9

building WATCHGOOZ3

Goose on the loose! In this chapter, you'll build WATCHGOOZ3 (Figure 9-1), a robot goose that can patrol and guard a room while moving on only two legs. This robot is inspired by a creation of Bruno Zarokian.

The mechanics of this robot are designed so that you can program the robot to walk, turn, and avoid obstacles with just the Brick Program App (see Chapter 10). No computer required! In this chapter I'll describe the key design ideas that allow us to simplify the software so that the limited Brick Program App is sufficient to program the robot. In addition to the building instructions, you'll find building techniques for working with structures, gears, and motor assemblies. You'll learn how to make sturdy, braced structures that hold gears; how to gear down a motor to increase its torque; and how to build parallelogram linkages.

how does WATCHGOOZ3 walk?

A creature that walks on two legs is called a *biped*. Humans are bipeds, and so are kangaroos, some primates, dinosaurs like *Tyrannosaurus rex* and velociraptors, and birds like ostriches (all the time) and geese (when not flying).

For the biped to maintain *static equilibrium* while walking on two legs (that is, to avoid falling), the projection of its *center of mass (COM)* must always lie inside the *support area* (the feet). Imagine the center of mass as the only spot where all of an object's mass is concentrated. An imaginary vertical line, always forming a 90-degree angle with the walking surface (like a string with a weight hung at its end), connects the center of mass to its *projection* on the ground. When a biped lifts a foot [Figure 9-2(c)], the support area decreases.

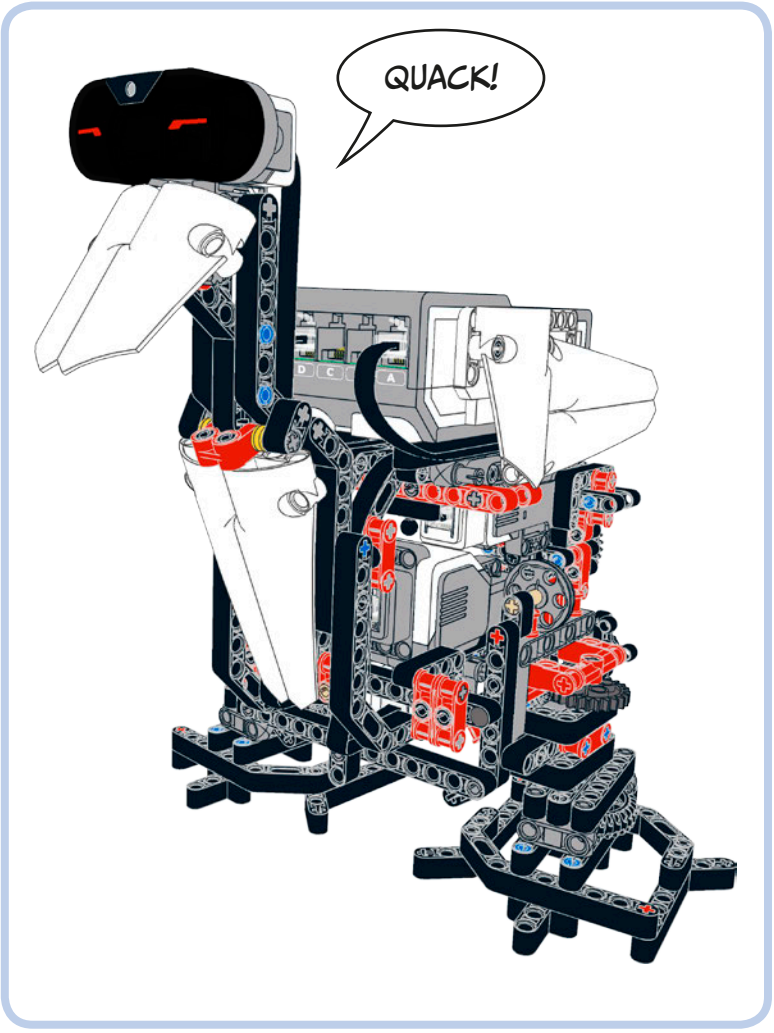


Figure 9-1: WATCHGOOZ3

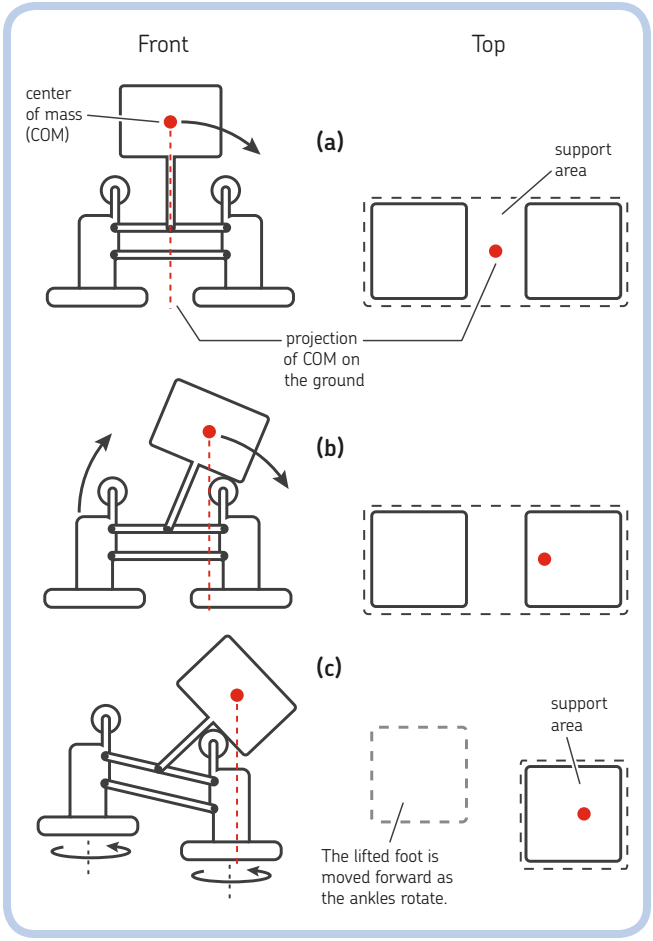


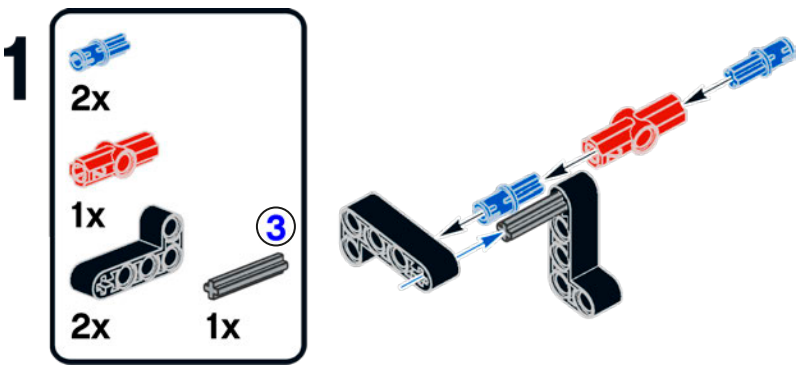
Figure 9-2: The workings of a weight-shifting biped robot

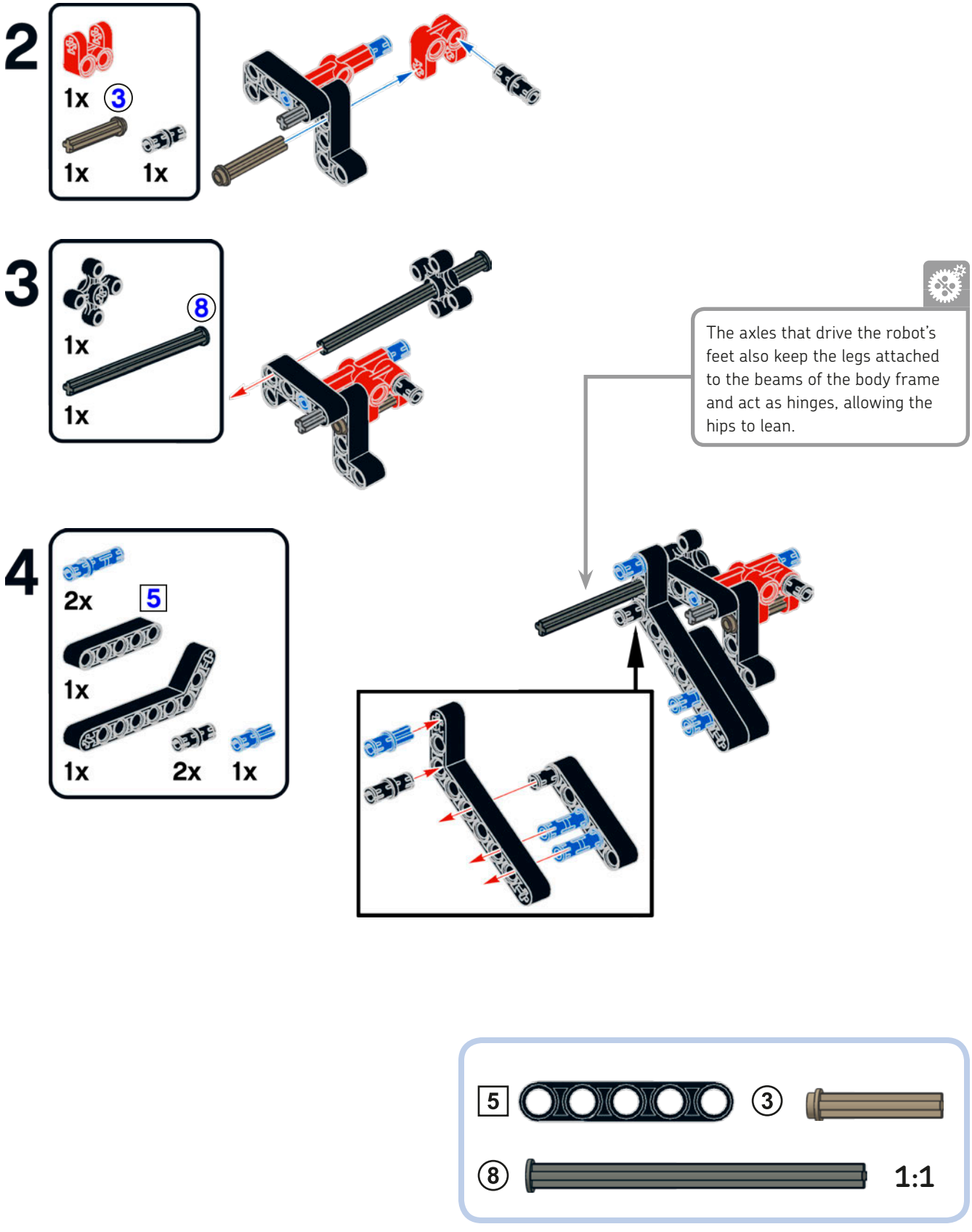
If the projection of the center of mass is not within the support area of the foot that's still on the ground, the biped falls over.

To move the center of mass inside the support area of its standing foot, a biped will naturally lean to one side. Figure 9-2 shows how WATCHGOOZ3 maintains static equilibrium while walking. As you can see, it shifts the weight of the EV3 Brick to the foot that remains on the ground (a); then the swinging frame touches a rolling wheel (b), unloading the other foot and lifting it with a parallel linkage. The robot takes steps by turning its feet, pivoting on the foot on the ground (c). WATCHGOOZ3 is thus a *weight-shifting biped robot*.

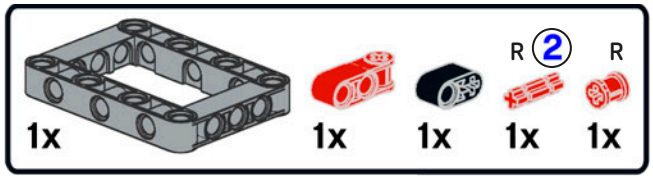
Because WATCHGOOZ3 walks with alternating weight-shifting and stepping actions, it has a kind of swinging gait. When the robot sees an object, it avoids it by turning the foot on the ground more than usual. In fact, the foot on the ground keeps turning until the object is no longer in its sight, at which point the robot shifts its weight to the other side so it can continue walking straight.

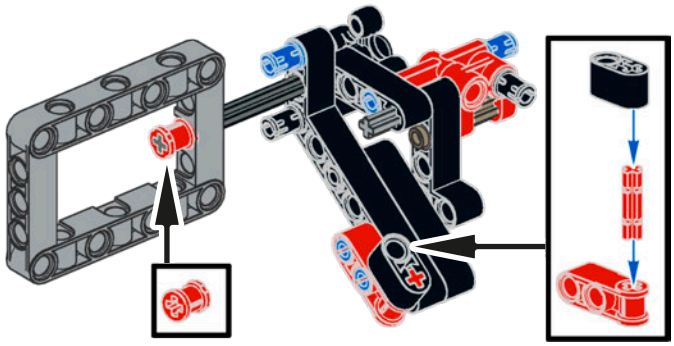
right leg assembly




2
1x
3
1x
1x
3
8
1x
1x
The axles that drive the robot's feet also keep the legs attached to the beams of the body frame and act as hinges, allowing the hips to lean.
4
2x
5
1x
1x
2x
1x
5
3
8
1:1

5





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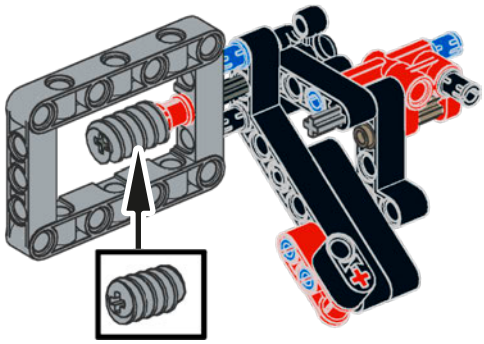

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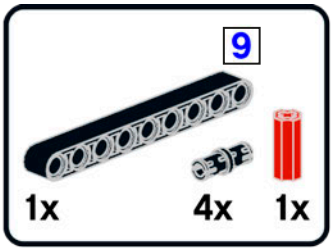
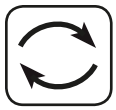
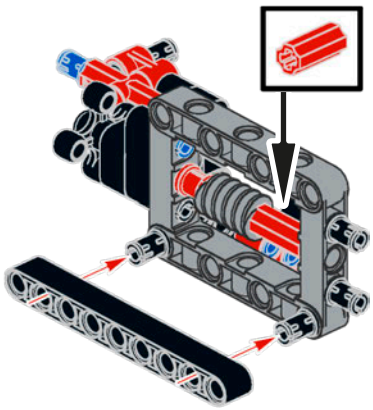
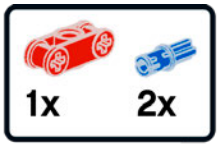


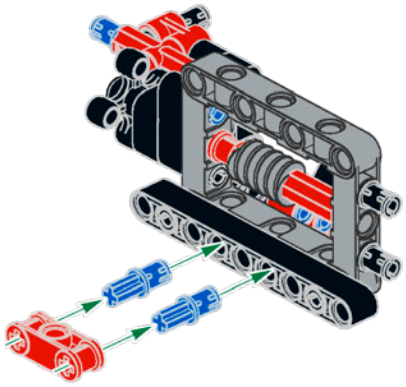




Place the axle connector. Then push the O-frame to lock the connector to the axle.

8





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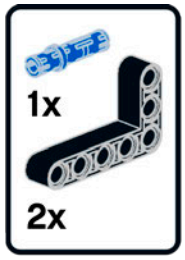
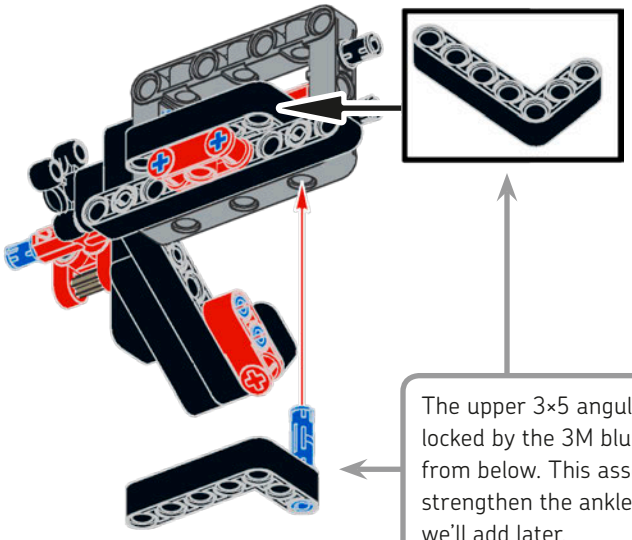
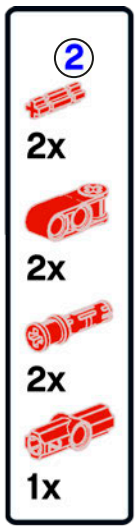
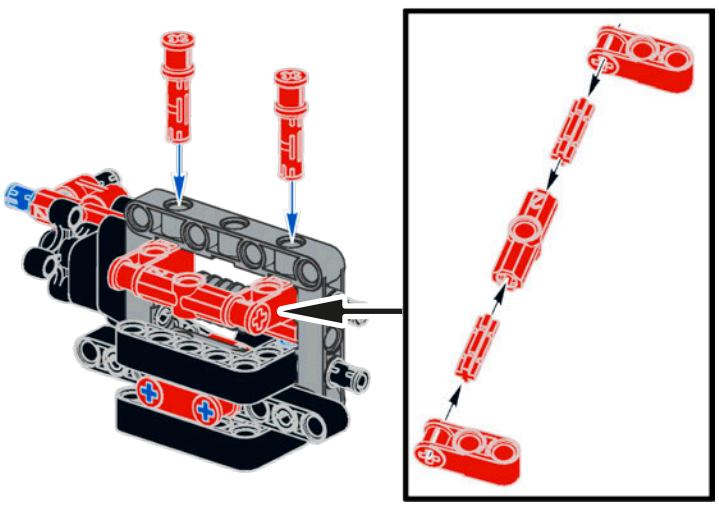




The upper 3×5 angular beam is locked by the 3M blue pin inserted from below. This assembly helps strengthen the ankle axle, which we'll add later.

10





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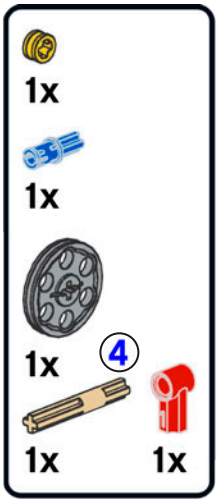
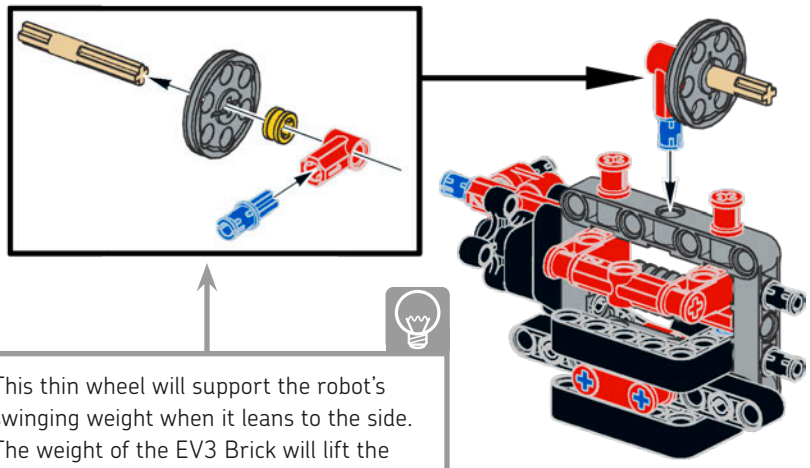
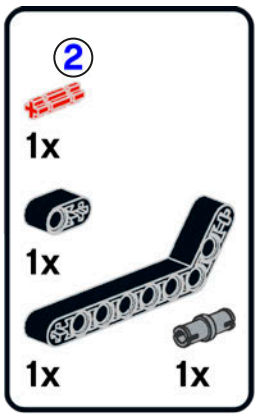
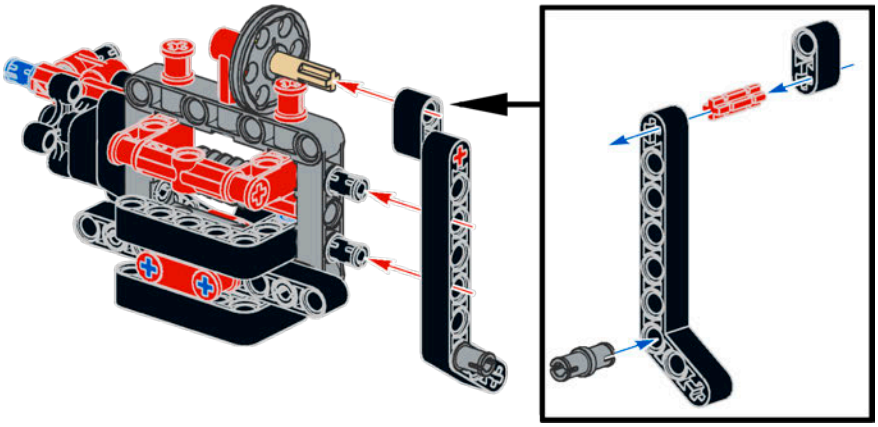




This thin wheel will support the robot's swinging weight when it leans to the side. The weight of the EV3 Brick will lift the opposite leg from the ground.

