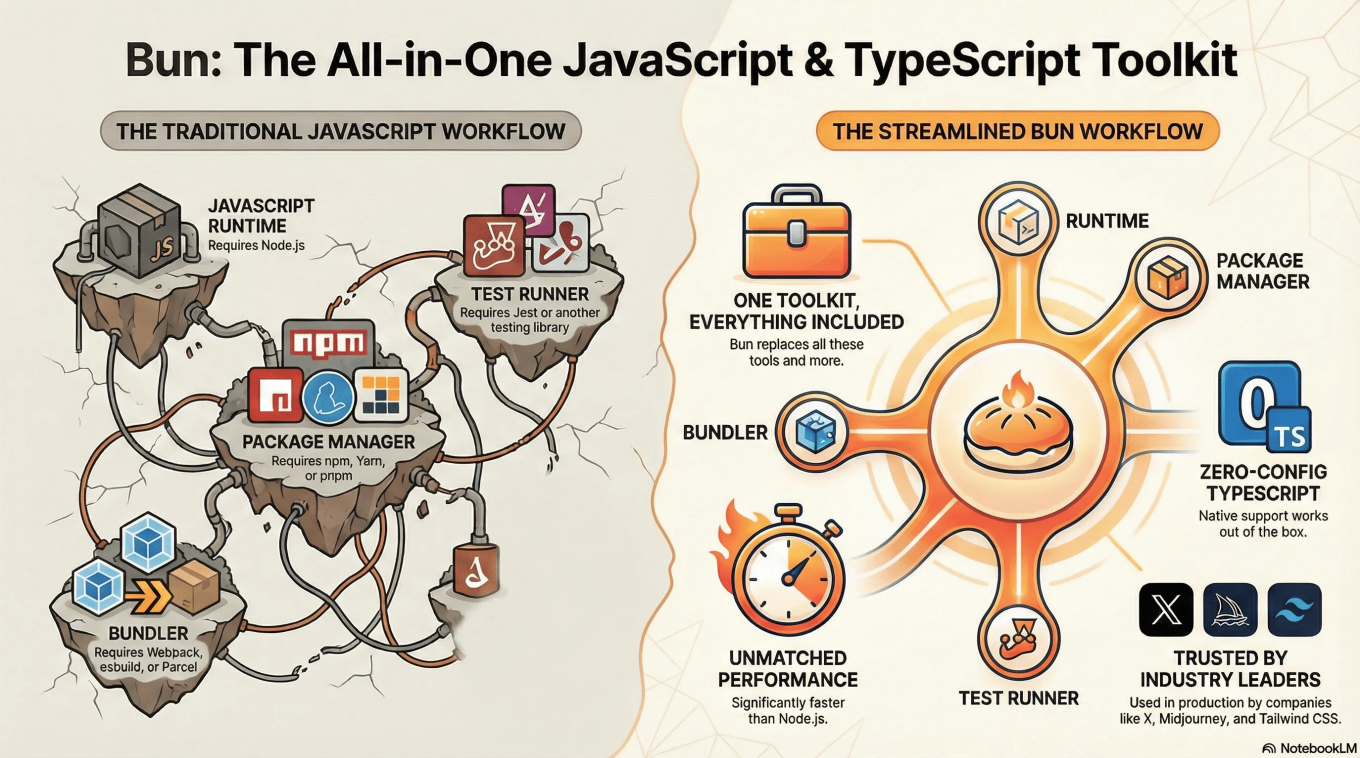
kintsugi-stack-bun

> “Bun aims to ship everything you need out of the box.” — Jarred Sumner

- Author: Kintsugi-Programmer



> Disclaimer: The content presented here is a curated blend of my personal learning journey, experiences, open-source documentation, and invaluable knowledge gained from diverse sources. I do not claim sole ownership over all the material; this is a community-driven effort to learn, share, and grow together.

Table of Contents

- kintsugi-stack-bun
  - Table of Contents
  - 1. Introduction to Bun
    - 1.1. What is Bun?
    - 1.2. Why Learn Bun?
      - 1.2.1. Key Reasons:
  - 2. Web Development Concepts Refresher
    - 2.1. What is JavaScript?
    - 2.2. What is a Runtime?
    - 2.3. What is a Server?
    - 2.4. What is an API?
    - 2.5. What is HTTP?
    - 2.6. Client vs Server
  - 3. Course Overview
    - 3.1. Topics Covered:

- 4. What is Bun? - Detailed Explanation
  - 4.1. Bun vs Node.js
    - 4.1.1. Similarities:
    - 4.1.2. Key Differences:
- 5. Bun Features Breakdown
  - 5.1. Fast JavaScript Runtime
  - 5.2. Fast JavaScript Package Manager
  - 5.3. Fast JavaScript Bundler
  - 5.4. Fast JavaScript Test Runner
  - 5.5. Node-Compatible Runtime
- 6. Companies Using Bun
- 7. Installation
  - 7.1. Windows (PowerShell)
  - 7.2. Linux & MacOS
  - 7.3. Using npm (The last npm command you'll ever need)
  - 7.4. Verify Installation
- 8. Quick Start Project Setup
  - 8.1. Initialize New Project
    - 8.1.1. Select a project template: Blank
    - 8.1.2. Select a project template: React + TailwindCSS + Shadcn (Select All)
    - 8.1.3. Select a project template: Library
  - 8.2. Project Structure
- 9. Bun as a Runtime
  - 9.1. What is a Runtime?
  - 9.2. Running Files
    - 9.2.1. Basic Execution
    - 9.2.2. Watch Mode (Auto-reload on save)
  - 9.3. Package.json Scripts
- 10. File Imports
  - 10.1. Importing Text Files
  - 10.2. Importing JSON Files
  - 10.3. Importing TypeScript Modules
- 11. Environment Variables
  - 11.1. What are Environment Variables?
  - 11.2. Basic Usage
  - 11.3. Three Ways to Access Environment Variables
    - 11.3.1. Method 1: process.env
    - 11.3.2. Method 2: Bun.env
    - 11.3.3. Method 3: import.meta.env
  - 11.4. Type Safety for Environment Variables
  - 11.5. Multiple Environment Files
  - 11.6. Using NODE_ENV
- 12. File I/O Operations
  - 12.1. What is File I/O?
  - 12.2. Reading Files with Bun.file
  - 12.3. File Properties

        - 12.3.1. MIME
    - 12.4. Check File Existence
    - 12.5. Writing Files
    - 12.6. Copying Files
- 13. Working with Directories
    - 13.1. Create Directory
    - 13.2. Read Directory
    - 13.3. Get Current Directory
- 14. import.meta Object
    - 14.1. Available Properties
        - 14.1.1. import.meta.dir
        - 14.1.2. import.meta.dirname (Alias)
        - 14.1.3. import.meta.env
        - 14.1.4. import.meta.file
        - 14.1.5. import.meta.path
        - 14.1.6. import.meta.filename (Alias)
        - 14.1.7. import.meta.url
        - 14.1.8. import.meta.resolve()
    - 14.2. Node.js Compatibility
- 15. Hashing & Encryption
    - 15.1. What is Password Hashing?
    - 15.2. Password Hashing
        - 15.2.1. Hash a Password
        - 15.2.2. Verify Password
    - 15.3. Complete Example
    - 15.4. Argon2 Algorithm
- 16. Bun Utilities
    - 16.1. Bun.version
    - 16.2. Bun.env
    - 16.3. Bun.sleep()
    - 16.4. crypto.randomUUID()
    - 16.5. Bun.nanoseconds()
    - 16.6. Bun.deepEquals()
- 17. HTTP Server with Bun.serve
    - 17.1. What is an HTTP Server?
    - 17.2. Basic Server Setup
    - 17.3. Routes Configuration
    - 17.4. Dynamic Route Parameters
    - 17.5. Better Routing with Routes Object
- 18. Complete CRUD API Example
    - 18.1. What is CRUD?
    - 18.2. What are HTTP Methods?
    - 18.3. Setup
    - 18.4. GET All Posts
    - 18.5. POST Create Post
    - 18.6. PUT Update Post

        - 18.7. DELETE Post
        - 18.8. Complete Server Code
    - 19. Query Parameters
        - 19.1. What are Query Parameters?
        - 19.2. Parsing Query Parameters
    - 20. Rendering HTML Pages
        - 20.1. What is HTML?
        - 20.2. Serving HTML Files
    - 21. URL Redirection
    - 22. Global Error Handling
    - 23. HTTPS/TLS Configuration
    - 24. Server Utilities
        - 24.1. Request Timeout
        - 24.2. Get Client IP
        - 24.3. Graceful Shutdown
    - 25. Console API
        - 25.1. Reading Terminal Input
    - 26. Color API
        - 26.1. Converting Color Formats
    - 27. Shell Scripting with Bun
        - 27.1. Basic Shell Commands
        - 27.2. Fetching and Piping
        - 27.3. Real-World Example
    - 28. Web APIs
        - 28.1. Available APIs:
    - 29. Bun as a Package Manager
        - 29.1. What is a Package Manager?
        - 29.2. Installing Dependencies
            - 29.2.1. Install All Dependencies
            - 29.2.2. Add Package
        - 29.3. Removing Dependencies
        - 29.4. Updating Dependencies
        - 29.5. Other Commands
            - 29.5.1. Check Outdated Packages
            - 29.5.2. Publish Package
            - 29.5.3. Link Local Package
        - 29.6. Speed Comparison
    - 30. Bun Create Command
        - 30.1. Creating Projects from Templates
            - 30.1.1. React + Vite Project
            - 30.1.2. Hono.js Project
        - 30.2. Available Templates
    - 31. Testing with Bun
        - 31.1. What is Testing?
        - 31.2. What is the Test Runner?
        - 31.3. Setting Up Tests

        - 31.3.1. Test File Structure
    - 31.4. Writing Tests
    - 31.5. Running Tests
    - 31.6. Testing Functions
    - 31.7. Test Output
- 32. Bun as a Bundler
    - 32.1. What is a Bundler?
    - 32.2. Building TypeScript to JavaScript
        - 32.2.1. Basic Build
    - 32.3. Build from Source Directory
    - 32.4. Minified Build
    - 32.5. Build Features
- 33. Important Notes & Best Practices
    - 33.1. Port 6000 Restriction
    - 33.2. Environment Variables Best Practices
    - 33.3. Package Manager Advantages
    - 33.4. TypeScript Support
    - 33.5. Testing Advantages
- 34. Common Patterns & Examples
    - 34.1. API Server Template
    - 34.2. File Operations Template
    - 34.3. Environment Setup Template
- 35. Comparison: Node.js vs Bun
- 36. Conclusion
    - 36.1. Key Takeaways:
    - 36.2. When to Use **Bun**
    - 36.3. When to Stick with **Node.js**
- 37. Resources

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1. Introduction to Bun

> Complete Bun JavaScript & TypeScript Runtime Documentation

1.1. What is Bun?

- **Bun** is a fast JavaScript runtime (alternative to Node.js)
- Introduced approximately 2-3 years ago
- Written in **Zig language** (not C++ like Node.js)
- Provides an **all-in-one toolkit** for JavaScript/TypeScript development

1.2. Why Learn Bun?

1.2.1. Key Reasons:

1. **Market Relevance**: Projects may require Bun expertise
2. **Performance**: Significantly faster than Node.js
3. **Built-in Features**: Reduces external dependencies

4. **Modern Development**: Stay ahead in the market
5. **Node.js Compatibility**: Can migrate Node.js projects with minimal changes

Important Note: Bun is NOT a replacement for Node.js, but rather an advanced alternative that complements your existing knowledge.

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2. Web Development Concepts Refresher

Before diving into Bun, let's understand the foundational concepts:

2.1. What is JavaScript?

- **JavaScript** is a programming language that runs on computers
- Originally created for web browsers (to make websites interactive)
- Now can run on servers too (backend) with tools like Node.js and Bun
- Used for: making interactive features, handling data, building entire applications

2.2. What is a Runtime?

- **Runtime** = An environment where code runs
- Think of it like an operating system for your code
- **Node.js** was the first JavaScript runtime for servers (created ~2009)
- **Bun** is a newer, faster JavaScript runtime alternative to Node.js

2.3. What is a Server?

- **Server** = A computer that listens for requests and sends responses
- When you visit a website, your browser (client) sends a request to a server
- The server processes the request and sends back data/HTML
- Example: When you visit Google.com, your request goes to Google's servers

2.4. What is an API?

- **API** = Application Programming Interface (a way for programs to talk to each other)
- **HTTP API** = A web server that responds to requests with data (usually JSON)
- Example: A weather API that returns current temperature
- Used for: Getting data from servers, sending data to servers, connecting apps

2.5. What is HTTP?

- **HTTP** = HyperText Transfer Protocol (the language of the web)
- A standardized way for clients and servers to communicate
- **Request** = Client asking server for something
- **Response** = Server sending back data or information
- **Status codes**: 200 (success), 404 (not found), 500 (server error)

2.6. Client vs Server

- **Client** = Your browser or app that requests data

- **Server** = Computer that stores data and responds to requests
- **Flow**: Client → Request → Server → Processing → Response → Client receives data

---

3. Course Overview

3.1. Topics Covered:

1. **Introduction & Setup**
    - What is Bun and why learn it
    - Differences from Node.js
    - Installation and quick start
2. **Bun as a Runtime**
    - `bun run` command
    - File imports
    - Environment variables
    - File I/O operations
    - `import.meta` object
    - Hashing & encryption
    - Utilities
3. **HTTP Server with Bun**
    - Using Bun.serve API
    - Building APIs
    - Console API
    - Color API
    - Shell scripting
    - Web APIs
4. **Bun as a Package Manager**
    - Installing packages
    - `bun create` command
    - Testing with Bun
    - Building and bundling

---

4. What is Bun? - Detailed Explanation

4.1. Bun vs Node.js

4.1.1. Similarities:

- Both are JavaScript runtimes
- Both allow running JavaScript on the backend
- Both allow you to write server code (not just browser code)

4.1.2. Key Differences:

1. End-to-End TypeScript Support

- **TypeScript** = JavaScript with type checking (helps catch errors early)
- **Bun**: Zero-configuration TypeScript support (built-in, works immediately)
- **Node.js**: Requires separate TypeScript installation and setup
- **Why it matters**: Less setup = faster development

2. Performance

- **Bun**: Significantly faster than Node.js (50%+)
- **What "faster" means**: Code runs quicker, servers respond quicker, pages load faster
- Reasons for speed:
  - Written in **Zig language(manual memory management)** (faster than C++(garbage collection))
  - Uses **JavaScriptCore (JSC)** engine instead of V8
  - Custom event loop (vs Node's libuv)
  - Manual memory management (vs garbage collection in C++)
- **Why it matters**: Faster applications = better user experience

3. All-in-One Toolkit

Bun provides built-in solutions for:

- **Fast Package Manager**: No need for npm installation
- **Fast Bundler**: Replaces Parcel, Webpack, esbuild. Compiles Code Faster. No need to install external Bundler.
- **Test Runner**: Replaces Jest, Built-in
- **TypeScript Compiler**: Built-in support

---

5. Bun Features Breakdown

5.1. Fast JavaScript Runtime

```
# Simple runtime like Node.js but faster
bun index.ts
```

What this means:

- Bun can execute (run) JavaScript code on your computer
- You write code, Bun executes it (like a calculator runs math)
- Faster than Node.js at starting up and running code

5.2. Fast JavaScript Package Manager

- **Package Manager** = Tool that downloads and installs code libraries other people wrote
- Built-in package manager (no npm needed)
- Extremely fast package installation

- Compatible with npm registry (same libraries as Node.js)

5.3. Fast JavaScript Bundler

- **Bundler** = Tool that combines multiple files into one optimized file
- Minifies code for production (makes files smaller)
- Replaces: Parcel, Webpack, esbuild
- Why: Faster websites (smaller files = faster download)

5.4. Fast JavaScript Test Runner

- **Testing** = Writing code to check if your other code works correctly
- Built-in testing (no Jest needed)
- Zero external dependencies for testing
- Example: "If I add 2+2, do I get 4?" tests

5.5. Node-Compatible Runtime

- Bun is Fast JS Node-compatible runtime
- Can run Node.js code with minimal changes
- Supports Node.js libraries
- Easy migration from Node.js to Bun

---

6. Companies Using Bun

Notable companies using Bun in production:

- **X (Twitter)**
- **Typi**
- **Midjourney** (AI image/video generation)
- **Tailwind CSS**

---

7. Installation

7.1. Windows (PowerShell)

```
powershell -c "irm bun.sh/install.ps1|iex"
```

7.2. Linux & MacOS

```
curl -fsSL https://bun.sh/install | bash
```

7.3. Using npm (The last npm command you'll ever need)

```
npm install -g bun
```

- The last npm command you'll ever need
- after this you don't need to use npm
- bun also supports npm packages

7.4. Verify Installation

```
bun --version
# Output: 1.2.5 (or current version)
```

---

8. Quick Start Project Setup

8.1. Initialize New Project

```
bun init
```

This creates:

- package.json
- tsconfig.json
- index.ts
- .gitignore

8.1.1. Select a project template: Blank

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/8_1_1_$ bun init

✓ Select a project template: Blank

 + .gitignore
 + index.ts
 + tsconfig.json (for editor autocomplete)
 + README.md

To get started, run:

    bun run index.ts

bun install v1.3.6 (d530ed99)

+ @types/bun@1.3.6
+ typescript@5.9.3
```

```
5 packages installed [219.00ms]

bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/8_1_1_$
```

8.1.2. Select a project template: React + TailwindCSS + Shadcn (Select All)

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/8_1_2_$ bun init

✓ Select a project template: React
✓ Select a React template: Shadcn + TailwindCSS

 + bunfig.toml
 + styles/globals.css
 + package.json
 + components.json
 + tsconfig.json
 + bun-env.d.ts
 + README.md
 + .gitignore
 + src/index.ts
 + src/App.tsx
 + src/index.html
 + src/index.css
 + src/components/ui/card.tsx
 + src/components/ui/label.tsx
 + src/components/ui/button.tsx
 + src/components/ui/select.tsx
 + src/components/ui/input.tsx
 + src/components/ui/textarea.tsx
 + src/APITester.tsx
 + src/lib/utils.ts
 + src/react.svg
 + src/frontend.tsx
 + src/logo.svg
 + build.ts

bun install v1.3.6 (d530ed99)

+ @types/bun@1.3.6
+ @types/react@19.2.9
+ @types/react-dom@19.2.3
+ tailwindcss@4.1.18
+ tw-animate-css@1.4.0
+ @radix-ui/react-label@2.1.8
+ @radix-ui/react-select@2.2.6
+ @radix-ui/react-slot@1.2.4
+ bun-plugin-tailwind@0.1.2
+ class-variance-authority@0.7.1
+ clsx@2.1.1
+ lucide-react@0.545.0 (v0.563.0 available)
+ react@19.2.3
```

```
+ react-dom@19.2.3
+ tailwind-merge@3.4.0

64 packages installed [238.00ms]

✨ New project configured!

Development - full-stack dev server with hot reload

    bun dev

Static Site - build optimized assets to disk (no backend)

    bun run build

Production - serve a full-stack production build

    bun start

Happy bunning! 🐇
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/8_1_2_$
```

8.1.3. Select a project template: Library

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/8_1_3_$ bun init

✓ Select a project template: Library
package name (8_1_3_):
entry point (index.ts):

 + .gitignore
 + index.ts
 + tsconfig.json (for editor autocomplete)
 + README.md

To get started, run:

    bun run index.ts

bun install v1.3.6 (d530ed99)

+ @types/bun@1.3.6
+ typescript@5.9.3

5 packages installed [13.00ms]

bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/8_1_3_$
```

8.2. Project Structure

```
project/
├── index.ts
├── package.json
├── tsconfig.json
└── .gitignore
```

---

9. Bun as a Runtime

9.1. What is a Runtime?

- **Runtime** = Environment where your code actually runs
- Think of it like a translator between your code and the computer
- Your code + Runtime = Working application
- **Example**: Bun reads your TypeScript, translates it, and executes it

9.2. Running Files

9.2.1. Basic Execution

```
# Method 1
bun index.ts

# Method 2
bun run index.ts
```

What's happening:

- You're telling Bun to execute (run) the code in index.ts
- Bun reads the file, translates it, and runs it
- Output appears in your terminal
- This is how servers start!

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9$ bun index.ts
Hello via Bun!
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9$ bun run index.ts
Hello via Bun!
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9$
```

9.2.2. Watch Mode (Auto-reload on save)

```
# Without "run"
bun --watch index.ts
```

```
# With "run"
bun run --watch index.ts
```

What watch mode does:

- Automatically detects when you save your file
- Reruns your code without you typing the command again
- Useful for development (see changes immediately)
- **Workflow**: Edit code → Save → Auto-runs → See result

Example `index.ts`:

```
console.log("Hello via Bun");
```

What console.log() does:

- Prints text to your terminal screen
- Used for displaying information, debugging, checking values
- You'll see: `Hello via Bun` in your terminal

```
console.log("Hello!");
console.log("I am Kintsugi-Programmer.");
```

```
Hello!
I am Kintsugi-Programmer.
^C
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9$
```

9.3. Package.json Scripts

```
{
  "name": "9_",
  "module": "index.ts",
  "type": "module",
  "private": true,
  "devDependencies": {
    "@types/bun": "latest"
  },
  "peerDependencies": {
    "typescript": "^5"
  }
  ,"scripts": {
    "dev": "bun --watch index.ts",
    "start": "bun index.ts"
```

```
  }
}
```

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9_$ bun dev
$ bun --watch index.ts
Hello!
I am Kintsugi-Programmer.



^C
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9_$ bun start
$ bun index.ts
Hello!
I am Kintsugi-Programmer.
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9_$
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9_$ bun run
Usage: bun run [flags] <file or script>

Flags:
      --silent                        Don't print the script command
      --elide-lines=<val>             Number of lines of script output shown when
using --filter (default: 10). Set to 0 to show all lines.
  -F, --filter=<val>                  Run a script in all workspace packages
matching the pattern
  -b, --bun                           Force a script or package to use Bun's
runtime instead of Node.js (via symlinking node)
      --shell=<val>                   Control the shell used for package.json
scripts. Supports either 'bun' or 'system'
      --workspaces                    Run a script in all workspace packages (from
the "workspaces" field in package.json)
      --watch                         Automatically restart the process on file
change
      --hot                           Enable auto reload in the Bun runtime, test
runner, or bundler
      --no-clear-screen               Disable clearing the terminal screen on
reload when --hot or --watch is enabled
      --smol                          Use less memory, but run garbage collection
more often
  -r, --preload=<val>                 Import a module before other modules are
loaded
      --require=<val>                 Alias of --preload, for Node.js
compatibility
      --import=<val>                  Alias of --preload, for Node.js
compatibility
      --inspect=<val>                 Activate Bun's debugger
      --inspect-wait=<val>            Activate Bun's debugger, wait for a
connection before executing
      --inspect-brk=<val>             Activate Bun's debugger, set breakpoint on
first line of code and wait
      --cpu-prof                      Start CPU profiler and write profile to disk
```

```
on exit
      --cpu-prof-name=<val>           Specify the name of the CPU profile file
      --cpu-prof-dir=<val>            Specify the directory where the CPU profile
will be saved
      --if-present                    Exit without an error if the entrypoint does
not exist
      --no-install                    Disable auto install in the Bun runtime
      --install=<val>                 Configure auto-install behavior. One of
"auto" (default, auto-installs when no node_modules), "fallback" (missing packages
only), "force" (always).
  -i                                  Auto-install dependencies during execution.
Equivalent to --install=fallback.
  -e, --eval=<val>                    Evaluate argument as a script
  -p, --print=<val>                   Evaluate argument as a script and print the
result
      --prefer-offline                Skip staleness checks for packages in the
Bun runtime and resolve from disk
      --prefer-latest                 Use the latest matching versions of packages
in the Bun runtime, always checking npm
      --port=<val>                    Set the default port for Bun.serve
      --conditions=<val>              Pass custom conditions to resolve
      --fetch-preconnect=<val>        Preconnect to a URL while code is loading
      --max-http-header-size=<val>    Set the maximum size of HTTP headers in
bytes. Default is 16KiB
      --dns-result-order=<val>        Set the default order of DNS lookup results.
Valid orders: verbatim (default), ipv4first, ipv6first
      --expose-gc                     Expose gc() on the global object. Has no
effect on Bun.gc().
      --no-deprecation                Suppress all reporting of the custom
deprecation.
      --throw-deprecation             Determine whether or not deprecation
warnings result in errors.
      --title=<val>                   Set the process title
      --zero-fill-buffers             Boolean to force Buffer.allocUnsafe(size) to
be zero-filled.
      --use-system-ca                 Use the system's trusted certificate
authorities
      --use-openssl-ca                Use OpenSSL's default CA store
      --use-bundled-ca                Use bundled CA store
      --redis-preconnect              Preconnect to $REDIS_URL at startup
      --sql-preconnect                Preconnect to PostgreSQL at startup
      --no-addons                     Throw an error if process.dlopen is called,
and disable export condition "node-addons"
      --unhandled-rejections=<val>    One of "strict", "throw", "warn", "none", or
"warn-with-error-code"
      --console-depth=<val>           Set the default depth for console.log object
inspection (default: 2)
      --user-agent=<val>              Set the default User-Agent header for HTTP
requests
      --main-fields=<val>             Main fields to lookup in package.json.
Defaults to --target dependent
      --preserve-symlinks             Preserve symlinks when resolving files
      --preserve-symlinks-main        Preserve symlinks when resolving the main
entry point
```

```
      --extension-order=<val>         Defaults to: .tsx,.ts,.jsx,.js,.json
      --tsconfig-override=<val>       Specify custom tsconfig.json. Default
<d>$cwd<r>/tsconfig.json
  -d, --define=<val>                  Substitute K:V while parsing, e.g. --define
process.env.NODE_ENV:"development". Values are parsed as JSON.
      --drop=<val>                    Remove function calls, e.g. --drop=console
removes all console.* calls.
      --feature=<val>                 Enable a feature flag for dead-code
elimination, e.g. --feature=SUPER_SECRET
  -l, --loader=<val>                  Parse files with .ext:loader, e.g. --loader
.js:jsx. Valid loaders: js, jsx, ts, tsx, json, toml, text, file, wasm, napi
      --no-macros                     Disable macros from being executed in the
bundler, transpiler and runtime
      --jsx-factory=<val>             Changes the function called when compiling
JSX elements using the classic JSX runtime
      --jsx-fragment=<val>            Changes the function called when compiling
JSX fragments
      --jsx-import-source=<val>       Declares the module specifier to be used for
importing the jsx and jsxs factory functions. Default: "react"
      --jsx-runtime=<val>             "automatic" (default) or "classic"
      --jsx-side-effects              Treat JSX elements as having side effects
(disable pure annotations)
      --ignore-dce-annotations        Ignore tree-shaking annotations such as
@__PURE__
      --env-file=<val>                Load environment variables from the
specified file(s)
      --no-env-file                   Disable automatic loading of .env files
      --cwd=<val>                     Absolute path to resolve files & entry
points from. This just changes the process' cwd.
  -c, --config=<val>                  Specify path to Bun config file. Default
<d>$cwd<r>/bunfig.toml
  -h, --help                          Display this menu and exit

Examples:
  Run a JavaScript or TypeScript file
  bun run ./index.js
  bun run ./index.tsx

  Run a package.json script
  bun run dev
  bun run lint

Full documentation is available at https://bun.com/docs/cli/run

package.json scripts (2 found):
  $ bun run dev
    bun --watch index.ts

  $ bun run start
    bun index.ts

bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/9_$
```

Setup scripts:

```
{
  "scripts": {
    "dev": "bun --watch index.ts",
    "start": "bun index.ts"
  }
}
```

What are scripts?

- Shortcuts for running long commands
- Instead of typing `bun --watch index.ts`, just type `bun run dev`
- `dev` = development (while building)
- `start` = production (when deployed)

Run scripts:

```
bun run dev    # Development with watch mode
bun run start  # Production start

# List all scripts
bun run        # Shows all available scripts
```

Why use scripts?

- Easier to remember short names
- Consistent across team projects
- Can add more complex commands later
- Standard practice in web development

---

10. File Imports

```
// index.ts
import info from "./info.txt";
// name: kintsugi-programmer
// target: coding_is_meditation

import user from "./user.json"
// {
//     "name":"Kintsugi-Programmer",
//     "age":25
// }

import { makeName } from "./module";// File extensions (.ts) are optional when
importing
```

```
// // module.ts
// export const makeName = (firstName: string, lastName: string) : string=> {
//     return `${firstName} ${lastName}`;
//     // ` , not '
// };

console.log("Hello via Bun!");
// Hello via Bun!

console.log(info);
// name: kintsugi-programmer
// target: coding_is_meditation

console.log(user);
// {
//   name: "Kintsugi-Programmer",
//   age: 25,
// }

console.log(makeName("Kintsugi","Programmer"));
```

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/10_$ bun index.ts
Hello via Bun!
name: kintsugi-programmer
target: coding_is_meditation
{
  name: "Kintsugi-Programmer",
  age: 25,
}
Kintsugi Programmer
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/10_$
```

Understanding File Imports in Bun:

- Bun allows direct importing of various file types (text, JSON, TypeScript modules) without special loaders
- Imported files are treated as native imports, returning their content or parsed objects
- This eliminates the need for fs module or parsing logic for common file types
- Reduces boilerplate code compared to traditional Node.js approaches
- **Import** = Loading code or data from another file into your current file
- **Why import?** Organize code into separate files, reuse code in multiple places

