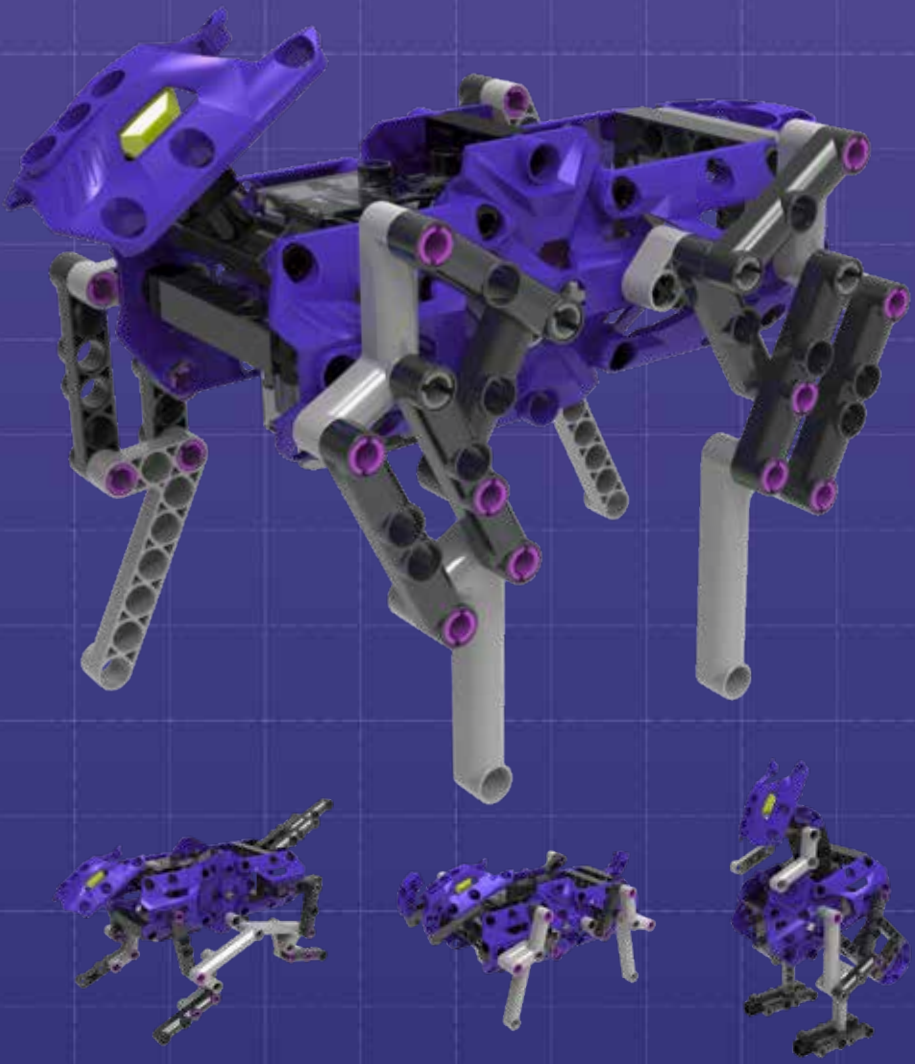
EXPERIMENT MANUAL

ENGINEERING MAKERSPACE

TERRAIN WALKERS



THAMES & KOSMOS

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››› SAFETY INFORMATION

Warning! Not suitable for children under 3 years. Choking hazard — small parts may be swallowed or inhaled. Strangulation hazard — long string may become wrapped around the neck.

Keep the packaging and the instructions as they contain important information.

Store the experiment materials and assembled models out of the reach of small children.

The models are intended for indoor use. Do not use your models in a sandbox or in water.

Dear Parents and Adults,

Before starting the experiments, read through the instruction manual together with your child and discuss the safety information. Check to make sure the models have been assembled correctly, and assist your child with the experiments.

We hope you and your child have a lot of fun with the experiments!

Safety Advice for Batteries

- ››› Three AA batteries (1.5-volt, type LR6) are required for operation.
- ››› The supply terminals are not to be short-circuited. A short circuit can cause the wires to overheat and the batteries to explode.
- ››› Different types of batteries (e.g., rechargeable and standard) or new and used batteries are not to be mixed.
- ››› Do not mix old and new batteries.
- ››› Do not mix alkaline, standard (carbon-zinc), or rechargeable (nickel-cadmium) batteries.
- ››› Batteries are to be inserted with the correct polarity. Press them gently into the battery compartment. See page 2.
- ››› Always close the battery compartment with the lid.
- ››› Non-rechargeable batteries are not to be recharged. They could explode!
- ››› Rechargeable batteries are only to be charged under adult supervision.
- ››› Rechargeable batteries are to be removed from the toy before being charged.
- ››› Exhausted batteries are to be removed from the toy.
- ››› Dispose of used batteries in accordance with environmental provisions, not in the household trash.
- ››› Be sure not to bring batteries into contact with coins, keys, or other metal objects.
- ››› Avoid deforming the batteries.
- ››› Please remove the batteries if the toy is likely to be unused for a long time.

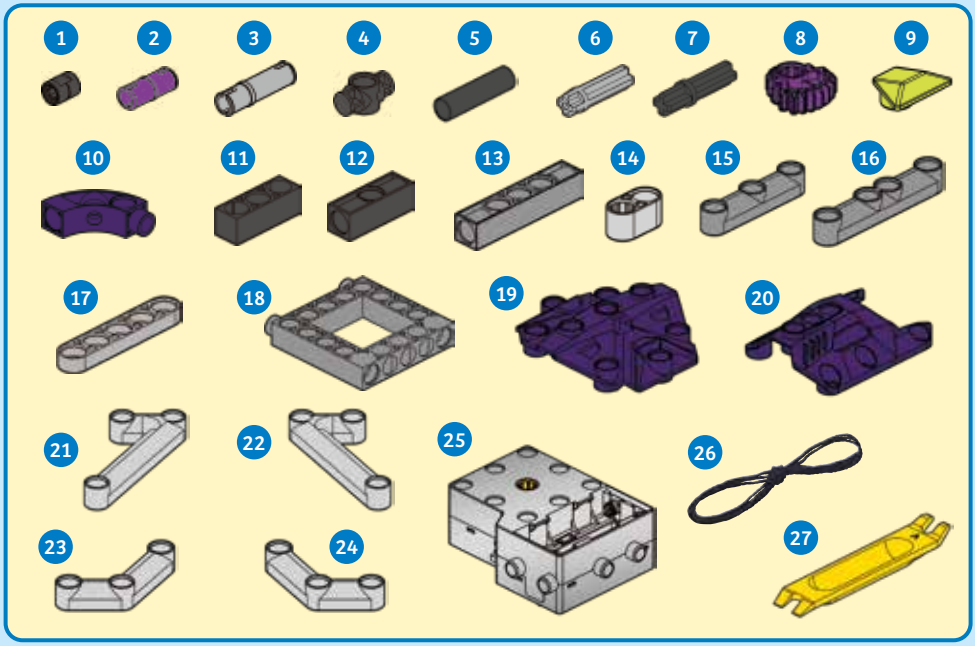
Notes on Disposal of Electrical and Electronic Components

The electronic components of this product are recyclable. For the sake of the environment, do not throw them into the household trash at the end of their lifespan.

They must be delivered to a collection location for electronic waste, as indicated by the following symbol:

Please contact your local authorities for the appropriate disposal location.

››› KIT CONTENTS



Checklist: Find – Inspect – Check off

✔	No.	Description	Qty.	Item No.
◯	1	Short anchor pin	30	7344-W10-C2D
◯	2	Joint pin	20	7413-W10-T1P2
◯	3	Long joint pin	8	7413-W10-U1S
◯	4	1-hole connector	6	7430-W10-B1D
◯	5	Tube, 30 mm	2	7400-W10-G1D
◯	6	Motor axle	2	7026-W10-L1S1
◯	7	Axle, 30 mm	4	7413-W10-N1D
◯	8	Non-circular gear	6	7427-W10-E1P
◯	9	Trapezoid pin	2	7128-W10-E4G
◯	10	Curved rod	5	7061-W10-V1P
◯	11	3-hole rod	2	7026-W10-Q2D
◯	12	3-hole cross rod	3	7026-W10-X1D
◯	13	5-hole cross rod	3	7413-W10-R1S3
◯	14	2-hole wide rounded rod	4	7427-W10-A1S
◯	15	5-hole arch rod	8	7427-W10-D1S

✔	No.	Description	Qty.	Item No.
◯	16	6-hole arch rod	8	7427-W10-D2S
◯	17	5-hole flat rounded rod	1	7443-W10-C1S
◯	18	Square frame	1	7413-W10-Q1S2
◯	19	Hexagonal body plate 1	2	7427-W10-F2P
◯	20	Hexagonal body plate 2	6	7427-W10-F1P
◯	21	Acute angle arch rod left	2	7427-W10-B1S
◯	22	Acute angle arch rod right	2	7427-W10-B2S
◯	23	Obtuse angle arch rod left	2	7427-W10-C1S
◯	24	Obtuse angle arch rod right	2	7427-W10-C2S
◯	25	Motor box	1	7427-W85-A
◯	26	Black string, 70 cm	1	R39-W85-70
◯	27	Anchor pin lever	1	7061-W10-B1Y

You will also need: *3 x AA batteries (1.5 Volt, type LR6)*

THE ANCHOR PIN LEVER

Side A of the lever can be used to easily remove anchor pins.

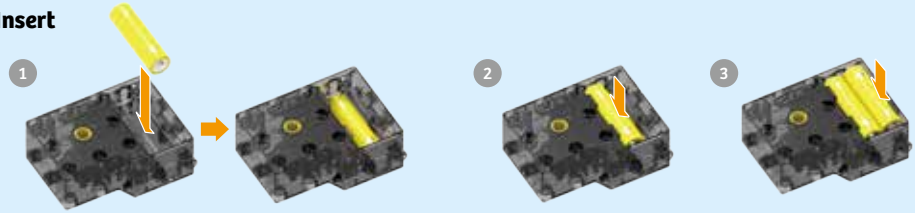
Side B can be used to loosen firmly inserted parts, such as axle plugs.

BATTERIES

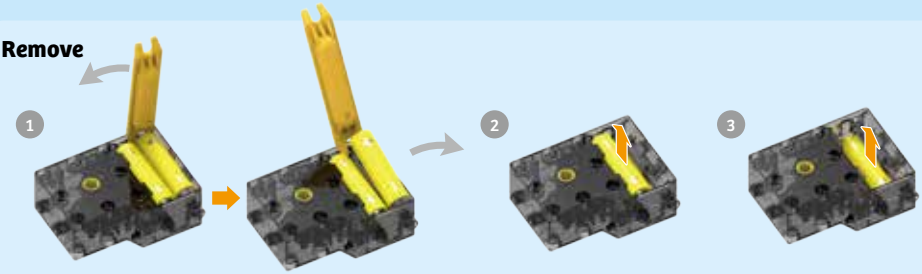
How to insert and remove the batteries

Insert: Insert three new AA batteries. Make sure you fit the positive and negative ends into the compartment in the direction indicated (with the correct polarity).
Remove: When it is time to replace the batteries, remove the old batteries by prying the first battery gently out of the compartment with the anchor pin lever. Then, it is easier to remove the other batteries with your fingers.

Insert



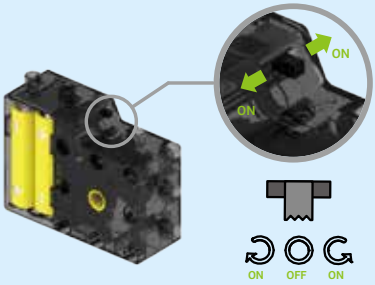
Remove



MOTOR BOX

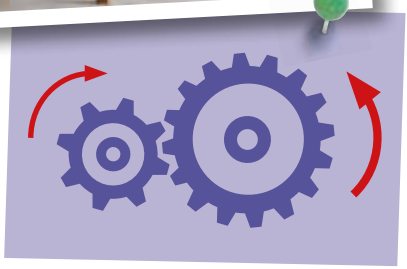
How to use

Inside the motor box, there is an electric motor, a gear train, and batteries. The batteries power the electric motor, which turns the gears and the axle shaft. Axles on your models are connected to the axle shaft. The motor can be run in two directions. A three-way switch allows you to choose between clockwise, off, and counterclockwise motion. After playing with your model, please turn off the switch. When storing, remove the batteries and store in a clean, dry place.



› › › TABLE OF CONTENTS

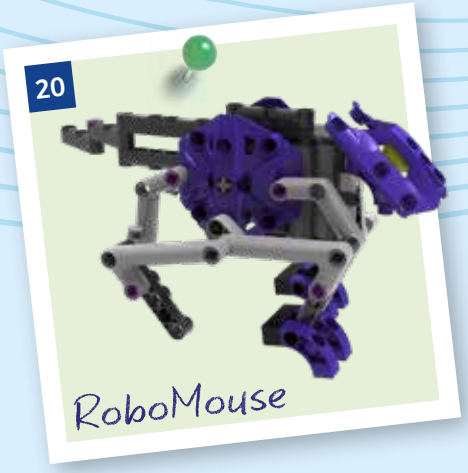
On pages 4–5 you can see all the models at a glance.



Learn more about the special, non-circular gears that make these models walk on page 23.

Build these functional models one at a time!

› › › OVERVIEW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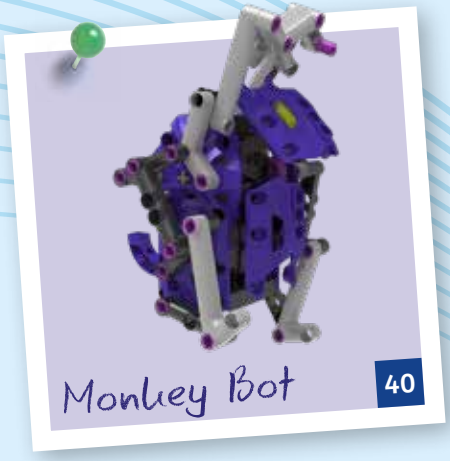
RoboMouse


24
Leopard Crawler


Kangaroobot
36


Monkey Bot
40

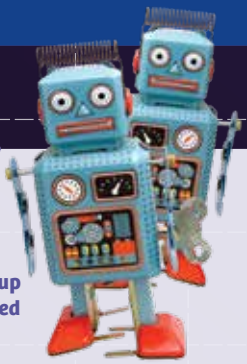
LEGGED ROBOTS

Legged robots are robots that walk on mechanical limbs. While many robots roll around on wheels — which are mechanically very efficient — legged robots have the ability to walk over obstacles and surfaces that wheeled robots cannot move over. Legged robots can go places that wheeled robots cannot.

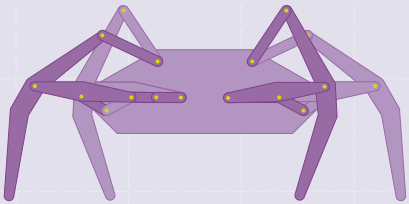
Designing a robot to walk on legs is more complicated than designing one that rolls on wheels. The ability for various animals, humans included, to walk on legs is actually quite a feat of nature. Robot engineers often look to nature for inspiration when it comes to designing legged robots.

Legged robots must keep their balance while shifting from one leg to another. They use sensors like gyroscopes and accelerometers to tell their motors how to move in order to stay balanced. It takes a lot of power to move a robot's legs, and when that power comes from heavy battery packs inside the robot's body, it can pose quite a challenge. As batteries get lighter, and sensor systems get more advanced, it is becoming increasingly popular for robots to mimic human and animal walking motion.

Legged robots can have any number of legs. The more legs, the more stable the robot is. But robots with fewer legs are more maneuverable.



These old wind-up toy robots walked on two legs.



This diagram shows a Klann linkage, a type of multi-leg walking mechanism. Learn about linkages on page 44.

