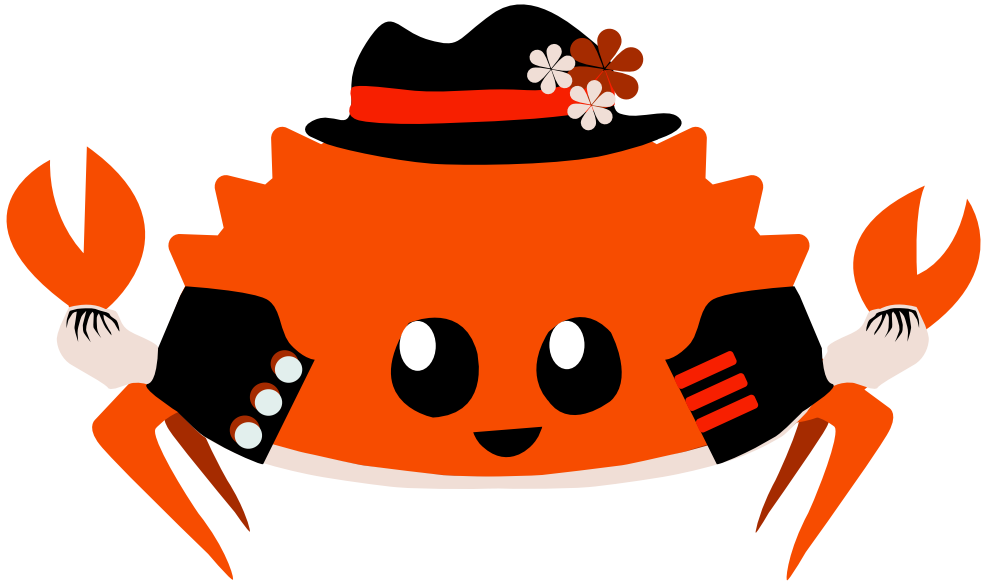


Rust Moravia

Functional Programming in Rust

github.com/tencek/rust-fp

Pavel Kučera (*1983)

- C++ developer since ~2006
- C#/.NET developer since ~2015
- Fan of FP since ~2018 (F#)
- Fan of Rust since 2023

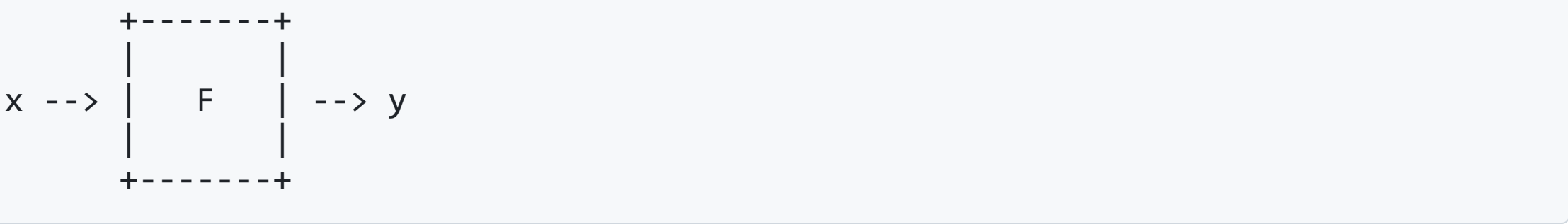
Rust and FP

Let's see which FP features we can use in Rust.

What is Functional Programming?

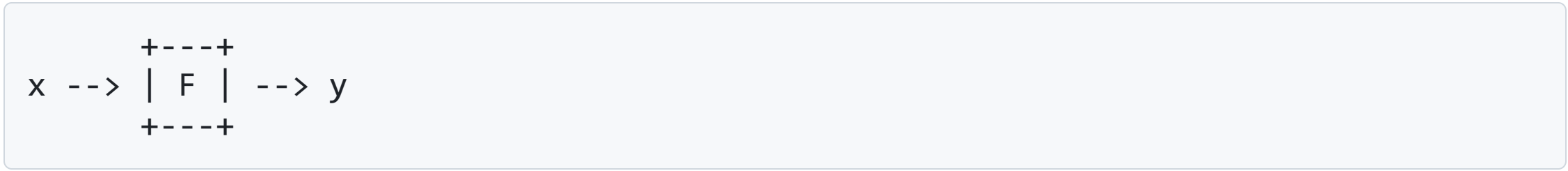
- Function is a basic building block
- Function is a "first class citizen" so a function can be
  - called (obviously)
  - assigned to a variable / expression and call by name
  - passed as an argument
  - returned from another function
  - composed

What is a Function?



