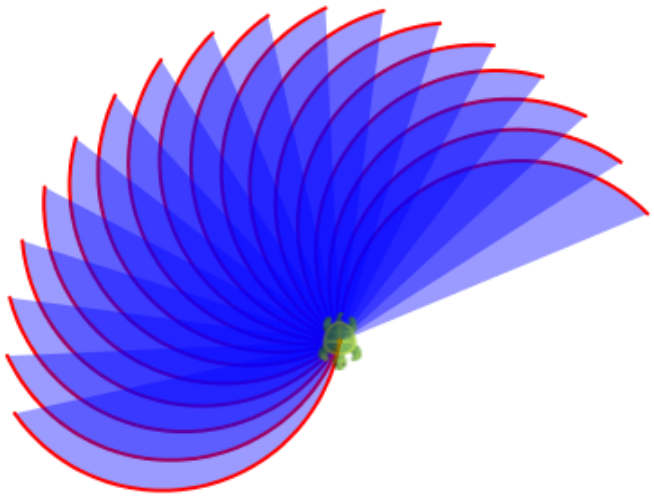
Introduction to Programming

with Kojo



by

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A word about Kojo

Kojo is a learning environment where *youngsters* (from ages 8 to 80!) *play, create, and learn*. They play with small Scala programs. They create drawings, animations, games, and Arduino based intelligent circuits (with appropriate additional hardware). And they learn logical and creative thinking, programming, problem solving, math, physics, emotional grit, collaboration (via pair programming), and a lot more. Very importantly, they also learn how to *learn with understanding*. All of this fosters in them a mindset of exploration, innovation, self-reliance, *growth*, mental discipline, and teamwork – with Kojo as the enabler.

A Note for Facilitators and Teachers

This book contains a series of activities for kids to play with.

Most activities contain a fully defined program and a picture of the output of the program. For such activities, ask a kid to type in the instructions of the program into the script editor, run the program, and then check that the actual output of the program matches the output shown in the book. Then, ask the kid to do some reflection, i.e., think about and discuss what was just learned.

Many activities contain new instructions. Ask kids to keep an eye out for this and to figure out what the new instructions do.

Some activities contain an incomplete program, with the incomplete areas marked with `???`, and a picture of the expected output of the (complete) program. For such activities, ask a kid to type in the program into the script editor, fill out the incomplete portions of the program by thinking about and applying what they have learned before, run the program, and then (as before) check that the actual output of the program matches the output shown in the book. This should be followed by some reflection, as before.

The activities as described above support sequences of (a) guided work, (b) exploration, and (c) challenges (marked with `???`) that need to be carried out . The challenges are very important, as they are the points in the learning material that focus on learning with understanding.

As kids go about doing these sequences of activities, you should encourage the following:

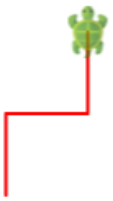
- exploration, discovery, and a sense of play.
- perseverance in the face of unexpected results, and joy in the process of figuring out what went wrong.
- commitment to solving the challenges.
- reflection and discussion about what was learned.
- digressions and diversions from the provided sequence of activities.

It is not important to finish all the activities. But it is vitally important to spend time with, go deep into, enjoy, and learn from each activity!

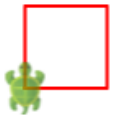
```
clear()
forward(50)
```

```
clear()
forward(50)
right()
forward(50)
right()
```

```
clear()
forward(50)
right()
forward(50)
left()
forward(50)
```



```
clear()
repeat(4) {
   forward(50)
   right()
}
```

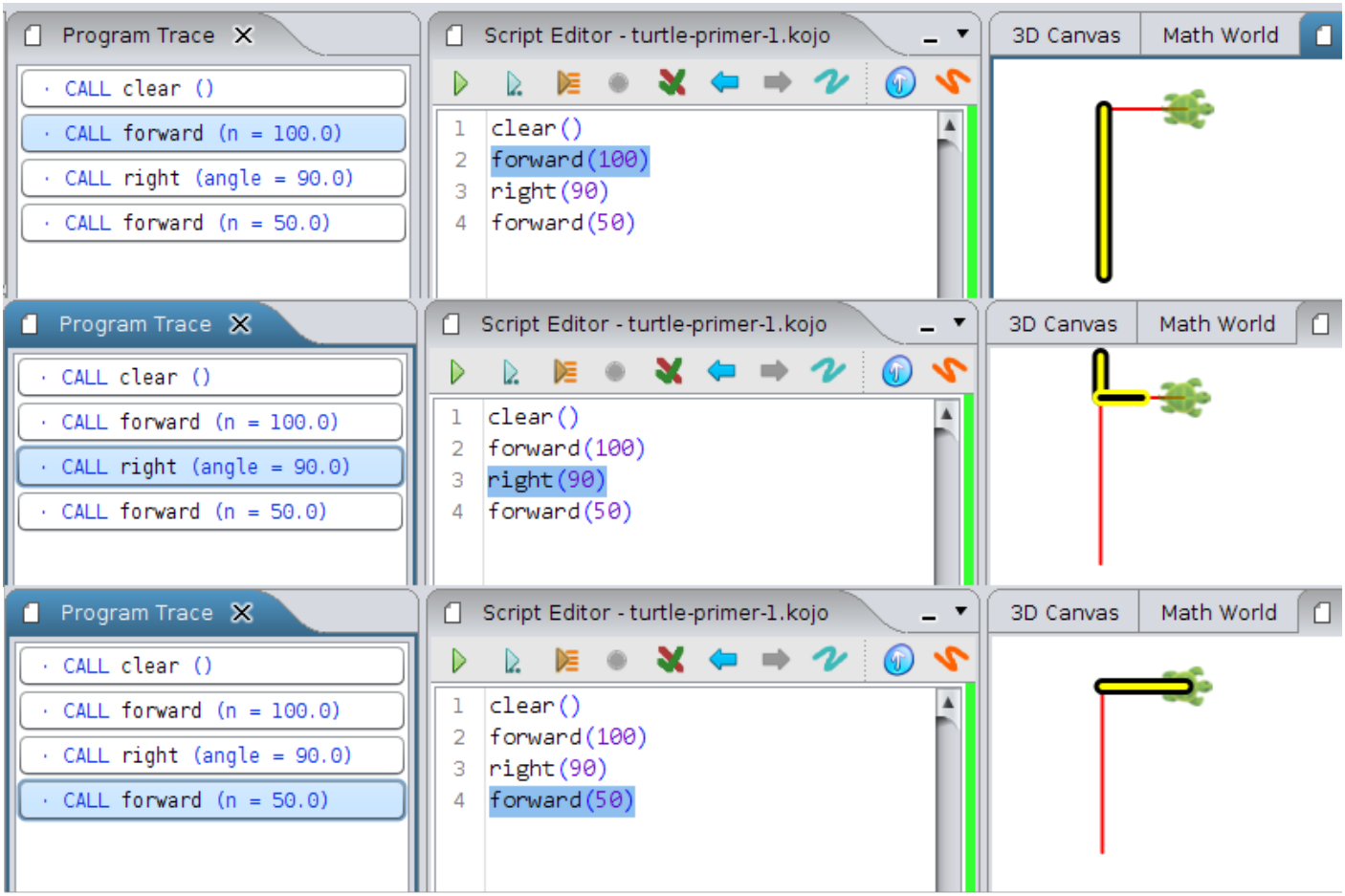


```
clear()
repeat(2) {
   ???
}
// if in doubt, first make the figure
   without using repeat, and then see
   what is repeated twice.
```

```
clear()
setSpeed(medium)
repeat(4) {
   ???
}
```

