MECHANICAL ENGINEERING
ROBOTIC ARMS

EXPERIMENTS

7411

204 PCS

8+

6 MODELS TO BUILD

LEARN ABOUT HOW ROBOTIC MACHINES PERFORM WORK

››› TABLE OF CONTENTS

Safety Information

Warning! Not suitable for children under 3 years.
Choking hazard — small parts may be swallowed or inhaled.

**Strangulation hazard —
long tubes may become wrapped around the neck.**

Store the experiment material and assembled models out of the reach of small children.
Keep packaging and instructions as they contain important information.

Dear Parents and Supervising Adults,

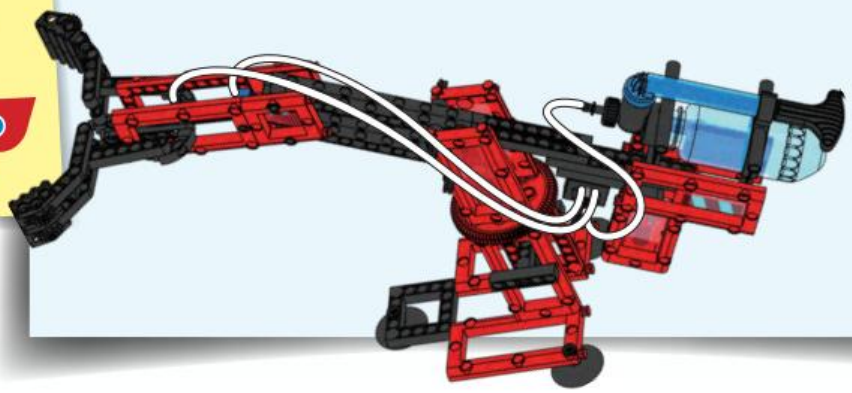
Before starting the experiments, read through the instruction manual together with your child and discuss the safety information. Check to make sure the models have been assembled correctly, and assist your child with the experiments.

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

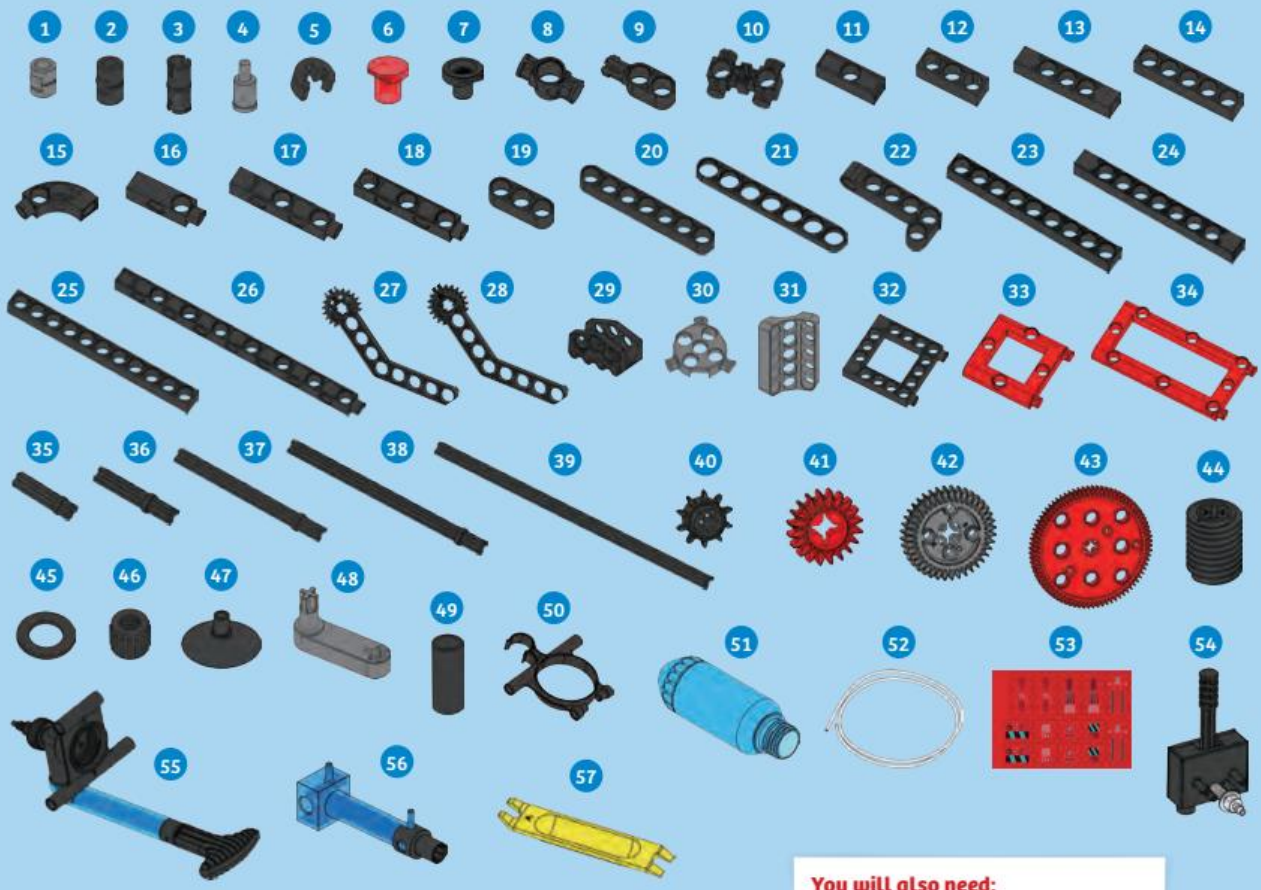
TIP!

At the top of each model assembly page, you will find a red bar:

››› It shows how difficult the model's assembly will be:



What's inside your experiment kit:



You will also need:
scissors, ruler or measuring tape

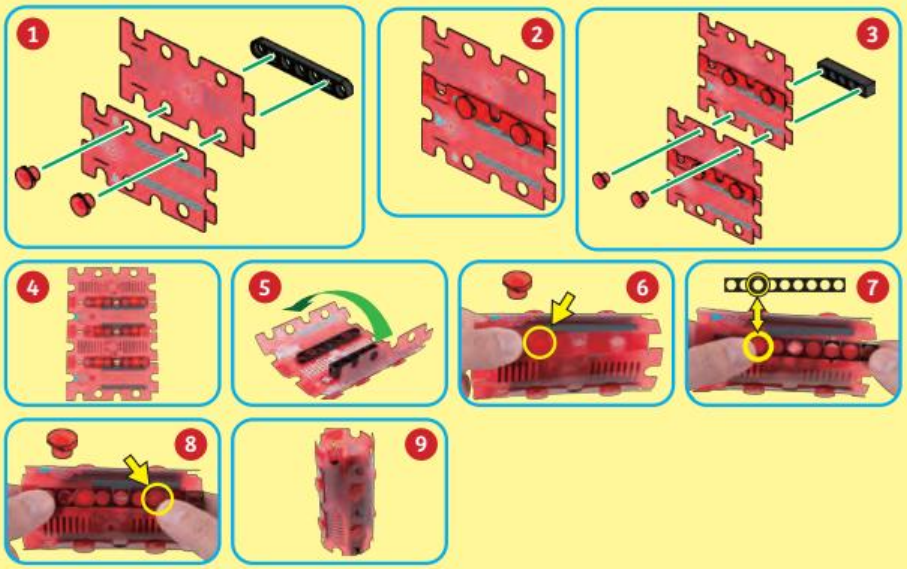
Checklist: Find – Inspect – Check off

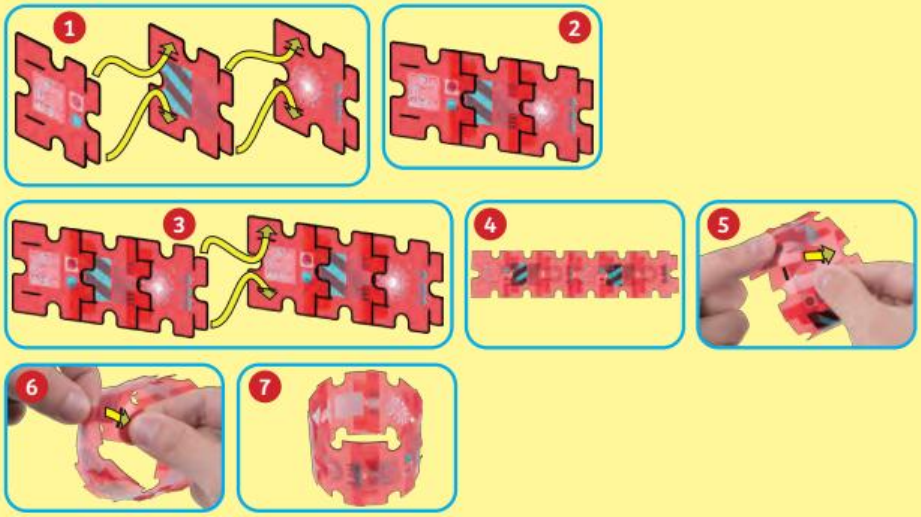
No.	Description	Qty.	Item No.
1	B-SHORT PEG	25	7344-W10-C2S
2	C-LONG PEG	26	7061-W10-C1D
3	C-AXLE CONNECTOR	13	1156-W10-A1D
4	C-CAM CONNECTOR	2	7026-W10-J3S
5	C-AXLE FIXING	7	3620-W10-A1D
6	C-LONG BUTTOM FIXER	16	7061-W10-W2TR
7	C-TUBE BOLT CAP	3	7409-W10-F2D
8	C-1 HOLE CONNECTOR	5	7430-W10-B1D
9	C-PNEUMATIC PISTON HANDLE	1	7411-W10-D3D
10	C-BOLT ROD WITH PINS	1	7406-W10-B1D
11	C-3 HOLE ROD FRONT CLOSED	4	7026-W10-X1D
12	C-3 HOLE ROD	1	7026-W10-Q2D
13	C-5 HOLE ROD FRONT CLOSED	1	7413-W10-K3D
14	C-5 HOLE ROD	4	7413-W10-K2D
15	C-BENDED ROD	2	7061-W10-V1D
16	C-3 HOLE DUAL ROD	2	7061-W10-R1D
17	C-5 HOLE DUAL ROD	2	7026-W10-S3D
18	C-5 HOLE DUAL ROD BOTTOM CLOSED	2	7026-W10-S2D
19	C-3 HOLE ROUND ROD	2	7404-W10-C1D
20	C-7 HOLE ROUND ROD	2	7404-W10-C2D
21	C-7 HOLE PROLATE ROD	2	7404-W10-C3D
22	C-5 HOLE L SHARP ROD	1	7406-W10-B2D
23	C-9 HOLE ROD	2	7407-W10-C1D
24	C-9 HOLE ROD FRONT CLOSED	2	7407-W10-C2D
25	C-11 HOLE ROD	3	7413-W10-P1D
26	C-15 HOLE DUAL ROD	5	7413-W10-H1D
27	C-145° CRANKSHAFT GEAR-A	2	7411-W10-C1D
28	C-145° CRANKSHAFT GEAR-B	2	7411-W10-C2D
29	C-GRIPPER	4	7411-W10-G1D

No.	Description	Qty.	Item No.
30	C-3-WAY ADAPTER	2	7411-W10-B1S
31	C-120° CONNECTOR	3	7411-W10-A1S
32	C-5x5 FRAME	1	7026-W10-T2D
33	C-5x5 ARCH FRAME	2	7411-W10-F1R
34	C-5x10 ARCH FRAME	12	7411-W10-E1R
35	C-MOTOR AXLE	3	7026-W10-L1D
36	C-35mm AXLE II	1	7413-W10-O1D
37	C-70mm AXLE II	2	7061-W10-Q1D
38	C-100mm AXLE II	4	7413-W10-L2D
39	C-150mm AXLE I	2	7026-W10-P1D
40	C-10T CHAIN GEAR	1	3569-W10-D2D
41	C-20T GEAR	2	7026-W10-D2R
42	C-40T GEAR	2	7346-W10-C1S
43	C-80T GEAR	1	7328-W10-G2R
44	C-WORM GEAR	3	7344-W10-A1D
45	C-OD15.8 FLAT O-RING	1	R12-05
46	C-S SECURITY NUT	1	1156-W10-J1D
47	C-SUCTION CUP	3	R12-25
48	C-CRANK	2	7063-W10-B1S1
49	C-OD8x20mm TUBE	4	7400-W10-G2D
50	C-FRONT FIXING RIM	1	7389-W10-B2D
51	C-PLASTIC BOTTLE	1	7389-W11-A1B
52	C-1200mm TUBE	1	1155-W85-120
53	P-DIE CUT PLASTIC SHEET	1	K41#7411
54	C-SECURED REVERSE SWITCH	1	1155-W85-I4DN
55	C-LITTLE AIR WATER SET	1	7389-W85-A1D
56	C-PNEUMATIC PISTON CYLINDER	1	7411-W85-A
57	B-PEG REMOVER	1	7061-W10-B1Y

Making the test objects

You can make these objects and use them to test your robotic arms. Trying picking these objects up with each robotic arm.





Cutting the tube to length

You must cut the 1200-mm tube into these lengths. The specific lengths needed for each model are indicated in the assembly instructions for each model. You can also write the lengths on the tubes with a pen so they are easier to tell apart.

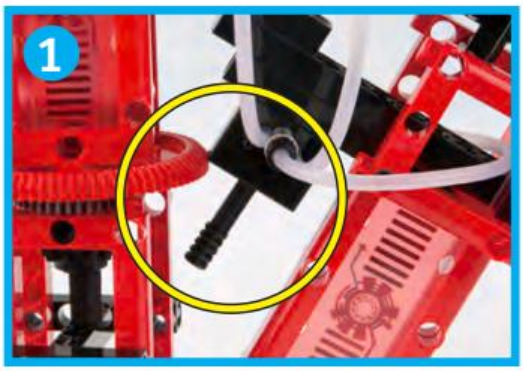
450 mm x 2 **300 mm x 1**

Tips for operating the little air water set

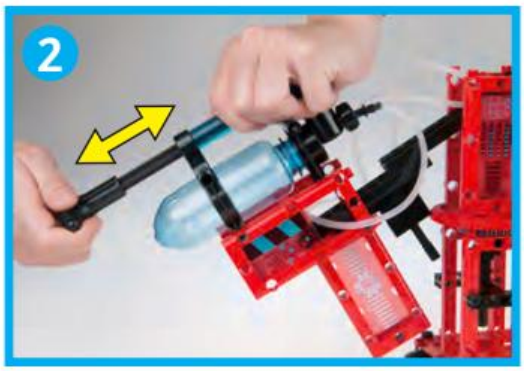
To operate all the models, you must pump up the plastic bottle. Always set the switch lever to the center position before pumping, so the air pressure builds up in the plastic bottle. Pump the little air water set 30-40 times. To operate the models, move the switch lever to one side or the other. For some models, it is easier if you remove the little air water set and plastic bottle first and then reattach them to operate the model. Pumping 30 times can operate model 10 -15 times. The carbon rod inside the little air water set can withstand the maximum bending force of 4 kg. (8.8 lb.).

General instructions for using the pneumatic system

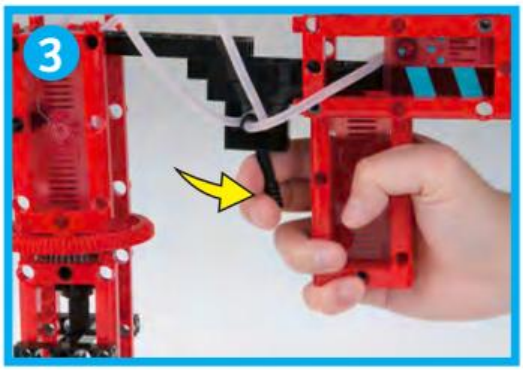
After following the step-by-step instructions to build one of the models (starting on page 6), follow these general instructions to operate the pneumatic system in the model. Each model works a little differently. There are specific instructions for using each model at the end of each set of assembly instructions. See page 25 for an explanation of how the pneumatic system works.



