Rust Programming Language

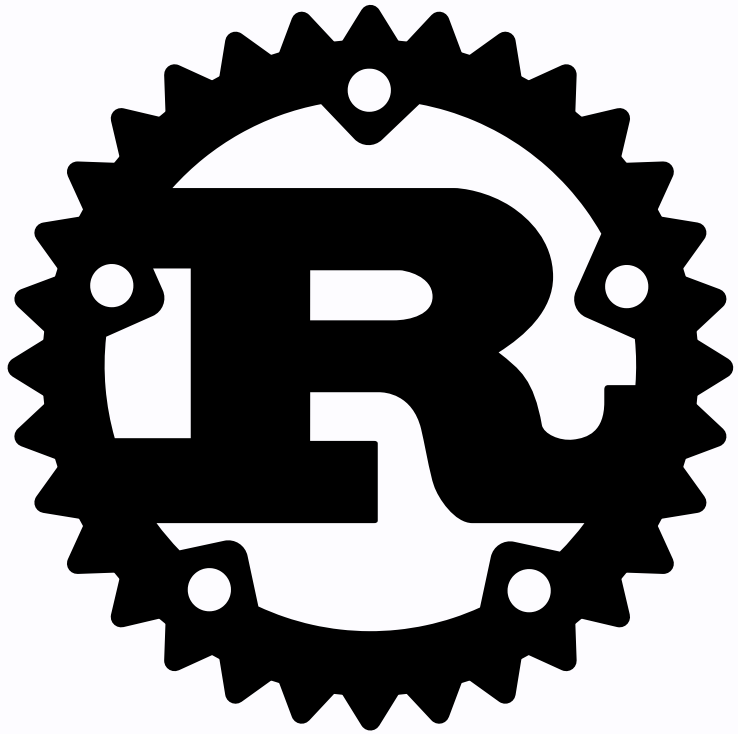
A high-level overview of the *latest* highly admired programming language by developers.

Foreword

📝 Contribute on GitHub

🔗 View Online neave.dev/rust

⬇️ Download PowerPoint and PDF



What is Rust?

Based of the
Rust Fungus.

The logo is a bike ring because most of the developers who started Rust like to ride bikes

Mascot

Ferris the Crab. When you learn Rust you become a Rustacean.

Why Rust?

Graydon Hoare created Rust as personal project while working at Mozilla Research in 2006.

He realised that memory safety bugs where likely causing the elevator to break down in his apartment building.

> It's ridiculous that we computer people couldn't even make an elevator that works without crashing!

> The short answer is that Rust solves pain points present in many other languages, providing a solid step forward with a limited number of downsides.
> Stack Overflow Blog - 2020

It's performant and memory optimized.

> Don't count your servers, make your servers count.

- Rust developers at Google are twice as productive as C++ teams

> "So we see reduced memory usage in the services that we've moved from Go ... and we see a decreased defect rate over time in those services that have been rewritten in Rust – so increasing correctness."

Make Cost a Non-Functional Requirement

> Ruby & Python are more than 50x more expensive than C++ and Rust

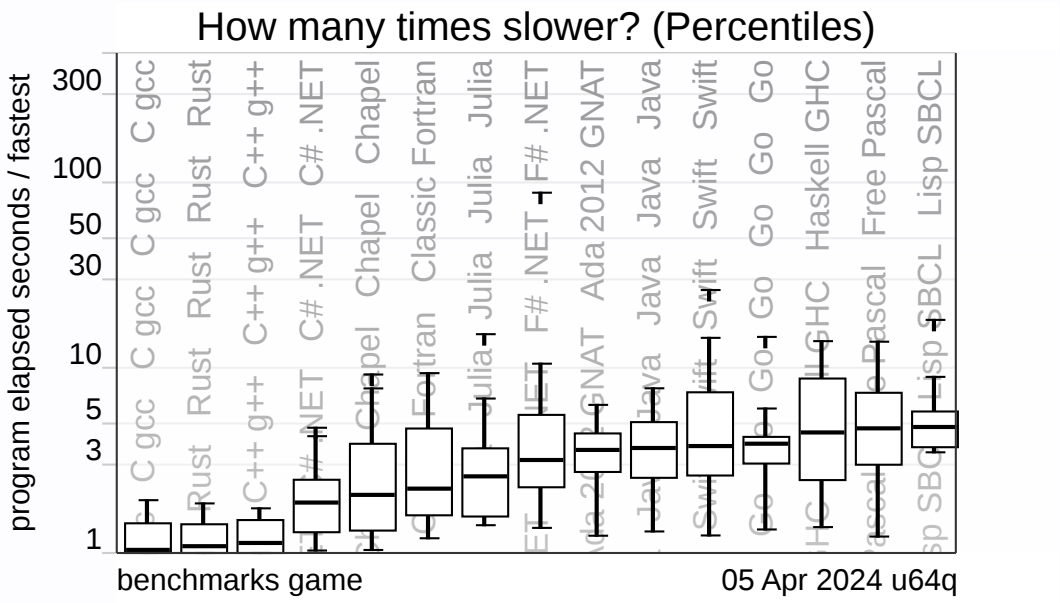
The Frugal Architect

(quoted in Why Rust? - Serverless Rust)

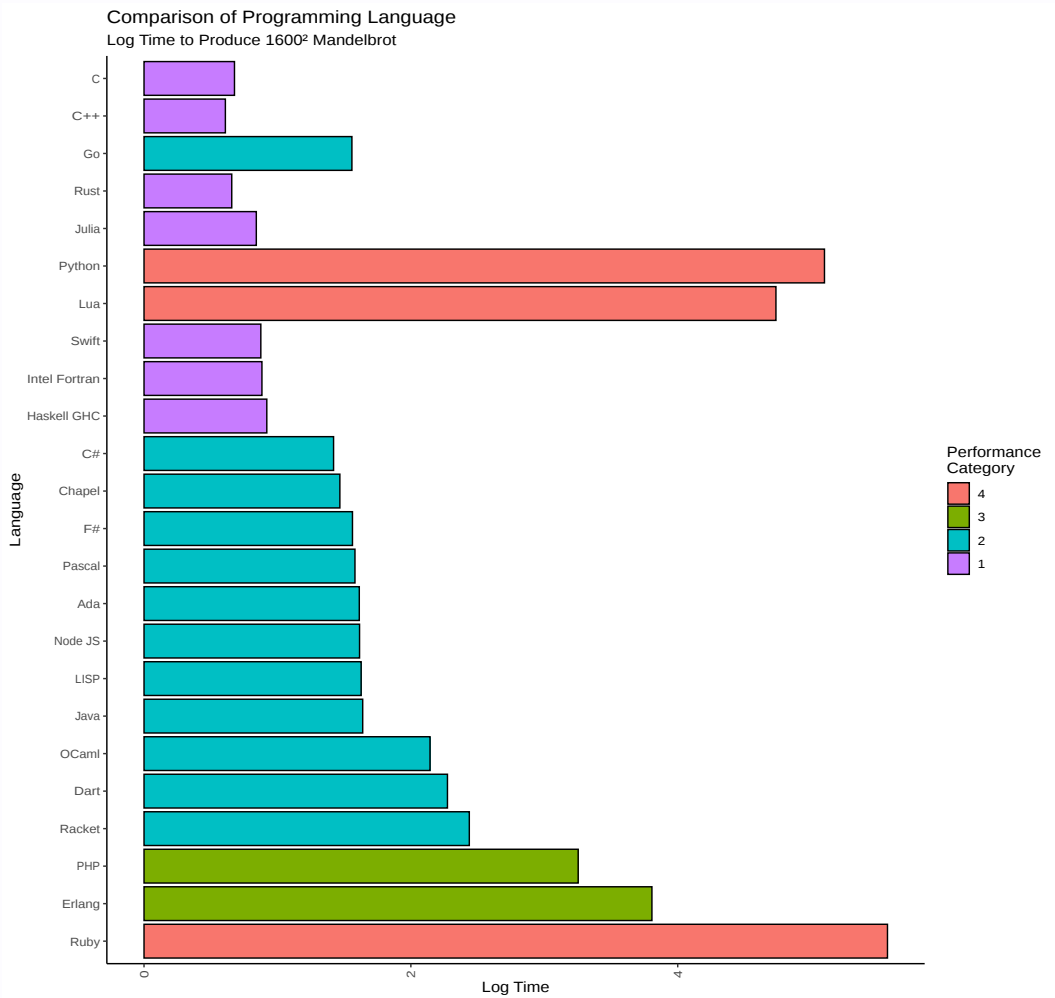
⚡ *Blazing Fast* ⚡

and *less memory*

Close to speed of C/C++.