10.1. Importing Text Files

Create `info.txt`:

```
name: kintsugi-programmer
target: coding_is_meditation
```

Import and use:

```
import info from "./info.txt";
console.log(info);
// Output: name: kintsugi-programmer
//         target: coding_is_meditation
```

Key Points:

- Text files are imported as raw strings
- Content is immediately available without requiring file system operations
- Useful for configuration files, messages, or templates
- No parsing or conversion needed for plain text content

10.2. Importing JSON Files

Create `user.json`:

```
{
  "name": "kintsugi-programmer",
  "age": 25
}
```

Import and use:

```
import user from "./user.json";
console.log(user);
// Output: { name: "kintsugi-programmer", age: 25 }
```

Key Points:

- JSON files are automatically parsed into JavaScript objects
- Type-safe: The imported object maintains proper structure
- No need for JSON.parse() or async file reading
- Perfect for storing configuration, data, or lookup tables
- Changes to the JSON file require module reload (in development)

10.3. Importing TypeScript Modules

Create `module.ts`:

```ts
export const makeName = (firstName: string, lastName: string): string => {
  return `${firstName} ${lastName}`;
};
```

Import and use:

```ts
import { makeName } from "./module";
console.log(makeName("Kintsugi", "Programmer"));
// Output: Kintsugi Programmer
```

Key Points:

- TypeScript modules are treated like standard ES6 imports
- Bun compiles TypeScript on-the-fly without configuration
- You can use named exports and default exports
- Type annotations are preserved and checked at runtime in Bun
- File extensions (.ts) are optional when importing
- Supports tree-shaking and dead code elimination

---

11. Environment Variables

```ts
// index.ts

// .env.local
// PORT=2000
// DATABASE_URL=mongodb://localhost:27017

// .env.development
// PORT=1000
// DATABASE_URL=mongodb://localhost:27017

// .env.production
// PORT=3000
// DATABASE_URL=mongodb://localhost:27017

// .env.staging
// PORT=
// DATABASE_URL=

// no need to import some lib for .env use

// Priority of import
// 1. .env.local
// 2. .env.development
// 3. .env.production

// way 2
```

```
const port_way_2 = Bun.env.PORT;

// way 3
const port_way_3 = import.meta.env.PORT;

// way 1
const port_way_1 = process.env.PORT;

console.log(port_way_1);
console.log(port_way_2);
console.log(port_way_3);
// 2000
// 2000
// 2000

// // env.d.ts
// declare module "bun" {
//     interface Env {
//         PORT: string;
//         DATABASE_URL: string;
//     }
// }

// .env.staging
// PORT=
// DATABASE_URL=

// when its get import , it will used as empty

// .env.empty
// EMPTY

// when its get import , it will used as undefined
```

```
{
  "name": "11_",
  "module": "index.ts",
  "type": "module",
  "private": true,
  "devDependencies": {
    "@types/bun": "latest"
  },
  "peerDependencies": {
    "typescript": "^5"
  },
  "scripts": {
    "dev":"bun --watch --env-file=.env.development index.ts"
    ,"start":"bun --env-file=.env.production index.ts"
  }
}
```

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ bun index.ts
2000
2000
2000
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ bun run dev
$ bun --watch --env-file=.env.development index.ts
1000
1000
1000
^C
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ bun run start
$ bun --env-file=.env.production index.ts
3000
3000
3000
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ bun --env-
file=.env.staging index.ts



bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ bun --env-file=.env.empty
index.ts
undefined
undefined
undefined
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ NODE_ENV=development bun
index.ts #another way but don't use as it's get overriden by bun
2000
2000
2000
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ NODE_ENV=empty bun
index.ts
2000
2000
2000
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ # see, it's got overriden
by bun priority
```

11.1. What are Environment Variables?

- **Environment Variables** = Settings/values your app reads at startup
- Stored outside your code (in .env files)
- Used for: passwords, API keys, configuration, database URLs
- **Why?** Keeps sensitive info out of your code, different settings for dev vs production
- Example: Database URL on local computer ≠ database URL on production server

11.2. Basic Usage

No external packages needed (no dotenv required!)

Create `.env.development`:

```
PORT=6000
DATABASE_URL=mongodb://localhost:27017
```

11.3. Three Ways to Access Environment Variables

11.3.1. Method 1: process.env

```
const port = process.env.PORT;
console.log(port); // 6000
```

11.3.2. Method 2: Bun.env

```
const port = Bun.env.PORT;
console.log(port); // 6000
```

11.3.3. Method 3: import.meta.env

```
const port = import.meta.env.PORT;
console.log(port); // 6000
```

11.4. Type Safety for Environment Variables

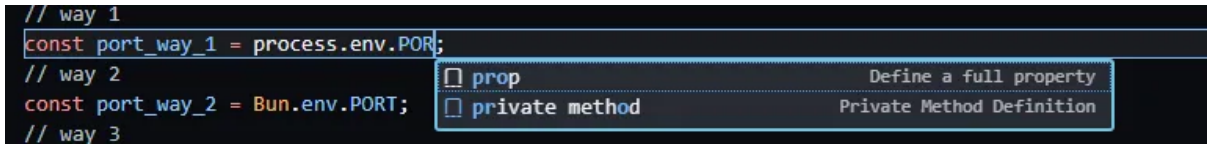
Create `env.d.ts`:

```
declare module "bun" {
  interface Env {
    PORT: string;
    DATABASE_URL: string;
  }
}
```

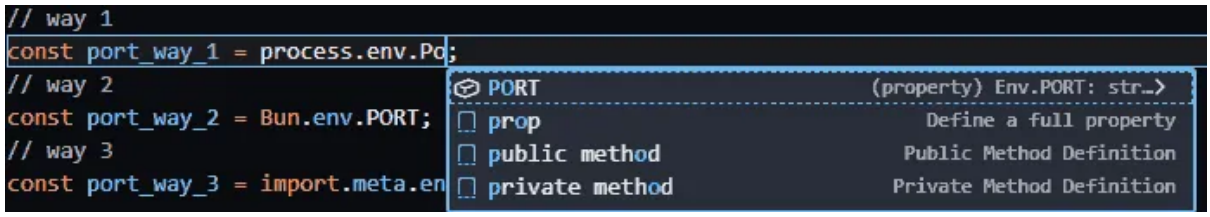
Now you get autocomplete and type checking:

```
process.env.PORT // ✓ Autocomplete works!
```

- without `env.d.ts`



    - no autocomplete/suggestions
- with `env.d.ts`



    - now we got suggestions

11.5. Multiple Environment Files

Bun automatically loads these files (in order of priority):

1. `.env.local`
2. `.env.development`
3. `.env.production`

Specify environment file in package.json:

```
{
  "scripts": {
    "dev": "bun --watch --env-file=.env.development index.ts",
    "start": "bun --env-file=.env.production index.ts"
  }
}
```

11.6. Using NODE_ENV

```
NODE_ENV=development bun index.ts
NODE_ENV=production bun index.ts
```

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ NODE_ENV=development bun
index.ts #another way but don't use as it's get overriden by bun
2000
2000
2000
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ NODE_ENV=empty bun
index.ts
2000
2000
2000
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/11_$ # see, it's got overriden
by bun priority
```

12. File I/O Operations

```
// index.ts
// {
//     "name":"kintsugi-programmer"
// }

const file = Bun.file("./user.json");

console.log(file);
// FileRef ("./user.json") {
//   type: "application/json;charset=utf-8"
// }

console.log(file.type);
// application/json;charset=utf-8

console.log(file.size);
// 36

console.log(file.name);
// ./user.json

const file_1 = Bun.file("./message.txt");
const check_if_exists_file_1 = await file_1.exists(); //Prevents crashes
console.log(check_if_exists_file_1);
// false

const data = "Si Vis Pacem Para Bellum !!!";
const bytes_written_from_data = await Bun.write("message_1.txt",data);
console.log(bytes_written_from_data);
// 2

// bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ cat  message_1.txt
// Si Vis Pacem Para Bellum !!!bali-king@war-machine:~/BaliGit/kintsugi-stack-
bun/12_$

const old_file = Bun.file("./message_1.txt");
const new_file = Bun.file("./copied_message_1.txt");
await Bun.write(new_file,old_file); // Doesn't load entire file into memory &
Preserves content

// bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ ls
// README.md  copied_message_1.txt  message_1.txt  package.json   user.json
// bun.lock   index.ts              node_modules   tsconfig.json
// bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ cat
copied_message_1.txt
// Si Vis Pacem Para Bellum !!!bali-king@war-machine:~/BaliGit/kintsugi-stack-
bun/12_$
```

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ bun index.ts
FileRef ("./user.json") {
  type: "application/json;charset=utf-8"
}
application/json;charset=utf-8
36
./user.json
false
28
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ ls
README.md  copied_message_1.txt  message_1.txt  package.json   user.json
bun.lock   index.ts              node_modules   tsconfig.json
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ cat  message_1.txt
Si Vis Pacem Para Bellum !!!
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ cat  copied_message_1.txt
Si Vis Pacem Para Bellum !!!
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$
```

12.1. What is File I/O?

- **I/O** = Input/Output (reading from and writing to files)
- **File I/O** = Reading data from files or saving data to files
- Needed for: storing data, loading configuration, saving user uploads, logs
- **Async** = Non-blocking (code continues while file is being read/written)

12.2. Reading Files with Bun.file

Create `user.json`:

```
{
  "name": "kintsugi-programmer"
}
```

Read file:

```
const file = Bun.file("./user.json");
console.log(file);
```

```
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$ bun index.ts
FileRef ("./user.json") {
  type: "application/json;charset=utf-8"
}
bali-king@war-machine:~/BaliGit/kintsugi-stack-bun/12_$
```

12.3. File Properties

```
const file = Bun.file("./user.json");

// Get file type
console.log(file.type); // "application/json"

// Get file size (in bytes)
console.log(file.size); // 28

// Get file name
console.log(file.name); // "user.json"
```

Key Points:

- `file.type` returns the MIME type based on file extension (useful for Content-Type headers)
- `file.size` provides the file size in bytes for quota checks or logging
- `file.name` gives only the filename without the directory path
- These properties are useful for validation, logging, and HTTP response headers
- MIME types help browsers and servers understand how to handle files

12.3.1. MIME

> MIME = Multipurpose Internet Mail Extensions.
>
> - It's a label that tells browsers, servers, and apps what kind of data a file contains and how it should be handled.
> - A MIME type is a sticker on a package:
>   - 📦 "Hey browser, this is an image."
>   - 📦 "Hey server, this is JSON."
>   - 📦 "Hey app, this is a video."
> - type/subtype
>   - index.html → text/html
>   - style.css → text/css

File	MIME type
HTML	`text/html`
CSS	`text/css`
JS	`application/javascript`
JSON	`application/json`
PNG	`image/png`
JPG	`image/jpeg`

File	MIME type
SVG	`image/svg+xml`
MP4	`video/mp4`
PDF	`application/pdf`

12.4. Check File Existence

```
const file = Bun.file("./message.txt");
const exists = await file.exists();
console.log(exists); // true or false
```

Key Points:

- **await keyword:** Required because file.exists() returns a Promise
- **exists() method:** Returns boolean (true if file exists, false otherwise)
- **Use case:** Check before reading to prevent errors
- **Prevents crashes:** Avoid "file not found" exceptions
- **Conditional logic:** Often paired with if/else statements

12.5. Writing Files

```
const data = "Don't forget to subscribe";
const bytesWritten = await Bun.write("message1.txt", data);
console.log(bytesWritten); // Returns file size in bytes
```

Key Points:

- **Bun.write():** Creates or overwrites a file with provided content
- **Returns bytes:** Number of bytes written to file
- **await required:** File operations are asynchronous
- **Creates directories:** Can create parent directories if needed
- **Content types:** Accepts strings, buffers, and Bun.file() objects
- **Overwrites:** Replaces entire file content (doesn't append)

12.6. Copying Files

```
const oldFile = Bun.file("./message.txt");
const newFile = Bun.file("./copied-message.txt");
await Bun.write(newFile, oldFile);
```

Key Points:

- **Source file:** Use Bun.file() to reference the file to copy

- **Destination file:** Another Bun.file() reference for target path
- **Bun.write():** Can accept file objects as source content
- **Efficient:** Doesn't load entire file into memory
- **Preserves content:** Exact copy of original file
- **Creates if needed:** Destination file is created if it doesn't exist

---

13. Working with Directories

```
import fs from "fs";
fs.mkdir("documentation",(err)=>
{
    if (err) {
        console.error(err);
    }
    else {
        console.log("Folder Created");
    }
}
);
// Folder Created

fs.readdir("documentation",(err,files)=>{
    if (err) {console.error(err);}
    else {console.log(files);}
});
// []

console.log(import.meta.dir);
// /workspaces/kintsugi-stack-bun/13_

fs.readdir(import.meta.dir,(err,files)=>{
    if(err) {console.error(err);}
    else {console.log(files);}
});
// [ "documentation", "tsconfig.json", "node_modules", "package.json",
".gitignore", "index.ts",
//   "bun.lock", "README.md"
// ]
```

13.1. Create Directory

```
import fs from "fs";

fs.mkdir("documentation", (err) => {
  if (err) {
    console.error(err);
  } else {
```

```
    console.log("Folder created");
  }
});
```

Key Points:

- **fs.mkdir():** Creates a new directory
- **Callback pattern:** Error-first callback (err, result)
- **Error handling:** Check if err exists to detect creation failures
- **Relative path:** Creates folder relative to current working directory
- **Single level:** Only creates the specified folder, not parent directories
- **Use mkdirSync():** For synchronous creation (blocks execution)

13.2. Read Directory

```
import fs from "fs";

fs.readdir("documentation", (err, files) => {
  if (err) {
    console.error(err);
  } else {
    console.log(files); // Array of file names
  }
});
```

Key Points:

- **fs.readdir():** Lists all files and folders in a directory
- **files array:** Contains names of items in the directory
- **Filenames only:** Returns names like ["file.txt", "folder"], not full paths
- **Error handling:** Catches issues like directory not found
- **Asynchronous:** Non-blocking, uses callback pattern
- **Shallow listing:** Only lists immediate children, not recursive

13.3. Get Current Directory

```
console.log(import.meta.dir);
// Output: Full path to current directory
```

---

14. import.meta Object

```
console.log(import.meta.dir);
// /workspaces/kintsugi-stack-bun/14_
```

```
console.log(import.meta.dirname); // for Node.js Compatibility // no need to use
it
// /workspaces/kintsugi-stack-bun/14_

console.log(import.meta.env);
// {
//   SHELL: "/bin/bash",
//   NUGET_XMLDOC_MODE: "skip",
//   COLORTERM: "truecolor",
//   CLOUDENV_ENVIRONMENT_ID: "76db0ef8-61ab-4e37-9aef-28af2d99ebbb",
//   NVM_INC: "/usr/local/share/nvm/versions/node/v24.11.1/include/node",
//   TERM_PROGRAM_VERSION: "1.108.2",
//   GITHUB_USER: "kintsugi-programmer",
//   rvm_prefix: "/usr/local",
//   CODESPACE_NAME: "cuddly-space-acorn-g44pvxrqppq3ppvw",
//   HOSTNAME: "codespaces-11e5f5",
//   JAVA_ROOT: "/home/codespace/java",
//   JAVA_HOME: "/usr/local/sdkman/candidates/java/current",
//   DOTNET_ROOT: "/usr/share/dotnet",
//   CODESPACES: "true",
//   PYTHON_ROOT: "/home/codespace/.python",
//   GRADLE_HOME: "/usr/local/sdkman/candidates/gradle/current",
//   NVS_DIR: "/usr/local/nvs",
//   NVS_OS: "linux",
//   DOTNET_SKIP_FIRST_TIME_EXPERIENCE: "1",
//   MY_RUBY_HOME: "/usr/local/rvm/rubies/ruby-3.4.7",
//   NVS_USE_XZ: "1",
//   SDKMAN_CANDIDATES_DIR: "/usr/local/sdkman/candidates",
//   SDKMAN_BROKER_API: "https://broker.sdkman.io",
//   RUBY_VERSION: "ruby-3.4.7",
//   PWD: "/workspaces/kintsugi-stack-bun/14_",
//   PIPX_BIN_DIR: "/usr/local/py-utils/bin",
//   rvm_version: "1.29.12 (latest)",
//   ORYX_DIR: "/usr/local/oryx",
//   ContainerVersion: "13",
//   VSCODE_GIT_ASKPASS_NODE: "/vscode/bin/linux-
x64/c9d77990917f3102ada88be140d28b038d1dd7c7/node",
//   HUGO_ROOT: "/home/codespace/.hugo",
//   GITHUB_CODESPACES_PORT_FORWARDING_DOMAIN: "app.github.dev",
//   NPM_GLOBAL: "/home/codespace/.npm-global",
//   HOME: "/home/codespace",
//   GITHUB_API_URL: "https://api.github.com",
//   LANG: "C.UTF-8",
//   GITHUB_TOKEN: "ghu_xKzHGw9Lg3LhWm23qeLslUl8ytFxPx4WHmRn",
//   LS_COLORS:
"rs=0:di=01;34:ln=01;36:mh=00:pi=40;33:so=01;35:do=01;35:bd=40;33;01:cd=40;33;01:o
r=40;31;01:mi=00:su=37;41:sg=30;43:ca=00:tw=30;42:ow=34;42:st=37;44:ex=01;32:*.tar
=01;31:*.tgz=01;31:*.arc=01;31:*.arj=01;31:*.taz=01;31:*.lha=01;31:*.lz4=01;31:*.l
zh=01;31:*.lzma=01;31:*.tlz=01;31:*.txz=01;31:*.tzo=01;31:*.t7z=01;31:*.zip=01;31:
*.z=01;31:*.dz=01;31:*.gz=01;31:*.lrz=01;31:*.lz=01;31:*.lzo=01;31:*.xz=01;31:*.zs
t=01;31:*.tzst=01;31:*.bz2=01;31:*.bz=01;31:*.tbz=01;31:*.tbz2=01;31:*.tz=01;31:*.
deb=01;31:*.rpm=01;31:*.jar=01;31:*.war=01;31:*.ear=01;31:*.sar=01;31:*.rar=01;31:
*.alz=01;31:*.ace=01;31:*.zoo=01;31:*.cpio=01;31:*.7z=01;31:*.rz=01;31:*.cab=01;31
:*.wim=01;31:*.swm=01;31:*.dwm=01;31:*.esd=01;31:*.avif=01;35:*.jpg=01;35:*.jpeg=0
```

```
1;35:*.mjpg=01;35:*.mjpeg=01;35:*.gif=01;35:*.bmp=01;35:*.pbm=01;35:*.pgm=01;35:*.
ppm=01;35:*.tga=01;35:*.xbm=01;35:*.xpm=01;35:*.tif=01;35:*.tiff=01;35:*.png=01;35
:*.svg=01;35:*.svgz=01;35:*.mng=01;35:*.pcx=01;35:*.mov=01;35:*.mpg=01;35:*.mpeg=0
1;35:*.m2v=01;35:*.mkv=01;35:*.webm=01;35:*.webp=01;35:*.ogm=01;35:*.mp4=01;35:*.m
4v=01;35:*.mp4v=01;35:*.vob=01;35:*.qt=01;35:*.nuv=01;35:*.wmv=01;35:*.asf=01;35:*
.rm=01;35:*.rmvb=01;35:*.flc=01;35:*.avi=01;35:*.fli=01;35:*.flv=01;35:*.gl=01;35:
*.dl=01;35:*.xcf=01;35:*.xwd=01;35:*.yuv=01;35:*.cgm=01;35:*.emf=01;35:*.ogv=01;35
:*.ogx=01;35:*.aac=00;36:*.au=00;36:*.flac=00;36:*.m4a=00;36:*.mid=00;36:*.midi=00
;36:*.mka=00;36:*.mp3=00;36:*.mpc=00;36:*.ogg=00;36:*.ra=00;36:*.wav=00;36:*.oga=0
0;36:*.opus=00;36:*.spx=00;36:*.xspf=00;36:*~=00;90:*#=00;90:*.bak=00;90:*.crdownl
oad=00;90:*.dpkg-dist=00;90:*.dpkg-new=00;90:*.dpkg-old=00;90:*.dpkg-
tmp=00;90:*.old=00;90:*.orig=00;90:*.part=00;90:*.rej=00;90:*.rpmnew=00;90:*.rpmor
ig=00;90:*.rpmsave=00;90:*.swp=00;90:*.tmp=00;90:*.ucf-dist=00;90:*.ucf-
new=00;90:*.ucf-old=00;90:",
//   DYNAMIC_INSTALL_ROOT_DIR: "/opt",
//   NVM_SYMLINK_CURRENT: "true",
//   PHP_PATH: "/usr/local/php/current",
//   DEBIAN_FLAVOR: "focal-scm",
//   GIT_ASKPASS: "/vscode/bin/linux-
x64/c9d77990917f3102ada88be140d28b038d1dd7c7/extensions/git/dist/askpass.sh",
//   PHP_ROOT: "/home/codespace/.php",
//   ORYX_ENV_TYPE: "vsonline-present",
//   HUGO_DIR: "/usr/local/hugo/bin",
//   DOCKER_BUILDKIT: "1",
//   GOROOT: "/usr/local/go",
//   INTERNAL_VSCS_TARGET_URL: "https://centralindia.online.visualstudio.com",
//   SHELL_LOGGED_IN: "true",
//   PYTHON_PATH: "/usr/local/python/current",
//   NVM_DIR: "/usr/local/share/nvm",
//   VSCODE_GIT_ASKPASS_EXTRA_ARGS: "",
//   rvm_bin_path: "/usr/local/rvm/bin",
//   VSCODE_PYTHON_AUTOACTIVATE_GUARD: "1",
//   GEM_PATH: "/usr/local/rvm/gems/ruby-3.4.7:/usr/local/rvm/gems/ruby-
3.4.7@global",
//   GEM_HOME: "/usr/local/rvm/gems/ruby-3.4.7",
//   GITHUB_CODESPACE_TOKEN: "A4MGAGAWSIPS5SECFFTXXMTJO4KXLANCNFSM4AS2MP4Q",
//   LESSCLOSE: "/usr/bin/lesspipe %s %s",
//   NVS_ROOT: "/usr/local/nvs",
//   GITHUB_GRAPHQL_URL: "https://api.github.com/graphql",
//   TERM: "xterm-256color",
//   LESSOPEN: "| /usr/bin/lesspipe %s",
//   USER: "codespace",
//   NODE_ROOT: "/home/codespace/nvm",
//   VSCODE_GIT_IPC_HANDLE: "/tmp/vscode-git-1044e88bb9.sock",
//   PYTHONIOENCODING: "UTF-8",
//   GITHUB_SERVER_URL: "https://github.com",
//   NVS_HOME: "/usr/local/nvs",
//   PIPX_HOME: "/usr/local/py-utils",
//   CONDA_SCRIPT: "/opt/conda/etc/profile.d/conda.sh",
//   MAVEN_HOME: "/usr/local/sdkman/candidates/maven/current",
//   SDKMAN_DIR: "/usr/local/sdkman",
//   SHLVL: "2",
//   NVM_CD_FLAGS: "",
//   ORYX_SDK_STORAGE_BASE_URL: "https://oryx-cdn.microsoft.io",
```

```
//   GIT_EDITOR: "code --wait",
//   CONDA_DIR: "/opt/conda",
//   PROMPT_DIRTRIM: "4",
//   SDKMAN_CANDIDATES_API: "https://api.sdkman.io/2",
//   DOTNET_RUNNING_IN_CONTAINER: "true",
//   DOTNET_USE_POLLING_FILE_WATCHER: "true",
//   ENABLE_DYNAMIC_INSTALL: "true",
//   MAVEN_ROOT: "/home/codespace/.maven",
//   ORYX_PREFER_USER_INSTALLED_SDKS: "true",
//   JUPYTERLAB_PATH: "/home/codespace/.local/bin",
//   DEBUGINFOD_URLS: "https://debuginfod.ubuntu.com ",
//   RVM_PATH: "/usr/local/rvm",
//   GITHUB_REPOSITORY: "kintsugi-programmer/kintsugi-stack-bun",
//   RAILS_DEVELOPMENT_HOSTS:
".githubpreview.dev,.preview.app.github.dev,.app.github.dev",
//   VSCODE_GIT_ASKPASS_MAIN: "/vscode/bin/linux-
x64/c9d77990917f3102ada88be140d28b038d1dd7c7/extensions/git/dist/askpass-main.js",
//   RUBY_ROOT: "/home/codespace/.ruby",
//   RUBY_HOME: "/usr/local/rvm/rubies/default",
//   BROWSER: "/vscode/bin/linux-
x64/c9d77990917f3102ada88be140d28b038d1dd7c7/bin/helpers/browser.sh",
//   PATH: "/usr/local/rvm/gems/ruby-3.4.7/bin:/usr/local/rvm/gems/ruby-
3.4.7@global/bin:/usr/local/rvm/rubies/ruby-3.4.7/bin:/vscode/bin/linux-
x64/c9d77990917f3102ada88be140d28b038d1dd7c7/bin/remote-
cli:/home/codespace/.local/bin:/home/codespace/.dotnet:/home/codespace/nvm/current
/bin:/home/codespace/.php/current/bin:/home/codespace/.python/current/bin:/home/co
despace/java/current/bin:/home/codespace/.ruby/current/bin:/home/codespace/.local/
bin:/usr/local/python/current/bin:/usr/local/py-
utils/bin:/usr/local/jupyter:/usr/local/oryx:/usr/local/go/bin:/go/bin:/usr/local/
sdkman/bin:/usr/local/sdkman/candidates/java/current/bin:/usr/local/sdkman/candida
tes/gradle/current/bin:/usr/local/sdkman/candidates/maven/current/bin:/usr/local/s
dkman/candidates/ant/current/bin:/usr/local/rvm/gems/default/bin:/usr/local/rvm/ge
ms/default@global/bin:/usr/local/rvm/rubies/default/bin:/usr/local/share/rbenv/bin
:/usr/local/php/current/bin:/opt/conda/bin:/usr/local/nvs:/usr/local/share/nvm/ver
sions/node/v24.11.1/bin:/usr/local/hugo/bin:/usr/local/sbin:/usr/local/bin:/usr/sb
in:/usr/bin:/sbin:/bin:/usr/share/dotnet:/home/codespace/.dotnet/tools:/usr/local/
rvm/bin",
//   CODESPACE_VSCODE_FOLDER: "/workspaces/kintsugi-stack-bun",
//   SDKMAN_PLATFORM: "linuxx64",
//   NVM_BIN: "/usr/local/share/nvm/versions/node/v24.11.1/bin",
//   IRBRC: "/usr/local/rvm/rubies/ruby-3.4.7/.irbrc",
//   FEATURE_SPARK_POST_COMMIT_CREATE_ITERATION: "true",
//   rvm_path: "/usr/local/rvm",
//   OLDPWD: "/",
//   GOPATH: "/go",
//   TERM_PROGRAM: "vscode",
//   VSCODE_IPC_HOOK_CLI: "/tmp/vscode-ipc-04f05c59-afe6-4b77-97aa-
b2d28d1ff18a.sock",
//   _: "/home/codespace/nvm/current/bin/bun",
//   TZ: undefined,
//   NODE_TLS_REJECT_UNAUTHORIZED: undefined,
//   BUN_CONFIG_VERBOSE_FETCH: undefined,
// }
```

```
console.log(import.meta.file);
// index.ts

console.log(import.meta.path);
// /workspaces/kintsugi-stack-bun/14_/index.ts

console.log(import.meta.filename);// for Node.js Compatibility // no need to use
it
// /workspaces/kintsugi-stack-bun/14_/index.ts

console.log(import.meta.url);
// file:///workspaces/kintsugi-stack-bun/14_/index.ts

console.log(import.meta.resolve("typescript")); // it gets module's path without
importing it
// file:///workspaces/kintsugi-stack-
bun/14_/node_modules/typescript/lib/typescript.js

// Bun also supports Node.js Conventions
console.log(__dirname);
// /workspaces/kintsugi-stack-bun/14_
console.log(__filename);
// /workspaces/kintsugi-stack-bun/14_/index.ts
```

14.1. Available Properties

14.1.1. import.meta.dir

```
console.log(import.meta.dir);
// Output: /path/to/project/bun
```

Purpose: Returns the absolute directory path of the current file

- **Use case:** Base path for relative file operations
- **Example:** Loading files relative to your script location

14.1.2. import.meta.dirname (Alias)

```
console.log(import.meta.dirname);
// Same as import.meta.dir
```

Purpose: Alias for `import.meta.dir` (same functionality)

- **Why:** Provides Node.js compatibility (`__dirname` equivalent)
- **Preference:** Use `.dir` for consistency

14.1.3. import.meta.env

```
console.log(import.meta.env);
// Output: All environment variables
```

Purpose: Access all environment variables as an object

- **Advantage:** Type-safe access to environment configuration
- **Use case:** Loading entire configuration at once

14.1.4. import.meta.file

```
console.log(import.meta.file);
// Output: index.ts
```

Purpose: Returns just the filename without directory path

- **Use case:** Logging which file is executing
- **Example:** Dynamic debugging or error reporting

14.1.5. import.meta.path

```
console.log(import.meta.path);
// Output: /path/to/project/bun/index.ts
```

Purpose: Returns the absolute file path (directory + filename)

- **Use case:** Creating absolute file paths for operations
- **Difference from `.url`:** Returns a normal path string, not a URL

14.1.6. import.meta.filename (Alias)