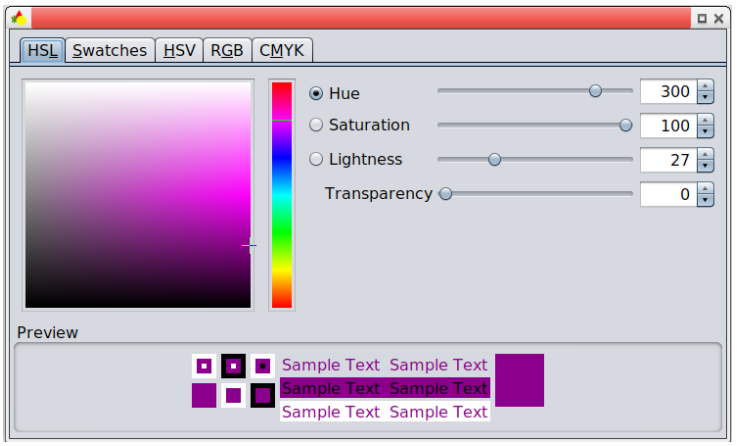
```
clear()
setSpeed(medium)
repeat(10) {
   ???
}
```

```
// run this program using the 'Trace Script' button (shown above) in the toolbar
clear()
forward(100)
right(90)
forward(100)

// The trace of the program is shown below. Can you see how tracing a program can
   help you understand exactly what the program does, step by step?
```



```
clear()
setSpeed(superFast)
setPenThickness(4)
setPenColor(ColorMaker.darkMagenta)
// Type 'ColorMaker.' and then press
   Ctrl+Space to access around 70
   predefined colors
setFillColor(ColorMaker.lightPink)
repeat(4) {
   forward(100)
   right(90)
}
```

```
// You can Ctrl+Click on a color in the
   script editor to bring up a color
   chooser (shown on the right).
// In the color chooser, you can:
// (1) choose the basic color (a number
   between 0 and 360) via the Hue
   slider. 0 is red, 120 is green, 240
   is blue, and 360 is again red.
// (2) add gray to the color via the
   Saturation slider. 100 is the pure
   color; 50 is half color and half
   gray; 0 is fully gray.
// (3) add white or black to the color
   via the Lightness slider. 50 is the
   pure color; numbers greater than 50
   add more and more white. Numbers less
   than 50 add more and more black.
// (4) Increse the transparency of the
   color via the Transparency slider.
```

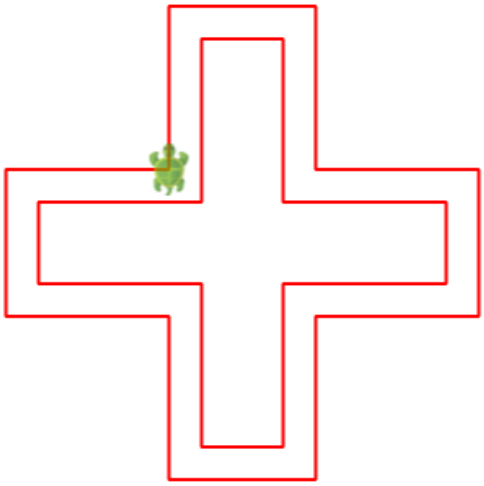


```
clear()
setPenThickness(8)
repeat(4) {
   forward(50)
   hop(50)
   right(90)
}
```

```
???

// How will you make the squares that
   lie above other squares partially
   transparent?
```

???