Why Rust


Comparison of Programming Language
Log Time to Produce 1600² Mandelbrot
C
C++
Go
Rust
Julia
Python
Lua
Swift
Intel Fortran
Haskell GHC
C#
Chapel
F#
Pascal
Ada
Node JS
LISP
Java
OCaml
Dart
Racket
PHP
Erlang
Ruby
Language
0
2
4
Log Time
Performance Category
4
3
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Memory Safety

> Rust programs are unable to compile if memory management rules are violated, essentially eliminating the possibility of a memory issue at runtime.

Does not have a runtime cost of a garbage collector - instead uses Lifetimes.

Secure

Reduced security vulnerabilities*

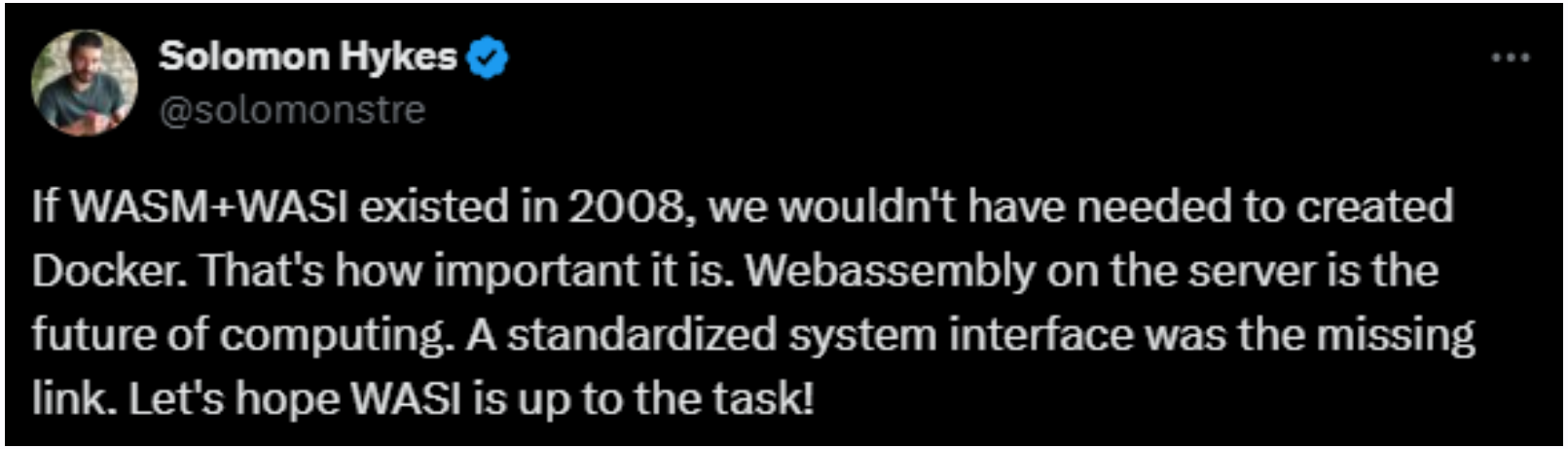
Look at memorysafety.org for some initiatives (cURL, Linux Kernel, TLS, sudo, NTP)

*20% of crates (packages) make use of unsafe keyword.

- NSA cybersecurity information sheet recommends we use memory safe languages C#, Go, Java, Ruby, Swift and **Rust**.
- The White House Office of the National Cyber Director (ONCD) called on developers to reduce the risk of cyberattacks by using **programming languages that don't have memory safety vulnerabilities**.
- TRACTOR Translating All C to Rust - The Defense Advanced Research Projects Agency (DARPA)

WASM

You can compile to WASM with Rust



Docker introduced experimental support for WebAssembly in July 2023.

Rust in the wild

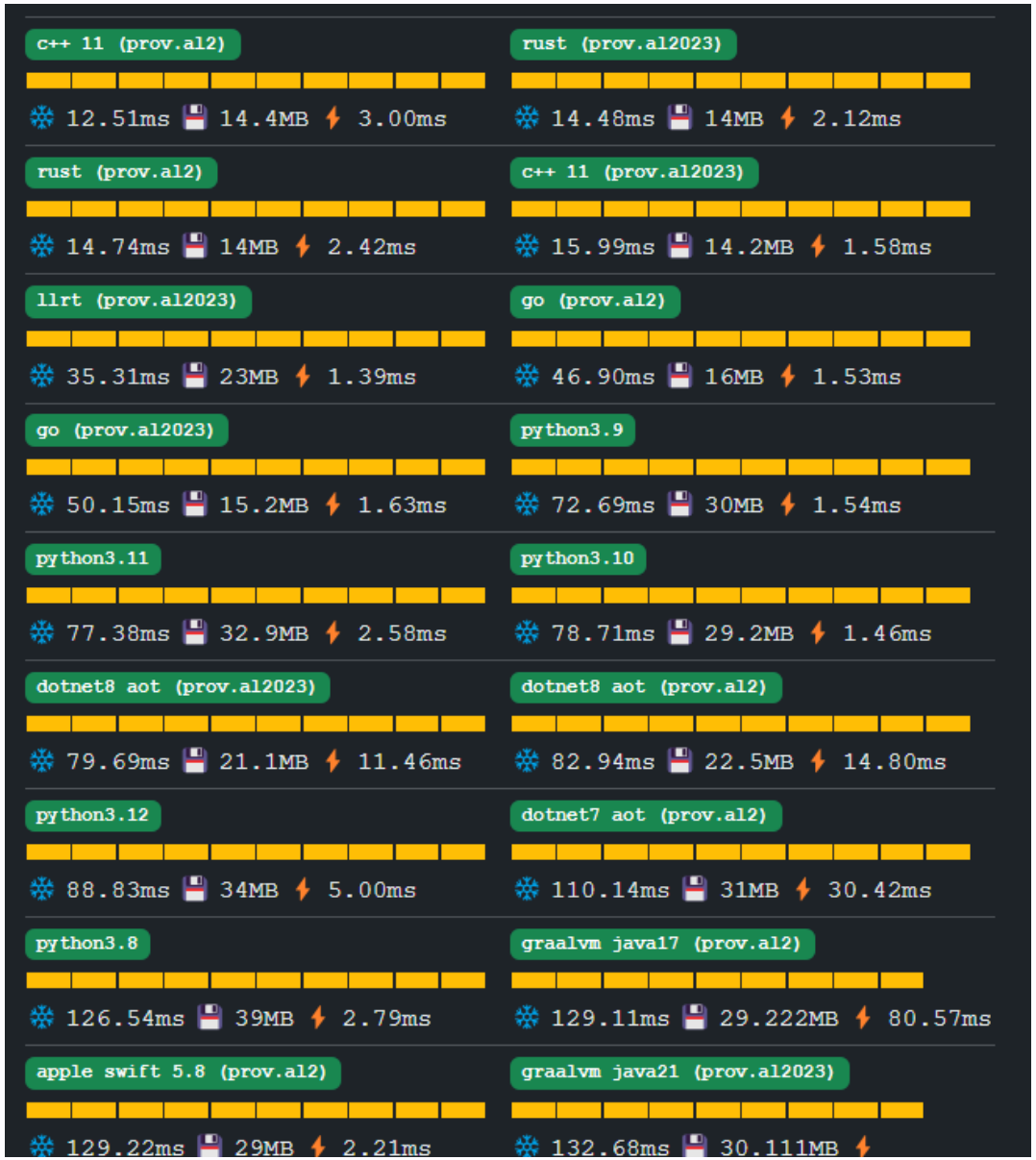
- Rust is in the Linux
- Microsoft seeks Rust developers to rewrite core C# code
- Mozilla re-focuses on Web Engine Rust based 'Servo' in 2024.