```
console.log(import.meta.filename);
// Same as import.meta.path
```

Purpose: Alias for `import.meta.path` (Node.js compatibility)

- **Why:** Equivalent to Node.js `__filename`
- **Preference:** Use `.path` for consistency

14.1.7. import.meta.url

```
console.log(import.meta.url);
// Output: file:///path/to/project/bun/index.ts
```

Purpose: Returns the file URL in RFC 3986 format

- **Use case:** Cross-platform file URL handling
- **Difference from `.path`:** Includes `file://` protocol prefix
- **Useful for:** Creating File URLs for APIs that require them

14.1.8. import.meta.resolve()

```
const path = import.meta.resolve("typescript");
console.log(path);
// Output: /path/to/node_modules/typescript/lib/typescript.js
```

Purpose: Resolves module paths without importing them

- **Use case:** Finding where packages are installed
- **Advantage:** No need for require() or dynamic imports
- **Example:** Build tools that need to locate dependencies

14.2. Node.js Compatibility

Bun also supports Node.js conventions:

```
console.log(__dirname);  // Works
console.log(__filename); // Works
```

---

15. Hashing & Encryption

```
import { password } from "bun";

const pass = "pass123";

const hashed_pass = await Bun.password.hash(
    pass,
    {
        algorithm: "bcrypt",
        cost:4 // Iterations (optional) // 4 to 31
        // rehashing the output
        // way of salting
        // more cost, more time !!!
    }
);
```

```
// Only Encrypt, no Decrypt !!!

console.log(hashed_pass);
// $2b$04$sKU8Cs.1ttGOKZkJiiikbe1.QKZh2e4HWaEfvarnsC7jrl4DulD8C

const pass_1 = "pas123";
const hashed_pass_1 = await Bun.password.hash(
    pass_1,
    {
        algorithm: "bcrypt"
        ,cost:4
    }
);

console.log(hashed_pass_1);
// $2b$04$mPayj76gwLg4C0/VsfpZ7.2B46czZbo1JvZ8AaRGwfGtjVLE3yGdS

const isValid = await Bun.password.verify(pass,hashed_pass);
const isValid_1 = await Bun.password.verify(pass_1,hashed_pass_1);
const isNotValid = await Bun.password.verify(pass,hashed_pass_1);
const isNotValid_2 = await Bun.password.verify("pass123",hashed_pass_1);

console.log(isValid);
console.log(isValid_1);
console.log(isNotValid);
console.log(isNotValid_2);
// true
// true
// false
// false

// Example
// Registration
const userPassword = "pass123";
const hashedPassword = await Bun.password.hash(
    userPassword,
    {
        algorithm: "bcrypt"
    }
);
// Save hashedPassword to database // not direct raw password to db

// Login
const loginPassword = "pass123";
const isValidPassword = await Bun.password.verify(loginPassword,hashedPassword);

// Validate During Login
if (isValidPassword) {console.log("Login Success");}
else {console.log("Invalid credentials");}
// Login Success

const hashed_pass_way_2= await Bun.password.hash(
    pass,
    {
```

```
        algorithm:"argon2d"// Alternative to bcrypt
    }

);console.log(hashed_pass_way_2);
//
$argon2d$v=19$m=65536,t=2,p=1$mU25/aPwbP42zPRfTzlmQA4LHyy8Wj2RBCMcF3cV6LM$oVy4A+6b
PtfJ9omgElZHaWnJtX2ny9QAK8yWMrPXIzk
```

15.1. What is Password Hashing?

- **Hashing** = Converting text into a fixed-length scrambled string
- **Why hash passwords?** Never store actual passwords in database (very dangerous)
- If database is hacked, hackers get hashes (not usable passwords)
- When user logs in: Hash their input → Compare to stored hash → If match, allow login
- **One-way**: You can't unhash a password (that's the point!)
- Only Encrypt, no Decrypt !!!
- Example: `password123` → `$2b$04$aL8zK9xK2...` (can't reverse it)
- eg: hashing a 500page novel to 64char is you are discarding the original data and keeping only a unique "fingerprint."
- you can't rebuild a flour from a bread.

15.2. Password Hashing

No bcrypt package needed! Bun provides built-in password hashing.

15.2.1. Hash a Password

```
const password = "password123";

const hashedPassword = await Bun.password.hash(password, {
  algorithm: "bcrypt",
  cost: 4  // Iterations (optional)
});

console.log(hashedPassword);
// Output: $2b$04$...
```

15.2.2. Verify Password

```
const password = "password123";
const hashedPassword = await Bun.password.hash(password, {
  algorithm: "bcrypt"
});

const isValid = await Bun.password.verify(password, hashedPassword);
console.log(isValid); // true
```

```
const isInvalid = await Bun.password.verify("wrongpass", hashedPassword);
console.log(isInvalid); // false
```

15.3. Complete Example

```
// Registration
const userPassword = "password123";
const hashedPassword = await Bun.password.hash(userPassword, {
  algorithm: "bcrypt"
});
// Save hashedPassword to database

// Login
const loginPassword = "password123";
const isValidPassword = await Bun.password.verify(
  loginPassword,
  hashedPassword
);

if (isValidPassword) {
  console.log("Login successful");
} else {
  console.log("Invalid credentials");
}
```

15.4. Argon2 Algorithm

```
const hashedPassword = await Bun.password.hash(password, {
  algorithm: "argon2"  // Alternative to bcrypt
});
```

---

16. Bun Utilities

```
console.log(Bun.version); // Bun version
// 1.3.6

console.log(Bun.env); // fast all .env return as obj
// {
//   SHELL: "/bin/bash",
//   NUGET_XMLDOC_MODE: "skip",
//   COLORTERM: "truecolor",
//   CLOUDENV_ENVIRONMENT_ID: "76db0ef8-61ab-4e37-9aef-28af2d99ebbb",
//   NVM_INC: "/usr/local/share/nvm/versions/node/v24.11.1/include/node",
//   TERM_PROGRAM_VERSION: "1.108.2"
```

```
// }

await Bun.sleep(5000); // 5sec pause execution // No need to construct wrapper
with Promises like trad. js // for Rate limiting

console.log(crypto.randomUUID());// Generate a cryptographically secure random
UUID // RFC 4122 Version 4 UUID (v4) // xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx
// b1f9b4dd-08f0-4f86-ad05-0d2ee998e430
 // Cryptographically secure (not just Math.random())

console.log(Bun.nanoseconds());
// 5682172144

const obj1 = {name:"bali-king", age: 18};
const obj2 = {name:"bali-king", age: 18};
const obj3 = {name:"bali-king"};
console.log(Bun.deepEquals(obj1,obj2)); // Compare two values for deep equality
// true
// Compares values, not references
// Built-in, faster than custom deep comparison

console.log(Bun.deepEquals(obj1,obj3));
// false
```

16.1. Bun.version

```
console.log(Bun.version);
// Output: "1.2.5"
```

Purpose: Returns the current Bun runtime version

- **Use case:** Version checking for compatibility
- **Example:** Log version on startup for debugging
- **Useful for:** Feature detection based on version

16.2. Bun.env

```
console.log(Bun.env);
// Output: All environment variables
```

Purpose: Access all environment variables as an object

- **Difference from process.env:** Slightly optimized for Bun
- **Use case:** Loading entire configuration objects
- **Benefit:** Fast access without individual variable lookups

16.3. Bun.sleep()

No need to create custom sleep function!

```
console.log("Hey");
await Bun.sleep(5000); // Sleep for 5 seconds
console.log("Subscribers");
```

Purpose: Pause execution for specified milliseconds

- **Parameter:** Time in milliseconds (5000 = 5 seconds)
- **Returns:** A resolved Promise after the delay
- **Advantage:** Built-in, no need for Promise wrappers
- **Use case:** Rate limiting, scheduled tasks, demos

Traditional way (without Bun):

```
const sleep = (n: number) => {
  return new Promise((resolve) => {
    setTimeout(() => {
      resolve(n);
    }, n * 1000);
  });
};

await sleep(5);
```

16.4. crypto.randomUUID()

No uuid package needed!

```
const uuid = crypto.randomUUID();
console.log(uuid);
// Output: "550e8400-e29b-41d4-a716-446655440000"
```

Purpose: Generate a cryptographically secure random UUID

- **Format:** RFC 4122 Version 4 UUID (v4)
- **Returns:** String in format `xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx`
- **Use case:** Generating unique IDs for database records, requests
- **Benefit:** Built-in, eliminates uuid dependency
- **Security:** Cryptographically secure (not just Math.random())

16.5. Bun.nanoseconds()

```
const ns = Bun.nanoseconds();
console.log(ns);
// Returns nanoseconds since process started
```

Purpose: Get high-precision elapsed time since process start

- **Precision:** Nanoseconds (billionths of a second)
- **Use case:** Performance measurement, benchmarking
- **Advantage:** Much more precise than Date.now()
- **Example:** Measure function execution time accurately

16.6. Bun.deepEquals()

```
const obj1 = { name: "kintsugi-programmer", age: 18 };
const obj2 = { name: "kintsugi-programmer", age: 18 };

const isEqual = Bun.deepEquals(obj1, obj2);
console.log(isEqual); // true
```

Purpose: Compare two values for deep equality

- **Recursion:** Checks nested objects and arrays
- **Reference vs Value:** Compares values, not references
- **Returns:** Boolean (true if all properties match)
- **Use case:** Testing, validation, object comparison
- **Benefit:** Built-in, faster than custom deep comparison

---

17. HTTP Server with Bun.serve

```
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve(
    {
        port:port,
        fetch(req){
            return new Response("Status: OK");
        }
    }
);

console.info(`Server is running on port ${server.port}`);
// Server is running on port 8000
```

```
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve ({
```

```
    port:port,
    fetch(req){
        const url = new URL(req.url);

        // Static Routes
        if (url.pathname === "/api/health") {
            return new Response("Status: OK");
        }

        return new Response("Route not found",{status:404});
    }
});

console.info(`Server is running on port ${server.port}`);
```

```
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve({
    port:port,
    fetch(req){
        const url = new URL(req.url);

        // Dynamic Routes
        const pathPaths = url.pathname.split('/');
        if (
            // pathPaths[0] is empty always
            pathPaths[1] === "api"
            &&
            pathPaths[2]
        ){
            const id = pathPaths[2];
            return new Response(`ID is: ${id}`); // Use backticks for dynamic
string construction
        }

        return new Response("Route not found",{status:404});
    }
});

console.info(`Server is running on port ${server.port}`);
```

```
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve({
    port:port,
    routes: {
        "/api/health": () => new Response("Status: OK"),
        "/api/:id": (req) => {return new Response(`ID is: ${req.params.id}`);}
    },
    fetch(){ // Catch all for unmatched routes
        return new Response("Route not found",{status:404});
```

```
    }
});

console.info(`Server is running on port ${server.port}`);
```

```
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve({
    port:port,
    routes: {
        "/api/health": () => new Response("Status: OK"),
        "/api/:id": (req) => {return new Response(`ID is: ${req.params.id}`);},
        "/*": new Response("Route not found",{status:404})
    },
    // fetch(){ // Catch all for unmatched routes
    //     return new Response("Route not found",{status:404});
    // }
});

console.info(`Server is running on port ${server.port}`);
```

17.1. What is an HTTP Server?

- **HTTP Server** = Program that listens for requests and sends responses
- Sits on a port (like 8000) and waits for connections
- When client (browser) connects, server handles the request
- **Real-world analogy**: Restaurant that takes orders and serves food
- **Port** = Virtual "door" on your computer (like apartment numbers)
- **Request** = Client saying "give me data"
- **Response** = Server saying "here's your data"

17.2. Basic Server Setup

```
const port = Bun.env.PORT || 8000;

const server = Bun.serve({
  port: port,
  fetch(req) {
    return new Response("Status: OK");
  }
});

console.info(`Server is running on port ${server.port}`);
```

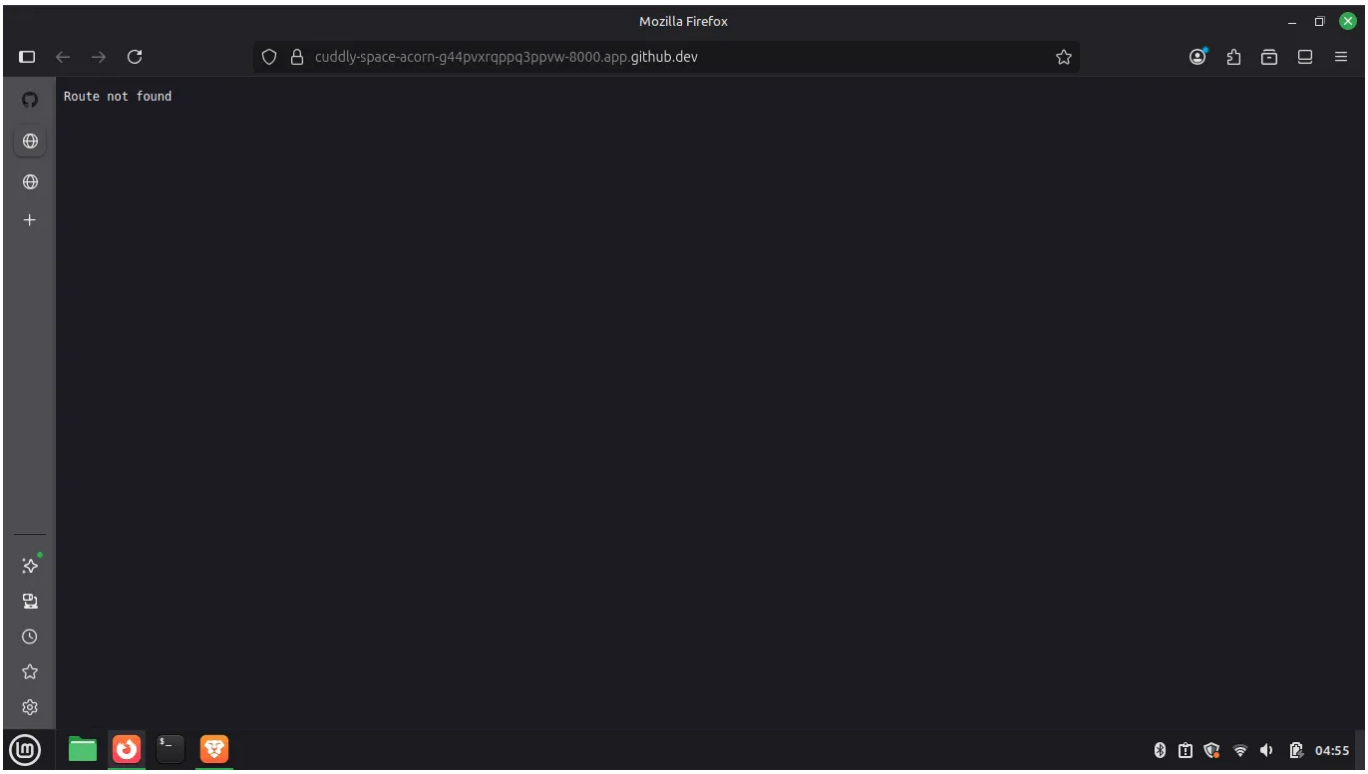
Key Points:

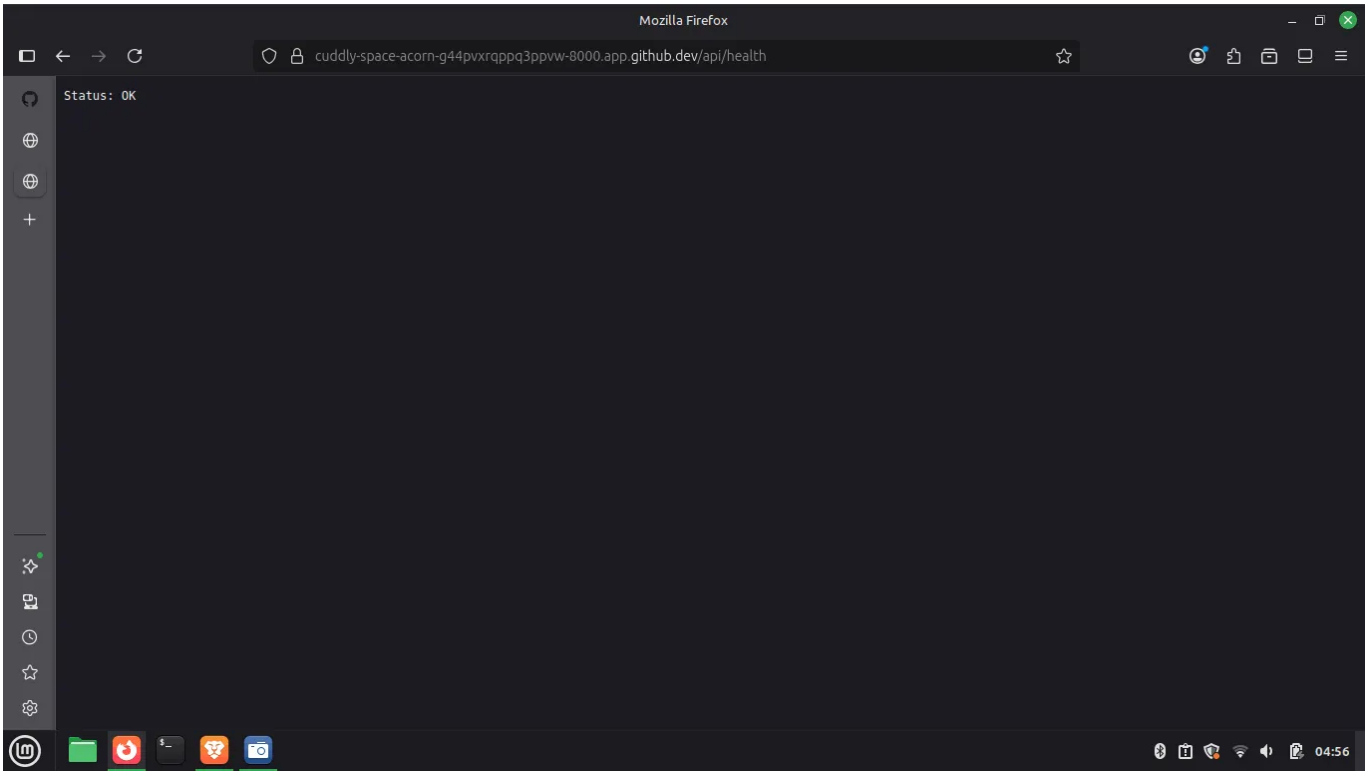
- **Bun.serve():** Creates and starts an HTTP server

- **port property:** Specifies which port the server listens on
- **Environment fallback:** `Bun.env.PORT || 8000` uses .env variable or defaults to 8000
- **fetch() handler:** Function called for every incoming request
- **Response object:** Wraps the response body and headers
- **Server object:** Returned from Bun.serve() with properties like port and methods like stop()
- **console.info():** Logs server startup confirmation

17.3. Routes Configuration

```
Bun.serve({
  port: 8000,
  fetch(req) {
    const url = new URL(req.url);

    if (url.pathname === "/api/health") {
      return new Response("Status: OK");
    }

    return new Response("Route not found", { status: 404 });
  }
});
```



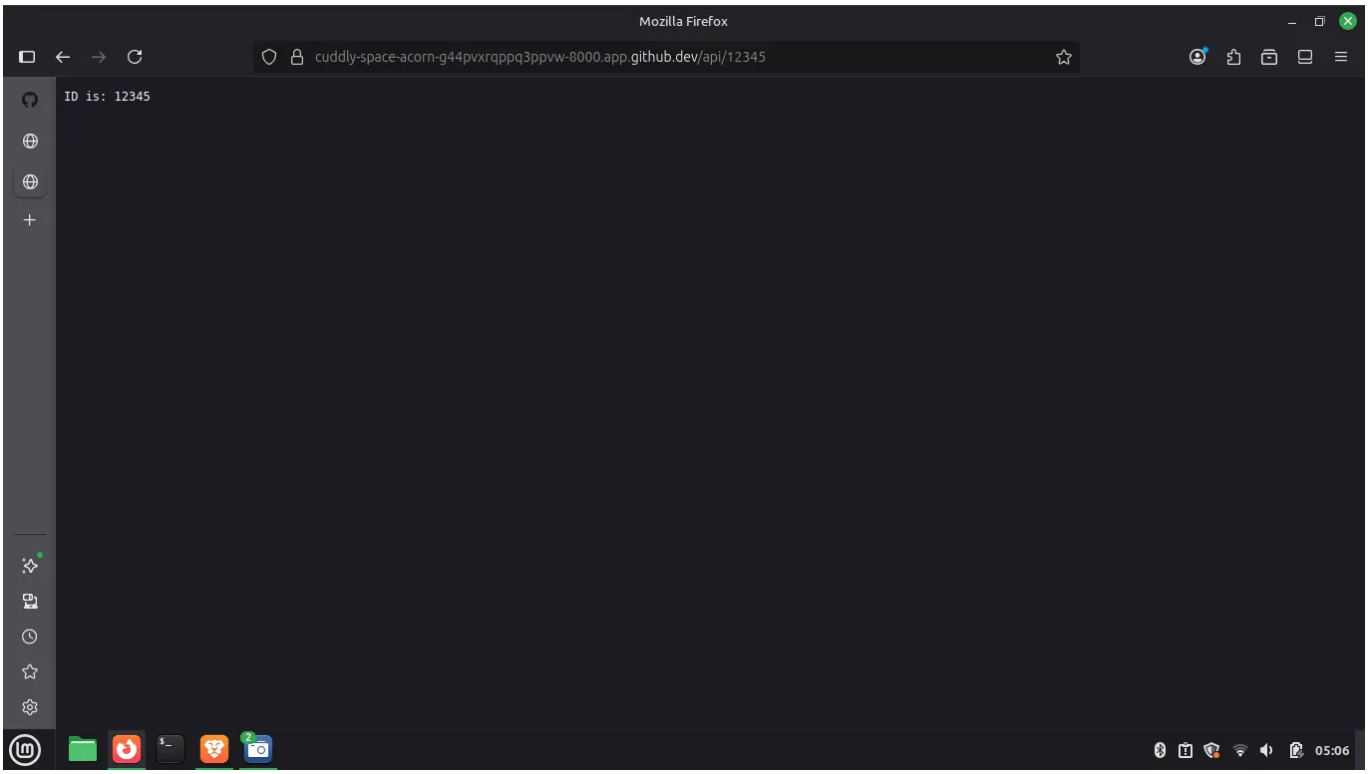


Key Points:

- **fetch() handler:** Called for every incoming HTTP request to the server
- **URL parsing:** `new URL(req.url)` extracts components from the request URL
- **pathname:** The path portion of the URL (e.g., "/api/health" from "http://localhost:8000/api/health")
- **Route matching:** Use conditional logic (if/else) to match request paths
- **Status codes:** Return appropriate HTTP status (200 for success, 404 for not found)
- **Request object:** Contains url, method (GET/POST), headers, and body
- **Scalability:** For many routes, use the routes object approach instead (see Better Routing section)

17.4. Dynamic Route Parameters

```
Bun.serve({
  port: 8000,
  fetch(req) {
    const url = new URL(req.url);
    const pathParts = url.pathname.split('/');

    if (pathParts[1] === "api" && pathParts[2]) {
      const id = pathParts[2];
      return new Response(`ID is: ${id}`);
    }

    return new Response("Not found", { status: 404 });
  }
});
```



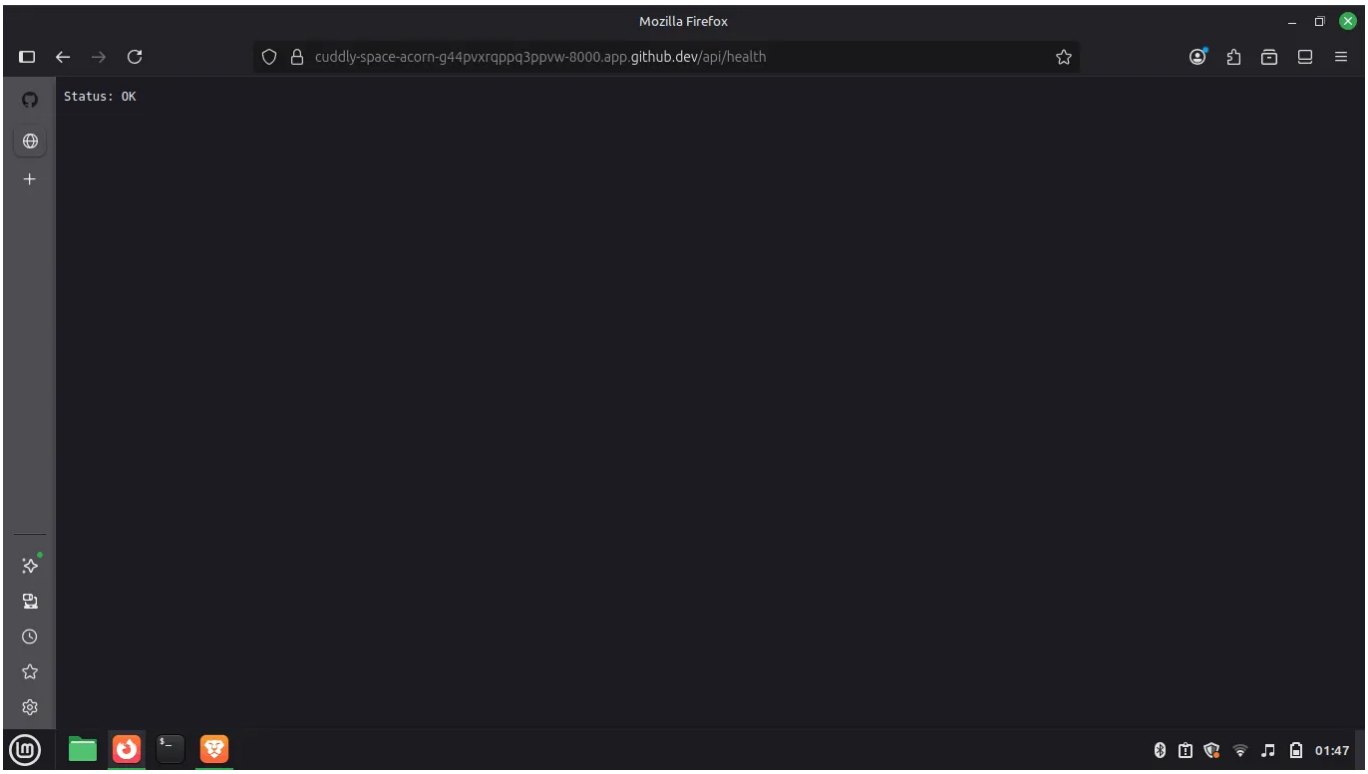
Key Points:

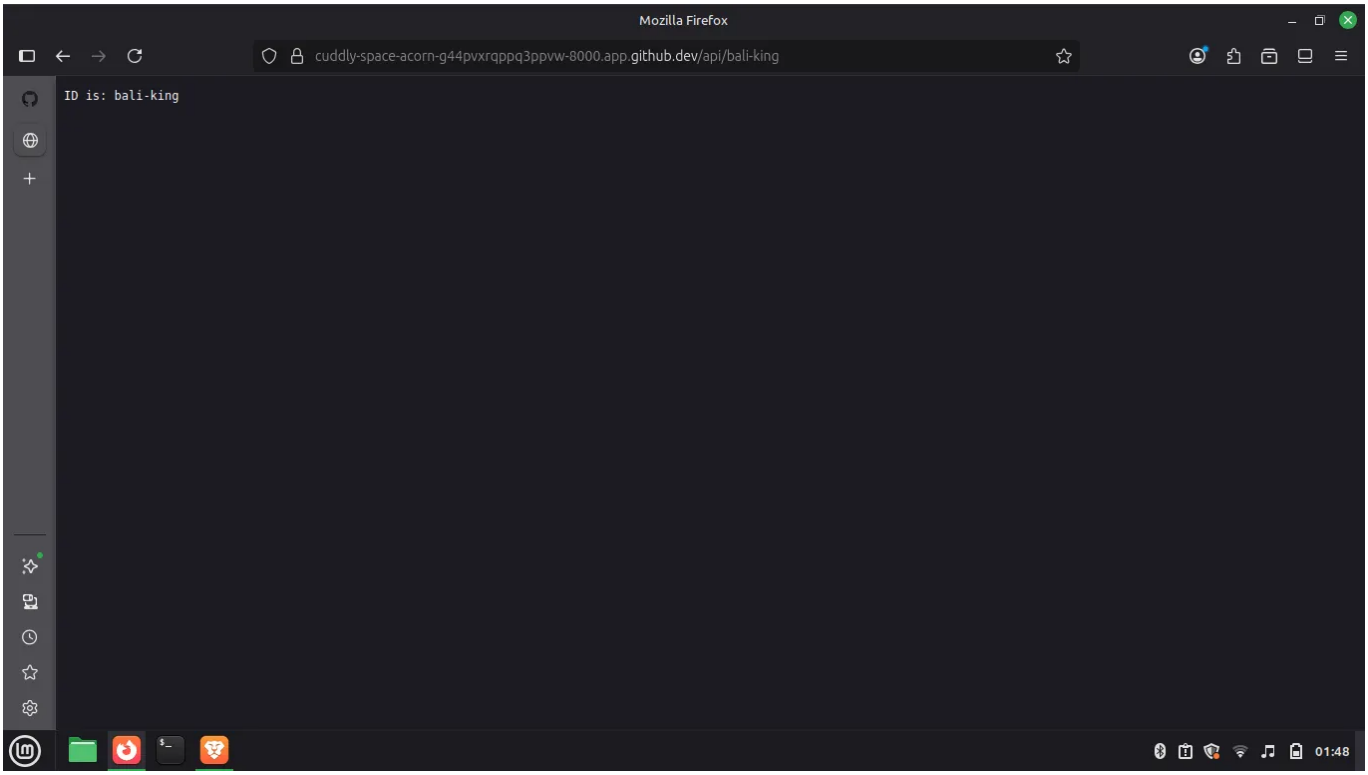
- **pathname.split('/'):** Splits URL path into segments (e.g., "/api/123" → ["", "api", "123"])
- **pathParts[0]:** Always empty string (before leading slash)
- **pathParts[1]:** First path segment ("api" in example)
- **pathParts[2]:** Second segment (dynamic ID value)
- **Conditional checks:** Verify path structure exists before accessing
- **Template literals:** Use backticks for dynamic string construction
- **Manual parsing:** Works but becomes verbose with many routes

17.5. Better Routing with Routes Object

