# Microsoft MakeCode
from C++ to TypeScript and Blockly (and back)

C++ Users Group Meeting
April 2018

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and MakeCode team

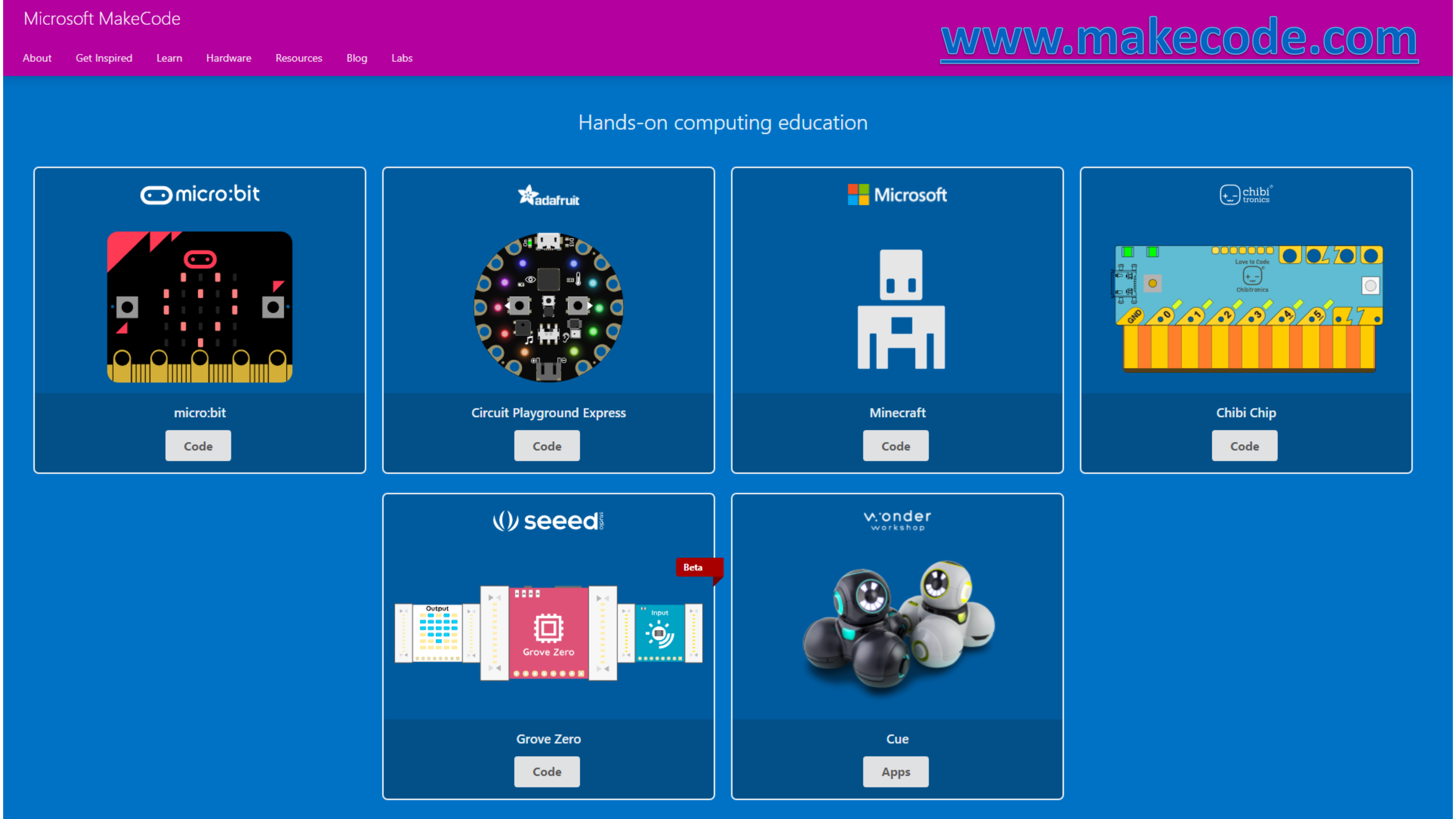
Microsoft MakeCode

Hands-on Computing for every student

- Just works always, everywhere
- Physical computing a more inclusive approach to CS education
- Path to real-world skills
- Extensible platform for partners

Microsoft MakeCode Objectives

1. Usage – Increased diversity and number of students engaged/interested in computing and technology
2. Brand – Microsoft recognized as an innovator in computing education
3. Ecosystem – Democratizing access to the world of intelligent edge devices and enabling a thriving partner ecosystem



Microsoft MakeCode

About Get Inspired Learn Hardware Resources Blog Labs

www.makecode.com

Hands-on computing education

micro:bit
micro:bit
Code

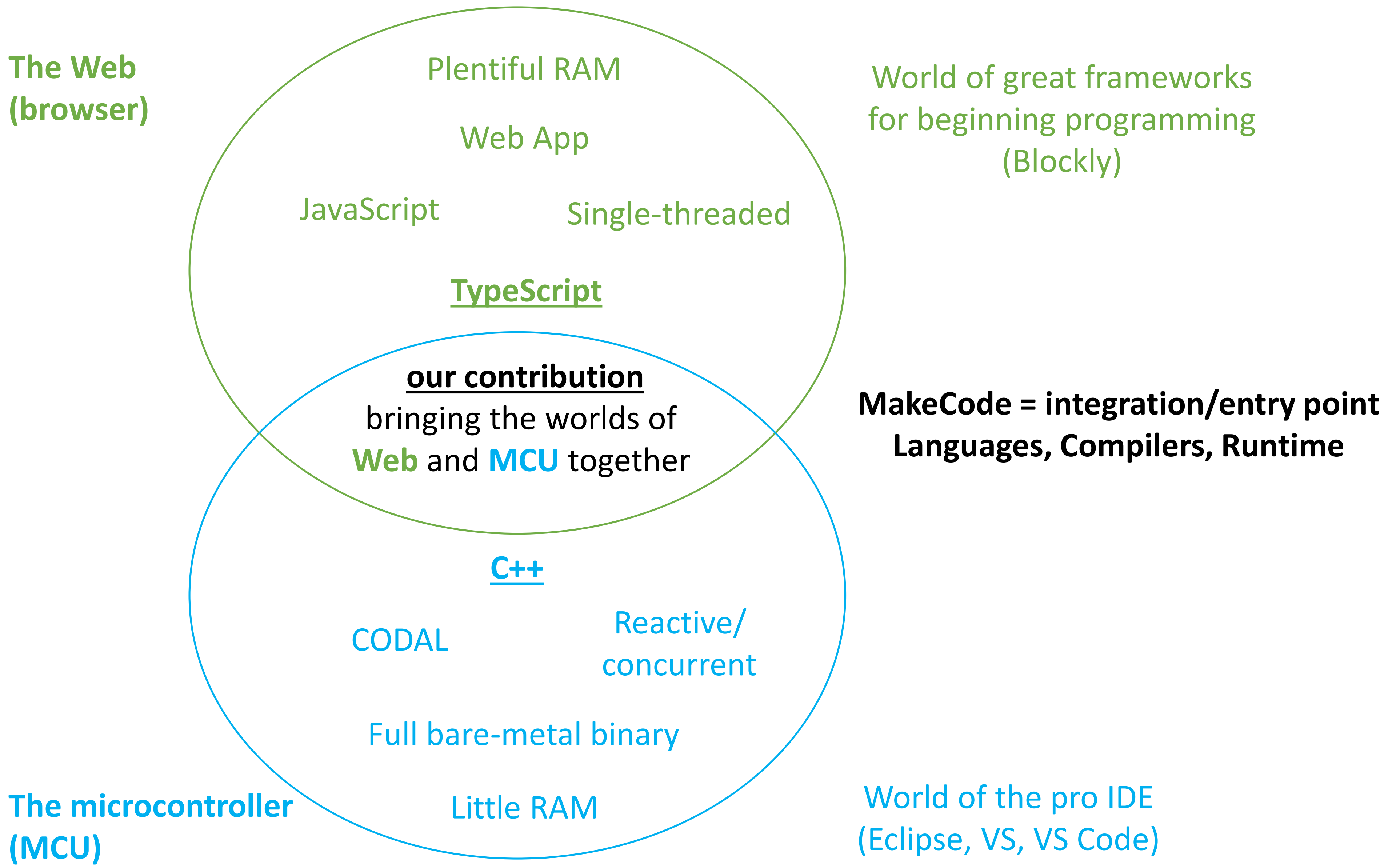
adafruit
Circuit Playground Express
Code