- CloudFlare open sources their http proxy (alternative to NGINX) called Pingora
- RedoxOS - Redox is a Unix-like Operating System written in Rust.
- Warp Terminal - an AI Powered Terminal
- Using WebAssembly for VS Code Extension Development
- Renault electric passenger car brand Ampere SDV platform is written in Rust.

- Zed.dev code editor. *(Not available for Windows yet)*
- Mozilla Project Oxidation is integration of Rust code into Firefox
- Rust to .NET compiler backend (experimental). Rust compiler to .NET assemblies

AWS Support

- AWS Lambda supports Amazon Linux 2023
- Cargo Lambda (see docs)
- AWS CodeArtifact now supports Cargo, the Rust package manager
- Serverless Rust - Your One Stop Shop For All Things Serverless Rust



AWS Lambda Cold Starts

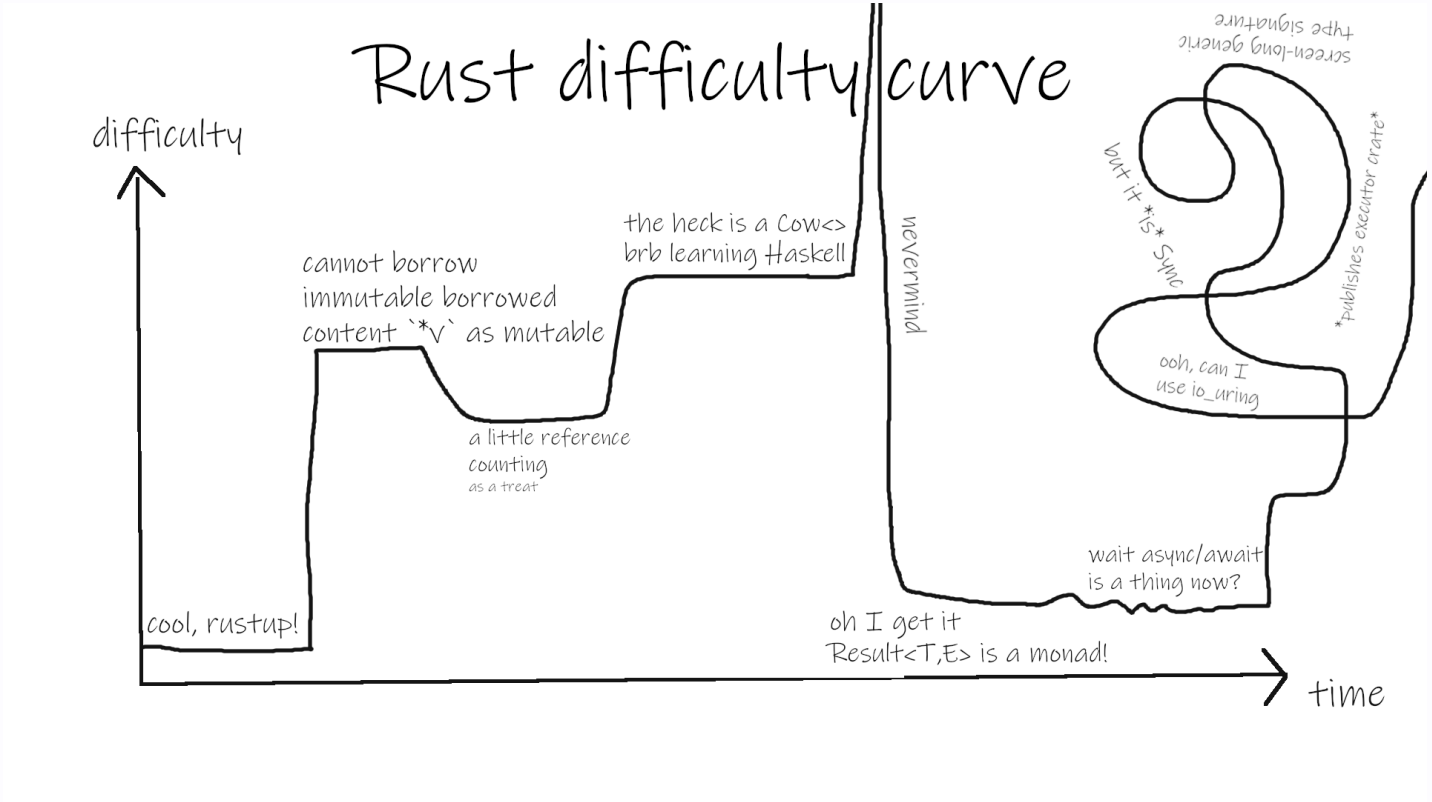
Lambda Cold Starts Benchmark

Web Development

> Yes! And it's freaking fast!
> Are We Web Yet?

- Rust has mature and production ready `frameworks` in Actix Web and Axum, and innovative ones like Warp and Tide.
- Rust can run on the browser by compiling to `WebAssembly`

Why not Rust?

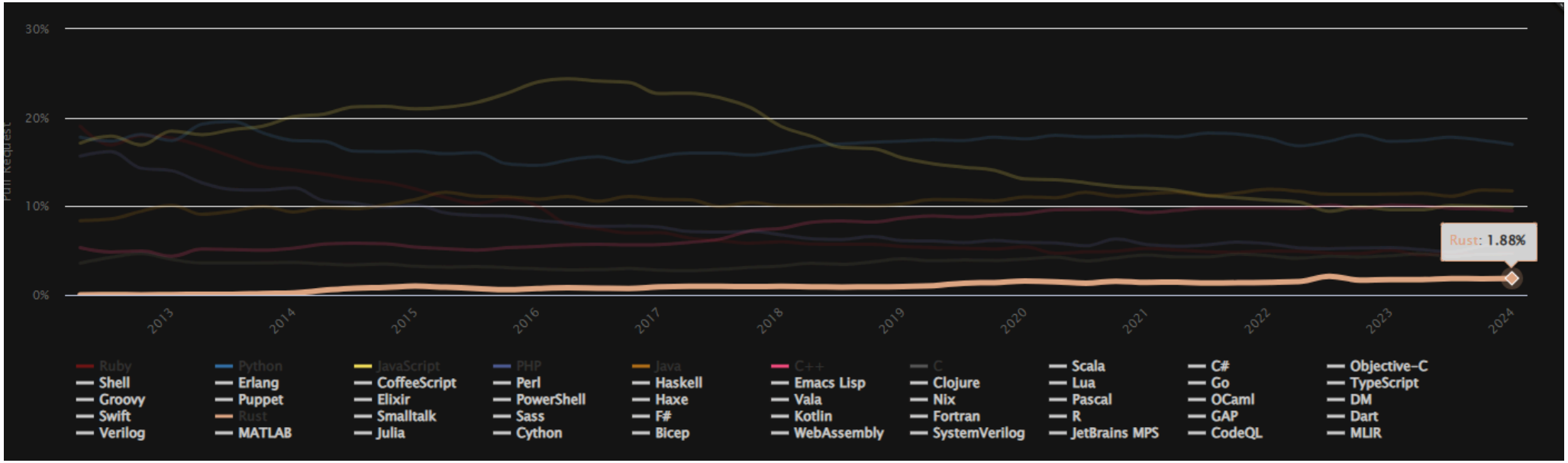


It's difficult to learn. Large cognitive load to learn.

- Limits the creative flow with it's constraints. No driving your car off the cliff for fun.
- Compiler is your friend and your foe. Lifetimes are difficult but the compiler will give you hints.
- Compile time is longer (than Go, etc) - many prefer Go (for webservers and quick prototyping)

- You want quick code to production and you are happy to have errors in production - Rust causes you to think about edge cases and errors earlier. **You pay early with Rust.**

- Not Popular - https://madnight.github.io/githut



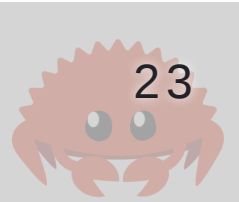
Thinking Non-Functional Requirements

✅ High maintainability - Get it right early; not later

✅ Testing - By design with unit, integration and even documentation testing

✅ Scalability - Low Memory as it's not a GC language

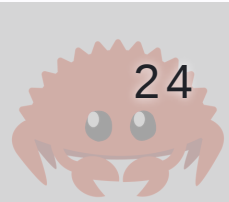
〰 Prototype - However, it encourages you to have polished code early.