12





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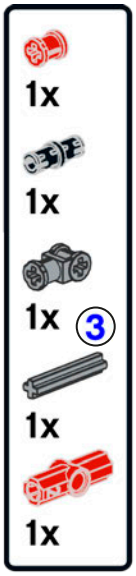

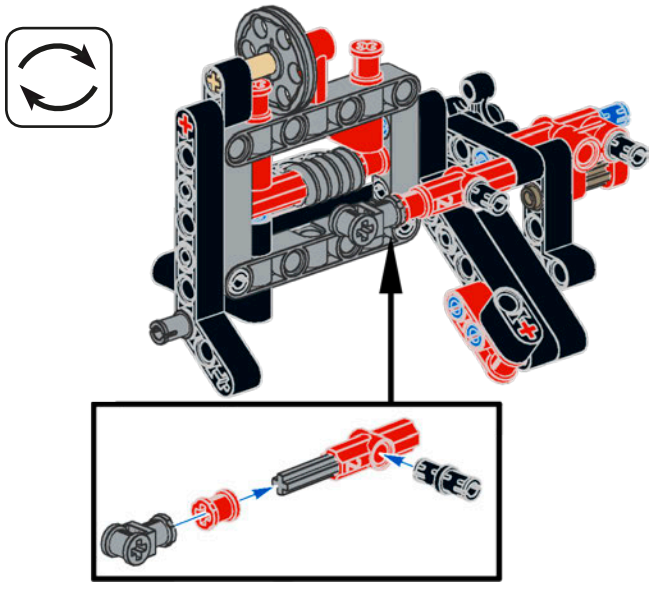

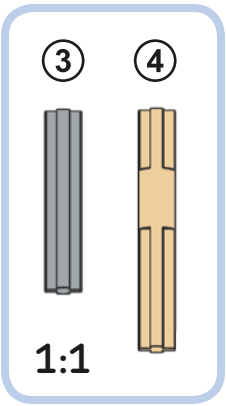

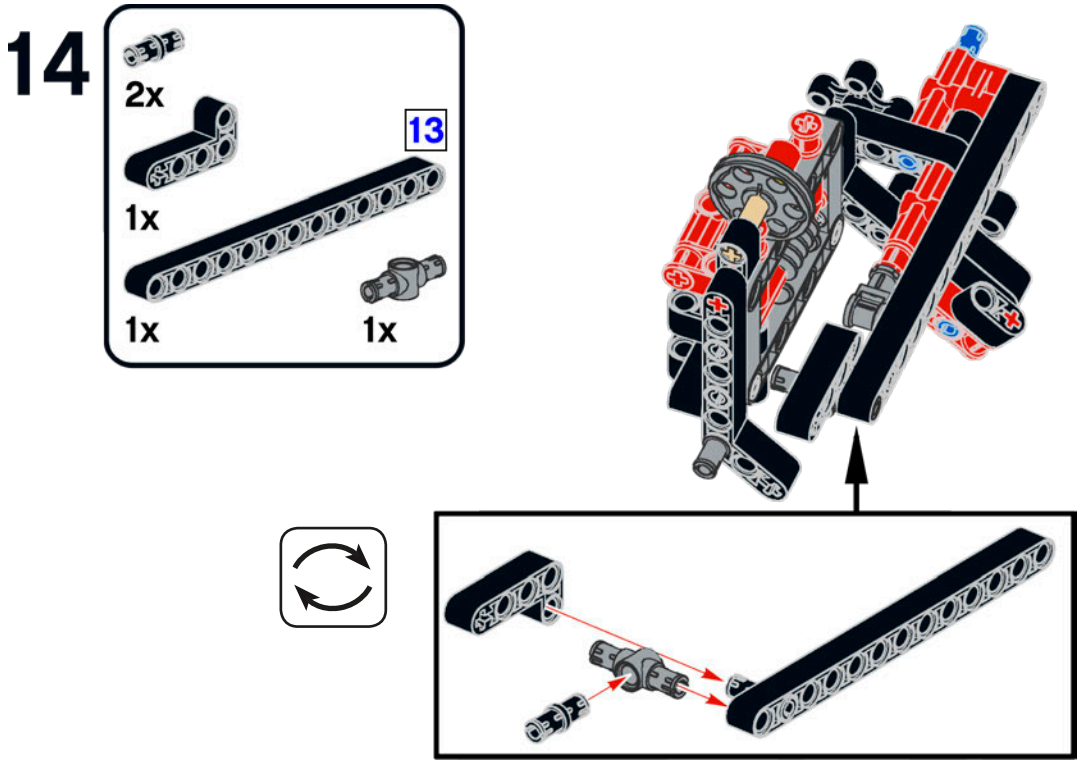
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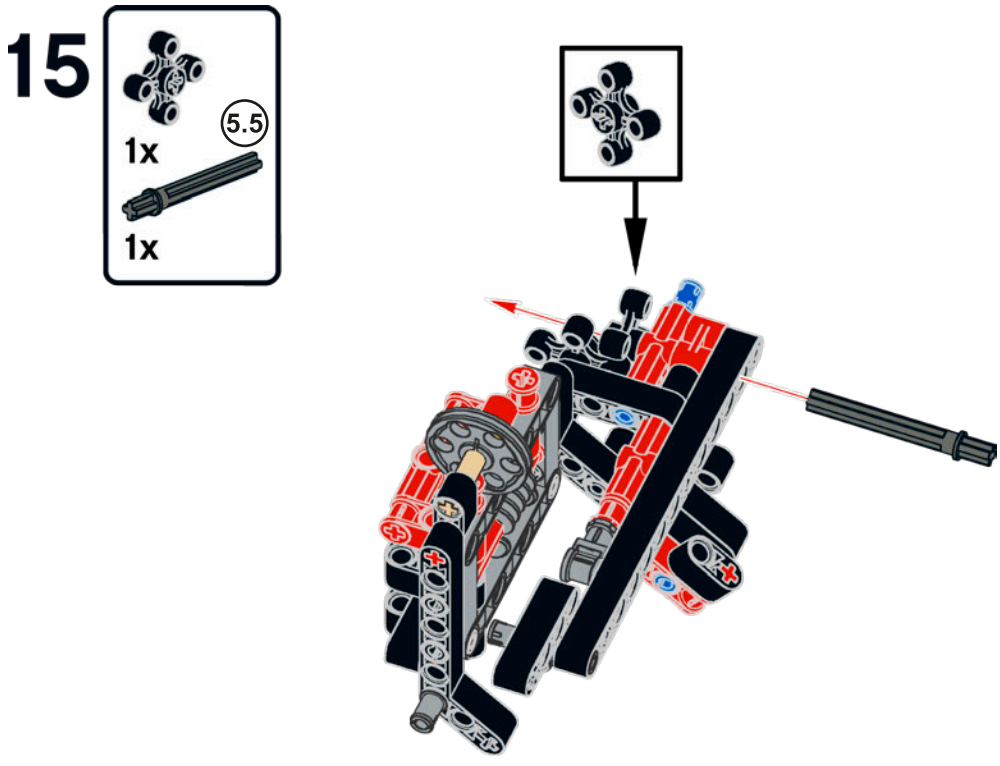
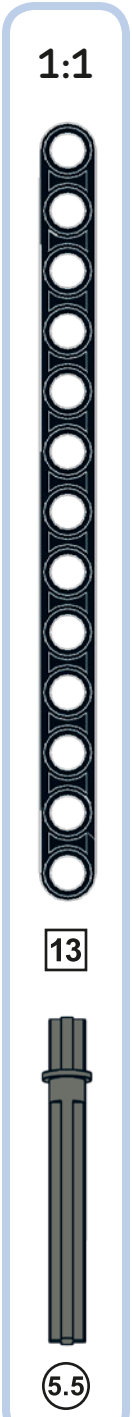
13
1x
1x
1x


15
1x
5.5
1x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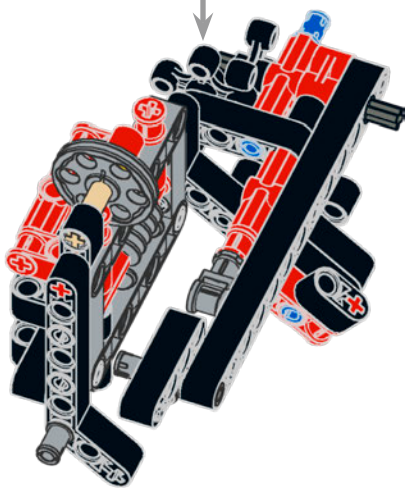
13
5.5

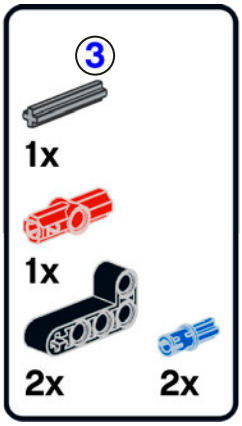
16

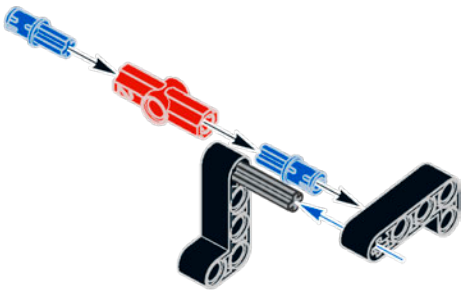


The knob wheels are ideal for transmitting the motion to perpendicular axles (axles that form a right angle).

left leg assembly

1





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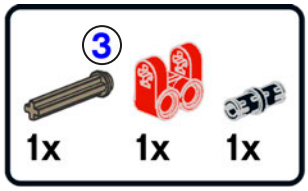

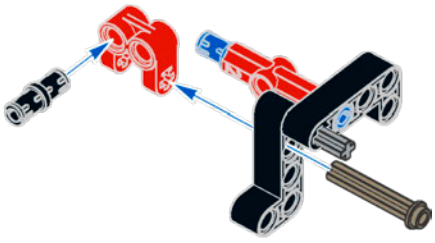

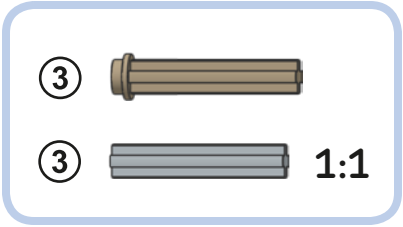

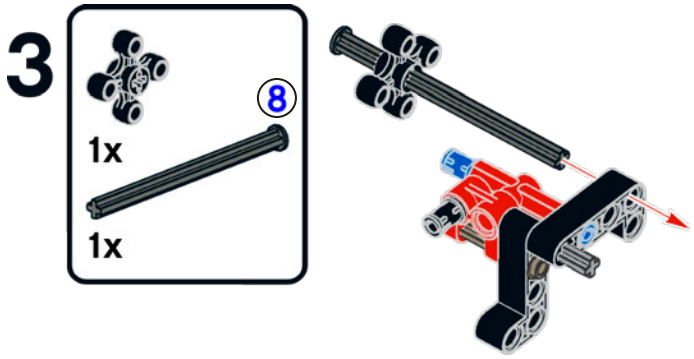
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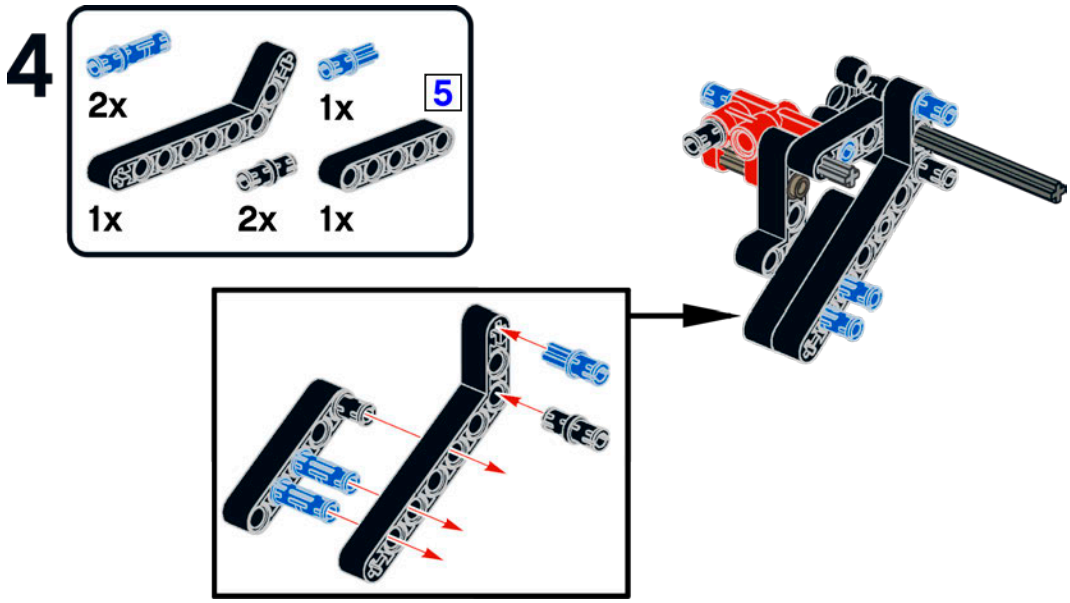
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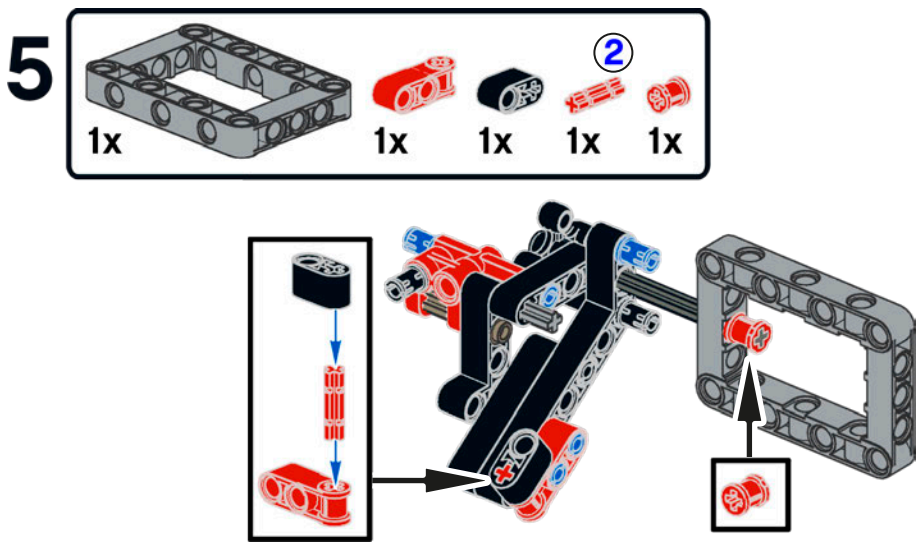
2x
1x
5
1x
2x
1x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1x
1x
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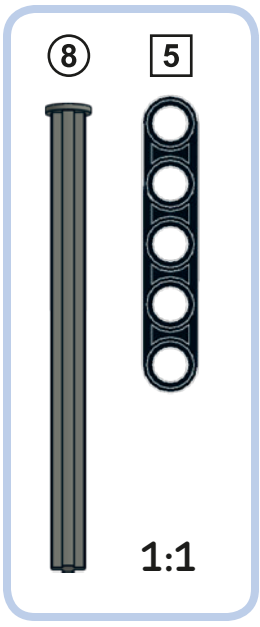
1x
1x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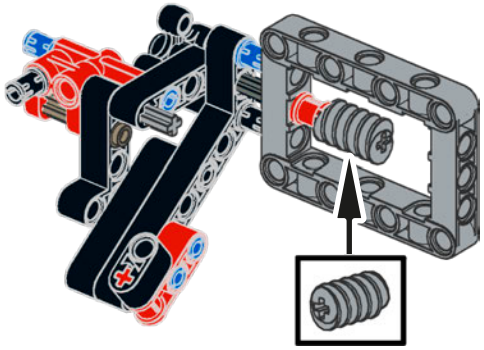

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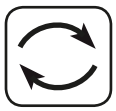
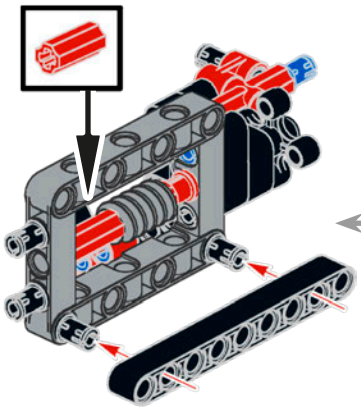
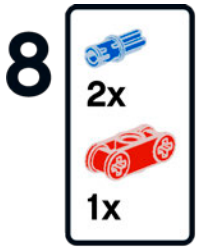
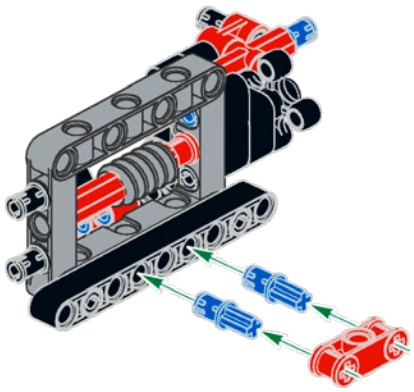




Place the axle connector. Then push the O-frame to lock the connector to the axle.

8





9  1:1

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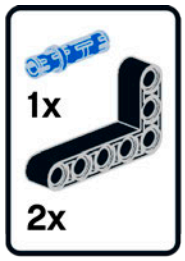

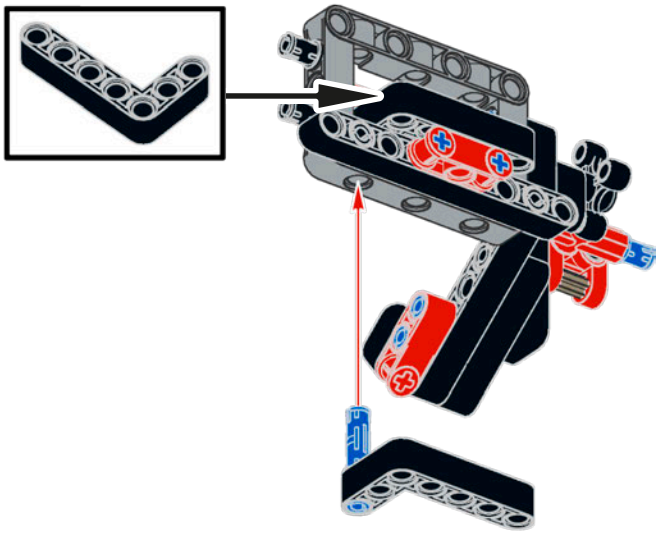

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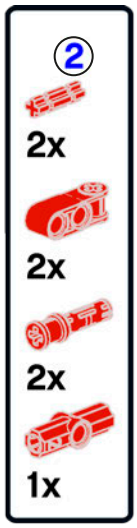

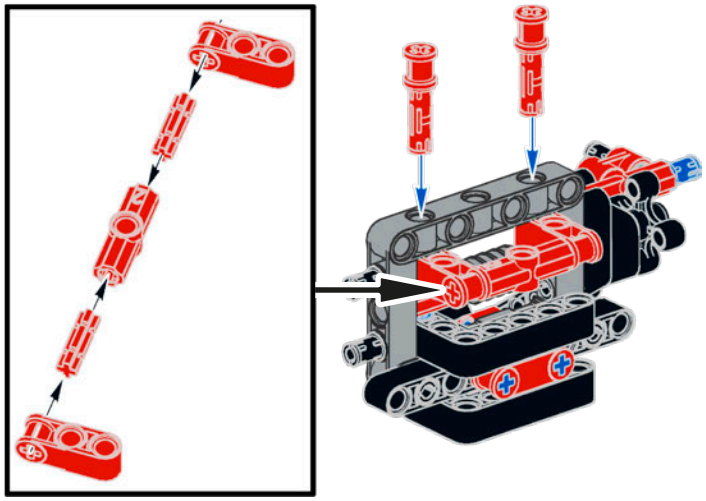

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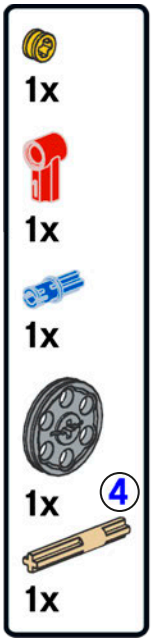

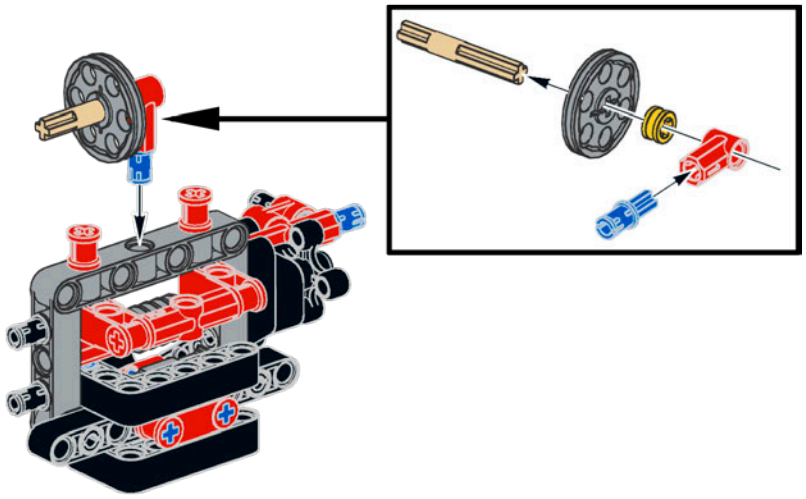

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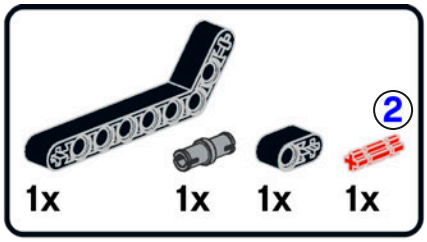