Microsoft
Minecraft
Code

chibi tronics
Chibi Chip
Code

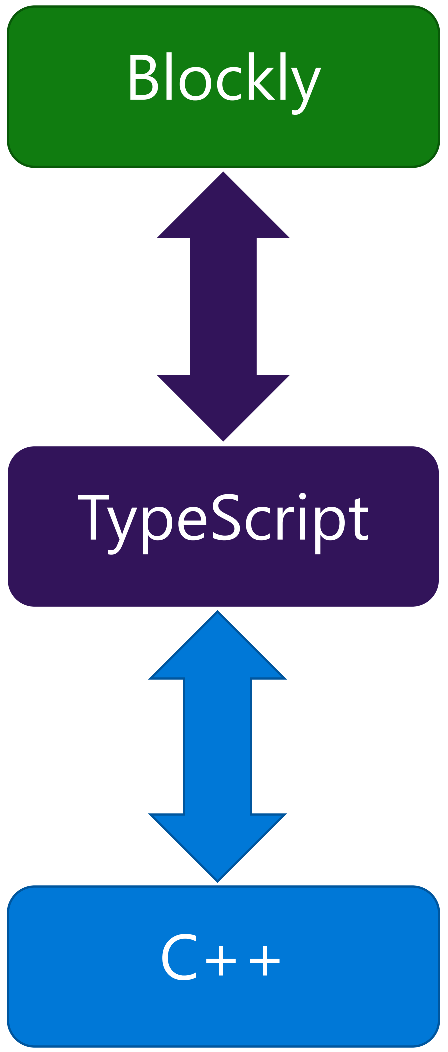
seeed studio
Beta
Grove Zero
Code

wonder workshop
Cue
Apps


The Web (browser)
Plentiful RAM
Web App
JavaScript
Single-threaded
TypeScript
World of great frameworks for beginning programming (Blockly)
our contribution
bringing the worlds of **Web** and **MCU** together
MakeCode = integration/entry point
Languages, Compilers, Runtime
C++
CODAL
Reactive/ concurrent
Full bare-metal binary
Little RAM
The microcontroller (MCU)
World of the pro IDE (Eclipse, VS, VS Code)

Innovations

- Web app for end-to-end experience
  - no install or need for C/C++ compiler for end-user
  - in-browser compilation to binary
- TypeScript as core language
  - API mapping: up to Blockly and down to C++
  - coverage of OO concepts
- Runtime abstractions
  - Events, message bus and co-routines
  - support concurrent, reactive programming