```
Bun.serve({
  port: 8000,
  routes: {
    "/api/health": () => new Response("Status: OK"),

    "/api/:id": (req) => {
      return new Response(`ID is: ${req.params.id}`);
    }
  },

  // Catch-all for unmatched routes
  fetch() {
    return new Response("Route not found", { status: 404 });
  }
});
```

```
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve({
    port:port,
    routes: {
        "/api/health": () => new Response("Status: OK"),
        "/api/:id": (req) => {return new Response(`ID is: ${req.params.id}`);},
        "/*": new Response("Route not found",{status:404})
    },
    // fetch(){ // Catch all for unmatched routes
    //     return new Response("Route not found",{status:404});
    // }
});

console.info(`Server is running on port ${server.port}`);
```





Key Points:

- **routes object:** Maps URL paths to handler functions (cleaner than if/else)
- **Parameter syntax:** Use `:paramName` to create dynamic segments (e.g., `:id`)
- **req.params:** Object containing matched path parameters
- **Static routes:** Exact path matching (e.g., "/api/health")
- **Dynamic routes:** Pattern matching (e.g., "/api/:id" matches "/api/123", "/api/abc")
- **fetch() fallback:** Handles routes not matched in routes object (404)
- **Readability:** Routes object is more maintainable than manual pathname parsing

---

18. Complete CRUD API Example

```
// Setup
type TPost = {id:string;title:string;};
let posts: TPost[] = [];

// Server
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve({
    port: port,
    routes: {
              "/api/health": new Response ("Status OK"),
        "/api/posts": {
            // GET All Posts
            GET: () => Response.json(posts),

            // POST Create Post
            POST: async (req) => {
                const body = await req.json() as Omit<TPost,"id">;
                posts.push({
                    id: crypto.randomUUID(),
                    title: body.title
                });
                return new Response("Created");
            }
        },
        "/api/posts/:id": {
            // PUT Update Post
            PUT: async(req) => {
                const id = req.params.id as string;
                const body = await req.json() as Omit<TPost,"id">;

                const postIndex = posts.findIndex(post => post.id === id);

                if (postIndex === -1){
                    return new Response("Post Not found",{status: 404});
                }
                posts[postIndex]!.title = body.title;
                return new Response("Updated");
            },

            // DELETE Post
            DELETE: (req) => {
                const id = req.params.id as string;

                const postIndex = posts.findIndex(post => post.id === id);

                if (postIndex === -1){
                    return new Response("Post Not found",{status: 404});
                }

                posts.splice(postIndex,1);
```

```
                return new Response("Deleted");
            },
        }
    }
})
```

18.1. What is CRUD?

- **CRUD** = Create, Read, Update, Delete (four basic operations on data)
- **Create** = Add new data (POST request)
- **Read** = Get existing data (GET request)
- **Update** = Modify existing data (PUT request)
- **Delete** = Remove data (DELETE request)
- Used in: databases, user management, todo apps, social media

18.2. What are HTTP Methods?

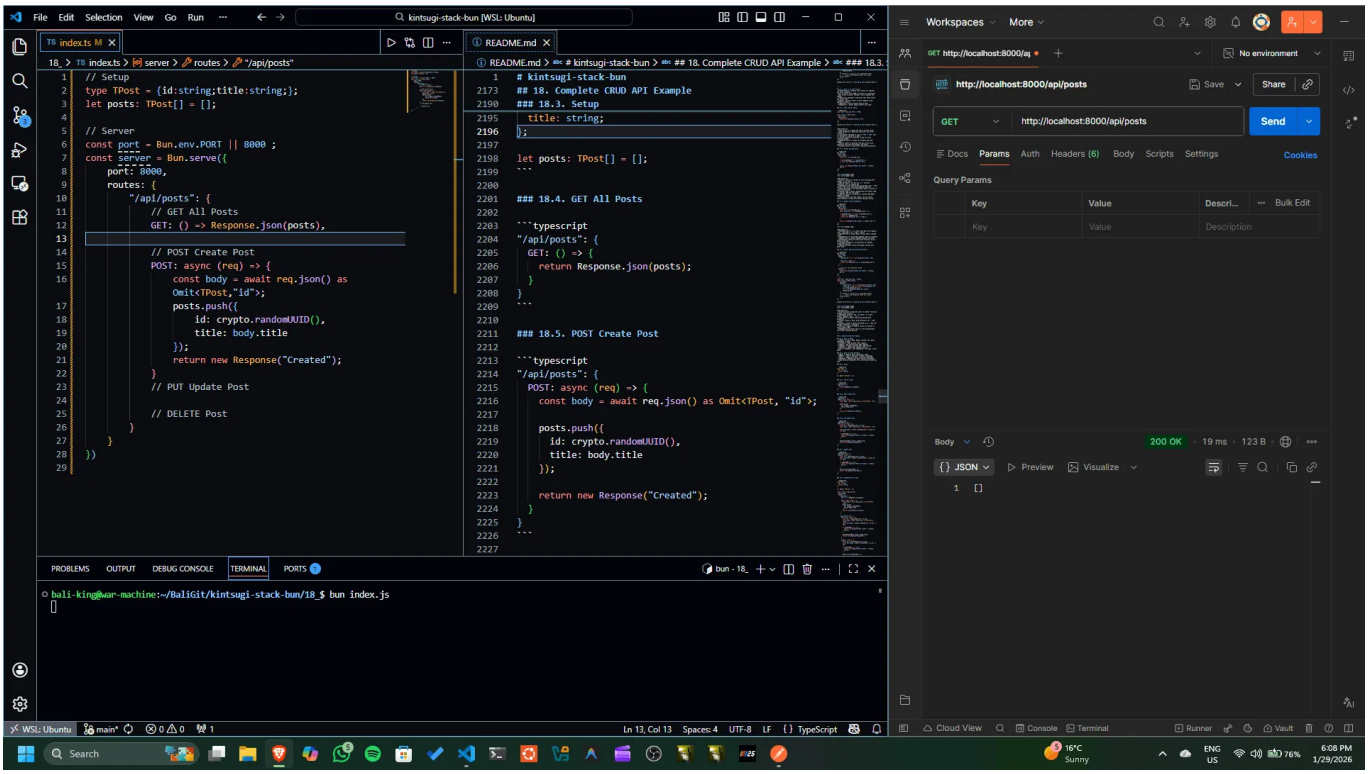
- **GET** = "Give me data" (read-only, safe)
- **POST** = "Here's new data" (creates something)
- **PUT** = "Update this data" (modifies something)
- **DELETE** = "Remove this data" (deletes something)
- **Why different methods?** Tell server what action you want

18.3. Setup

```
type TPost = {
  id: string;
  title: string;
};

let posts: TPost[] = [];
```

18.4. GET All Posts

```
"/api/posts": {
  GET: () => {
    return Response.json(posts);
  }
}
```

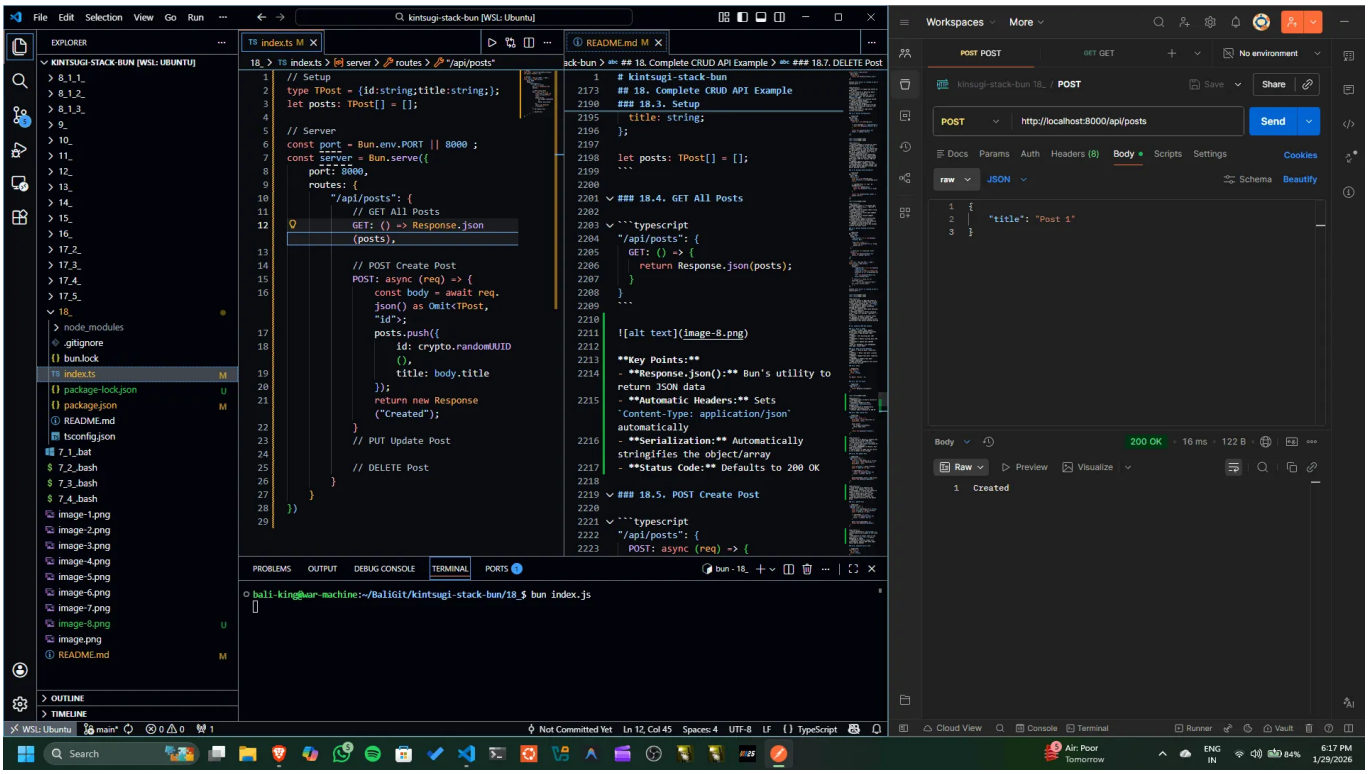


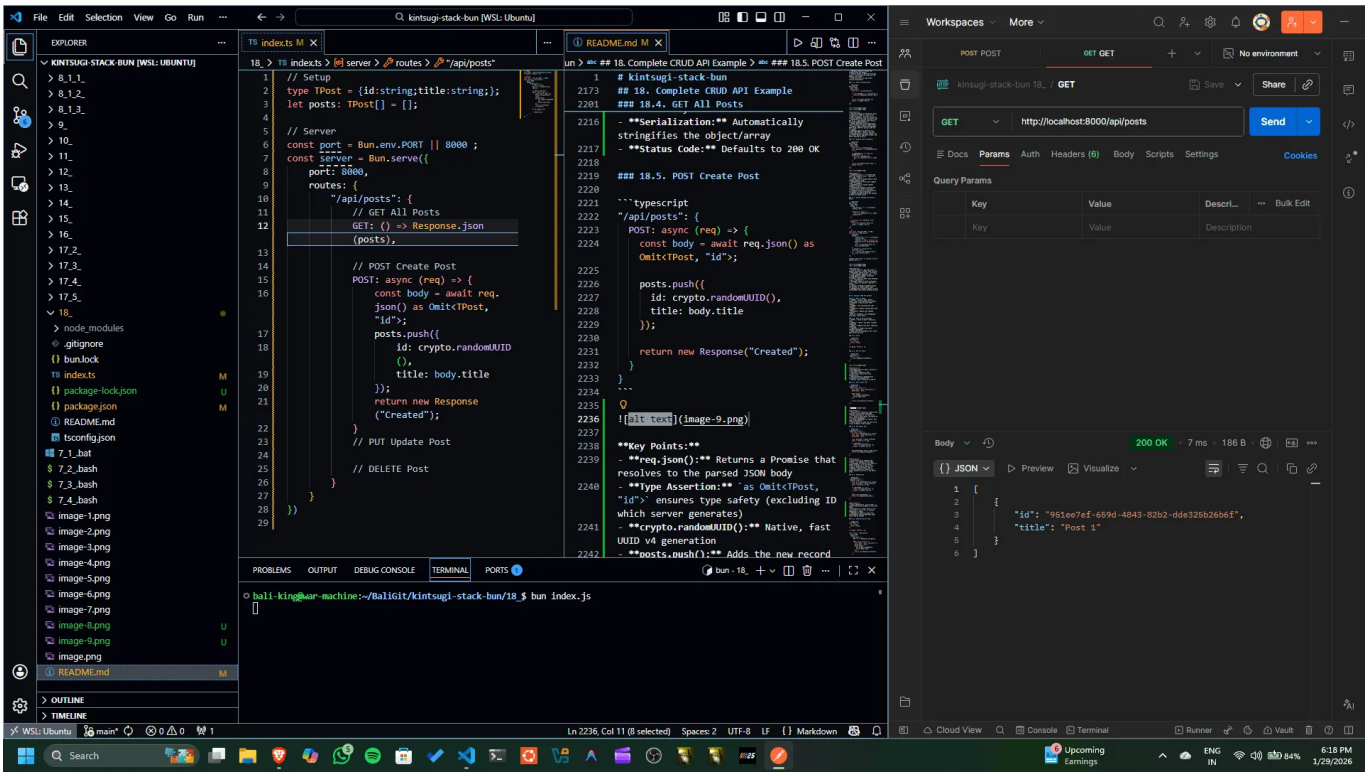
Key Points:

- **Response.json():** Bun's utility to return JSON data
- **Automatic Headers:** Sets `Content-Type: application/json` automatically
- **Serialization:** Automatically stringifies the object/array
- **Status Code:** Defaults to 200 OK

18.5. POST Create Post

```
"/api/posts": {
  POST: async (req) => {
    const body = await req.json() as Omit<TPost, "id">;

    posts.push({
      id: crypto.randomUUID(),
      title: body.title
    });

    return new Response("Created");
  }
}
```



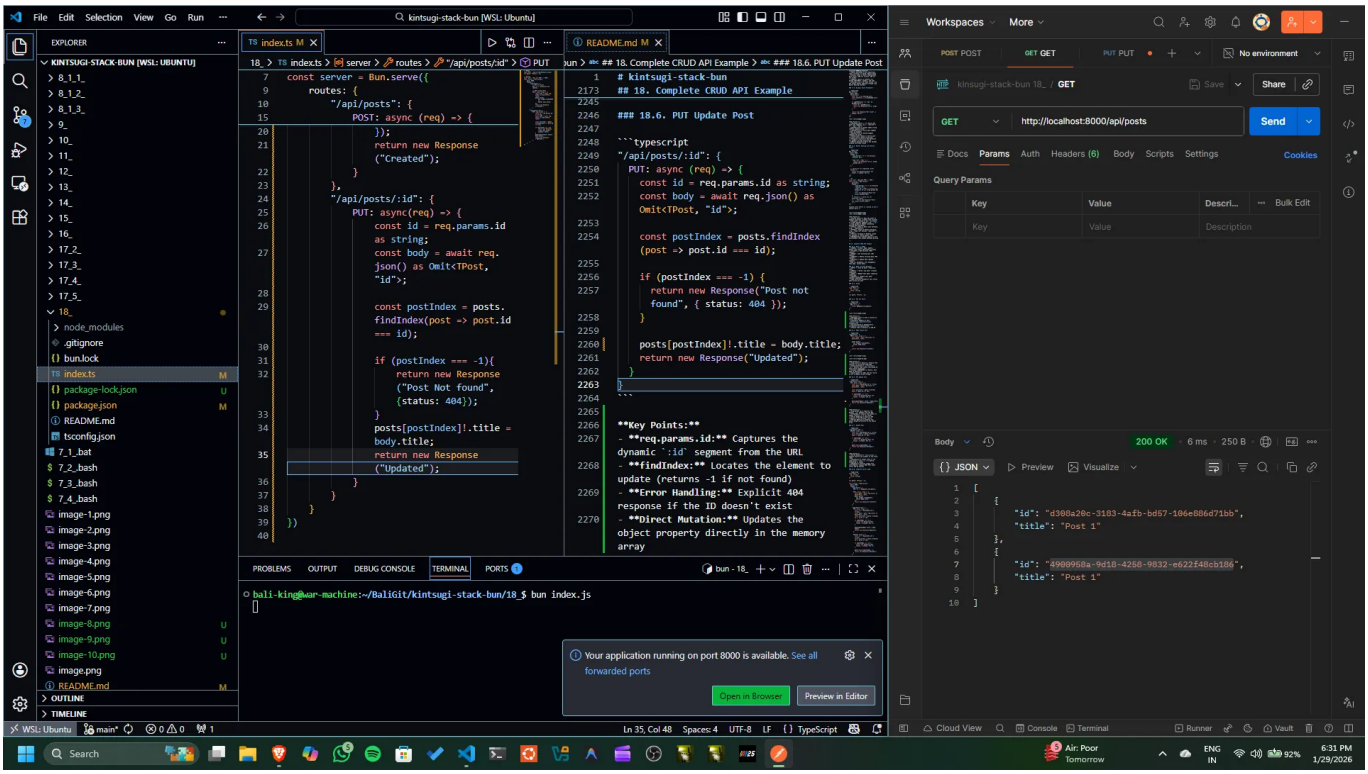


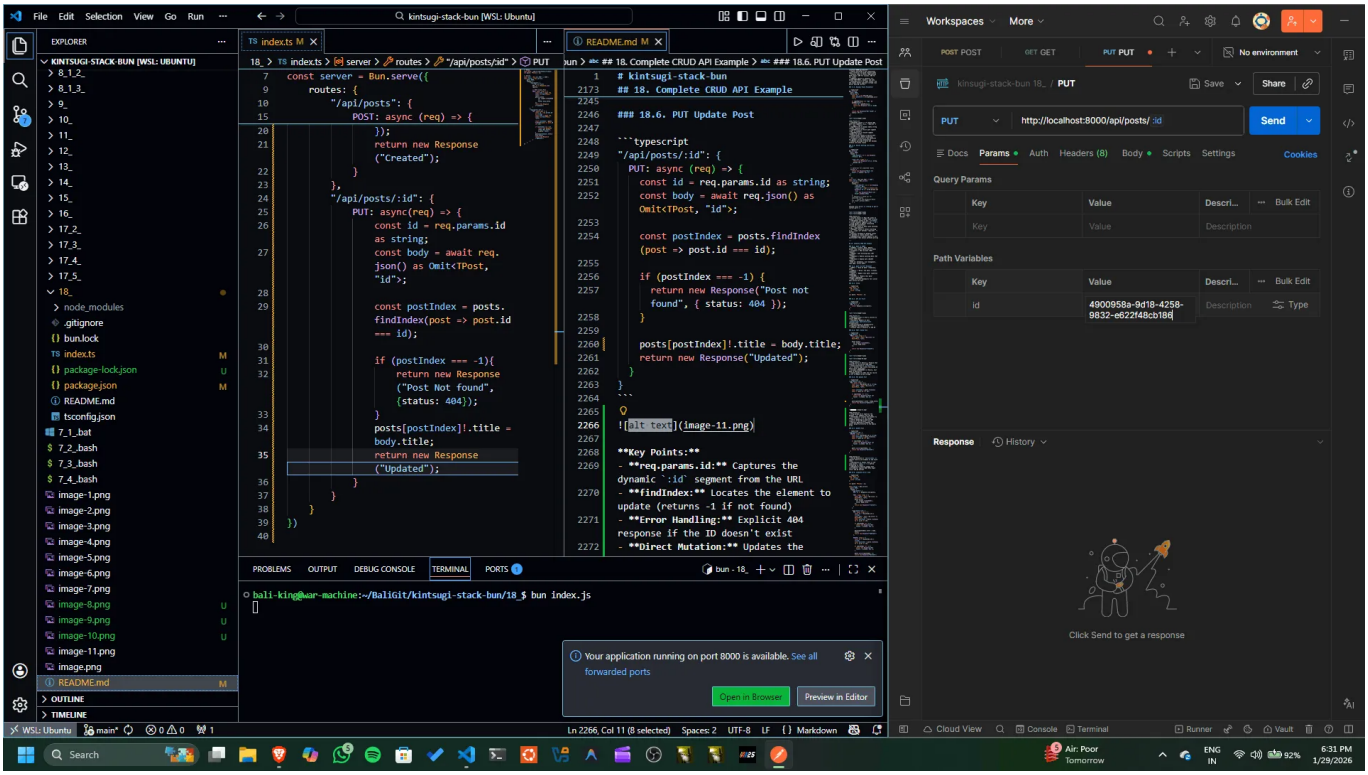
Key Points:

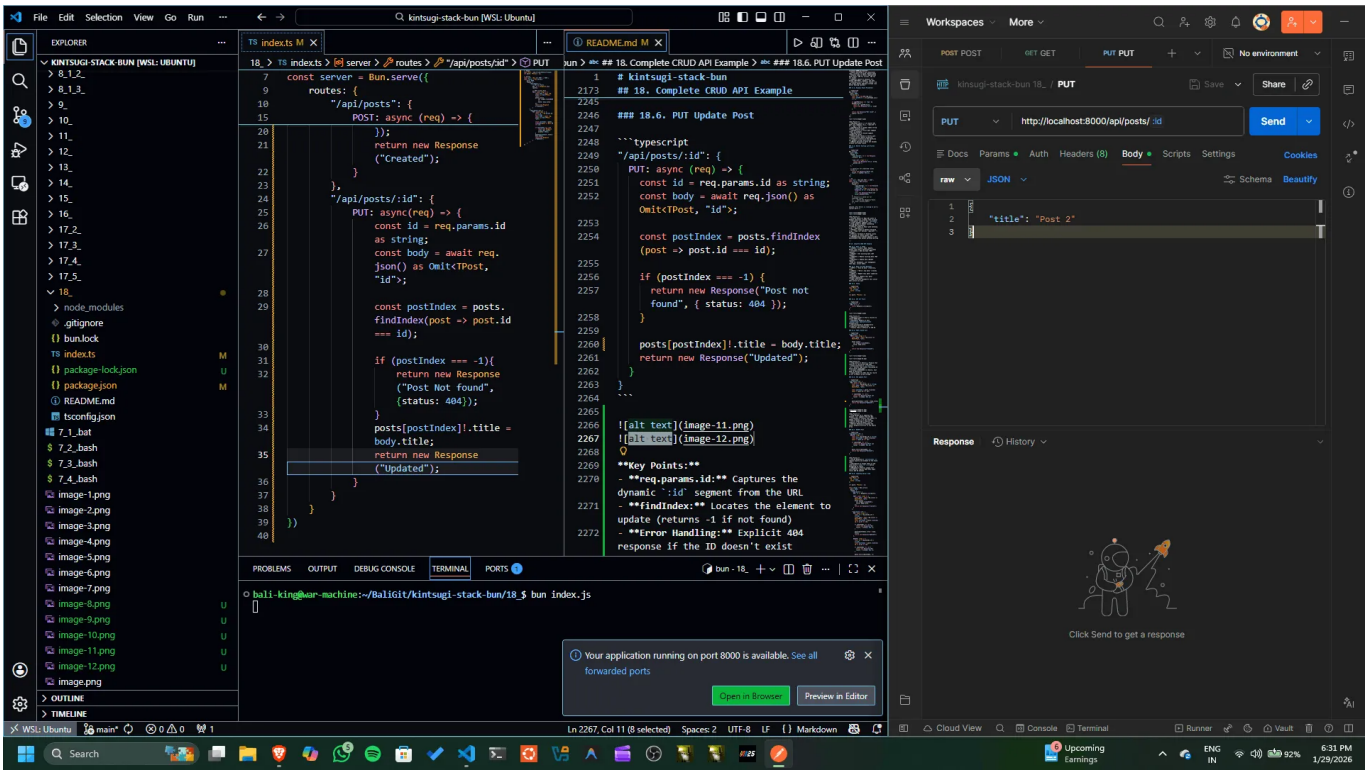
- **req.json():** Returns a Promise that resolves to the parsed JSON body
- **Type Assertion:** `as Omit<TPost, "id">` ensures type safety (excluding ID which server generates)
- **crypto.randomUUID():** Native, fast UUID v4 generation
- **posts.push():** Adds the new record to our in-memory array storage

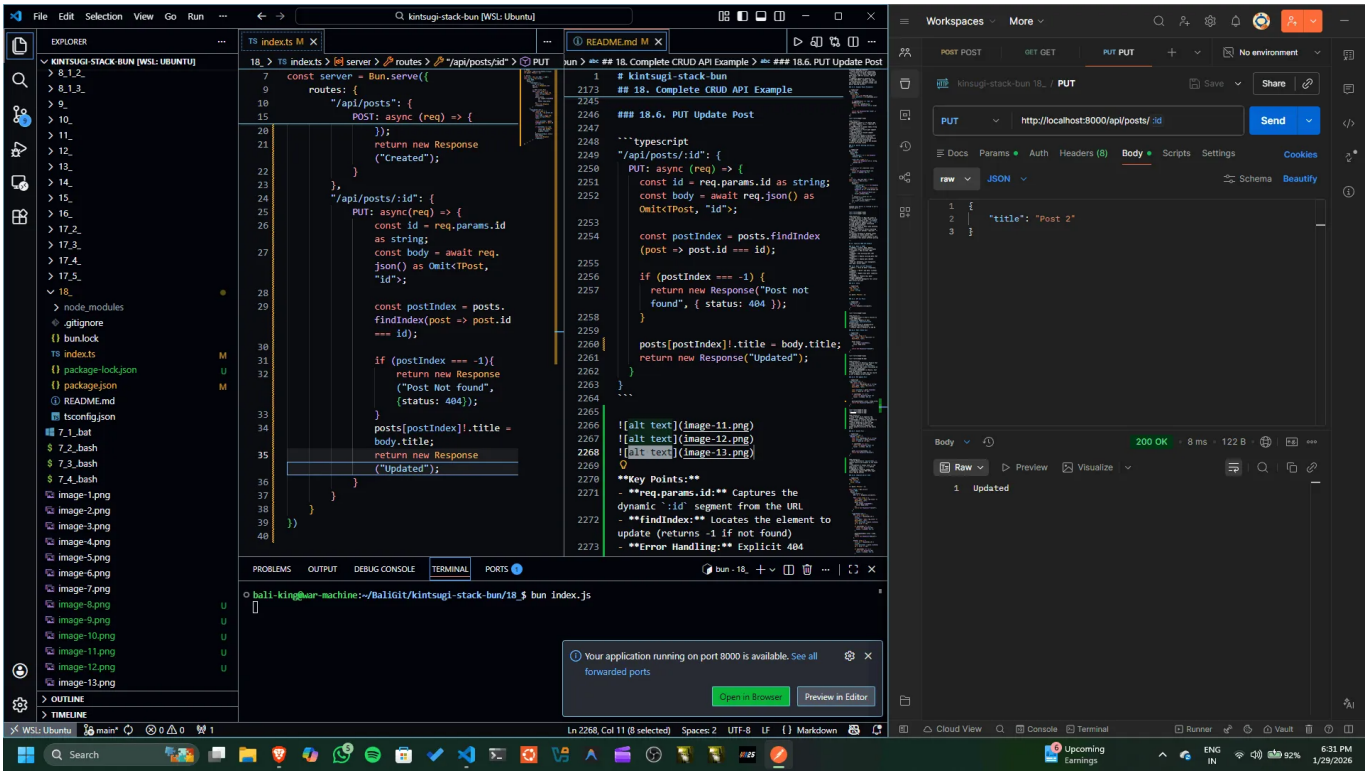
18.6. PUT Update Post

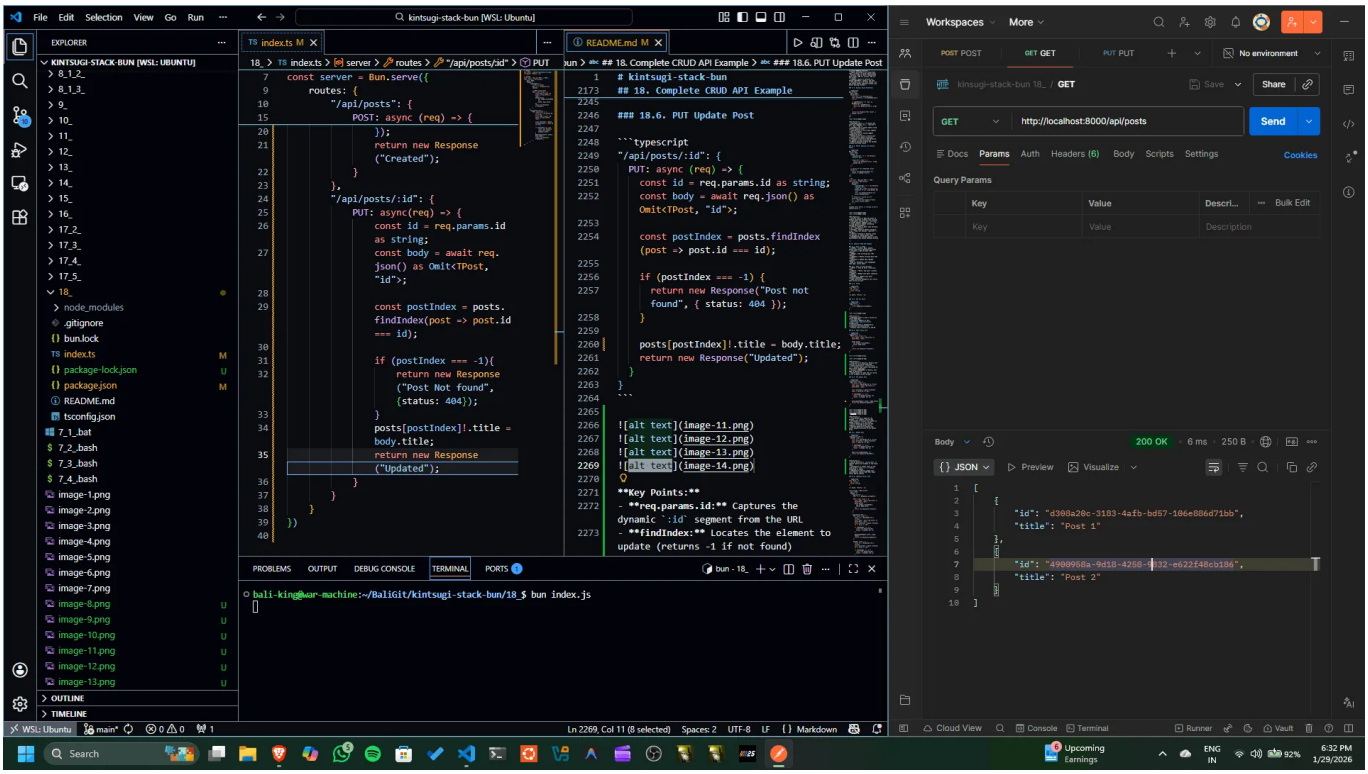
```
  "/api/posts/:id": {
    PUT: async (req) => {
      const id = req.params.id as string;
      const body = await req.json() as Omit<TPost, "id">;