This four-legged robot is called the SpotMini and is made by a company called Boston Dynamics.

Boston Dynamics also designed Atlas, this two-legged, or bipedal, robot that mimics the way a human walks. This robot can walk, run, jump, and even pick things up and carry them in its arms.

› › › CHECK IT OUT

GEAR WHEELS AND GEAR TRAINS

If you look at the complicated machines that exist today, it's hard to imagine that gears and gear trains have been around for such a long time. In fact, they have been in use for thousands of years. One impressive example is the mysterious "Antikythera mechanism," built over 2,000 years ago in Greece. It is a geared machine that was used to perform automatic calculations of the position of the sun and the moon. Even back then, gears were hard at work.

The Antikythera mechanism

Gears are simply wheels with teeth on them that mesh with the teeth on other gears. There is no point to having just one gear all by itself. But as soon as you have two of them, you have a system that transmits force and rotating motion. This kind of transmission system is called a **gear train.**

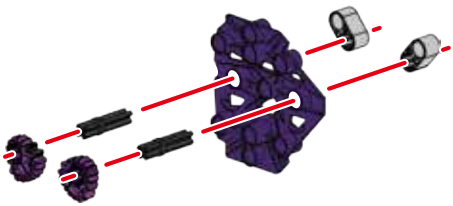
Of course, there are also transmission systems without gears. Pulley blocks, used for lifting loads, are a good example. They are made of pulleys and a rope. But most transmission systems work with gears. Sometimes, chains interlock with the gears as well. If you have a bicycle with a **derailleur system** for shifting gears, you have seen this before.

Some gear trains use gears that aren't round. In a **rack and pinion,** a round gear called the pinion engages with the teeth on a linear bar called the rack. In this way, rotating motion is converted into linear motion. Gears also come in spiral, oval, and ring shapes. And the gears in this kit have a very unique shape that enables the walking motion of the models.

›› Build the first models and look for gears in them.

TERRAIN WALKER

1



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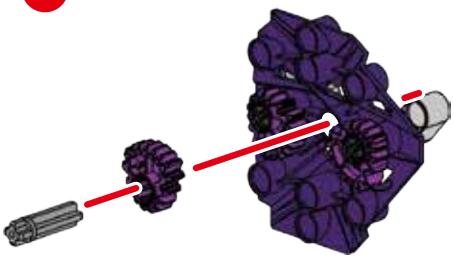
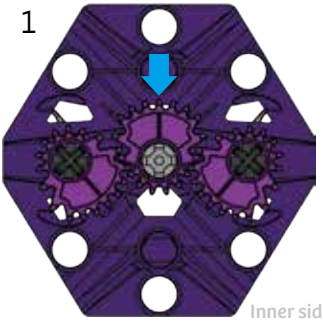


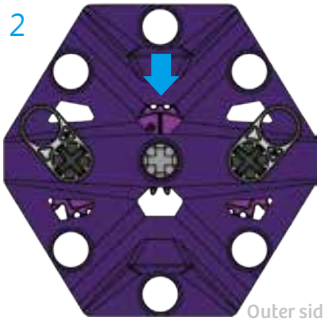
Important! Check both sides and make sure the parts are oriented exactly as shown:

1



Inner side

2



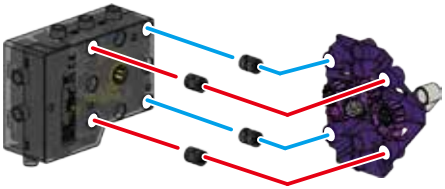
Outer side

1. The gears must mesh together.

Turn one of the gears all the way around and make sure all of the gears turn smoothly.

2. The middle tooth of the middle gear must be pointing straight up.

3



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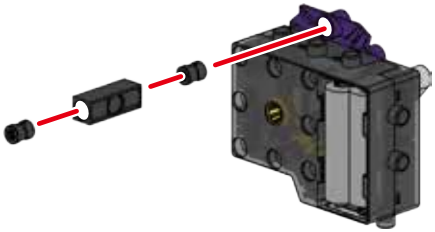
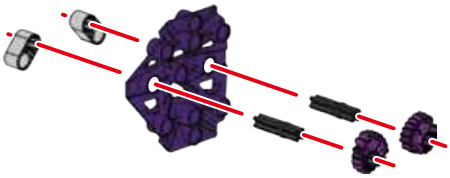


Make sure there are batteries in the motor box first.

TERRAIN WALKER

5



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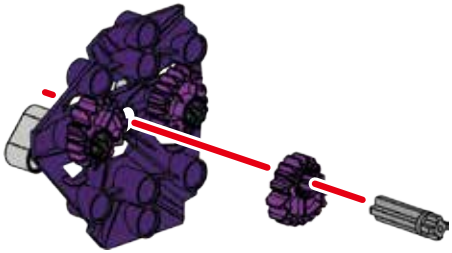

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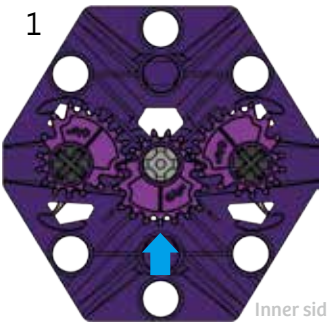
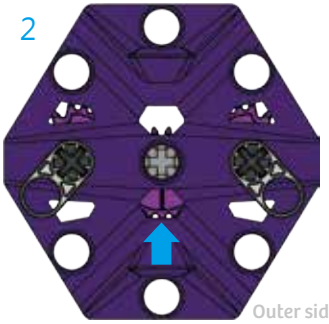
1



Inner side

2



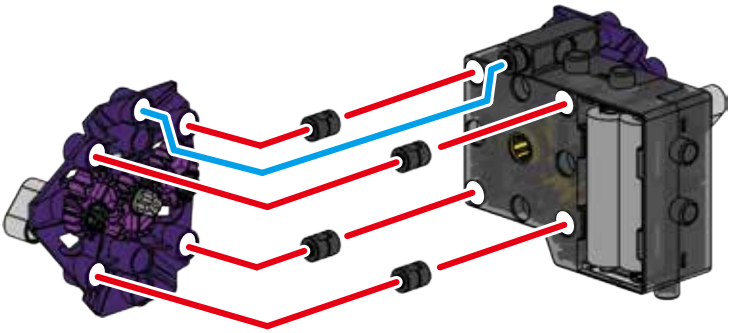
Outer side

1. The gears must mesh together.

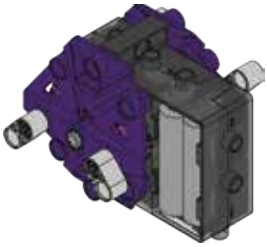
Turn one of the gears all the way around and make sure all of the gears turn smoothly.

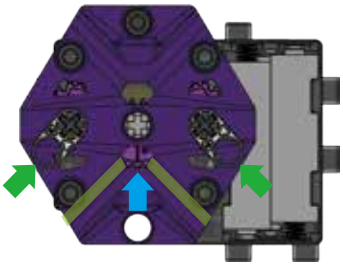
2. The middle tooth of the middle gear must be pointing straight down.

7



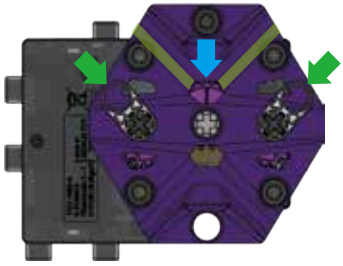
Important! Check both sides again.





The middle tooth of the middle gear is pointing straight down.

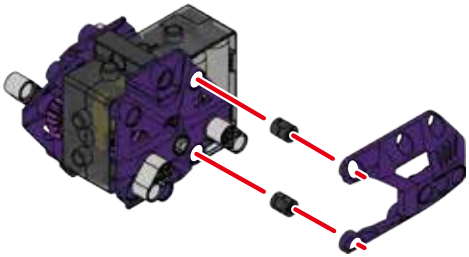
The 2-hole wide rounded rods are aligned with the green arrows as shown.

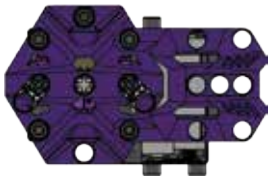


The middle tooth of the middle gear is pointing straight up.

The 2-hole wide rounded rods are aligned with the green arrows as shown.

8





side view

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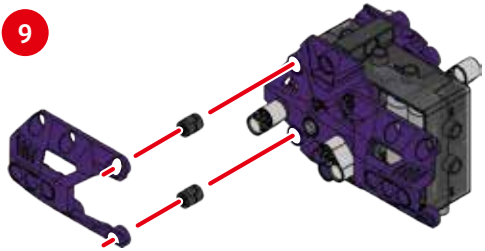

side view

TERRAIN WALKER

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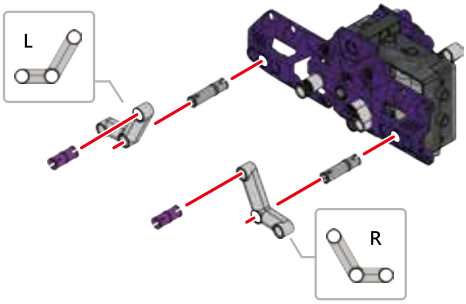

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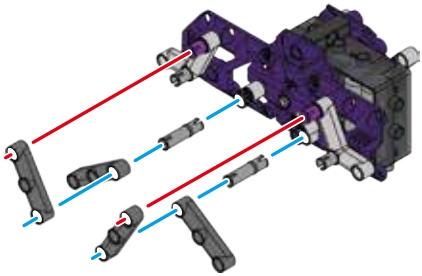

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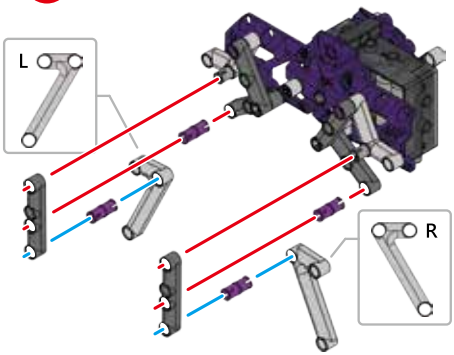

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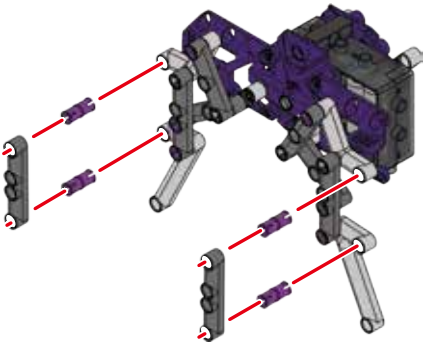

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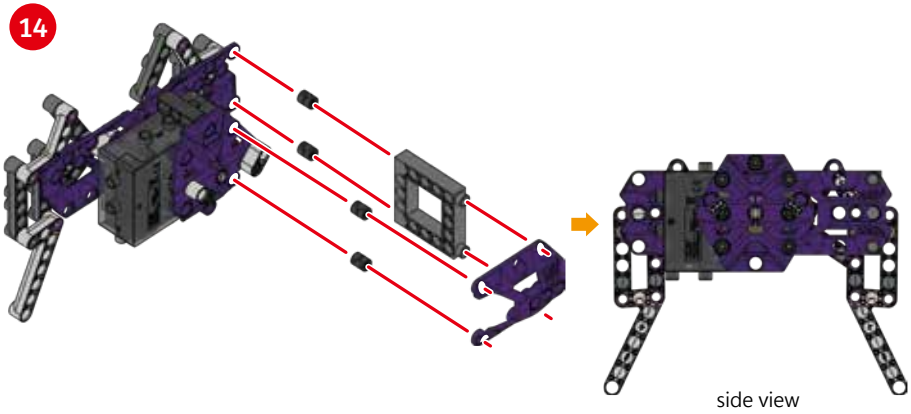

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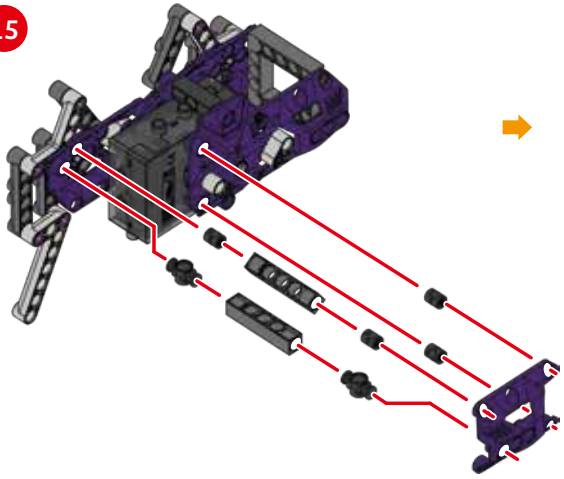
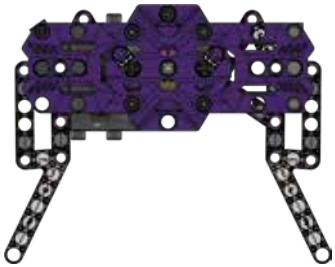
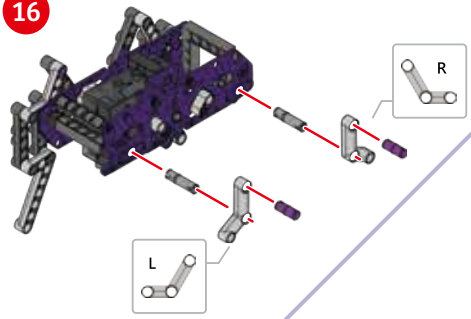




side view

16



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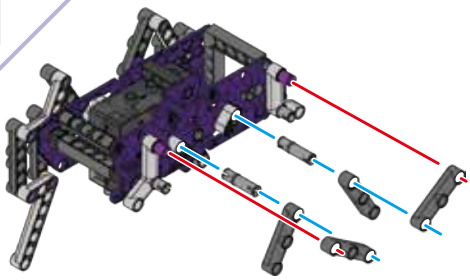

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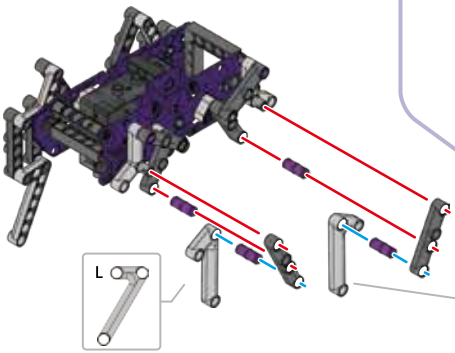

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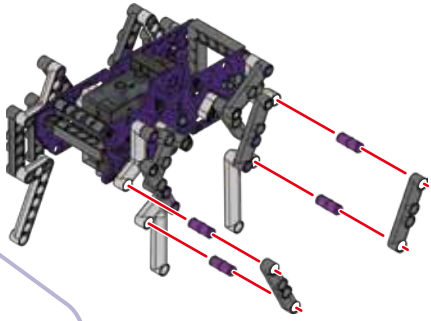

TERRAIN WALKER

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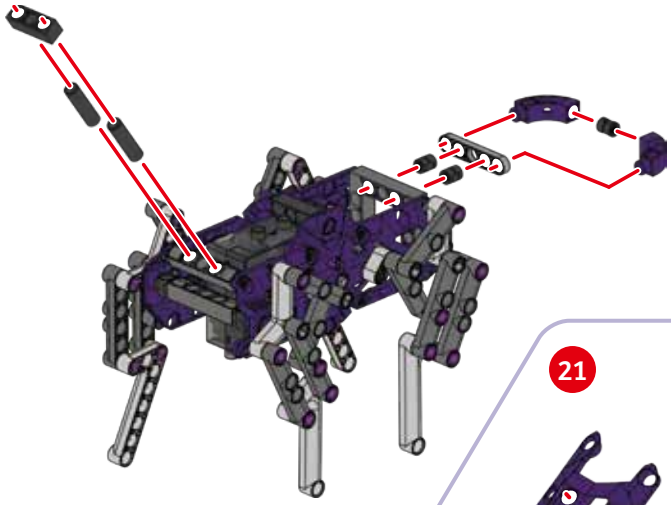

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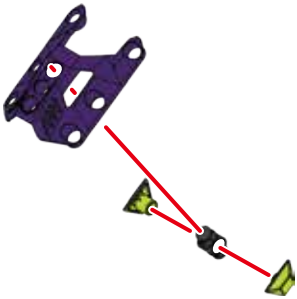

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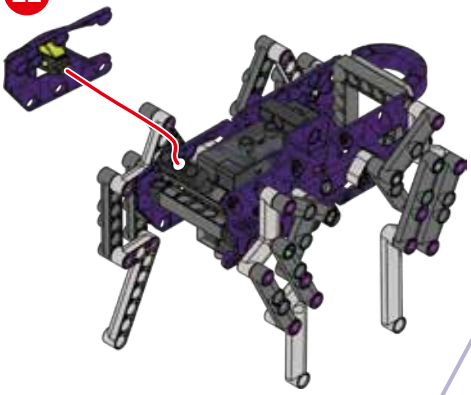
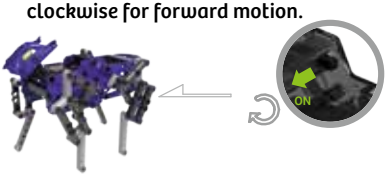


23

Done!