TypeScript

Gradually typed superset of JavaScript

- Compiles to JavaScript
- Supports ECMAScript 2015 and latest language features

Types enable productivity tools

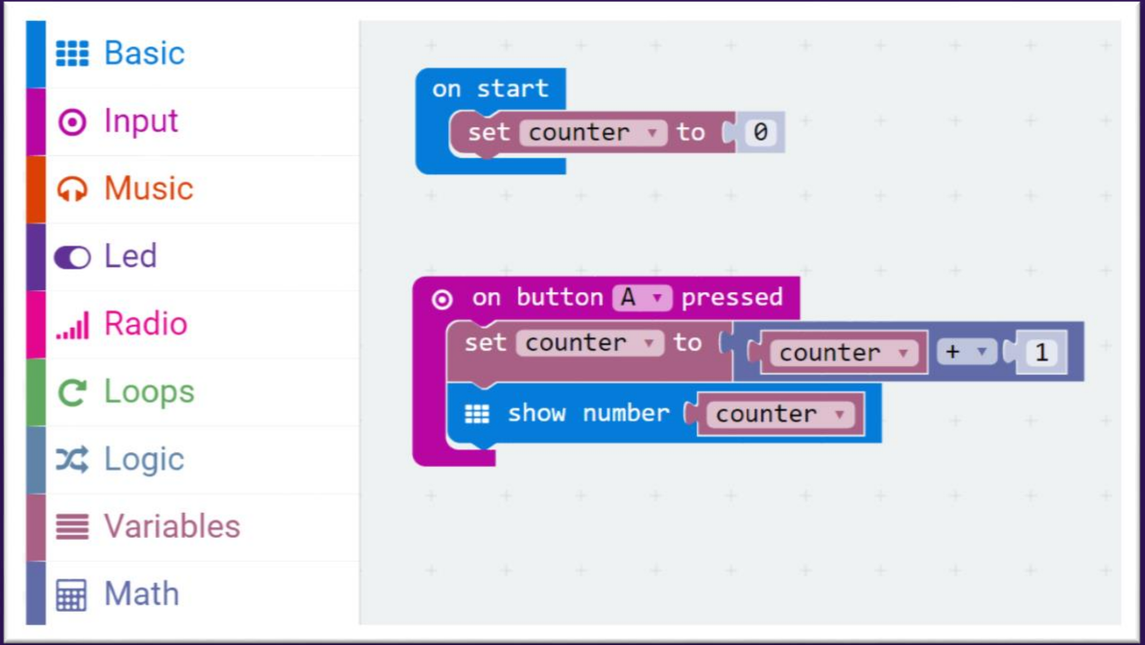
- intellisense, navigation, refactoring

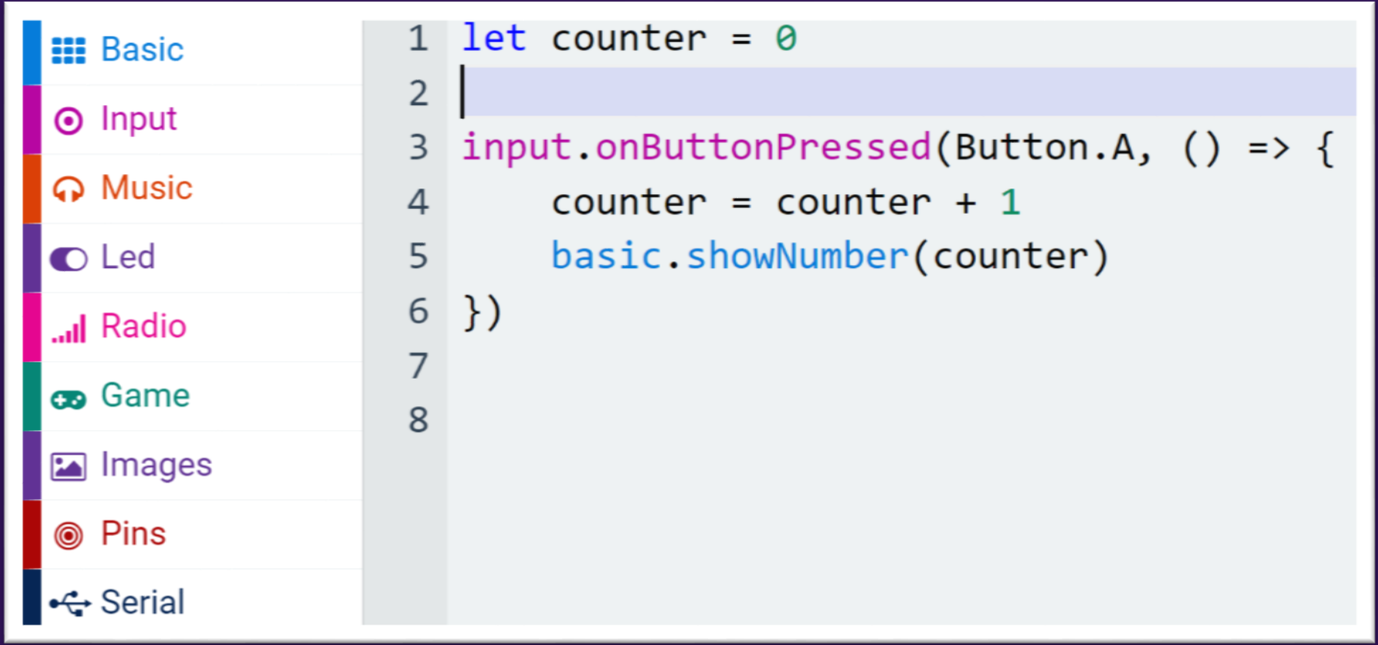
http://www.typescriptlang.org/

Blocks and TypeScript

Blockly

TypeScript





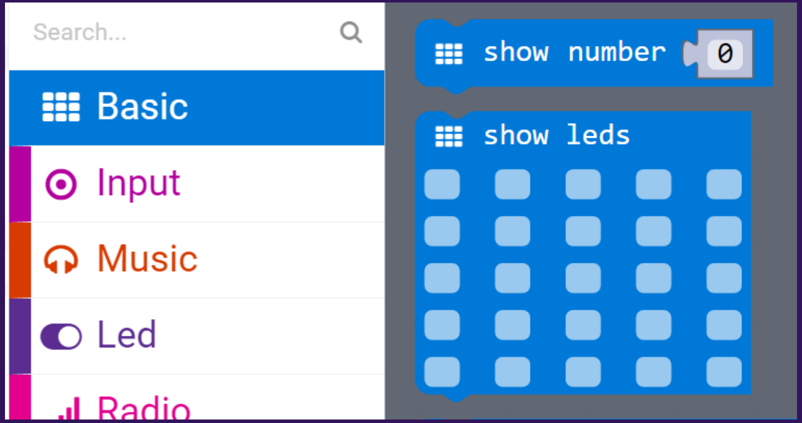
```
let counter = 0

input.onButtonPressed(Button.A, () => {
    counter = counter + 1
    basic.showNumber(counter)
})
```

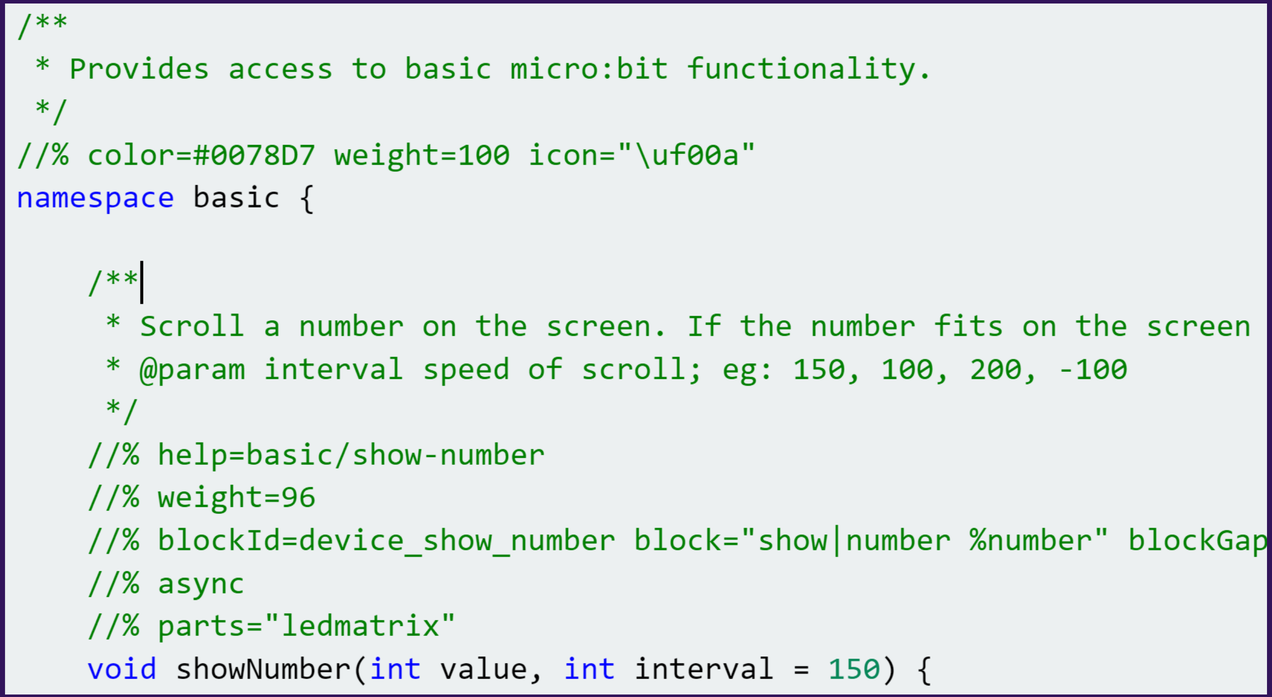
Categories

Namespaces

API Binding (1)

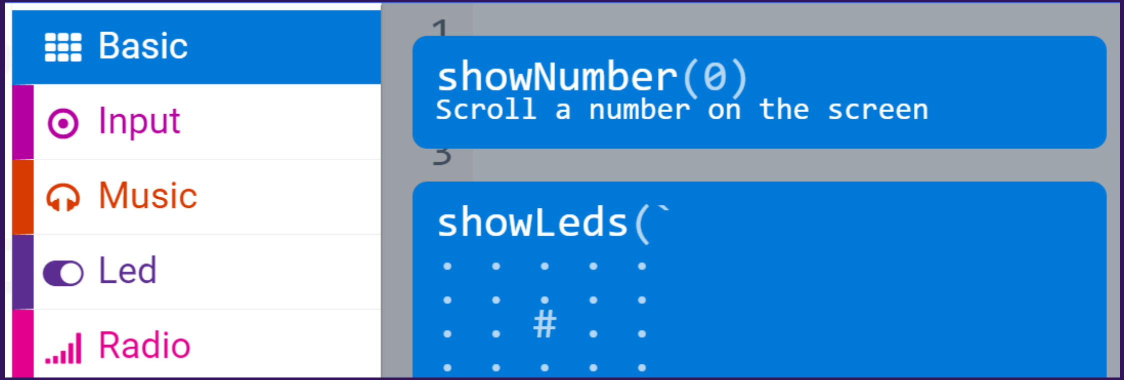
Blockly





```
/**
 * Provides access to basic micro:bit functionality.
 */
//% color=#0078D7 weight=100 icon="\uf00a"
namespace basic {

    /**
     * Scroll a number on the screen. If the number fits on the screen
     * @param interval speed of scroll; eg: 150, 100, 200, -100
     */
    //% help=basic/show-number
    //% weight=96
    //% blockId=device_show_number block="show|number %number" blockGap
    //% async
    //% parts="ledmatrix"
    void showNumber(int value, int interval = 150) {
```

C++



```
showNumber(0)
Scroll a number on the screen
showLeds(`
 . . . . .
 . . . . .
 . . # . .
 . . . . .
```

TypeScript

API Binding (2)

```
/**
 * Turns all LEDS on
 */
//% help=led/plot-all
//% parts="ledmatrix"
export function plotAll(): void {
    for (let i = 0; i < 5; i++) {
        for (let j = 0; j < 5; j++) {
            led.plot(i, j);
        }
    }
}
```