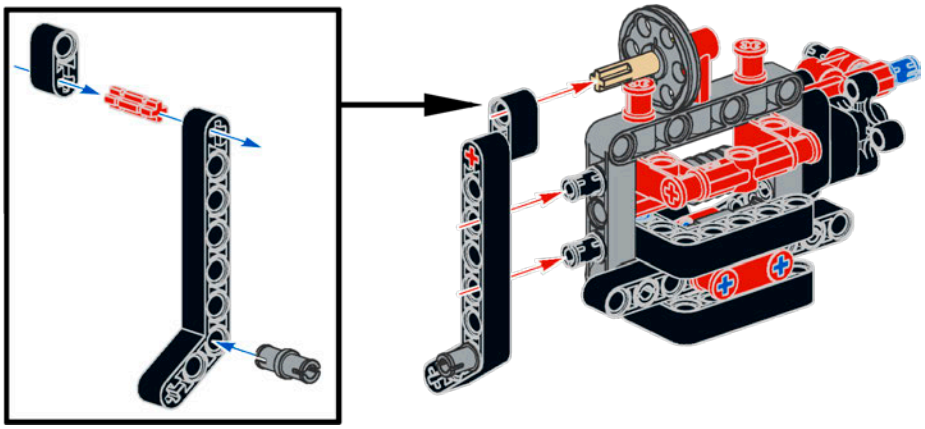

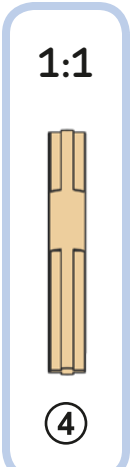

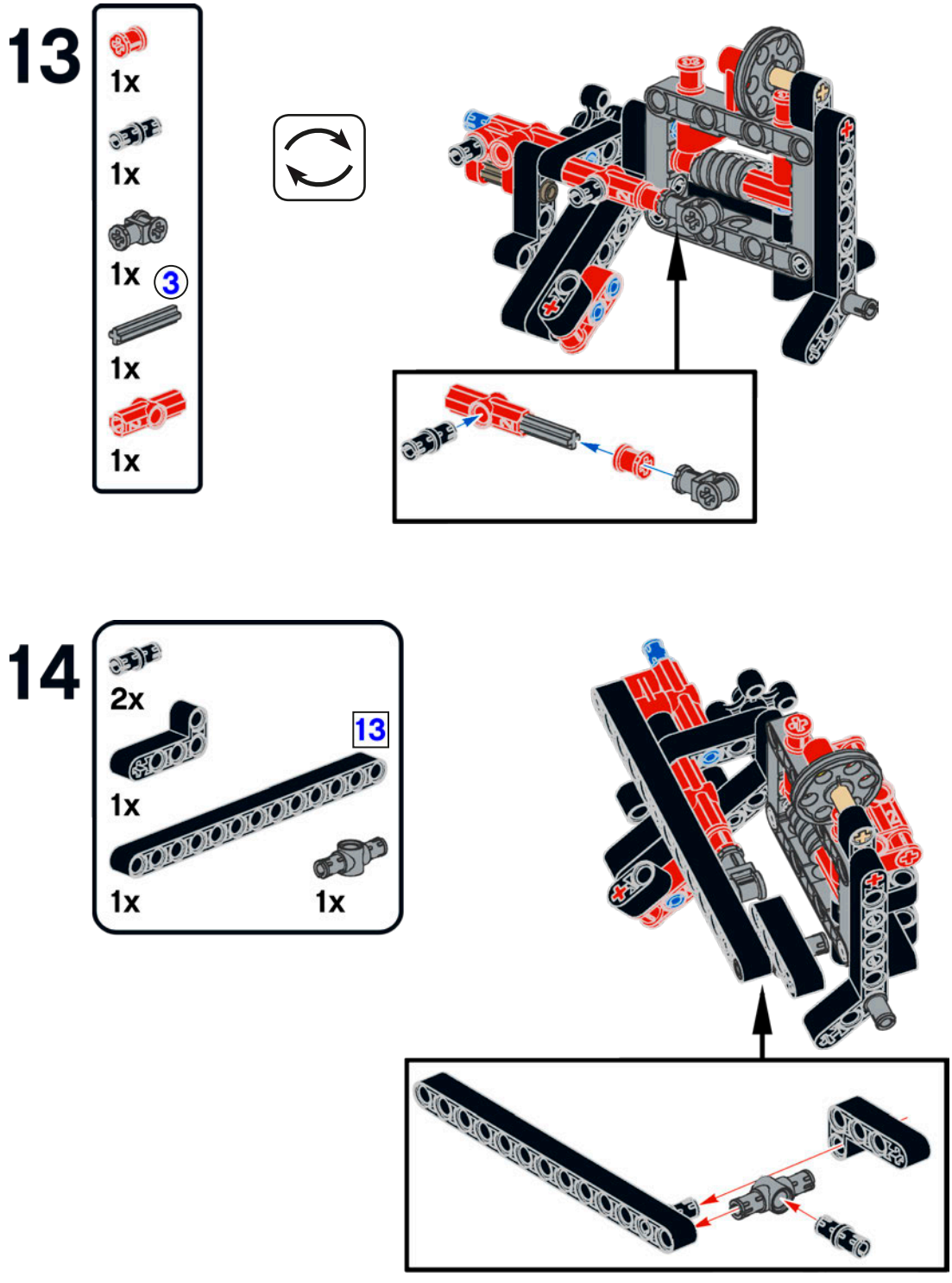
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1x
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2x
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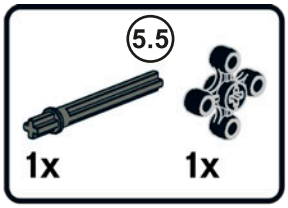
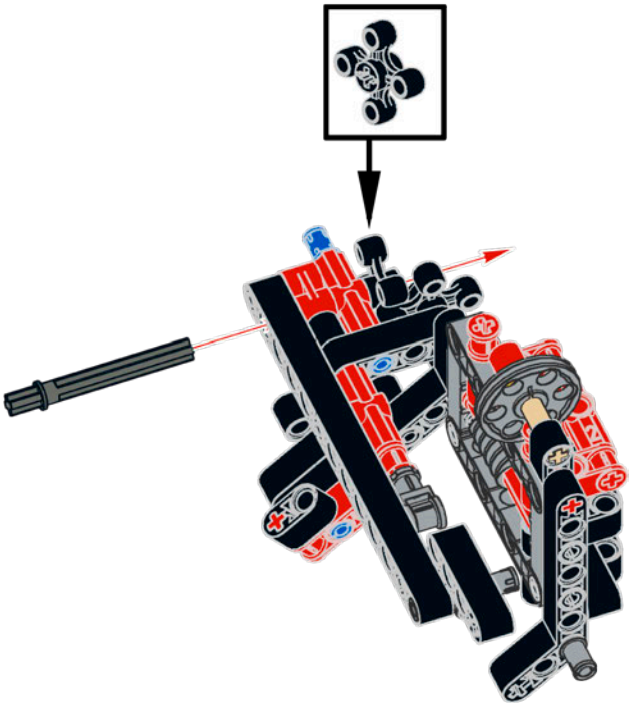
1x
1x
1:1
3
13

15





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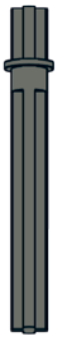
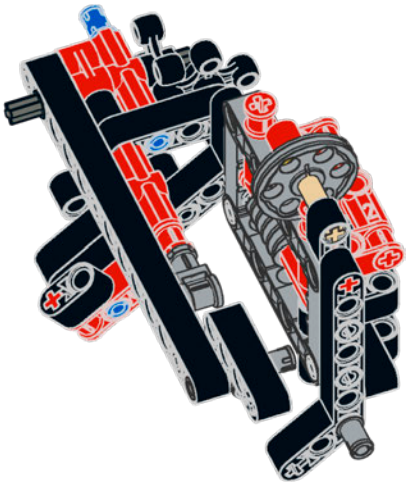
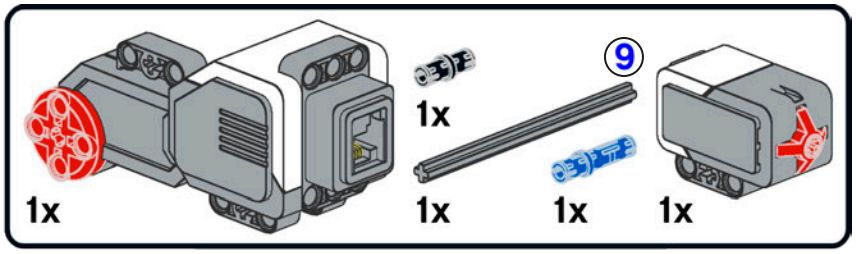


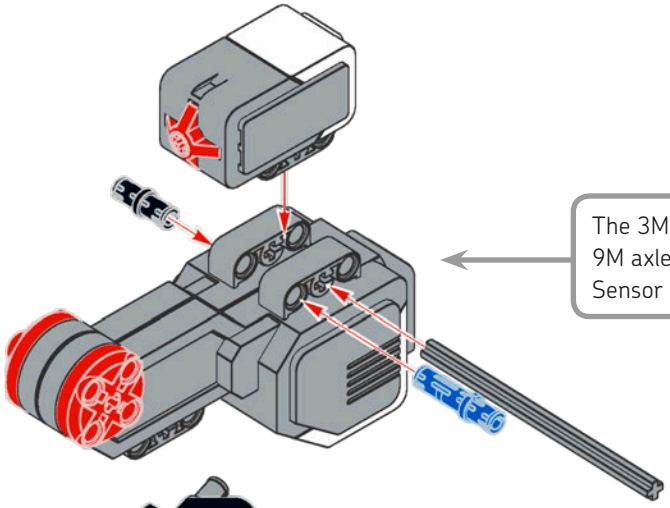
16



main assembly

1



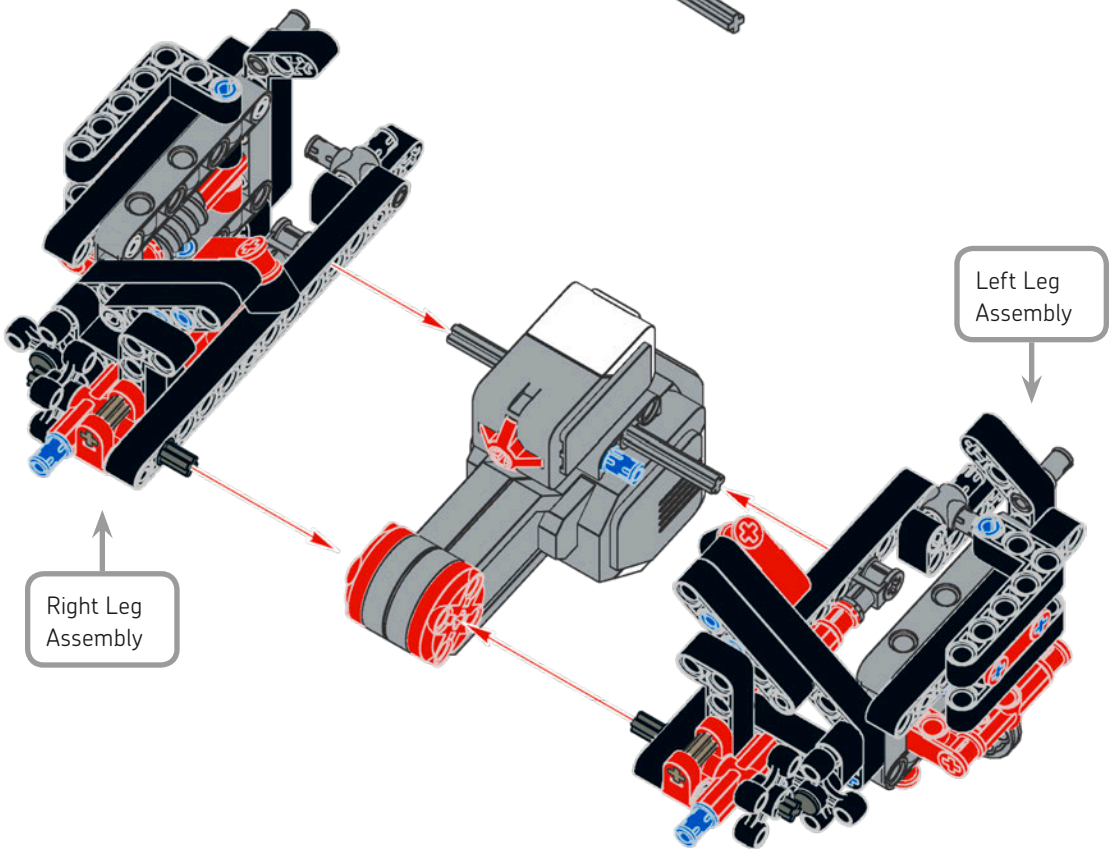


The 3M blue pin and the 9M axle lock the Touch Sensor to the Large Motor.

1:1

9

2



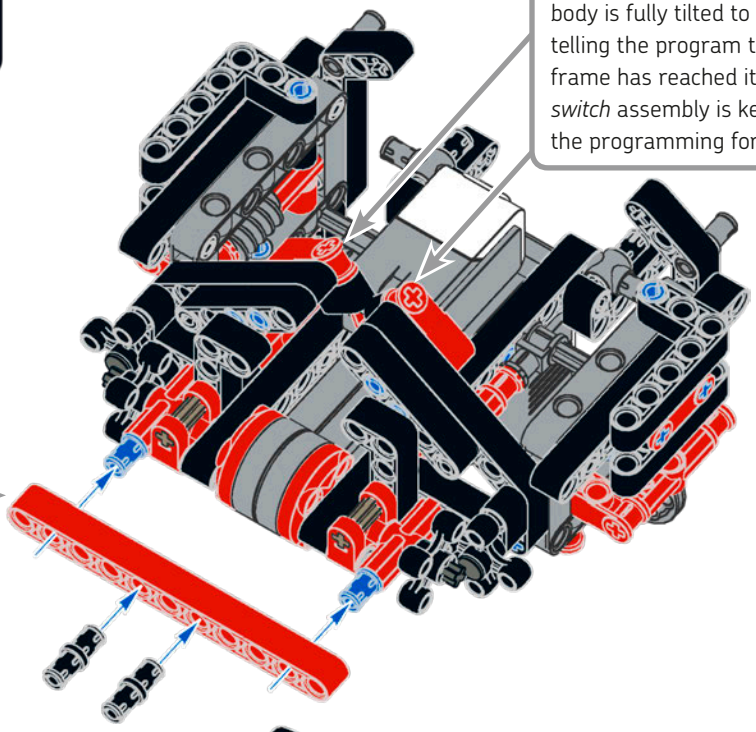
3

R 11

1x 2x

The 2M beams attached to these two cross blocks alternately close the contact of the Touch Sensor, when the body is fully tilted to the left or right, telling the program that the swinging frame has reached its limit. This *limit switch* assembly is key to simplifying the programming for this robot.

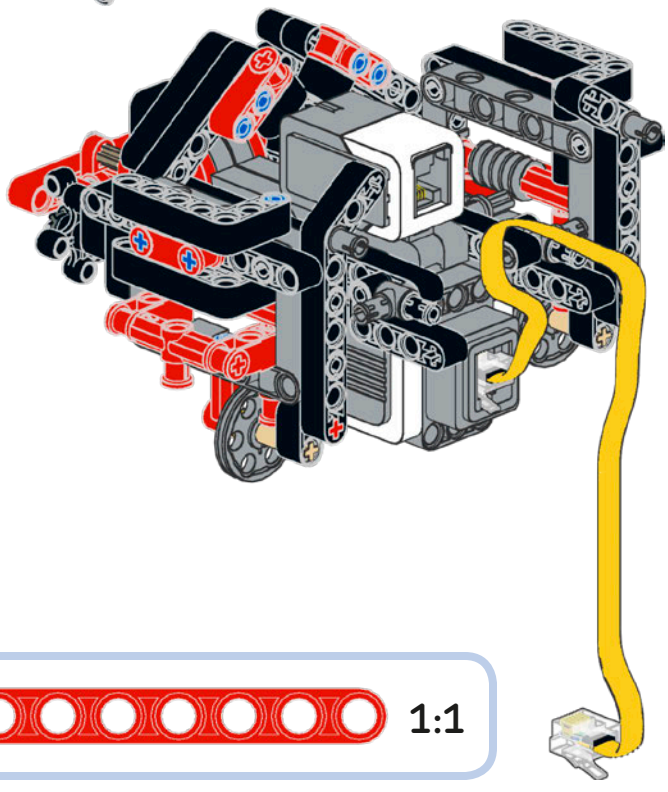
This 11M red beam braces the leg assemblies.



4

25cm

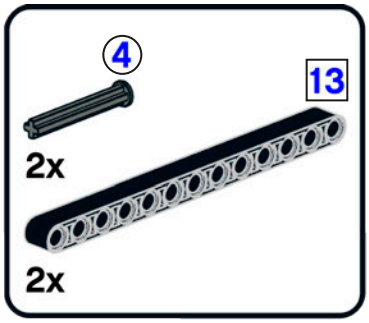
1x

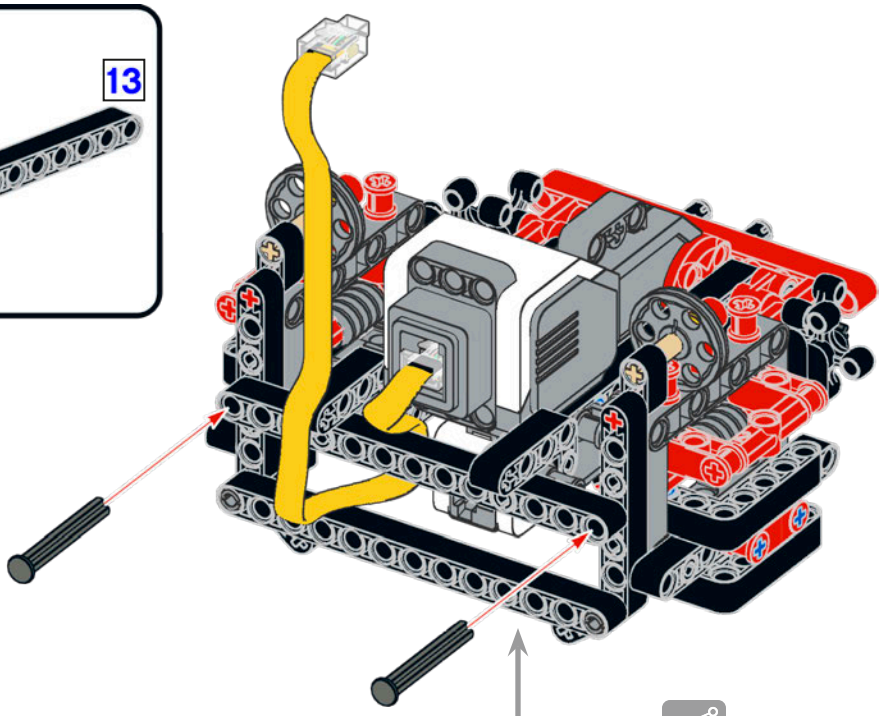


11

1:1

5





The 13M beams also brace the leg assemblies, and they form a parallelogram-like linkage that keeps the legs vertical and parallel to each other.