››› Use the string to make a leash for your model and take it for a walk!

Switch the motor to turn clockwise for forward motion.



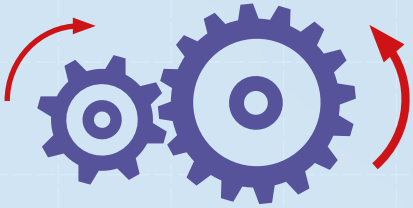
- The model walks best on a smooth tabletop or hard floor, but if the surface is too smooth, it might slip. Test different surfaces and see what works! The model will not walk on carpet except very low-pile carpet.
- Pick up the model by the middle body plates.
- The model works best if you give it a little forward momentum when letting it go on the tabletop.

UNDERSTANDING GEAR RATIOS

DIRECTION OF MOTION

When two gear wheels are placed next to each other, their teeth mesh together. When one of the gears turns, the other gear will turn as well, automatically moving along with the first gear. Interlocking gear wheels transmit a **rotational movement.**

When you pay close attention to the directions that two interlocking gears are turning, you will see that one gear turns in one direction (for example, clockwise) and the other gear turns in the other direction (for example, counterclockwise). So gears can be used to reverse the **direction of rotation.**

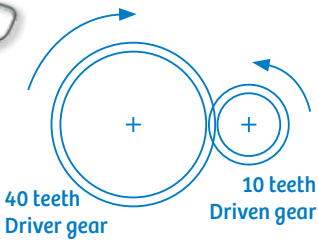


SPEED AND TORQUE

When gear wheels have different diameters and, as a result, a different number of teeth, their **rotational speeds** will also be different. The larger wheel turns slower than the smaller one.

This shows that gear wheels can be used to convert a slow rotational movement into a faster rotational movement and vice versa. For example, if the larger gear wheel has 40 teeth and the smaller wheel has ten, the smaller wheel will complete four rotations in the time it takes the larger wheel to do one rotation. This relationship between the input speed and the output speed is known as the **gear ratio.** In this case, the ratio is 1:4.

If you were to use your hand to slow down the second gear while you turned the first gear, you would notice that you needed to apply force to do it. Interlocking gears also transmit **force.** The force of rotary motion is called **torque.**



$$\text{Velocity ratio} = \frac{\text{Number teeth driven gear}}{\text{Number teeth driver gear}}$$

$$= \frac{10}{40} = \frac{1}{4} \quad (1:4)$$

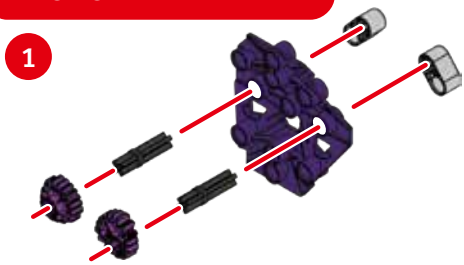
Speed and torque have an **inverse** relationship in a gear train. This means that if the driven gear is turning slower than the driver gear, the driven gear can exert more torque at its circumference than the driver gear.

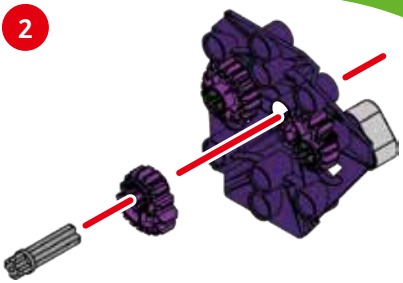
The fact that gear trains don't just transmit rotational speeds — that they also transmit force — has significant advantages in machines. Bicycles use gears to make pedaling easier. If you want to cycle over flat terrain or downhill, you can switch into a large gear at the pedal and a small gear at the rear wheel. This optimizes for speed at the rear wheel, but also requires more torque at the pedal. But when you're cycling uphill, you can switch to a small gear at the pedal and a large gear at the rear wheel. This allows you to apply a smaller force on the pedals and turn them at a faster rate, converting that force into a larger torque, but slower speed, at the rear wheel.

Gear trains can be found inside many machines and devices. For example, in mechanical clocks, the kind you might see in a museum, gear wheels enable the movement of a gear wheel propelled by a spring or weights to be transmitted to the hands of the clock. Thanks to the different gear ratios, the hands can move quickly (the second hand), slowly (the minute hand), or even slower (the hour hand).

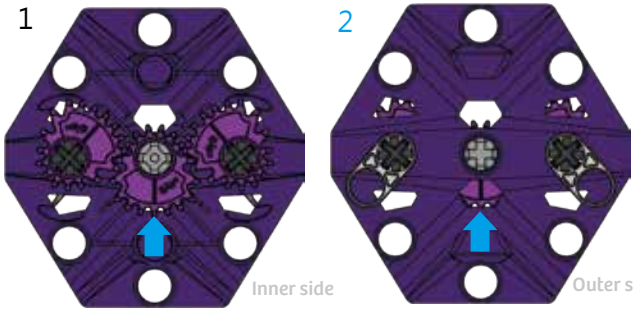
››› Read the next Check It Out section to learn about the unique gears in this kit.

ROBOAR





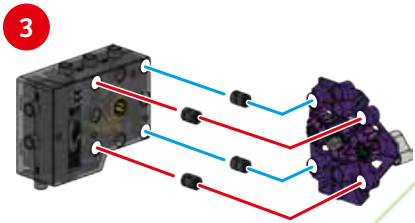
Important! Make sure the parts are oriented exactly as shown:

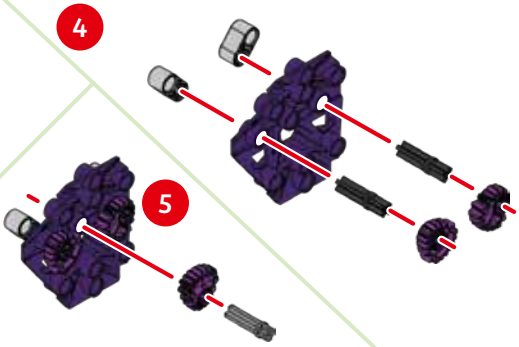


1. The gears must mesh together.

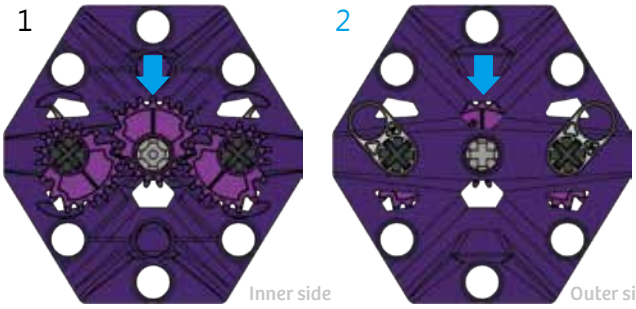
Turn one of the gears all the way around and make sure all of the gears turn smoothly.

2. The middle tooth of the middle gear must be pointing straight down.





Important! Make sure the parts are oriented exactly as shown:



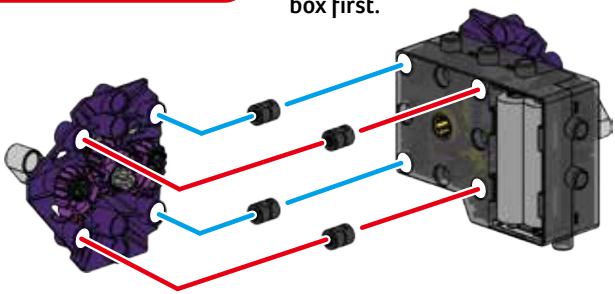
1. The gears must mesh together.

Turn one of the gears all the way around and make sure all of the gears turn smoothly.

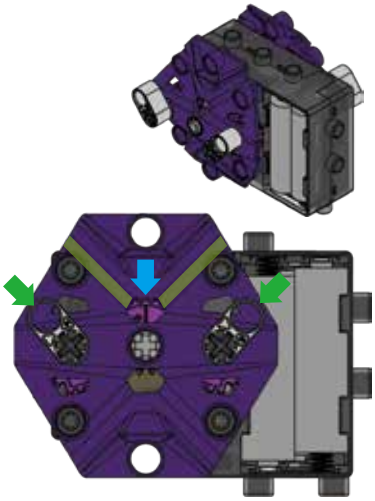
2. The middle tooth of the middle gear must be pointing straight up.

Make sure there are batteries in the motor box first.

6

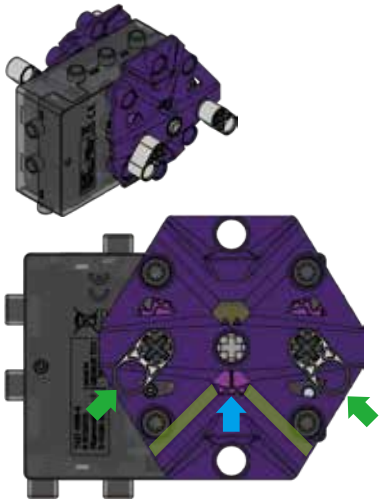


Important! Check both sides again.



The middle tooth of the middle gear is pointing straight up.

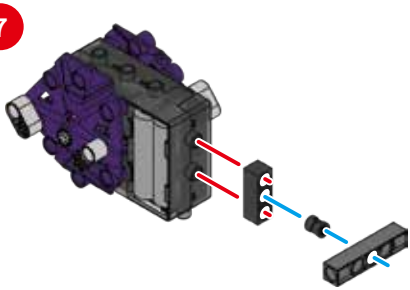
The 2-hole wide rounded rods are aligned with the green arrows as shown.



The middle tooth of the middle gear is pointing straight down.

The 2-hole wide rounded rods are aligned with the green arrows as shown.

7



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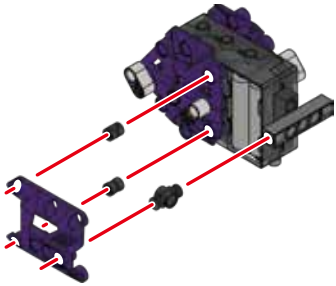
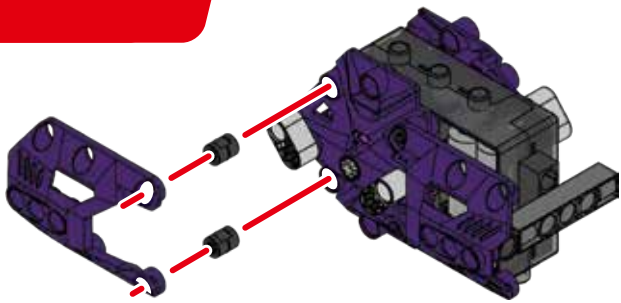


ROBOAR

9



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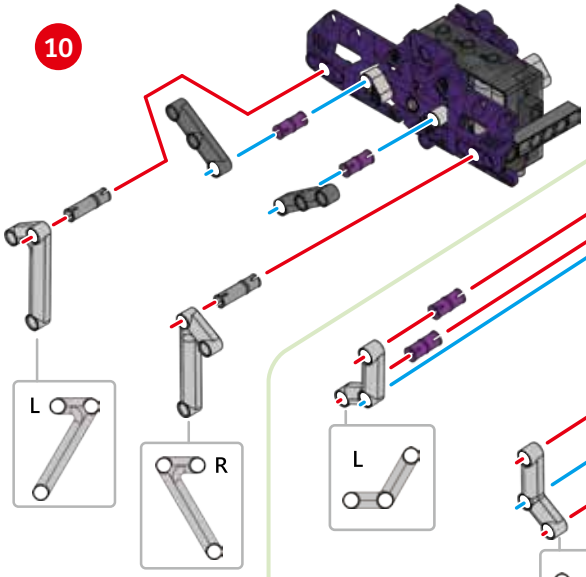

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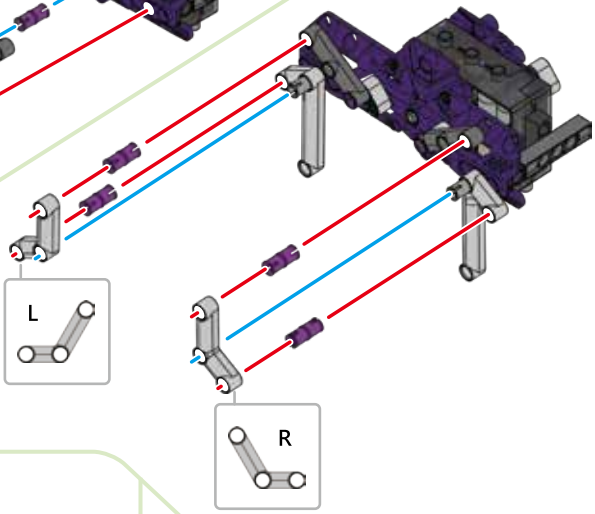

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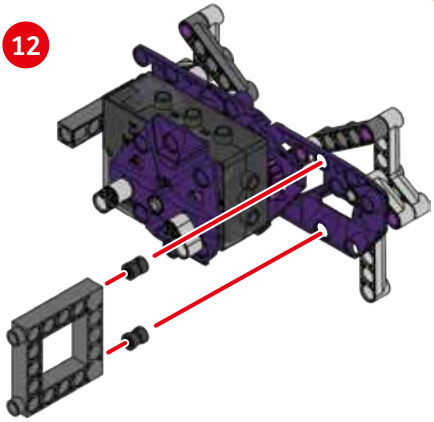

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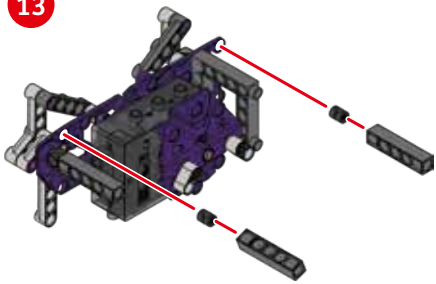

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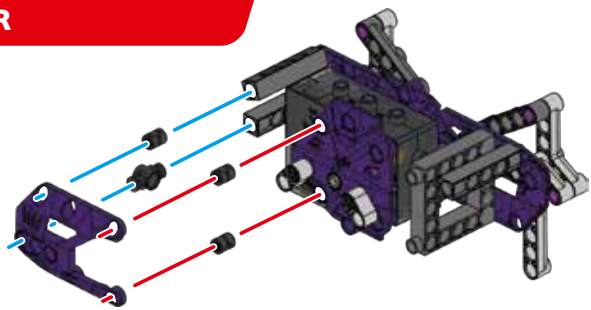