Runtime extension

TypeScript

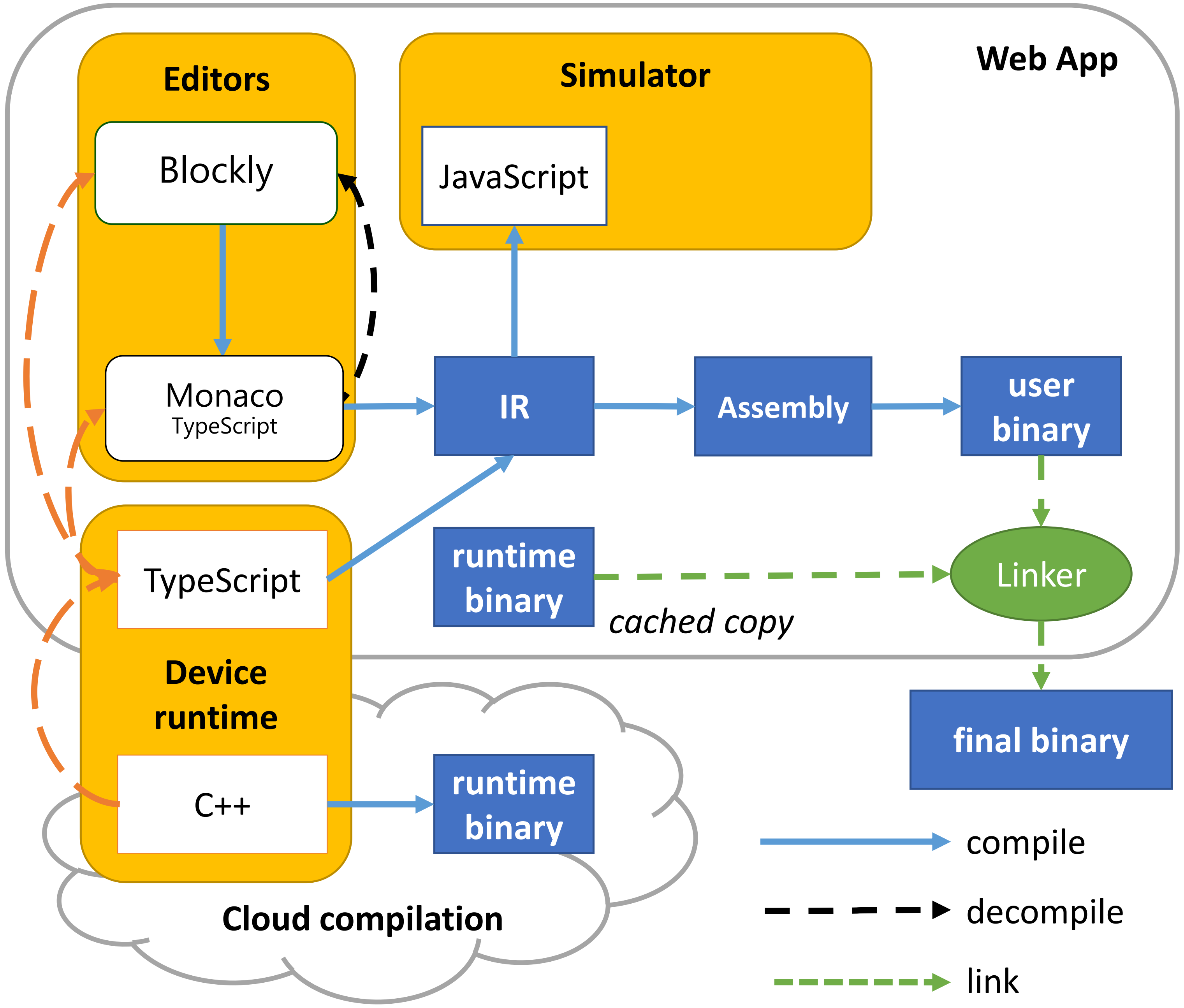
```
//% color=3 weight=35 icon="\uf205"
namespace led {

    /**
     * Turn on the specified LED using x, y coordinates
     * @param x TODO
     * @param y TODO
     */
    //% help=led/plot weight=78
    //% blockId=device_plot block="plot|x %x|y %y" block
    //% parts="ledmatrix"
    void plot(int x, int y) {
      uBit.display.image.setPixelValue(x, y, 1);
    }
```

C++

Wrapping micro:bit runtime

```
namespace pxsim.led {
    export function plot(x: number, y: number) {
        board().ledMatrixState.image.set(x, y, 255);
        runtime.queueDisplayUpdate()
    }
```

Simulator implementation

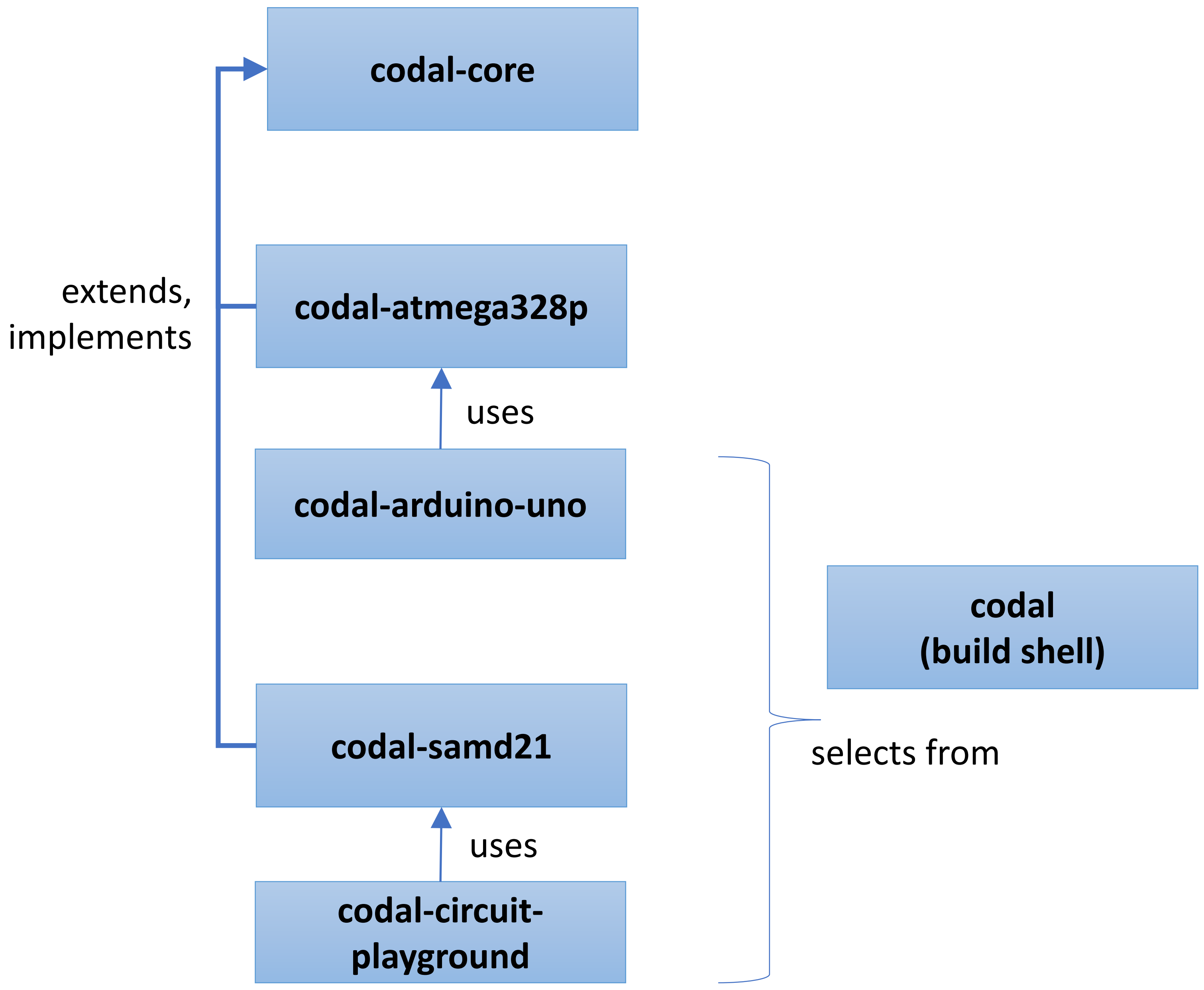

Web App
Editors
Blockly
Monaco
TypeScript
Simulator
JavaScript
IR
Assembly
user binary
runtime binary
cached copy
Linker
final binary
TypeScript
Device runtime
C++
runtime binary
Cloud compilation
compile
decompile
link