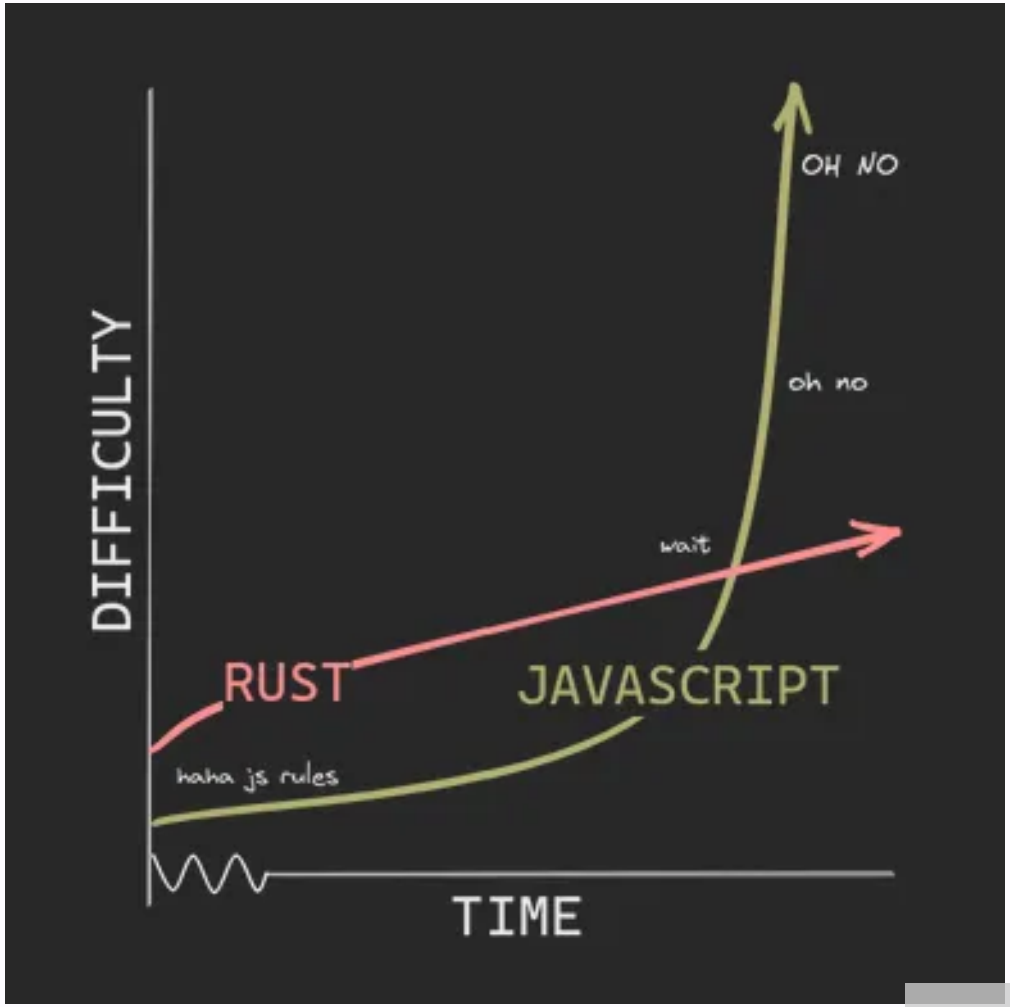
Getting Started

Great! - where do I get started? Do you want to become a Rustacean?

Official https://www.rust-lang.org/learn



> In other languages, simple things are easy and complex things are possible, in Rust simple things are possible and complex things are *easy*.