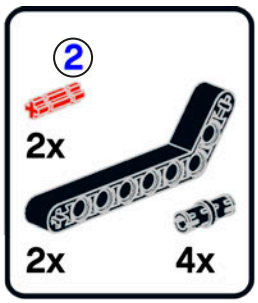
1:1

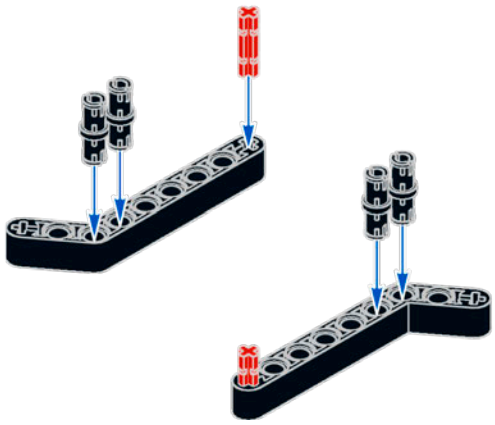
4

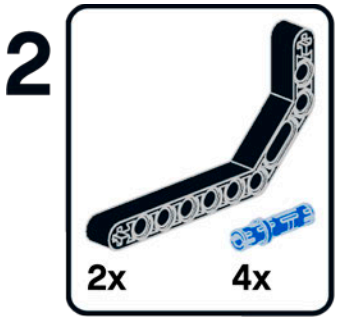
13

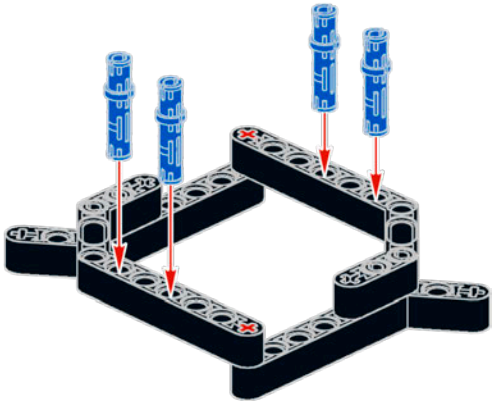
left foot assembly

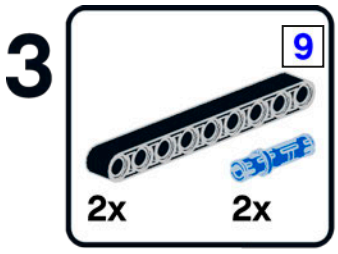
1

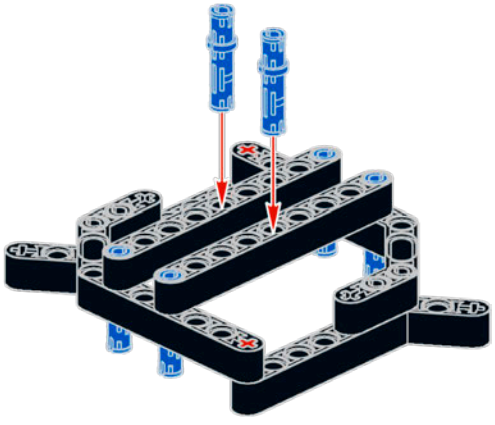


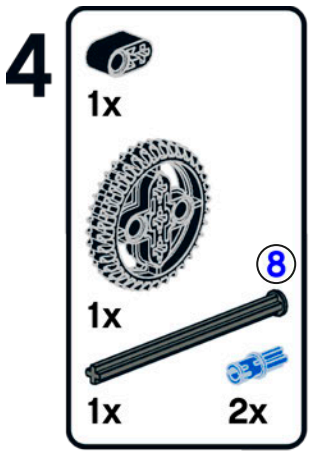


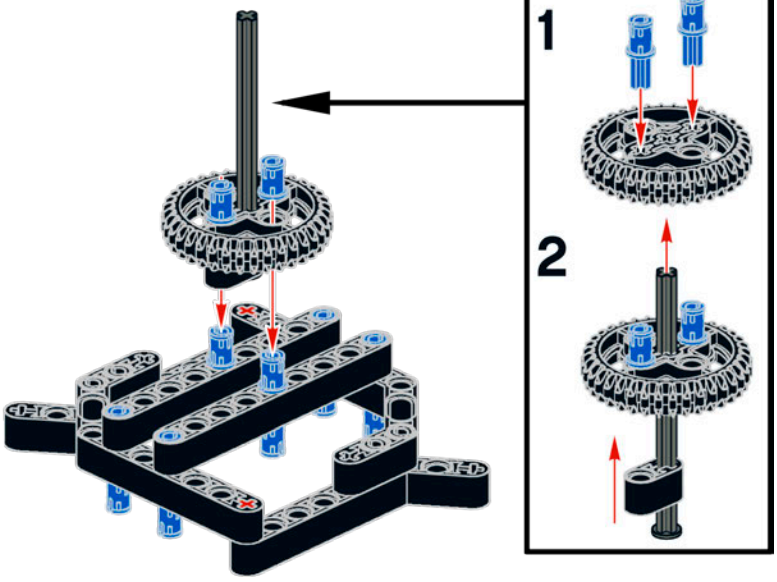

2
2x
4x

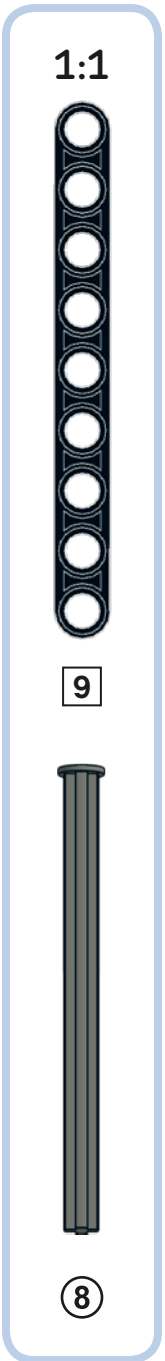



3
9
2x
2x

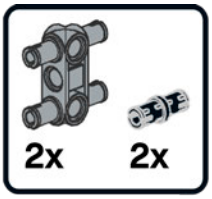


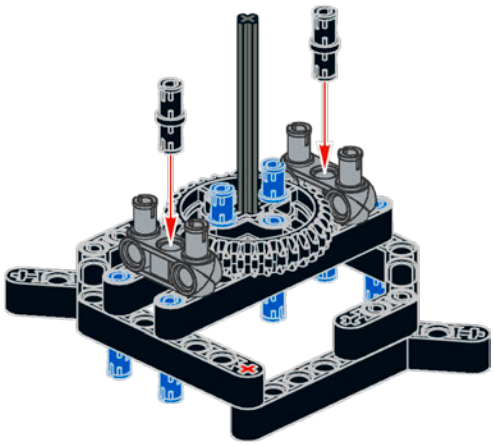

4
1x
8
1x
1x
2x


1
2


1:1
9
8

5





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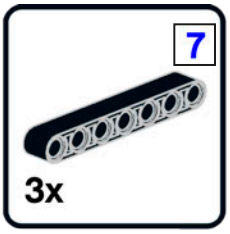
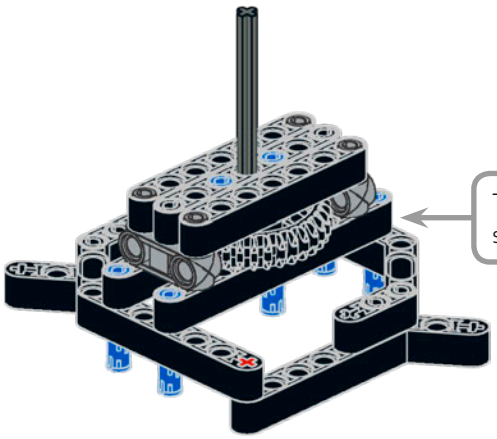
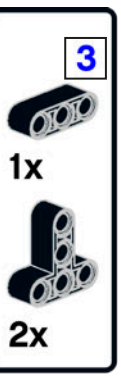


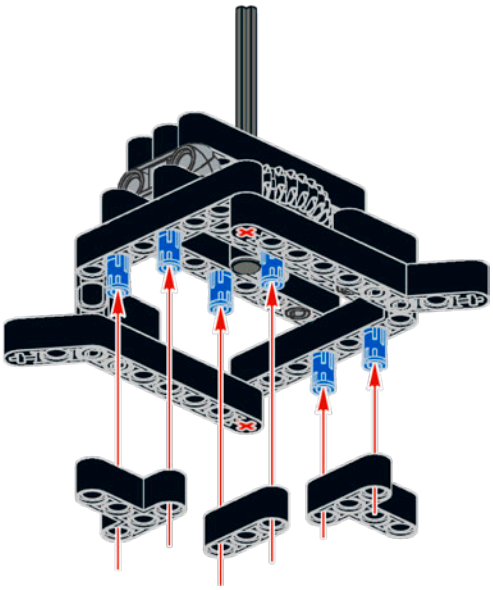


The 36z gear is used as a structural element here.

1:1

7





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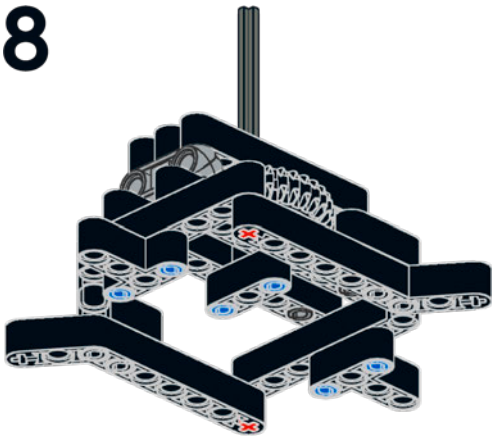
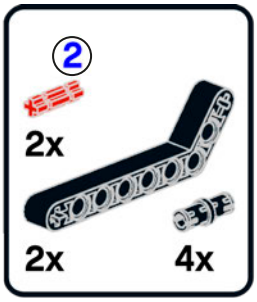
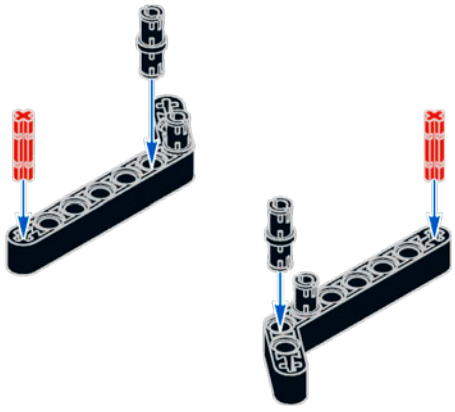


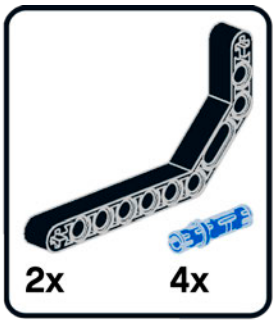
right foot assembly

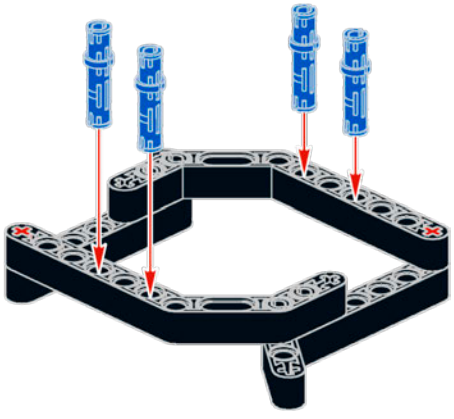
1



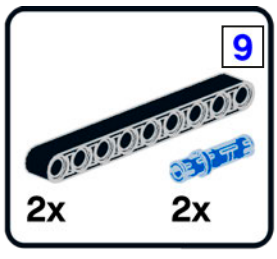


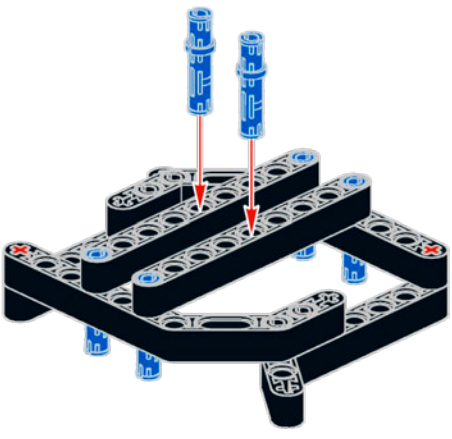
2





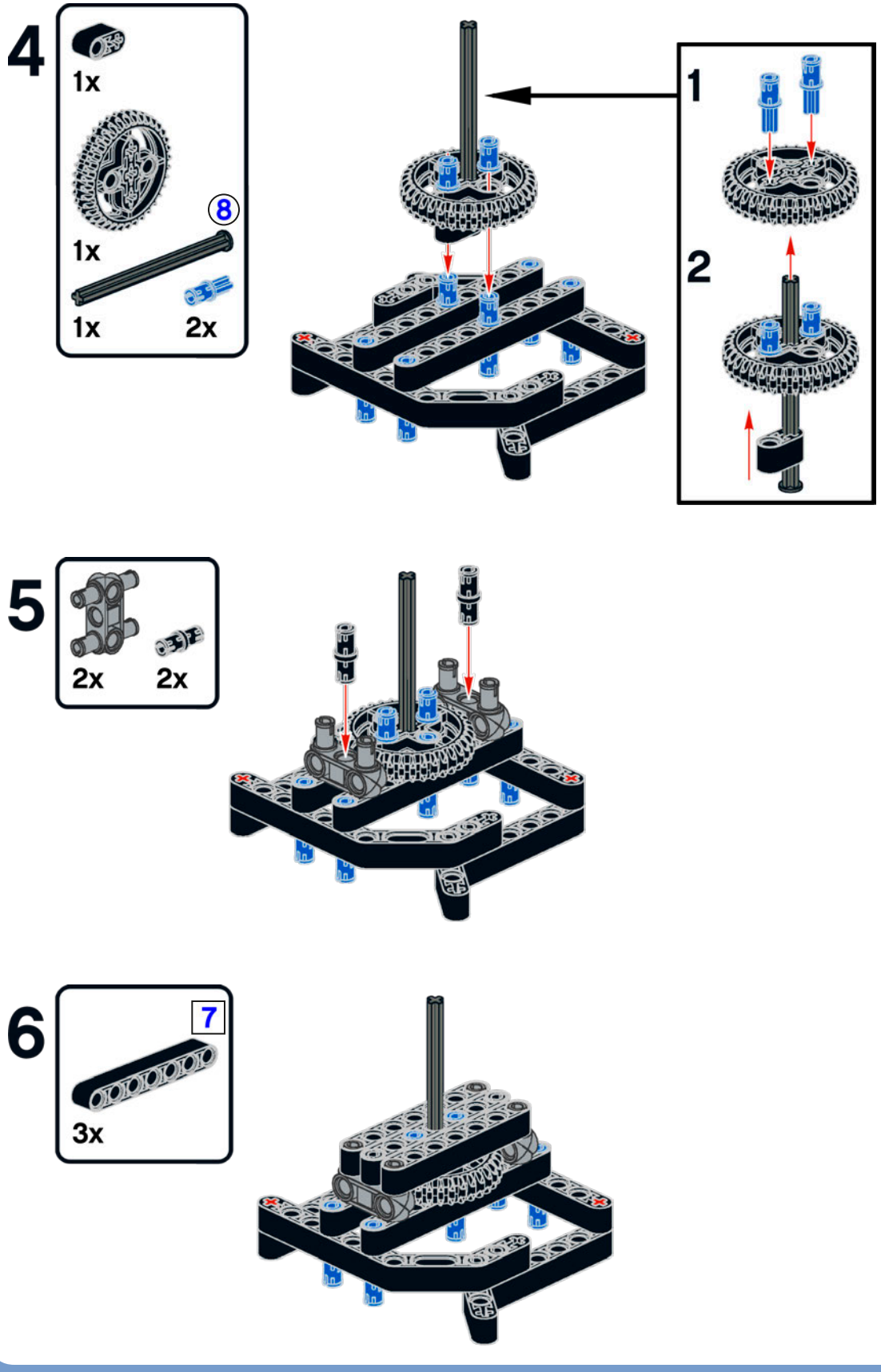
3



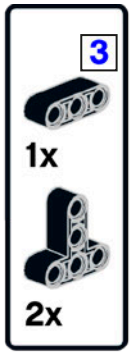


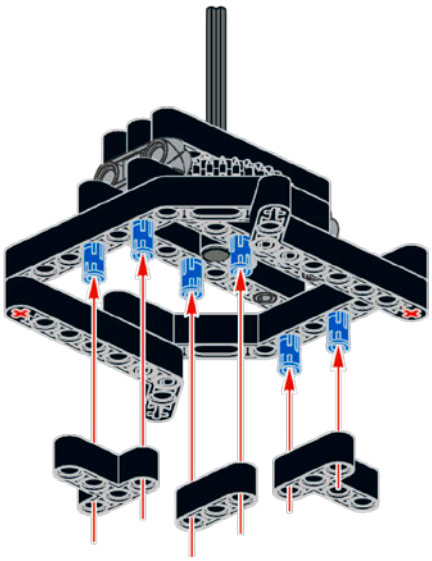
1:1

9


4
1x
8
1x
1x
2x
1
2
5
2x
2x
6
7
3x
1:1
8
7

7





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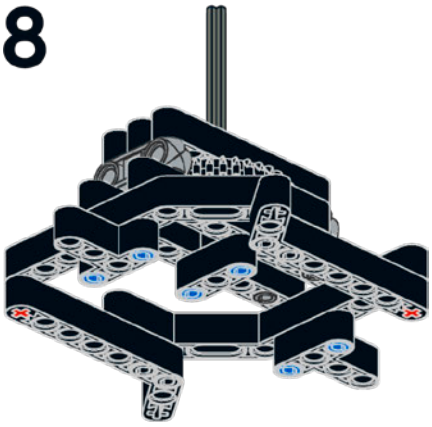
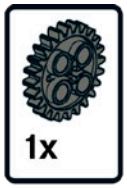
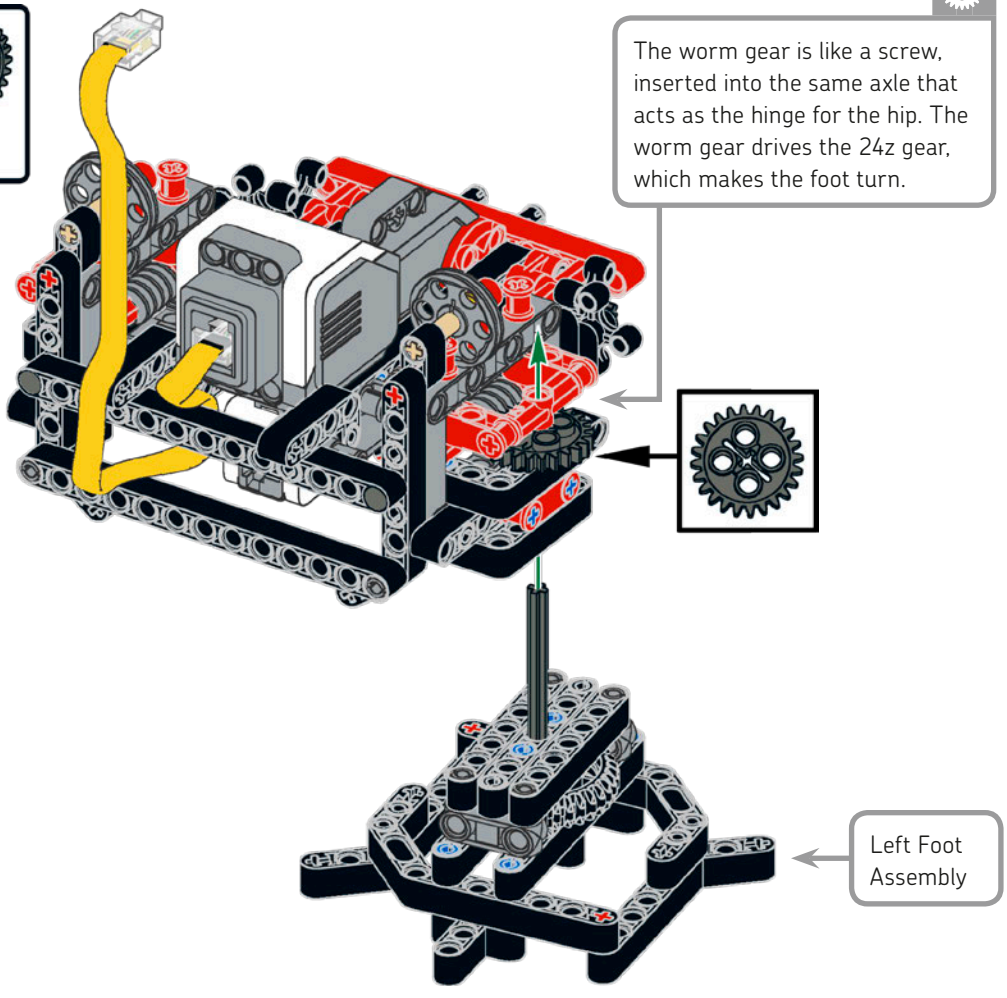


main assembly

6

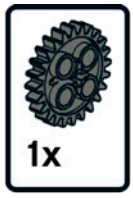


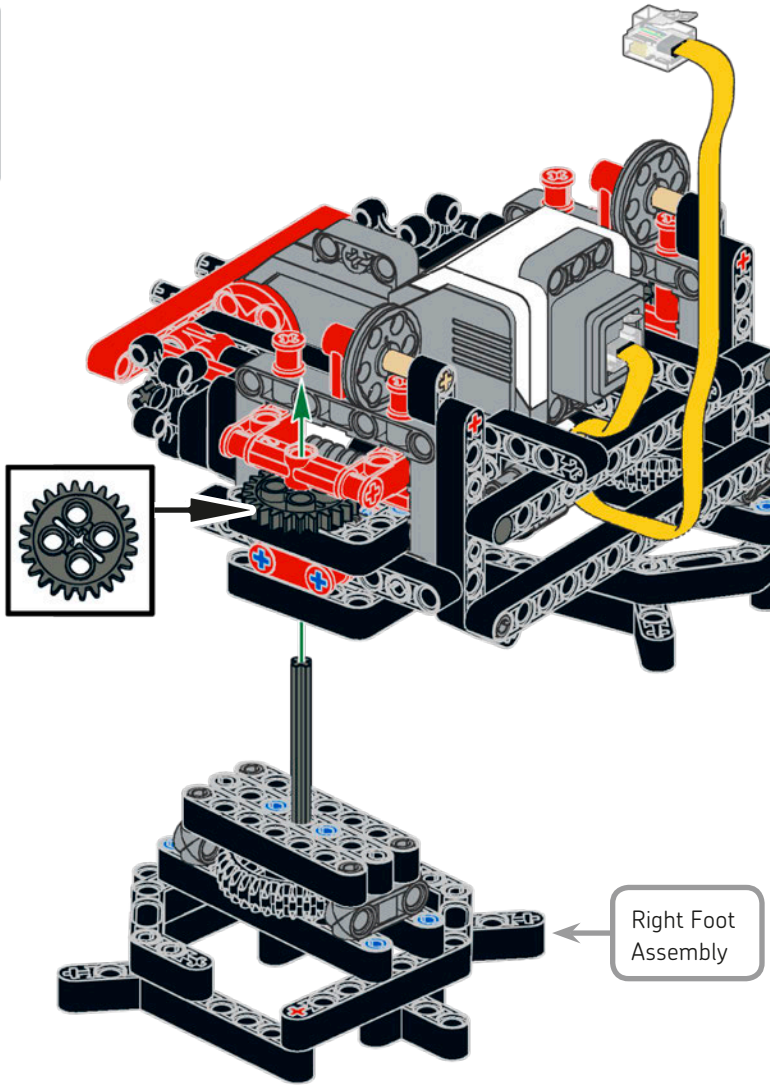


The worm gear is like a screw, inserted into the same axle that acts as the hinge for the hip. The worm gear drives the 24z gear, which makes the foot turn.