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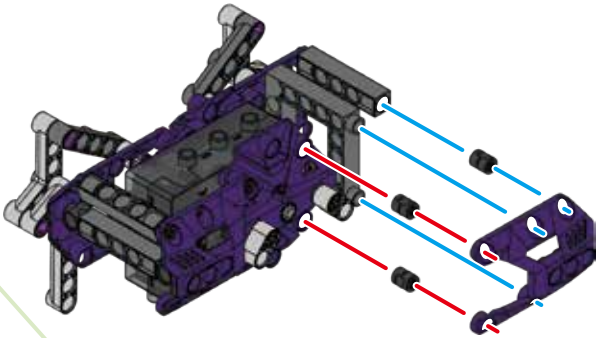

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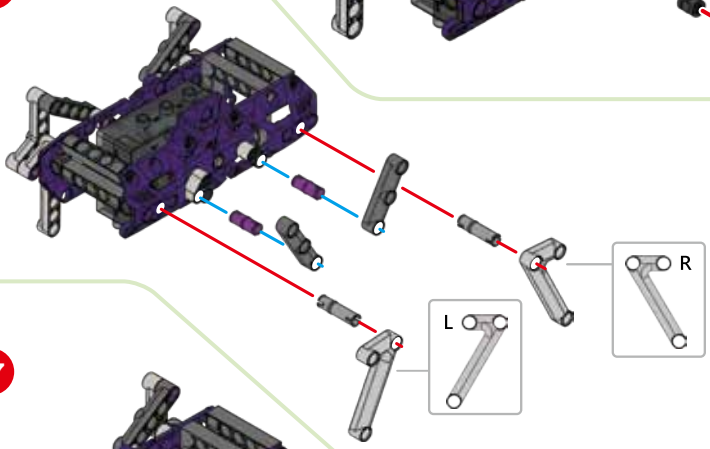

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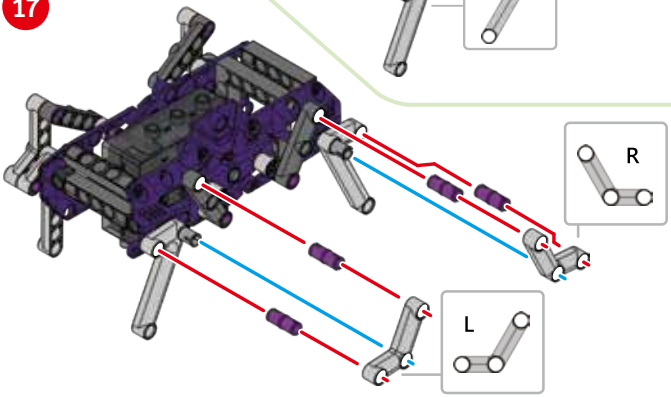
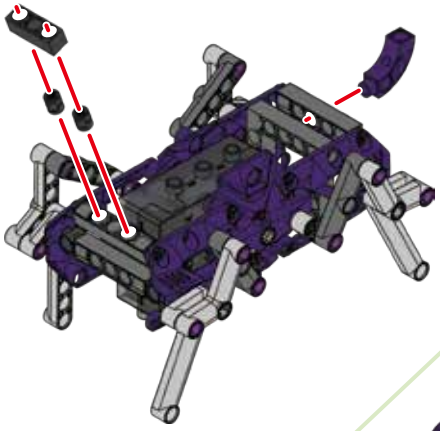


ROBOAR

18



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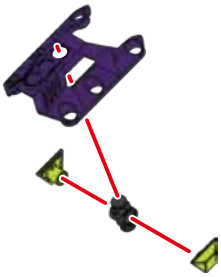

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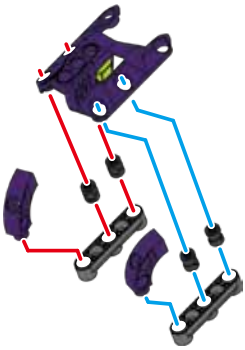

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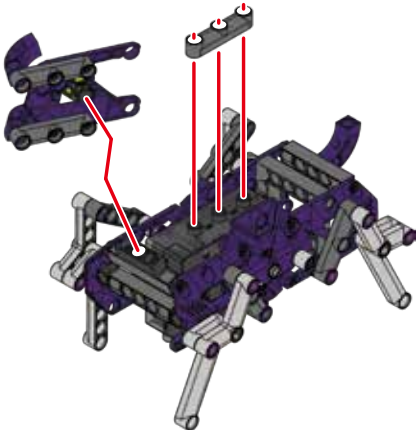

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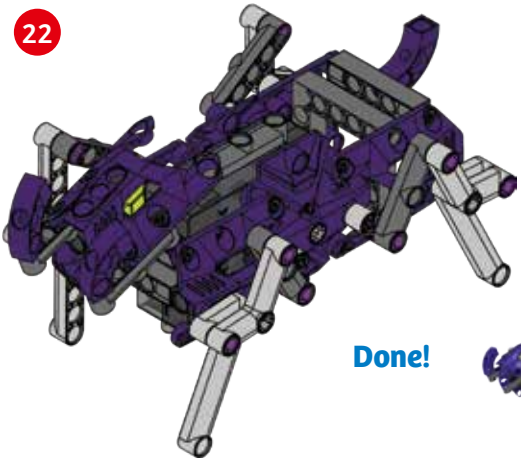


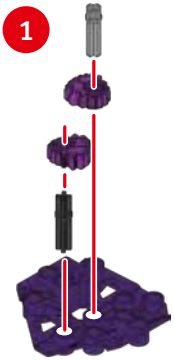
Done!

Switch the motor to turn clockwise for forward motion.

ROBOMOUSE

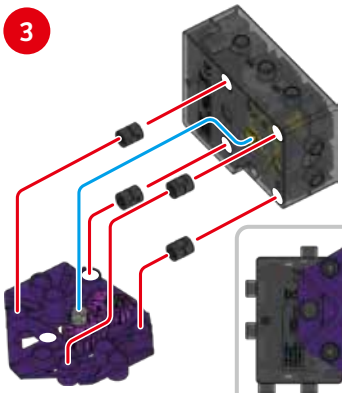
Repeat steps 1 and 2 twice. **x2**

1



2

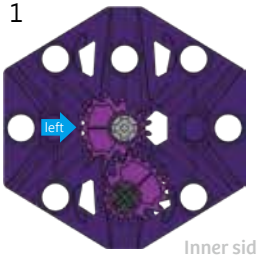
3



Align the 2-hole wide rounded rod with the green arrow as shown.

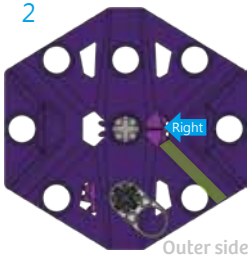
Important! Make sure the parts are oriented exactly as shown:

1



Inner side

2



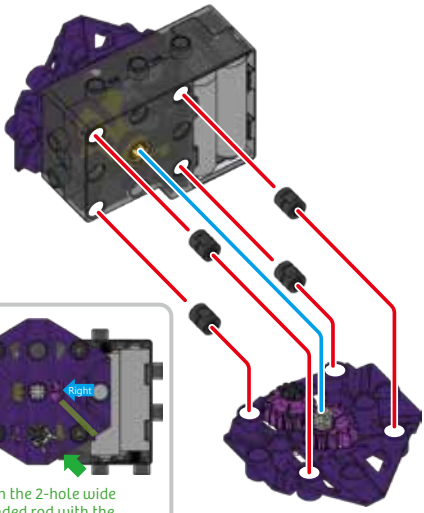
Outer side

1. The gears must mesh together.

Turn one of the gears all the way around and make sure both gears turn smoothly.

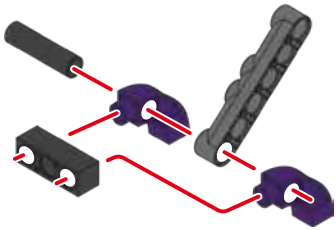
2. The middle tooth of the upper gear must be pointing straight to the left/right.

4



Align the 2-hole wide rounded rod with the green arrow as shown.

5



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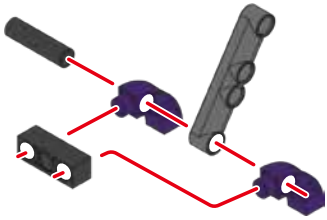
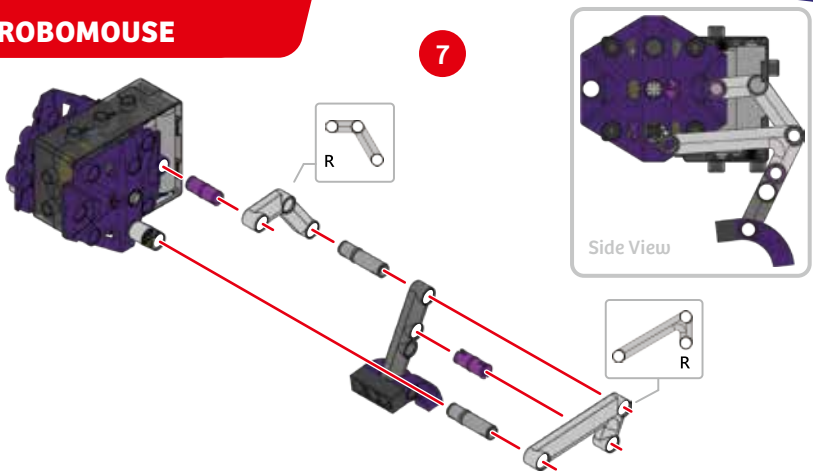


ROBOMOUSE

7



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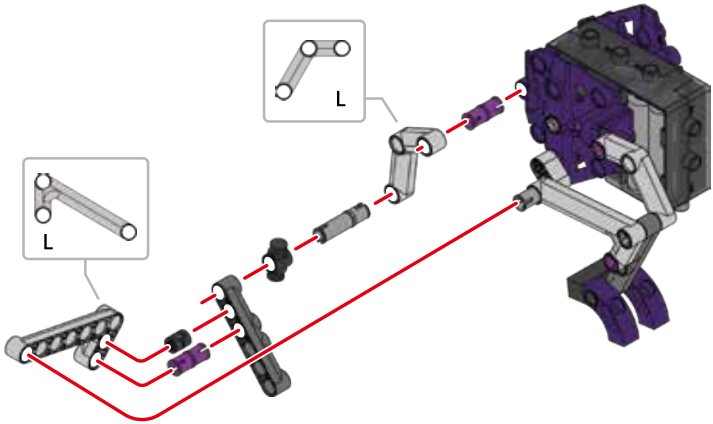

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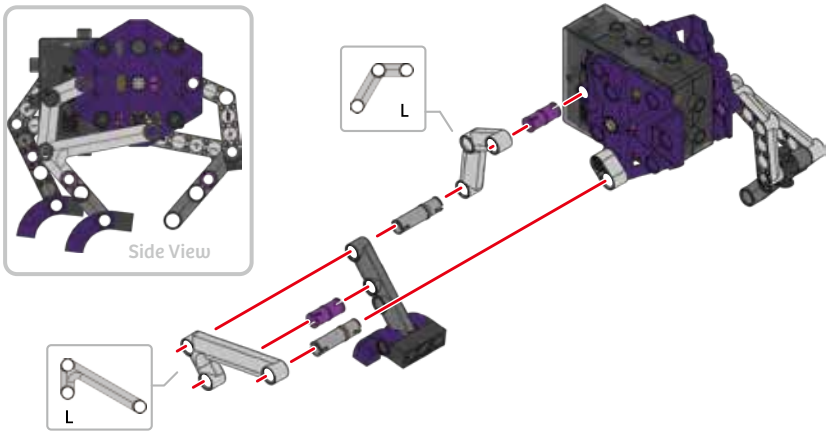

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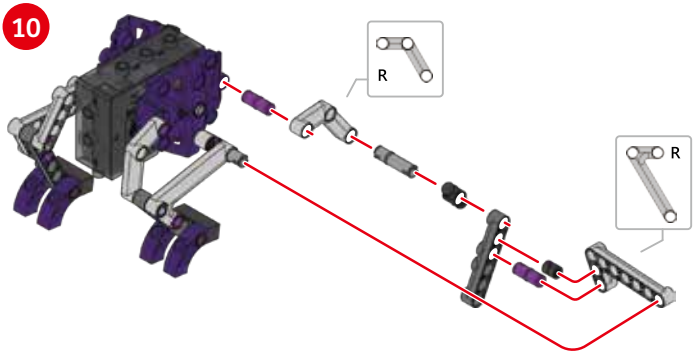

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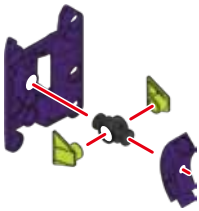

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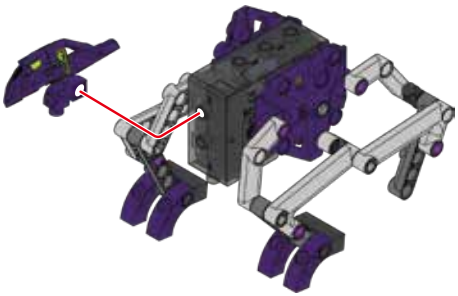
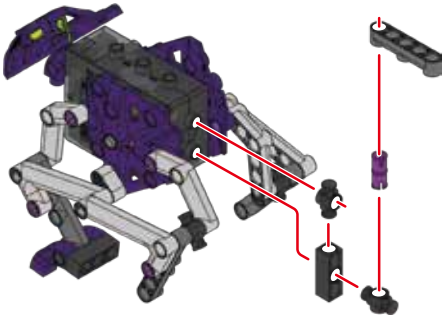
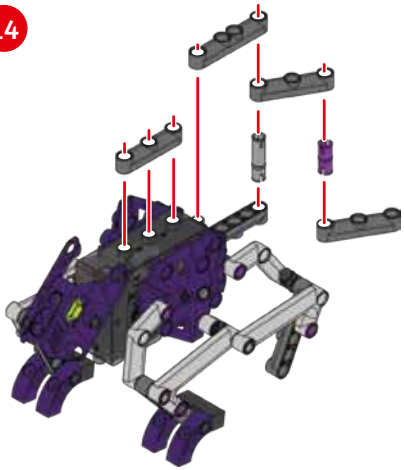


13



14



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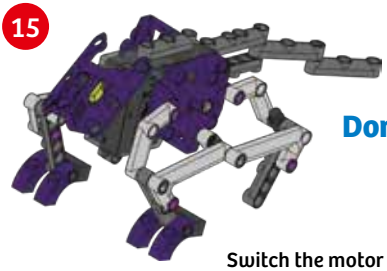
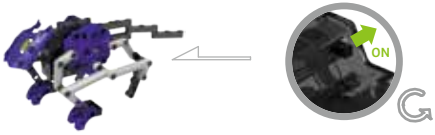


Done!

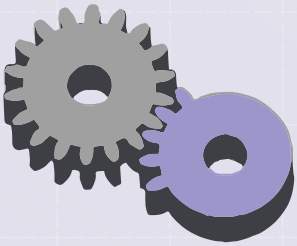
Switch the motor to turn counterclockwise for forward motion.



› › › CHECK IT OUT

INTERMITTENT GEARS AND NON-CIRCULAR GEARS

Imagine a set of gears in which the driver gear (the gear connected to the motor axle) is missing some of its teeth. The driver gear turns continuously, but it only meshes with the driven gear some of the time. When the toothless part of the driver gear gets around to the driven gear, the teeth don't mesh, so the driven gear stops turning. These types of gears are called **intermittent gears.**



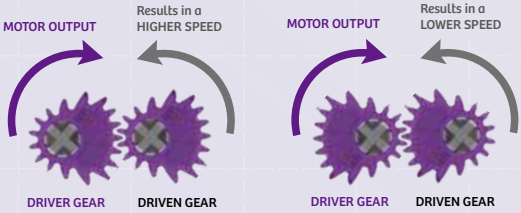
An intermittent gear train can produce a discontinuous movement, where periods of motion are interrupted by periods of stillness. These types of gears are often used in counting mechanisms and other machines that need periodic motion.