      const postIndex = posts.findIndex(post => post.id === id);

      if (postIndex === -1) {
        return new Response("Post not found", { status: 404 });
      }

      posts[postIndex]!.title = body.title;
      return new Response("Updated");
    }
  }
```









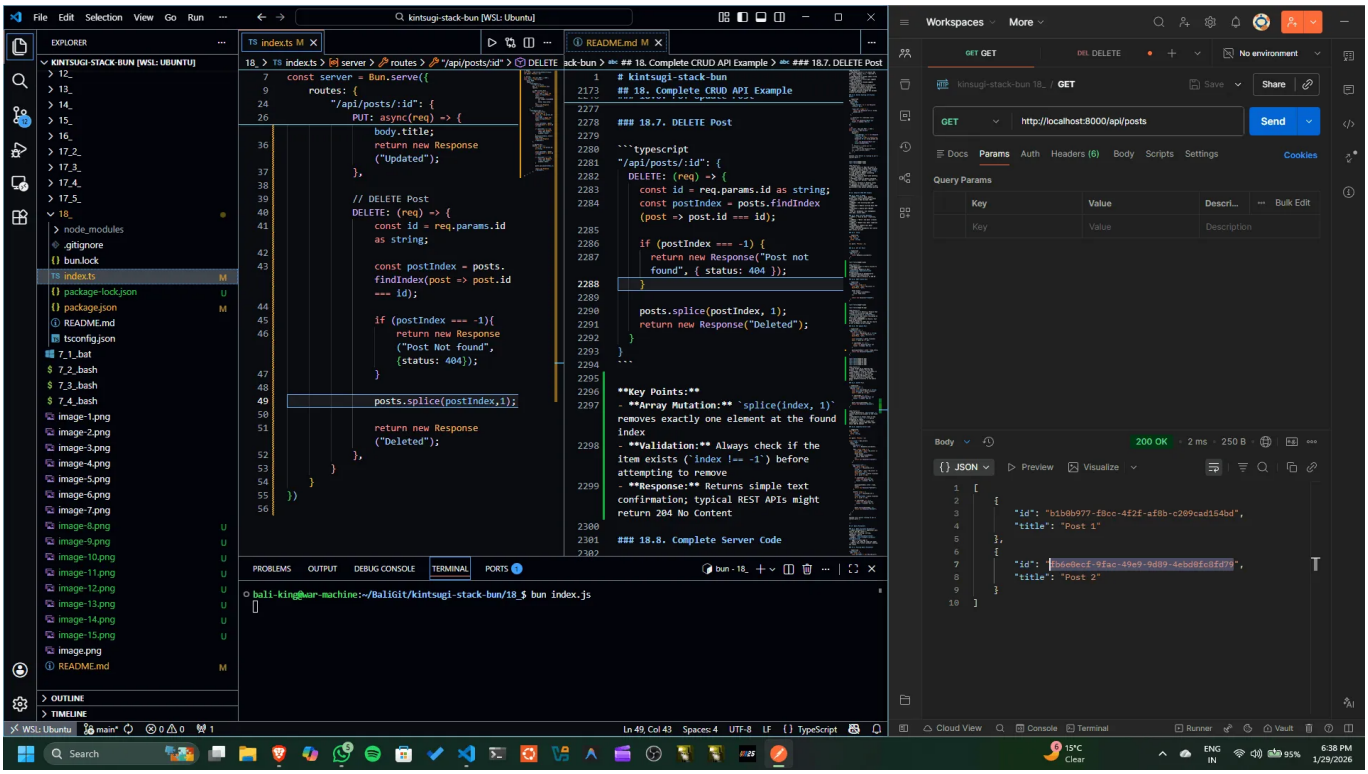


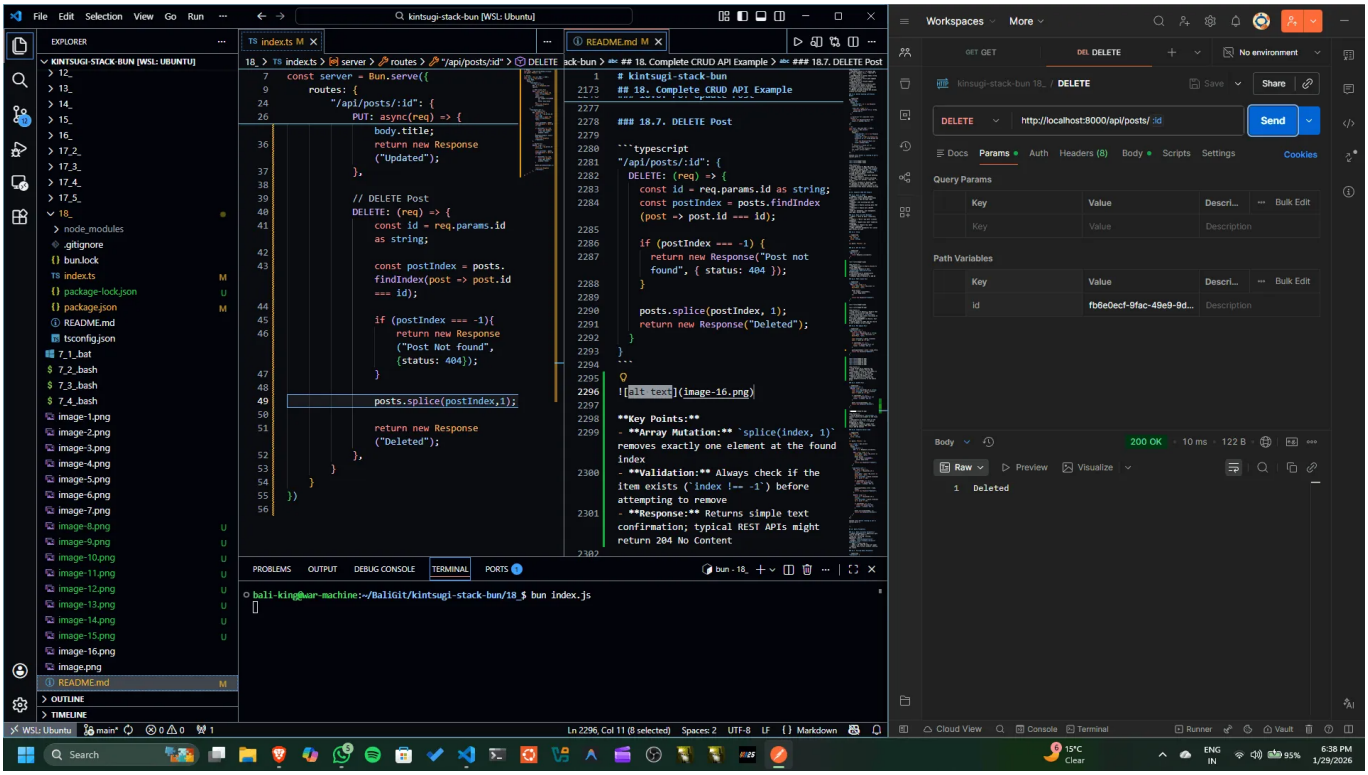
Key Points:

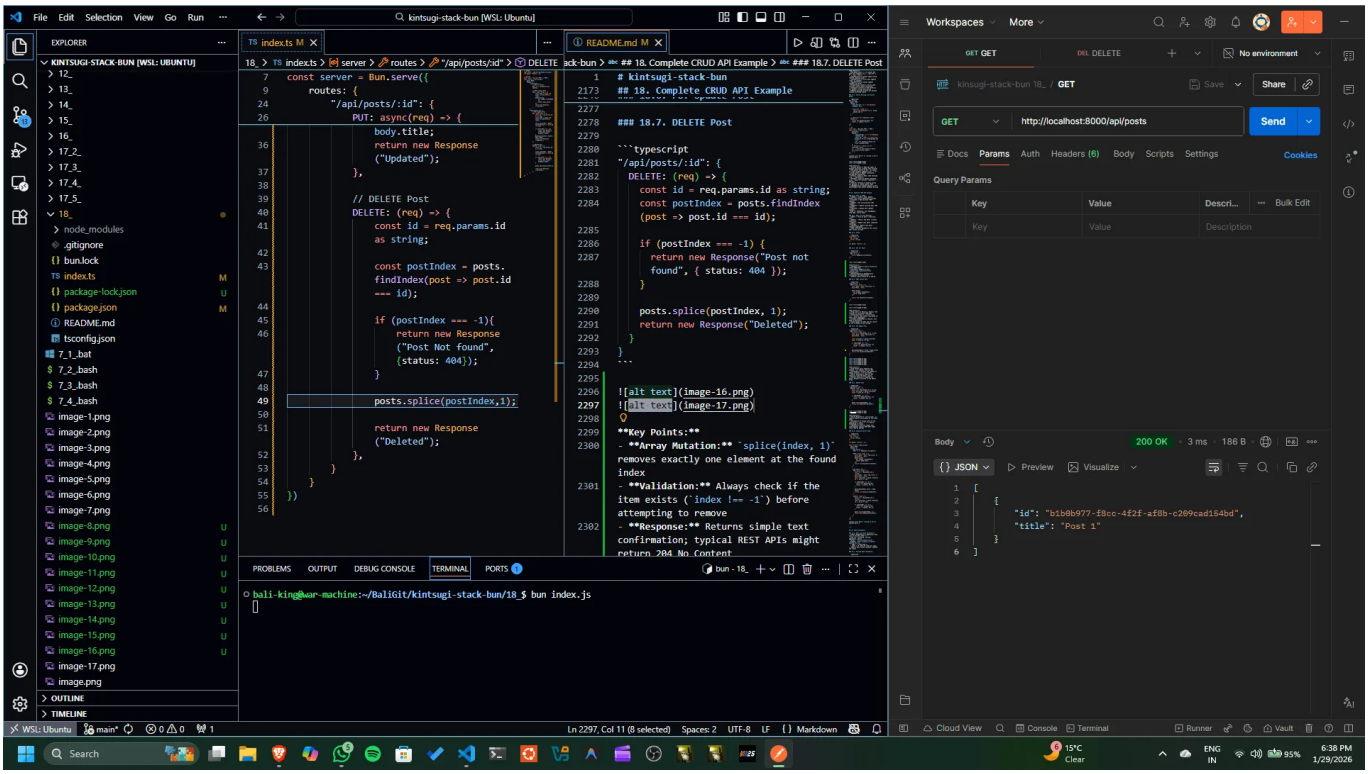
- **req.params.id:** Captures the dynamic `:id` segment from the URL
- **findIndex:** Locates the element to update (returns -1 if not found)
- **Error Handling:** Explicit 404 response if the ID doesn't exist
- **Direct Mutation:** Updates the object property directly in the memory array

18.7. DELETE Post

```
"/api/posts/:id": {
  DELETE: (req) => {
    const id = req.params.id as string;
    const postIndex = posts.findIndex(post => post.id === id);

    if (postIndex === -1) {
      return new Response("Post not found", { status: 404 });
    }

    posts.splice(postIndex, 1);
    return new Response("Deleted");
  }
}
```







Key Points:

- **Array Mutation:** `splice(index, 1)` removes exactly one element at the found index
- **Validation:** Always check if the item exists (`index !== -1`) before attempting to remove
- **Response:** Returns simple text confirmation; typical REST APIs might return 204 No Content

18.8. Complete Server Code

```
type TPost = {
  id: string;
  title: string;
};

let posts: TPost[] = [];

const server = Bun.serve({
  port: 8000,
  routes: {
    "/api/posts": {
      GET: () => Response.json(posts),

      POST: async (req) => {
        const body = await req.json() as Omit<TPost, "id">;
        posts.push({
          id: crypto.randomUUID(),
          title: body.title
        });
        return new Response("Created");
      }
    },
```

```
    "/api/posts/:id": {
      PUT: async (req) => {
        const id = req.params.id as string;
        const body = await req.json() as Omit<TPost, "id">;
        const postIndex = posts.findIndex(p => p.id === id);

        if (postIndex === -1) {
          return new Response("Not found", { status: 404 });
        }

        posts[postIndex].title = body.title;
        return new Response("Updated");
      },

      DELETE: (req) => {
        const id = req.params.id as string;
        const postIndex = posts.findIndex(p => p.id === id);

        if (postIndex === -1) {
          return new Response("Not found", { status: 404 });
        }

        posts.splice(postIndex, 1);
        return new Response("Deleted");
      }
    }
  }
});

console.info(`Server running on port ${server.port}`);
```

---

19. Query Parameters

```
// Setup
type TPost = {id:string;title:string;};
let posts: TPost[] = [];

// Server
const port = Bun.env.PORT || 8000 ;
const server = Bun.serve({
    port: port,
    routes: {
        "/api/health": new Response ("Status OK"),
        "/api/posts": {
            // GET All Posts
            // GET: () => Response.json(posts), // Old
            GET: (req) => {
                  const parsedUrl = new URL(req.url);
    // Method 1: Get individual parameters
    const page = parsedUrl.searchParams.get("page");
```

```
    const limit = parsedUrl.searchParams.get("limit");
    console.log(page, limit); // "1" "10"

    // Method 2: Get all parameters as object
    const params = Object.fromEntries(parsedUrl.searchParams.entries());
    console.log(params) // { page: "1", limit: "10" }

                return Response.json(posts);
            },


            // POST Create Post
            POST: async (req) => {
                const body = await req.json() as Omit<TPost,"id">;
                posts.push({
                    id: crypto.randomUUID(),
                    title: body.title
                });
                return new Response("Created");
            }
        },
        "/api/posts/:id": {
            // PUT Update Post
            PUT: async(req) => {
                const id = req.params.id as string;
                const body = await req.json() as Omit<TPost,"id">;

                const postIndex = posts.findIndex(post => post.id === id);

                if (postIndex === -1){
                    return new Response("Post Not found",{status: 404});
                }
                posts[postIndex]!.title = body.title;
                return new Response("Updated");
            },

            // DELETE Post
            DELETE: (req) => {
                const id = req.params.id as string;

                const postIndex = posts.findIndex(post => post.id === id);

                if (postIndex === -1){
                    return new Response("Post Not found",{status: 404});
                }

                posts.splice(postIndex,1);

                return new Response("Deleted");
            },
        }
    }
})
```

19.1. What are Query Parameters?

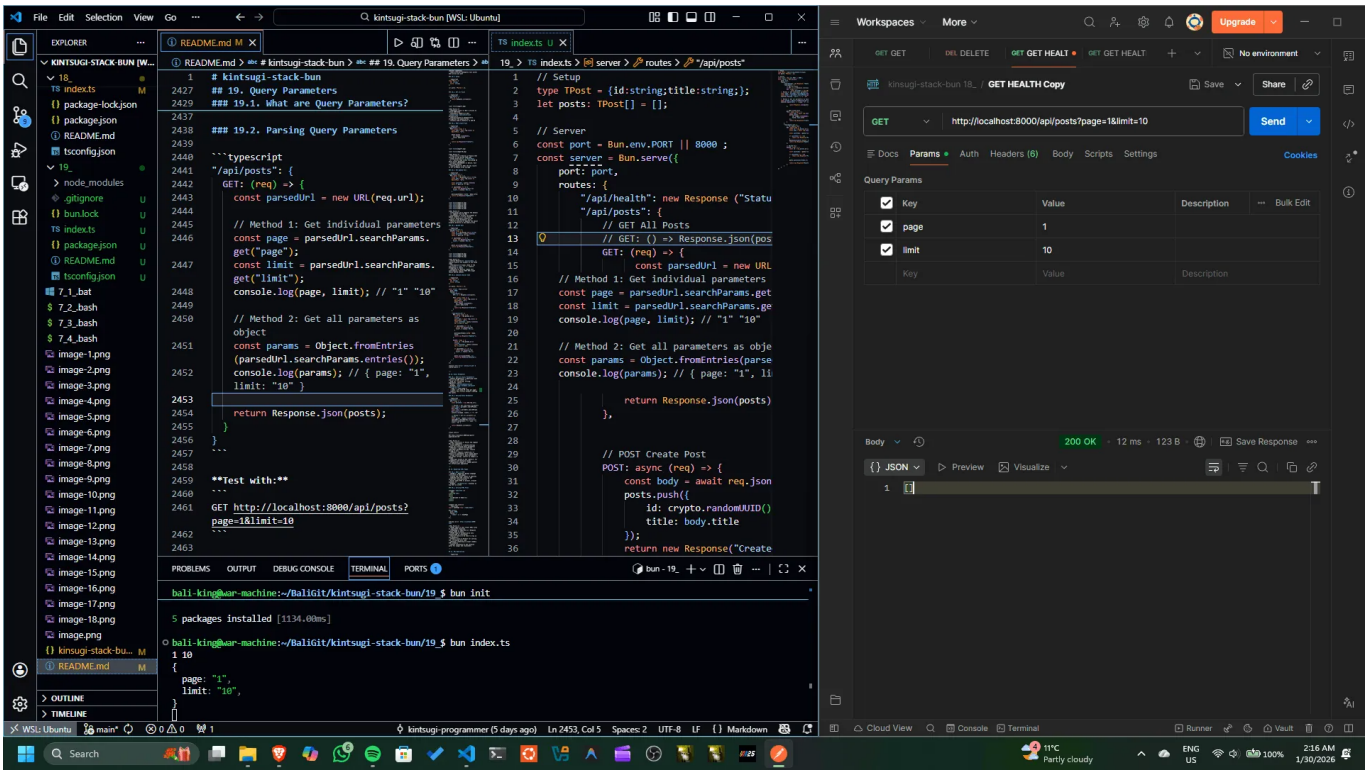
- **Query Parameters** = Additional data sent in the URL (after ?)
- Used for: filtering, sorting, pagination, search
- Format: `?key=value&key2=value2`
- Example: `http://example.com/posts?page=1&limit=10`
  - page = 1 (show page 1)
  - limit = 10 (show 10 items per page)
- **Why?** Pass filters without creating new routes

19.2. Parsing Query Parameters

```
"/api/posts": {
  GET: (req) => {
    const parsedUrl = new URL(req.url);

    // Method 1: Get individual parameters
    const page = parsedUrl.searchParams.get("page");
    const limit = parsedUrl.searchParams.get("limit");
    console.log(page, limit); // "1" "10"

    // Method 2: Get all parameters as object
    const params = Object.fromEntries(parsedUrl.searchParams.entries());
    console.log(params); // { page: "1", limit: "10" }

    return Response.json(posts);
  }
}
```

Test with:

```
GET http://localhost:8000/api/posts?page=1&limit=10
```



Key Points:

- **URL constructor:** Parses the request URL into components
- **searchParams:** A URLSearchParams object for accessing query parameters
- **Method 1 (.get()):** Retrieve individual parameters by key, returns string or null
- **Method 2 (Object.fromEntries):** Convert all parameters to a single object
- **Type conversion:** Query parameters are always strings, convert to numbers if needed
- **Multiple values:** Use .getAll() for parameters with multiple values
- **Pagination example:** Common pattern for offset/limit pagination

---

20. Rendering HTML Pages

```
<!DOCTYPE html>
<html>
<body>
    <h1>
        Welcome to Home
    </h1>
</body>
</html>
```

```
import homePage from "./home.html";
Bun.serve({
    port:8000,
    routes:{ "/home": homePage } // automatic serialize
}
)
```

20.1. What is HTML?

- **HTML** = HyperText Markup Language (structure of web pages)
- Creates the visual layout of websites
- Combined with CSS (styling) and JavaScript (interactivity)
- Server sends HTML to browser, browser displays it
- Example: `<h1>Hello</h1>` displays as big text on screen

20.2. Serving HTML Files

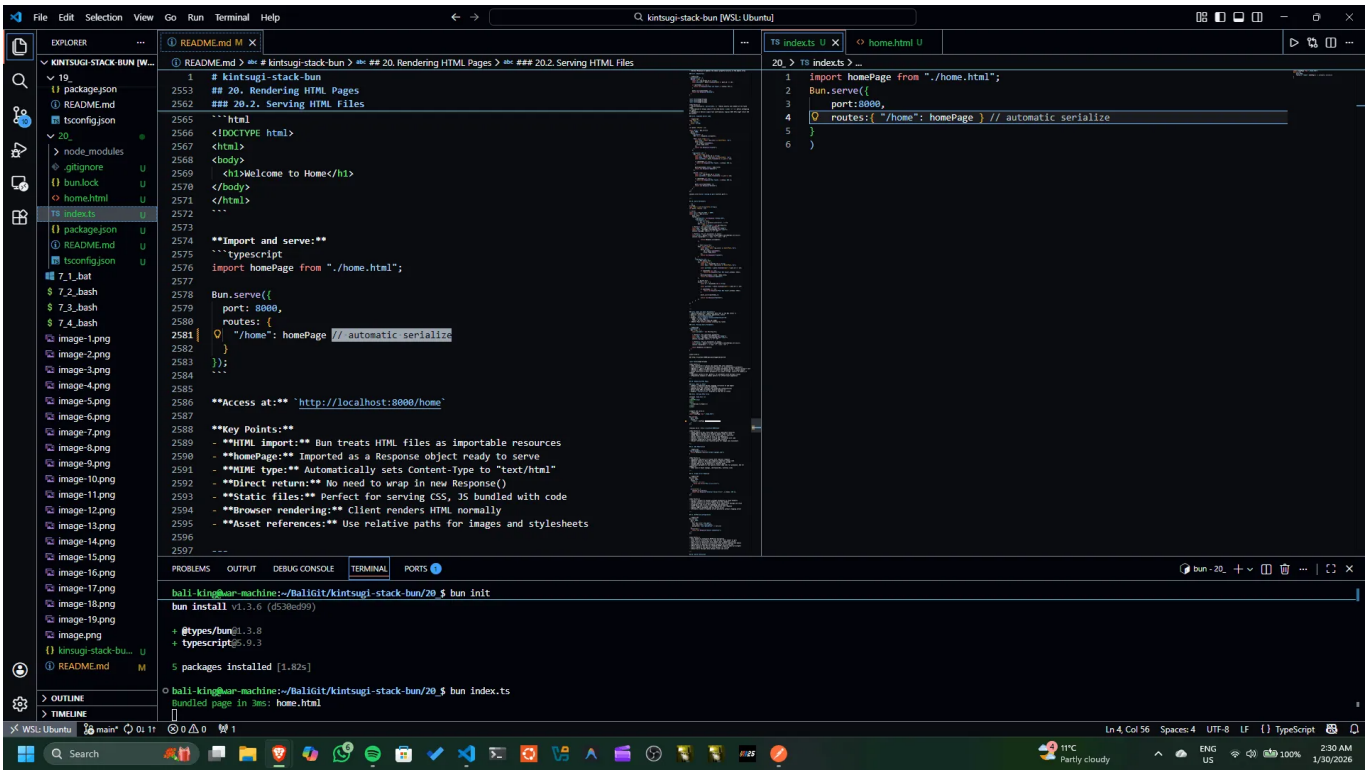
Create `home.html`:

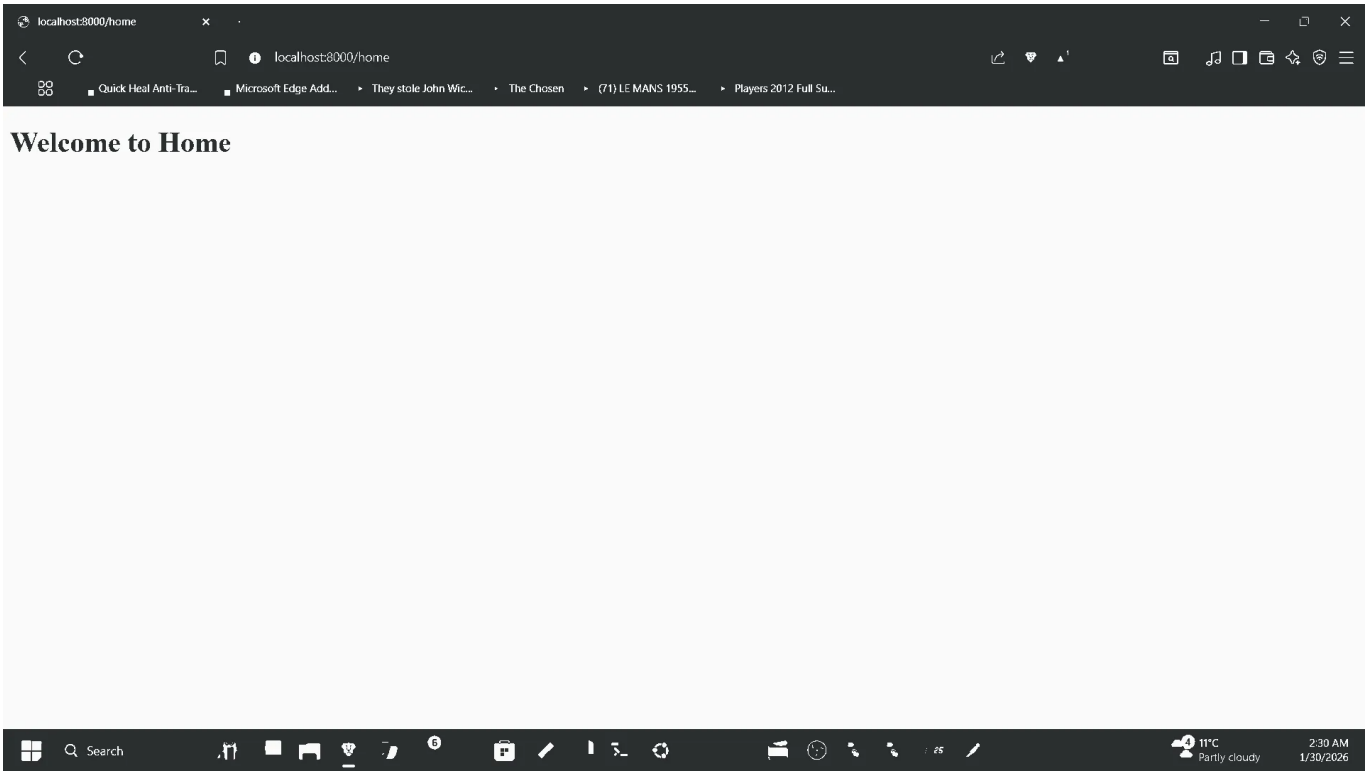
```
<!DOCTYPE html>
<html>
<body>
  <h1>Welcome to Home</h1>
</body>
</html>
```

Import and serve:

```
import homePage from "./home.html";