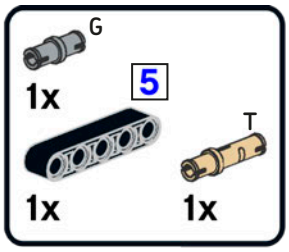
Left Foot Assembly

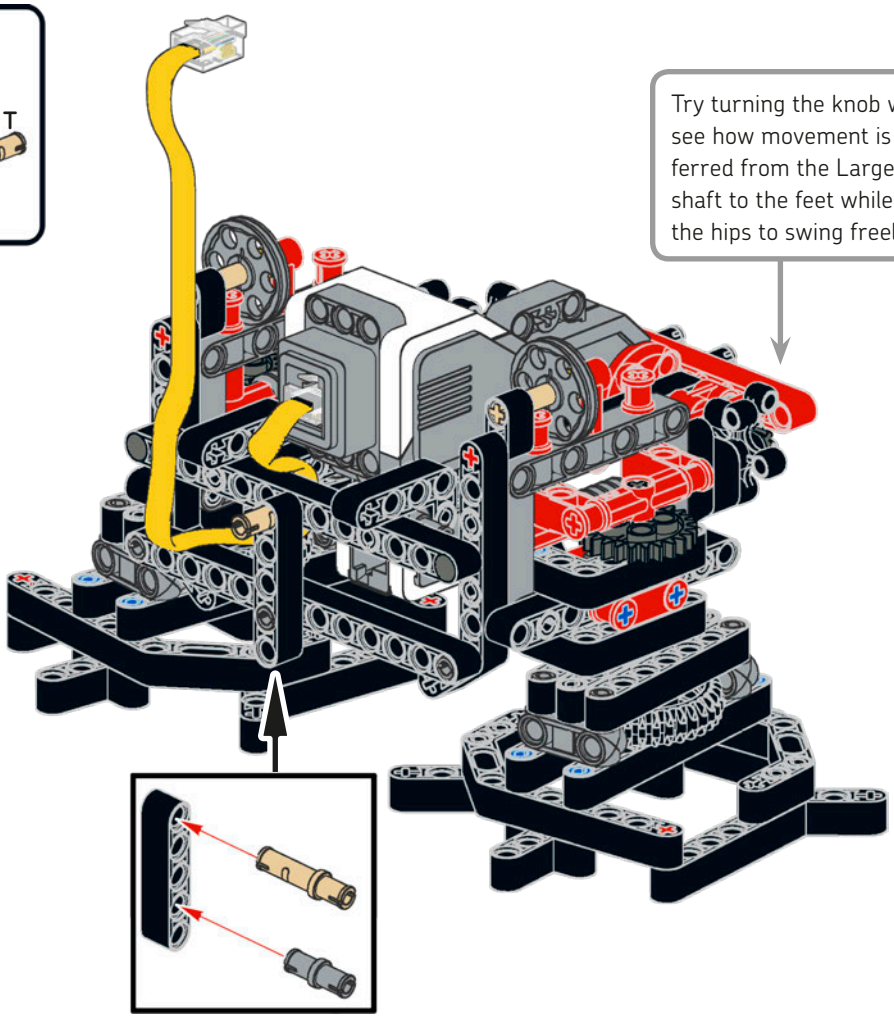
7





8



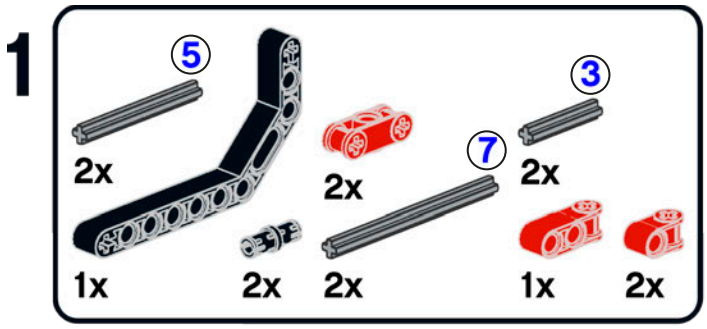


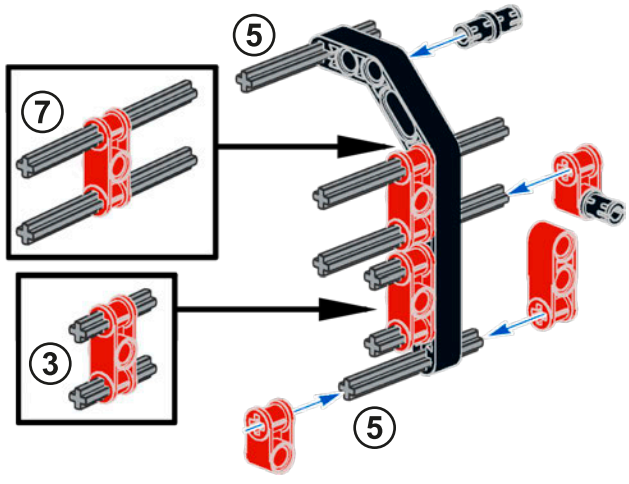
Try turning the knob wheel to see how movement is transferred from the Large Motor shaft to the feet while allowing the hips to swing freely.

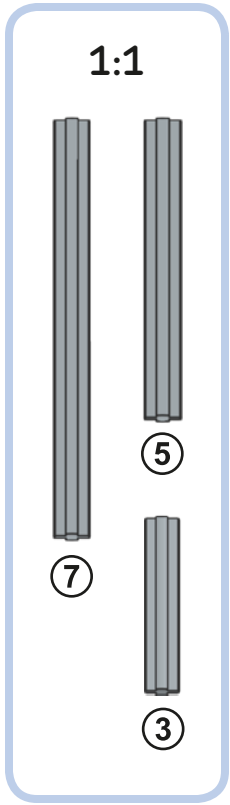
1:1

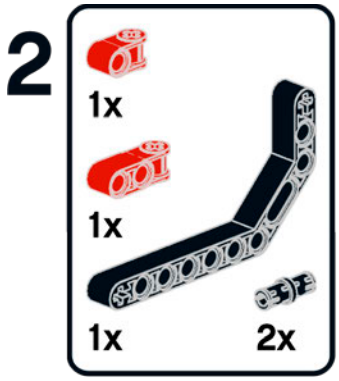
5

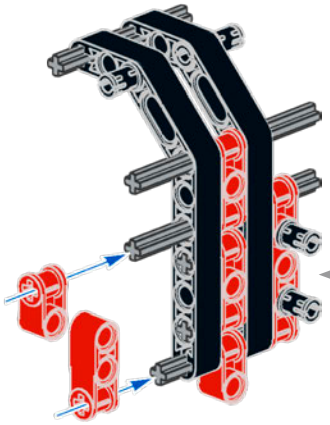
back bracket assembly



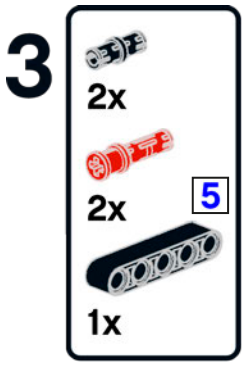


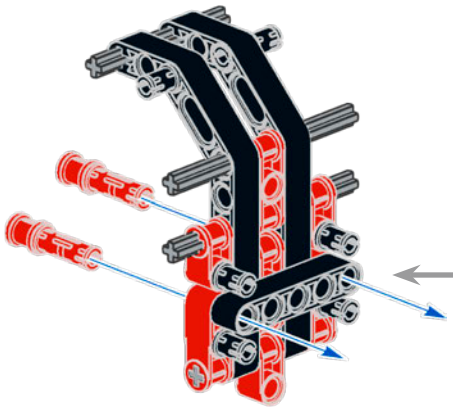


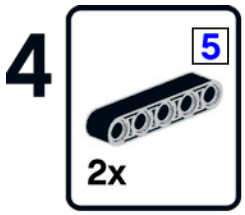


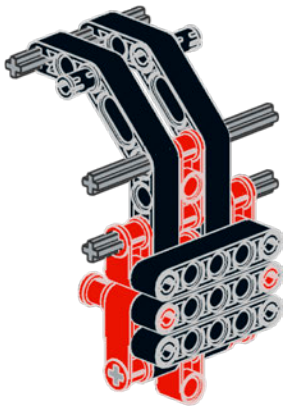


Cross blocks can be used to hold gears as well as to build 3-D structures.

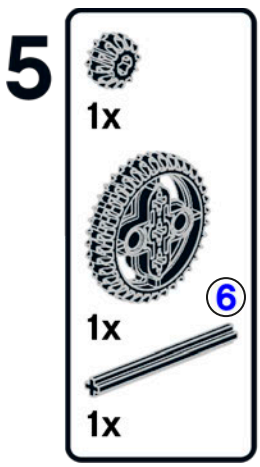


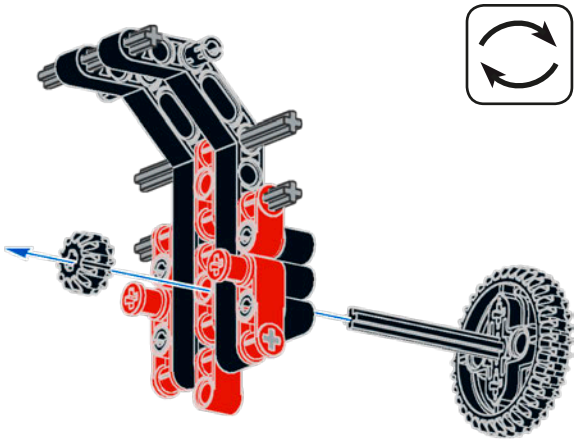




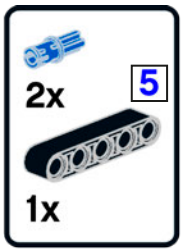


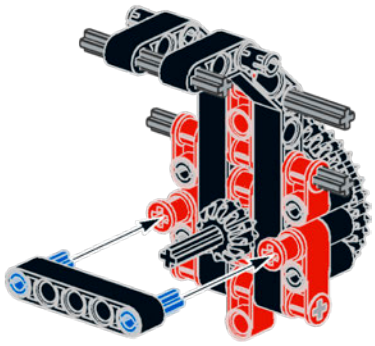
The 5M beams brace the cross blocks and enforce the structure, ensuring that the gears we'll add later won't disengage while working under stress.



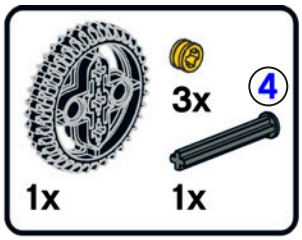


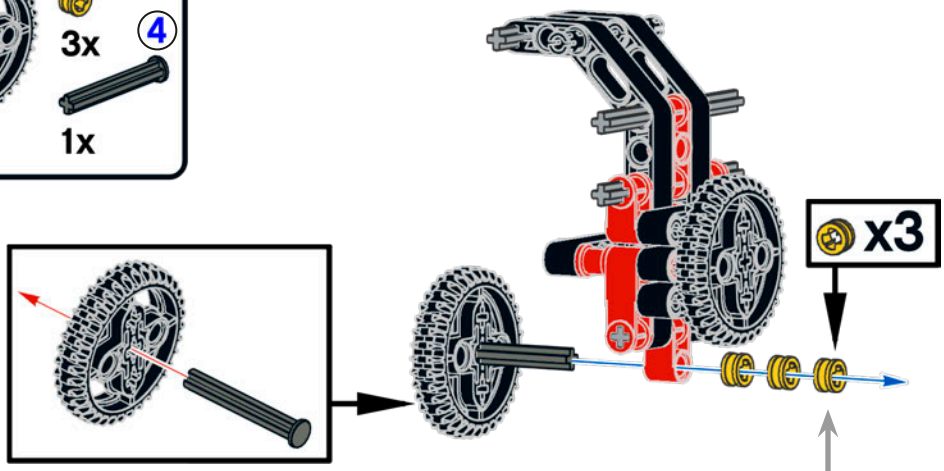
6



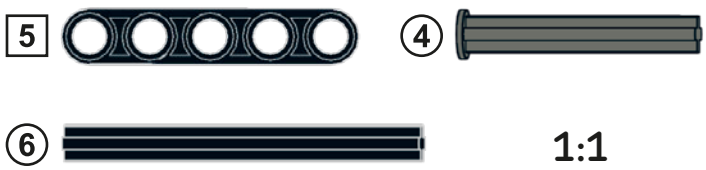


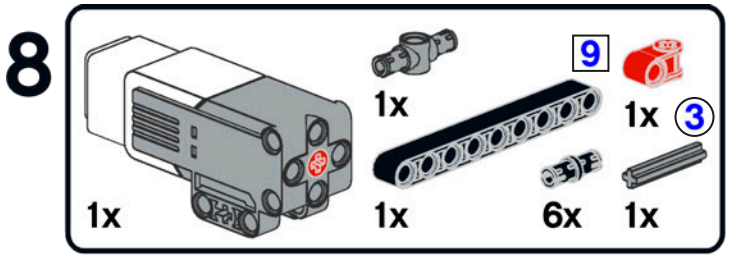
7

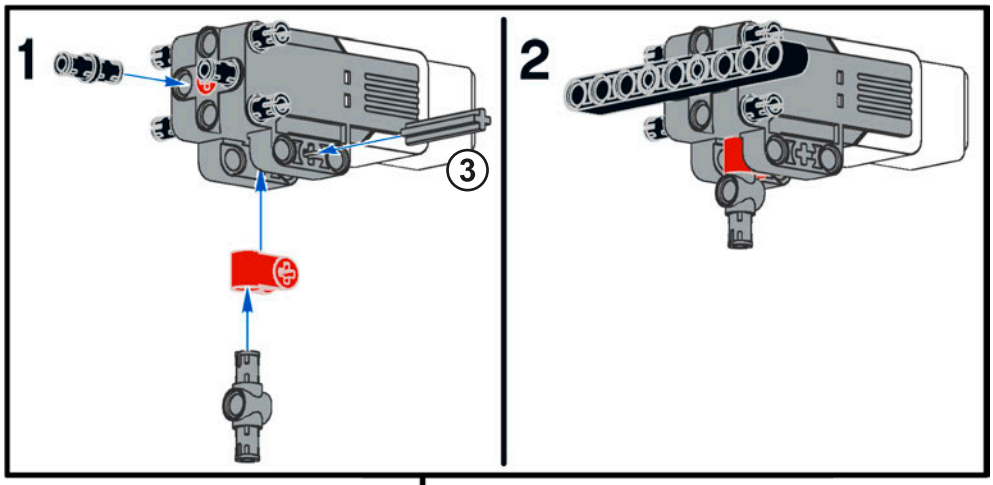


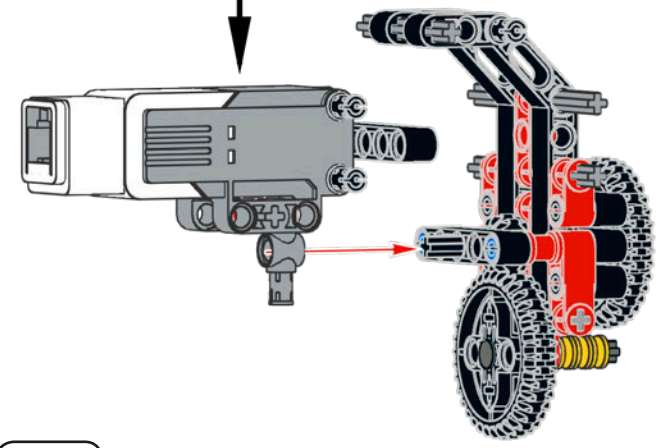


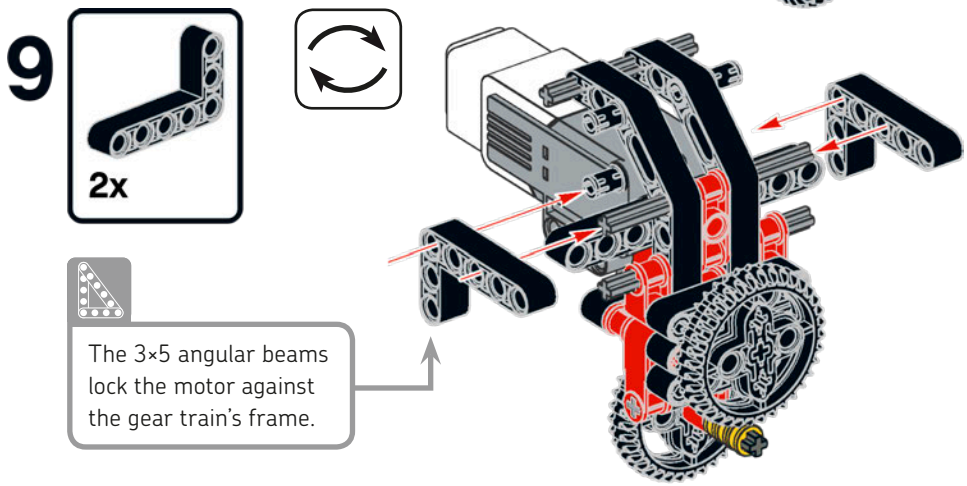
Three thin yellow bushes have more friction and hold better than one red bush.




8
1x
1x
9
1x
3
1x
6x
1x

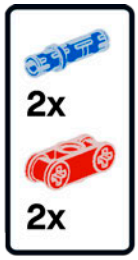

1
3
2

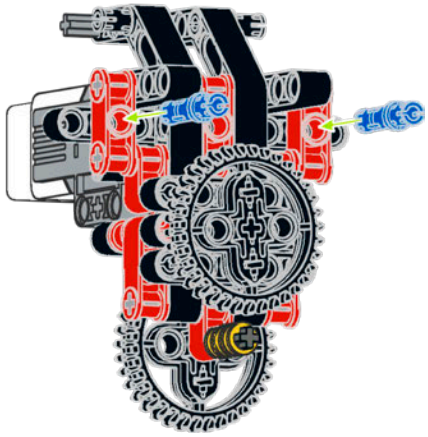



9
2x
The 3×5 angular beams lock the motor against the gear train's frame.


1:1
9
6
3

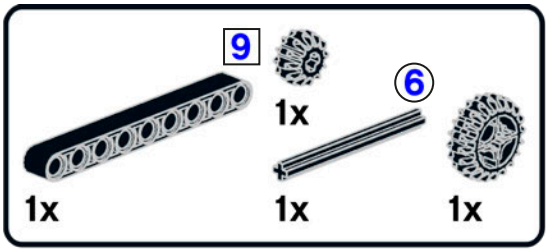
10

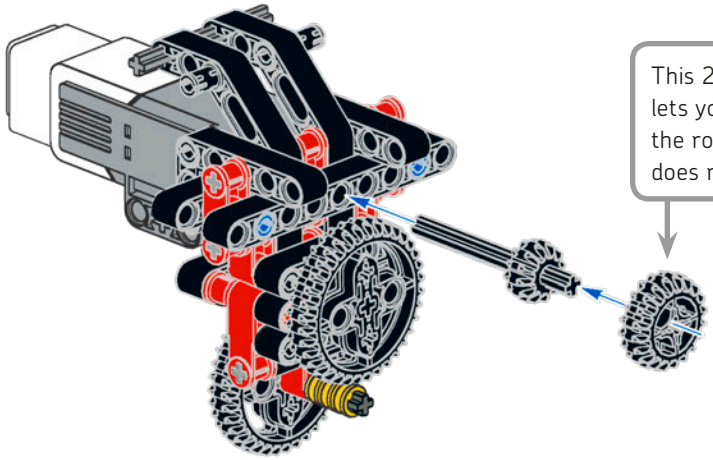




Inserting the 3M blue pins into the red cross blocks locks the 3×5 angular beams added in the previous step. In this way, the motor is double braced, making this assembly super sturdy.