1. From C++ to TypeScript and Blockly

- CODAL: C++ Component-oriented Device Abstraction Layer
  - https://github.com/lancaster-university/codal-core
  - Joe Finney and James Devine

- http://github.com/microsoft/pxt-common-packages
  - glue between CODAL and MakeCode
  - annotated C++ provides standard TypeScript/Blockly APIs for common features

- http://github.com/microsoft/pxt-adafruit
  - Defines full web app
  - Using common packages and base PXT framework


codal-core
extends, implements
codal-atmega328p
uses
codal-arduino-uno
codal-samd21
uses
codal-circuit-playground
codal (build shell)
selects from

CODAL repos

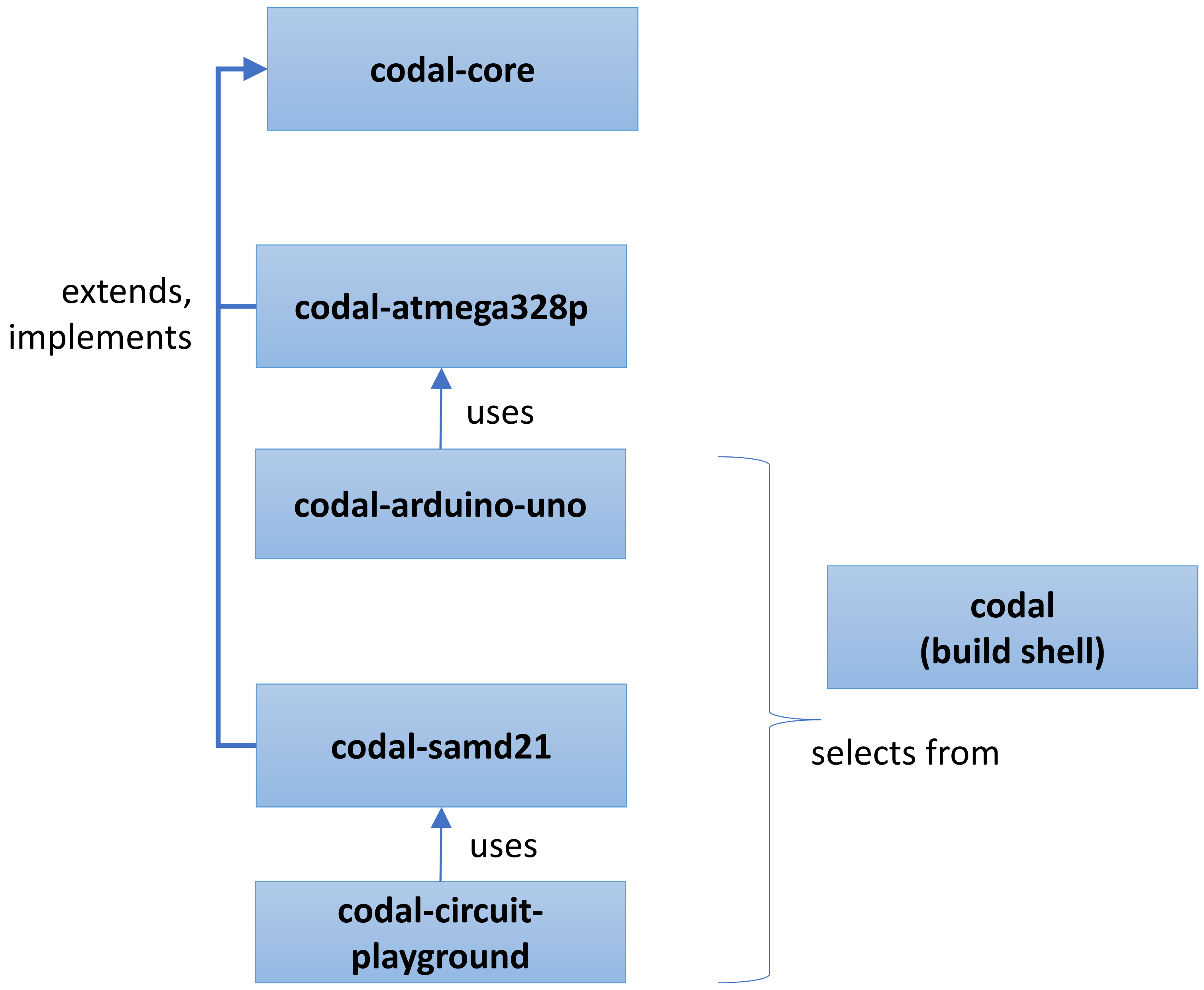
Build: https://github.com/lancaster-university/codal

Base: https://github.com/lancaster-university/codal-core

- https://github.com/lancaster-university/codal-mbed
  - https://github.com/lancaster-university/codal-samd21
    - https://github.com/lancaster-university/codal-circuit-playground

- https://github.com/lancaster-university/codal-atmega328p
  - https://github.com/lancaster-university/codal-arduino-uno