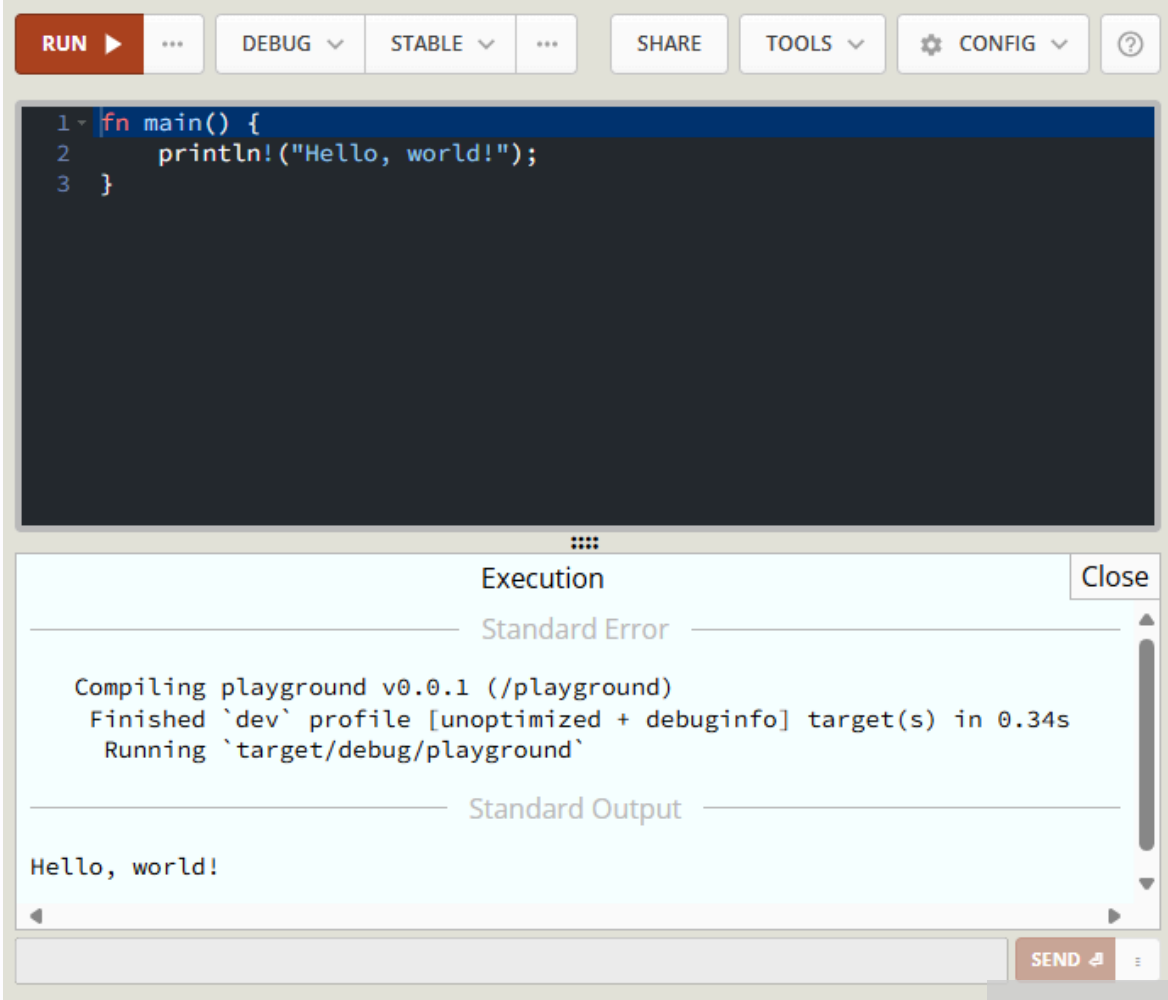


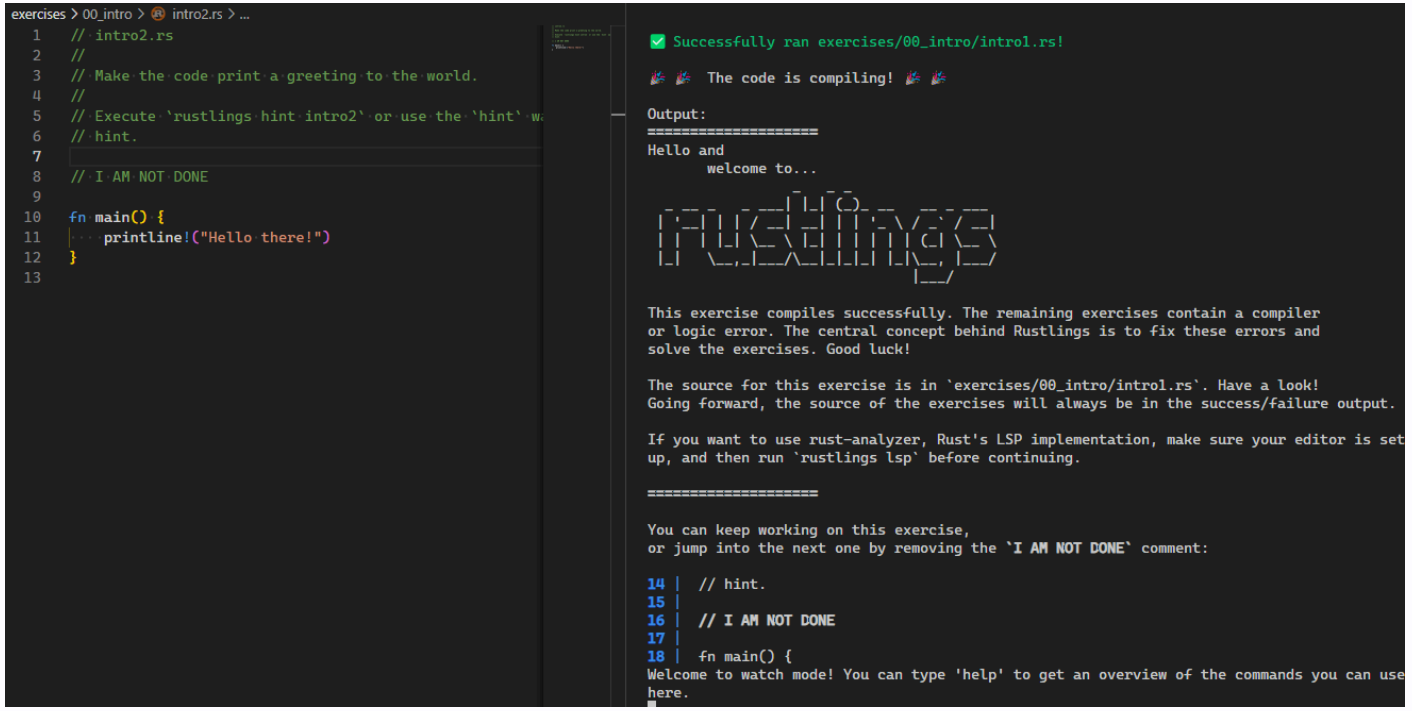
- The Book - The most comprehensive resource for learning Rust, but a bit theoretical sometimes. Available in paperback and ebook format. *You can execute the code examples within 'The Book'*
- Rust Book (Interactive) - Different version of the Rust Book, featuring: quizzes, highlighting, visualizations, and more.

- Rust by Example - Learn Rust by solving little exercises. It's almost like `rustlings`, but online
- Stay up to date with This Week in Rust - weekly newsletter and RSS Feed
- Rust Cheat Sheet

Practise

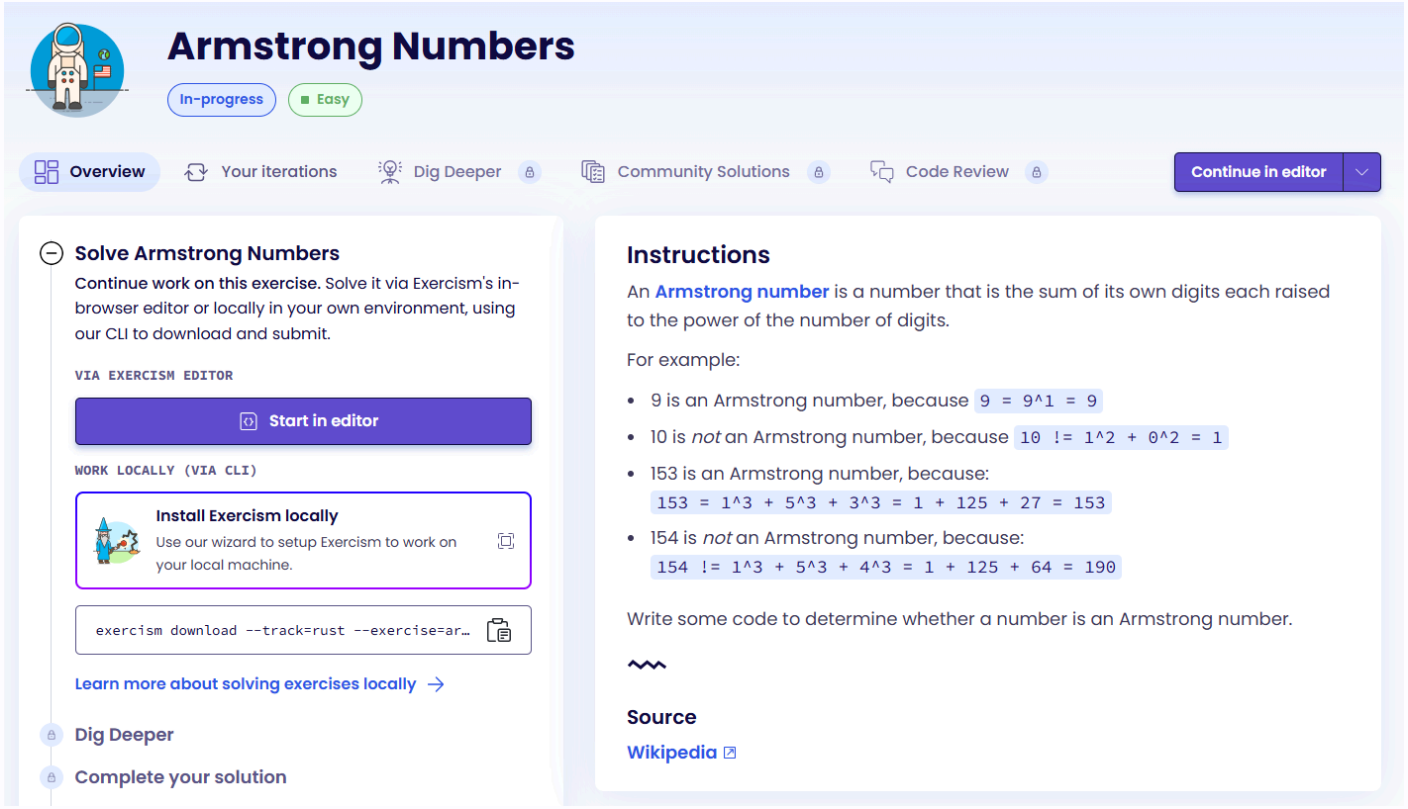
- Rust Playground - Run rust without installing anything





- Rustlings - Contains small exercises to get you used to reading and writing Rust code

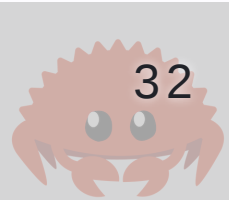
- Exercism - Rust Track - Series of exercises to learn rust



- Tour of Rust
- A half-hour to learn Rust
- Rust for C#/.Net developers
- 100 Exercises To Learn Rust
- Rustfinity
- Embedded Training
- And more...(github page)

Learn by Video (cont...)