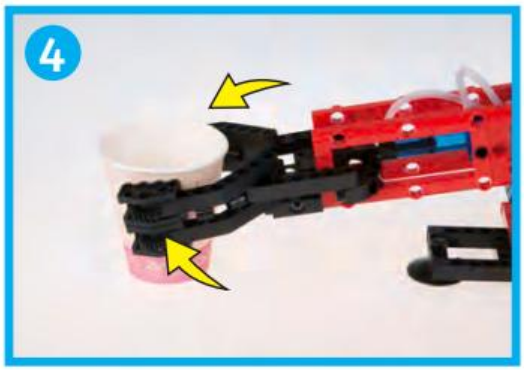
Put the switch lever in the center position.



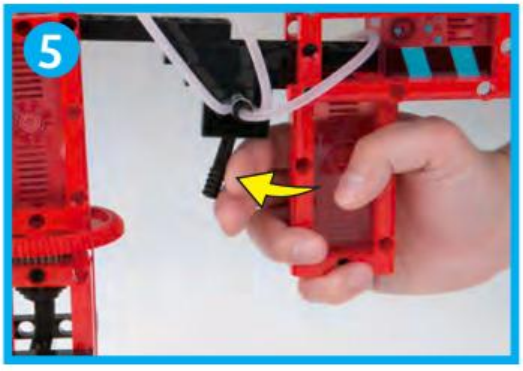
Pump about 30 times to fill the plastic bottle.



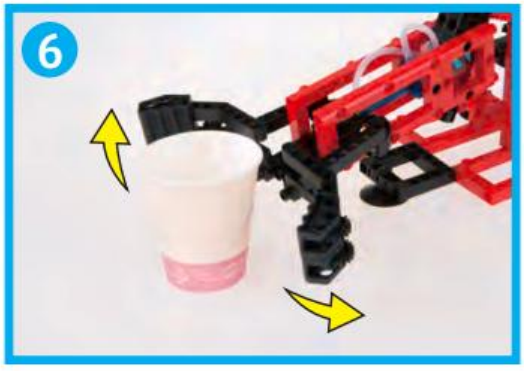
Depending on the model, you will need to push or pull the switch lever to operate the device in one direction.



For example, here the gripper closes when you pull the lever.



Again, depending on the model, you will need to push or pull the switch lever to operate the device in the other direction.



In this example, the gripper opens when you push the lever.

CHECK IT OUT

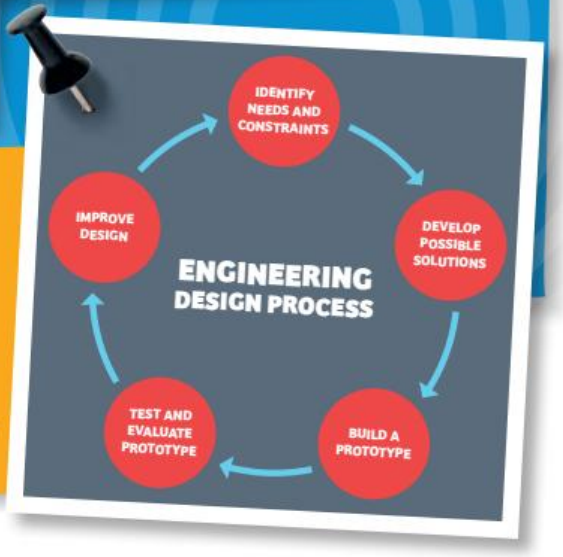
What Is a Robotic Arm?

A robotic arm is a machine that may look and function somewhat like a human arm, but is able to perform tasks with greater strength, accuracy, and speed, or perform tasks that are too dangerous for a human. Robotic arms are one of the most common types of robots used in manufacturing.

A robotic arm is a combination of mechanical, electrical, and computer systems. This kit focuses on the mechanical portion of designing robotic arms, which is the expertise of mechanical engineers. Engineers apply physical laws and empirical knowledge to build complex systems. Empirical knowledge is simply information you learn by observing the results of experiments and observing occurrences in the world around you. Mechanical engineers focus on the design, construction, and operation of machines.

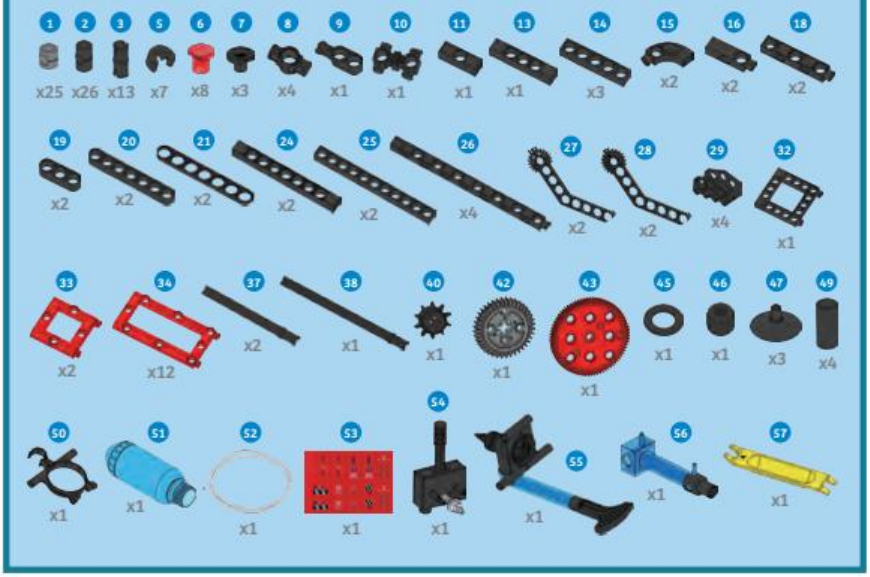
WHAT IS DESIGN?

Engineers often use the word "design" to describe what they do. Design is a sequence of steps that are used to take an idea from concept to functioning product or process. The engineering design process is iterative, meaning steps can be repeated multiple times and then improvements can be made each time, until the correct or optimal outcome is achieved.

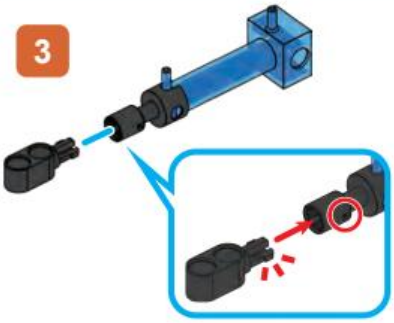


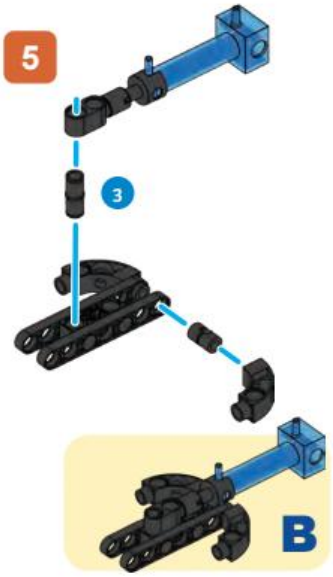
Model 1 Pivoting Robotic Arm

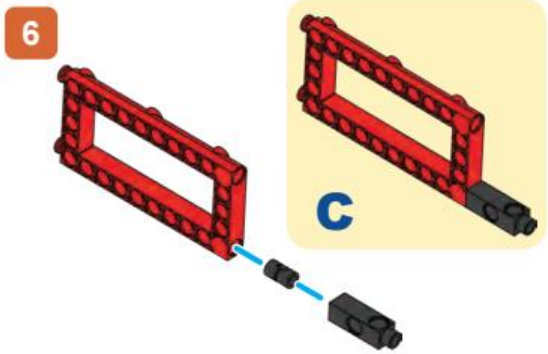
Parts Needed

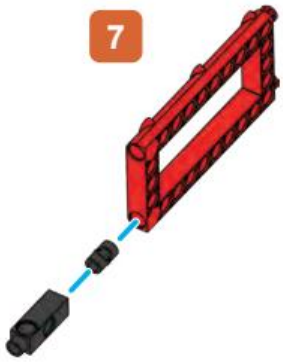


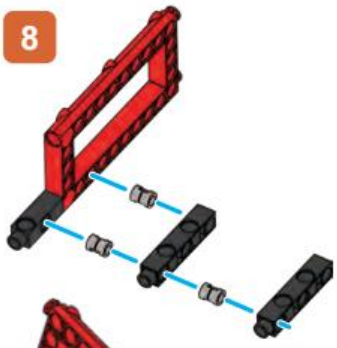
Repeat steps 1 and 2 four times.

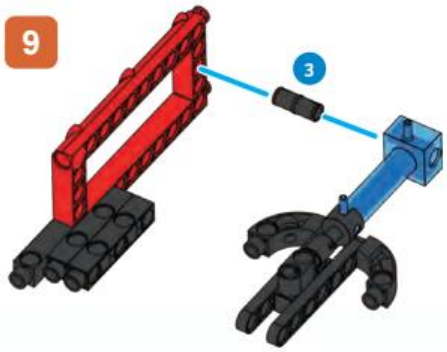


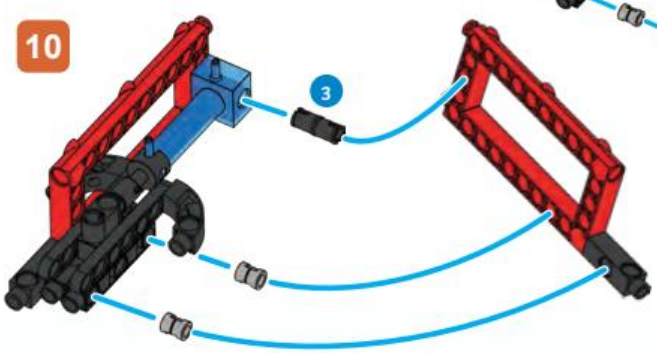




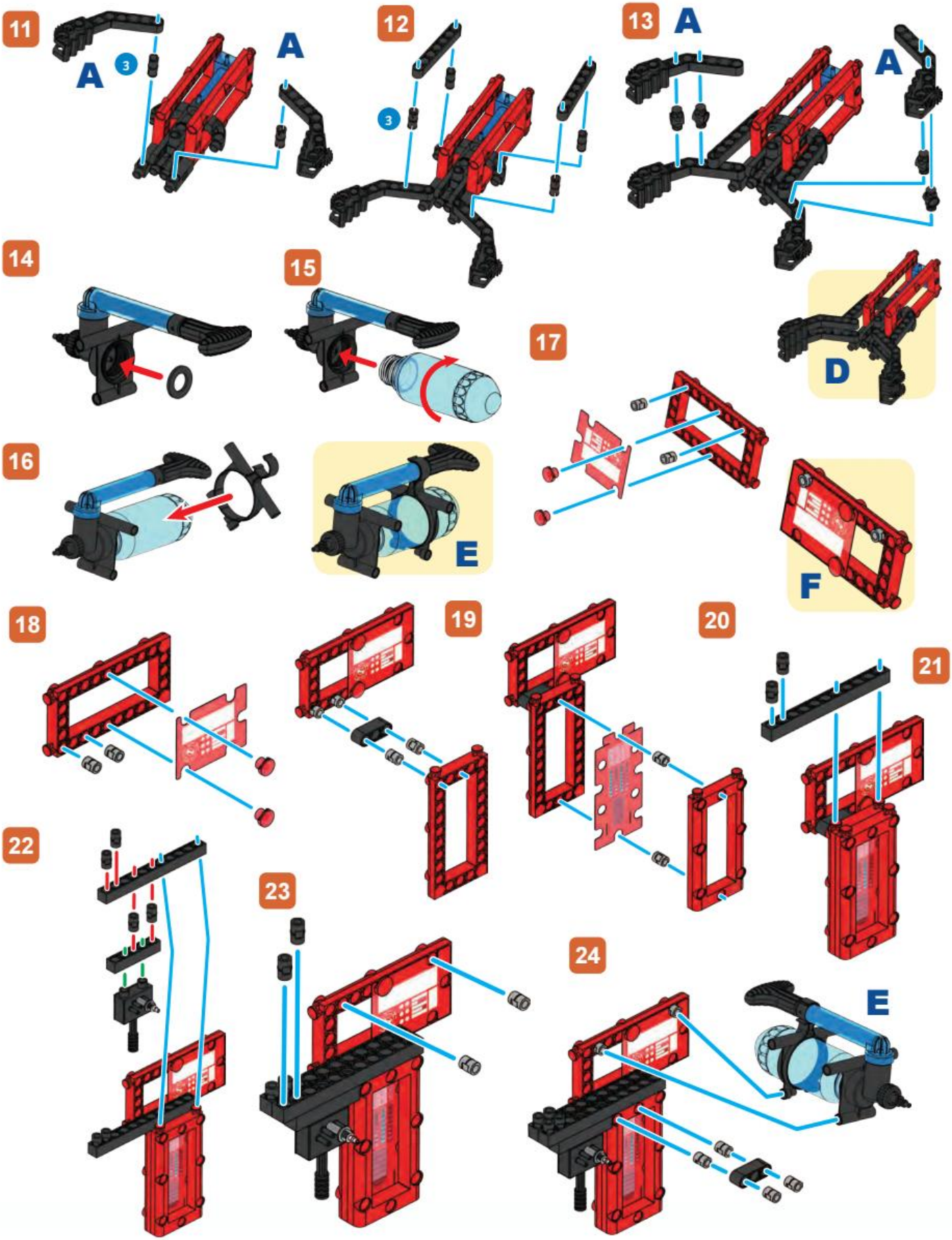








Pivoting Robotic Arm Model 1



Model 1 Pivoting Robotic Arm

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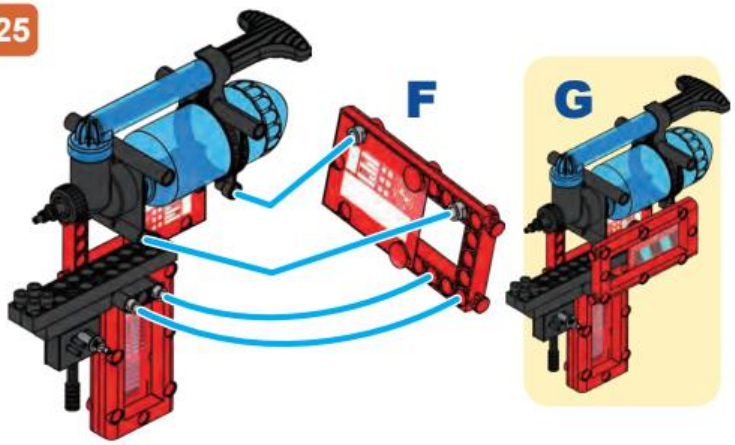

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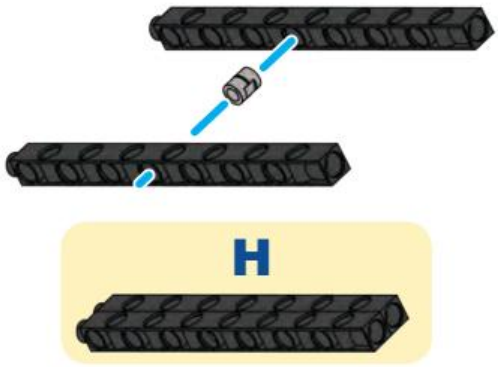

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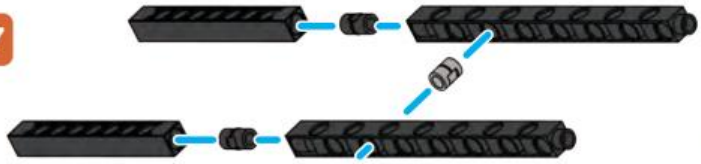

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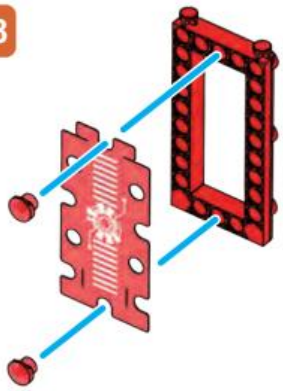