Bun.serve({
  port: 8000,
  routes: {
    "/home": homePage // automatic serialize
  }
});
```

Access at: `http://localhost:8000/home`





Key Points:

- **HTML import:** Bun treats HTML files as importable resources
- **homePage:** Imported as a Response object ready to serve
- **MIME type:** Automatically sets Content-Type to "text/html"
- **Direct return:** No need to wrap in new Response()
- **Static files:** Perfect for serving CSS, JS bundled with code
- **Browser rendering:** Client renders HTML normally
- **Asset references:** Use relative paths for images and stylesheets

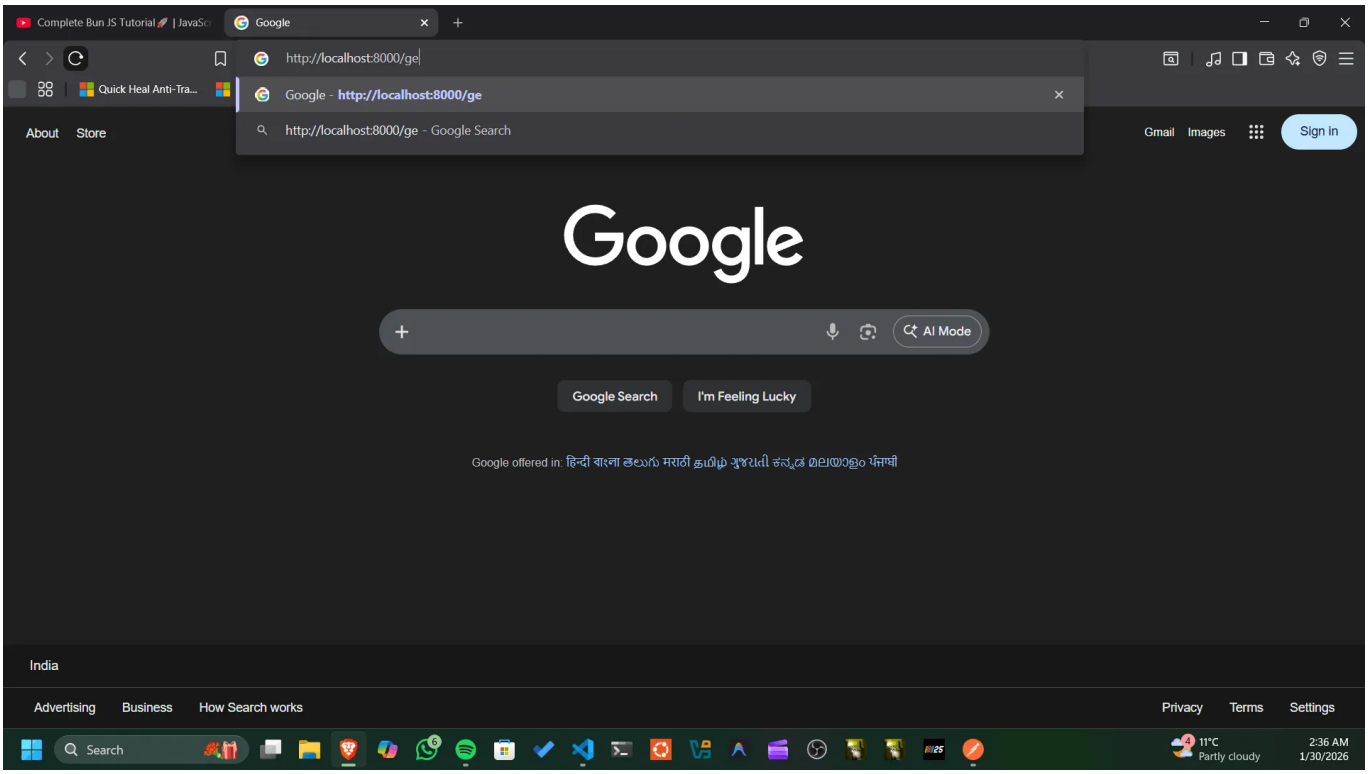
---

21. URL Redirection

```
import homePage from "./home.html";
Bun.serve({
    port:8000,
    routes:{
        "/home": homePage,
        "/ge": Response.redirect("https://google.com")

     } // automatic serialize
}
)
```

```
<!DOCTYPE html>
<html>
<body>
    <h1>
        Welcome to Home
    </h1>
</body>
</html>
```

```
"/go-to-google": () => {
  return Response.redirect("https://google.com");
}
```



Key Points:

- **Response.redirect():** Creates HTTP redirect response
- **Default status:** Uses 302 (temporary redirect) status code
- **Browser behavior:** Automatically navigates to new URL
- **Target URL:** Can be absolute or relative paths
- **Optional parameter:** Can specify status code (301 for permanent, 302 for temporary)
- **Use case:** Route changes, shortened URLs, external links

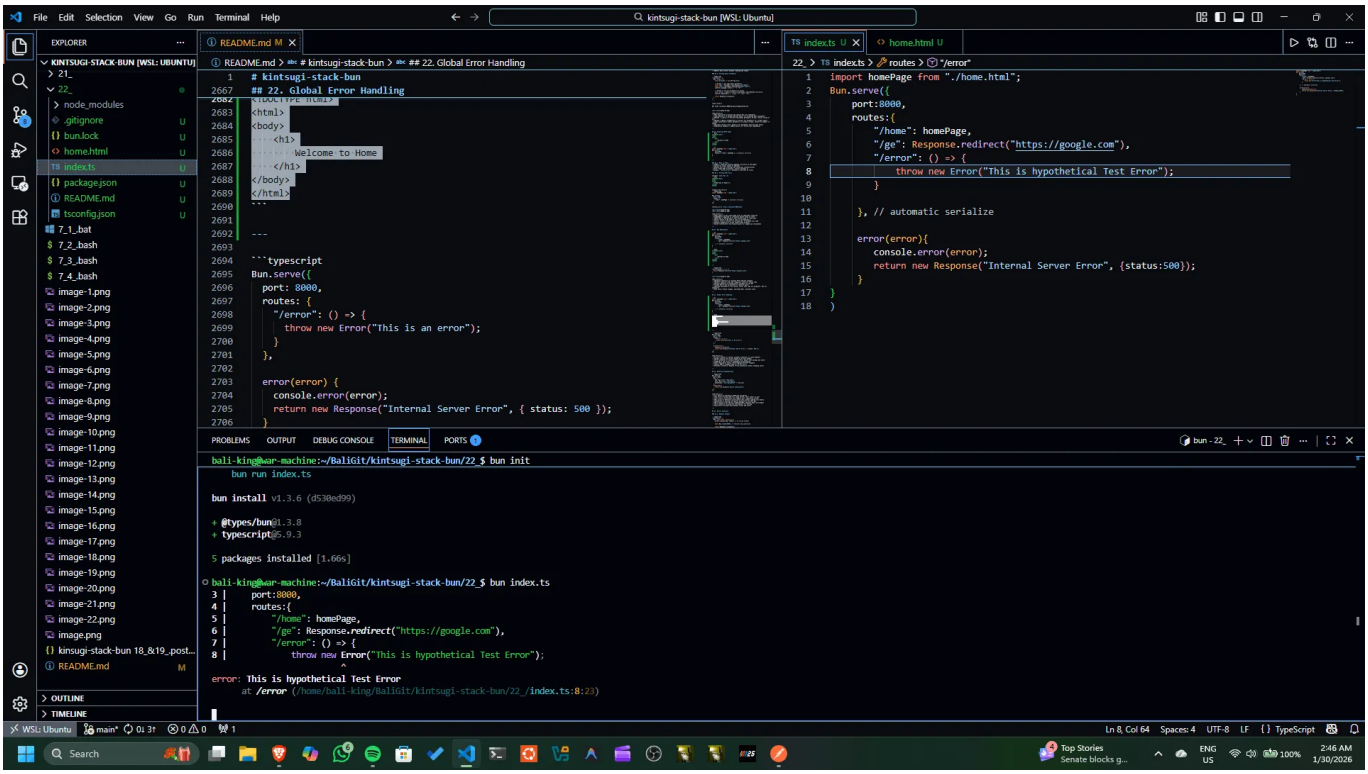
---

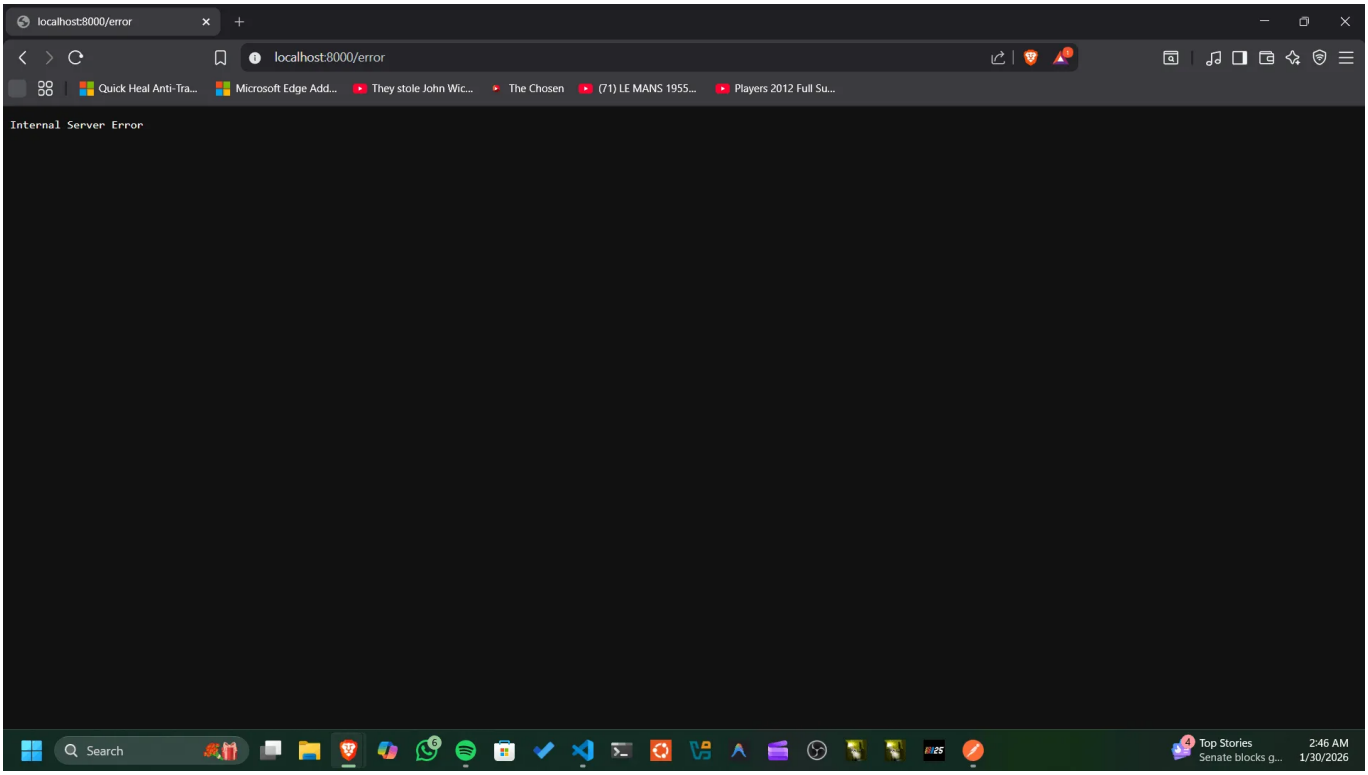
22. Global Error Handling

```
import homePage from "./home.html";
Bun.serve({
    port:8000,
    routes:{
        "/home": homePage,
        "/ge": Response.redirect("https://google.com"),
        "/error": () => {
            throw new Error("This is hypothetical Test Error");
        }

     }, // automatic serialize

     error(error){
        console.error(error);
        return new Response("Internal Server Error", {status:500});
     }
}
)
```

```
<!DOCTYPE html>
<html>
<body>
    <h1>
        Welcome to Home
    </h1>
</body>
</html>
```

```
Bun.serve({
  port: 8000,
  routes: {
    "/error": () => {
      throw new Error("This is an error");
    }
  },

  error(error) {
    console.error(error);
    return new Response("Internal Server Error", { status: 500 });
  }
});
```





Key Points:

- **error() handler:** Catches uncaught exceptions in route handlers
- **Global catch:** All errors bubble up to this handler
- **Error parameter:** Contains thrown Error object with message and stack
- **Logging:** Log errors for debugging and monitoring
- **User response:** Always return appropriate HTTP response
- **Status 500:** Standard code for server errors
- **Prevents crashes:** Handles errors gracefully without stopping server

---

23. HTTPS/TLS Configuration

```
Bun.serve({
    port: 443, // 443 for standard https, req. admin privileges
    tls: { // config https/tls encryption
        key: Bun.file("./key.pem"), // private key, never commit // Bun.file()
reference cert. files without loading into memory
        cert: Bun.file("./cert.pem"), // cert file, identifies server
        passphrase: "your-passphase" // Optional encryption password for private
key
    },
    fetch(req){
        return new Response("Secure Connection");
    }
})

// openssl for testing, generate, self signed
```

```
Bun.serve({
  port: 8000,
  tls: {
    key: Bun.file("./key.pem"),
    cert: Bun.file("./cert.pem"),
    passphrase: "your-passphrase" // Optional
  },
  fetch(req) {
    return new Response("Secure connection");
  }
});
```

Key Points:

- **tls object:** Configures HTTPS/TLS encryption
- **key file:** Private key file (keep secret, never commit to git)
- **cert file:** Certificate file (public part, identifies server)
- **Bun.file():** Reference certificate files without loading into memory
- **passphrase:** Optional encryption password for private key
- **Port choice:** Use 443 for standard HTTPS (requires admin privileges)
- **Self-signed:** Can generate with OpenSSL for testing
- **Security:** Encrypts data between client and server

---

24. Server Utilities

```
const server = Bun.serve({
    port: 3000,
```

```
    async fetch(request,server) {
        const ip = server.requestIP(request);// get client IP address
        server.timeout(request,10000);// 10 second timeout // Max time for req
processing, after that Bun will return 408 Request Timeout
        await Bun.sleep(2000); // simulate long processing 2sec // need async to
use await
        console.log(ip);
        return new Response(`OK`);
    }
})
// ➜  24_ git:(main) ✗ bun index.ts
// {
//   address: "::1",
//   family: "IPv6",
//   port: 50124,
// }
// {
//   address: "::1",
//   family: "IPv6",
//   port: 50124,
// }

process.on("SIGINT", () => { // Handle Ctrl+C
  console.log("Shutting down...");
  server.stop();
  process.exit(0);
});


// server.stop(); // Gracefully stop the server // wait for all requests to finish
// server.stop(true); // Forcefully stop the server // immediately terminate all
connections

// To test timeout, run the server and use curl:
// curl http://localhost:3000
// After 10 seconds, you should see a "408 Request Timeout" response.

// To test, run the server and use curl:
// curl http://localhost:3000
// You should see "OK" after 2 seconds and the client IP logged in the console.

// To run the server, use the command:
// bun index.ts
```

24.1. Request Timeout

```
"/api/posts": {
  GET: async (req, server) => {
    server.timeout(req, 10000); // 10 second timeout
```

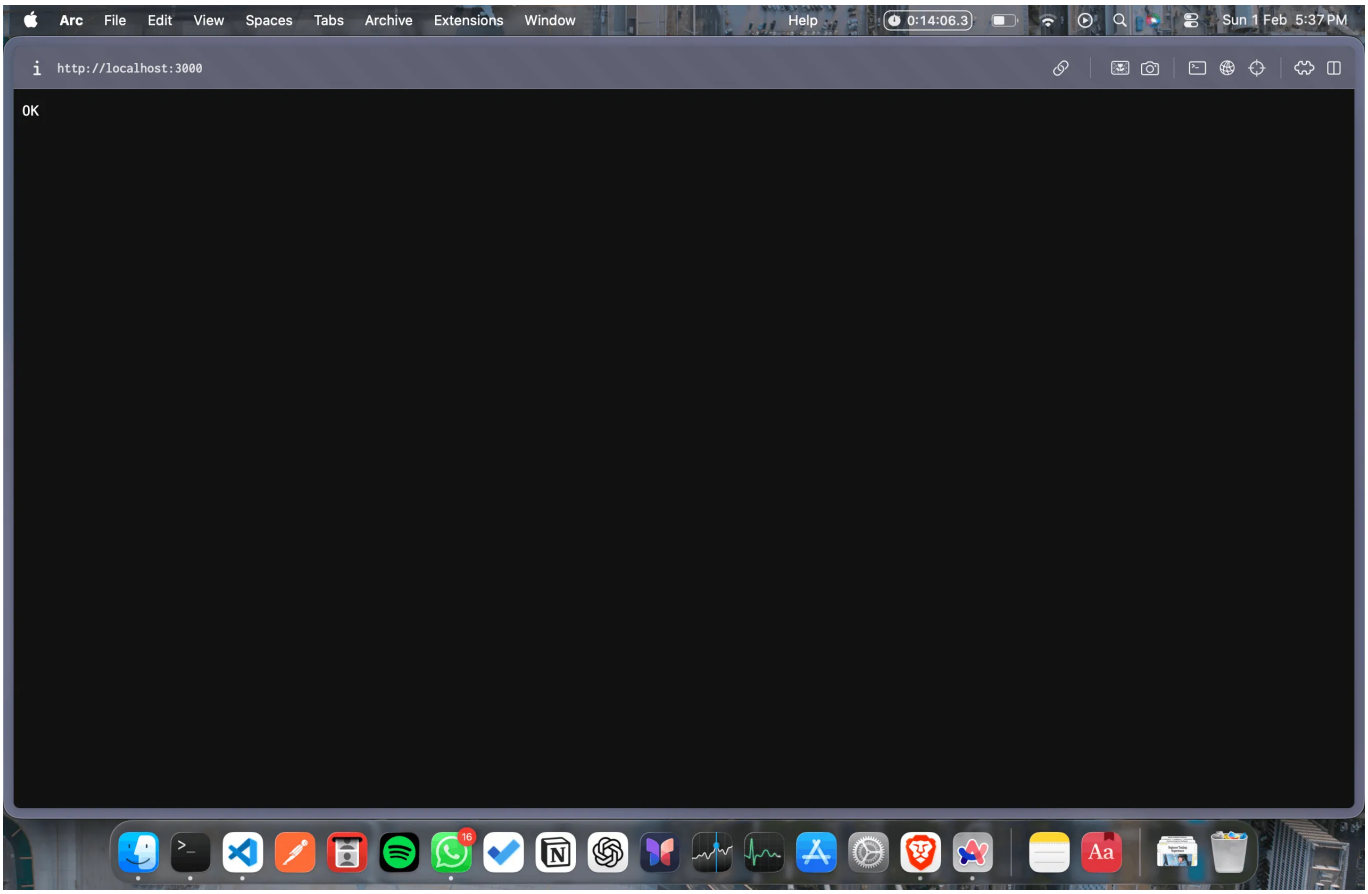
```
      await Bun.sleep(20000); // Simulate long operation

      return Response.json(posts);
    }
  }
```

Key Points:

- **server.timeout():** Sets maximum time for request processing
- **Milliseconds:** Parameter is in milliseconds (10000 = 10 seconds)
- **Automatic abort:** Request aborts if handler takes too long
- **Prevents hanging:** Stops stuck requests from blocking resources
- **Server parameter:** Second parameter to handler function
- **Error response:** Client receives error when timeout occurs
- **Resource cleanup:** Server stops waiting and frees resources

24.2. Get Client IP

```
fetch(req, server) {
  const ip = server.requestIP(req);
  console.log(ip);
  // Output: { address: "::1", port: 54321 }

  return new Response("OK");
}
```



Key Points:

- **server.requestIP():** Retrieves client's IP address and port
- **Returns object:** { address, port } format
- **address:** IPv4 or IPv6 format ("::1" is localhost)
- **port:** Client's source port (varies per connection)
- **Use cases:** Logging, analytics, rate limiting, IP filtering
- **Proxies:** May return proxy IP instead of actual client (check X-Forwarded-For header)
- **Availability:** Server parameter needed (from handler function)

24.3. Graceful Shutdown

```
// Graceful shutdown (wait for ongoing requests)
server.stop();

// Force shutdown (close immediately)
server.stop(true);
```

Key Points:

- **server.stop():** Stops accepting new requests
- **Graceful:** Waits for in-flight requests to complete
- **Force parameter:** Pass true to immediately close all connections
- **Cleanup:** Best practice for proper resource cleanup
- **Zero downtime:** Handle active requests before stopping
- **Process exit:** Typically called on SIGTERM signal
- **Timing:** Graceful may take time if requests are slow

---

25. Console API

```
console.log("Hello via Bun!");
console.log("Let's add some numbers:");
let count = 0;
console.log("Initial Count:", count);
for await (const line of console){ // Iterate over console input line by line
    count += Number(line);
    console.log("Updated Count:", count);
}

// ➜  25_ git:(main) ✗ bun index.ts
// Hello via Bun!
// ➜  25_ git:(main) ✗ bun index.ts
// Hello via Bun!
// Let's add some numbers:
// Initial Count: 0
// 10
// Updated Count: 10
```

```
// 10
// Updated Count: 20
// 2
// Updated Count: 22
// 23
// Updated Count: 45

// Updated Count: 45
// 45
// Updated Count: 90
// 6754
// Updated Count: 6844
// 32
// Updated Count: 6876

// 3Updated Count: 6876
// 456
// Updated Count: 10332

// Updated Count: 10332

// Updated Count: 10332
// ^C
// ➜  25_ git:(main) X
```

25.1. Reading Terminal Input

```
console.log("Let's add some numbers");
console.log("Initial count: 0");

let count = 0;

for await (const line of console) {
  count += Number(line);
  console.log(`Count: ${count}`);
}
```

Usage:

```
bun run dev
# Enter: 5
# Output: Count: 5
# Enter: 10
# Output: Count: 15
```

Key Points:

- **for await...of loop:** Iterates over console input line by line
- **Real-time interaction:** Read user input during program execution
- **Type conversion:** Line is a string, convert with Number() if needed
- **Async/await:** Requires async context to work properly
- **Use case:** Interactive CLIs, real-time calculators, user prompts
- **Termination:** Press Ctrl+C to stop the program

---

26. Color API

```
const whiteToRGBA = Bun.color("white","rgba"); // css to rgba
console.log(whiteToRGBA);
// rgba(255, 255, 255, 1)

const whiteToHEX = Bun.color("white","hex"); // css to hex
console.log(whiteToHEX);
// #ffffff

const rgbaToCSS = Bun.color("rgba(255, 0, 0, 1)","css"); // rgba to css
console.log(rgbaToCSS);
// red

const RGBToHEX = Bun.color("rgb(0, 255, 0)","hex"); // rgb to hex
console.log(RGBToHEX);
// #00ff00
```

26.1. Converting Color Formats

```
// CSS to RGBA
const whiteRGBA = Bun.color("white", "rgba");
console.log(whiteRGBA); // rgba(255, 255, 255, 1)

// CSS to HEX
const whiteHex = Bun.color("white", "hex");
console.log(whiteHex); // #ffffff

// RGB to HEX
const color = Bun.color("rgb(255, 0, 0)", "hex");
console.log(color); // #ff0000
```

Key Points:

- **Format support:** Handles CSS color names, RGB, HEX formats
- **Output formats:** Convert to "rgba", "hex", "rgb", or other formats
- **CSS names:** Named colors like "white", "red", "blue" are recognized
- **Use case:** Design tools, color manipulation, theme systems

- **Normalization:** Standardizes color formats for consistent usage
- **Return type:** Always returns a string representation

---

27. Shell Scripting with Bun

```
import { $ } from "bun"; // $ library for shell scripting

// Basic Shell Command Execution
await $`echo "Hello, World!"`; // echo command // async/await syntax // template literal syntax `` backticks
// runs the command in a shell and waits for it to complete
// Hello, World!

// Fetching and Piping
const response = await fetch("https://example.com");

const clone = response.clone();

await $`cat < ${clone} | wc -c`; // consumes clone
const html = await response.text(); // original still usable

console.log(html)

// ➜  27_ git:(main) ✗ bun index.ts
// Hello, World!
//      513
// <!doctype html><html lang="en"><head><title>Example Domain</title><meta name="viewport" content="width=device-width, initial-scale=1">
<style>body{background:#eee;width:60vw;margin:15vh auto;font-family:system-ui,sans-serif}h1{font-size:1.5em}div{opacity:0.8}a:link,a:visited{color:#348}</style><body><div><h1>Example Domain</h1><p>This domain is for use in documentation examples without needing permission. Avoid use in operations.<p><a href="https://iana.org/domains/example">Learn more</a></div></body></html>
//
// ➜  27_ git:(main) ✗
```

27.1. Basic Shell Commands

```
import { $ } from "bun";

// Echo command
await $`echo "Hello World"`;
// Output: Hello World
```

Key Points:

- **Template literals:** Uses backticks for shell commands

- **Async:** Commands are awaited and return promises
- **Direct execution:** Run any shell command available on your system
- **Use case:** File operations, system commands, automation

27.2. Fetching and Piping

```
import { $ } from "bun";

// Fetching and Piping
const response = await fetch("https://example.com");
await $`cat < ${response} | wc -c`; // size
```

Key Points:

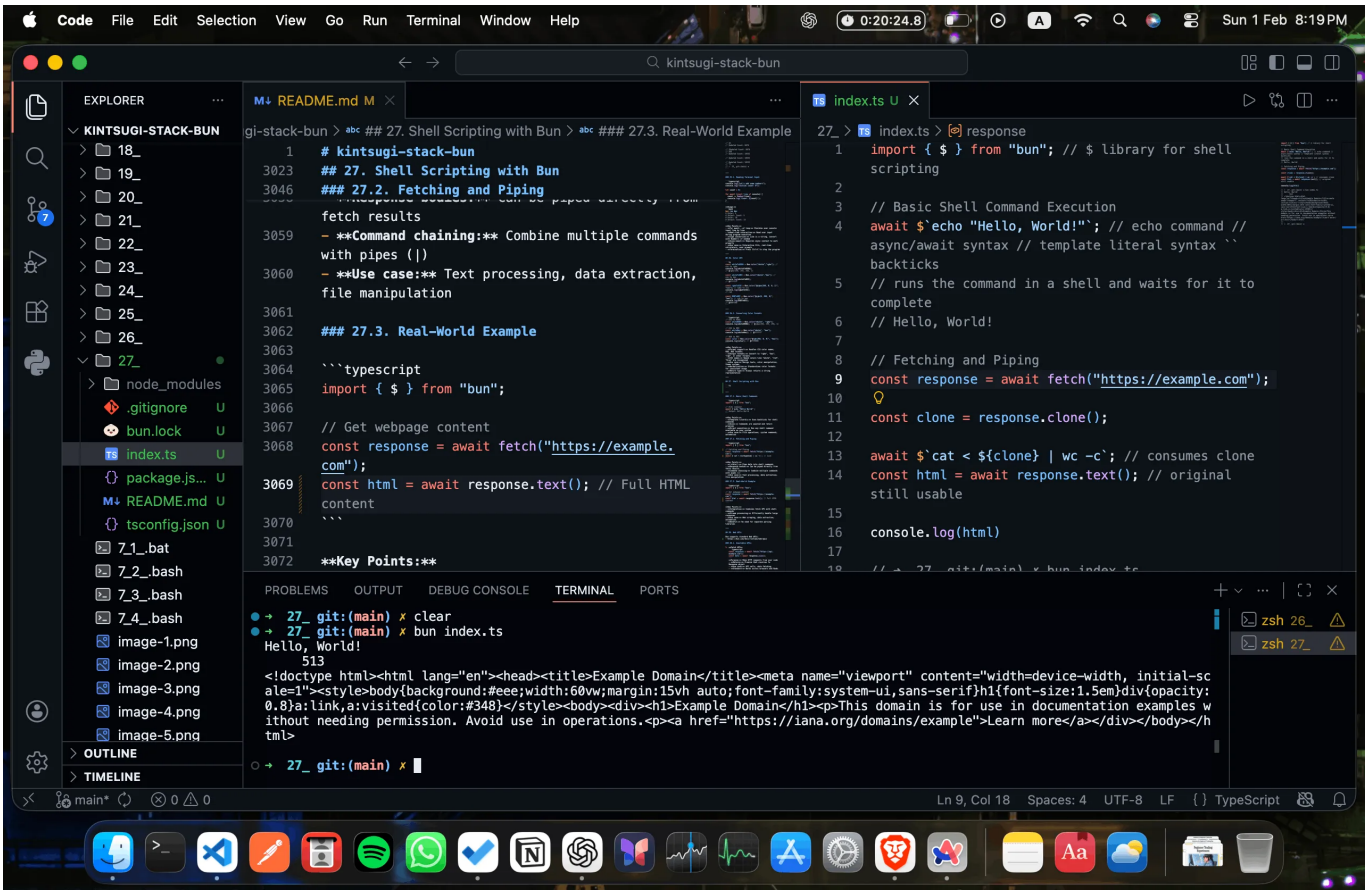
- **.stdin():** Pipe data into shell commands
- **Response bodies:** Can be piped directly from fetch results
- **Command chaining:** Combine multiple commands with pipes (|)
- **Use case:** Text processing, data extraction, file manipulation

27.3. Real-World Example

```
import { $ } from "bun";