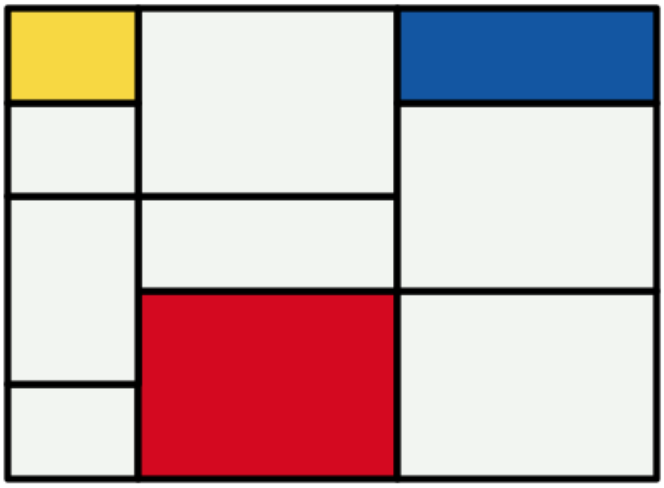
```
// use your own pen thickness, pen
    color(s), and fill color(s)
```



???

```
// use your own pen thickness, pen
    color(s), and fill color(s)
```

???



???

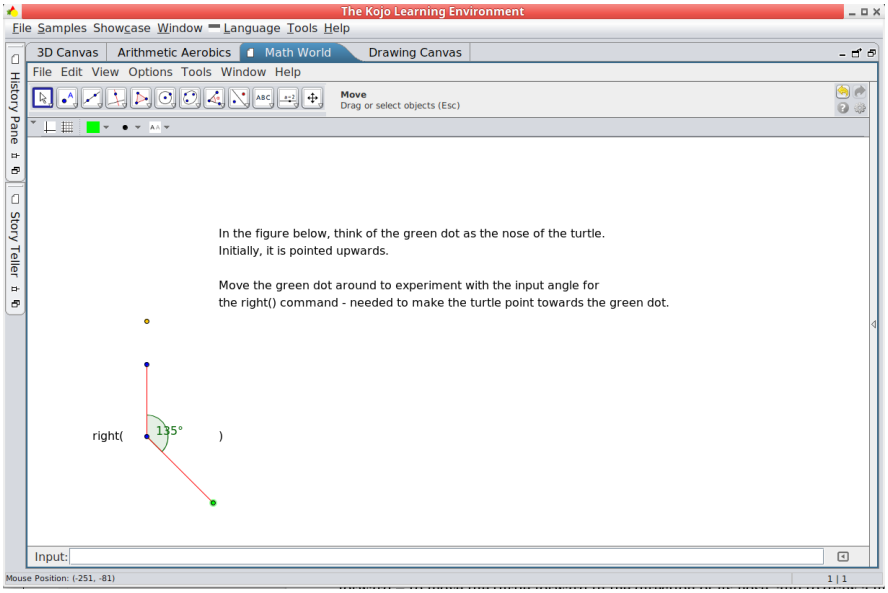
```
// After making this figure, make your
    own drawing with multiple rectangles
    and squares. Use different colors
    with different transparencies.
```

Playing with Angles

As you know, for drawing with the turtle, you have two basic commands available to you:

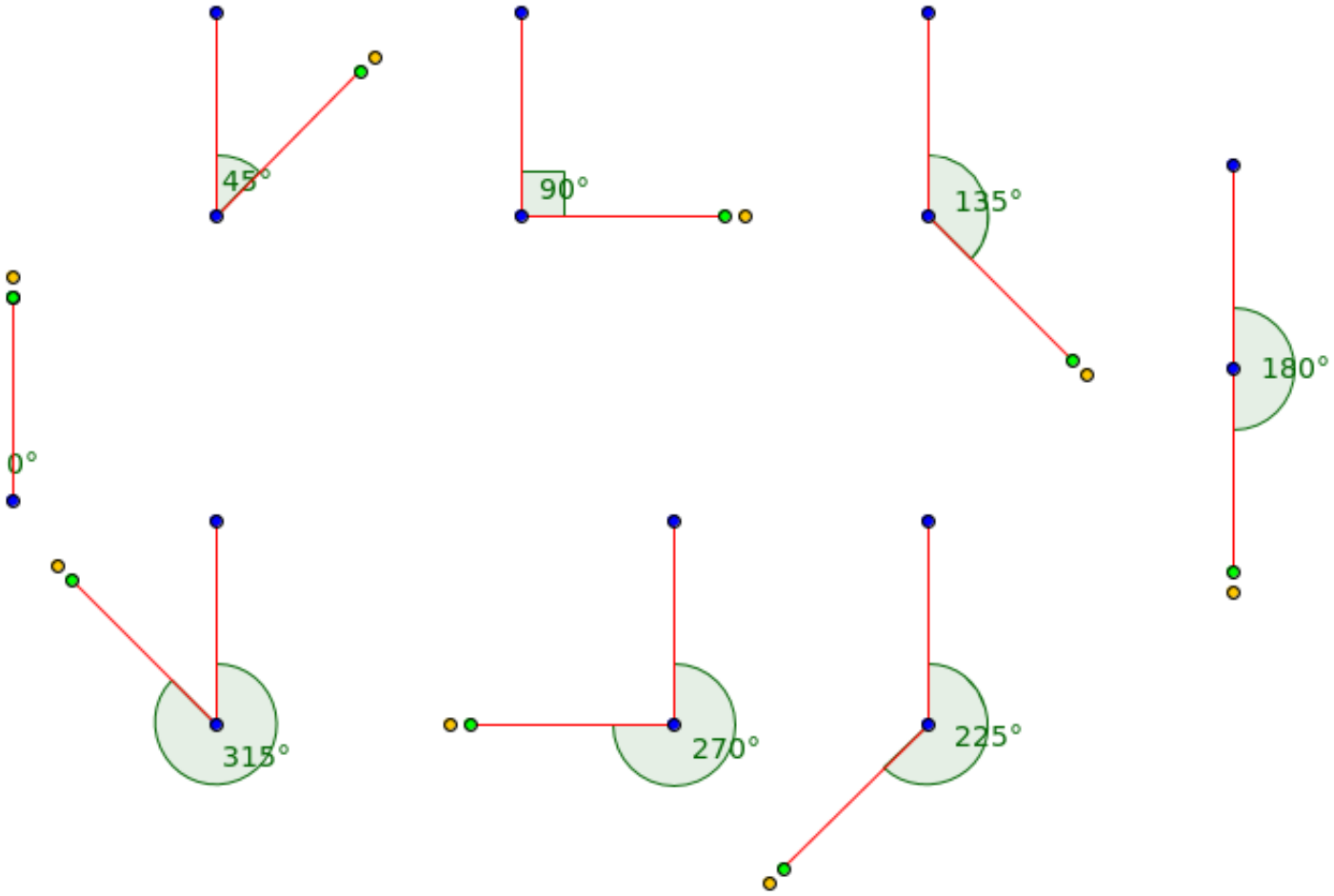
- `forward` – to move the turtle forward in the direction of its nose, and to draw a line as it moves forward.
- `right` (or `left`) – to change the direction (or heading) of the turtle's nose.