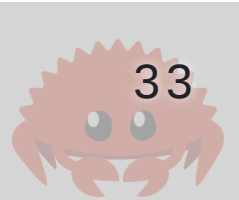
- How to Learn Rust
- Beginners Series To Rust - Microsoft Learn
- Rust First Steps - Microsoft Learn Training
- 100 Exercises To Learn Rust
- Rust In Motion (Paid)



Tools

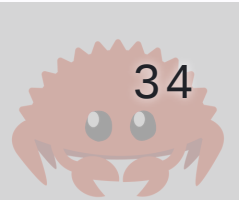
Tools

- VSCode - rust expansion pack - docs can help
- RustRover - Free for individual non-commercial
- Sublime text, Eclipse, VIM, Nano, EMACS, Visual Studio, Notepad, NeoVIM



Dev Container

Rust might be flagged by anti-virus software - develop in a dev container instead 😏



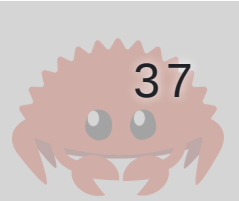
devcontainer.json

```
{
  "name": "Rust",
  "image": "mcr.microsoft.com/devcontainers/rust:latest",
  "postCreateCommand": "rustup update; curl -L https://github.com/cordx56/rustowl/releases/download/v0.1.1/install.sh | sh",
  "customizations": {
    "vscode": {
      "settings": {
        "editor.defaultFormatter": "rust-lang.rust-analyzer",
        "editor.formatOnSave": true,
        "explorer.fileNesting.enabled": true,
        "explorer.fileNesting.expand": false,
        "explorer.fileNesting.patterns": {
          "Cargo.toml": ".clippy.toml, .rustfmt.toml, Cargo.lock, clippy.toml, cross.toml, rust-toolchain.toml, rustfmt.toml"
        },
        "todo-tree.regex.regex": "(//|#|<!--|;|/\\*|^|^[ \\t]*(-|\\d+.))\\s*($TAGS)|todo!",
        "editor.inlayHints.enabled": "offUnlessPressed" //CTRL + ALT to show inlay hints
      },
      "extensions": [
        "rust-lang.rust-analyzer",
        "vadimcn.vscode-lldb",
        "dustypomerleau.rust-syntax",
        "lorenzopirro.rust-flash-snippets",
        "Swellaby.vscode-rust-test-adapter",
        "tamasfe.even-better-toml",
        "fill-labs.dependi",
        "Gruntfuggly.todo-tree",
        "usernamehw.errorlens",
        "streetsidesoftware.code-spell-checker",
        "cordx56.rustowl-vscode"
      ]
    }
  }
}
```

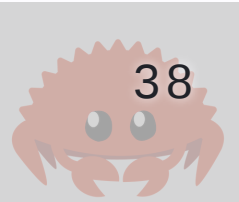
Tooling

- **Cargo** - build tool, dependency manager, test runner and project bootstrapper - rarely use `rustc`
- **RustFmt** - standardize formatter
- **Clippy** - better code feedback than the compiler
- creates.io - Rust's Packages Manager - more details at blessed.rs

Rust has large compile times due to downloading creates and compiling them into your binary.



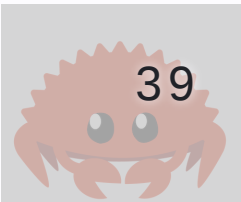
Rust Language



Installation

Install and upgrade with rustup

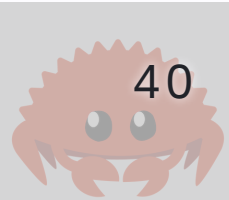
> rustup is an installer for the systems programming language Rust



Editions

2024 is the current version (Released in Feb 2025)

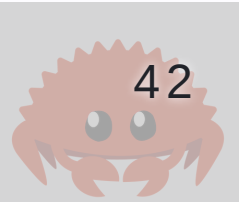
Released every three years (2015, 2018, 2021, 2024). Defaults to 2015 if you don't specify otherwise. Can have breaking changes. You can choose the edition in the Cargo.toml and choose when to upgrade. They provide tooling to automate the upgrade or use tools like RustFix to auto upgrade.



Hello World

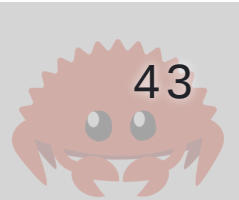
```
$ cargo new hello_world
     Created binary (application) `hello_world` package
$ cd hello_world/
$ cargo run
   Compiling hello_world v0.1.0 (/workspaces/rust/hello_world)
    Finished dev [unoptimized + debuginfo] target(s) in 1.27s
     Running `target/debug/hello_world`
Hello, world!
```

```
$ tree
.
├── Cargo.lock
├── Cargo.toml
├── src
│   └── main.rs
└── target
    └── debug
        └── hello_world //native executable

10 directories, 18 files (redacted)
```



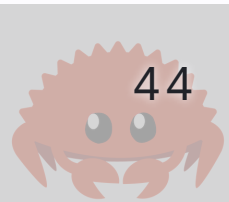
Hello World Code

```
//main.rs
fn main() {
    println!("Hello World");
}
```



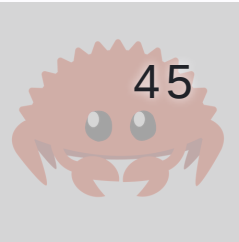
Inside `Cargo.toml` (Tom's Obvious, Minimal Language)

```
[package]
name = "my_project"
version = "0.1.0"
edition = "2024"
rust-version = "1.85"

[dependencies]
# insert dependencies here
```



How to minimize Rust binary sizes. You must build in release mode with `cargo build --release`

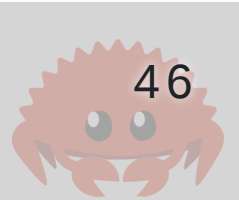
```
# Add to Cargo.toml
[profile.release]
codegen-units = 1   # Reduce number of codegen units to increase optimizations
lto = true          # Enable link-time optimization
opt-level = 'z'     # Optimize for size
panic = 'abort'     # Abort on panic
strip = true        # Strip symbols from binary
```



Rust is Complex

When compiled, macros are expanded, imports standard libraries and more

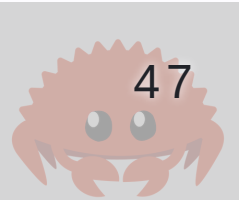
```
#![feature(prelude_import, print_internals)]
#[prelude_import]
use std::prelude::rust_2024::*;
#[macro_use]
extern crate std;
fn main() {
  {
    ::std::io::_print(format_args!("Hello, world!\n"));
  };
}
```



Syntax

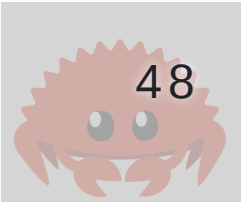
'Variables' (actually binding) - immutable by default.

```
let x = 4;        // Compiler decides
let x: i32 = 4; // Explicit Definition
let x = 4i32;    // Suffix Annotations
let long_variable_name = 1; //snake case
```



Mutating a binding

```
let mut x = 5;
println!("x = {x}");
x = 6;
println!("x = {x}");
```

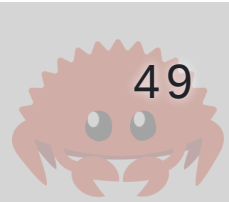


Strings

`String` - an *owned* String. It owns the data and it's responsible for freeing up the memory. It has three parts (Length, Capacity and Data Pointer)

```
let str1 = String::from("string");
let str1 = "string".to_string();
```

- UTF-8 Encoded - 1 to 4 bytes
- Non-Null-Byte Terminated
- Not a collection of characters
- There are multiple string types



String Slices

`&str` - a *borrowed* string slice - it does not own it's data, data is not freed when the value is dropped. It is a view or window (aka slice) into string data. Has two parts in memory - length and data pointer.

```
let sentence: String = String::from("This is a sentence");
let string_slice: &str = &sentence[..4];
println!("'{}'", string_slice); // 'This'
let string_slice: &str = &sentence[5..9];
println!("'{}'", string_slice); // 'is a'
let string_slice: &str = &sentence[10..];
println!("'{}'", string_slice); // 'sentence'
```

Data Types

Length	Signed	Unsigned
8-bit	i8	u8
16-bit	i16	u16
32-bit	i32	u32
64-bit	i64	u64
128-bit	i128	u128
arch	isize	usize

"arch": 64 bits if you're on a 64-bit architecture and 32 bits if you're on a 32-bit architecture.