// Get webpage content
const response = await fetch("https://example.com");
const html = await response.text(); // Full HTML content
```

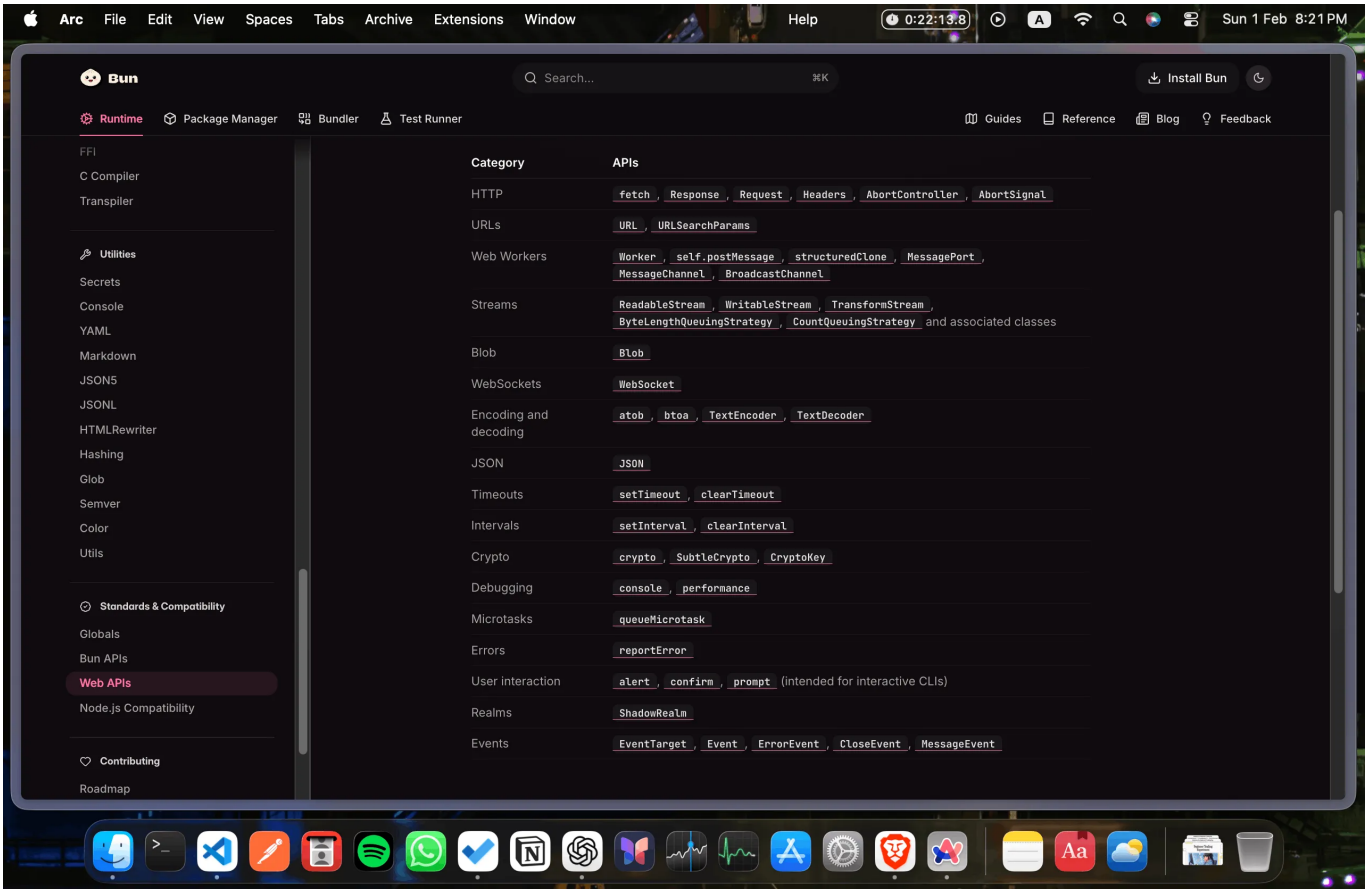
Key Points:

- **Integration:** Combines fetch API with shell commands
- **Stream processing:** Efficiently handle large responses
- **Use case:** Web scraping, data extraction, automation
- **Benefit:** No need for separate parsing libraries



28. Web APIs

Bun supports standard Web APIs: https://bun.com/docs/runtime/web-apis



28.1. Available APIs:

1. **Fetch API**

```
const response = await fetch("https://api.example.com");
const data = await response.json();
```

Purpose: Make HTTP requests from your code

- **Returns:** Promise that resolves to Response object
- **Use case:** API calls, data fetching
- **Standard:** Works across browsers and Node.js

2. **Request/Response**

```
const req = new Request("https://example.com");
const res = new Response("Hello");
```

Purpose: Work with HTTP request/response objects

- **Request:** Represents incoming or outgoing HTTP requests
- **Response:** Represents HTTP responses with body and headers
- **Use case:** Building APIs, middleware, handlers

3. **Headers**

```
const headers = new Headers();
headers.set("Content-Type", "application/json");
```

Purpose: Manage HTTP headers

- **Methods:** .set(), .get(), .delete(), .entries()
- **Use case:** Setting content-type, authentication, custom headers
- **Case-insensitive:** Header names are automatically normalized

4. **AbortController**

```
const controller = new AbortController();
fetch(url, { signal: controller.signal });
controller.abort();
```

Purpose: Cancel asynchronous operations

- **Use case:** Timeout requests, cancel file uploads

- **Benefit:** Clean up resources, prevent memory leaks
- **How:** Pass signal to fetch, call abort() to cancel

5. **URL/URLSearchParams**

```
const url = new URL("https://example.com?page=1");
console.log(url.searchParams.get("page"));
```

Purpose: Parse and manipulate URLs

- **URL:** Parse URL into components (hostname, pathname, query)
- **URLSearchParams:** Access query string parameters
- **Use case:** Routing, query parsing, URL building

6. **WebSocket**

```
const ws = new WebSocket("ws://localhost:3000");
```

Purpose: Real-time bidirectional communication

- **Use case:** Chat, live updates, real-time notifications
- **Benefit:** Persistent connection, lower latency than HTTP polling
- **Events:** open, message, close, error

7. **JSON**

```
JSON.parse('{"name": "test"}');
JSON.stringify({ name: "test" });
```

Purpose: Convert between JSON strings and JavaScript objects

- **parse():** Convert JSON string to object
- **stringify():** Convert object to JSON string
- **Use case:** API communication, data serialization

8. **Timers**

```
setTimeout(() => console.log("Hello"), 1000);
setInterval(() => console.log("Tick"), 1000);
```

Purpose: Execute code after delays or at intervals

- **setTimeout:** Execute once after delay (milliseconds)
- **setInterval:** Repeat at fixed intervals

- **Use case:** Scheduling tasks, debouncing, animations

9. **Crypto**

```
const uuid = crypto.randomUUID();
```

Purpose: Cryptographic operations

- **randomUUID():** Generate random UUIDs
- **getRandomValues():** Fill typed arrays with random values
- **Use case:** Security, generating unique identifiers

---

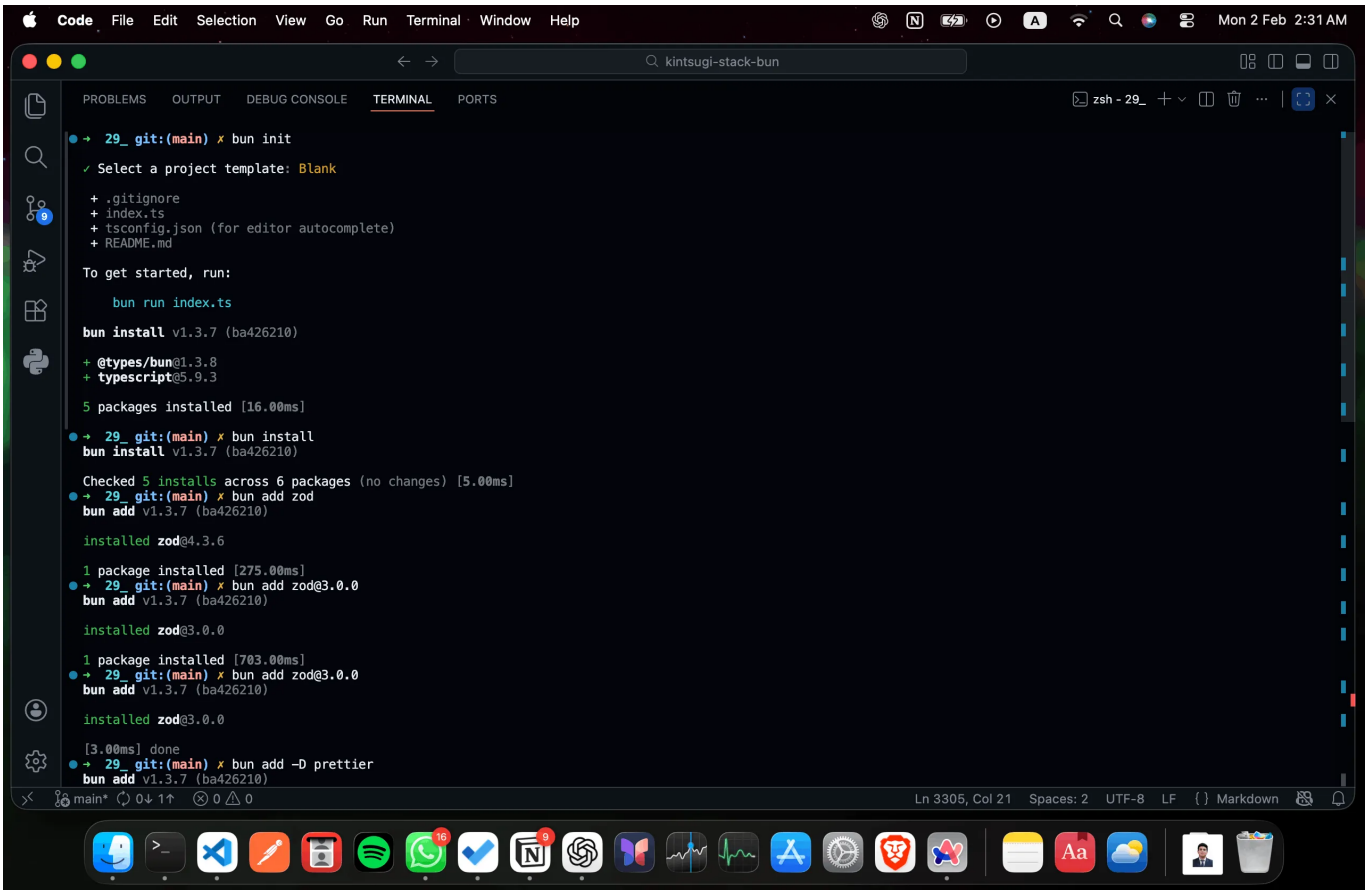
29. Bun as a Package Manager

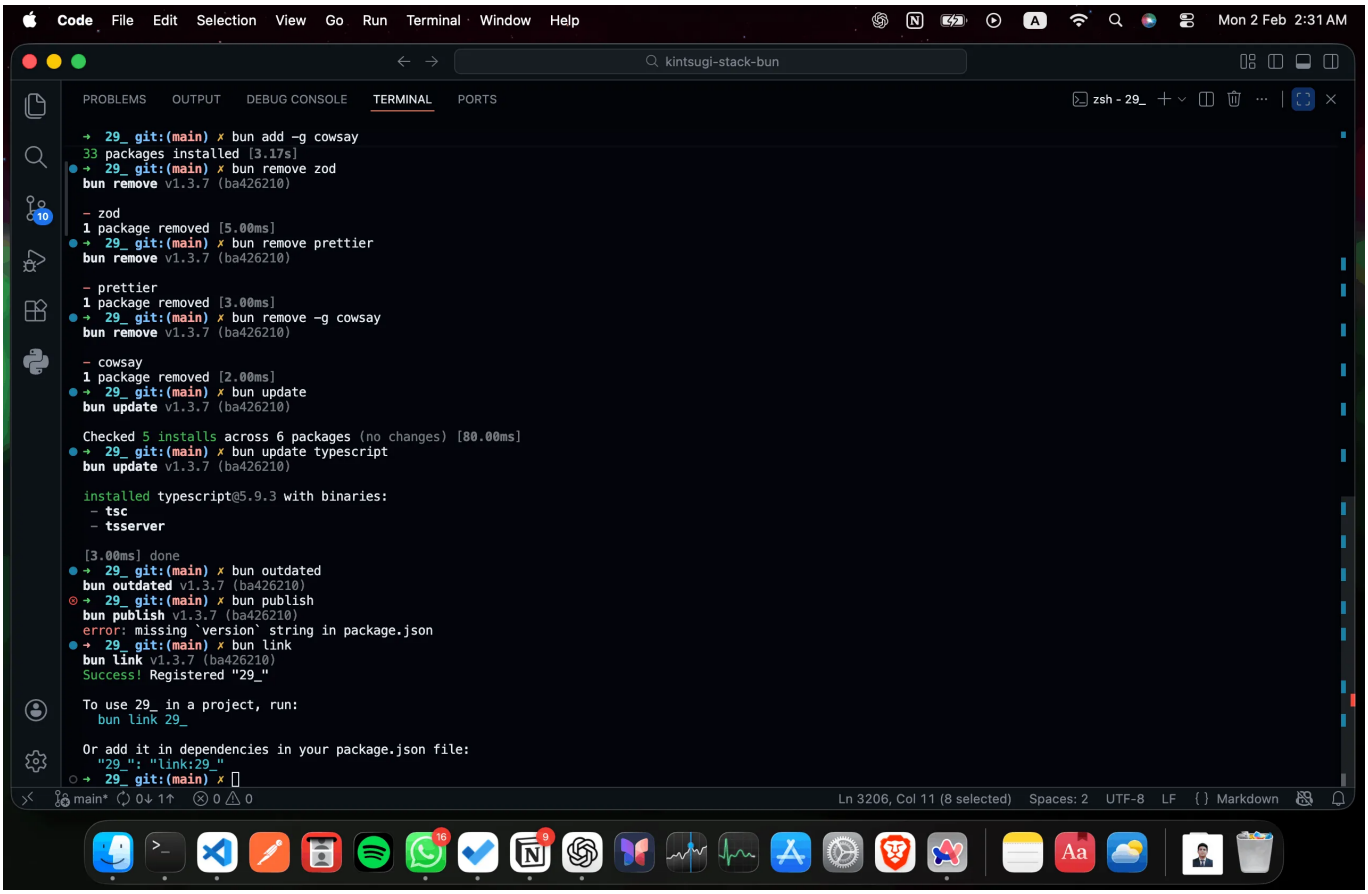
```
bun init                    # initialize a new Bun project (creates package.json,
bun.lockb)
bun install                 # install all deps from package.json
bun add zod                 # add latest version of a dependency
bun add zod@3.0.0           # add a specific version of a dependency
bun add zod@3.0.0           # to demonstrate: Second install (cached) will be
much faster
bun add -D prettier         # add a dev-only dependency
bun add -g cowsay           # install a package globally
bun remove zod              # remove a local dependency
bun remove prettier         # remove a dev dependency
bun remove -g cowsay        # uninstall a global package
bun update                  # update all dependencies (within version ranges)
bun update typescript       # update a specific dependency
bun outdated                # list outdated dependencies
bun publish                 # publish package to npm
bun link                    # link local package globally for development
```

```
➜  29_ git:(main) ✗ bun init

✓ Select a project template: Blank

 + .gitignore
 + index.ts
 + tsconfig.json (for editor autocomplete)
 + README.md

To get started, run:

    bun run index.ts

bun install v1.3.7 (ba426210)
```

```
+ @types/bun@1.3.8
+ typescript@5.9.3

5 packages installed [16.00ms]

➜  29_ git:(main) ✗ bun install
bun install v1.3.7 (ba426210)

Checked 5 installs across 6 packages (no changes) [5.00ms]
➜  29_ git:(main) ✗ bun add zod
bun add v1.3.7 (ba426210)

installed zod@4.3.6

1 package installed [275.00ms]
➜  29_ git:(main) ✗ bun add zod@3.0.0
bun add v1.3.7 (ba426210)

installed zod@3.0.0

1 package installed [703.00ms]
➜  29_ git:(main) ✗ bun add zod@3.0.0
bun add v1.3.7 (ba426210)

installed zod@3.0.0

[3.00ms] done
➜  29_ git:(main) ✗ bun add -D prettier
bun add v1.3.7 (ba426210)

installed prettier@3.8.1 with binaries:
 - prettier

1 package installed [1.57s]
➜  29_ git:(main) ✗ bun add -g cowsay
bun add v1.3.7 (ba426210)

installed cowsay@1.6.0 with binaries:
 - cowsay
 - cowthink

33 packages installed [3.17s]
➜  29_ git:(main) ✗ bun remove zod
bun remove v1.3.7 (ba426210)

- zod
1 package removed [5.00ms]
➜  29_ git:(main) ✗ bun remove prettier
bun remove v1.3.7 (ba426210)

- prettier
1 package removed [3.00ms]
➜  29_ git:(main) ✗ bun remove -g cowsay
bun remove v1.3.7 (ba426210)
```

```
- cowsay
1 package removed [2.00ms]
➜  29_ git:(main) ✗ bun update
bun update v1.3.7 (ba426210)

Checked 5 installs across 6 packages (no changes) [80.00ms]
➜  29_ git:(main) ✗ bun update typescript
bun update v1.3.7 (ba426210)

installed typescript@5.9.3 with binaries:
 - tsc
 - tsserver

[3.00ms] done
➜  29_ git:(main) ✗ bun outdated
bun outdated v1.3.7 (ba426210)
➜  29_ git:(main) ✗ bun publish
bun publish v1.3.7 (ba426210)
error: missing `version` string in package.json
➜  29_ git:(main) ✗ bun link
bun link v1.3.7 (ba426210)
Success! Registered "29_"

To use 29_ in a project, run:
  bun link 29_

Or add it in dependencies in your package.json file:
  "29_": "link:29_"
➜  29_ git:(main) ✗
```





29.1. What is a Package Manager?

- **Package** = Pre-written code libraries (like building blocks)
- **Package Manager** = Tool to download and manage these libraries

- Think of it like an app store for code
- Popular packages: database tools, HTTP clients, authentication, utilities
- **npm** = First package manager (old, slower)
- **Bun's package manager** = Newer, faster alternative
- **Why use packages?** Don't reinvent the wheel, use tested code

29.2. Installing Dependencies

29.2.1. Install All Dependencies

```
bun install
# Equivalent to: npm install
```

29.2.2. Add Package

```
# Regular dependency
bun add zod

# Specific version
bun add zod@3.0.0

# Dev dependency
bun add -D prettier

# Global package
bun add -g cowsay

# even update/readd is much faster because bun knows that it's version is
installed and do relevant changes
```

29.3. Removing Dependencies

```
# Remove package
bun remove zod

# Remove dev dependency
bun remove prettier

# Remove global package
bun remove -g cowsay
```

29.4. Updating Dependencies

```
# Update all packages
bun update

# Update specific package
bun update typescript
```

29.5. Other Commands

29.5.1. Check Outdated Packages

```
bun outdated
# Shows packages with available updates
```

29.5.2. Publish Package

```
bun publish
```

29.5.3. Link Local Package

```
bun link
```

29.6. Speed Comparison

First install:

```
bun add zod
# Completed in 1278ms
```

Second install (cached):

```
bun add zod@3.0.0
# Completed in 67ms
```

---

30. Bun Create Command

```
bun create vite              # Scaffold a Vite frontend project with Bun
bun create hono              # Scaffold a Hono backend project
```

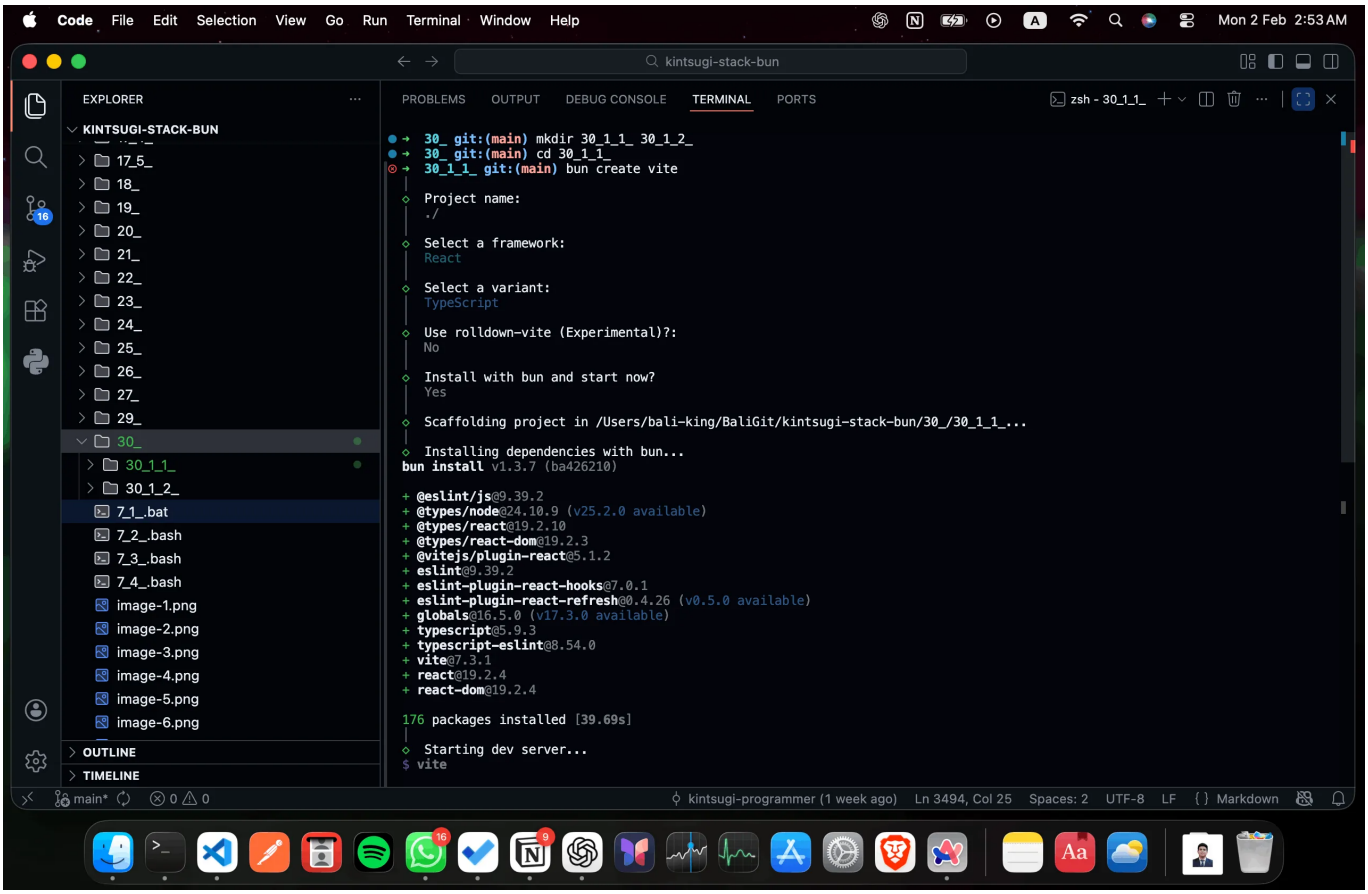
```
bun create next               # Scaffold a Next.js project (modern CLI)
bun create next-app           # Scaffold a Next.js app (older/alternate CLI)
```

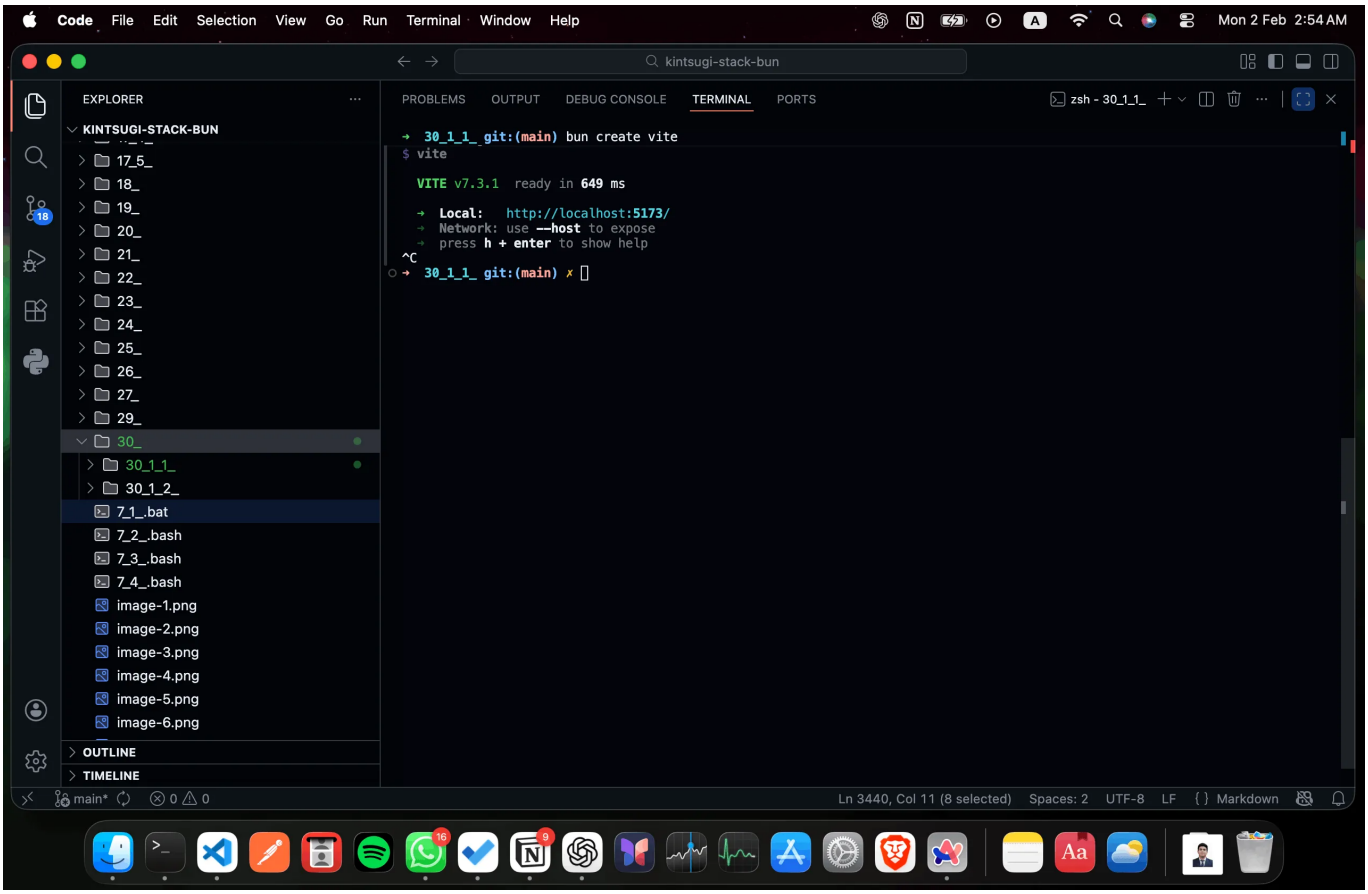
30.1. Creating Projects from Templates

- https://bun.com/docs/guides/ecosystem/vite
- https://bun.com/docs/guides/ecosystem/hono
- https://bun.com/docs/guides/ecosystem/nextjs

30.1.1. React + Vite Project

```
bun create vite react-app
# Select: React
# Select: TypeScript

cd react-app
bun install
bun run dev
```

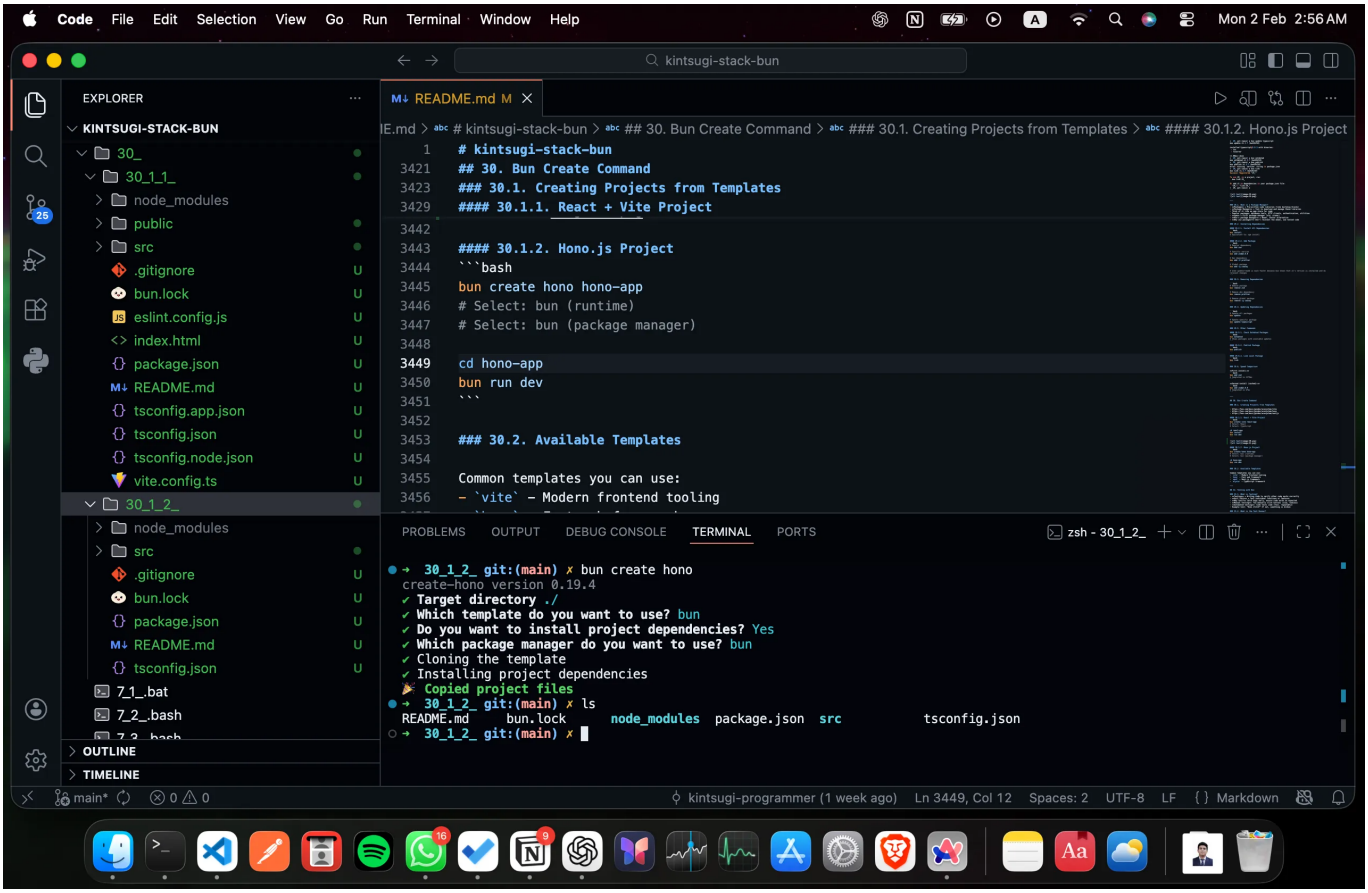




30.1.2. Hono.js Project