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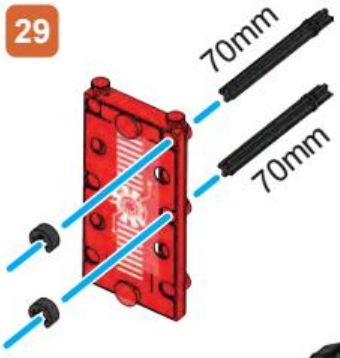

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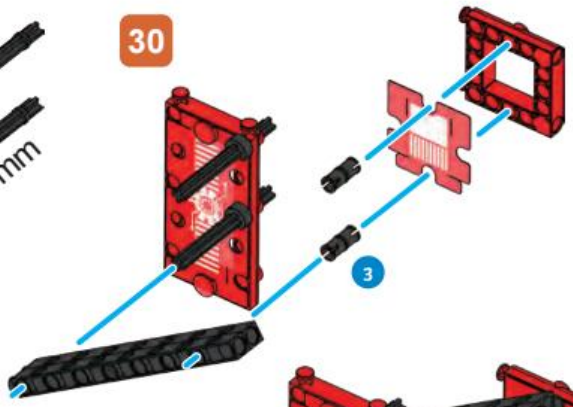

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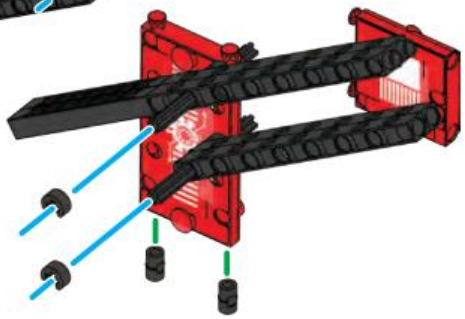

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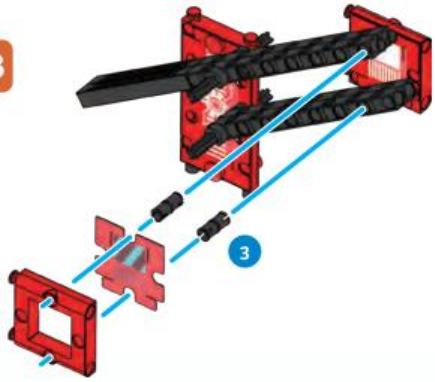

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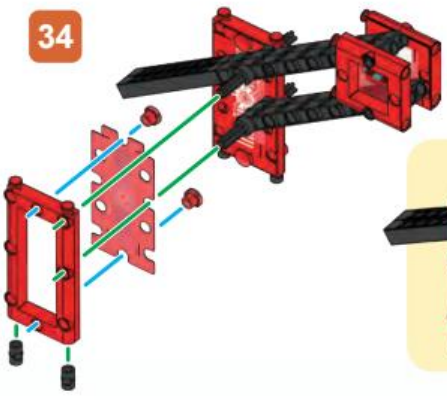
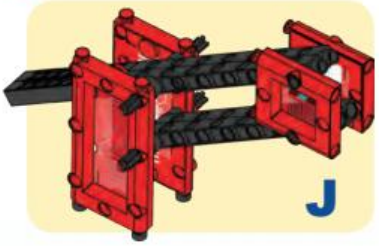
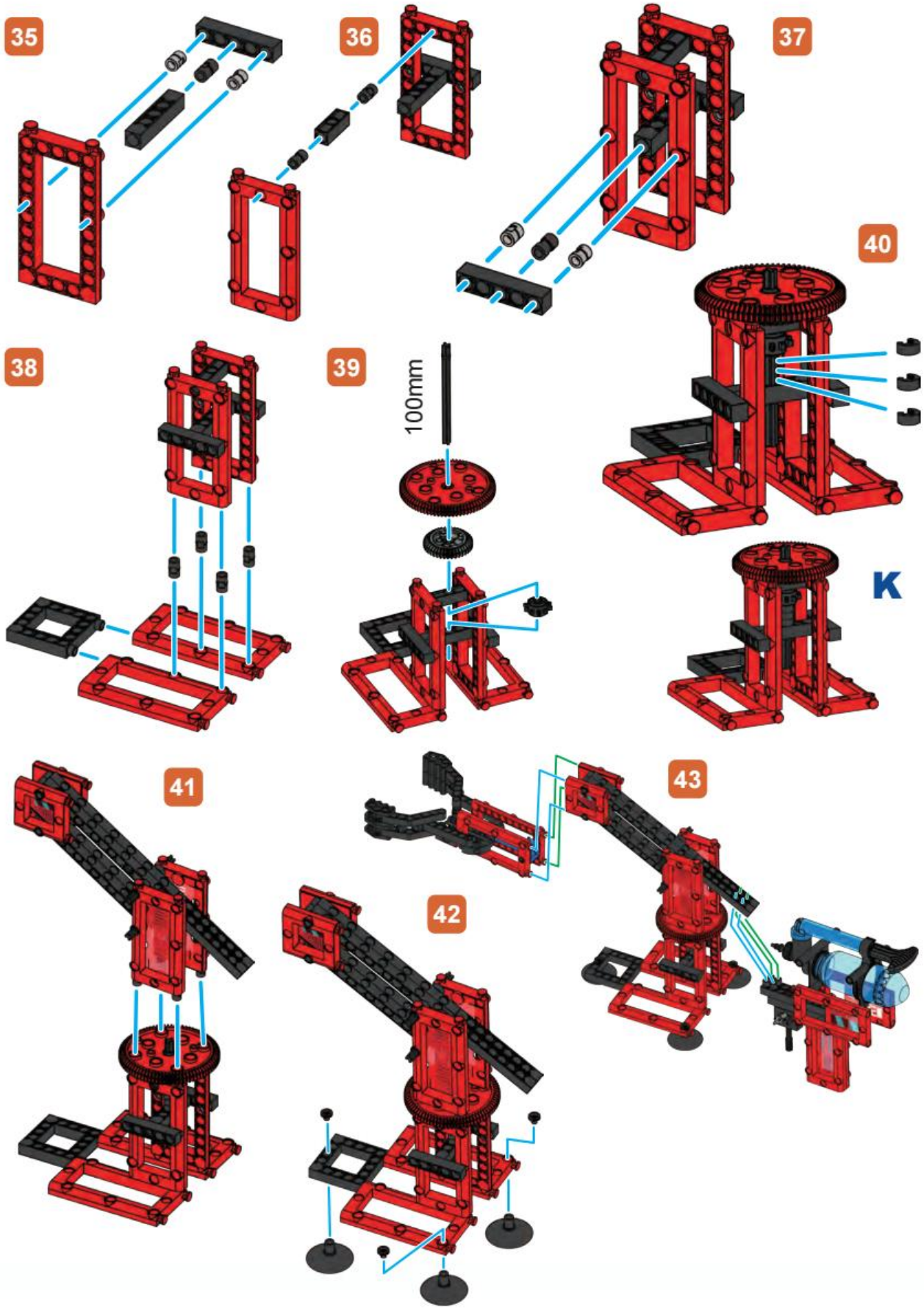




Pivoting Robotic Arm Model 1



Model 1 Pivoting Robotic Arm

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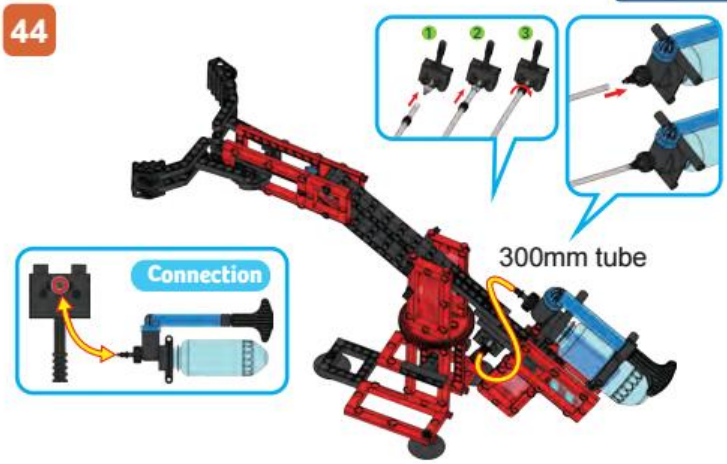

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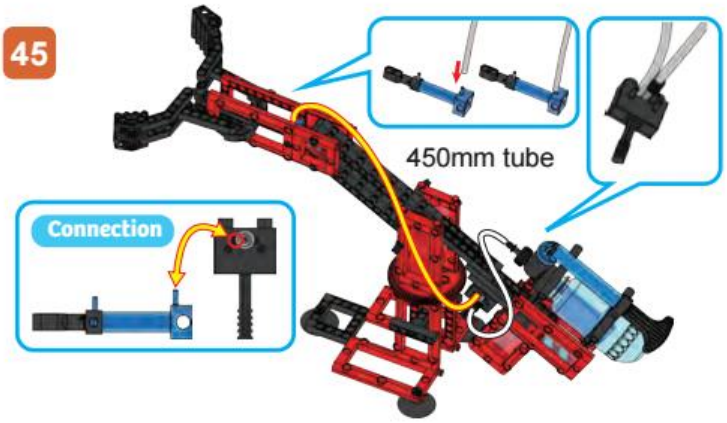

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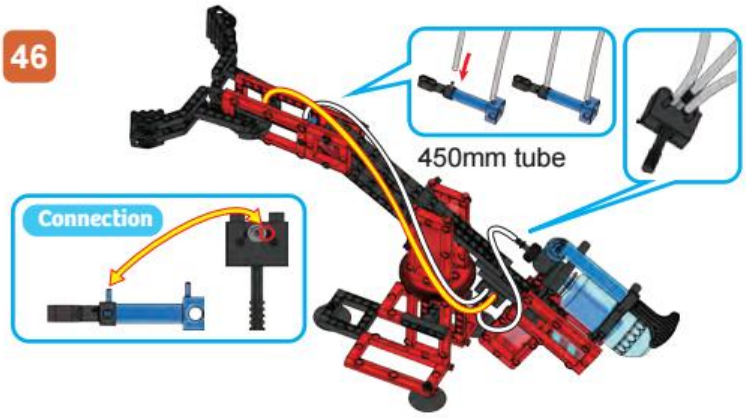

HOW TO USE

Put the switch lever in the center position.

Pump about 30 times to fill the plastic bottle.

The gripper will close when you pull the switch lever.

Rotate the handle to move the gripper.

The gripper will open when you push the switch lever.

EXPERIMENT 1

Can you move it?

HERE'S HOW

Place a cylinder in front of the pivoting robotic arm. Use the robot arm to move the cylinder from one location to another using two different paths. What positions can the pivoting robotic arm not reach?

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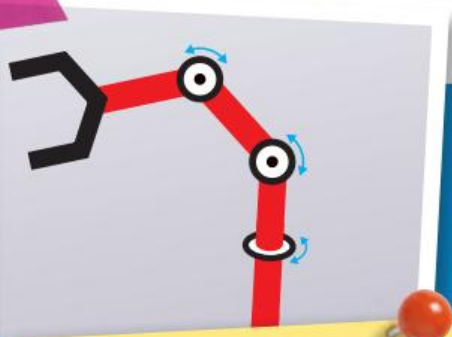
Done!

CHECK IT OUT

LINKS AND JOINTS

In engineering, it is often necessary to create simplified models of structures or systems in order to better understand their physical characteristics or behaviors. When simplifying a robotic arm to better understand it, the mechanical parts can be thought of as either links or joints. **Links** are the rigid structural elements of the robotic arm. In this kit, this includes the frames and rods. The **joints** are the pieces that allow for movement, such as the axle connector, axle fixing, gears, and pneumatic piston cylinder in this kit. Joints allow a link to move by either rotation or translation (moving from one point in space to another).



Together, links and joints form what is called a **kinematic chain.** The word "kinematic" refers to how objects move. In a robotic arm, the links in the kinematic chain are constrained by their connection points to the other links — like how your elbow is constrained by the range of motion of your shoulder. To understand how a robotic arm can move as a whole, you can look about how each element in the kinematic chain can move.

Often the end of the robotic arm, called the **end effector**, is designed separately from the rest of the arm. It is designed to interact with objects in its environment, like a human hand, but for specialized tasks such as welding, gripping, spinning, applying materials, and so on.

MOVEMENT THROUGH SPACE

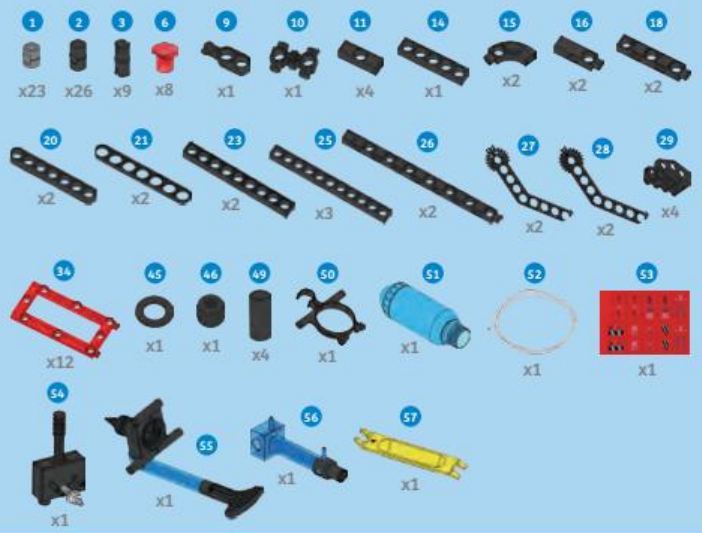
Unlike a human arm, a robotic arm can have a lot more freedom to move through space in different ways. The movement of a robotic arm can be described by the term **"degrees of freedom."** The position and orientation of an object in space can be given by three components of movement in the x, y, and z directions, and three components of rotation around those axes. For a single object in space, there are at most six degrees of freedom.

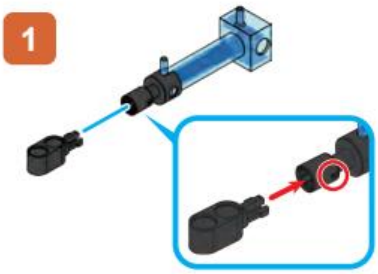
Each joint in a robotic arm has a certain number of degrees of freedom, which might be less than the maximum number of six. For example, not all of the pivoting robotic arm's joints can rotate 360 degrees.

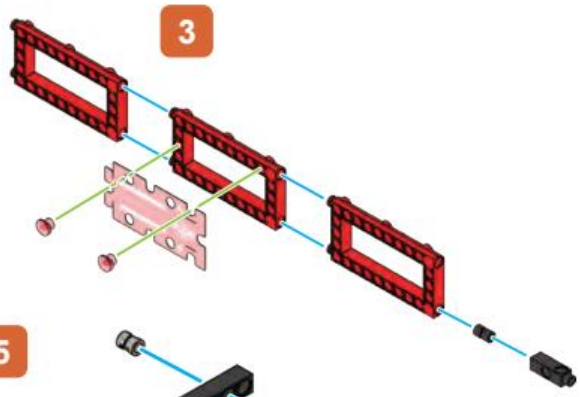
The area defined by all of the positions in space that the end of the robotic arm can reach is known as the **workspace.** If the object that the robotic arm needs to pick up is not in the workspace, the robot cannot pick it up! The workspace depends on the degrees of freedom, limitations of the joints, lengths of the linkages, and the angles at which the object must be picked up.