Intermittent gears are also called mutilated gears. The name refers to the fact that the teeth have been removed from part of the gear.

Now, take a close look at the gears in this kit. What do you notice? The gears are not perfectly circular like normal gears. The teeth on part of the gear are farther away from the center than they are on the rest of the gear.

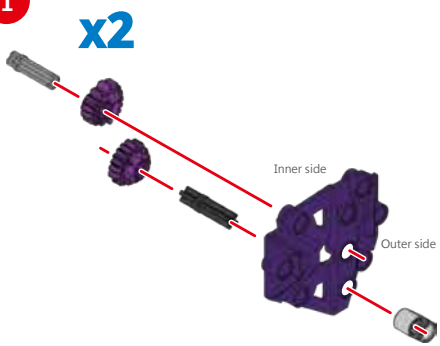
As you read on page 14, when two gears of different sizes (with different numbers of teeth) mesh, they will turn at different speeds. A gear with 40 teeth rotates completely just once for every two rotations of a meshing 20-tooth gear.

The gears in this kit have a special design in which half the gear is like a larger gear and half the gear is like a smaller gear. While the motor and thus the driver gear turn at a continuous speed, the **non-circular** design of the gears results in a varying speed of rotation on the driven gear(s). For about half its rotation, the non-circular driven gear turns faster than it does for the other half of its rotation. This results in varying speeds at the output axles, allowing different parts of the model to move at different speeds. For example, when one leg is moving fast to step forward, the other three legs can be holding the model up. Each model uses the varying speed gears in different ways.



LEOPARD CRAWLER

1



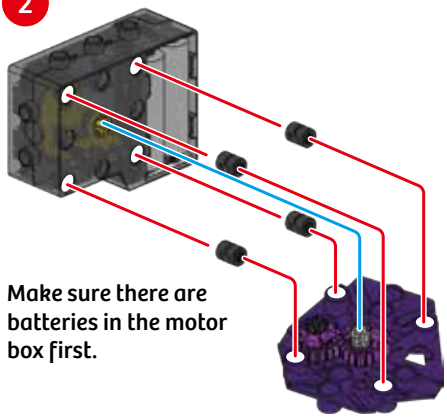
Important! Check both sides:

1. The gears must mesh together.

Turn one of the gears all the way around and make sure both gears turn smoothly.

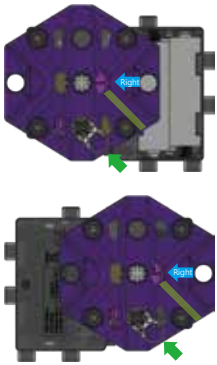
2. The middle tooth of the upper gear must be pointing straight to the left/right.

2



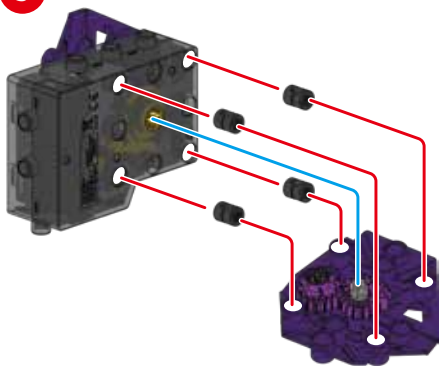
Make sure there are batteries in the motor box first.

Important! Check both sides again.



The 2-hole wide rounded rods are aligned with the green arrows as shown.

3



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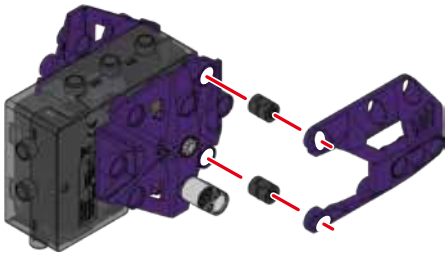
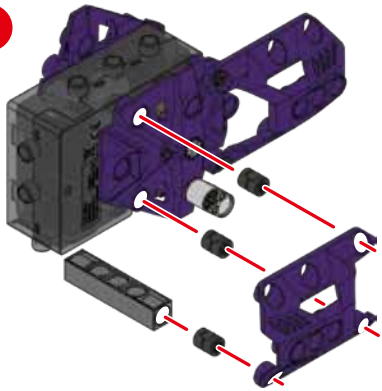
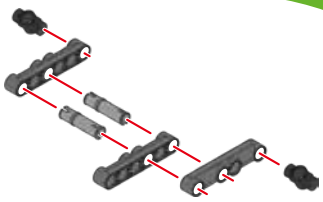


LEOPARD CRAWLER

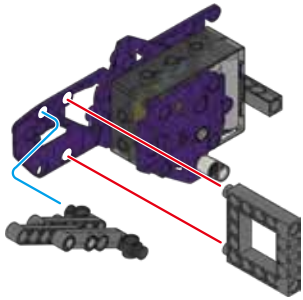
5



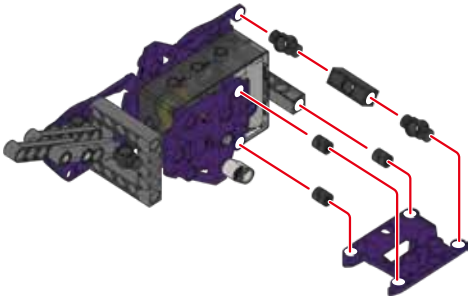
6



7



8



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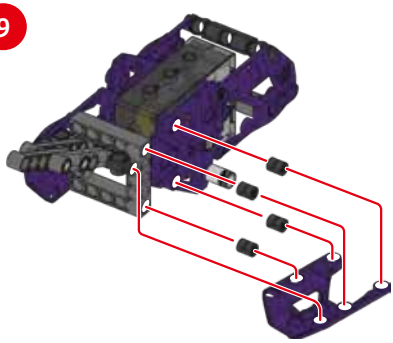
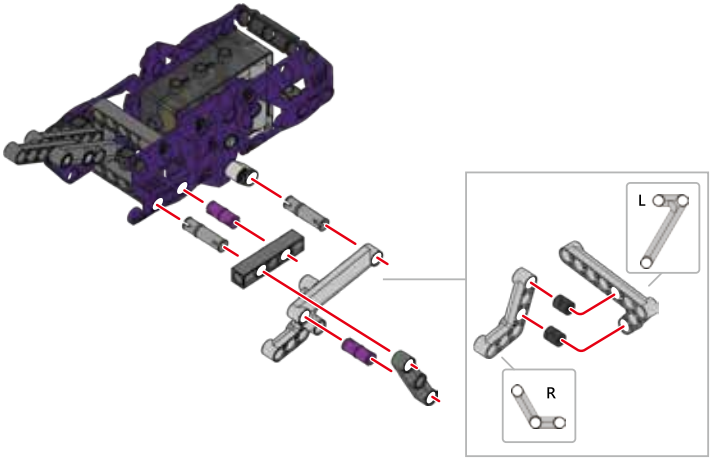
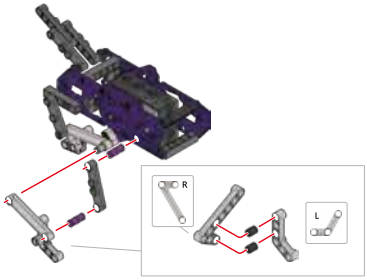


10

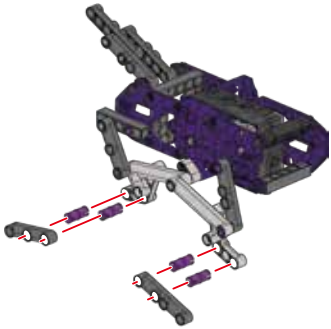


LEOPARD CRAWLER

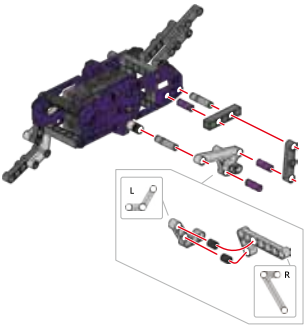
11



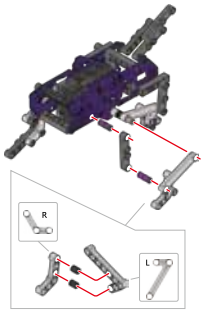
12



13



14



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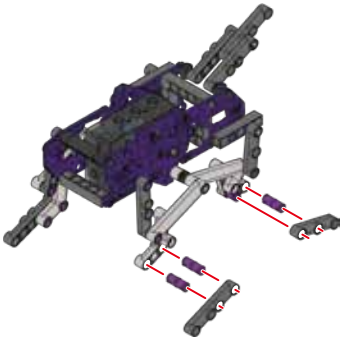
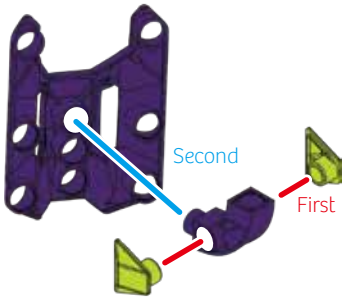
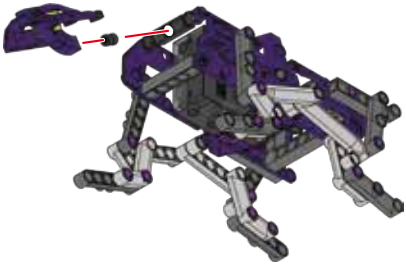


16



17



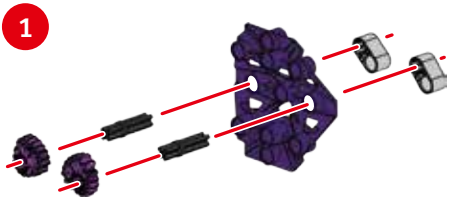
18

Done!

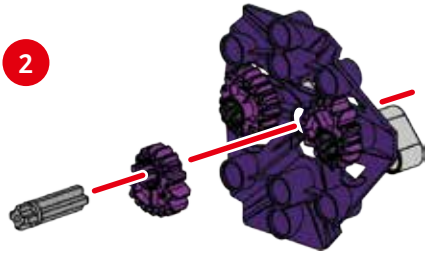
Switch the motor to turn counter-clockwise for forward motion.

WATER BEAR ROBOT

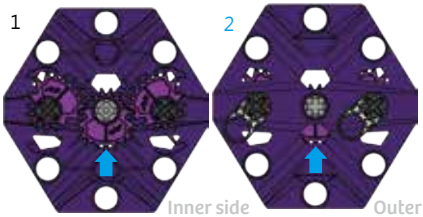
1



2



Important! Make sure the parts are oriented exactly as shown:

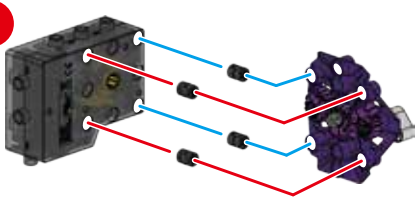


1. The gears must mesh together.

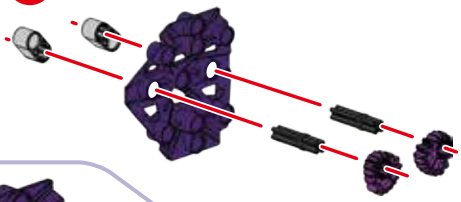
Turn one of the gears all the way around and make sure all of the gears turn smoothly.

2. The middle tooth of the middle gear must be pointing straight down.

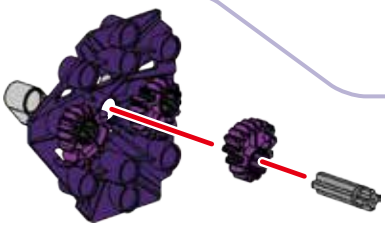
3



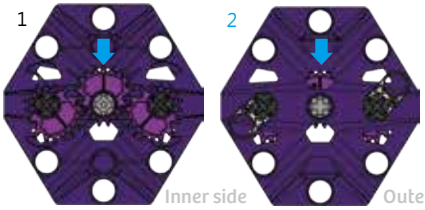
4



5



Important! Make sure the parts are oriented exactly as shown:



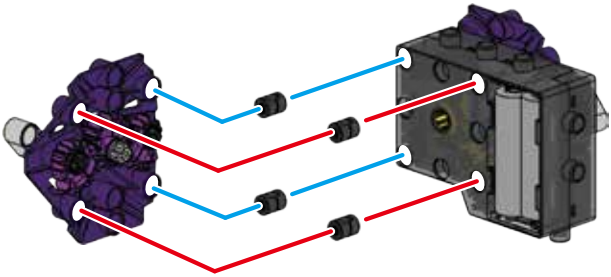
1. The gears must mesh together.

Turn one of the gears all the way around and make sure all of the gears turn smoothly.

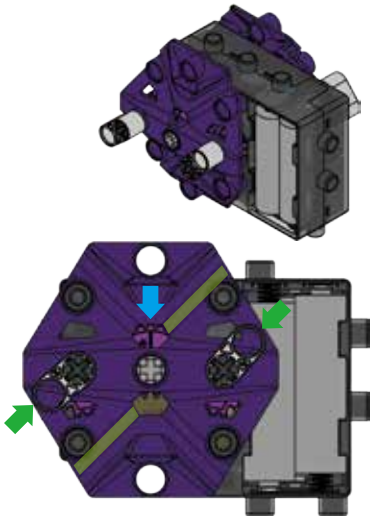
2. The middle tooth of the middle gear must be pointing straight up.

Make sure there are batteries in the motor box first.

6

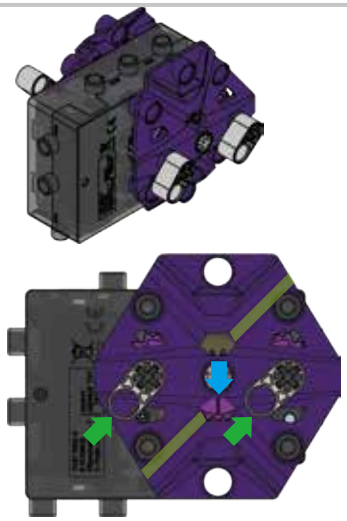


Important! Check both sides again.



The middle tooth of the middle gear is pointing straight up.

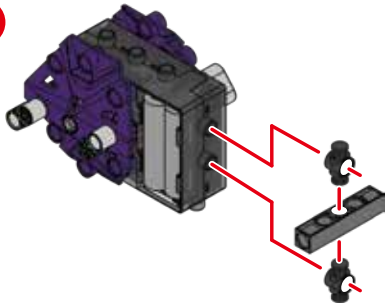
The 2-hole wide rounded rods are aligned with the green arrows as shown.



The middle tooth of the middle gear is pointing straight down.

The 2-hole wide rounded rods are aligned with the green arrows as shown.