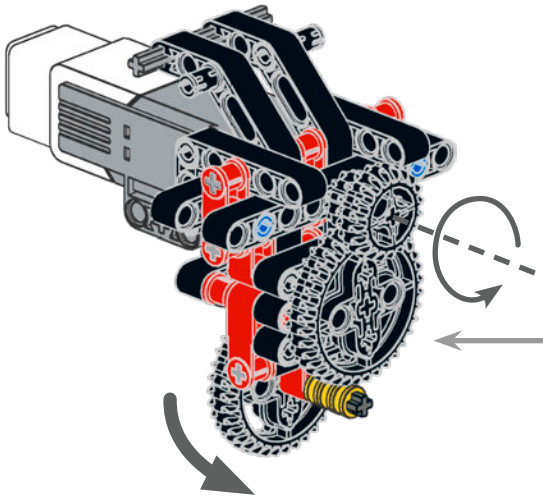
11





This 20z gear is used as a knob, which lets you manually adjust the position of the robot's swinging frame. This gear does not engage with another gear.

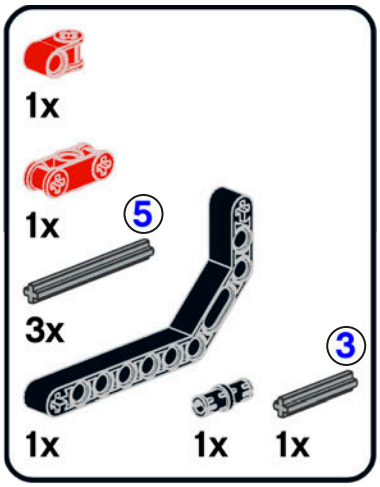
12

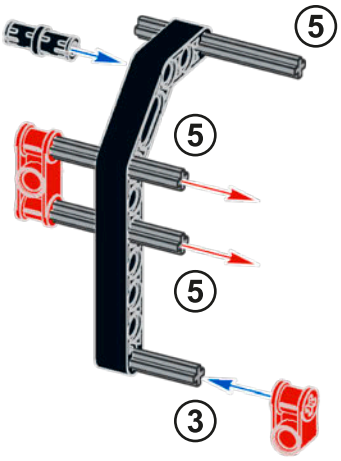


Try turning the 20z gear attached to the Medium Motor shaft to see how much the final 36z gear is slowed down. The ratio is 12:36 × 12:36 = 1:9, which means that it takes nine motor shaft rotations to make the final 36z gear perform one rotation. The 36z gear is thus one-ninth as fast but nine times stronger than the motor shaft. It's geared down to increase the torque of the Medium Motor, allowing the robot to shift the weight of the EV3 Brick from side to side.

front bracket assembly

1





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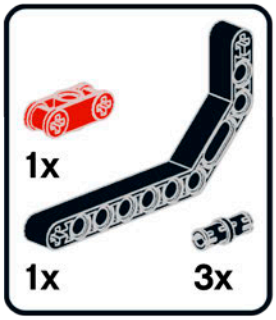
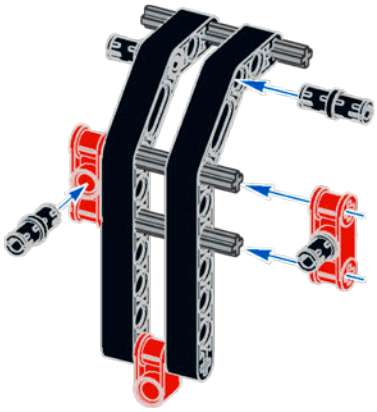
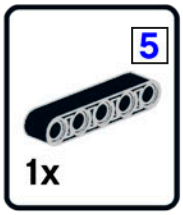
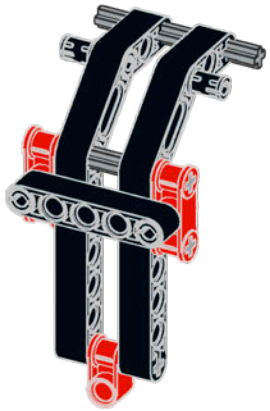


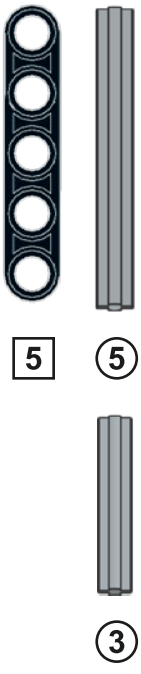


3



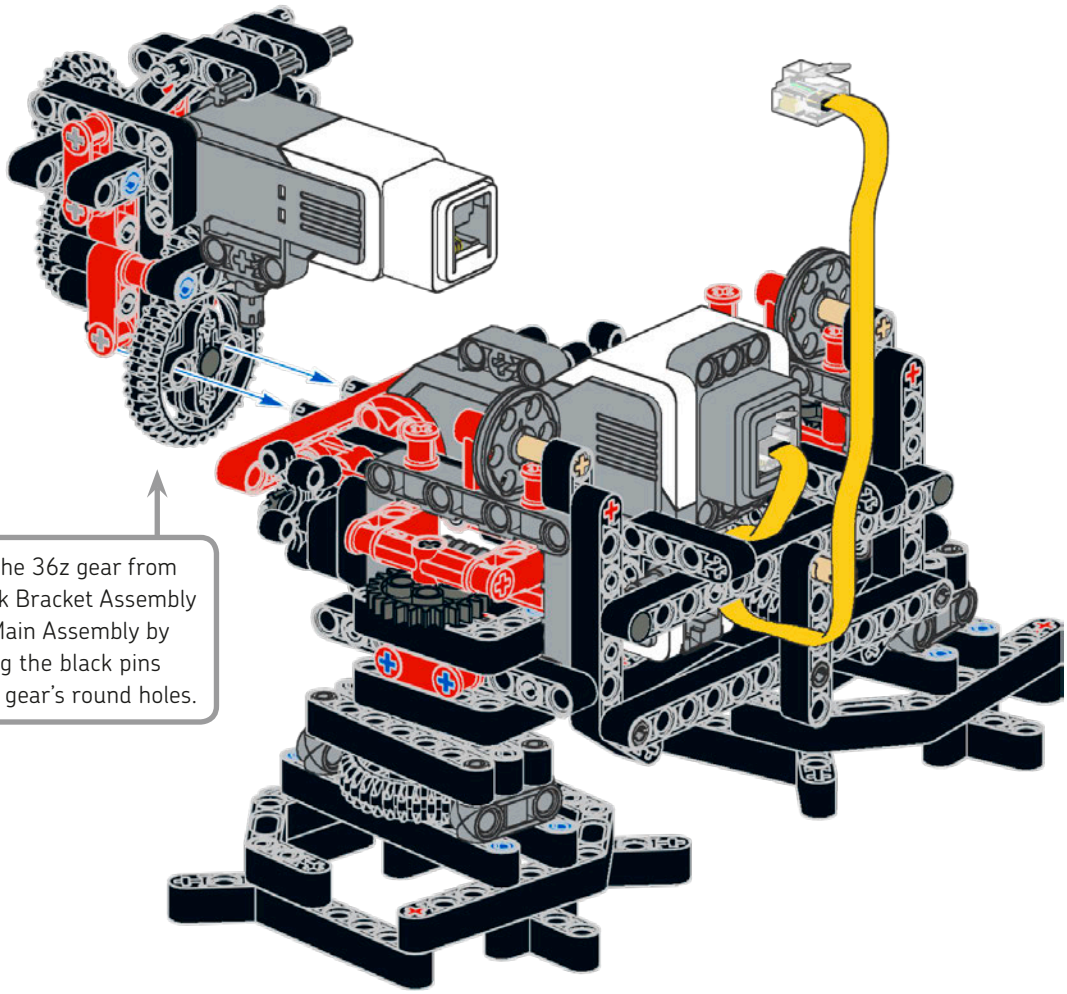


1:1



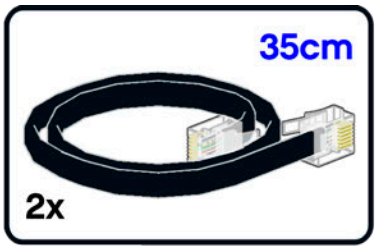
main assembly

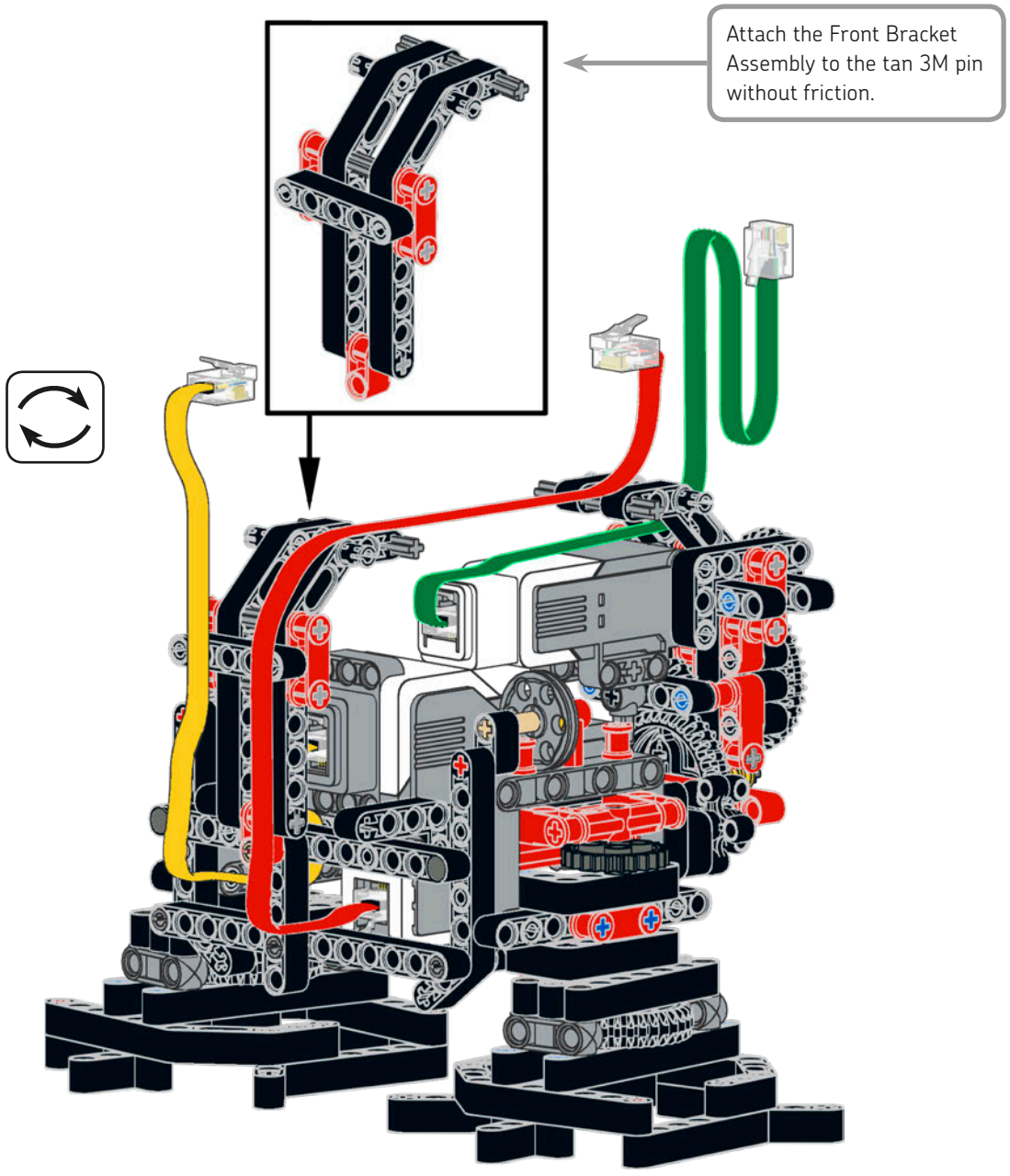
9



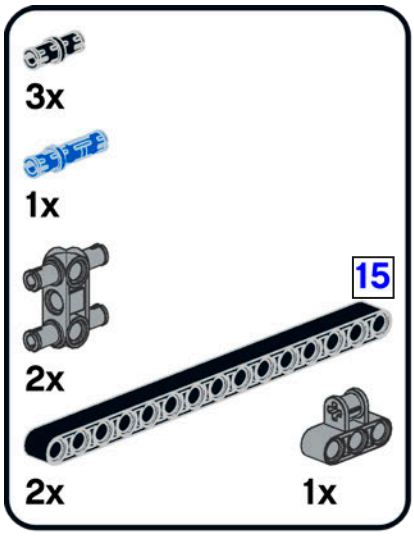
Attach the 36z gear from the Back Bracket Assembly to the Main Assembly by inserting the black pins into the gear's round holes.

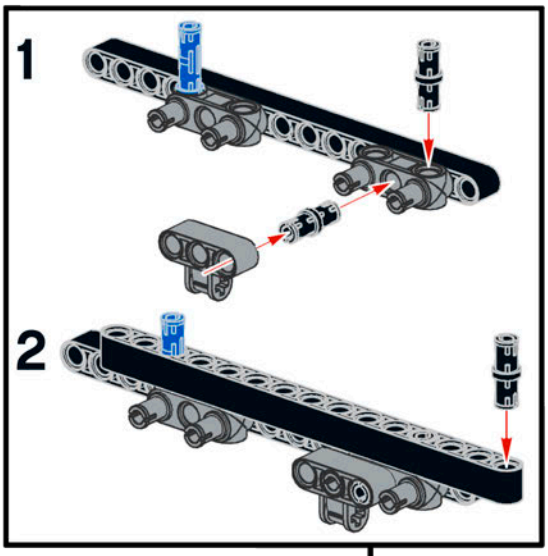
10

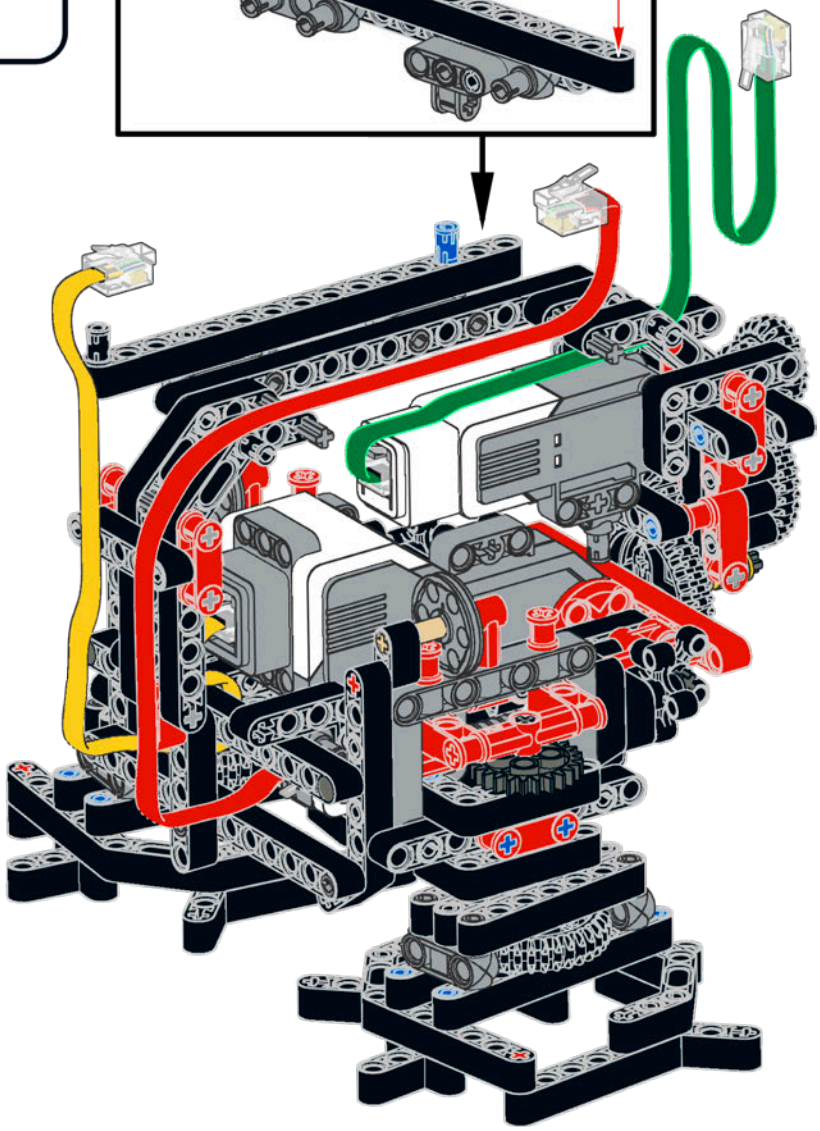

35cm
2x


Attach the Front Bracket Assembly to the tan 3M pin without friction.