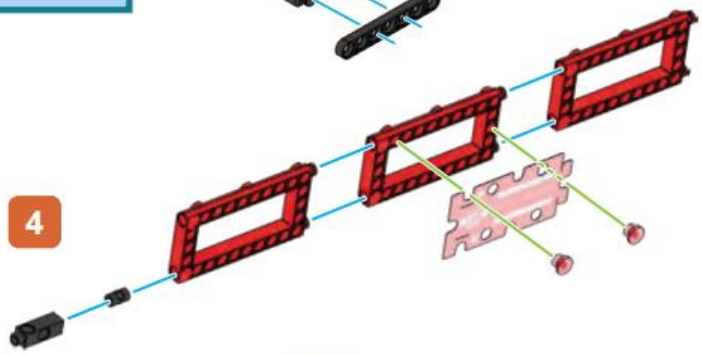
Model 2 Robotic Grabber

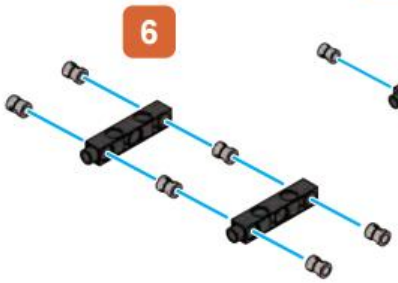
Parts Needed

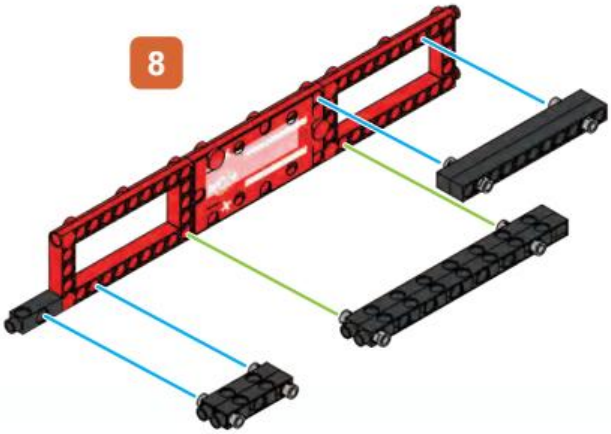


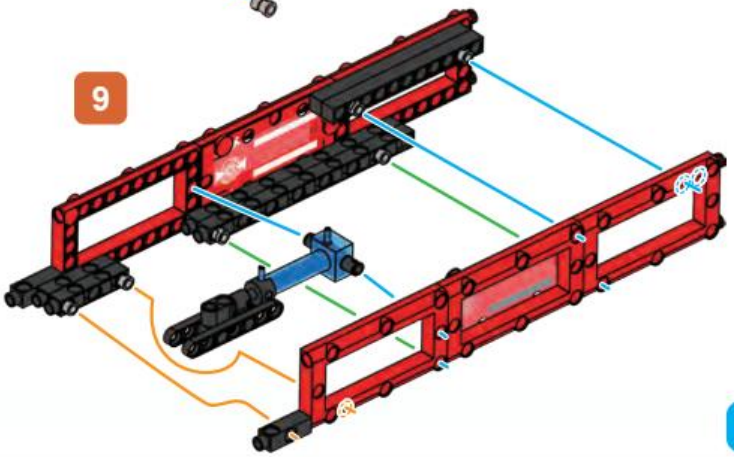




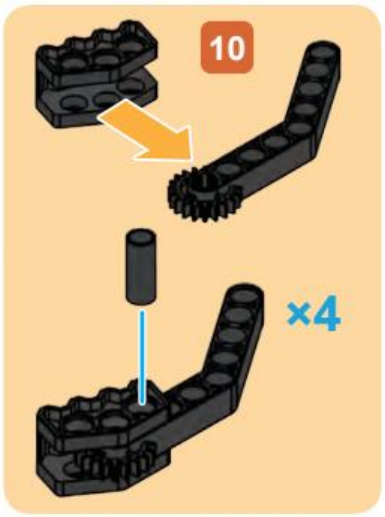


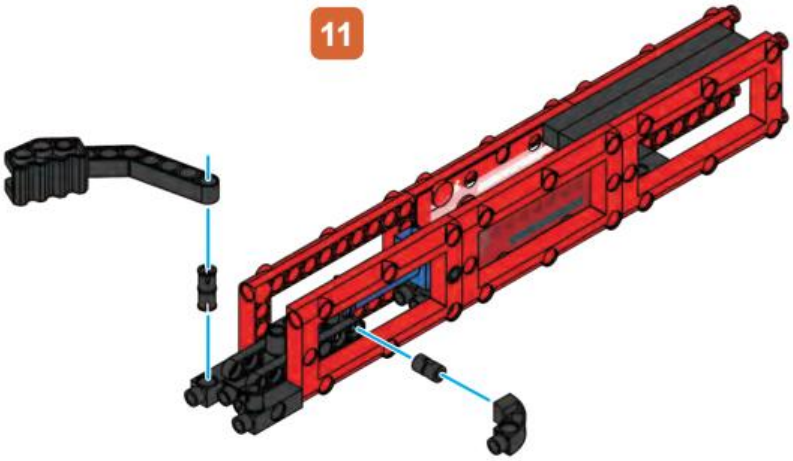


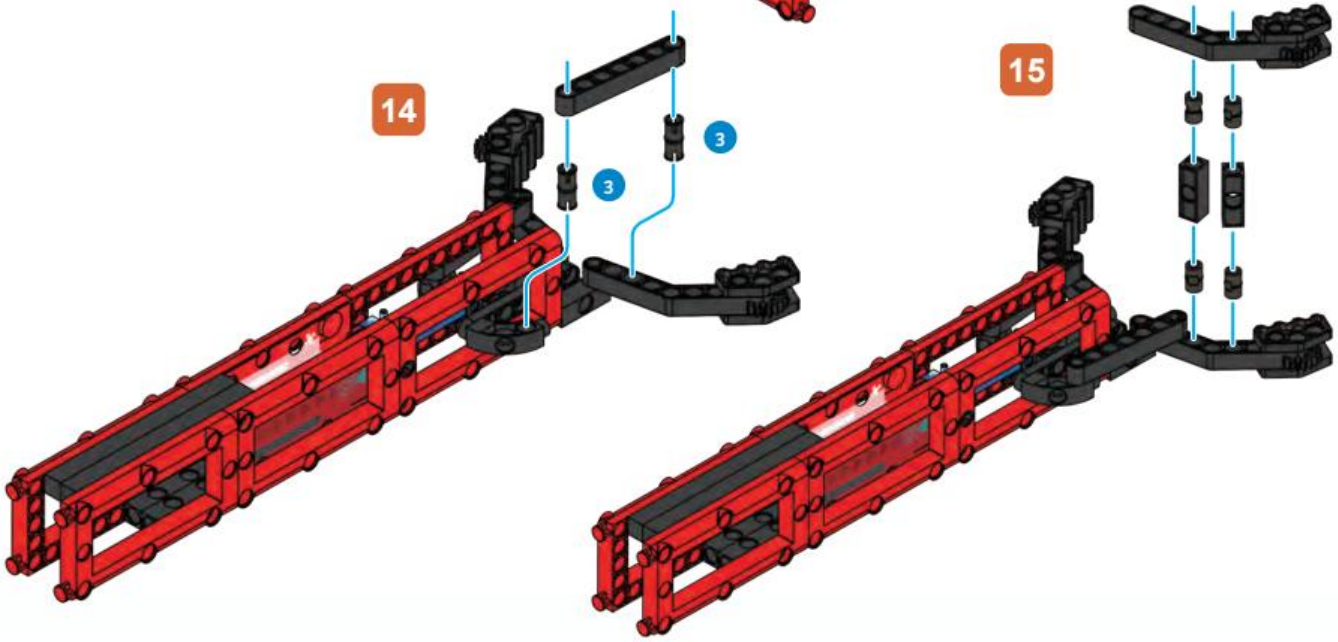




Robotic Grabber Model 2







Model 2 Robotic Grabber

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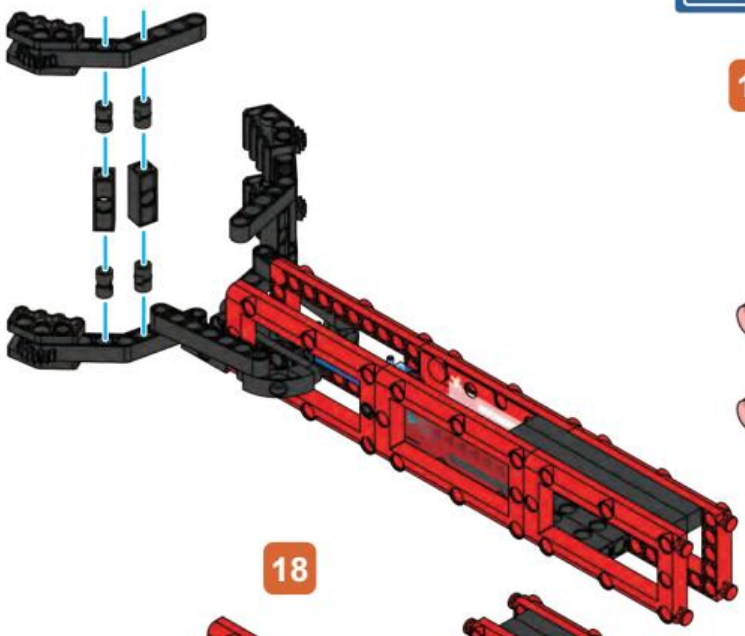

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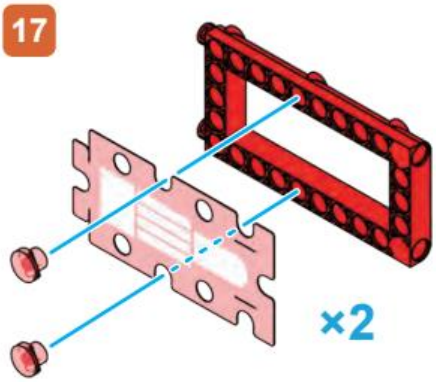

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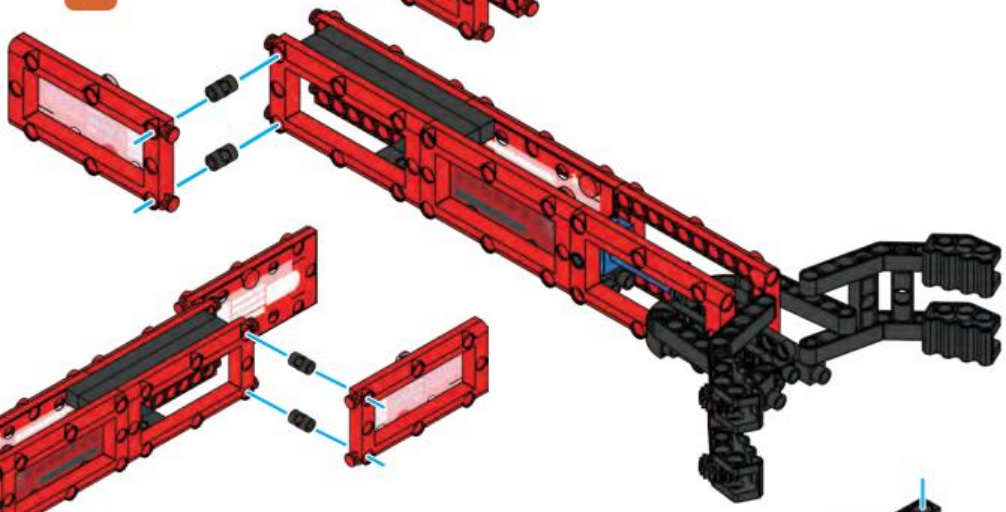

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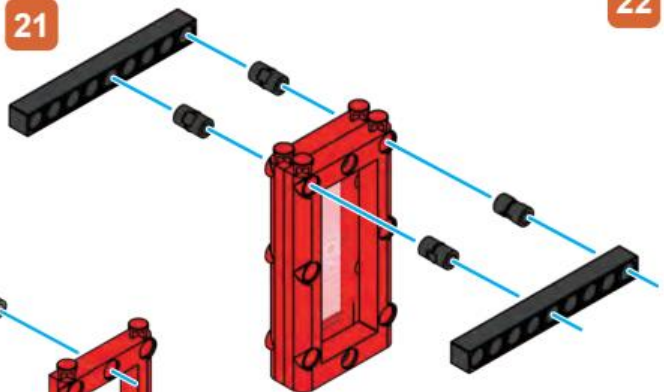

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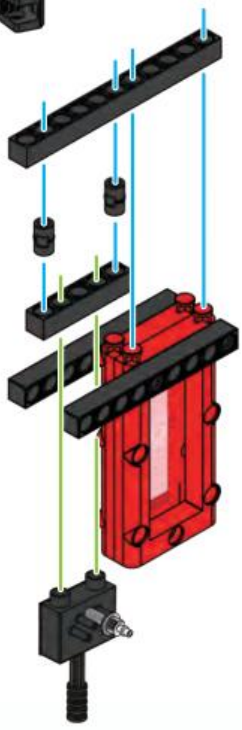

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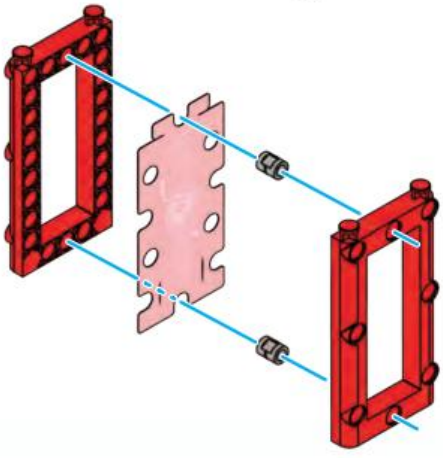
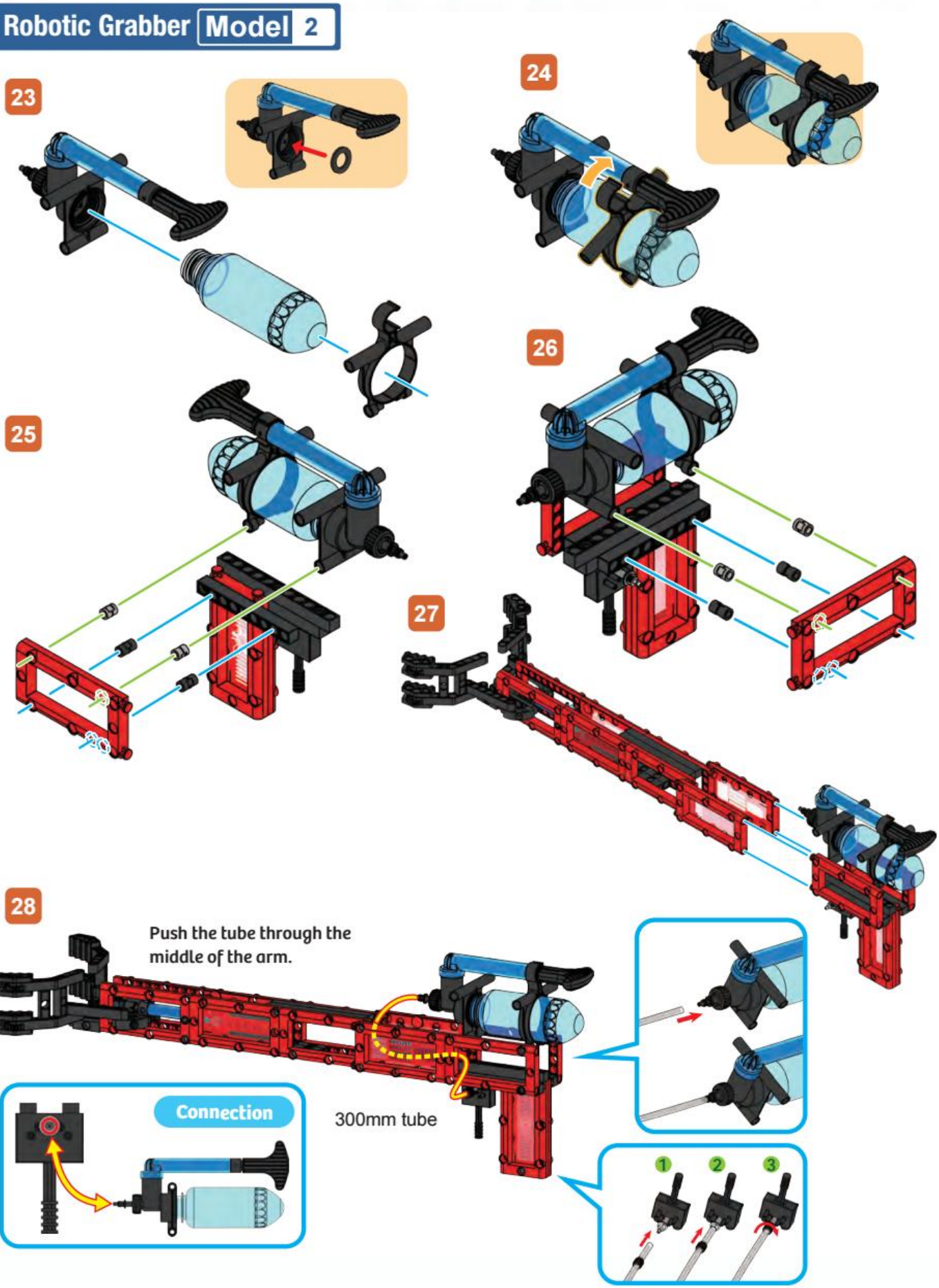
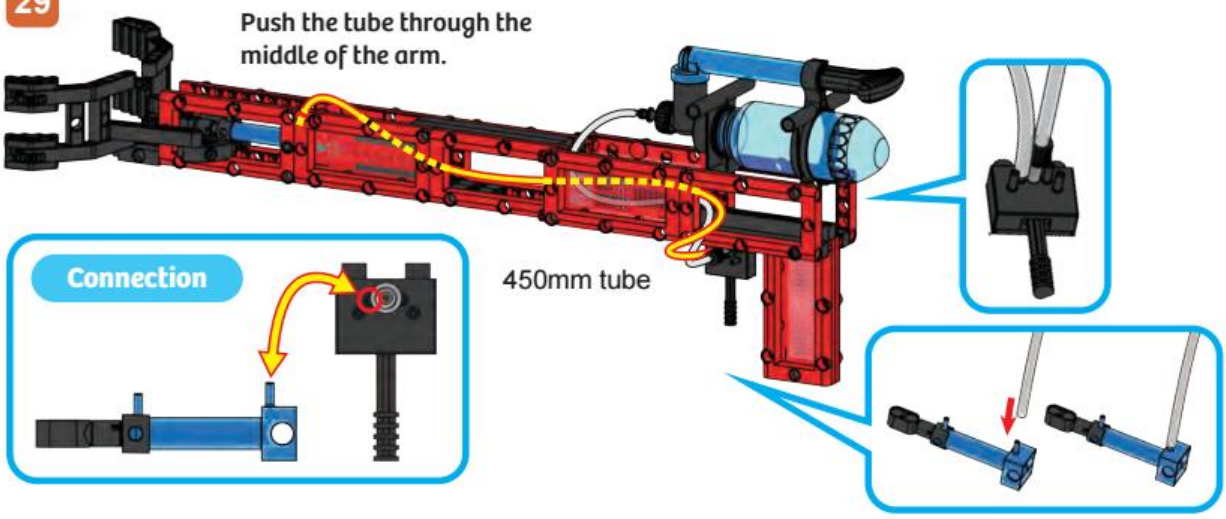