Before you progress any further, it is important for you to understand how the `right` (or `left`) command changes the direction of the turtle's nose. To experiment with this, go to *Samples -> Math Learning Modules -> Playing with Angles* in the Kojo Menu (and also look at some well known angles shown on the next page):



```
// trace this program to understand the
   angles
clear()
forward(50)
right(30)
forward(50)
right(45)
forward(50)
right(60)
forward(50)
right(90)
forward(50)
```

Well Known Angles



???

```
// use your own pen thickness, pen
   color(s), and fill color(s)
```

???

```
// use your own pen thickness, pen
   color(s), and fill color(s)
```

```
// You can teach Kojo new commands using
   the def instruction.

def square() {
   repeat(4) {
      forward(50)
      right(90)
   }
}
clear()

// 'call' the new command to use it.
square()
```

```
def square() {
   // same as before
}
clear()
setSpeed(medium)
repeat(3) {
   square()
   right(30)
}
```

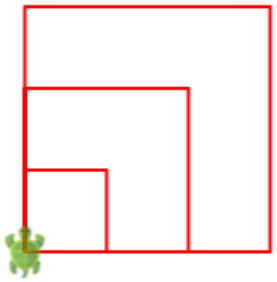
```
def square() { /* same as before */ }
clear()
setSpeed(medium)
repeat(2) {
   square()
   hop(25)
   right(90)
   hop(25)
   left(90)
}
```

```
def square() { /* similar to before;
   size 15 */ }
clear()
setSpeed(fast)
repeat(10) {
   ???
}
```

```
def square() { /* same as before */ }
def ladder() {
   setPenColor(randomColor)
   ???
}
clear()
setSpeed(fast)
ladder()
```

```
def square() { /* same as before */ }
def ladder() {/* same as before */ }
clear()
setSpeed(fast)
setPenThickness(4)
repeat(10) {
   ladder()
   ???
}
```

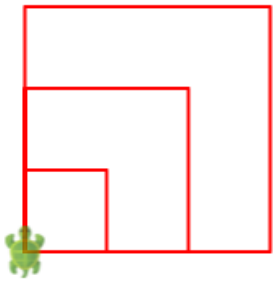
```
// New commands that you teach Kojo can
   also take inputs

def square(n: Int) {
   repeat(4) {
      forward(n)
      right(90)
   }
}
clear()
square(50)
square(100)
square(150)
```



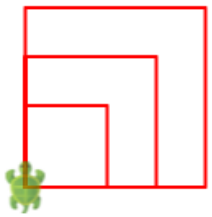
This is a good time to go to the *getting started* book, to around page 15 – where it says "Next, let's work with patterns in a systematic way...".

Work through the material there on the systematic analysys and creation of patterns. Do some (or all) of the forty patterns at the end of that book, and then come back here...

```
def square(n: Int) {
   // same as before
}
clear()
setSpeed(medium)
repeatFor(1 to 3) { n =>
   square(n * 50)
}
```

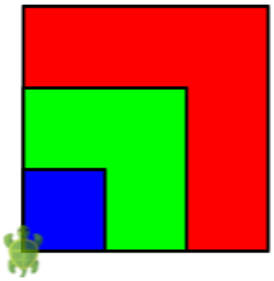


```
def square(n: Int) { /* same as before
   */ }
clear()
setSpeed(medium)
// make squares of sizes 50, 80, and 110
repeatFor(1 to 3) { n =>
   ???
}
```

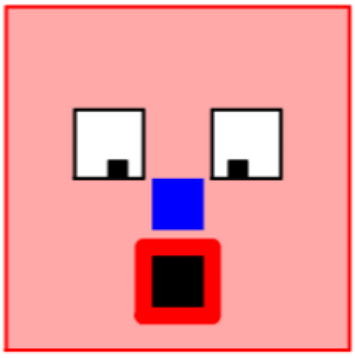


```
def square(n: Int) { /* same as before
   */ }
clear()
setSpeed(medium)
setPenThickness(20)
setBackground(yellow)
setPenColor(blue)
repeatFor(1 to 3) { n =>
   square(10 + n * 40)
}
```

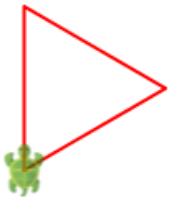
```
def square(n: Int) { /* same as before
   */ }
// A Seq lets you organize/structure
   your data in a sequence
val sizes = Seq(150, 100, 50)
val colors = Seq(red, green, blue)
clear()
setSpeed(medium)
setPenColor(black)
repeatFor(0 to 2) { n =>
// You can access elements in a sequence
   via a 0-based index: seq(idx)
   setFillColor(colors(n))
   square(sizes(n))
}
```



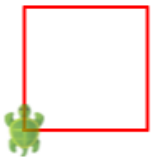
```
def square(n: Int) { /* same as before
   */ }
clear()
setSpeed(medium)
???
```