- …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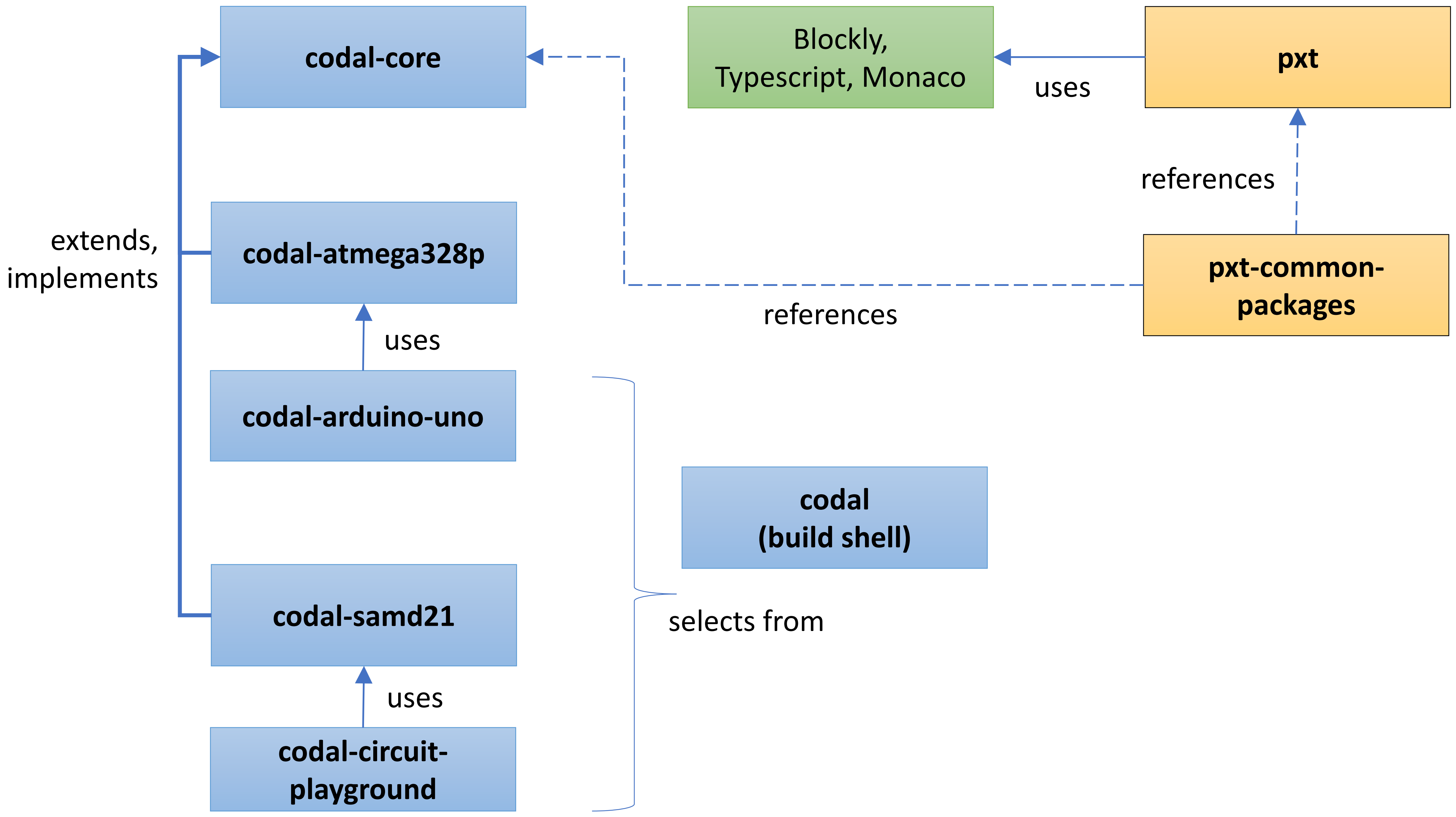
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Blockly, Typescript, Monaco
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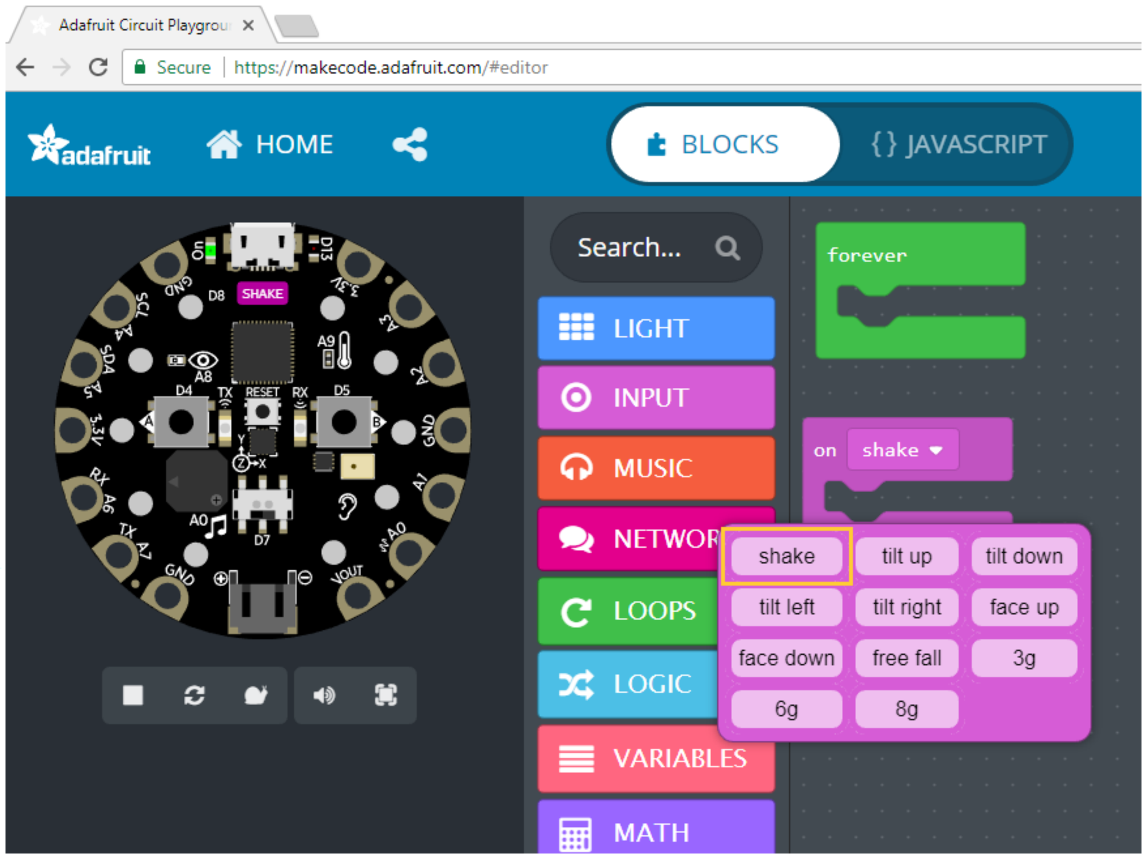
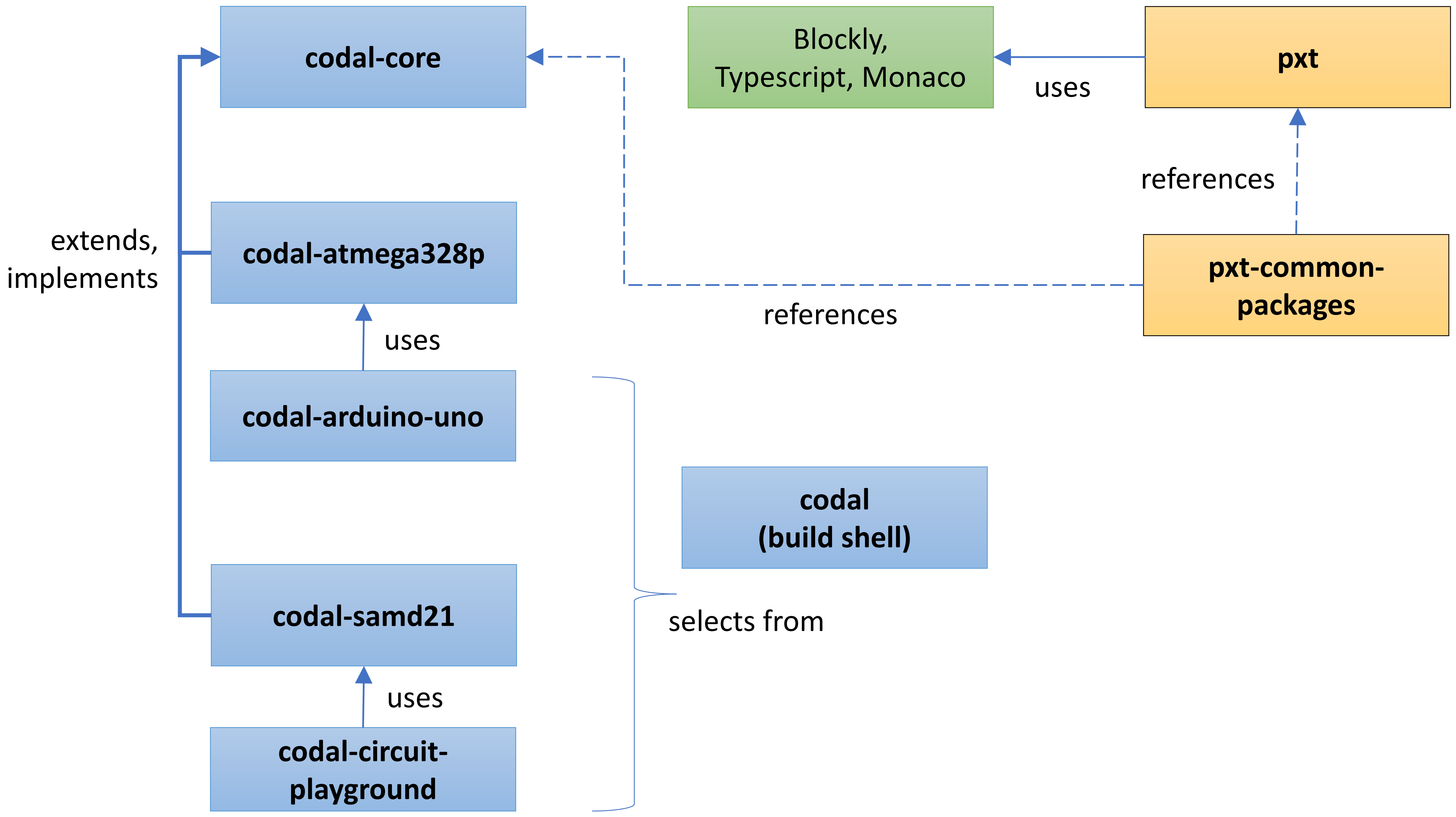
codal (build shell)
selects from
codal-samd21
uses
codal-circuit-playground

```
enum class Gesture {
    /**
     * Raised when shaken
     */
    //% block=shake
    Shake = ACCELEROMETER_EVT_SHAKE,
    /**
     * Raised when the device tilts up
     */
    //% block="tilt up"
    TiltUp = ACCELEROMETER_EVT_TILT_UP,
    /**
     * Raised when the device tilts down
     */
    //% block="tilt down"
    TiltDown = ACCELEROMETER_EVT_TILT_DOWN,
```