Robotic Grabber Model 2

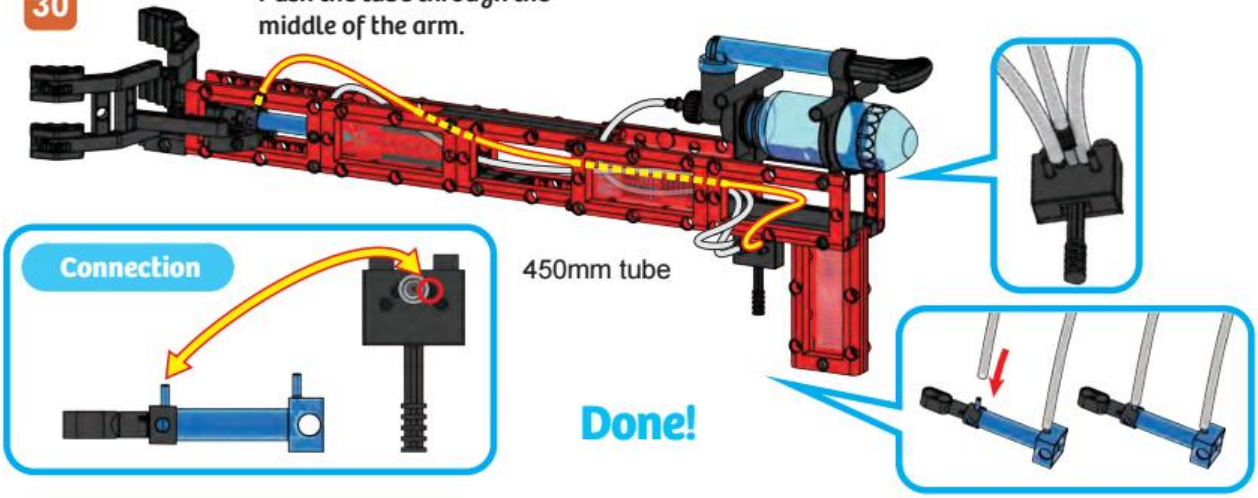


Model 2 Robotic Grabber

29 Push the tube through the middle of the arm.



30 Push the tube through the middle of the arm.



Done!

EXPERIMENT 2

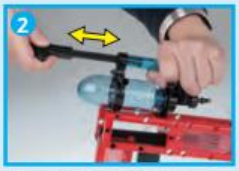
Lifting a bottle

HERE'S HOW

Try to lift a filled water bottle using the robotic grabber with your arms outstretched. Then try to pick up the water bottle with the robotic grabber close to your body. Which way is easier?

HOW TO USE

Put the switch lever in the center position.



Pump about 30 times.

The gripper will open when you push the switch lever.

The gripper will close when you pull the switch lever.

CHECK IT OUT

Forces and Moments

Understanding how **forces** and **moments** influence a robotic arm is critical for its design, because a mistake in these calculations could cause the robotic arm to break.

ACCELERATION

To understand force, you must first understand **acceleration**. Acceleration is a measure of how much the velocity of an object is changing. For example, a car is accelerating when it speeds up, slows down, or changes direction.

MOMENT

A force tends to cause an object to move, but depending on where the force is applied on an object, the force can also cause an object to rotate. For example, if you push on the end of wrench, the force of your push causes it to turn. How much a force causes an object to rotate is measured by its **moment**. A moment depends on how far the force is from the axis of rotation and how big of a force is applied. This can be written as the formula:

$$M = F \times d$$

You can increase the moment by increasing the force or the distance from the axis on which the force is exerted. You felt this in Experiment 2 when you stretched your arm out with the grabber robotic arm.

FORCE

A force can simply be thought of as a push or pull. A force is equal to the mass of the object multiplied by its acceleration. This is summarized by the formula:

$$F = m \times a.$$

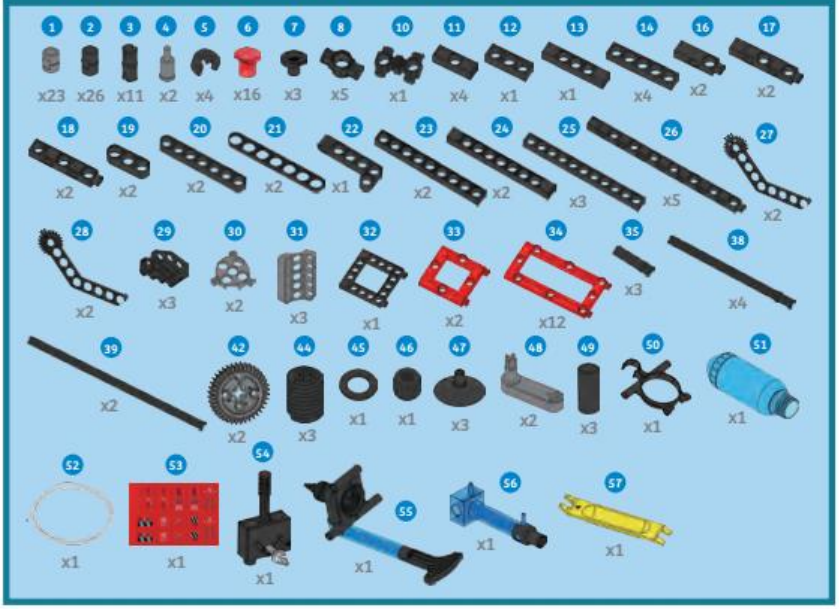
Each linkage and joint in a robotic arm has a weight, which is a force that points downward towards the Earth. A robotic arm must not only be able to support the weight of the arm itself, but also the weight of what the robot arm will carry. The maximum weight that a robot can lift is called the **carrying capacity**.

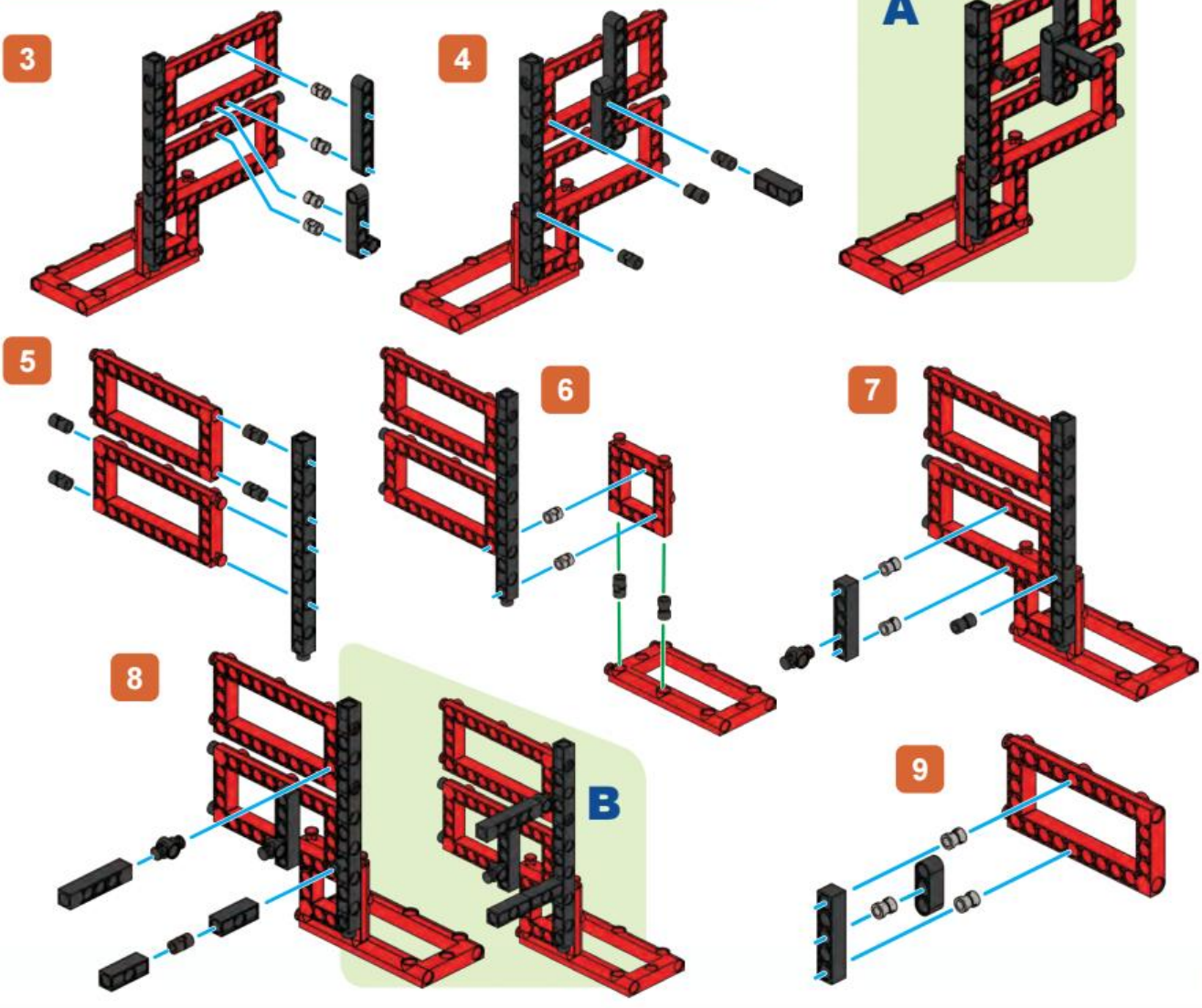
ARM SAGGING

Arm sagging occurs when the robotic arm is too long and heavy, causing it to bend when it is stretched out. This is undesirable. You want your robotic arm to be as rigid and light as possible. This can be overcome partially by positioning the heaviest components as close to the base of the robotic arm as possible.

Model 3 Robotic Claw

Parts Needed





Robotic Claw Model 3

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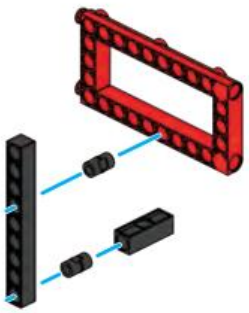

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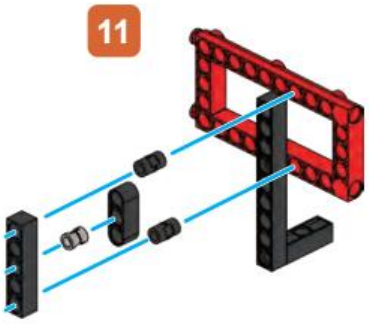

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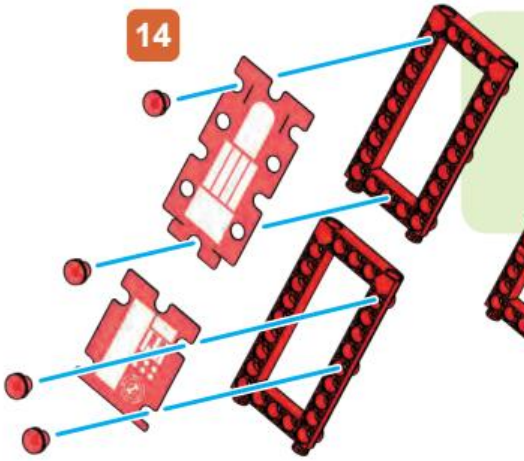

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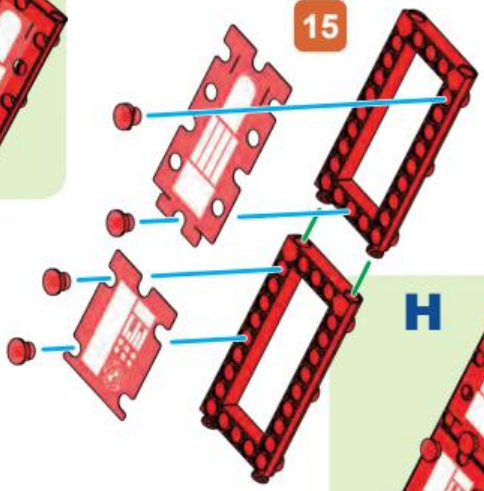

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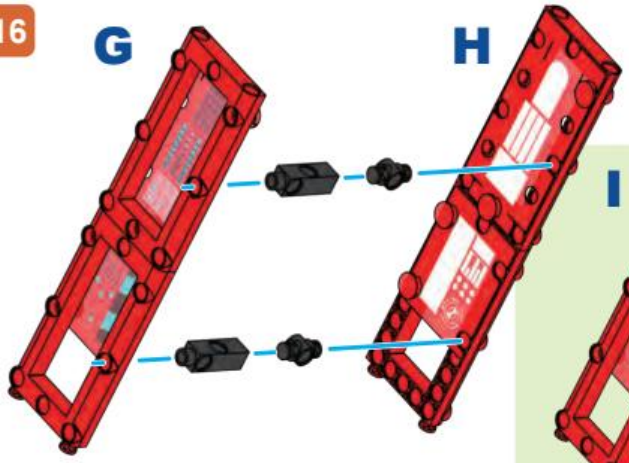