- A "box"
- Single input, Single output
- Every input produces an output (**totality**)
- Same input => same output (**stateless**)
- No side effects (**immutability**)

Quite an limitation! (For good reasons, FPs believe)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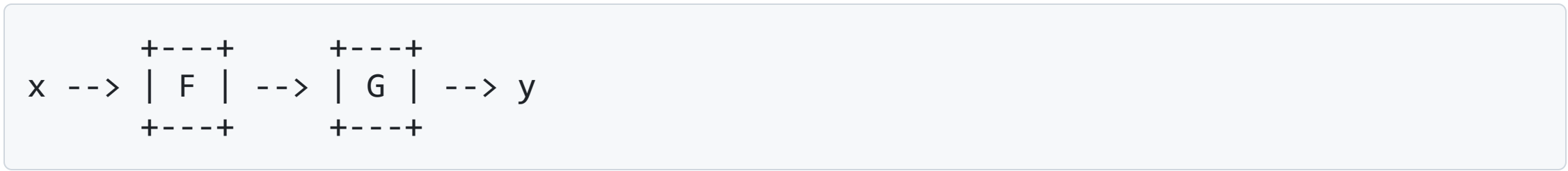
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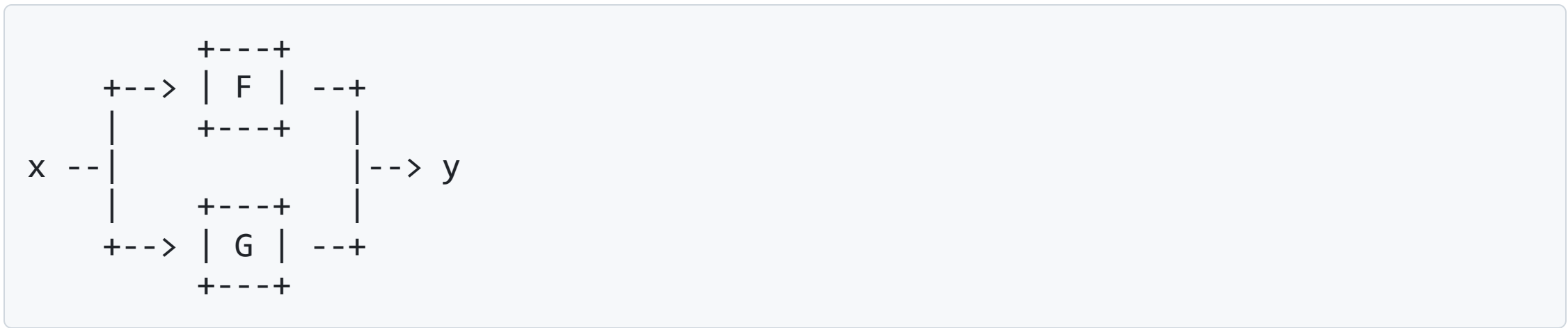
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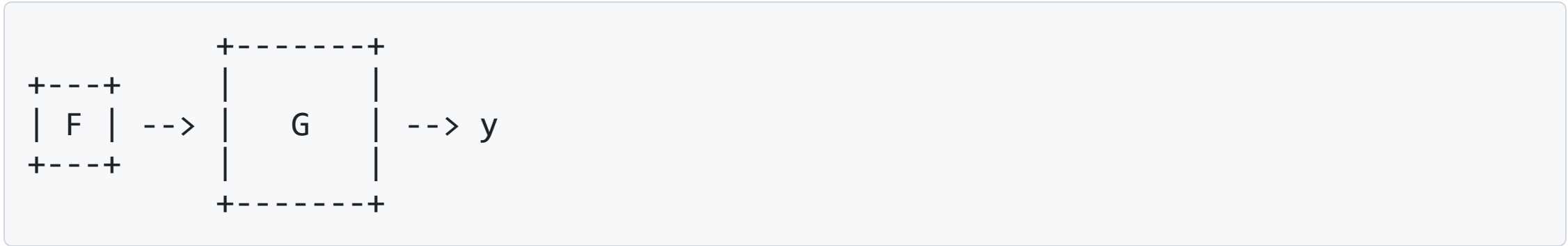
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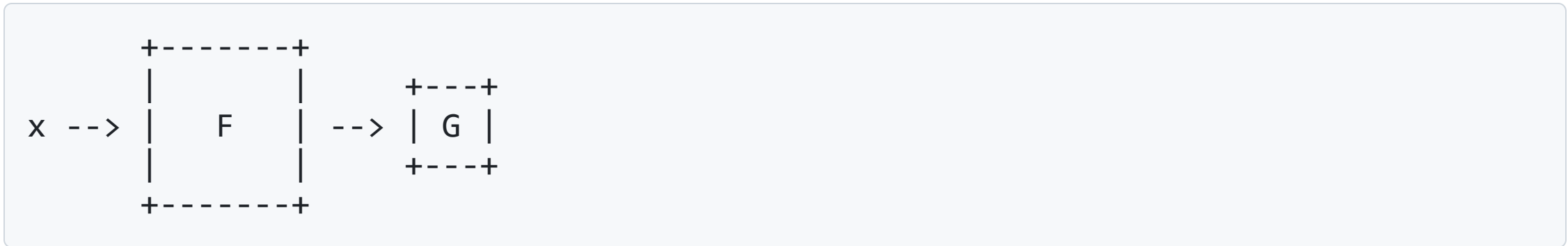
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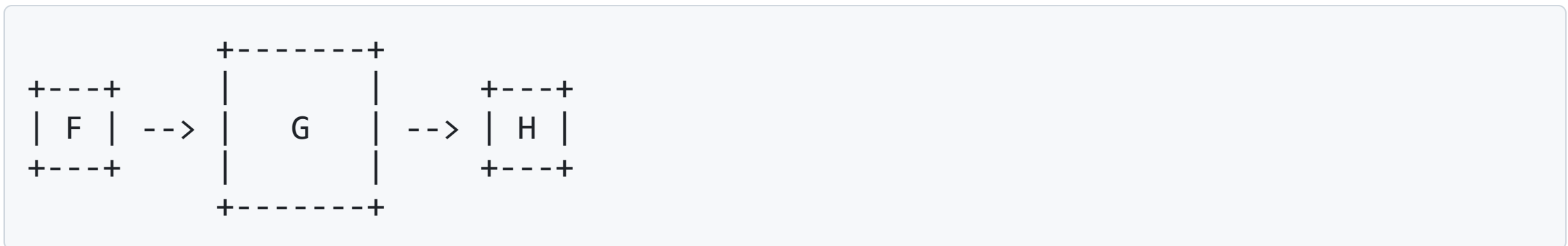
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H

