# Macros

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# Attendance

https://forms.gle/qofgCg7VDTnfGpQ87

# Outline

# Macros in Other Languages

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What are the uses of macros?

# C(++) Macros

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- constant expressions

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… but this system is a bit unwieldy

# Real C Code, Written by Real C Programmers

```
LOCAL VOID      gsort(from,to)
        STRING          from[], to[];
{
        INT             k, m, n;
        REG INT         i, j;

        IF (n=to-from)<=1 THEN return FI

        FOR j=1; j<=n; j*=2 DONE

        FOR m=2*j-1; m/=2;
        DO  k=n-m;
            FOR j=0; j=0; i-=m
                DO  REG STRING *fromi; fromi = &from[i];
                    IF cf(fromi[m],fromi[0])>0
                    THEN break;
                    ELSE STRING s; s=fromi[m]; fromi[m]=fromi[0]; fromi[0]=s;
                    FI
                OD
            OD
        OD
}
```

# Pitfalls

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```c
#define TWO 1 + 1

int main() {
    printf("%d\n", 2 * TWO);
    return 0;
}
```

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# Lexing

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fn main() {
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into a list of tokens:

```
FN IDENT LPAREN RPAREN LCURLY LET IDENT EQ INT_LIT SEMICOLON RCURLY
```

# Syntax Trees

Once we have a list of tokens:

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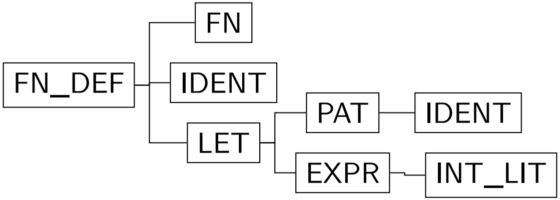
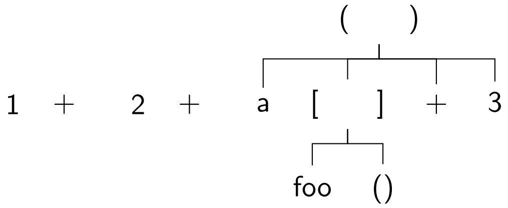



This is an abstract syntax tree (AST).

# Token Trees

This isn't the only way to parse tokens into trees though!

```
1 + 2 + (a[foo()] + 3)
```




Rust macros will primarily operate on token trees, but we also need to be aware of the AST.

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Broadly speaking there are 3 (or 4) different syntaxes for using macros in Rust:

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- Inner attributes, e.g., `#![warn(rust_2018_idioms)]`.

Why (or 4)? There's a special internal syntax-extension syntax we'll see later, but it's currently only used by some compiler built-ins (`macro_rules!`).

# Rules for Macros

Like we said before, these operate on token trees. How does the compiler know what token tree something like `println!` is going to operate on?

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Function-like macros always operate on the immediately following token tree, which is required to be a non-leaf. This means all of these are accepted:

```
print!("This is a test");
print![" of the emergency"];
print!{" broadcast system.\n"};
```

# Rules for Macros

When expanding a macro, it expands to fill the corresponing place in the token tree.
Suppose we have a macro `two!` which expands to `1 + 1`.
Then if we have something like:

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println!("Two times two is {}", 2 * two!());
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in Rust this will always become

```
println!("Two times two is {}", 2 * (1 + 1));
```

Note that we had to add parens, because it expands to fill the location in the token tree, replacing the current AST node, instead of just spewing out tokens.

# Why Use a Macro?

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- variadic operations
- domain-specific languages
- boilerplate code generation

# Why Use a Macro? Example: `assert_eq!`

Let's take a look at `assert_eq!`. We've seen this before, with writing test cases.

```
#[test]
fn my_test_fn() {
    assert_eq!(fib(6), 8);
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Why might this be a macro instead of a function?

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Why might this be a macro instead of a function?