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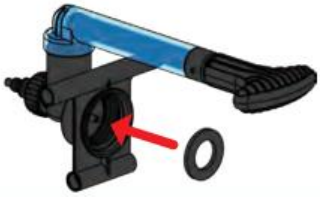
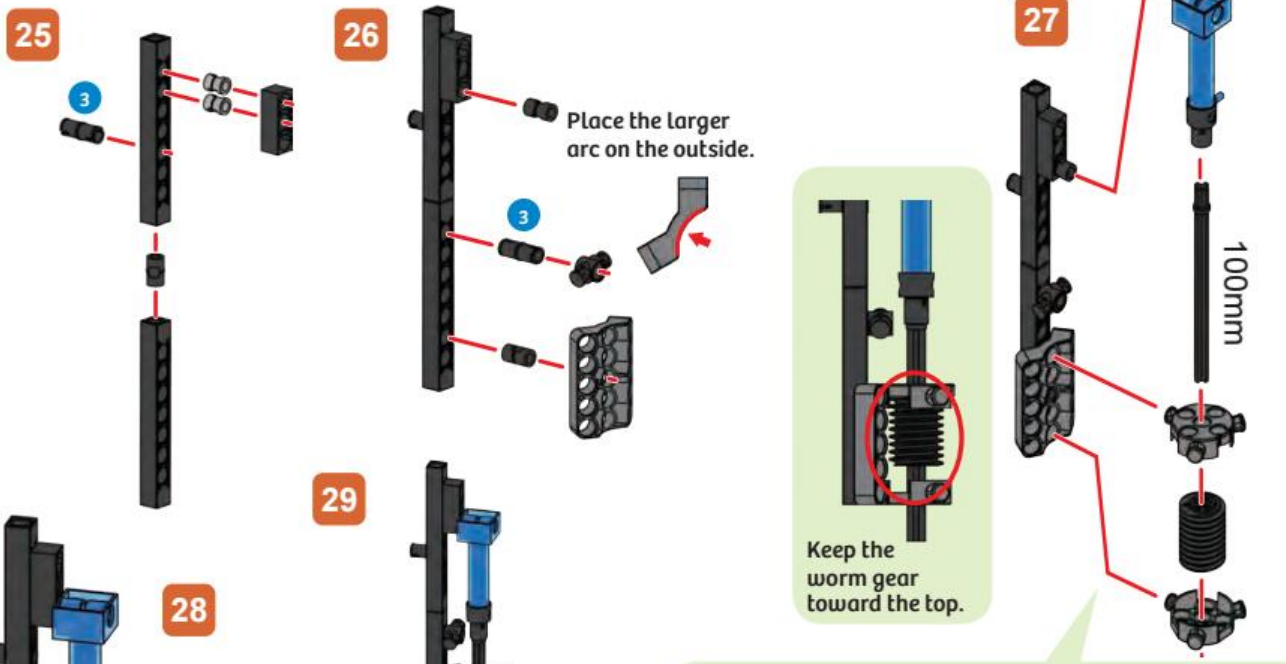


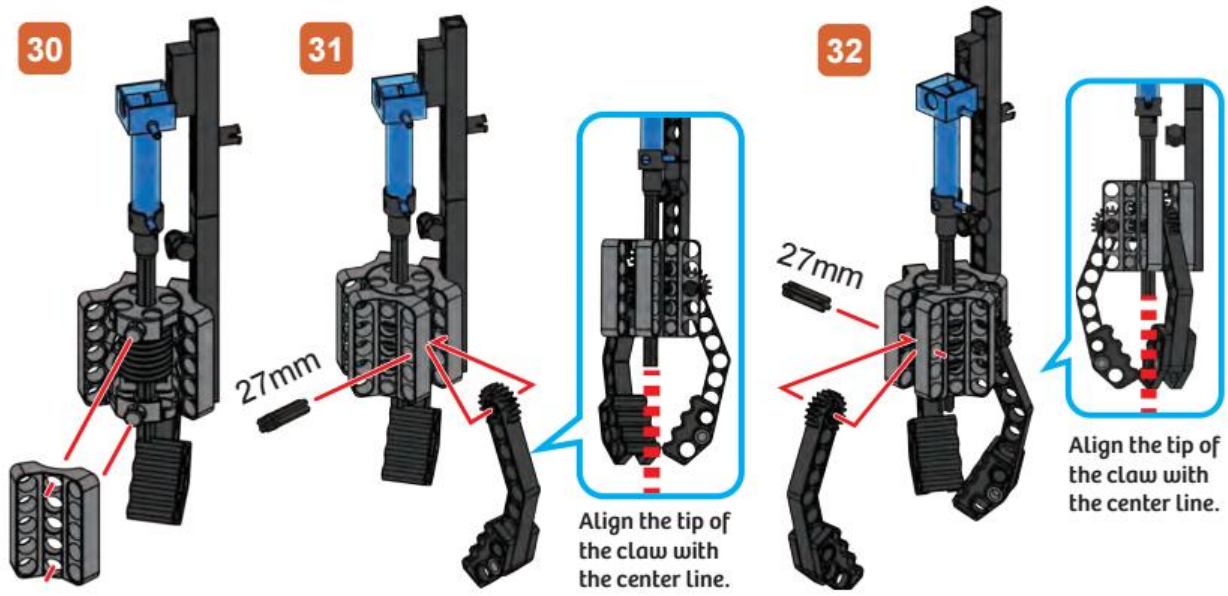
Model 3 Robotic Claw

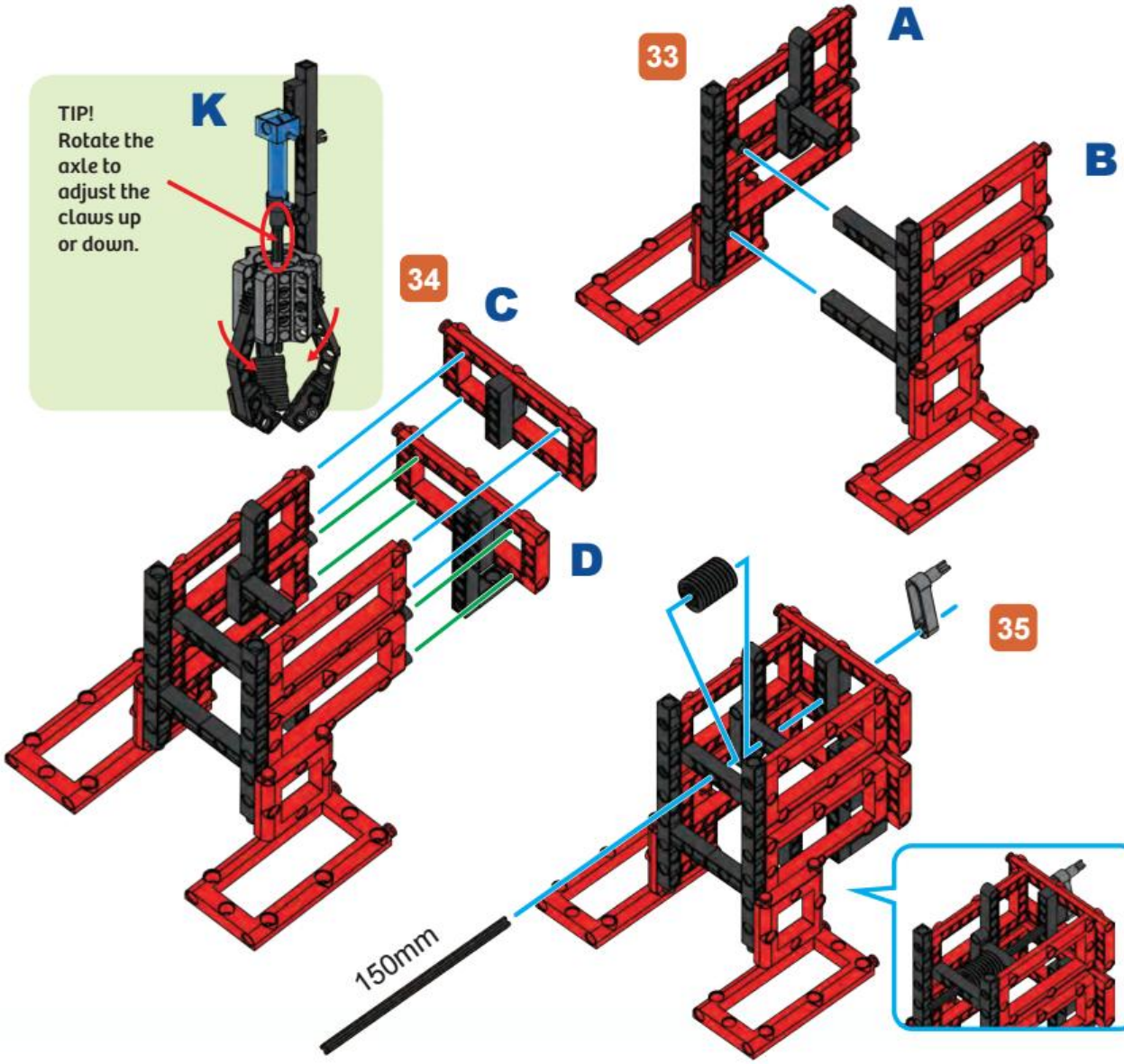


How to remove the pneumatic piston cylinder handle

1. Push the pneumatic piston handle back into the pneumatic piston cylinder.
2. Slide the peg remover around the neck of the pneumatic piston handle.
3. Gently use the peg remover to pry the pneumatic piston handle from the pneumatic piston cylinder.
4. Pull the pneumatic piston handle out of the pneumatic piston cylinder.

Robotic Claw Model 3





Model 3 Robotic Claw

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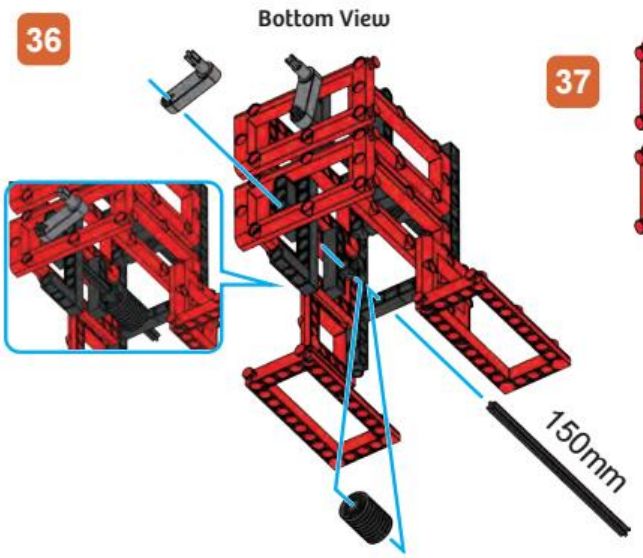

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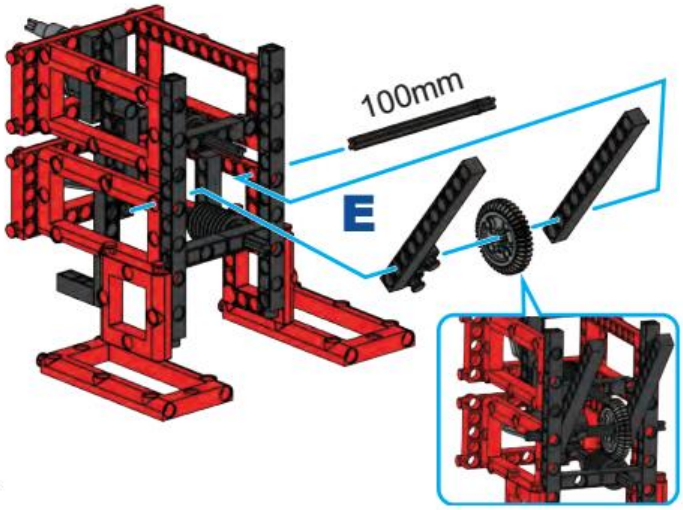

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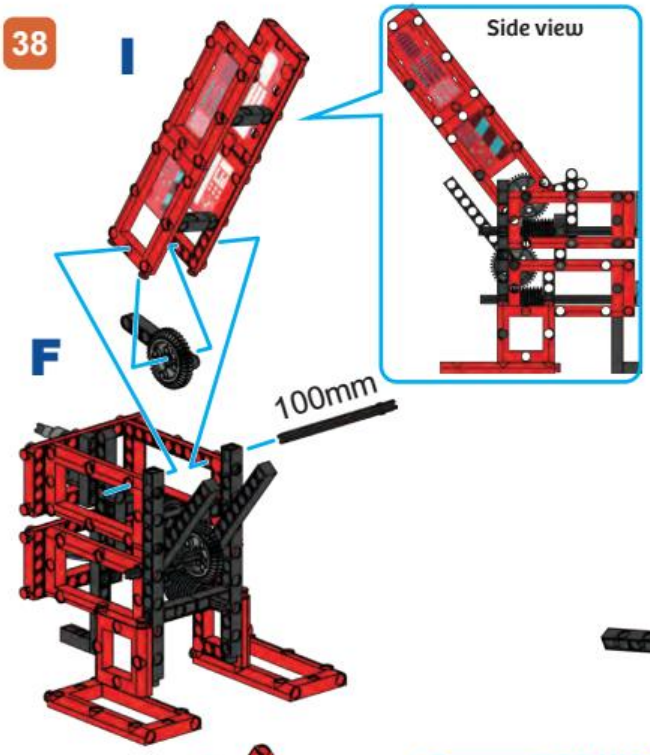

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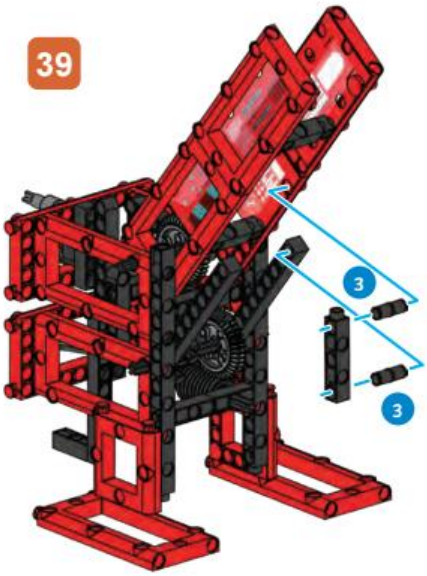

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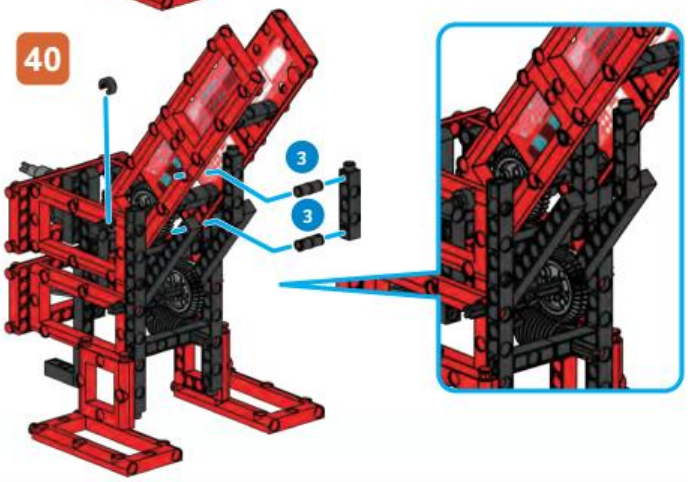

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Robotic Claw Model 3

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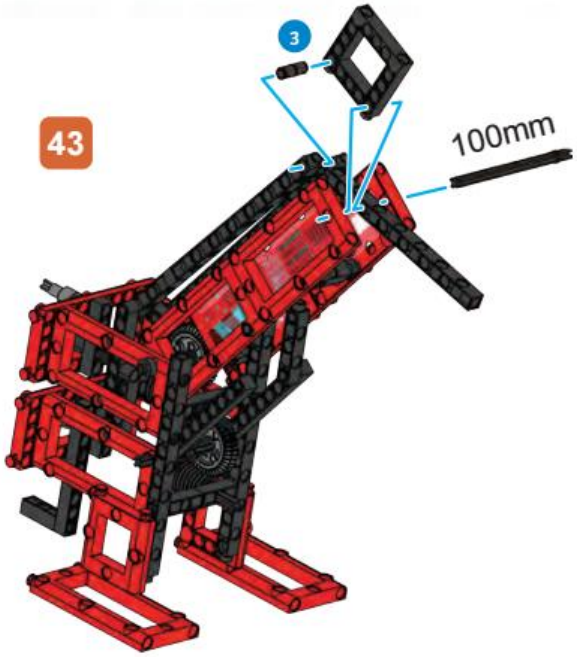