11



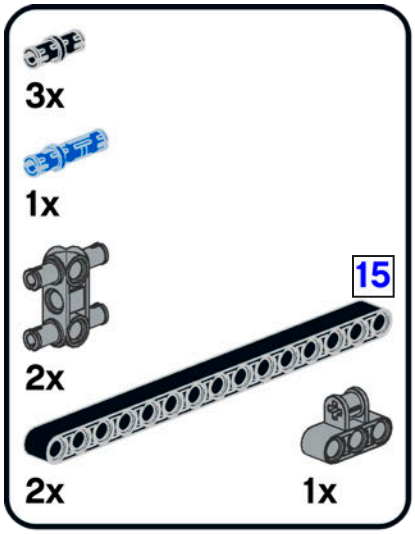


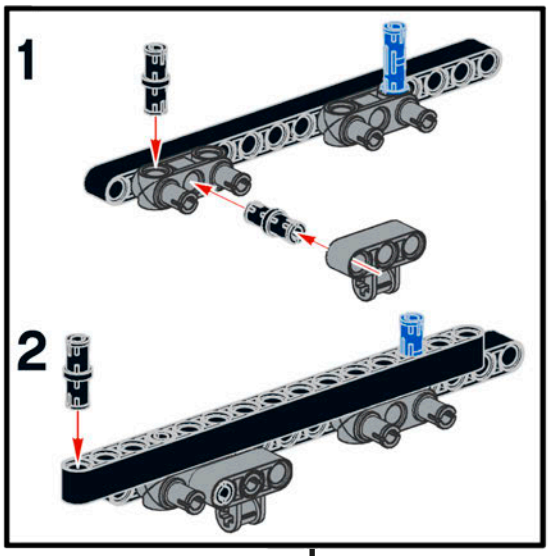


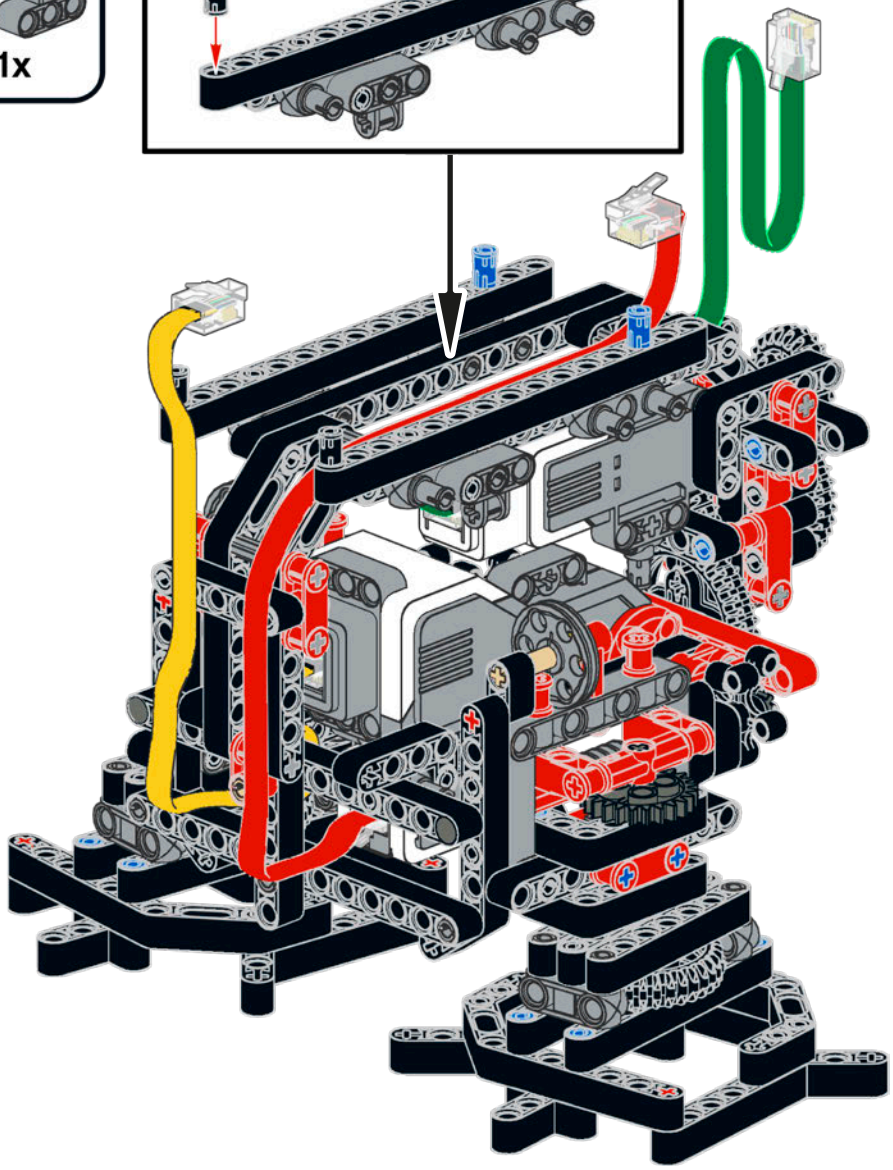
1:1

15

12







1:1

15

13

1x 3

2x

1x 3

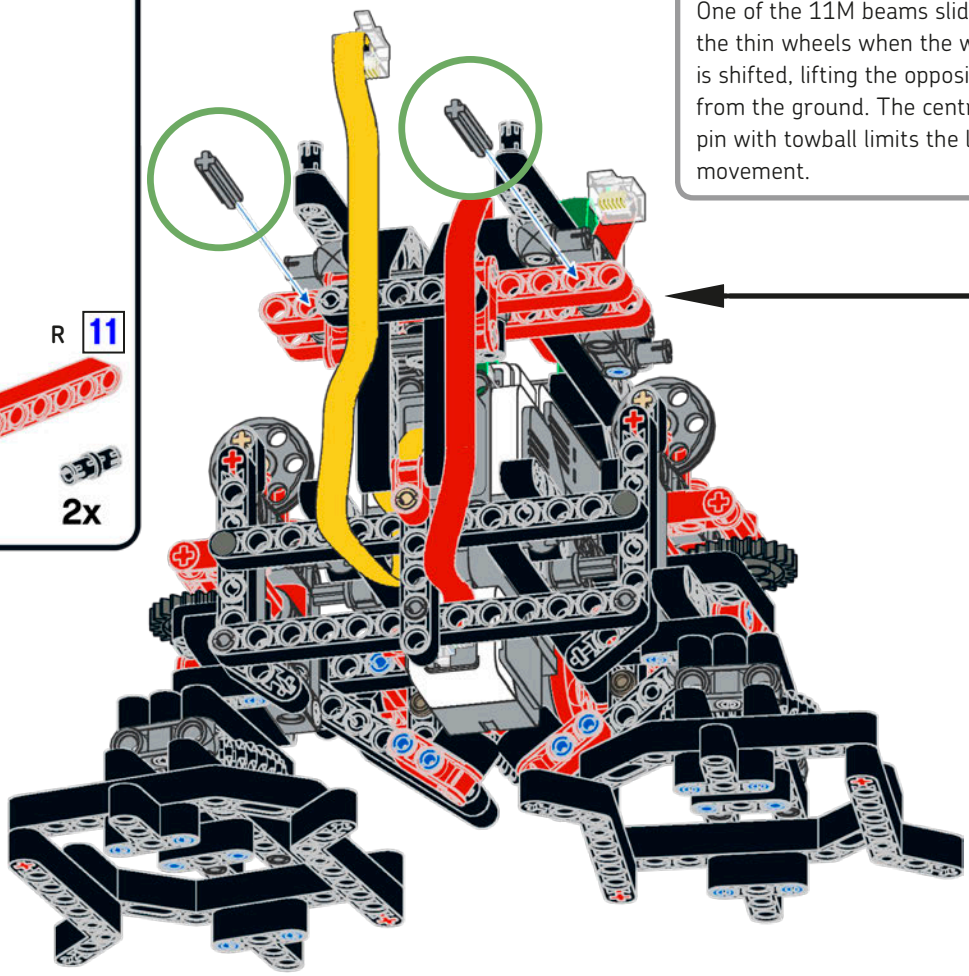
R 11

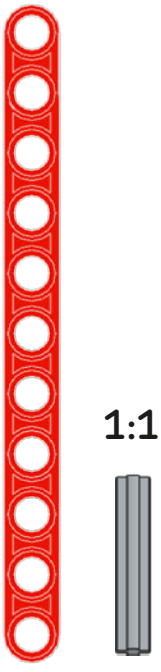
1x

2x

2x

One of the 11M beams slides on the thin wheels when the weight is shifted, lifting the opposite leg from the ground. The central pin with towball limits the lateral movement.

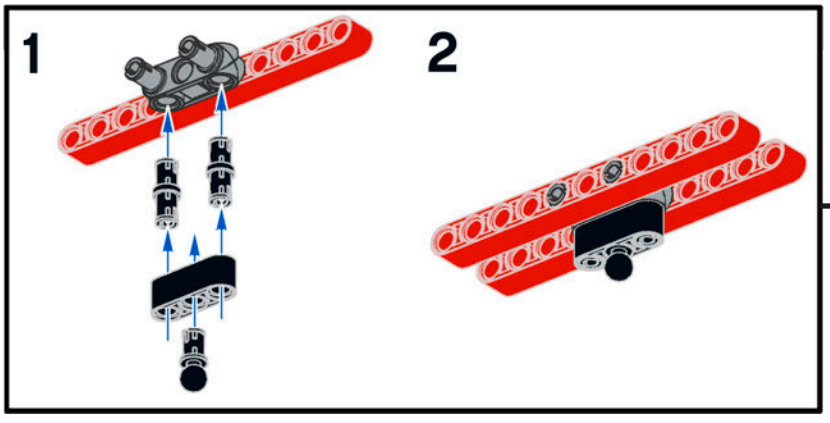




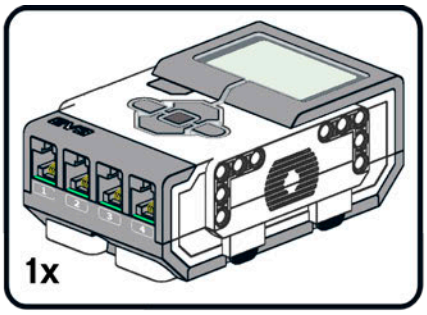
1:1

11

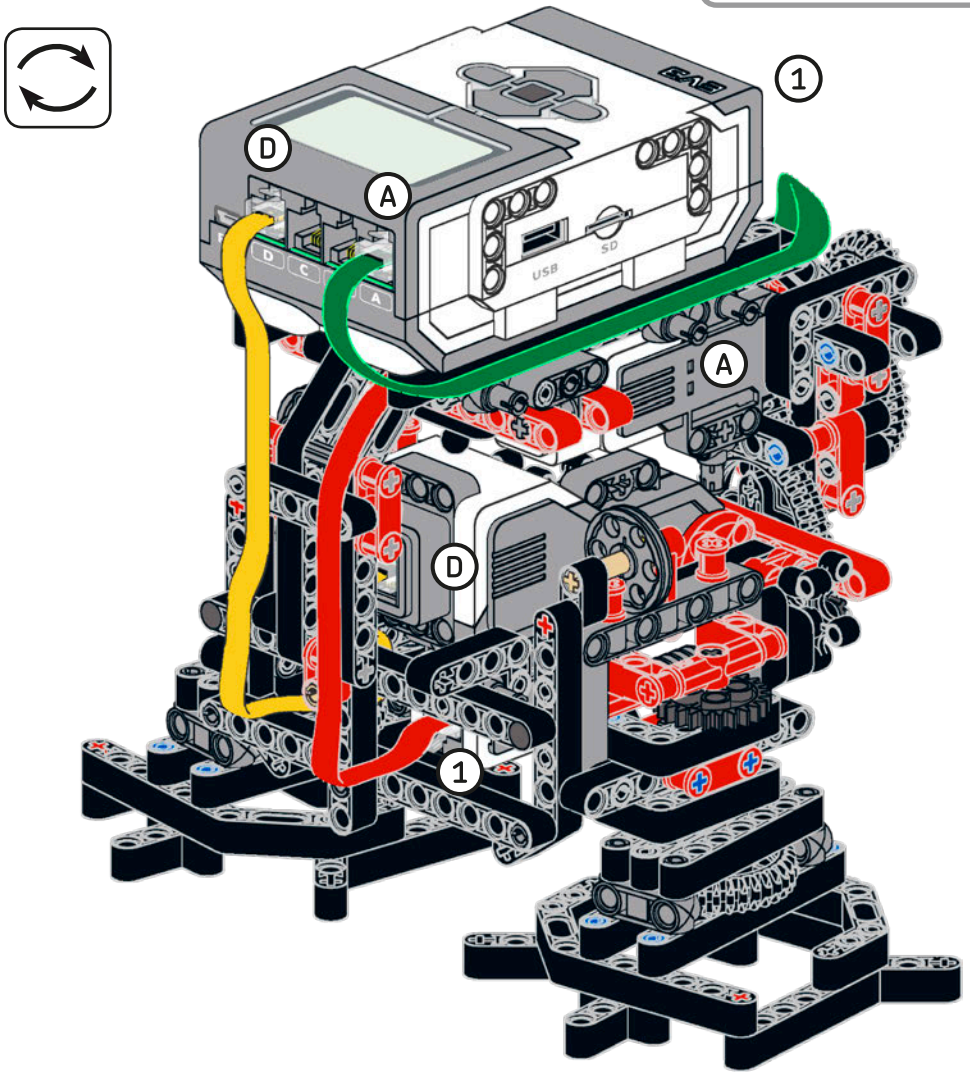
3



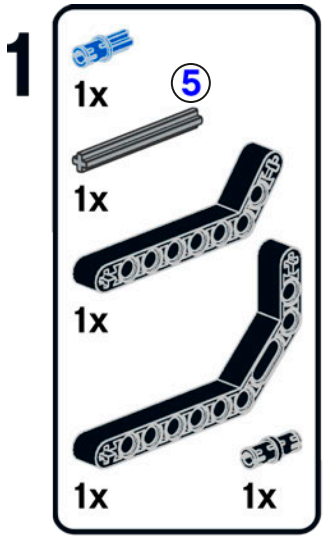
14

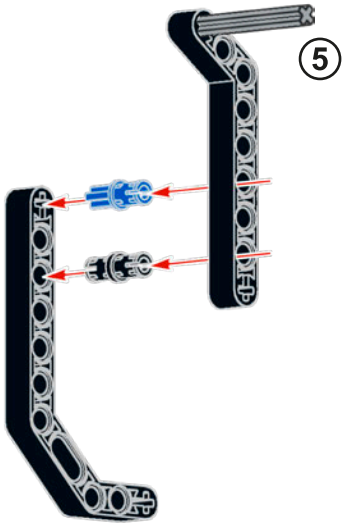


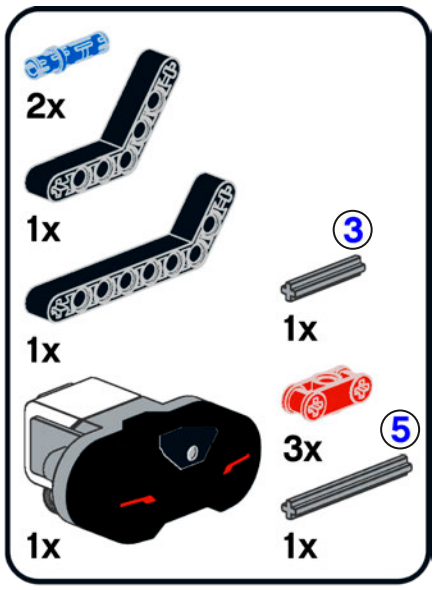
Attach the Touch Sensor cable to input port 1.