```
bun create hono hono-app
# Select: bun (runtime)
```

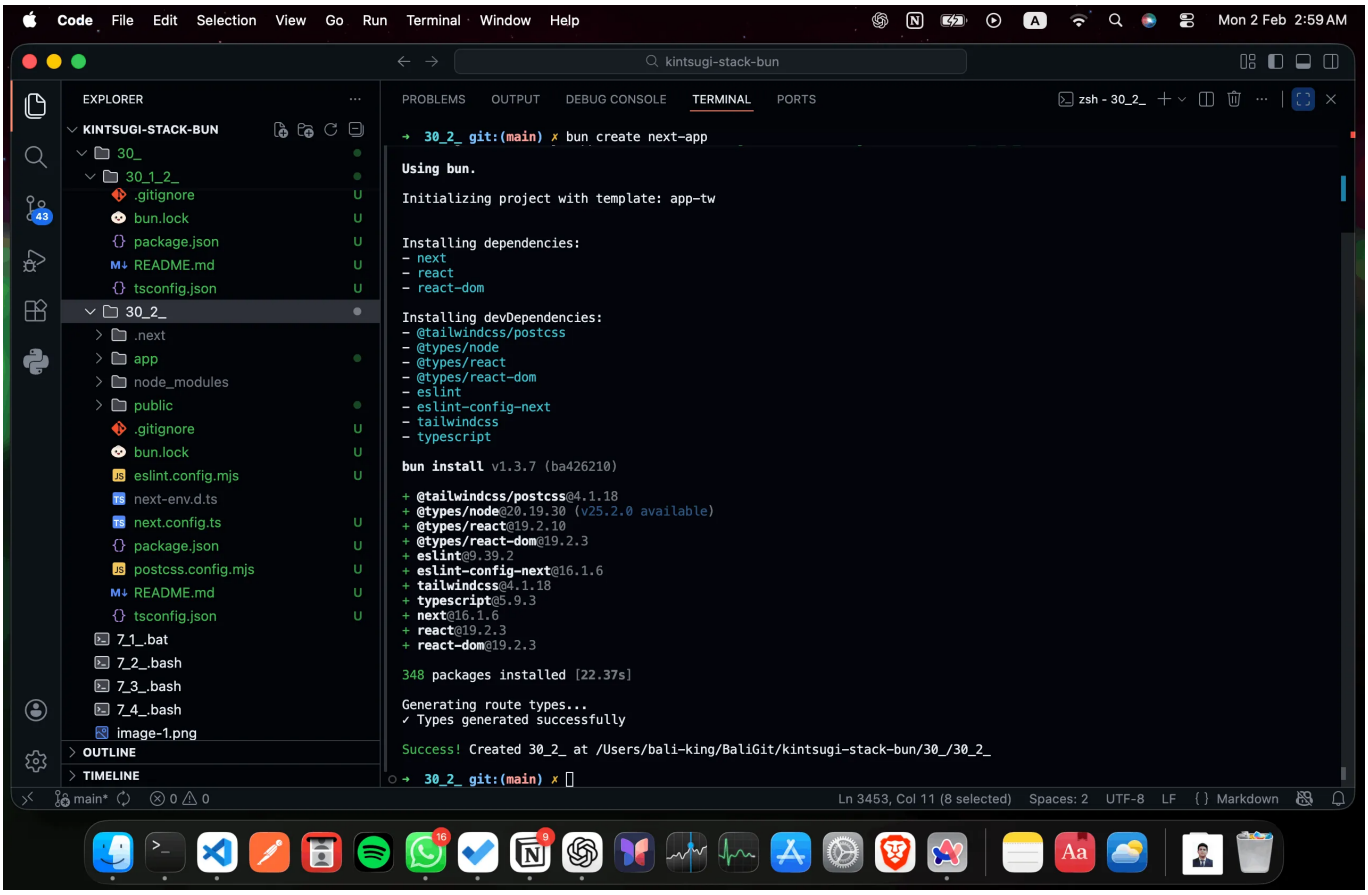
```
# Select: bun (package manager)

cd hono-app
bun run dev
```



30.2. Available Templates

Common templates you can use:

- `vite` - Modern frontend tooling
- `hono` - Fast web framework
- `next` - Next.js framework
- `elysia` - TypeScript framework



31. Testing with Bun

```
// test/example.test.ts

import { expect, test } from "bun:test" ; // libs

// simple test for syntax
test("simple: hecking 2 + 2 addition",() => {expect(2+2).toBe(4);}); // PASS

// actual tests

// // index.ts
// export const add = (a: number, b:number) : number => {
//     return a+b;
// }; // correct code

// export const add_1 = (a:number, b:number) : number => {
//     return a+b+b;
// }; // wrong code

import { add,add_1 } from "../index";

test("index/add: checking 2 + 2 addition",()=>{expect(add(2,2)).toBe(4);}) // PASS
test("index/add_1: checking 2 + 2 addition",
    ()=>{
        expect(
            add_1(2,2)
```

```
        )
        .toBe(4);
    }
); // FAIL

// ➜  31_ git:(main) X bun test
// bun test v1.3.7 (ba426210)

// test/example.test.ts:
// ✓ simple: hecking 2 + 2 addition [0.03ms]
// ✓ index/add: checking 2 + 2 addition [0.02ms]
// 22 | test("index/add_1: checking 2 + 2 addition",
// 23 |     ()=>{
// 24 |         expect(
// 25 |             add_1(2,2)
// 26 |         )
// 27 |         .toBe(4);
//                ^
// error: expect(received).toBe(expected)

// Expected: 4
// Received: 6

//       at <anonymous> (/Users/bali-king/BaliGit/kintsugi-stack-
bun/31_/test/example.test.ts:27:10)
// X index/add_1: checking 2 + 2 addition [0.50ms]

//  2 pass
//  1 fail
//  3 expect() calls
// Ran 3 tests across 1 file. [9.00ms]
// ➜  31_ git:(main) X
```

```
// index.ts
export const add = (a: number, b:number) : number => {
    return a+b;
}; // correct code

export const add_1 = (a:number, b:number) : number => {
    return a+b+b;
}; // wrong code
```

31.1. What is Testing?

- **Testing** = Writing code to verify other code works correctly
- **Unit Tests** = Test individual functions or features
- **Why test?** Catch bugs early, ensure code works as expected
- **Manual testing**: You manually click buttons (slow, tedious)
- **Automated testing**: Code tests code (fast, repeatable)

- Example test: "Does 2+2=4?" If not, something is broken

31.2. What is the Test Runner?

- **Test Runner** = Tool that finds and executes your tests
- Runs all tests and shows which ones passed/failed
- Bun has built-in test runner (no extra installation needed)

31.3. Setting Up Tests

No Jest needed! Bun has built-in testing.

31.3.1. Test File Structure

Create test files with any of these naming patterns:

- `*.test.ts`
- `*.spec.ts`
- `*_test.ts`
- `*_spec.ts`

31.4. Writing Tests

Create `test/example.test.ts`:

```
import { expect, test } from "bun:test";

test("checking 2 + 2 addition", () => {
  expect(2 + 2).toBe(4);
});
```

31.5. Running Tests

```
bun test
```

Output:

```
test/example.test.ts:
  ✓ checking 2 + 2 addition

1 pass
0 fail
```

31.6. Testing Functions

```
import { expect, test } from "bun:test";

const add = (a: number, b: number): number => {
  return a + b;
};

test("checking 2 + 2 addition", () => {
  expect(add(2, 2)).toBe(4);
});

test("checking 5 + 5 addition", () => {
  expect(add(5, 5)).toBe(10);
});
```

31.7. Test Output

```
bun test

# Output:
# test/example.test.ts:
#   ✓ checking 2 + 2 addition
#   ✓ checking 5 + 5 addition
#
# 2 pass
# 0 fail
```

---

32. Bun as a Bundler

32.1. What is a Bundler?

- **Bundler** = Tool that combines multiple files into optimized output
- Reads all your code files and combines them into one (or a few)
- **Why?** Smaller files load faster, better performance
- **Minification** = Removes unnecessary characters to reduce file size
- **Tree-shaking** = Removes unused code
- Example: 10 files (100KB each) → 1 file (500KB total after bundling)

32.2. Building TypeScript to JavaScript

32.2.1. Basic Build

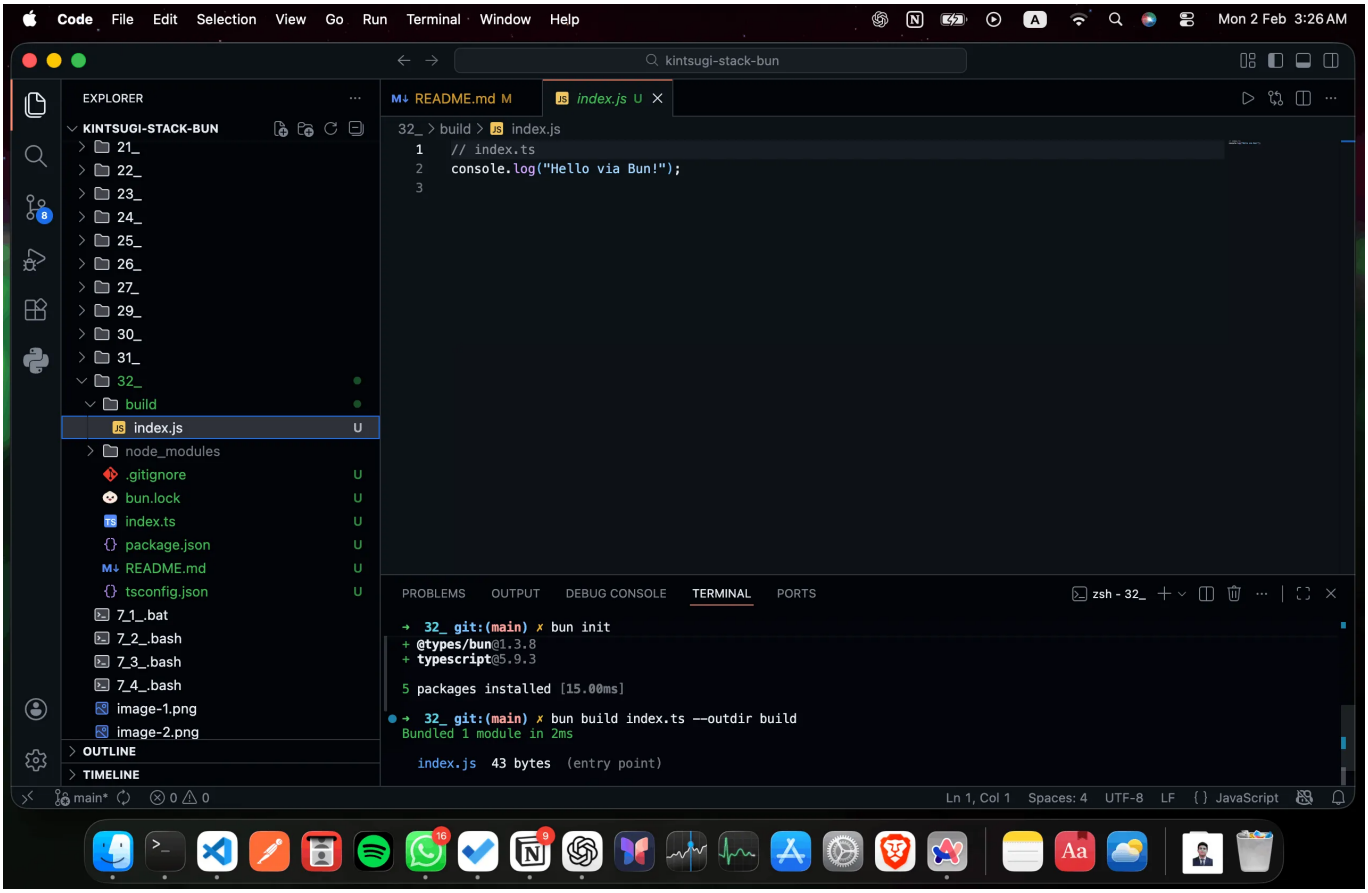
```
bun build ./index.ts --outdir ./build
bun build index.ts --outdir build # or
```

What's happening:

- `bun build` = Start the bundler
- `./index.ts` = Your main file (entry point)
- `--outdir ./build` = Put results in "build" folder
- **Output**: One .js file that contains everything
- **Why .js?** JavaScript runs everywhere (servers, browsers, etc.)

This creates:

```
build/
└── index.js
```



32.3. Build from Source Directory

Project structure:

```
src/
├── index.ts
└── config/
    └── index.ts
```

src/index.ts:

```
import { getConfigs } from "../config";
console.log(getConfigs());
```

src/config/index.ts:

```
export const getConfigs = () => {
  return { env: "development" };
};
```

Build command:

```
bun build ./src/index.ts --outdir ./build
```

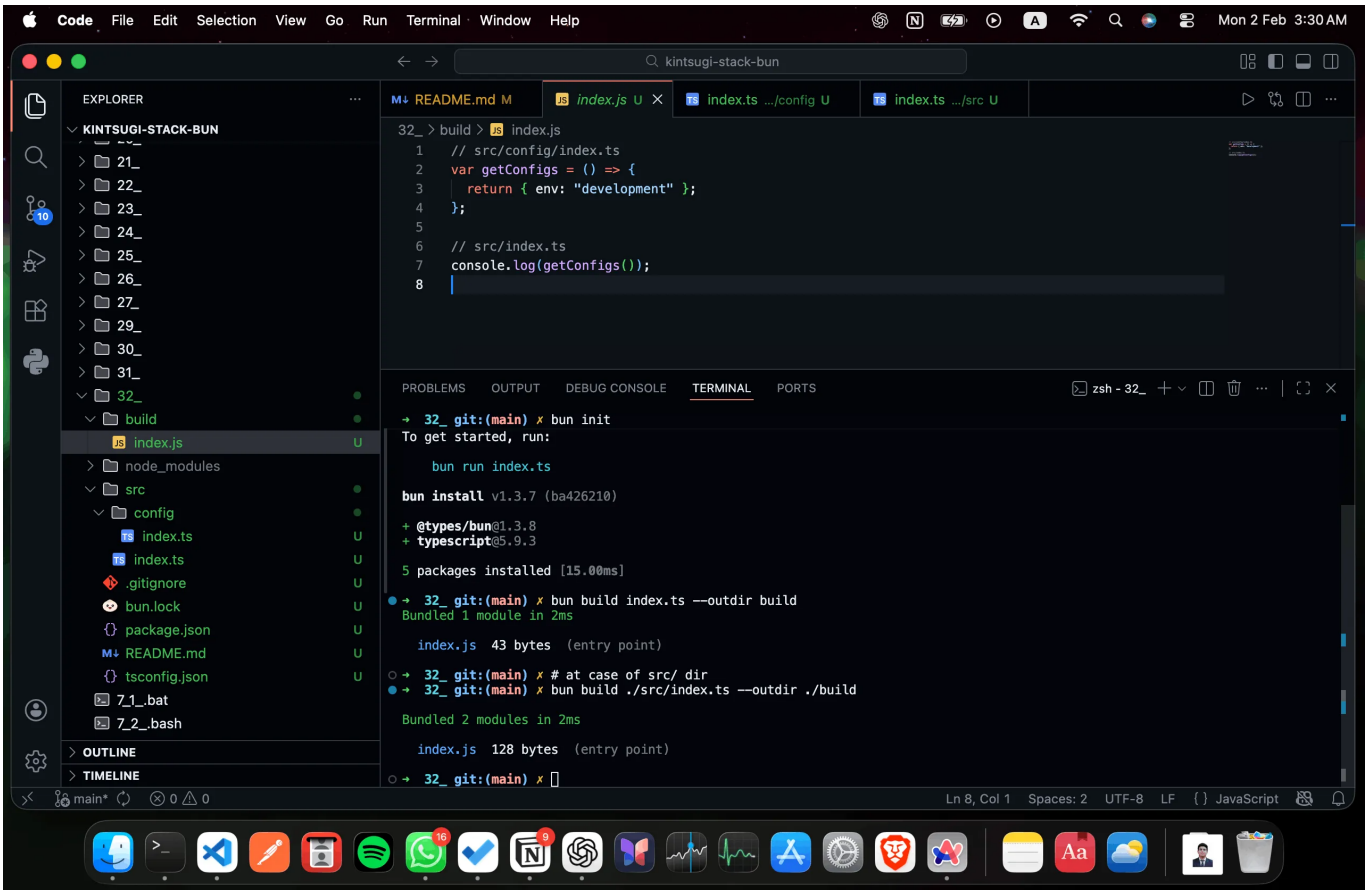
Update package.json:

```
{
  "scripts": {
    "start": "bun ./build/index.js"
  }
}
```

```
{
  "name": "bun",
  "module": "index.ts",
  "devDependencies": {
    "@types/bun": "latest"
  },
  "peerDependencies": {
    "typescript": "^5"
  },
  "private": true,
  "scripts": {
    "start": "bun --env-file=.env.production build/index.js",
    // .ts -> .js
    "dev": "bun --watch --env-file=.env.development index.ts"
  },
  "type": "module"
}
```

Run:

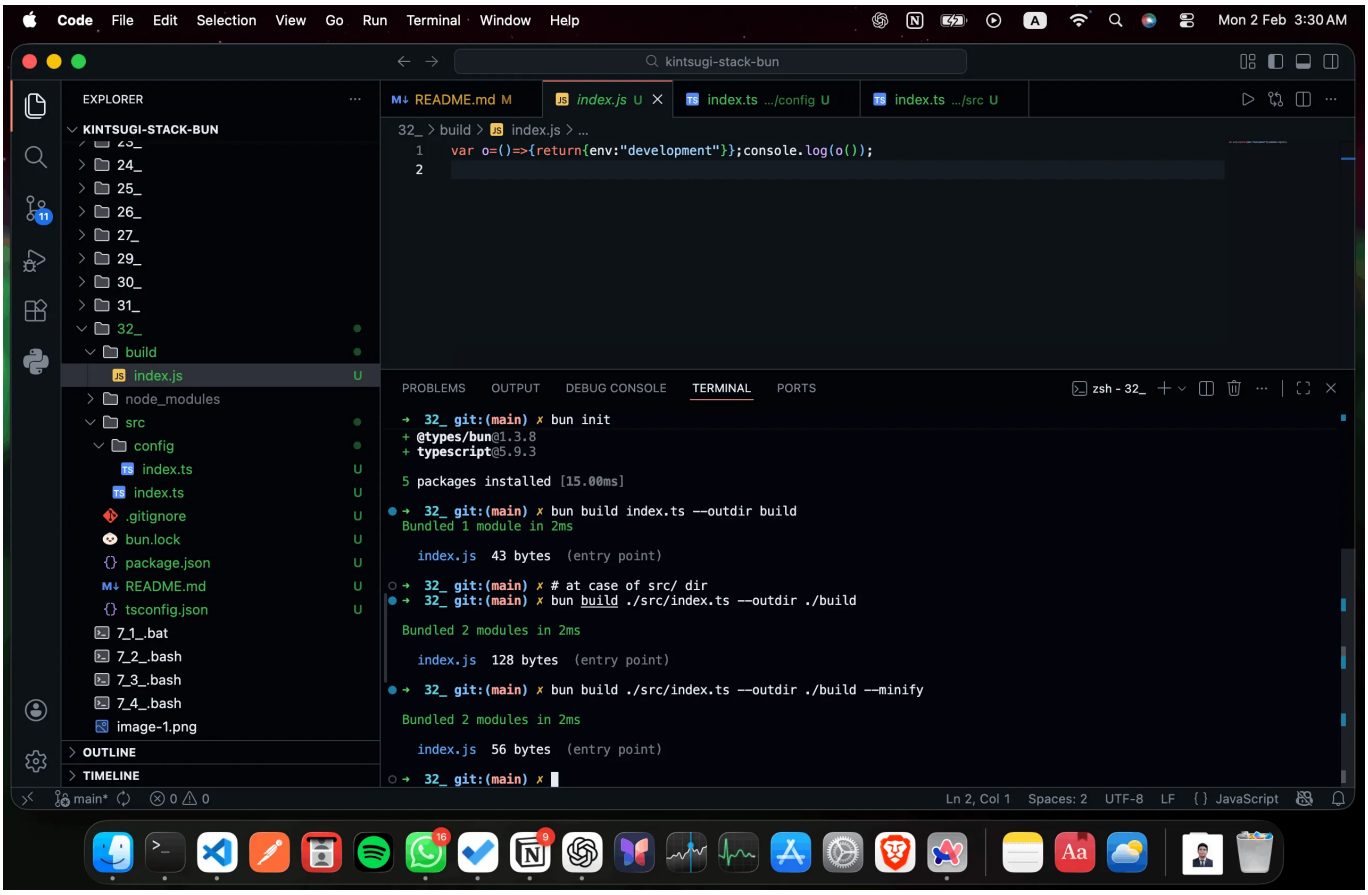
```
bun start
# Output: { env: "development" }
```



32.4. Minified Build

```
bun build ./src/index.ts --outdir ./build --minify
```

Result: Compressed, unreadable code (smaller file size)



32.5. Build Features

What Each Feature Does:

- **Single file output**: All imports bundled into one file
  - Why: Easier deployment, faster loading
  - Result: One JavaScript file contains everything needed
- **Minification**: Reduces file size
  - How: Removes whitespace, shortens variable names, strips comments
  - Benefit: Smaller download size, faster load times
  - Trade-off: Unreadable code (can't debug easily in production)
- **TypeScript compilation**: Converts .ts to .js
  - Automatic: No configuration required
  - Result: JavaScript files that run in any environment
  - Type information: Removed during compilation (types are only for development)
- **No configuration needed**: Works out of the box
  - Advantage: Simple CLI commands are enough
  - Default settings: Optimized for common use cases
  - Customization: Advanced options available if needed

---

33. Important Notes & Best Practices

33.1. Port 6000 Restriction

Chrome blocks port 6000 for security reasons. Use port 8000 or other ports instead.

What is a port?

- **Port** = Virtual "door" to your server (like apartment numbers)
- Port 80 = HTTP (default web)
- Port 443 = HTTPS (secure web)
- Port 8000, 3000, 5000 = Common for development
- Port 6000 = Reserved/blocked by some browsers

33.2. Environment Variables Best Practices

1. Use `.env.development` for development
2. Use `.env.production` for production
3. Always use `--env-file` flag in scripts
4. Add type definitions for autocomplete

33.3. Package Manager Advantages

- **Speed**: 5-10x faster than npm
- **Compatibility**: Works with npm packages (same ecosystem)
- **Built-in**: No separate installation needed
- **Why faster?** Better algorithms, parallel processing, caching

33.4. TypeScript Support

- **Zero configuration**: Works immediately
- **Type inference**: Automatic type detection
- **Fast compilation**: No separate build step
- **What TypeScript does**: Catches errors before running code (type safety)

33.5. Testing Advantages

- **No Jest dependency**: Built-in test runner (less to install)
- **Fast execution**: Optimized for speed
- **Simple syntax**: Familiar API (less to learn)

---

34. Common Patterns & Examples

34.1. API Server Template

```
type TPost = {
  id: string;
  title: string;
};

let posts: TPost[] = [];
```

```
const server = Bun.serve({
  port: Bun.env.PORT || 8000,

  routes: {
    // Health check
    "/api/health": () => new Response("OK"),

    // CRUD operations
    "/api/posts": {
      GET: () => Response.json(posts),
      POST: async (req) => {
        const body = await req.json() as Omit<TPost, "id">;
        const post = { id: crypto.randomUUID(), ...body };
posts.push(post);
        return new Response("Created", { status: 201 });
      }
    },

    "/api/posts/:id": {
      PUT: async (req) => {
        const id = req.params.id as string;
        const body = await req.json() as Omit<TPost, "id">;
        const index = posts.findIndex(p => p.id === id);

        if (index === -1) {
          return new Response("Not found", { status: 404 });
        }

        posts[index] = { ...posts[index], ...body };
        return new Response("Updated");
      },

      DELETE: (req) => {
        const id = req.params.id as string;
        const index = posts.findIndex(p => p.id === id);

        if (index === -1) {
          return new Response("Not found", { status: 404 });
        }

        posts.splice(index, 1);
        return new Response("Deleted");
      }
    },

    // Catch-all 404
    "/*": () => new Response("Not found", { status: 404 })
  },

  // Global error handler
  error(error) {
    console.error(error);
    return new Response("Internal error", { status: 500 });
```

```
  }
});

console.info(`Server running on port ${server.port}`);
```

34.2. File Operations Template

```
// Read file
const file = Bun.file("./data.json");
const exists = await file.exists();

if (exists) {
  const data = await file.json();
  console.log(data);
}

// Write file
await Bun.write("output.json", JSON.stringify({ key: "value" }));

// Copy file
await Bun.write("backup.json", Bun.file("data.json"));
```

34.3. Environment Setup Template

env.d.ts:

```
declare module "bun" {
  interface Env {
    PORT: string;
    DATABASE_URL: string;
    JWT_SECRET: string;
    NODE_ENV: "development" | "production";
  }
}
```

.env.development:

```
PORT=8000
DATABASE_URL=mongodb://localhost:27017/dev
JWT_SECRET=dev-secret
NODE_ENV=development
```

.env.production:

```
PORT=8000
DATABASE_URL=mongodb://prod-server:27017/prod
JWT_SECRET=prod-secret-key
NODE_ENV=production
```

package.json:

```
{
  "scripts": {
    "dev": "bun --watch --env-file=.env.development src/index.ts",
    "start": "bun --env-file=.env.production build/index.js",
    "build": "bun build ./src/index.ts --outdir ./build --minify"
  }
}
```

---

35. Comparison: Node.js vs Bun

Feature	Node.js	Bun
Runtime	V8 Engine	JavaScriptCore
TypeScript	Requires setup	Built-in
Package Manager	npm (separate)	Built-in
Speed	Standard	5-10x faster
Bundler	Webpack/Parcel	Built-in
Test Runner	Jest (external)	Built-in
Environment Variables	dotenv package	Built-in
Watch Mode	nodemon package	Built-in
Password Hashing	bcrypt package	Built-in

What this table means:

- **Engine** = The core that executes JavaScript (different implementations)
- More "Built-in" features = Less setup, fewer packages to install
- **"Separate"** = You have to install extra tools
- Bun bundles everything together (hence the name "all-in-one")

---

36. Conclusion

36.1. Key Takeaways:

1. **Bun is NOT a replacement for Node.js** - It's an enhancement

2. **All-in-one toolkit** - Runtime, package manager, bundler, test runner
3. **Performance** - Significantly faster than Node.js (50%+)
4. **Developer Experience** - Less configuration, more productivity
5. **Compatibility** - Can run Node.js code with minimal changes

36.2. When to Use **Bun**

- **Faster(50%+) startup & execution** than Node.js for many workloads
- **Built-in toolchain**: runtime + bundler + test runner + package manager
- **Lower memory usage** in dev and small services
- **Native TypeScript support** (no transpilation step)
- **Very fast package installs** (`bun install` often beats npm/yarn/pnpm)
- **Great for modern tooling**: CLIs, internal tools, side projects
- **Good fit for greenfield projects** where ecosystem risk is acceptable
- **Simpler DX**: fewer dependencies, fewer configs

36.3. When to Stick with **Node.js**

- **Production-critical systems** (banks, fintech, healthcare, infra)
- **Mature ecosystem** with millions of battle-tested packages
- **Full compatibility** with existing npm libraries
- **Stable, long-term support (LTS)** guarantees
- **Enterprise & cloud support** (AWS, GCP, Azure optimized)
- **Large teams** where predictability > speed
- **Legacy codebases** already built on Node
- **Compliance-heavy environments** (audits, security reviews)

37. Resources

- **Official Website**: https://bun.sh
- **Documentation**: https://bun.sh/docs
- **GitHub**: https://github.com/oven-sh/bun

End-of-File

The KintsugiStack repository, authored by Kintsugi-Programmer, is less a comprehensive resource and more an Artifact of Continuous Research and Deep Inquiry into Computer Science and Software Engineering. It serves as a transparent ledger of the author's relentless pursuit of mastery, from the foundational algorithms to modern full-stack implementation.

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