7



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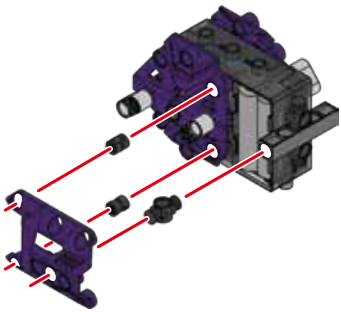
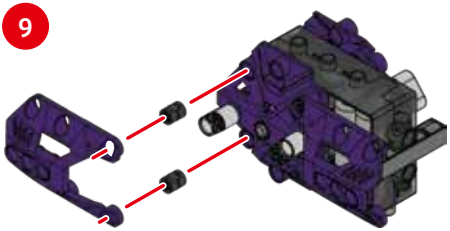


WATER BEAR ROBOT

9



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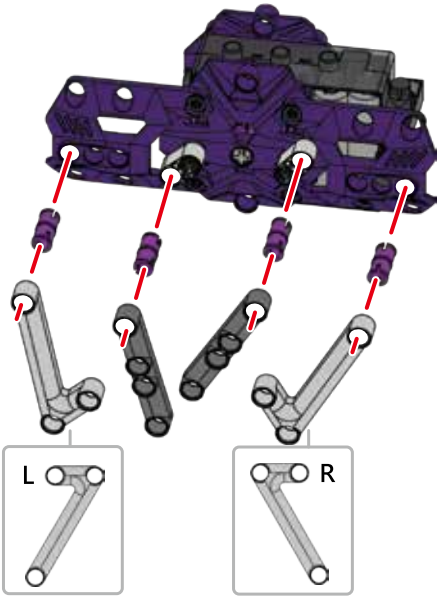

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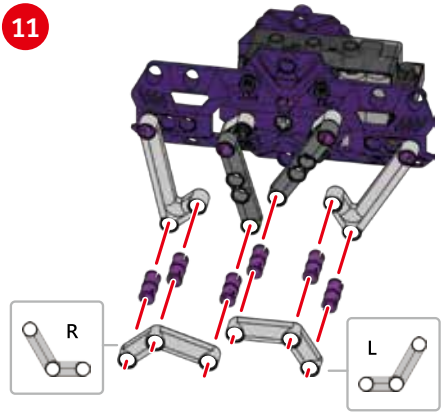

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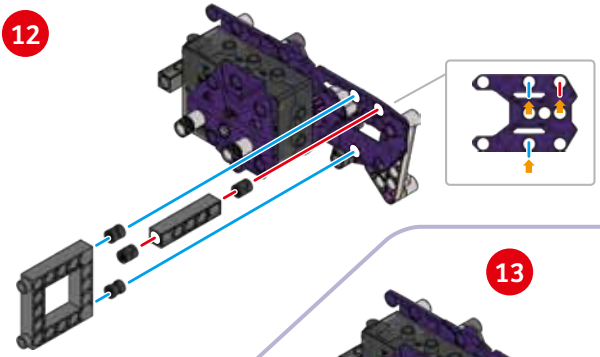

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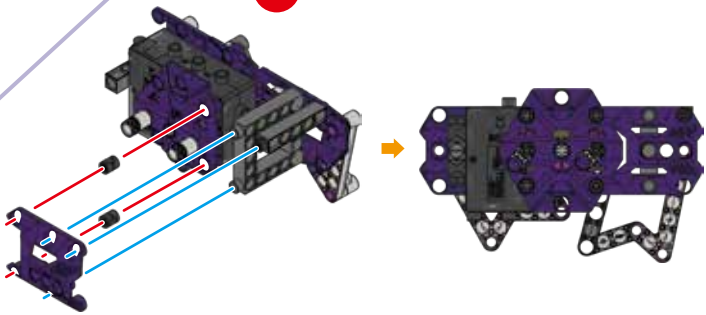

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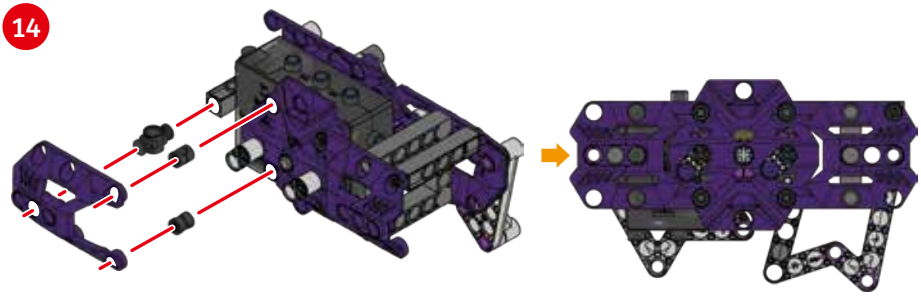

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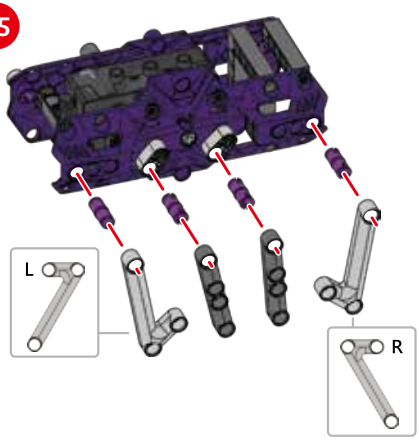

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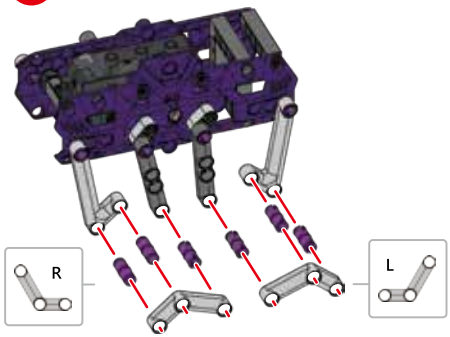

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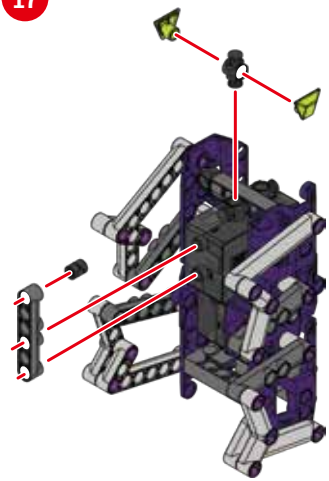

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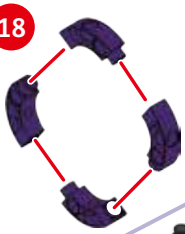

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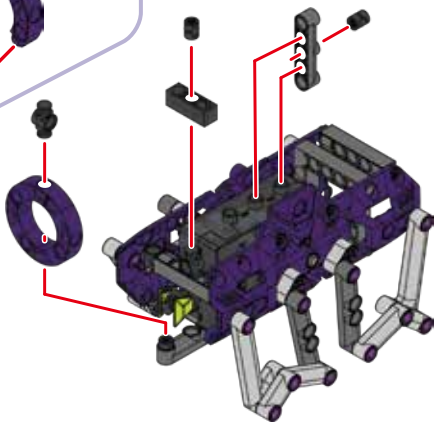
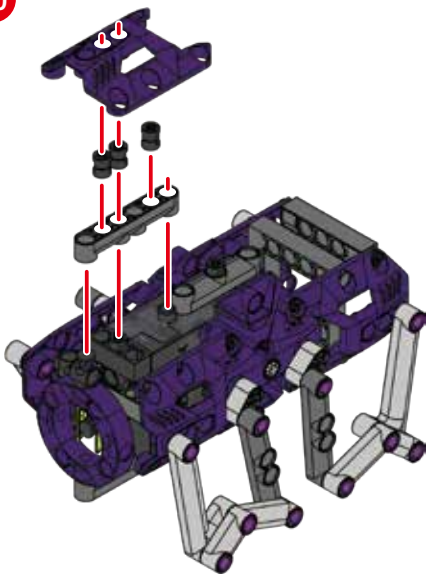
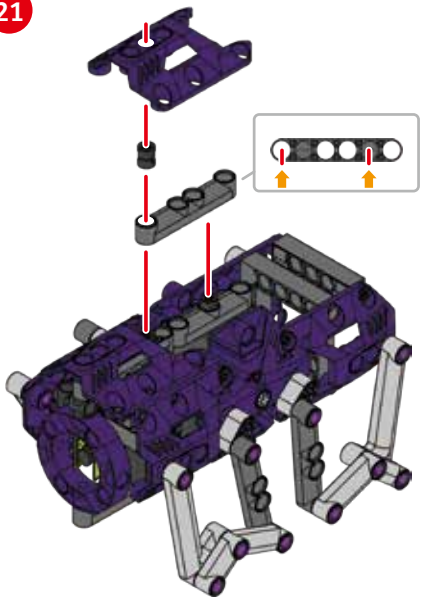


WATER BEAR ROBOT

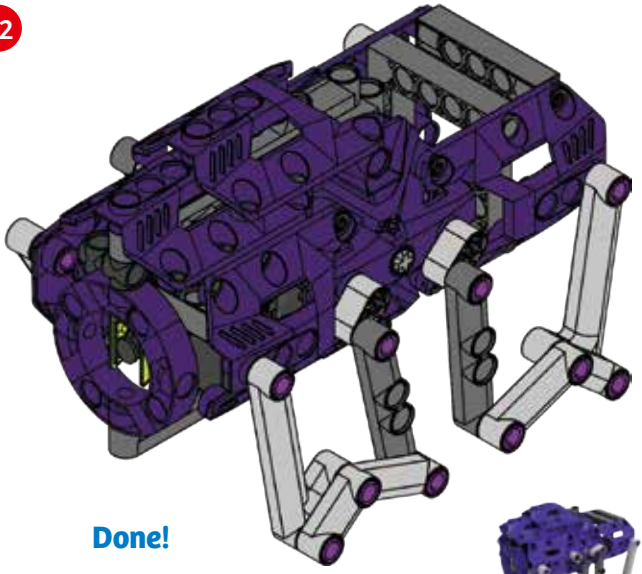
20



21



22

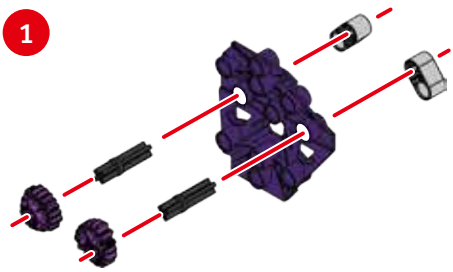


Done!

Switch the motor to turn clockwise for forward motion.

FAIRY SHRIMP BOT

1



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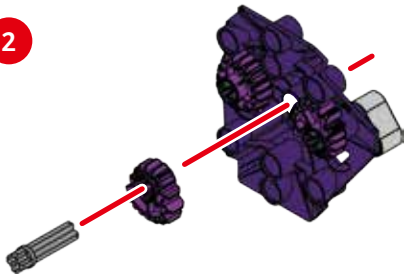


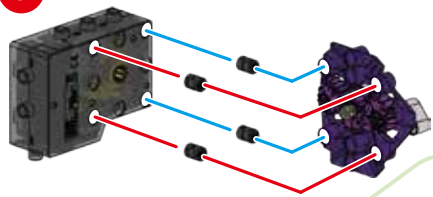
Important! Make sure the parts are oriented exactly as shown:

1. The gears must mesh together.

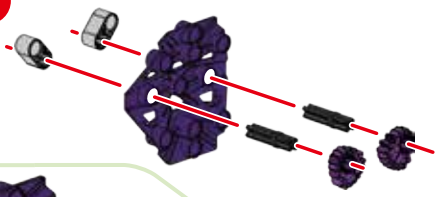
Turn one of the gears all the way around and make sure all of the gears turn smoothly.

2. The middle tooth of the middle gear must be pointing straight down.

3



4



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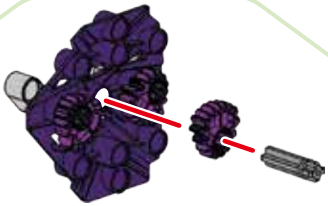


Important! Make sure the parts are oriented exactly as shown:

1. The gears must mesh together.

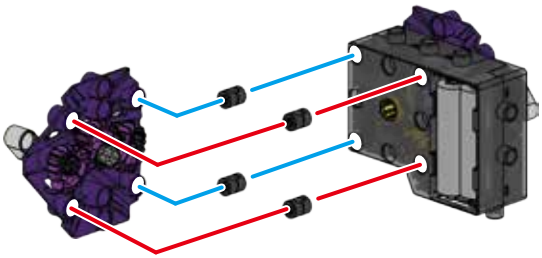
Turn one of the gears all the way around and make sure all of the gears turn smoothly.

2. The middle tooth of the middle gear must be pointing straight up.

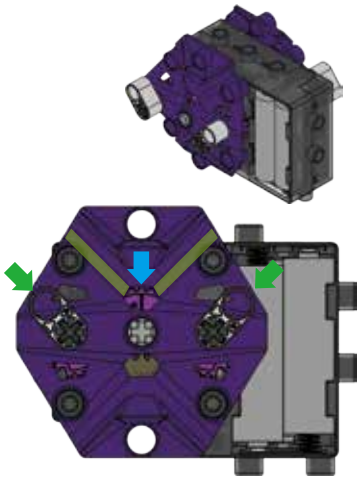
FAIRY SHRIMP BOT

Make sure there are batteries in the motor box first.

6

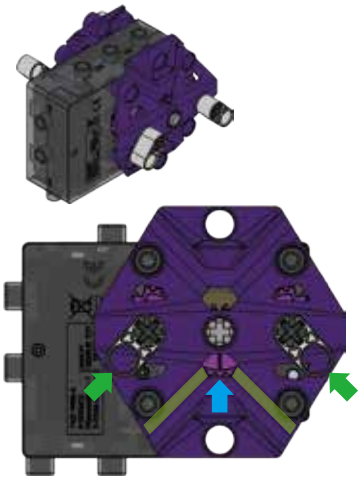


Important! Check both sides again.



The middle tooth of the middle gear is pointing straight up.

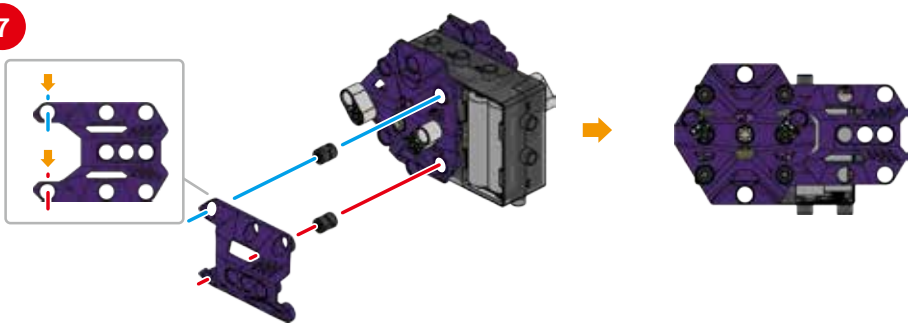
The 2-hole wide rounded rods are aligned with the green arrows as shown.



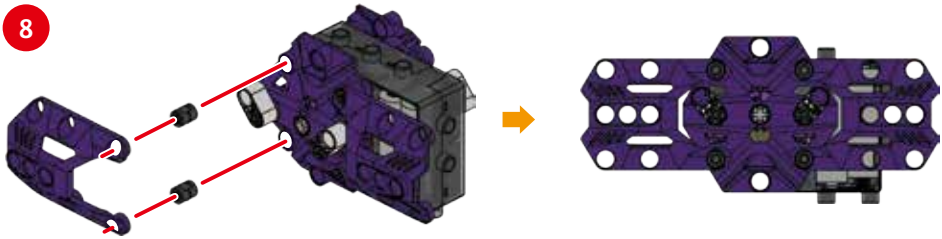
The middle tooth of the middle gear is pointing straight down.

The 2-hole wide rounded rods are aligned with the green arrows as shown.