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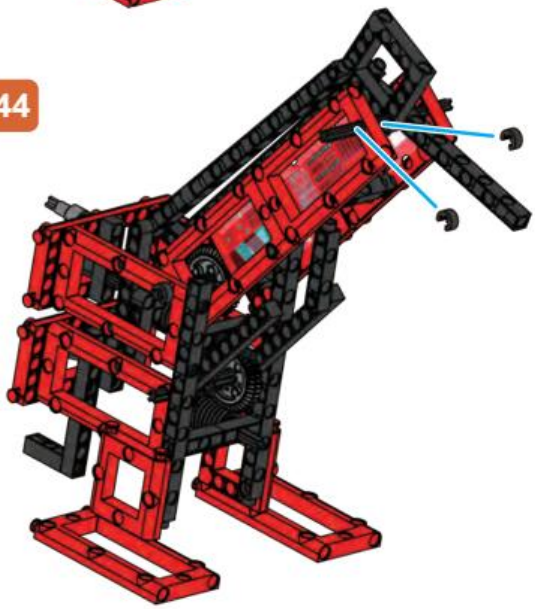

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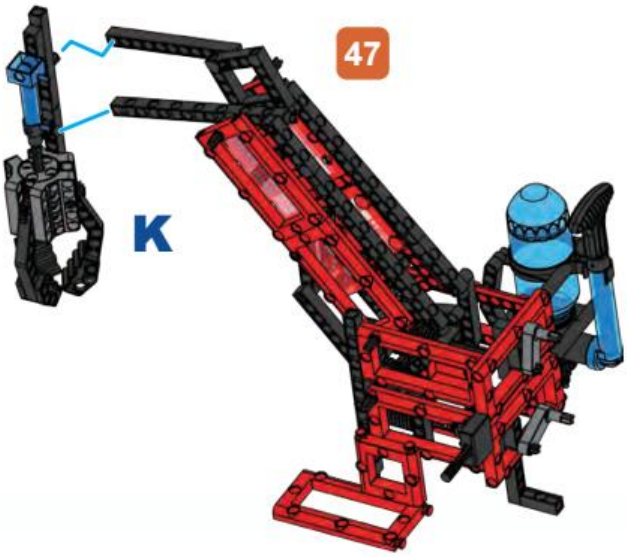

Model 3 Robotic Claw

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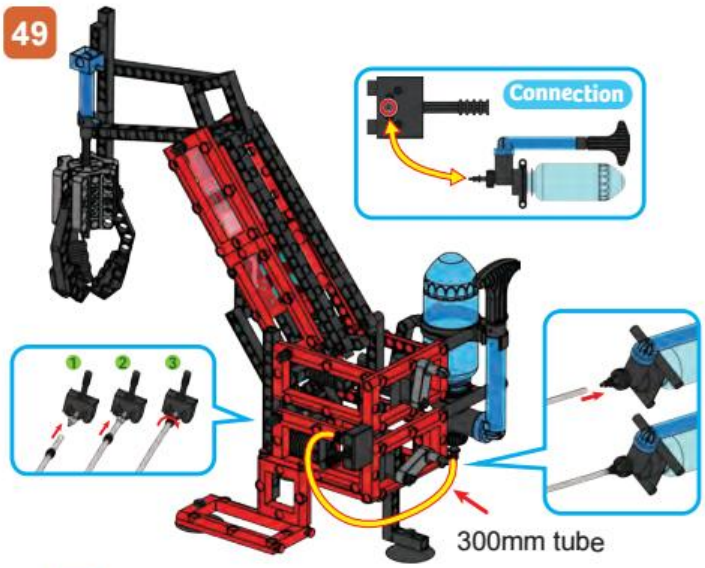

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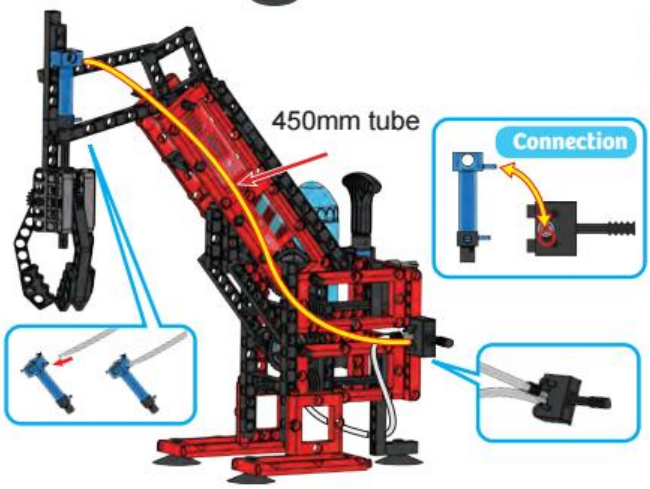

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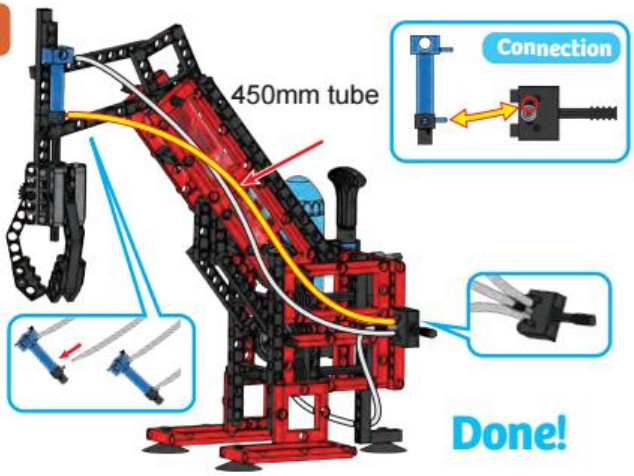


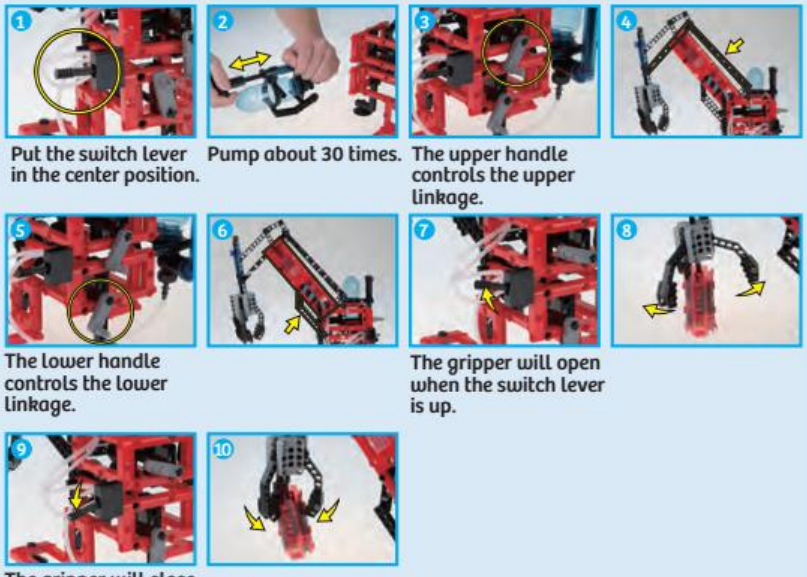
EXPERIMENT 3

Pneumatic strength

HERE'S HOW

Instead of the normal 30 pumps to fill the plastic bottle, use only 15 pumps. Then try to pick up one of the cylinders. Repeat this experiment using 30 pumps and then 40 pumps. Compare the speed and strength of the grabber each time.

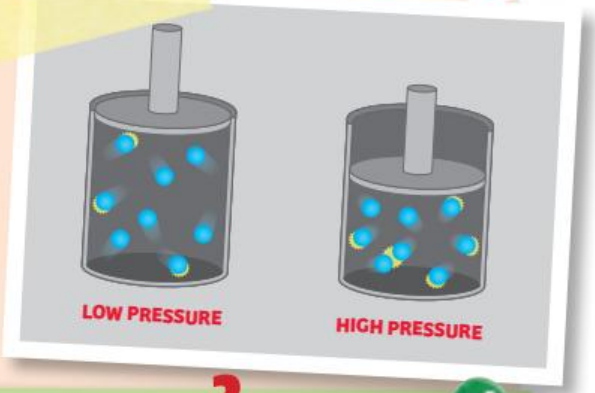
HOW TO USE



CHECK IT OUT

Pneumatics

In a machine, the parts that are responsible for moving or controlling a mechanism are called **actuators**. The robotic arms in this kit use mechanical parts (gears and axles) to move the robotic arm and a pneumatic piston cylinder to open and close the gripper. The tubes, pneumatic piston cylinder, little air water set, and plastic bottle together are known as a pneumatic system.



WHAT IS PRESSURE?

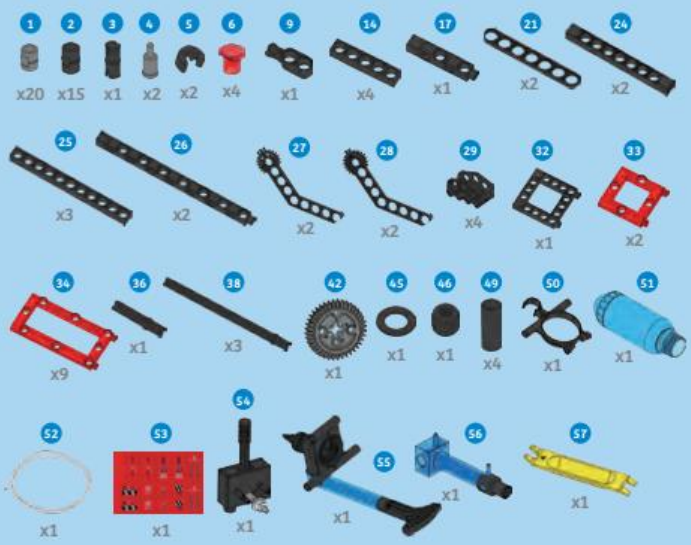
Air is a gas consisting of many very small molecules that are constantly moving in all directions. When these molecules bump against an object they push against it. **Pressure** is a measure of how hard and how often these gas molecules are pushing on an area. In physics, pressure is a force over an area and has units of pounds per square inch (psi), Pascal, or Bar.

1. When you pump the little air water set handle, you are pushing air from the atmosphere into the plastic bottle. Because there are now more air molecules bouncing around inside the plastic bottle, the pressure inside the plastic bottle has increased.
2. When the secured reverse switch is opened, it releases the pressurized air from the plastic bottle. The pressurized air travels through the tube into the pneumatic piston cylinder. The pressure in the pneumatic piston cylinder then increases, pushing the pneumatic piston cylinder handle outward.
3. When the secured reverse switch is pushed to the third position, the air is released from the pneumatic piston cylinder, pulling the pneumatic piston cylinder handle inward.

Most industrial robotic arms use electric motors because they are usually cheaper than pneumatic systems and provide faster and more precise control over movement. However, pneumatic actuators are stronger and advantageous in applications where an electrical spark could start a fire.

Model 4 Robotic Hand

Parts Needed



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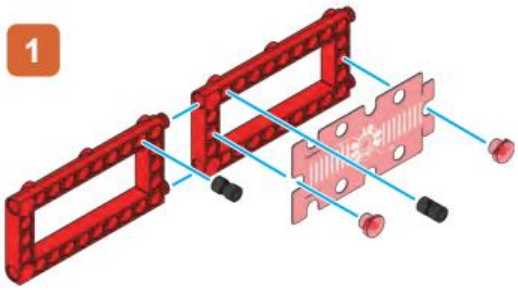

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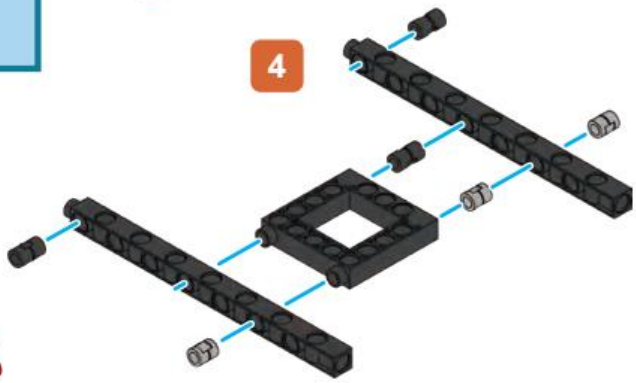

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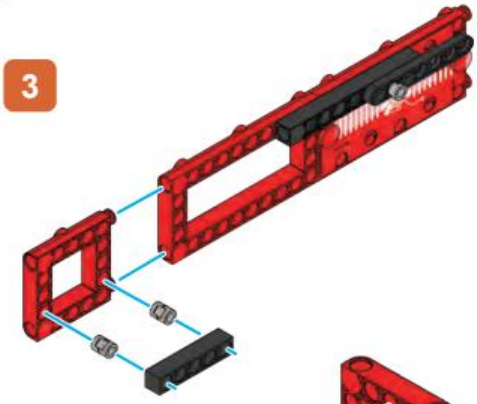

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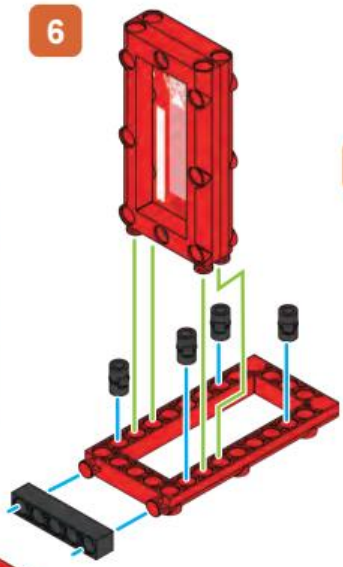

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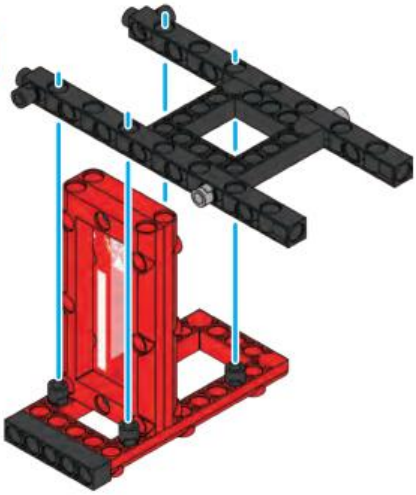

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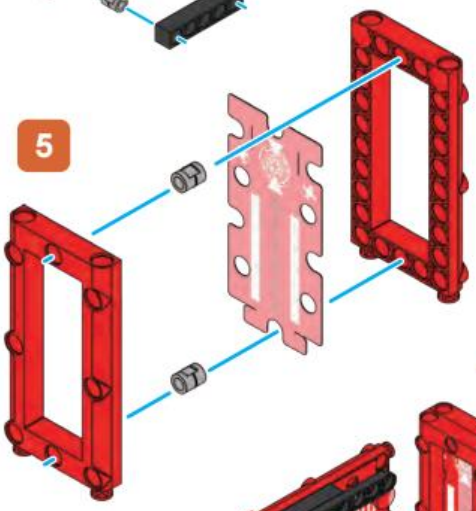

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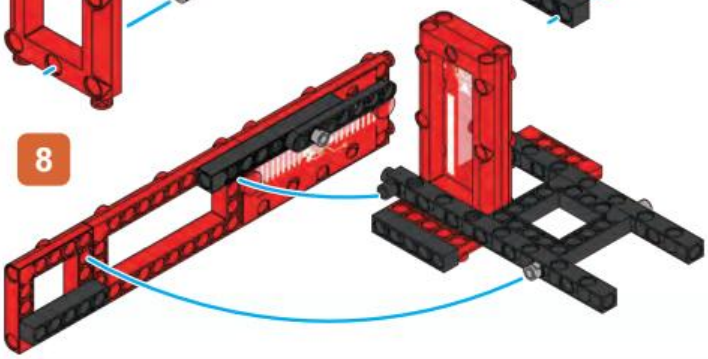