01 - `let`

- **Nechť** (Czech for "let")
- Originates from LISP
- Resembles mathematics
- **immutable** by default (not a "variable")
- Expressions over statements
- keywords in other languages: `var`, `Dim`, `def`, `set`, `my`
  - `let` is a good choice (-:

01 - `let` - shadowing

```
#[test]
fn test_coffee_machine() {
    let coffee_machine = CoffeeMachine::from(CoffeeMachineSettings::default());
    let coffee_machine = coffee_machine.with_small_size();
    let coffee_machine = coffee_machine.with_max_strength();

    let coffee = coffee_machine.brew();
    assert!(coffee.is_ok());

    let coffee = coffee.unwrap();
    assert_eq!(coffee.water_ml, 30);
    assert_eq!(coffee.caffeine_mg, 40);
}
```

01 - `let`

Summary

- `let` keyword
- immutable
- shadowing (expression evaluation)

💚 A++

demo_01_let.rs

02 - partial (non-total) functions

Recap

- Every input produces an output (**totality**)
- What if not?
- Partial function == undefined behavior

Example

```
// Undefined behavior if bean_weight_mg == 0
pub fn count_beans(portion_weight_mg: i32, bean_weight_mg: i32) -> i32 {
    portion_weight_mg / bean_weight_mg
}
```

02 - partial (non-total) functions

- Rust behavior - panics
- many languages (F# included) have some sort of exceptions

Solution in rust

The only option in Rust is to create a total function instead:

```
pub fn count_beans(portion_weight_mg: i32, bean_weight_mg: i32) -> Option<i32> {
    portion_weight_mg.checked_div(bean_weight_mg)
}
```

- Client code is forced to check the returned `Option`
- The `checked_div` is a Rust `std` function. There are others as well for intiger overflow, string parse, etc.

02 - partial (non-total) functions

Summary

- Rust is even more FP than e.g. F#

💚 A++

demo_02_partial_fn.rs

Algebraic data types

- Sum type
- Product type
- Tuple
- unit type
- Newtype
- type alias
- ...

`enum` - the sum type

- So called **Discriminated union**
- The **OR** type
- `enum` is not a great name but who cares
- Different kinds of enum variants
- Exhaustive pattern matching

example

```
pub enum CoffeeOrder {
    Instant3In1,                                  // the unit variant
    Espresso { size: Size, strength: Strength }, // the struct variant
    PourOver(Temperature, Time),                  // the tuple variant
    Other(BrewingMethod),                         // another enum inside
}
```

`enum` - why sum type?