We can also use it like so:

```
#[test]
fn my_test_fn() {
    assert_eq!(fib(6), 8, "Testing the 6th fibbonacci number");
}
```

# Defining a Declarative Macro

The first way to define macros, which we'll call declarative macros, uses `macro_rules!`

```
macro_rules! assert_eq {
    ($left : expr, $right : expr $(,) ?) => { ... };
    ($left : expr, $right : expr, $($arg : tt) +) => { ... };
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Some things to note:

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Some things to note:

- The macro name
- We introduce arguments with `$name`
- and list the "types" of them
- We also have some control over repeated constructs

# “Types” of Token Trees

- block: a block (i.e. a block of statements and/or an expression, surrounded by braces)
- expr: an expression
- ident: an identifier (this includes keywords)
- item: an item, like a function, struct, module, impl, etc.
- lifetime: a lifetime (e.g. `'foo`, `'static`, ...)
- literal: a literal (e.g. `"Hello World!"`, `3.14`, `'X'`, ...)
- meta: a meta item; the things that go inside the `#[...]` and `#![...]` attributes
- pat: a pattern
- path: a path (e.g. `foo`, `::std::mem::replace`, `transmute::<_, int>`, ...)
- stmt: a statement
- tt: a single token tree
- ty: a type
- vis: a possible empty visibility qualifier (e.g. `pub`, `pub(in crate)`, ...)

# Repetition Constructs

We can use the following sequence

```
$ ( ... ) sep rep
```

where `( ... )` is the group being repeated; `sep` is some token which separates the groups (think something like `,`); and `rep` is one of:

- `?`—at most one (no `sep`)
- `+`—at least one
- `*`—any amount

You then would use this same syntax when dealing with the repeated group.

# Declarative Macro Example

Let's define a simpler version of the `vec!` macro, which supports the syntax `vec![1, 2, 3, 4]` (and allows a trailing comma).

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```
macro_rules! vec {
    ( $( $x:expr ) , * $ (,) ?) => {
        {
            let mut v = Vec::new();
            $(
                v.push($x);
            )*

            v
        }
    };

}
```

While we can only defined a function-like macro with declarative macros, proc macros allow us to also defined attributes.

Here, instead of writing something like a `match` expression, we'll write a function which operates on token trees.

However, proc macros are a little bit more cumbersome.

For instance,

```
[lib]
proc-macro = true
```

is required in your `Cargo.toml`, and they can't be used in the same crate, because the compiler needs to compile them.

# Defining a Procedural Macro

There are a couple different ways we define proc macros, depending on their use. For function-like macros, it'll take one argument, and have *#[proc_macro]*:

```
#[proc_macro]
pub fn my_proc_macro(input: TokenStream) -> TokenStream {
    TokenStream::new()
}
```

For general attribute macros, it'll take two arguments, one for attribute args and another for the item itself, with *#[proc_macro_attribute]*:

```
#[proc_macro_attribute]
pub fn my_attribute(input: TokenStream, annotated_item: TokenStream)
    -> TokenStream {
    TokenStream::new()
}
```

For derive macros, it'll take two arguments, one for attribute args and another for the item itself, with *#[proc_macro_derive]*:

```
#[proc_macro_derive(MyDerive)]
pub fn my_derive(annotated_item: TokenStream) -> TokenStream {
    TokenStream::new()
}
```

# Proc Macros: Function-like Example

The simplest thing we could write for a function-like proc macro would just be the identity macro:

```
#[proc_macro]
pub fn ident(x: TokenStream) -> TokenStream {
    x
}
```

So if we used `ident!(foo)` it would just expand to `foo`.
We could implement much the same thing as our `vec!` macro, but we'd have to go through the `TokenStream` and manually validate all of it—that's a lot of work! In general, if we can use a declarative macro we'll want to, and if we can avoid a macro, we'll perfer that to both.

# Proc Macros: Derive

A more motivating example is that of derive macros. We can imagine lots of cases where we have trait we want to make easy to implement for clients of a library we're implementing, but the implementation is often rote, and just invovles recursing on the fields of a struct.

Let's imagine we have a trait `Hello`, defined like so:

```
trait Hello {
    fn hello() -> String;
}
```

```rust
use proc_macro::TokenStream;
use quote::quote;
use syn;

#[proc_macro_derive(Hello)]
pub fn hello_macro_derive(input: TokenStream) -> TokenStream {
    // Construct a representation of Rust code as a syntax tree
    // that we can manipulate
    let ast = syn::parse(input).unwrap();

    // Build the trait implementation
    impl_hello_macro(&ast)
}
```

```rust
fn impl_hello_macro(ast: &syn::DeriveInput) -> TokenStream {
    let name = &ast.ident;
    let gen = quote! {
        impl HelloMacro for #name {
            fn hello_macro() {
                println!("Hello, Macro! My name is {}!",
                    stringify!(#name));
            }
        }
    };
    gen.into()
}
```

So, we've already had to pull in two dependencies `quote` and `syn`, in order to implement this, and that's for a relative simple example.

This is somewhat constant overhead, but less than ideal.

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Another factor is compile time—proc macros can lead to greatly expanded compilation times, especially with `quote` and `syn`.