAMPTZ NOT NULL
);
```

6.3.2 Weather Observation Tables

```
CREATE TABLE weather_observations (
    id SERIAL PRIMARY KEY,
    latitude DOUBLE PRECISION NOT NULL,
    longitude DOUBLE PRECISION NOT NULL,
    timestamp TIMESTAMPTZ NOT NULL,
    precipitation_mm DOUBLE PRECISION,
    weathercode SMALLINT
);

CREATE TABLE weather_condition (
    code SMALLINT PRIMARY KEY,
    description TEXT
);
```

6.4 Writing the Transformation SQL

6.4.1 What is a Common Table Expression (CTE)?

A **CTE** is a temporary named result set defined with `WITH`. It makes complex queries readable:

```
WITH step1 AS (
    -- first calculation
),
step2 AS (
    -- uses step1
)
SELECT * FROM step2;
```

Think of CTEs as named scratch paper for your query. You break the problem into steps, then combine them.

6.4.2 Flight Transformation

```
BEGIN;

WITH raw AS (
    SELECT id, timestamptz,
           jsonb_array_elements(raw_json->'states') AS state
    FROM flight_json_data
),
parsed AS (
    SELECT
        state->>0 AS icao24,
        state->>1 AS callsign,
        state->>2 AS country,
        (state->>6)::DOUBLE PRECISION AS longitude,
        (state->>5)::DOUBLE PRECISION AS latitude,
        (state->>7)::DOUBLE PRECISION AS altitude_meters,
        (state->>9)::DOUBLE PRECISION AS velocity_knots,
        (state->>10)::DOUBLE PRECISION AS heading_degrees,
        (state->>11)::DOUBLE PRECISION AS vertical_rate,
        timestamptz
    FROM raw
)
INSERT INTO flights (
    icao24, callsign, country, latitude, longitude,
    altitude_meters, velocity_knots, heading_degrees,
    vertical_rate, timestamp
)
SELECT * FROM parsed;

DELETE FROM flight_json_data;

COMMIT;
```

6.4.3 Weather Transformation

```
BEGIN;

WITH raw AS (
    SELECT raw_json, timestamptz
    FROM weather_json_data
),
```

```
parsed AS (
    SELECT
        (raw_json->'latitude')::DOUBLE PRECISION AS latitude,
        (raw_json->'longitude')::DOUBLE PRECISION AS longitude,
        (raw_json->'current'->'precipitation')::DOUBLE PRECISION
            AS precipitation_mm,
        (raw_json->'current'->'weathercode')::SMALLINT
            AS weathercode,
        timestamptz AS timestamp
    FROM raw
)
INSERT INTO weather_observations (
    latitude, longitude, precipitation_mm,
    weathercode, timestamp
)
SELECT * FROM parsed;

DELETE FROM weather_json_data;

COMMIT;
```

6.4.4 Why Transactions?

The `BEGIN` / `COMMIT` wrapper ensures **atomicity**:

- Either **all** operations succeed, or **none** of them do
- Prevents partial writes and data corruption
- If the INSERT fails, the DELETE never happens
- Your data stays consistent even when things go wrong

This is not optional. This is how adults write SQL.

6.5 Deploying the Transformation Service

6.5.1 Use the GitHub Template

1. Go to the db_transform template
2. Click **"Use this template"**
3. Name your repo: `weather_flight_db_transform`
4. Create the repository

6.5.2 Add Your SQL

1. Open the repo on GitHub
2. Edit the `clean.sql` file (click the pencil icon)
3. Paste both transformation queries (flights + weather)
4. Commit the changes

6.5.3 Deploy on Railway

1. Click **New** > **Deploy from GitHub Repo**
2. Click **"Configure GitHub App"** to grant Railway access
3. Select your `weather_flight_db_transform` repo
4. Add environment variable:

Key	Value
`DATABASE_URL`	`${{Postgres.DATABASE_PUBLIC_URL}}`

5. Set cron trigger: `0 * * * *` (runs hourly, at the top of the hour)

6.5.4 Verify the Transformation

After the first cron run:

```
SELECT * FROM flights
ORDER BY timestamp DESC LIMIT 10;

SELECT * FROM weather_observations
ORDER BY timestamp DESC LIMIT 10;
```

If you see structured rows, the transformation is working. Raw JSON in, clean tables out. Beautiful.

7 Stage 4: Dashboard with Grafana

7.1 Views: The Foundation

7.1.1 What is a View?

A **View** is a virtual table based on a SQL query. It does not store data – it runs the query on demand.

Why views are great for dashboards:

- Abstract complex joins behind a simple name
- Reusable by multiple clients (Grafana, APIs, etc.)
- Restrict access to specific data using Postgres roles
- Pre-join and pre-aggregate for efficient visualization

7.1.2 Create the Dashboard View

This view joins flights and weather to answer our research question: *Are there "no-fly windows" correlated with weather?*