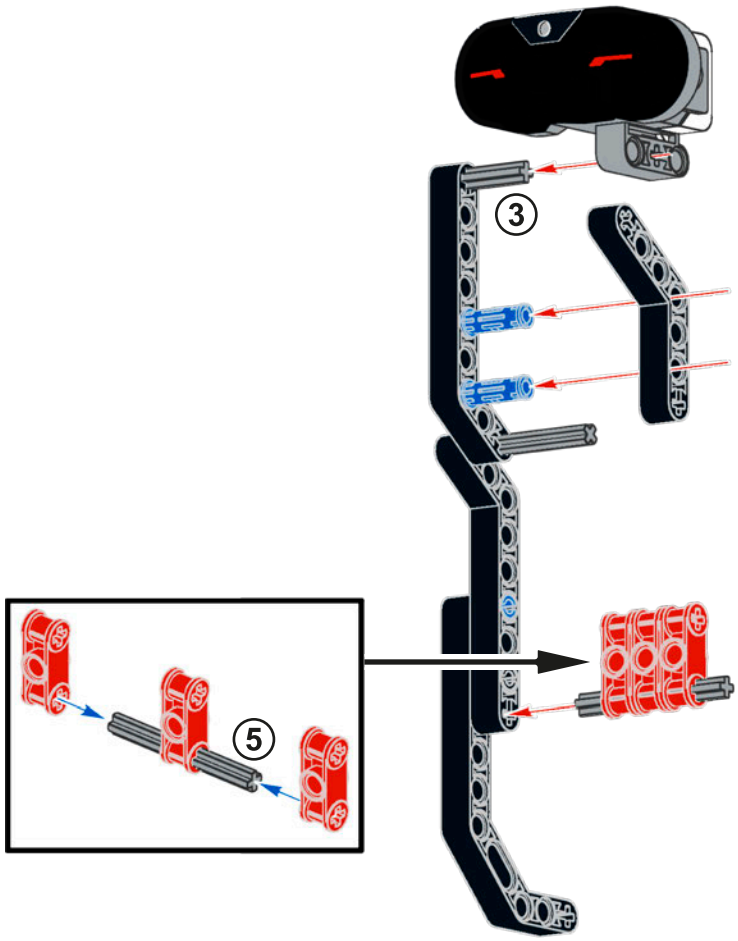


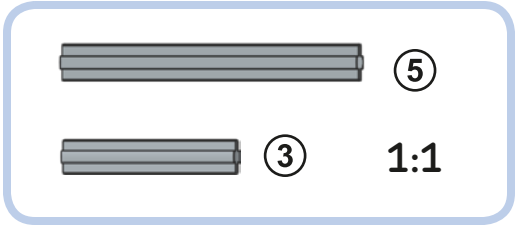
neck assembly

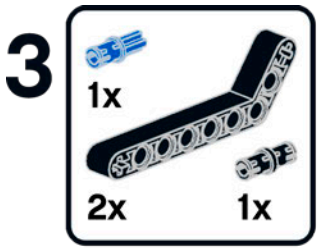


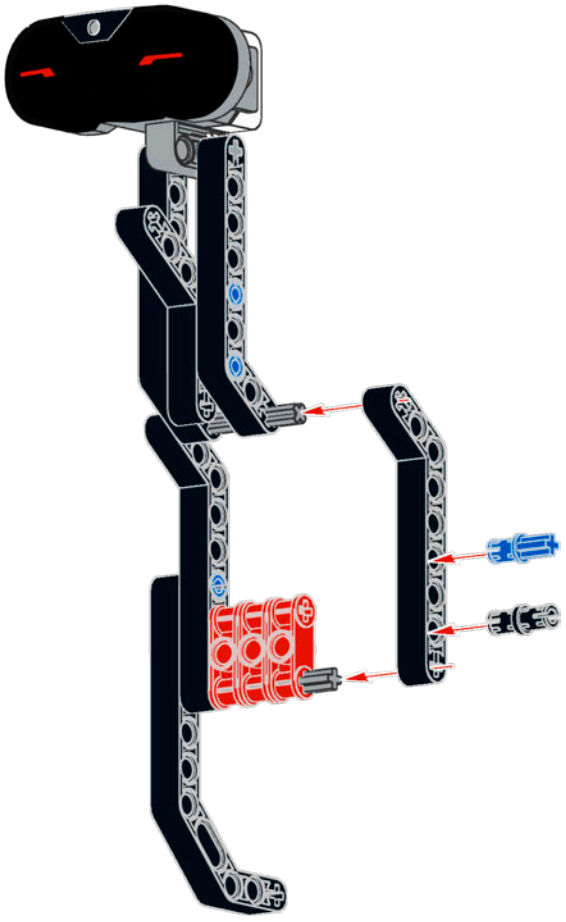


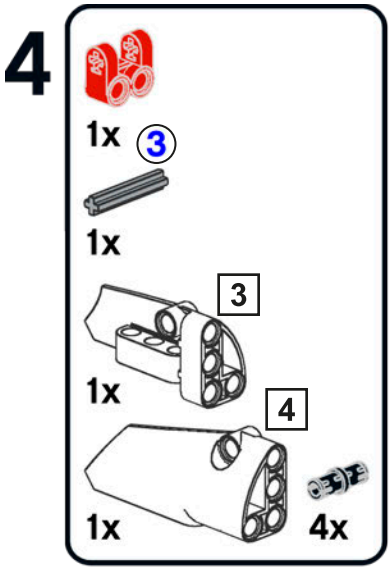


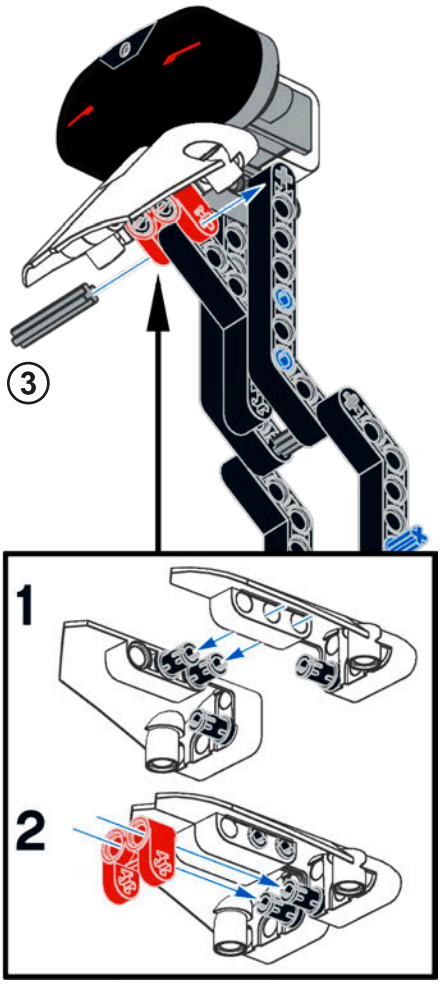


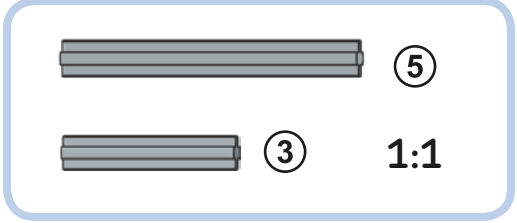


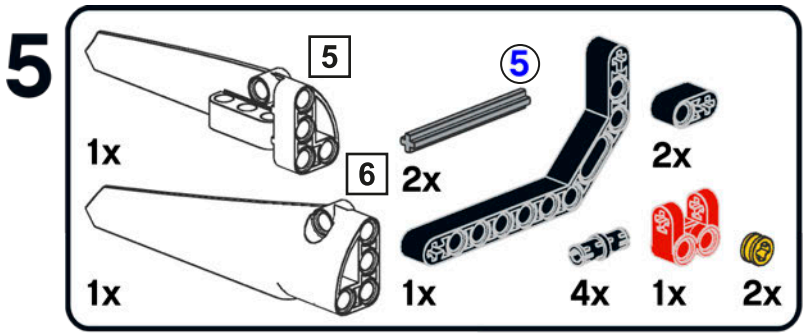

3
1x
2x
1x

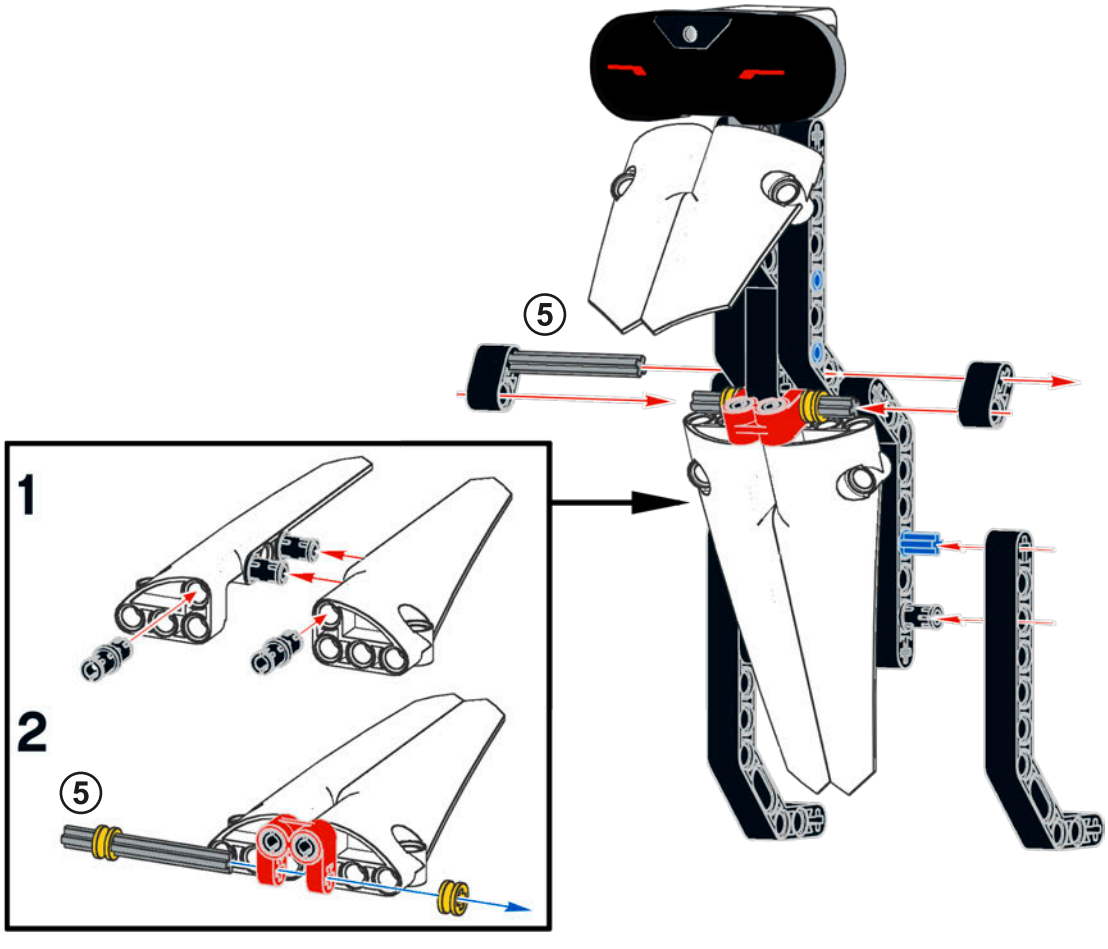



4
1x
3
1x
3
1x
4
1x
4x

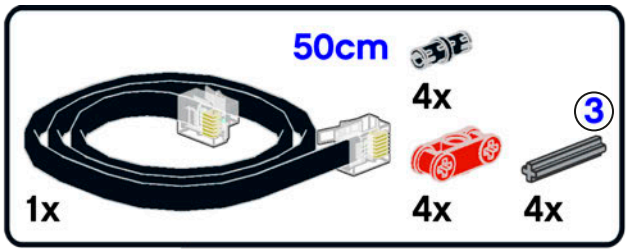

3
1
2

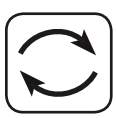

5
3
1:1

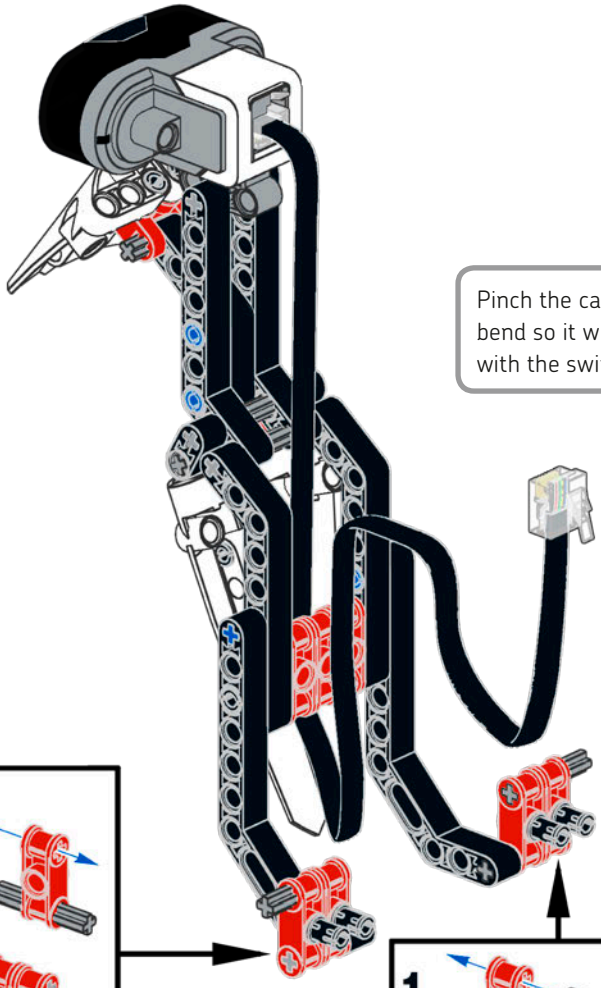

5
5
1x
6
2x
5
2x
1x
1x
4x
1x
2x


1
2
5
5

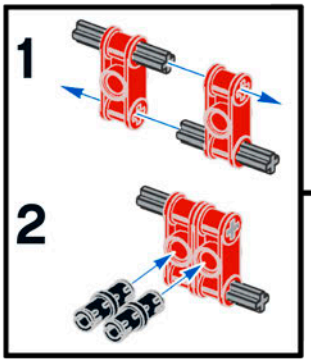
6

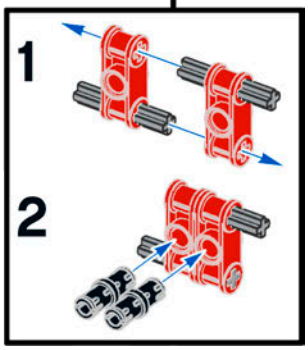






Pinch the cable at the bottom bend so it will not interfere with the swinging mechanism.

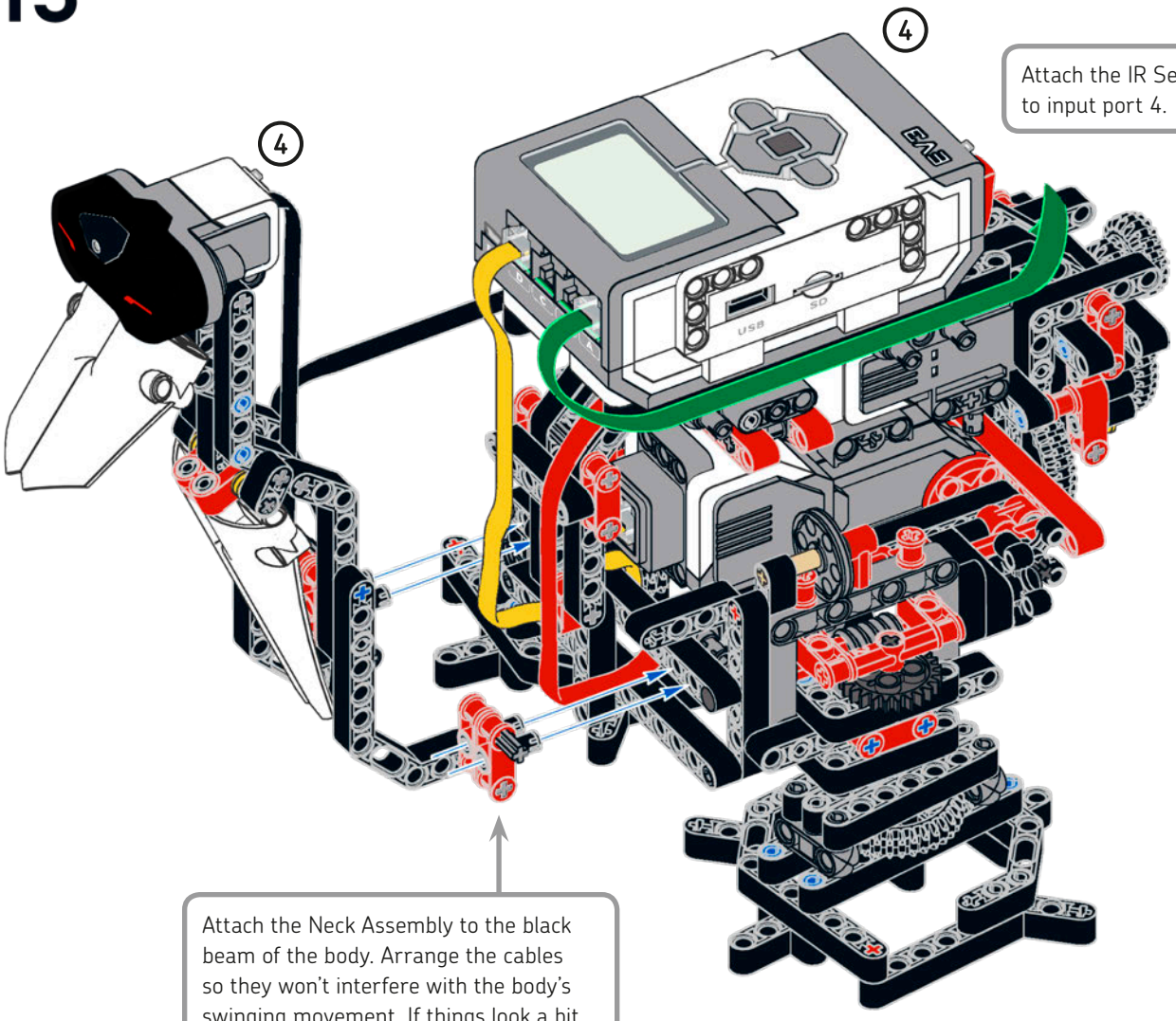




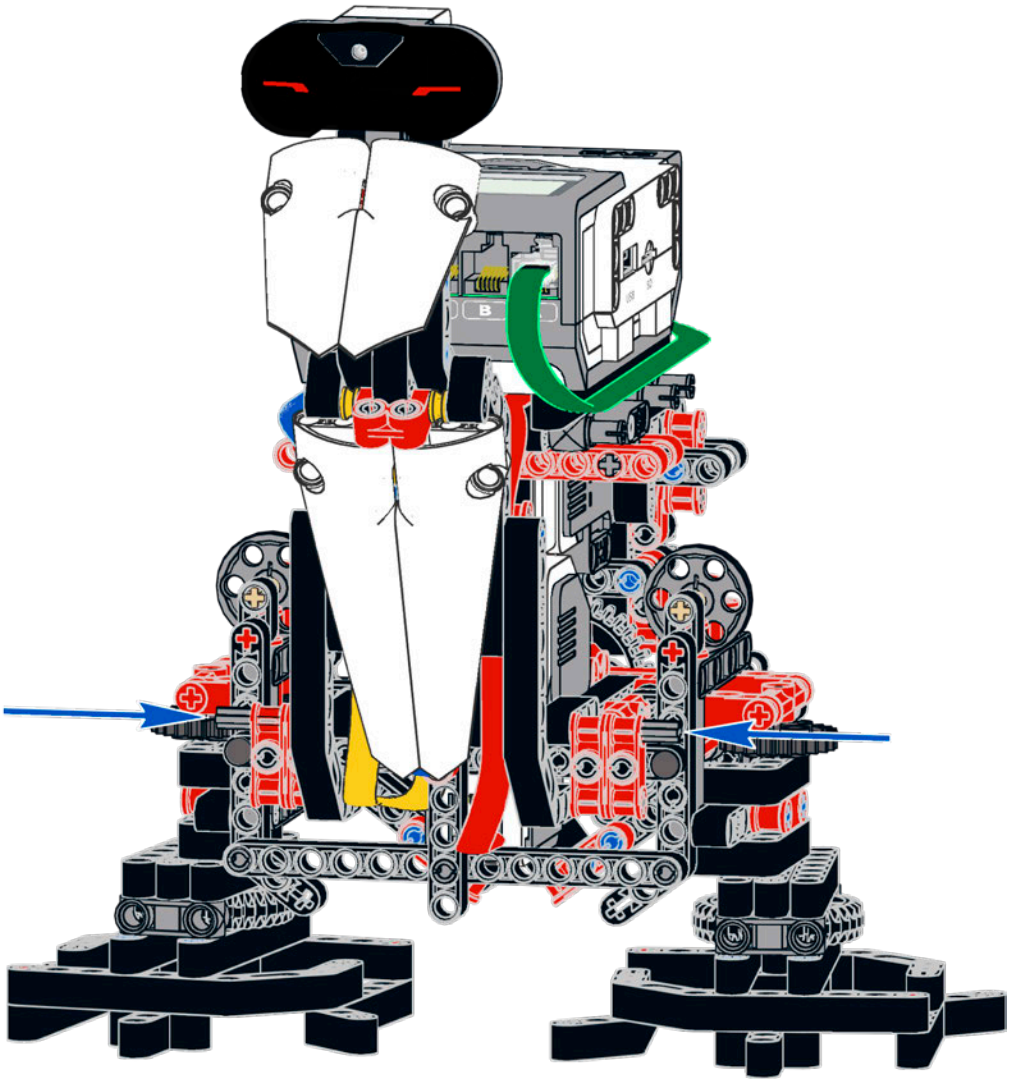
3 1:1

main assembly

15

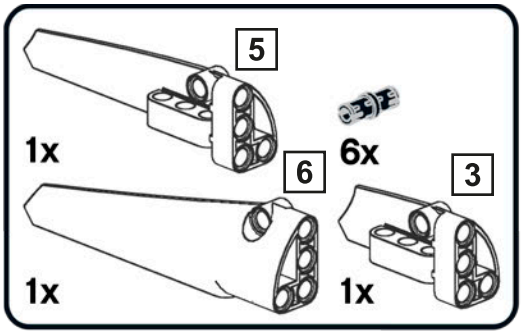


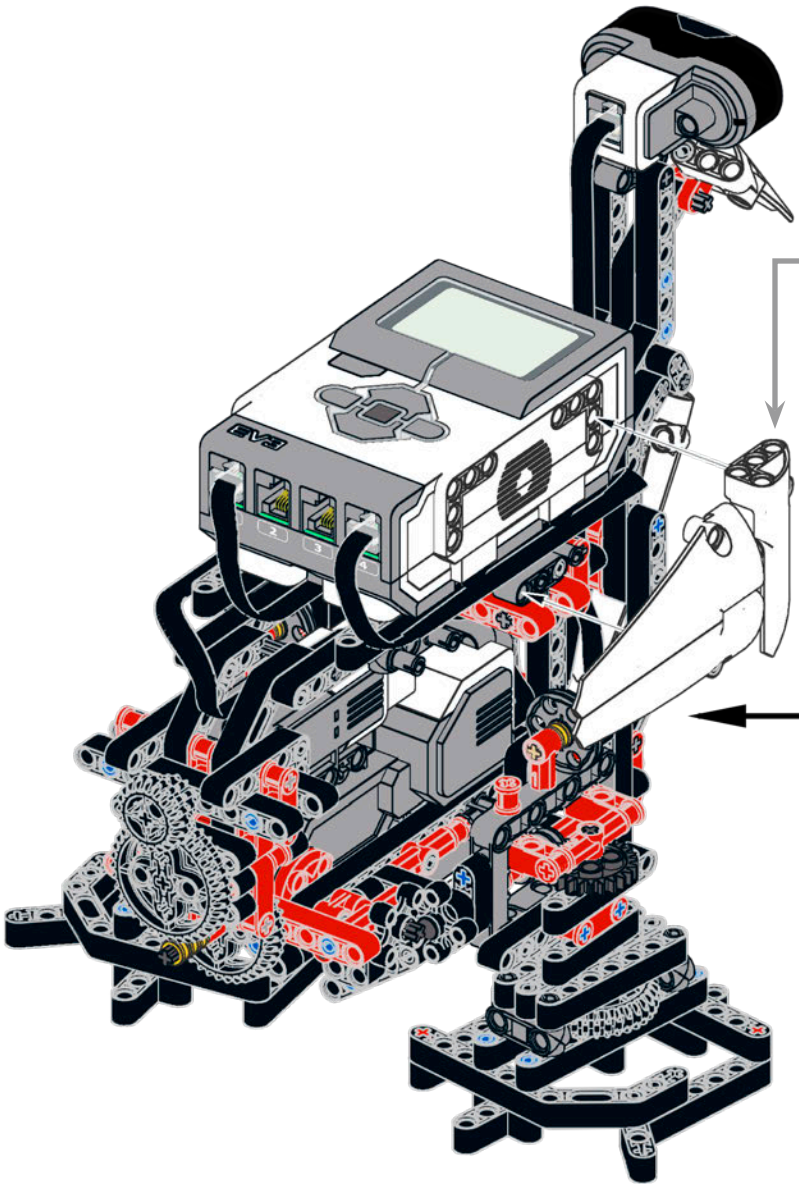
16



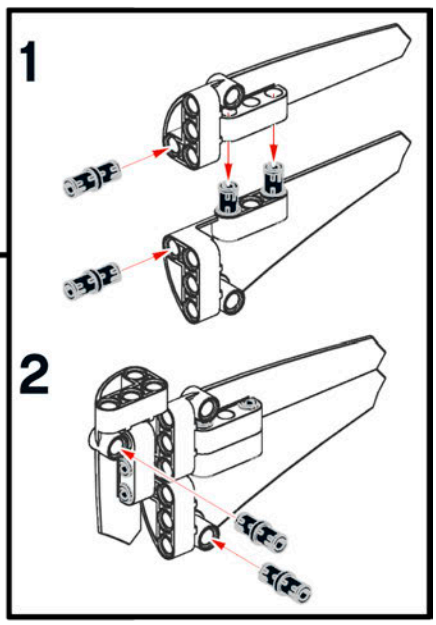
Push the 3M axles into the cross holes of the 2×4 black angular beams to lock the Neck Assembly to the Main Assembly.

17

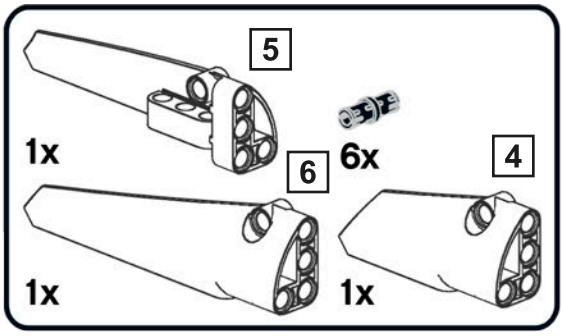


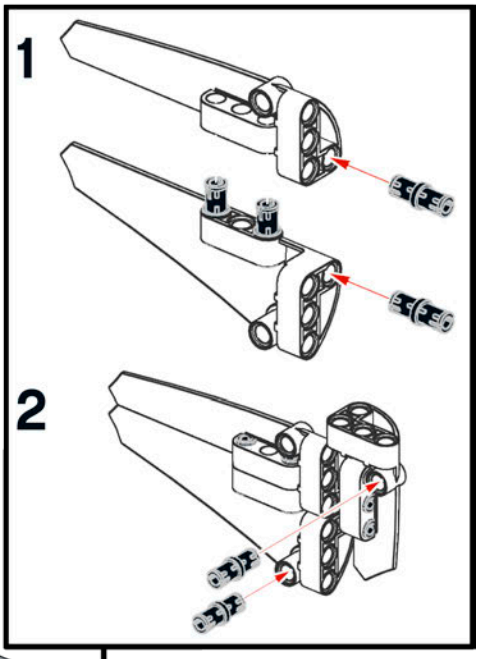


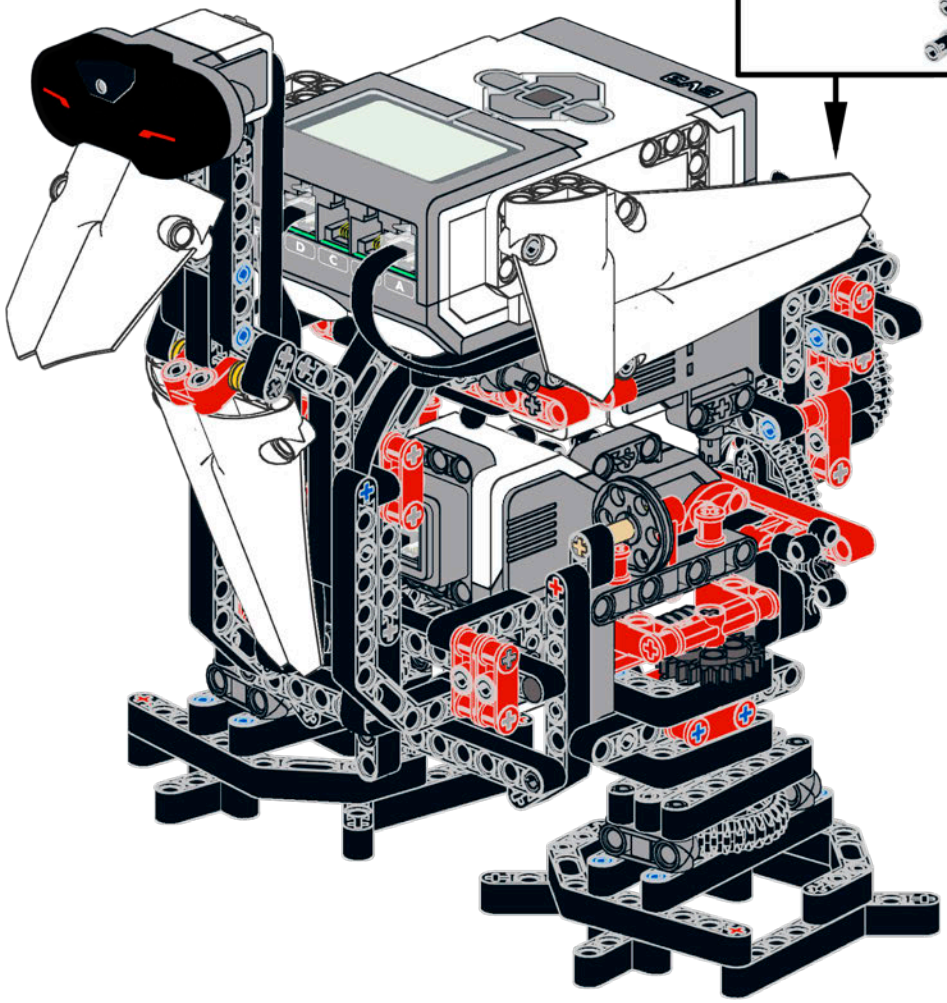
The wings aren't just decorative; they hold the EV3 Brick to the swinging bracket. (This is yet another creative example of the bracing technique.)



18







WATCHGOOZ3 is complete.