Other types

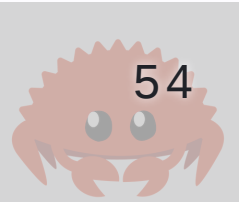
- Floating Types: `f32`, `f64`
- Boolean: `true`, `false`
- Chars
- Arrays

Tuples

```
//empty tuples are called 'unit'
let unit = (); //empty value or an empty return type.

let tuple: (bool, i32, f64) = (true, 2, 3.0);
let (b, i, f) = tuple; //destructuring
println!("{b}, {i}, {f}");
```

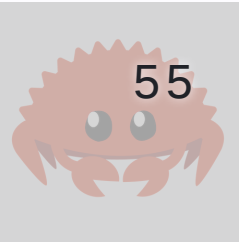
Functions

```
fn exclaim(input: String) -> String {
    let mut output = input.to_uppercase();
    output.push('!');
    output //NB: same as "return output;"
}
```



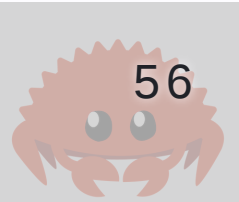
Control Flow

```
let x: i32 = -1000;

if x > 0 && x < 100 {
    println!("x has a value");
} else if x > 100 {
    println!("x is a big number")
} else {
    println!("x is negative")
}

let boolean: bool = true;
let binary: i32 = match boolean {
    false => 0,
    true => 1,
};
```



Loops

```
loop {
    //forever
}
```

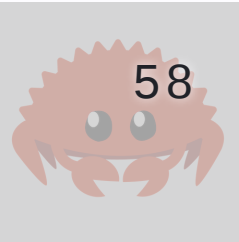


```
let mut number = 3;
while number != 0 {
    println!("{}", number);
    number -= 1;
}
println!("Lift Off!");
```

```
let a: [i32; 5] = [10, 20, 30, 40, 50];

for element in a.iter() {
    println!("the value is: {}", element);
}
```

Iterators

```
let v: Vec<i32> = [1, 2, 3].into_iter()
                           .map(|x| x + 1)
                           .rev()
                           .collect();

assert_eq!(v, [4, 3, 2]);
```



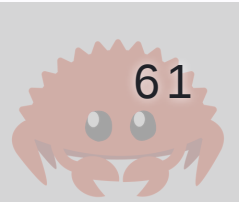
```
let strings = vec!["tofu", "93", "18"];
let numbers: Vec<_> = strings
    .into_iter()
    .filter_map(|s| s.parse::<i32>().ok())
    .collect();
println!("Results: {:?}", numbers);
```

Enums

```
enum CardinalDirections {
    North,
    South,
    East,
    West,
}

let north = CardinalDirections::North;
```

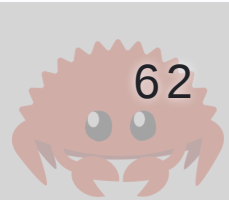
Vectors

```
let mut shopping_list: Vec<&str> = Vec::new();
//Vec<&str> not needed as the compiler can infer it from the next line
shopping_list.push("milk");
```



Structures

```
#[derive(Debug)]
struct Car {
    make: String,
    model: String,
    year: u32,
}

fn print_car(car: &Car) {
    println!(
        "Car is {} {} and was built in {}",
        car.make, car.model, car.year
    );
}
```



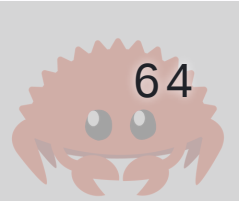
Formatting for structs

```
println!("{:?}", car1); //Single line - good for small structs
//Car { make: "Ford", model: "Mustang", year: 1967 }

println!("{:#?}", car1); //Multiple line - good for larger structs
/*
Car {
    make: "Ford",
    model: "Mustang",
    year: 1967,
}
*/

dbg!(&car1); //Multiple lines - includes line of code for debugging purposes
```

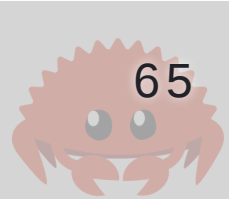
Traits

A trait defines functionality a particular type has and can share with other types. We can use traits to **define shared behaviors in an abstract way**. We can use trait bounds to specify that a generic type can be any type that has certain behaviors.

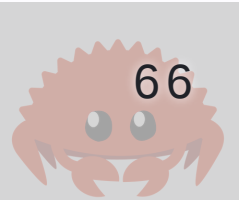
Allows for **Polymorphism by default**. Traits are like **interfaces** with some differences. Forces **early abstraction** - which can be good and bad.



```
struct Film {
    title: String,
    director: String,
    studio: String,
}

trait Catalog {
    fn describe(&self) {
        println!("We need more information about this type of media")
    }
}

impl Catalog for Film {
    fn describe(&self) {
        println!(
            "{} was directed by {} through {} studio",
            self.title, self.director, self.studio
        );
    }
}
```

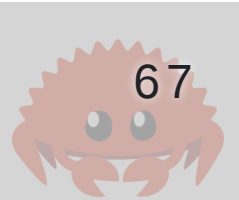


```
fn main() {
    let captain_marvel = Film {
        title: String::from("Captain Marvel"),
        director: String::from("Anna Boden and Ryan Fleck"),
        studio: String::from("Marvel"),
    };

    captain_marvel.describe();
}
```



Error Handling

```
panic!("at the disco"); //🪩🕺
```



Result Enum

Used for recoverable errors that are more common.

```
pub enum Result<T, E> {
    Ok(T),
    Err(E),
}
```

Rather than having at catch and only catching specific exceptions. Return a custom error enum and the caller to your function has to handle all types of errors.

Result Example

```
// #1
let f = File::open("hello.txt");
let f = match f { //shadow variable
    Ok(file) => file,
    Err(error) => panic!("Can't open the file: {:?}", error),
};

// #2
let f = File::open("hello.txt").unwrap();
//Returns the value inside the OK variant.
//Returns a panic! macro for the Err variant. Default error message of 'No such file or directory'.

// #3
let f = File::open("hello.txt").expect("Failed to open hello.txt");
//allows us to write a detailed error message when it returns a panic! macro.
//You 'expect' it to work but if you are wrong then you get a loud failure.
```

Idiomatic Solution Example

```
result.is_some() ❌

match result { 👌
      Ok => ...
      Err => ...
}

result? ✅
```

```
let mut file = match File::create("my_best_friends.txt") {
    Ok(f) => f,
    Err(e) => return Err(e),
};
```

```
let mut file = File::create("my_best_friends.txt")?;
//Unwraps the value if Ok variant and returns an error if Err variant
```

No Nulls 🥳

Does not use Nulls but instead uses a `Option of type T` return that either gives you a value of type T or None - which you can match on.

```
pub enum Option<T> {
    Some(T),
    None,
}
```

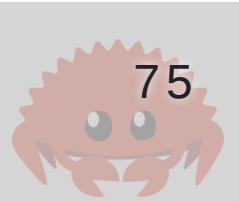
It describes the possibility of an absence of a value.

```
// An integer division that doesn't `panic!`
fn checked_division(dividend: i32, divisor: i32) -> Option<i32> {
    if divisor == 0 {
        // Failure is represented as the `None` variant
        None
    } else {
        // Result is wrapped in a `Some` variant
        Some(dividend / divisor)
    }
}
```

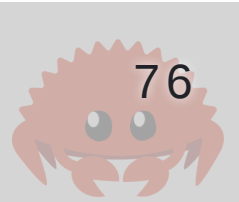
```
fn try_division(dividend: i32, divisor: i32) {
    // `Option` values can be pattern matched, just like other enums
    match checked_division(dividend, divisor) {
        None => println!("{} / {} failed!", dividend, divisor),
        Some(quotient) => {
            println!("{} / {} = {}", dividend, divisor, quotient)
        },
    }
}
```

Rules of Ownership

- Each value in Rust has a variable that is called it's *owner*
- There can only be *one owner* at a time
- When the owner goes *out of scope*, the *value* will be dropped.