```
CREATE OR REPLACE VIEW flight_weather AS
SELECT
    f.timestamp,
    f.callsign,
    f.altitude_meters,
    f.velocity_knots,
    f.latitude AS flight_latitude,
    f.longitude AS flight_longitude,
    w.precipitation_mm,
    w.weathercode,
    w.latitude AS weather_latitude,
    w.longitude AS weather_longitude
FROM flights f
JOIN weather_observations w
  ON date_trunc('minute', f.timestamp)
   = date_trunc('minute', w.timestamp)
ORDER BY f.timestamp DESC;
```

7.2 Deploying Grafana

7.2.1 Add the Grafana Template

1. In Railway, click **"Create"** > **"Template"**
2. Search for **Grafana**
3. Select the version by **Andre Lademann's Projects**
4. Add these environment variables:

Key	Value
`GF_SECURITY_ADMIN_USER`	`grafanareader`

Key	Value
`GF_DEFAULT_INSTANCE_NAME`	`grafanapg`
`GF_SECURITY_ADMIN_PASSWORD`	`your-password`

5. Leave the 4 pre-configured variables as-is and click **Deploy**

7.2.2 Enable Serverless Mode

After deployment:

1. Go to Grafana service **Settings**
2. Scroll to **Serverless**
3. Toggle **Enable Serverless** and click **Deploy**

This makes Grafana sleep when idle and wake on demand. Your wallet will appreciate this.

7.3 Securing Database Access

7.3.1 Create a Read-Only Grafana User

Do not give Grafana the keys to the kingdom. Create a restricted user:

```
CREATE USER grafanareader
WITH PASSWORD 'your_password';

GRANT USAGE ON SCHEMA "public"
TO grafanareader;

GRANT SELECT ON "public".flight_weather
TO grafanareader;
```

This user can only `SELECT` from the `flight_weather` view. Nothing else. Principle of least privilege in action.

7.4 Connecting Grafana to Postgres

7.4.1 Step 1: Get PGHOST

1. Go to your **Postgres** service in Railway
2. Under **Environment Variables**, copy `PGHOST`
3. It looks like: `postgres.railway.internal`

7.4.2 Step 2: Log In to Grafana

1. Open your Grafana URL from the **Deployments** tab
2. Log in with the admin credentials you set

7.4.3 Step 3: Add Data Source

1. Click **Connections** > **Data Sources**
2. Search for **PostgreSQL**
3. Fill in:

Field	Value
Host	`postgres.railway.internal:5432`
Database	`railway`
User	`grafanareader`
Password	`your_password`

4. Click **Save & Test**

7.5 Creating Your First Dashboard

7.5.1 Build a Visualization

1. Go to **Home** > **"Create your first dashboard"**
2. Click **"Add Visualization"**
3. Select your PostgreSQL data source
4. Choose the `flight_weather` view as the table
5. Add `timestamp` and a data column (e.g., `altitude_meters` or `precipitation_mm`)
6. Click **Run Query**
7. Switch between **Table Mode** and chart visualizations

You now have a live dashboard powered by your pipeline. Go impress someone.

7.6 Grafana Persistence (Addendum)

7.6.1 Making Dashboards Survive Restarts

By default, Grafana stores dashboards in SQLite inside the container. Container restarts = dashboards gone. Let us fix that.

1. Create a `grafana` database in your Railway Postgres instance (via Beekeeper)
2. Add these environment variables to the Grafana service:

```
GF_DATABASE_TYPE=postgres
GF_DATABASE_HOST=postgres.railway.internal:5432
GF_DATABASE_NAME=grafana
GF_DATABASE_USER=postgres
GF_DATABASE_SSL_MODE=disable
GF_DATABASE_PASSWORD=<your-db-password>
GF_SERVER_ROOT_URL=<your-grafana-url>
```

3. Redeploy Grafana. Dashboards now persist in Postgres!

7.6.2 Sharing Dashboards Publicly

1. On a dashboard, click the **Share** icon
2. Click **External Link**
3. Accept the warning and check the confirmation box
4. Copy the external link
5. Test in an incognito window

Your dashboard is now publicly viewable. Data storytelling at its finest.

8 Stage 5: DB API Bridge (PostgREST)

8.1 Why an API?

8.1.1 From Database to REST

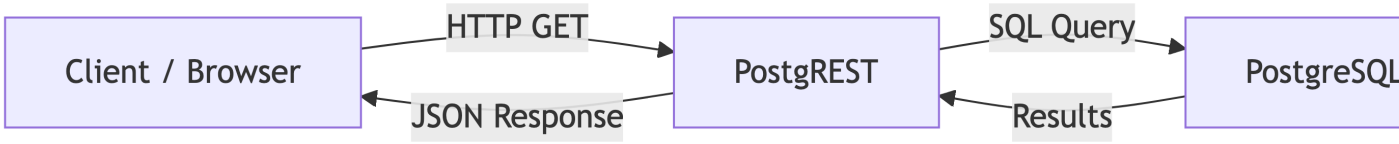
Dashboards are great for humans. But what about other applications?

PostgREST turns your Postgres database into a RESTful API automatically. No backend code required.

Key features:

- Generates REST endpoints for tables, views, and stored procedures
- Uses PostgreSQL's native roles for access control
- Lightweight and open-source

8.1.2 Architecture



8.2 Deploying PostgREST

8.2.1 Step 1: Create the Service

1. Click **Create** in Railway
2. Choose **Docker Image**
3. Enter: `postgrest/postgrest`
4. Click **Deploy**

8.2.2 Step 2: Configure Networking

1. Go to **Settings** tab
2. Under **Public Networking**, click **Generate Domain**
3. Copy the public URL
4. Scroll to **Serverless**, toggle **Enable Serverless**, and deploy

8.2.3 Step 3: Set Environment Variables

Key	Value
`PGRST_DB_ANON_ROLE`	`web_anon`
`PGRST_DB_SCHEMA`	`api`
`PGRST_DB_URI`	`${{DATABASE_URL}}`
`PGRST_OPENAPI_SERVER_PROXY_URI`	`<your public hostname>`

8.3 Database Permissions for the API

8.3.1 Create a Schema and Role

We expose data through a dedicated `api` schema with a restricted role:

```sql
-- Create the API schema
CREATE SCHEMA IF NOT EXISTS api;

-- Create a view in the API schema
CREATE OR REPLACE VIEW api.general_aviation_weather_view AS
SELECT * FROM flight_weather;

-- Create an anonymous access role
CREATE ROLE web_anon NOLOGIN;
GRANT USAGE ON SCHEMA api TO web_anon;
GRANT SELECT ON api.general_aviation_weather_view
TO web_anon;
```

8.3.2 Create an Authenticator Role

Instead of connecting as the all-powerful `postgres` user:

```sql
CREATE ROLE authenticator
NOINHERIT LOGIN PASSWORD '<your password>';
GRANT web_anon TO authenticator;
```

- `NOINHERIT` – cannot directly access anything
- `LOGIN` – can authenticate from PostgREST
- `GRANT web_anon` – can act as the read-only role

Separation of concerns. Even your database roles practice good architecture.

8.3.3 Test the API

Visit your PostgREST URL with the view name appended:

`https://<your-domain>.up.railway.app/general_aviation_weather_view`

You should see JSON data. If you do, your database is now a REST API. That was disturbingly easy.

9 Stage 6: API Developer Portal (Swagger)

9.1 Why Swagger?

9.1.1 Self-Documenting APIs

An API without documentation is like a library without a catalog. Swagger UI provides:

- Automatic API documentation from the OpenAPI spec
- Interactive endpoint testing in the browser
- Parameter and response schema visualization
- A shareable portal for API consumers

PostgREST automatically generates an OpenAPI spec. Swagger reads it. They are best friends.

9.2 Deploying Swagger UI

9.2.1 Step 1: Create the Service

1. In Railway, click **Create** > **New Service**
2. Select **Docker Image**
3. Enter: `swaggerapi/swagger-ui`
4. Click **Deploy**

9.2.2 Step 2: Set Environment Variable

Key	Value
`API_URL`	`${{postgrest.PGRST_OPENAPI_SERVER_PROXY_URI}}`

This tells Swagger where to find the OpenAPI spec generated by PostgREST.

9.2.3 Step 3: Generate Public URL

1. Go to **Settings**
2. Under **Networking**, click **Generate Domain**
3. Choose **default port: 8080**
4. Click **Deploy**

9.2.4 Test It

Open the public URL. You should see the Swagger UI loaded with your API documentation. You can:

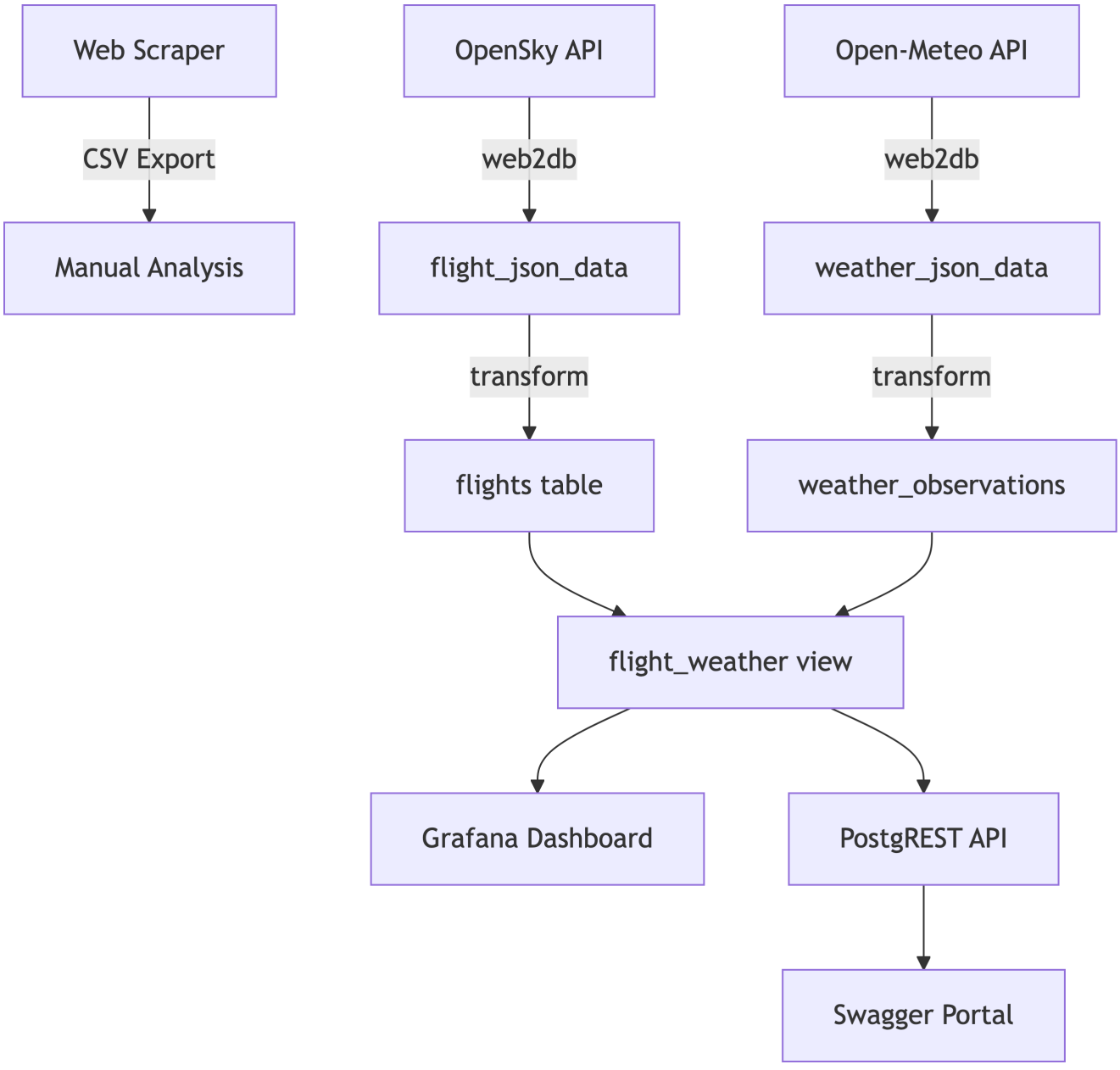
- View the `general_aviation_weather_view` endpoint
- Expand to see parameters and response schema
- Run test requests directly from the browser

Your API is now self-documenting, testable, and shareable. Chef's kiss.

10 Recap: The Full Pipeline

10.1 What We Built

10.1.1 From Web to Portal



10.1.2 Seven Services, One Pipeline

Stage	Service	Purpose
1	PostgreSQL	Central data store
2a	web2db (flights)	Flight data ingestion
2b	web2db (weather)	Weather data ingestion
3	db_transform	JSON to structured tables
4	Grafana	Visualization dashboard
5	PostgREST	REST API from database
6	Swagger UI	API documentation portal

11 References

11.1 References

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