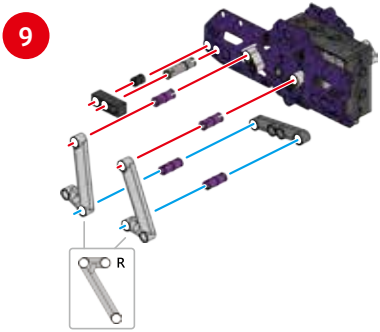
7



8



9



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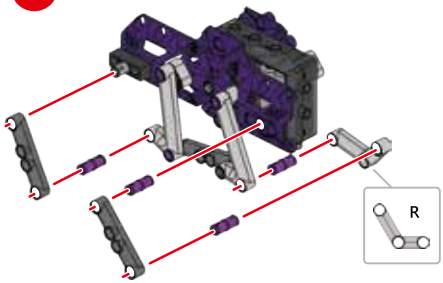
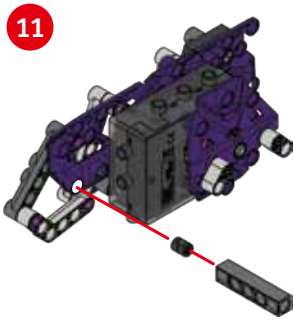
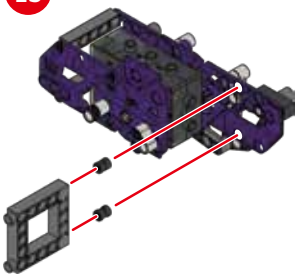


11



12

13



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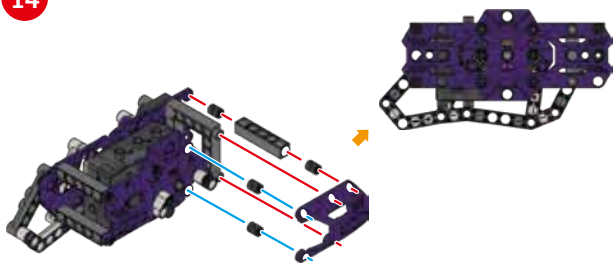
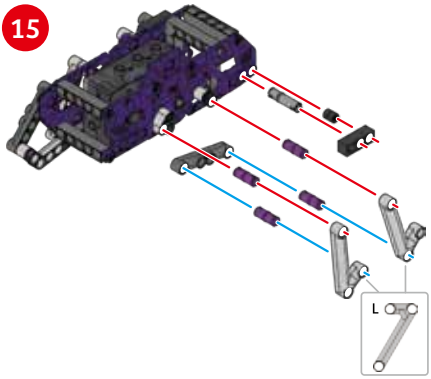


FAIRY SHRIMP BOT

15



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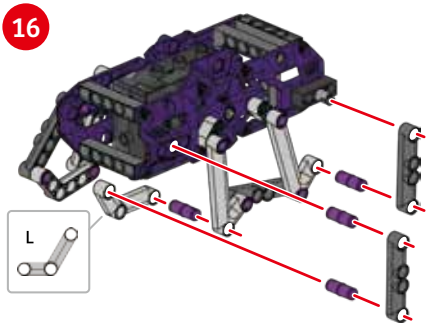

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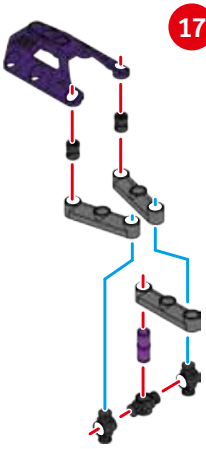

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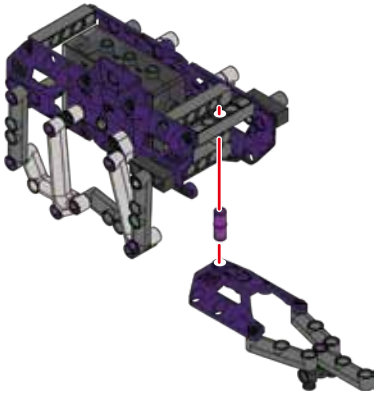

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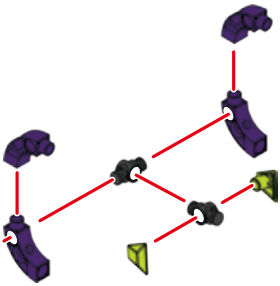

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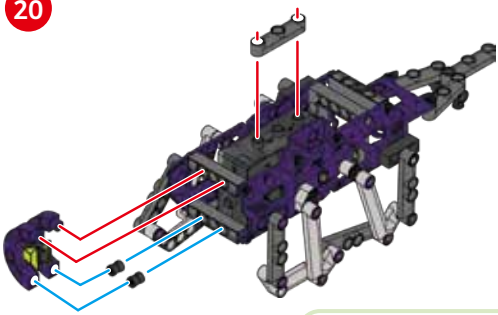

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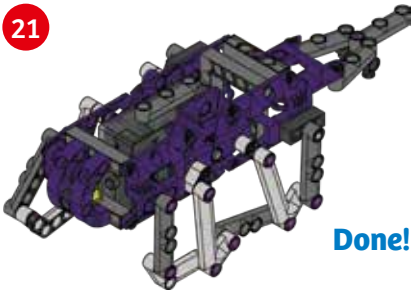
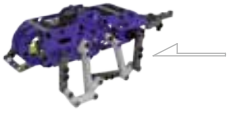


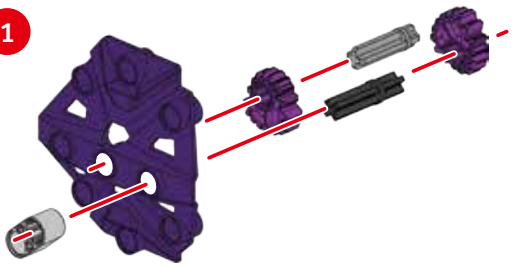
Done!



Switch the motor to turn clockwise for forward motion.

KANGAROOBOT

1



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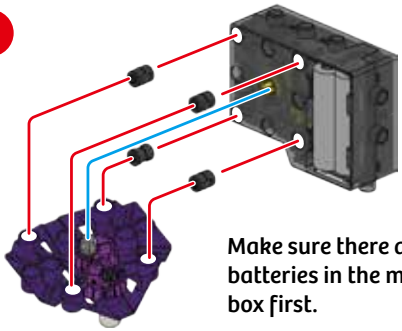


Make sure there are batteries in the motor box first.

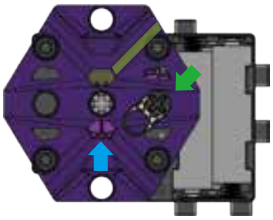
Important! Check the orientation:

1. The gears must mesh together.

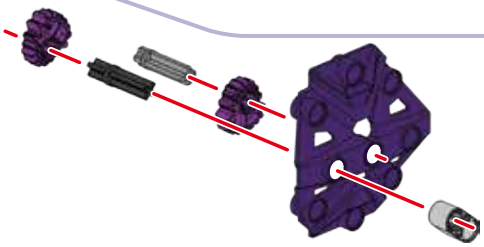
Turn one of the gears all the way around and make sure both gears turn smoothly.

2. The middle tooth of the gear in the center of the plate must be pointing straight down.

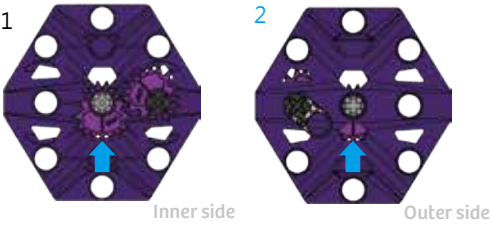
3



Align the 2-hole wide rounded rod with the green arrow as shown.



Important! Make sure the parts are oriented exactly as shown:



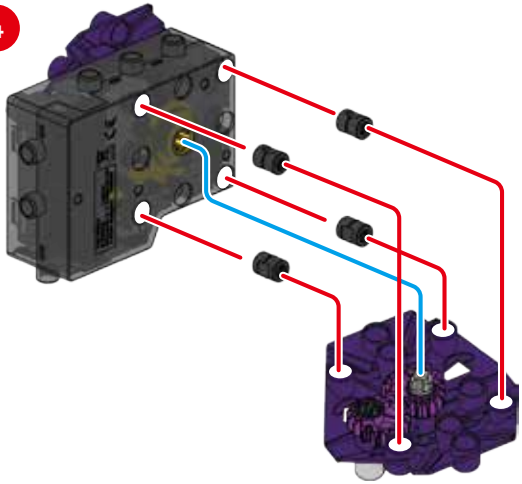
1. The gears must mesh together.

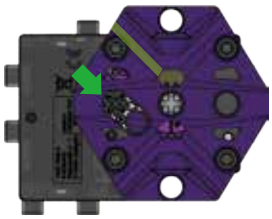
Turn one of the gears all the way around and make sure both gears turn smoothly.

2. The middle tooth of the gear in the center of the plate must be pointing straight down.

KANGAROOBOT

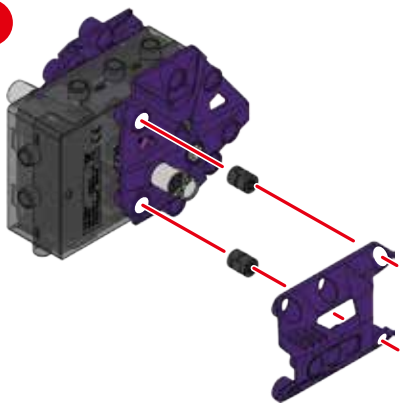
4





Align the 2-hole wide rounded rod with the green arrow as shown.

5



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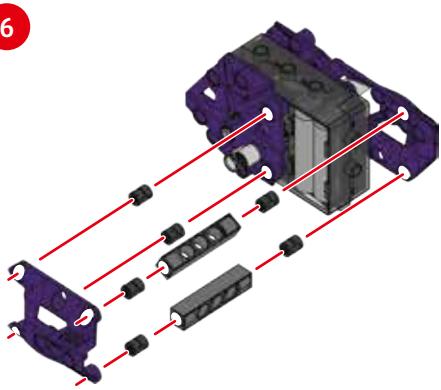

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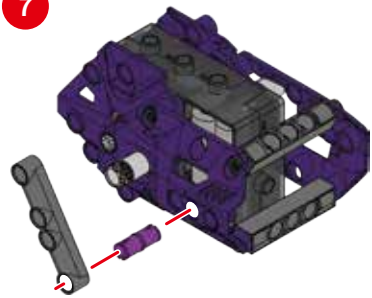

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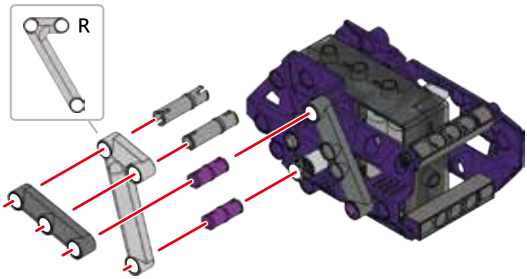

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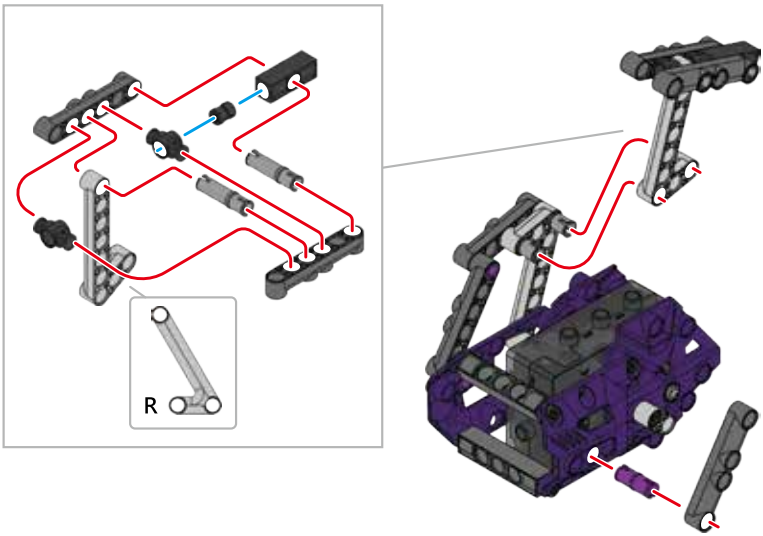

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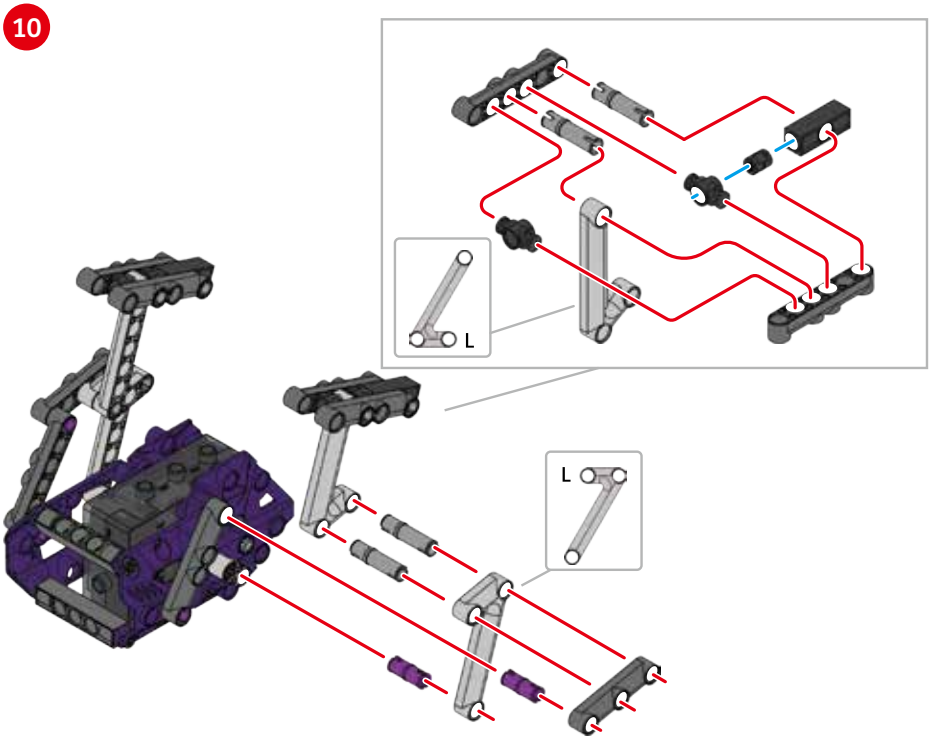
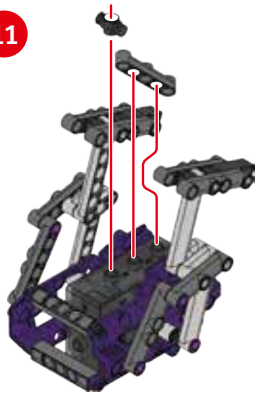


KANGAROOBOT

11



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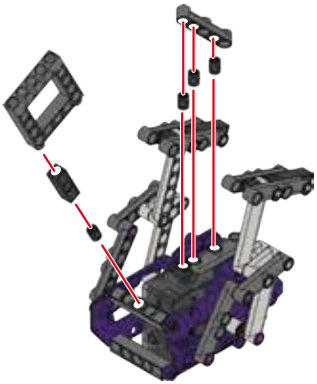

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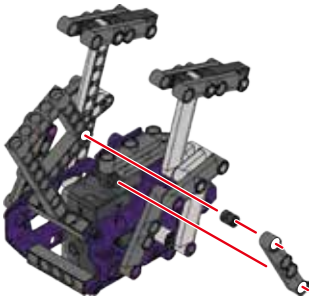

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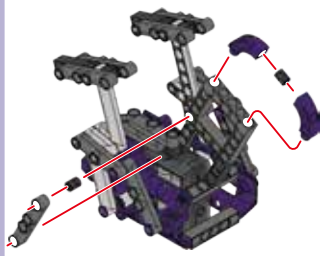

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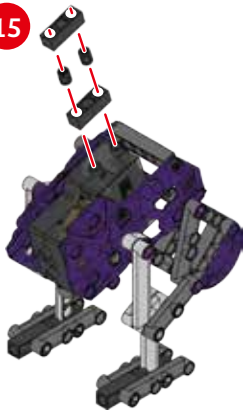

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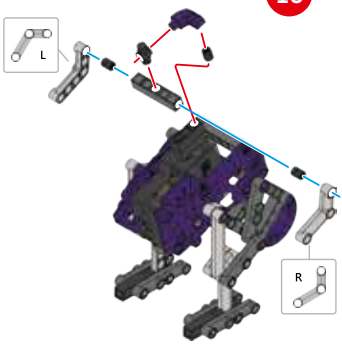

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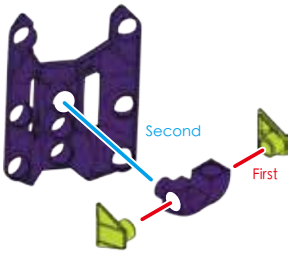

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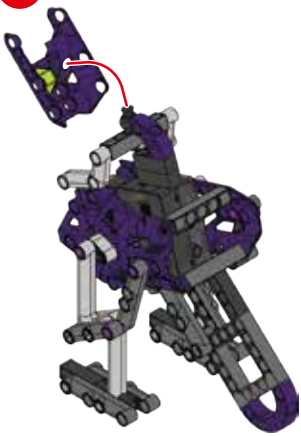
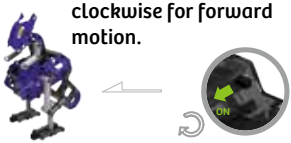


19

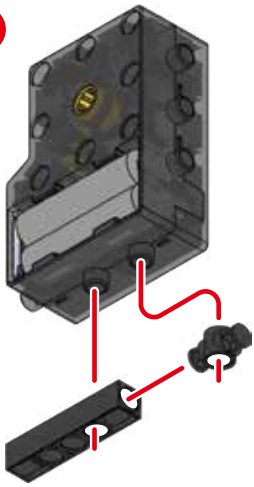
Done!