https://github.com/Microsoft/pxt-common-packages/blob/master/libs/accelerometer/accelerometer.cpp

```
namespace input {
/**
 * Do something when when a gesture is done (like shaking the board).
 * @param gesture the type of gesture to track, eg: Gesture.Shake
 * @param body code to run when gesture is raised
 */
//% help=input/on-gesture
//% blockId=device_gesture_event block="on |%NAME"
//% parts="accelerometer"
//% gesture.fieldEditor="gridpicker"
//% gesture.fieldOptions.width=220
//% gesture.fieldOptions.columns=3
//% weight=92 blockGap=12
void onGesture(Gesture gesture, Action body) {
```

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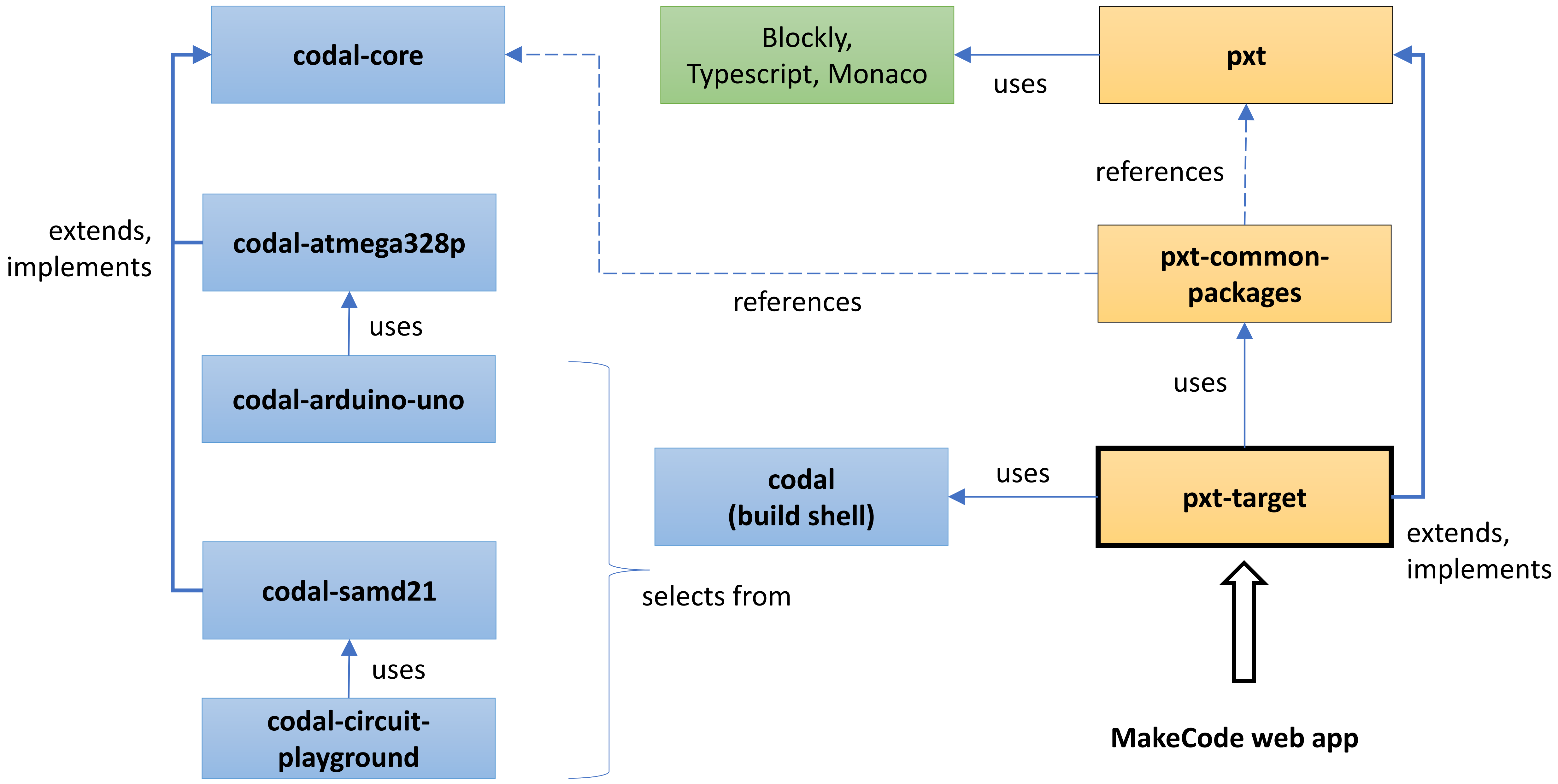
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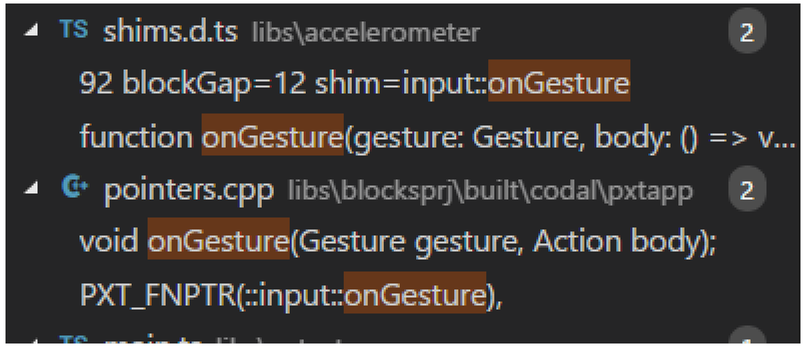
uses
codal-arduino-uno
uses
codal (build shell)
uses
pxt-target
extends, implements
codal-samd21
selects from
uses
codal-circuit-playground
MakeCode web app

Compiling C++ for MakeCode

- Preprocessing of C++
  - https://makecode.com/simshim
  - Determines which C++ entities will be visible/exported via TypeScript Declaration File
- Mosly 1-1 mappings between C++ and TypeScript entities
  - bool, number(s), string, enums
  - lambdas, functions
  - namespaces
  - runtime collections
  - plus a hack for exposing methods of a C++ class
- Invoke C++ compiler to generate runtime binary
  - With exported points
  - Binary incorporated into web app



```
shims.d.ts libs\accelerometer                          2
    92 blockGap=12 shim=input::onGesture
    function onGesture(gesture: Gesture, body: () => v...
pointers.cpp libs\blocksprj\built\codal\pxtapp         2
    void onGesture(Gesture gesture, Action body);
    PXT_FNPTR(::input::onGesture),
```