- Ownership - have to add `mut` and add `pub` public keywords
  - Each piece of data has one owning variable.
  - Owner is responsible for cleaning up that data
  - Clean up happens when the owner goes out of scope `{ }`
  - The owner decides on mutability



- Ownership is more than memory
  - Socket management (GC doesn't release unused sockets)
  - Mutex, RC, File, our own struts that implement `Drop` trait - `drop(&mut self)`

This does not compile

```
fn main() {
    let s1 = String::from("hello");
    let s2 = s1;

    println!("{}, world!", s1);
}
```

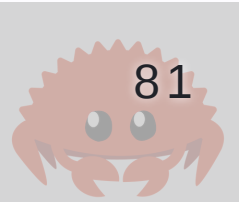
Compiler message

```
error[E0382]: borrow of moved value: `s1`
 --> src/main.rs:5:28
  |
2 |     let s1 = String::from("hello");
  |         -- move occurs because `s1` has type `String`,
  |                  which does not implement the `Copy` trait
3 |     let s2 = s1;
  |              -- value moved here
4 |
5 |     println!("{}, world!", s1);
  |                            ^^ value borrowed here after move
  |
  | help: consider cloning the value if the performance cost is acceptable
  |
3 |     let s2 = s1.clone();
  |                ++++++++
```


Borrowing

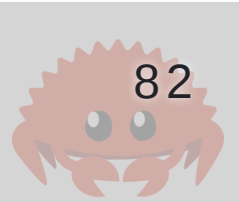
- Borrowing is the most idiomatic solution. Get access data without taking ownership over it.
  - Avoids cloning as that uses extra memory and time unnecessarily
  - Catches issues at compile time
    - C: Segment on fault
    - JavaScript: Undefined is not a function

```
fn main() {
    let s1 = String::from("hello");
    let s2 = &s1; //borrow here with &

    println!("{}, world!", s1);
    println!("{}, world!", s2);
}
```



Unit Tests

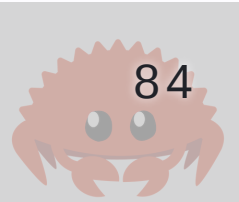
Unit tests exercise different parts of a library separately and can test private implementation details.



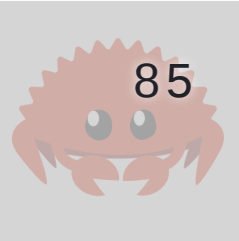
```
pub fn is_even(num: i32) -> bool {
    num % 2 == 0
}

#[cfg(test)]
mod tests {
    use super::*;

    #[test]
    fn is_true_when_even() {
        assert!(is_even(2));
    }
}
```

Integration Tests

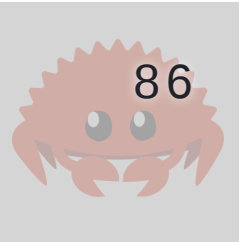
Integration tests check that many parts of the library work together correctly, and they use the library's public API to test the code in the same way external code will use it.



```
pub struct Pizza {
    pub topping: String,
    pub inches: u8,
}

impl Pizza {
    pub fn pepperoni(inches: u8) -> Self {
        Pizza::bake("pepperoni", inches)
    }

    pub fn mozzarella(inches: u8) -> Self {
        Pizza::bake("mozzarella", inches)
    }

    fn bake(topping: &str, inches: u8) -> Self {
        Pizza {
            topping: String::from(topping),
            inches,
        }
    }
}
```

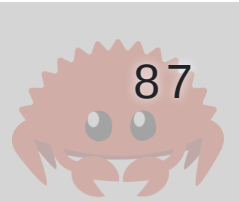


```
use integration_tests::Pizza;

#[test]
fn can_make_pepperoni_pizza() {
    let pizza = Pizza::pepperoni(12);
    assert_eq!(pizza.topping, "pepperoni");
    assert_eq!(pizza.inches, 12);
}

#[test]
fn can_make_mozzarella_pizza() {
    let pizza = Pizza::mozzarella(16);
    assert_eq!(pizza.topping, "mozzarella");
    assert_eq!(pizza.inches, 16);
}
```



SQL Unit Test

SQL is actually run at compile time in a transaction to ensure that the SQL is valid and then rolled back



Document Tests

Rust will run tests within the documentation

```
/// ```
/// let result = document_tests::add(2, 3);
/// assert_eq!(result, 5);
/// ```
pub fn add(a: i32, b: i32) -> i32 {
    a + b
}
```

Run `cargo test` and check the output

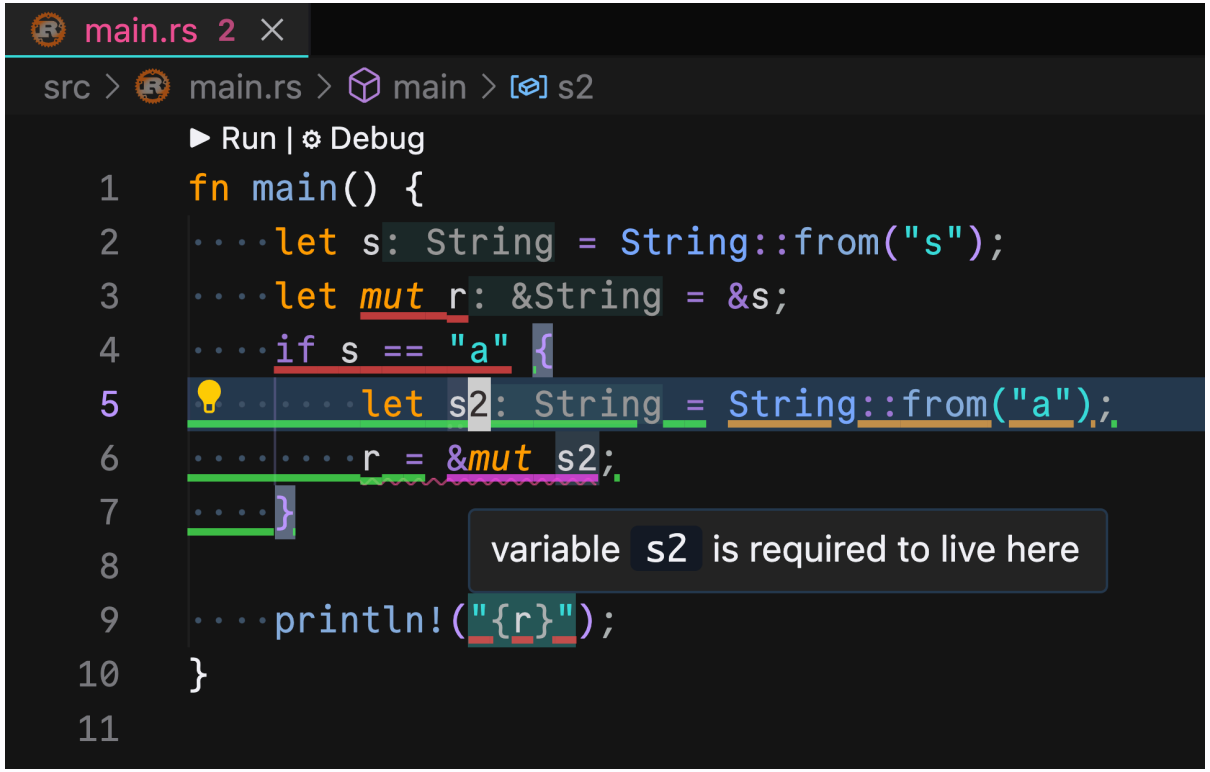
Lifetimes

`'a` is the lifetime annotation for our value x. `'b` is the lifetime annotation for our value y.

```
fn main() {
    let x;                    // ----------+-- 'a
    {                         //           |
        let y = 42;           // -+-- 'b   |
        x = &y;               //  |        |
    }                         // -+        |
    println!("x: {}", x); //              |
}
```

Visualize Lifetimes with RustOwl

- green: variable's actual lifetime
- blue: immutable borrowing
- purple: mutable borrowing
- orange: value moved / function call
- red: lifetime error - diff of lifetime between actual and expected



Other languages

Rust bindings for Python, including tools for creating native Python extension modules. Running and interacting with Python code from a Rust binary is also supported. https://github.com/PyO3/pyo3

Controversy

- Leadership issues - Rust Foundation created
- Trademark Policies
- Choice of Malware writers (ie RustDoor)

Conclusion

Rust is everywhere - including Elevators.