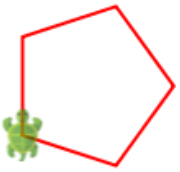
```
clear()
repeat(3) {
   forward(100)
   right(120)
}
```



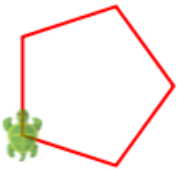
```
clear()
repeat(4) {
   forward(75)
   right(90)
}
```



```
clear()
repeat(5) {
   forward(60)
   ???
}
```

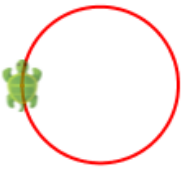


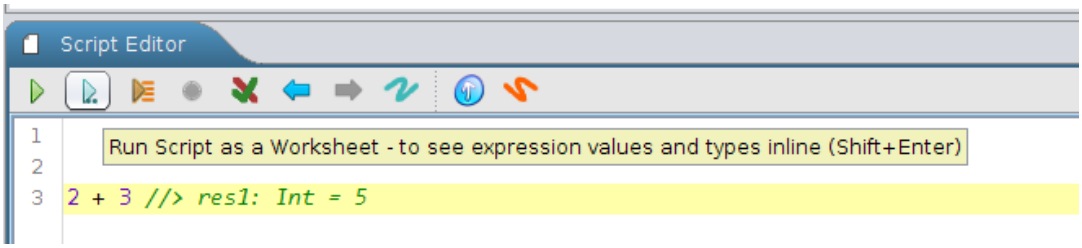
```
def polygon(sides: Int) {
   repeat(sides) {
      ???
   }
}
clear()
polygon(5)
```

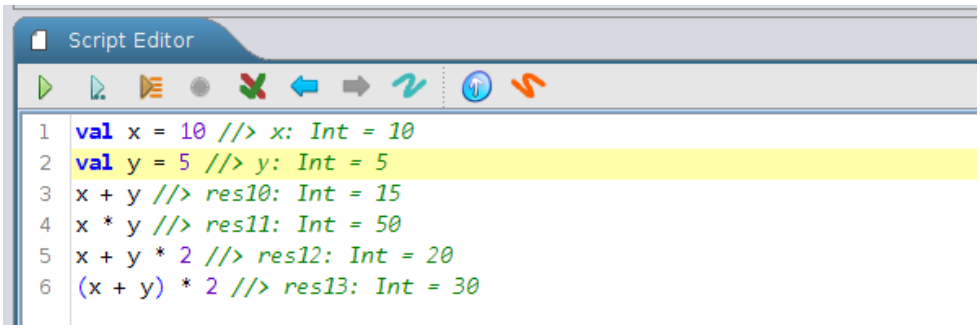


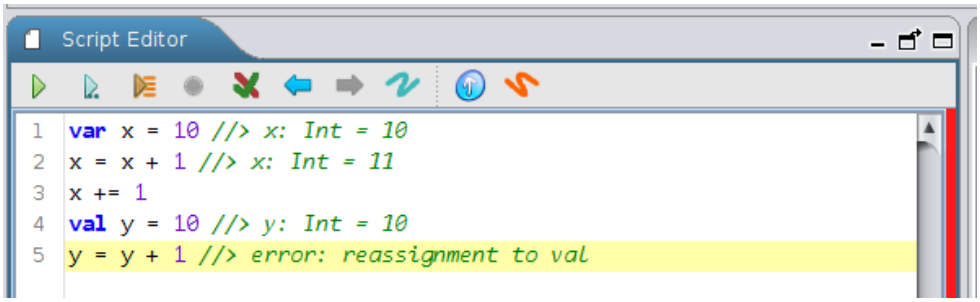
```
def polygon(sides: Int) {
   // same as before
}
clear()
polygon(8)
```

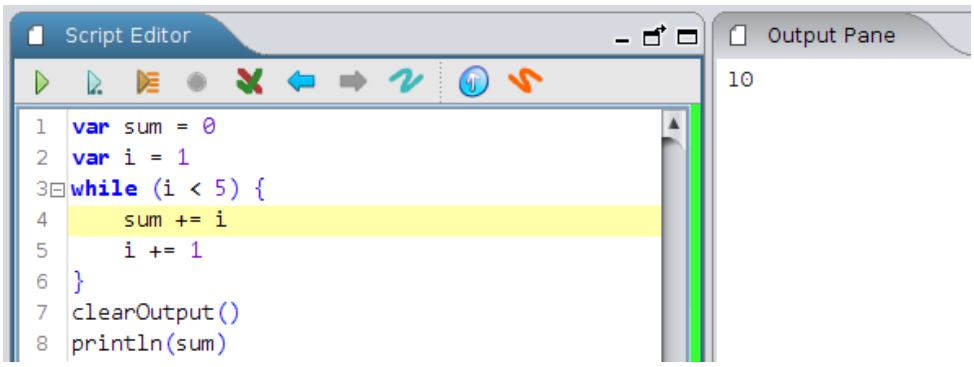
```
def polygon(sides: Int) {
   // same as before
}
clear()
setSpeed(medium)
polygon(???)
```











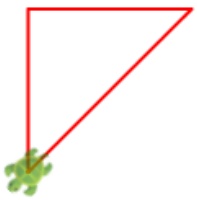

```
// The val instruction lets you give a name to a value. This name can be
   used multiple times in the rest of the program.
// The var instruction lets you create a variable.
// The right hand side (after the equal sign) of both the above
   instructions contain an expression. An expression is any piece of code
   that can be evaluated to produce a (data) value.
```