Target specific override and shim file

https://github.com/Microsoft/pxt-adafruit/blob/master/libs/accelerometer/axis.h

```
// Override in target to change inversion of axis

#define ACC_SYSTEM NORTH_EAST_UP
#define ACC_UPSIDEDOWN true
#define ACC_ROTATION COORDINATE_SPACE_ROTATED_0

/*
                        X  Y  Z
Laying flat:            0  0 -1
Standing normally:      0  1  0
Standing on left side: -1  0  0
*/
```

https://github.com/Microsoft/pxt-adafruit/blob/master/libs/accelerometer/shims.d.ts

```
// Auto-generated. Do not edit.
declare namespace input {

    /**
     * Do something when when a gesture is done (like shaking the board).
     * @param gesture the type of gesture to track, eg: Gesture.Shake
     * @param body code to run when gesture is raised
     */
    //% help=input/on-gesture
    //% blockId=device_gesture_event block="on |%NAME"
    //% parts="accelerometer"
    //% gesture.fieldEditor="gridpicker"
    //% gesture.fieldOptions.width=220
    //% gesture.fieldOptions.columns=3
    //% weight=92 blockGap=12 shim=input::onGesture
    function onGesture(gesture: Gesture, body: () => void): void;
```

MakeCode GitHub repos

- Framework and support
  - https://github.com/Microsoft/pxt
  - https://github.com/Microsoft/pxt-blockly
  - https://github.com/Microsoft/pxt-monaco-typescript
  - https://github.com/Microsoft/pxt-common-packages (CODAL-specific)

- Targets
  - https://github.com/Microsoft/pxt-adafruit
  - https://github.com/Microsoft/pxt-microbit
  - https://github.com/Microsoft/pxt-maker
  - https://github.com/Microsoft/pxt-chibitronics

2. From Blocky to TypeScript to Binary (C++)

- Static TypeScript
- Blocky to Static TypeScript
- Compiling Static TypeScript to Machine Code

Static TypeScript

- Considerations
  - Compile for low-memory footprint
  - Link against pre-compiled C++ runtime
  - All types known at compile time, no runtime checks

- TypeScript without the <u>Any</u> type and “bad parts”
  - a <u>subset</u> of TypeScript, with some type substitutions (number -> int32)
  - excludes
    - the **eval** function, the **with** statement, the **typeof** expression
    - type assertions, **var** statement
    - access to prototype property and computed properties
    - access to the “**this**” pointer outside of a class

What's Left in Static TypeScript?

- standard **control-flow statements**
- **let** and **const:** lexically-scoped variable declarations

- **functions** (nested) and lambdas
- **classes** with instance fields, methods and constructors
- **interfaces**
- **generic** classes, methods, and functions for code reuse
- **namespaces**

Blocky to Static TypeScript

- Blockly has limited notion of type
- Perform Hindley-Milner type inference over Blockly AST
- Type errors possible in Blockly, but very rare

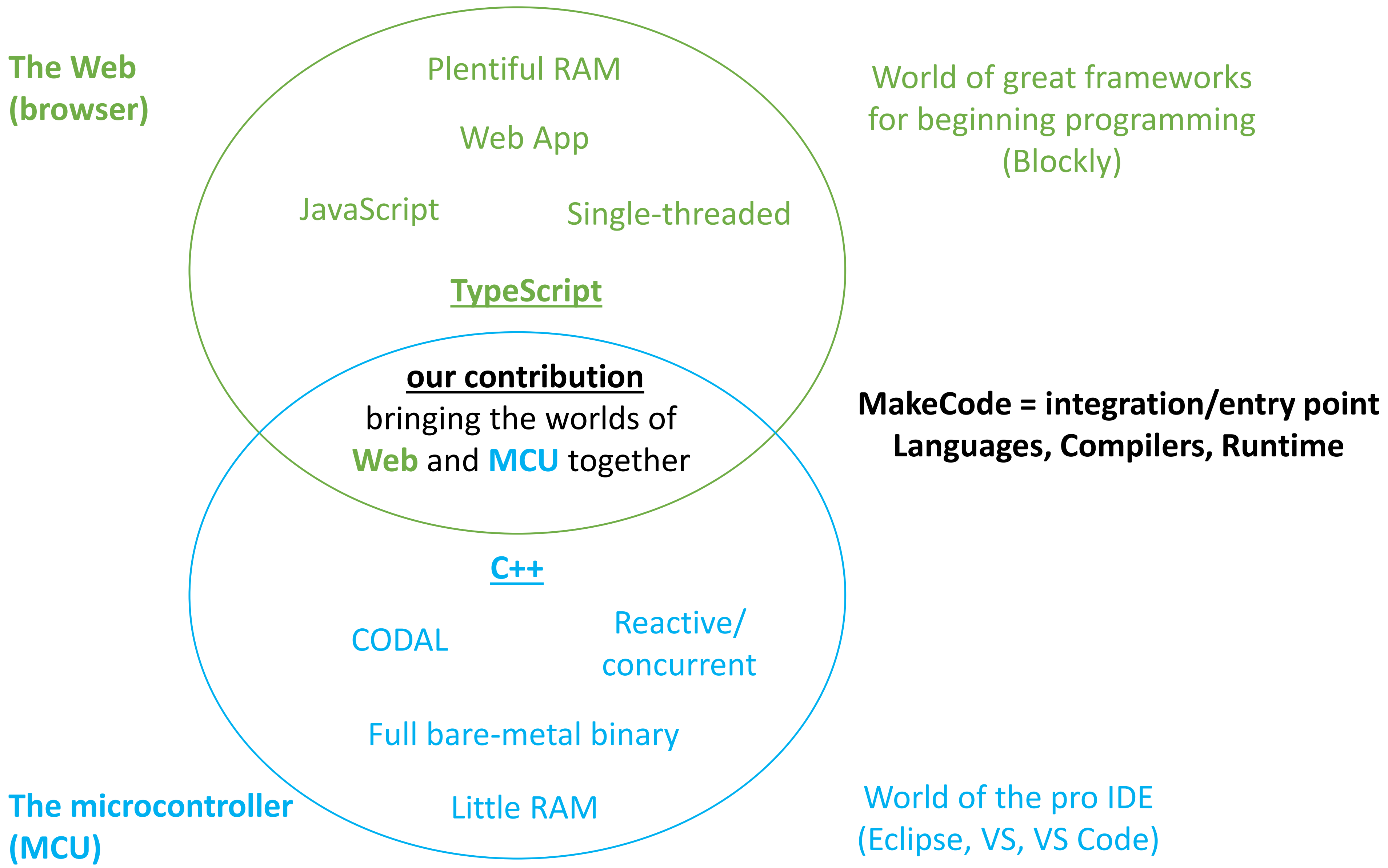
Static TypeScript to Machine Code

- TypeScript language service -> typed AST
- Extra checks for Static TypeScript subset
- AST -> IR -> Assembly -> Machine Code
- Tree shaking of AST to remove all unneeded STS code

Compiler and Runtime

- Tagged integers, boxing to move to doubles (JavaScript)
- Automatic conversion from STS numbers to various C++ types in glue code
- Reference counting, closures
- Vtable-based layout of (nominally typed) classes
- Interfaces (i.e., multiple inheritance)
  - per-method, so classes do not have to declare they implement a particular interface
- Generics, through code duplication for now
- Many ES6 features (for-in, lambdas, get/set accessors, etc.)
- Custom debugger support for both native and JS compilers

https://github.com/Microsoft/pxt-common-packages/blob/master/libs/base/pxtbase.h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