- The cardinality (number of possible values) are the sum of the cardinalities of all the variants

Quiz I

What is the cardinality of `Bean` type?

```
pub enum Bean {
    Arabica,
    Robusta,
    Blend(BlendType),
}

pub enum BlendType { Arabica50Robusta50, Arabica40Robusta60, Arabica60Robusta40 }
```

`enum` - pattern matching

```
impl Display for CoffeeOrder {
    fn fmt(&self, f: &mut Formatter) -> fmt::Result {
        match self {
            CoffeeOrder::Instant3In1 => write!(f, "Instant 3-in-1 coffee"),
            CoffeeOrder::Espresso { bean, strength } => write!(
                f,
                "Espresso with {:?} beans and {:?} strength",
                bean, strength
            ),
            CoffeeOrder::PourOver(temperature, time) => {
                write!(f, "Pour-over at {}°C for {} seconds", temperature, time)
            }
            CoffeeOrder::Other(method) => write!(f, "Other method: {:?}", method),
        }
    }
}
```

`struct` - the product type

- Also called **record**
- The **AND** type
- destructuring
- exhaustive pattern matching

example

```
pub struct Espresso {
    pub size: Size,
    pub strength: Strength,
    pub milk: Option<Milk>,
}
```

`struct` - why product type?

- The cardinality (number of possible values) is the product of cardinalities of all the fields

Quiz II

What is the cardinality of `Espresso`?

```
pub struct Espresso { pub size: Size, pub strength: Strength }

pub enum Size     { Small, Medium, Large, ExtraLarge }
pub enum Strength { Light, Medium, Strong }
```

`struct` - destructuring

```
pub fn make_espresso(espresso: Espresso) -> Coffee {
    let Espresso {
        size,
        strength,
        milk,
    } = espresso;

    todo!("Let's make it!")
}
```

tuples

- anonymous structs
- mainly for intermediate results
- exhaustive pattern matching
- destructuring

```
pub fn choose_cup_color(espresso: Espresso) -> String {
    let color_args = (espresso.size, espresso.strength);
    let cup_color = match color_args {
        (Size::Small, Strength::Strong) => "black",
        (Size::Medium, Strength::Strong) => "red",
        (Size::Large, Strength::Strong) => "brown",
        _ => "white",
    };
    cup_color.to_string()
}
```

03 - Algebraic data types

Summary

- **AND** and **OR** types
- The **New type** idiom
- Destructuring
- Pattern matching
- A struct in an enum

💚 **A++**

demo_03_algebraic_data_types.rs

04 - Currying, partial application

Cuurrying and partial aplication

Motivation

- Function has single input
- "I want more!" (-:
- A function can return a function...

Currying

- Named after Haskell Brooks Curry
- *F(x,y,z) => F(x)(y)(z)*
- What is it good for? **Partial application**.
- in FP languages, the currying is automatic
- in Rust, currying is not automatic
- We can make it manually
- We can use macros

Partial application

- Create a function G out of function F by fixing some of F's arguments
- Can utilize **Currying** if available
- May be done manually as well
- Examples
  - Building web requests (fixing base url)
  - Logging (fixing severity)
  - Making a coffee

Partial application - no currying

```
// standard function, no cyrrying
pub fn make_espresso(strength: Strength, size: Size) -> Espresso {
    Espresso { strength, size }
}
```

```
let espresso = make_espresso(Strength::Strong, Size::Small);
```

```
let make_strong = |size| make_espresso(Strength::Strong, size);

let strong_small = make_strong(Size::Small);
let strong_medium = make_strong(Size::Medium);
let strong_large = make_strong(Size::Large);
```

Partial application - manual currying

```
// curried function
pub fn make_espresso(strength: Strength) -> impl Fn(Size) -> Espresso {
    move |size| Espresso { strength, size }
}
```

```
let espresso = make_espresso(Strength::Strong)(Size::Small);
```

```
let make_strong = make_espresso(Strength::Strong);
let espresso_small = make_strong(Size::Small);
let espresso_medium = make_strong(Size::Medium);
let espresso_large = make_strong(Size::Large);
```

Does not work for more than 2 arguments - #99697

Partial application - `curried` crate

```
use curried::curry;

#[curry]
pub fn make_espresso(beans: Beans, strength: Strength, size: Size) -> Espresso {
    Espresso { beans, strength, size, }
}

let make_robusta = make_espresso(Beans::Robusta);
let make_strong_robusta = make_robusta(Strength::Strong);

let strong_small = make_strong_robusta(Size::Small);
let strong_medium = make_strong_robusta(Size::Medium);
let strong_large = make_strong_robusta(Size::Large);
```

Utilizes `Box<dyn FnOnce>`

Does not work either - because of `FnOnce`.

04 - Currying, partial application

Summary

- Currying not supported natively
  - Workarounds exists but are limited
- Partial application possible, though

💛 B-

demo_04_partial_application.rs

demo_04_curried.rs

Recap

Pure function, Total function, immutability, `let`, shadowing, partial functions, sum type, product type, tuple, pattern matching, destructuring, cardinality, currying, partial application,

05 - Todo

```
todo!("Recursive types")
todo!("new type")
todo!("unit type")
todo!("Higher order functions")
todo!("Function composition")
todo!("Function passing")
todo!("Recursion")
```

06 - Q/A

github.com/tencek/rust-fp