Script Editor

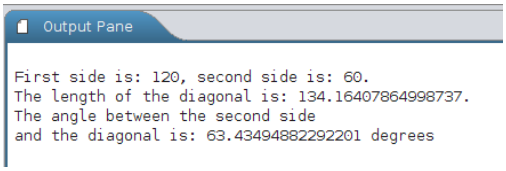
```
1  def twice(n: Int) = n * 2 //> twice: (n: Int)Int
2  twice(5) //> res17: Int = 10
3  def sum(n1: Int, n2: Int) = n1 + n2 //> sum: (n1: Int, n2: Int)Int
4  sum(3, 4) //> res18: Int = 7
5  def diagonal(side1: Double, side2: Double) = {
6      val dsquare = math.pow(side1, 2) + math.pow(side2, 2)
7      math.sqrt(dsquare)
8  } //> diagonal: (side1: Double, side2: Double)Double
9  diagonal(3, 4) //> res19: Double = 5.0
10 diagonal(4, 5) //> res20: Double = 6.4031242374328485
11
```

```
// In the above code - twice, sum, and
   diagonal are functions (and not
   commands).
// So what's the difference between
   commands and functions?
// A commands lets you carry out an
   action or affect a future action.
   Actions are effects produced by your
   program that you can see, hear, etc.
// A function takes one or more input
   values and returns one or more output
   values. Functions carry out
   computations (or calculations) to
   convert inputs to outputs. A function
   call is an expression.
```

```
def diagonal(side1: Double, side2:
   Double) = {
   // same as before
}
clear()
forward(100)
right(90)
forward(100)
right(135)
forward(diagonal(100, 100))
```



```
def diagonal(side1: Double, side2:
    Double) = {
    // same as before
}
var more = "yes"
while (more == "yes") {
    clear(); clearOutput()
    val s1 = readInt("First side of
        triangle")
    val s2 = readInt("Second side of
        triangle")
    val s3 = diagonal(s1, s2)
    val angle = math.atan2(s1,
        s2).toDegrees
    println(s"""
First side is: $s1, second side is: $s2.
The length of the diagonal is: $s3.
The angle between the second side
and the diagonal is: $angle degrees
""")
    forward(s1)
    right(90)
    forward(s2)
    right(180 - angle)
    forward(s3)
    more = readln("More triangles?")
}
```



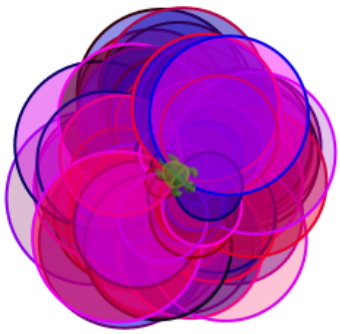
```
// Let's explore a series of functions that will allow us to find all the primes
   below a certain number

def factor(n1: Int, n2: Int) = n2 % n1 == 0

def factors(n: Int) = {
   (2 to n/2).filter { x =>
      factor(x, n)
   }
}

factors(20) //> Vector(2, 4, 5, 10)

def prime(n: Int) = {
   factors(n).size == 0
}

prime(11) //> true

def primesTill(n: Int) = {
   (3 to n).filter { x =>
      prime(x)
   }
}

primesTill(30) //> Vector(3, 5, 7, 11, 13, 17, 19, 23, 29)

// ??? Use the above functions to answer:
// - What are the factors of 27
// - Is 29 a prime number
// - What are all the primes below 40
```

```
// You can use the test command to test your functions. If a test passes, you
   will see green output in the Output Pane for that test. If a test fails, you
   will see red output for that test, and a test FAILED message

// This test should pass
test("primes till 10") {
   primesTill(10) shouldBe Vector(3, 5, 7)
}

// This test should fail
test("primes till 15") {
   primesTill(15) shouldBe Vector(3, 5, 7, 11, 12, 13)
}

// Writing tests to ensure the correctness your functions becomes very important
   as you write bigger pieces of software
```

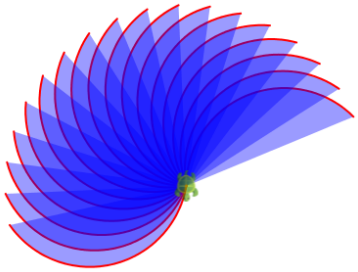
```
// Objects combine data, and functions that act on that data. You can define your
   own objects in Kojo using classes.

// First define the structure of your object (via its fields) and it's functions
   (called methods) using a case class
case class Fraction(num: Int, den: Int) {
   require(den != 0)
   def +(other: Fraction) =
      Fraction(num * other.den + other.num * den,
         den * other.den)
}


// Then create object instances of your class and use them
Fraction(1, 2) + Fraction(1, 2) //> Fraction(4,4)
```

```
// euler problem 2:
// Each new term in the Fibonacci sequence is generated by adding the previous
   two terms. By starting with 1 and 2, the first 10 terms will be:
// 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, ...
// By considering the terms in the Fibonacci sequence whose values do not exceed
   four million, find the sum of the even-valued terms.

// A map allows you to store keys and corresponding values
// An lru cache is a map which stores recently used data

// Here we use a cache to store values of the 'fib' function, to avoid
   recalculation of values
val cache = lruCache[Long, Long](10)

def fib(n: Long): Long = {
   // If required value is in the cache, return it. Else compute it, put it in
      the cache, and return it.
   cache.getOrElseUpdate(n,
      n match {
         case 1 => 1
         case 2 => 2
         case _ => fib(n - 1) + fib(n - 2)
      })
}

// Streams let you work with lazily generated and conceptually infinitely long
   data.
val s = Stream.from(1).map(n => fib(n)) //> Stream(1, ?)
s.takeWhile(n => n < 4000000).filter(n => n % 2 == 0).sum //> 4613732
```

```
clear()
setSpeed(fast)
repeat(100) {
   setPenColor(Color(random(256), 0,
      random(256)))
   setFillColor(Color(random(256), 0,
      random(256), random(100) + 50))
   left(random(360))
   circle(random(50) + 10)
}
```