Switch the motor to turn clockwise for forward motion.



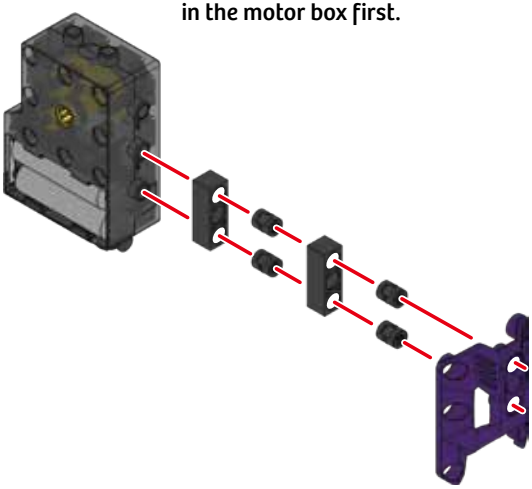
MONKEY BOT

1



2

Make sure there are batteries in the motor box first.



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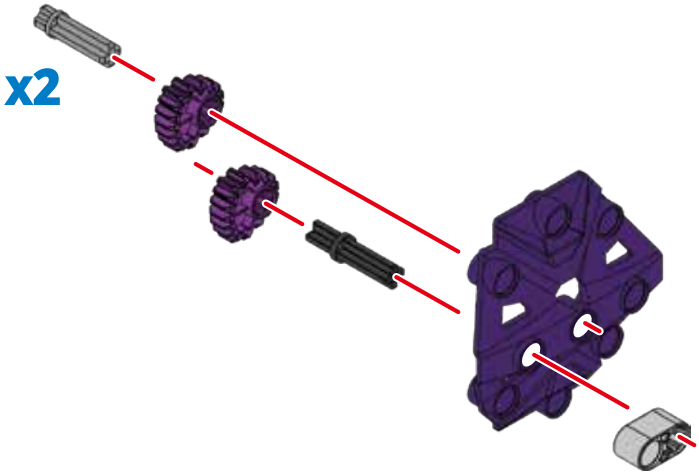
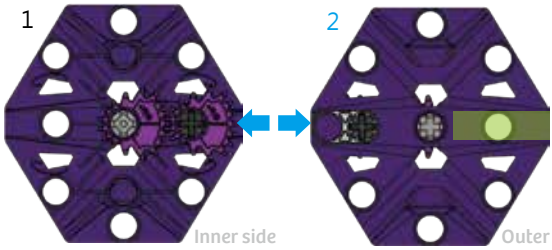


Important! Make sure the parts are oriented exactly as shown:



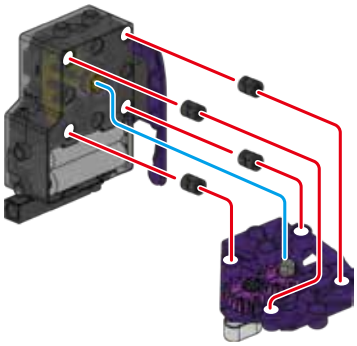
1. The gears must mesh together.

Turn one of the gears all the way around and make sure both gears turn smoothly.

2. The middle teeth of both gears must be pointing straight left/ right.

MONKEY BOT

4



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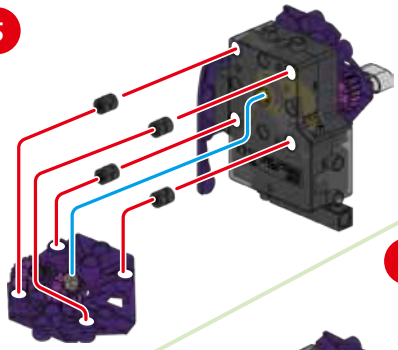

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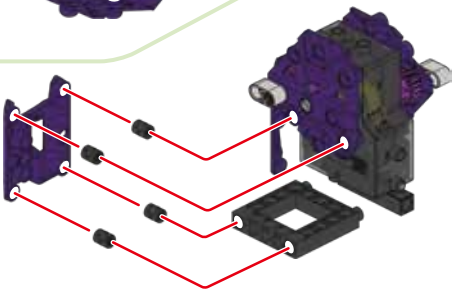
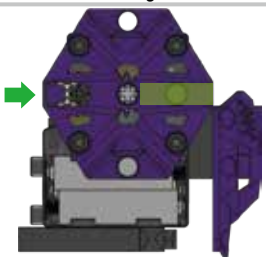
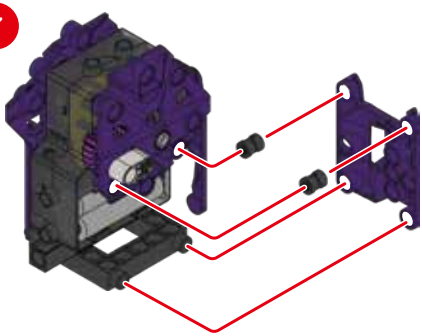


Important!
Check both sides again.



Align the 2-hole wide rounded rods with the green arrows as shown.

7



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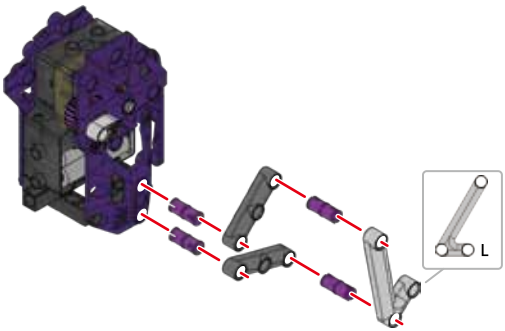
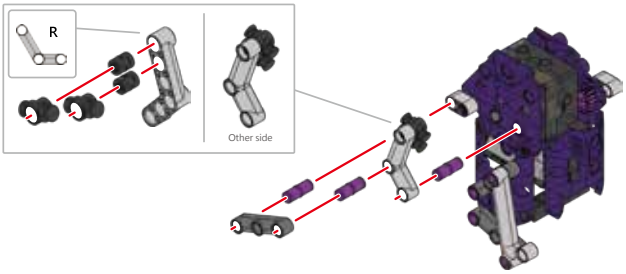


MONKEY BOT

9



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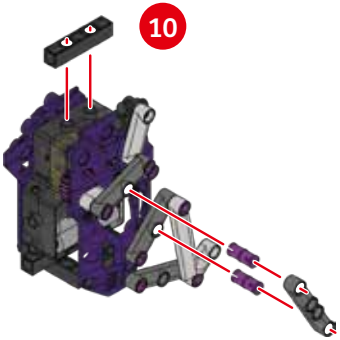

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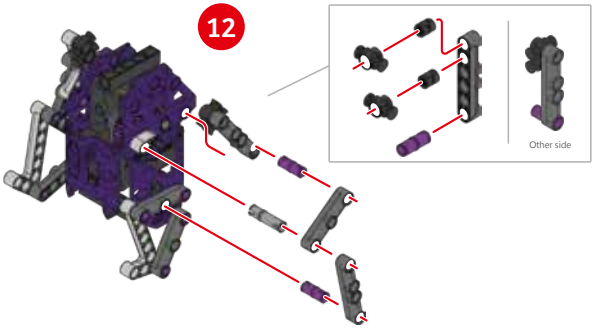

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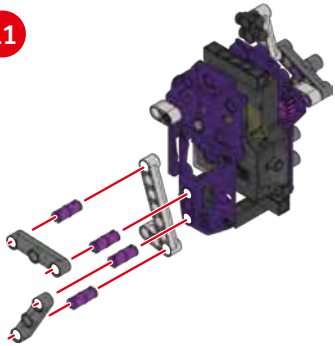

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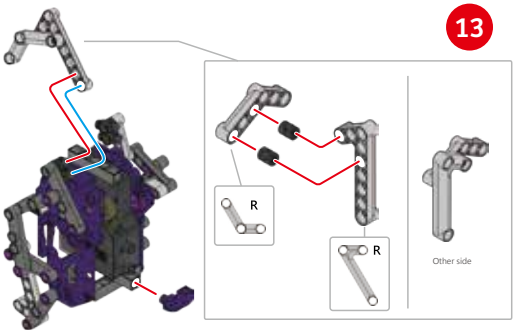

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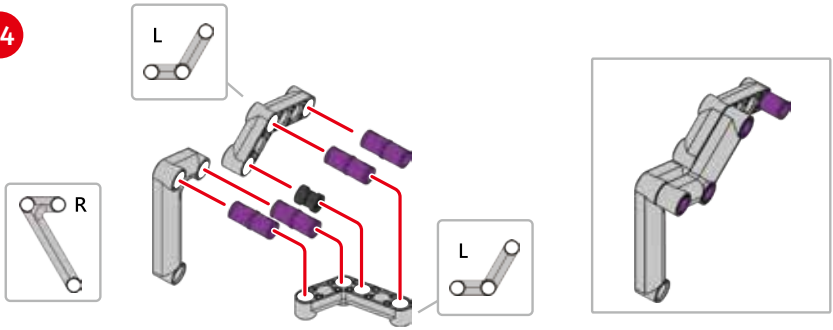
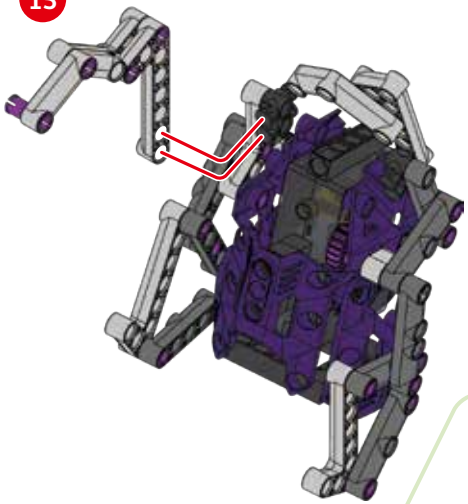


MONKEY BOT

15



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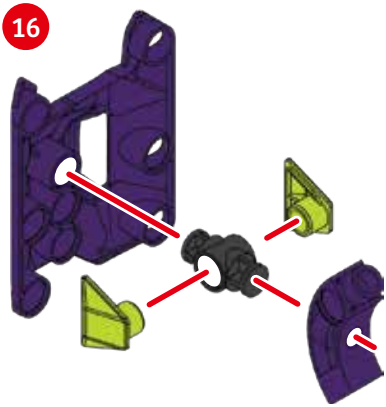

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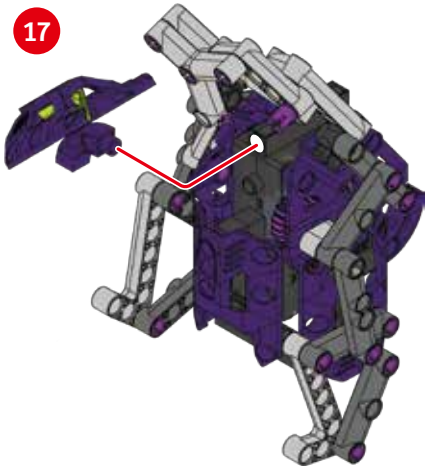
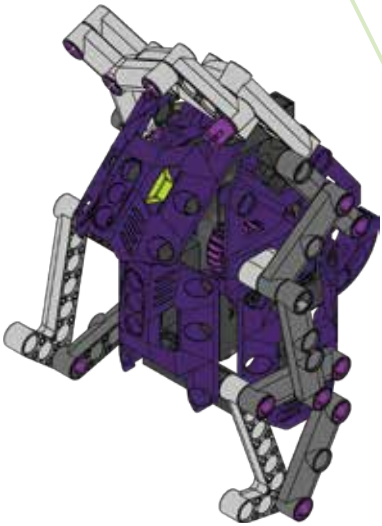
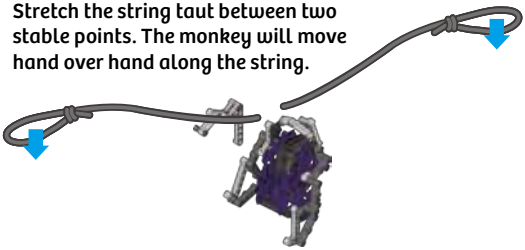


18

Done!



Stretch the string taut between two stable points. The monkey will move hand over hand along the string.



Switch the motor to turn counterclockwise for forward motion.

LINKAGES

All of the models in this kit make use of mechanisms called linkages.

A **linkage** is a mechanical assembly of rigid links (or rods) connected at movable joints. Picture the rigid rods in this kit linked together with the rotating joint pins: that is a linkage! Linkages can be open or closed chains, in which each link is connected to at least one other link. In open linkages, the end of a rod is not connected to another rod. In closed linkages, all of the rods' ends are connected to other rods.

Engineers use linkages to change the direction of a motion or change the size of a force. Applying a force on one part of a linkage produces a predictable resulting force at another part of a linkage. Linkages can be used in very clever ways to achieve exactly the direction and magnitude of force desired.

Linkages are often grouped by the number of rods: **two-bar, three-bar,** and **four-bar linkages** are common.

Four very common types of linkages are as follows. Try building these linkages with the pieces in your kit.

1. Reverse Motion Linkage: One rod moves in one direction when the other moves in the opposite direction.

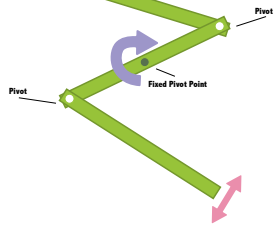
2. Parallel Motion Linkage: The rods move but at least two rods remain parallel to each other at all times.

3. Crank and Slider Linkage: A rod moves along a straight line in a slider.

4. Bell Crank Linkage: Horizontal movement is converted perpendicularly into vertical movement.

Make these linkages with your kit! Can you find all the linkages in the models you built?

1.



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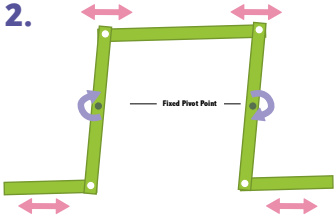

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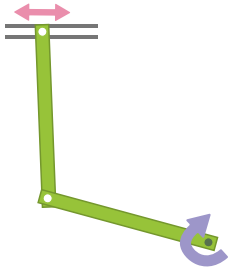
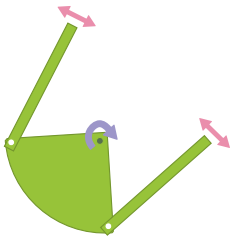


4.



››› **Did you know? A lever is a two-bar linkage!**

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