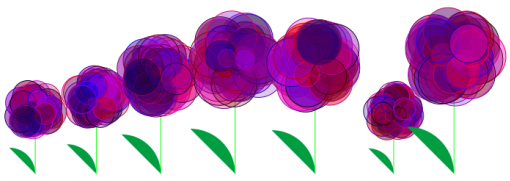


```
clear()
setSpeed(fast)
setFillColor(Color(0, 0, 255, 100))
repeat(18) {
   savePosHe()
   right(135, 100)
   restorePosHe()
   left(10)
}
```



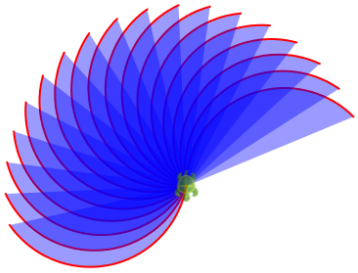
```
def flower(size: Int) {
   savePosHe()
   ???
   repeat(100) {
      ???
   }
   restorePosHe()
}
clear()
setSpeed(fast)
flower(20)
```

```
def flower(size: Int) {
   // same as before
}

def garden(flowers: Int) {
   repeat(flowers) {
      ???
   }
}
clear()
setSpeed(fast)
garden(7)
```

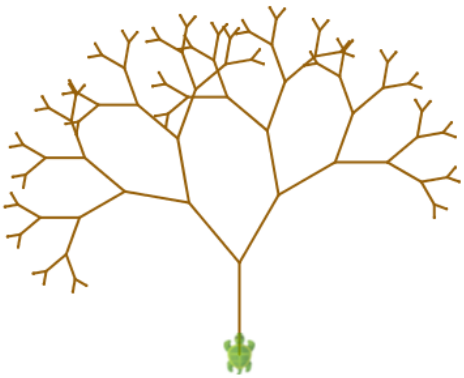


```
def figure(n: Int) {
   if (n < 10) {
      forward(n)
   }
   else {
      forward(n)
      right(90)
      figure(n - 5)
   }
}
clear()
figure(100)
// use tracing to understand this program
```

```
def pattern(n: Int) {
   if (n > 0) {
      savePosHe()
      right(135, 100)
      restorePosHe()
      left(10)
      pattern(n - 1)
   }
}
clear()
setSpeed(fast)
setFillColor(Color(0, 0, 255, 100))
pattern(18)
```



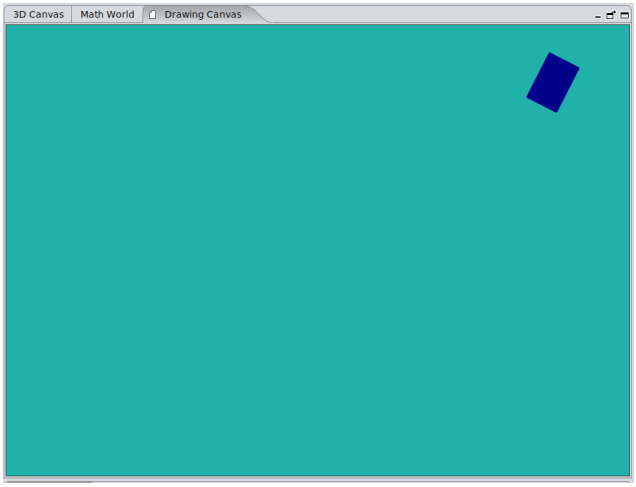
```
def tree(n: Int) {
   savePosHe()
   if (n < 10) {
      ???
   }
   else {
      forward(n)
      right(30)
      tree(n - 10)
      left(70)
      tree(n - 10)
   }
   restorePosHe()
}
clear()
setSpeed(fast)
setPenColor(Color(150, 95, 8))
tree(70)
```



```
// A traffic light animation

def light = Picture {
   setPenColor(darkGray)
   circle(20)
}

cleari()

val r = light
val y = light
val g = light
y.translate(0, 40)
r.translate(0, 80)

draw(r, y, g)

r.setFillColor(red)
var lightOn = r

timer(1000) {
   if (lightOn == r) {
      r.setFillColor(white)
      y.setFillColor(yellow)
      lightOn = y
   }
   else if (lightOn == y) {
      y.setFillColor(white)
      g.setFillColor(green)
      lightOn = g
   }
   else if (lightOn == g) {
      g.setFillColor(white)
      r.setFillColor(red)
      lightOn = r
   }
}
```

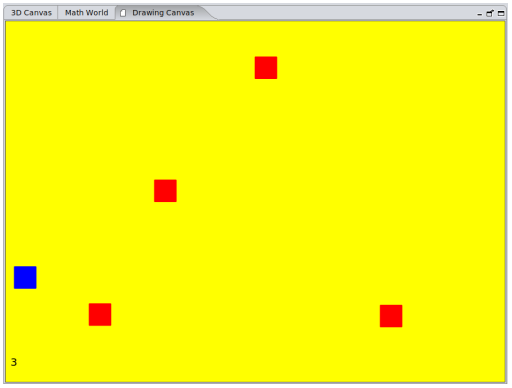
```
// ??? Make the lights blink faster. And
   then slower.
// ??? Put a rectangle around the lights.
```

```
// A simple game. You need to keep the
   rectangle within the canvas. The
   rectangle moves and grows in size.
   Its speed goes up as its size
   increases. You can rotate it by
   pressing the 'P' key. You can make it
   smaller by clicking on it

switchToDefault2Perspective()
cleari()
drawStage(ColorMaker.lightSeaGreen)

val p1 = Picture {
   setPenColor(ColorMaker.darkBlue)
   setFillColor(ColorMaker.darkBlue)
   repeat(2) {
      forward(40)
      right(90)
      forward(60)
      right(90)
   }
}
draw(p1)

animate {
   p1.translate(2, 0)
   p1.scale(1.001)
   if (isKeyPressed(Kc.VK_P)) {
      p1.rotate(1)
   }
   if (p1.collidesWith(stageBorder)) {
      p1.setFillColor(red)
      stopAnimation()
   }
}

p1.onMouseClick { (x, y) =>
   p1.scale(0.9)
}

activateCanvas()
```



```
// ??? How can you make the game more
   difficult?
// Increase the speed of the rectangle
   at a faster rate?
// Make the rectangle grow bigger faster?
// Try these ideas (and any others that
   you come up with).
```

```
// Another game. The blue square (controlled by
    you) is hunted by the red squares.

switchToDefault2Perspective()
clear()
drawStage(yellow)
val cb = canvasBounds

def gameShape(color: Color) = Picture {
   setFillColor(color)
   setPenColor(color)
   repeat(4) {
      forward(40)
      right(90)
   }
}

val r1 = gameShape(red)
val r2 = gameShape(red)
val r3 = gameShape(red)
val r4 = gameShape(red)
val player = gameShape(blue)
r1.setPosition(150, 150)
r2.setPosition(-150, 150)
r3.setPosition(0, 150)
r4.setPosition(250,0 )

draw(r1, r2, r3,r4, player)

val playerspeed = 9
var vel1 = Vector2D(3, 2) * 2
var vel2 = Vector2D(-3, 2) * 2
var vel3 = Vector2D(0, 4) * 2
var vel4 = Vector2D( 4,0) * 2

animate {
   r1.transv(vel1)
   r2.transv(vel2)
   r3.transv(vel3)
   r4.transv(vel4)

   // r1, r2, r3, r4 motion
   if (r1.collidesWith(stageBorder)) {
      vel1 = bouncePicVectorOffStage(r1, vel1)
   }
   if (r2.collidesWith(stageBorder)) {
      vel2 = bouncePicVectorOffStage(r2, vel2)
   }
   if (r3.collidesWith(stageBorder)) {
      vel3 = bouncePicVectorOffStage(r3, vel3)
   }
```



```
    if (r4.collidesWith(stageBorder)) {
        vel4 = bouncePicVectorOffStage(r4, vel4)
    }

    // player keyboard control
    if (isKeyPressed(Kc.VK_UP)) {
        player.translate(0, playerspeed)
    }
    if (isKeyPressed(Kc.VK_DOWN)) {
        player.translate(0, -playerspeed)
    }
    if (isKeyPressed(Kc.VK_LEFT)) {
        player.translate(-playerspeed, 0)
    }
    if (isKeyPressed(Kc.VK_RIGHT)) {
        player.translate(playerspeed, 0)
    }

    // player-r1, r2, r3, r4 collision
    if (player.collidesWith(r1)) {
        gameLost()
    }
    if (player.collidesWith(r2)) {
        gameLost()
    }
    if (player.collidesWith(r3)) {
        gameLost()
    }
    if (player.collidesWith(r4)) {
        gameLost()
    }

    // player-border collision
    if (player.collidesWith(stageBorder)) {
        gameLost()
    }
}

def gameLost() {
    drawCenteredMessage("You Loose", purple, 20)
    stopAnimation()
    player.setFillColor(red)
    player.scale(1.1)
}

showGameTime(60, "You loose", black)
activateCanvas()
```

```
// ??? Make the game look better by changing the shapes of the hunters and the
    hunted.
// For example, the hunters could be stars, and the hunted could be a pentagon.
```

```
// Here's a slightly better organized version of the previous game. It uses a
   sequence and a map to remove code duplication.

switchToDefault2Perspective()
clear()
drawStage(yellow)
val cb = canvasBounds

def gameShape(color: Color) = Picture {
   setFillColor(color)
   setPenColor(color)
   repeat(4) {
      forward(40)
      right(90)
   }
}

val r1 = gameShape(red)
val r2 = gameShape(red)
val r3 = gameShape(red)
val r4 = gameShape(red)
r1.setPosition(150, 150)
r2.setPosition(-150, 150)
r3.setPosition(0, 150)
r4.setPosition(250, 0)

val player = gameShape(blue)

draw(r1, r2, r3, r4, player)

val playerspeed = 9
var vel1 = Vector2D(3, 2) * 2
var vel2 = Vector2D(-3, 2) * 2
var vel3 = Vector2D(0, 4) * 2
var vel4 = Vector2D(4, 0) * 2

val rs = Seq(r1, r2, r3, r4)
var rsVels = Map(
   r1 -> vel1,
   r2 -> vel2,
   r3 -> vel3,
   r4 -> vel4
)

animate {
   rs.foreach { r =>
      r.translate(rsVels(r))
   }
```

```
    rs.foreach { r =>
        if (r.collidesWith(stageBorder)) {
            val newVel = bouncePicVectorOffStage(r, rsVels(r))
            rsVels += (r -> newVel)
        }
    }

    rs.foreach { r =>
        if (player.collidesWith(r)) {
            gameLost()
        }
    }

    // player keyboard control
    if (isKeyPressed(Kc.VK_UP)) {
        player.translate(0, playerspeed)
    }

    if (isKeyPressed(Kc.VK_DOWN)) {
        player.translate(0, -playerspeed)
    }

    if (isKeyPressed(Kc.VK_LEFT)) {
        player.translate(-playerspeed, 0)
    }

    if (isKeyPressed(Kc.VK_RIGHT)) {
        player.translate(playerspeed, 0)
    }

    // player-border collision
    if (player.collidesWith(stageBorder)) {
        gameLost()
    }
}

def gameLost() {
    drawCenteredMessage("You Loose", purple, 20)
    stopAnimation()
    player.setFillColor(purple)
    player.scale(1.1)
}

showGameTime(60, "You loose", black)
activateCanvas()
```

```
// ??? Add a fifth hunter to the game. Make use of the rs sequence and rsVels map
    so that you don't have to add any code to the 'animate' loop.
```