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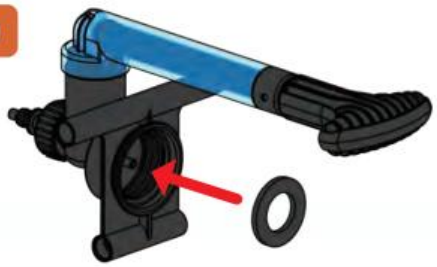
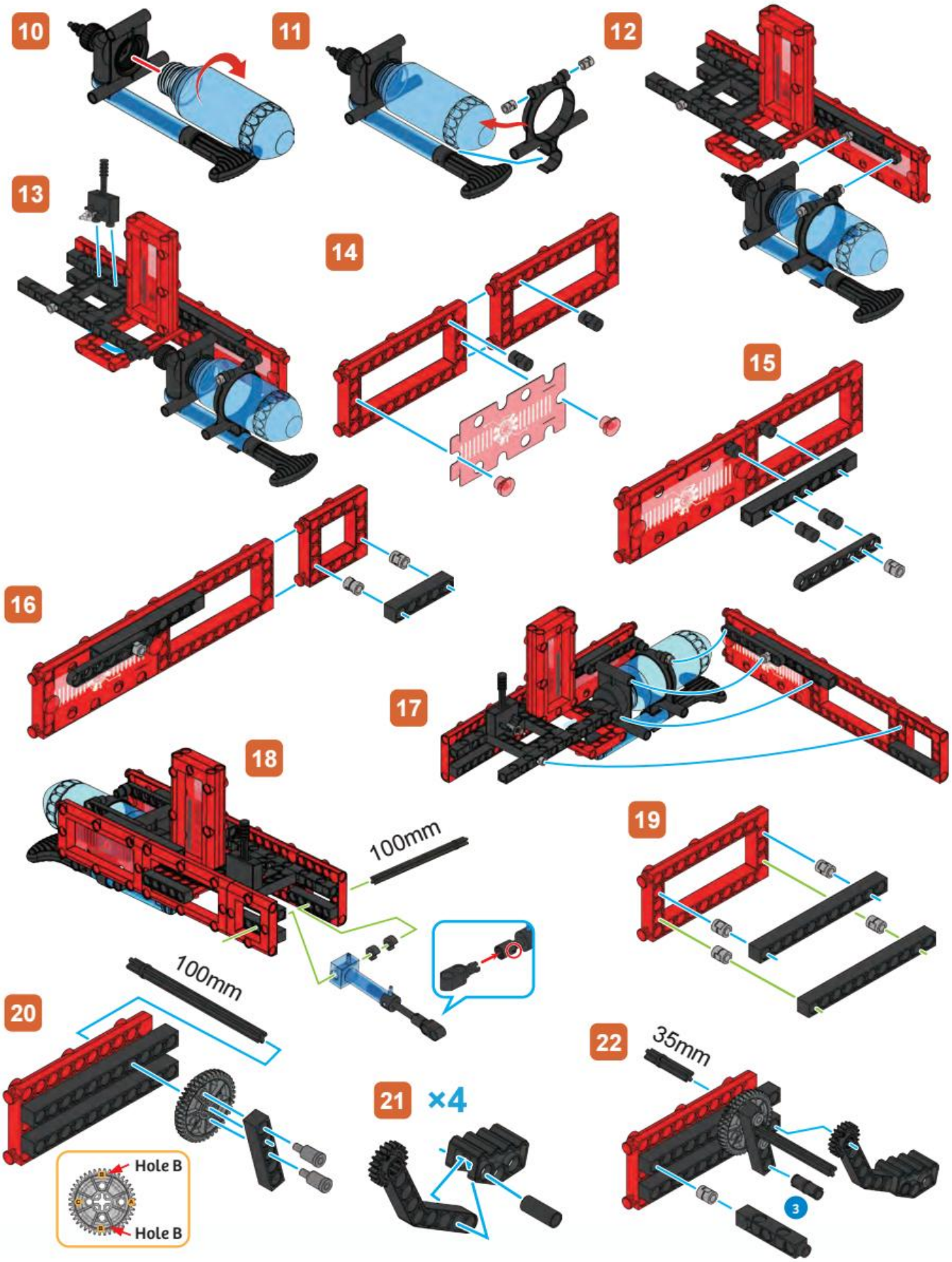


Robotic Hand Model 4



Model 4 Robotic Hand

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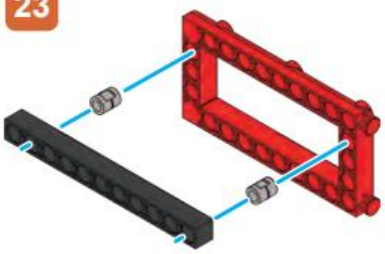

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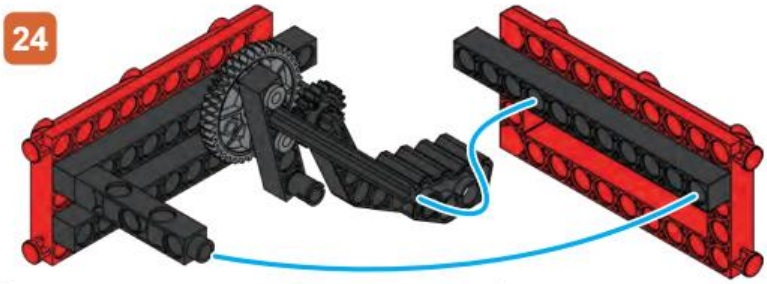

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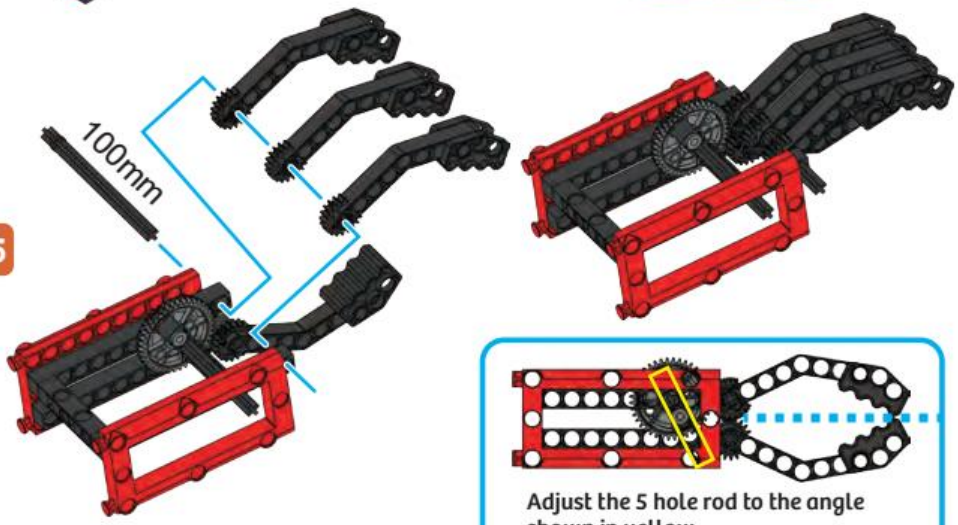
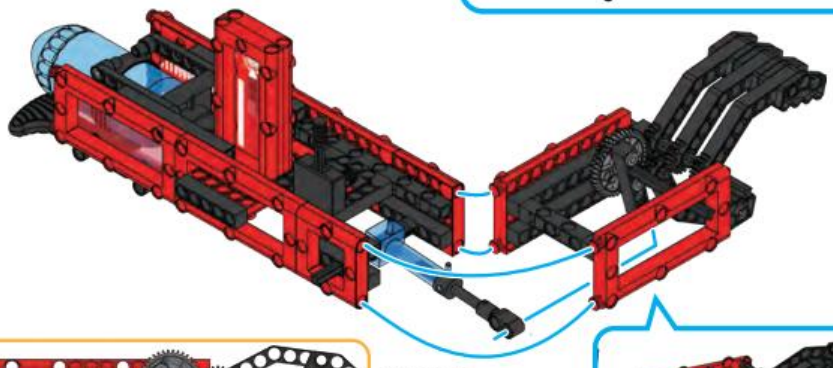
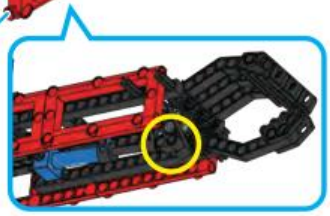


Adjust the 5 hole rod to the angle shown in yellow.

26



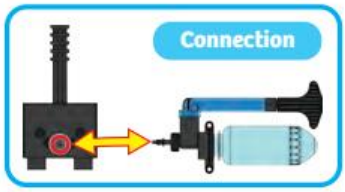
When the cylinder is pulled all the way out, the two grippers should be closed.

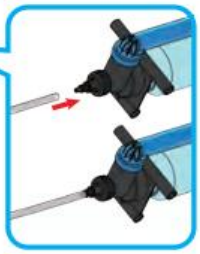


Connect the cylinder to the 5 hole rod.

27

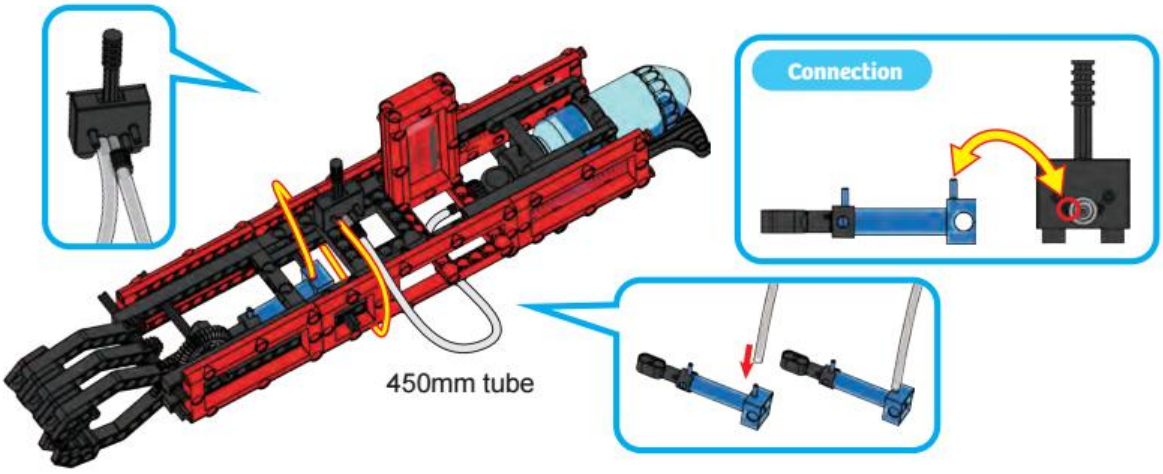
300mm tube





Robotic Hand Model 4

28



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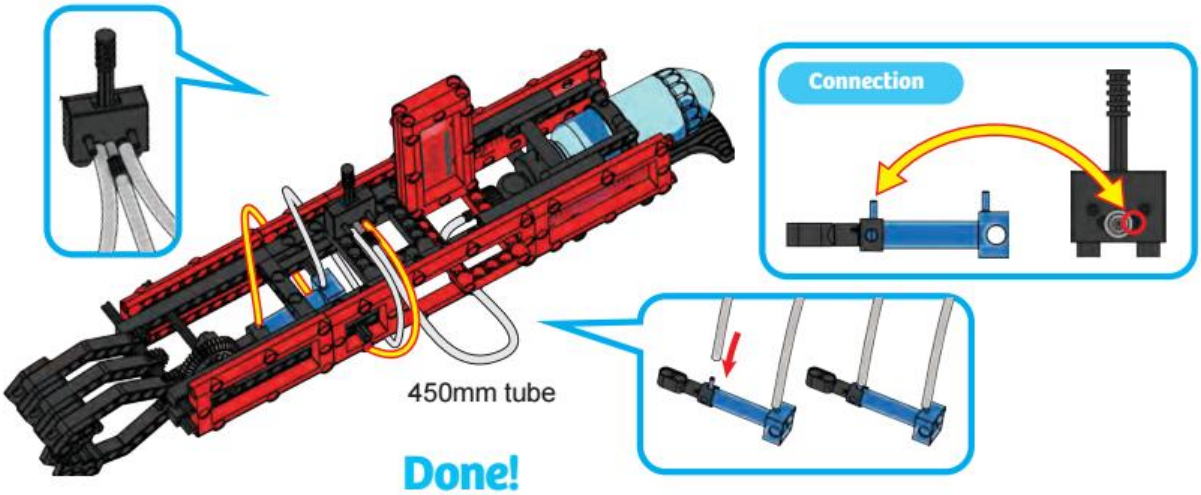


Done!

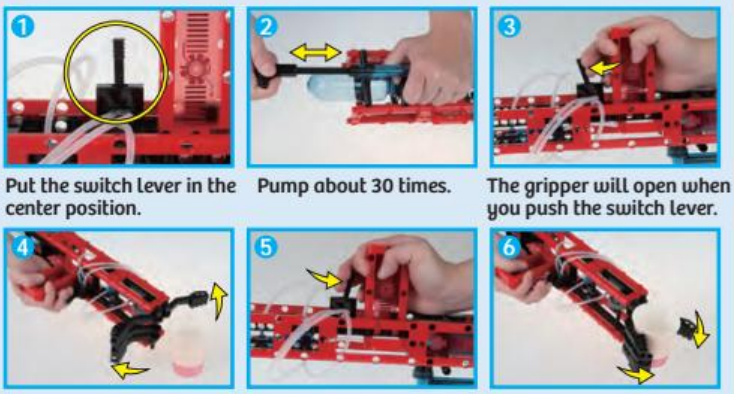
EXPERIMENT 4

Coming in handy

HERE'S HOW

If you wear an oversized sweater or sweatshirt with large sleeves, you can slide the robotic hand up your sleeve so that only the hand is outside the sleeve. Operate the trigger inside the sleeve. Now try to pick up various objects. Can you pick up some items and not others?

HOW TO USE



1. Put the switch lever in the center position.
2. Pump about 30 times.
3. The gripper will open when you push the switch lever.
4.
5.
6. The gripper will close when you pull the switch lever.

CHECK IT OUT

Robotic Exoskeletons

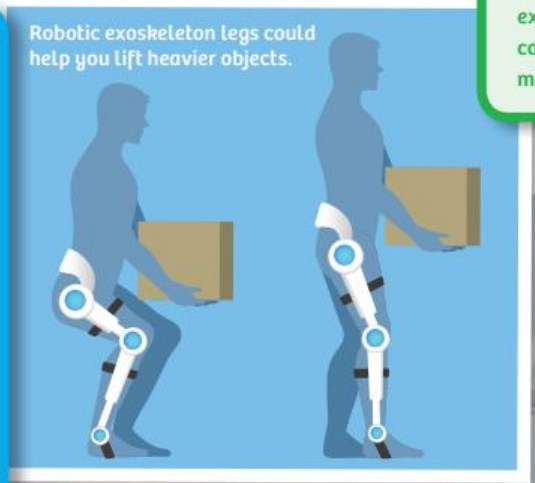
What you have learned about robotic arms can also be applied to the design of robotic exoskeletons. An exoskeleton is a wearable mobile machine that is used to increase limb strength and endurance. Exoskeletons could be used in the medical field to improve people's quality of life or to make tasks easier and safer. They could also be used in industrial or commercial applications — wherever increased strength would come in handy. However, currently there are several challenges to creating viable exoskeletons.

MATERIALS

The materials needed to build an exoskeleton require trade-offs between strength, weight, and cost. The materials used must be strong enough so that they do not fail or break easily but also need to light to reduce the power needed to move the exoskeleton. However, the use of lighter and stronger materials, such as titanium or carbon-fiber, can be more expensive and require more complex construction and manufacturing methods.

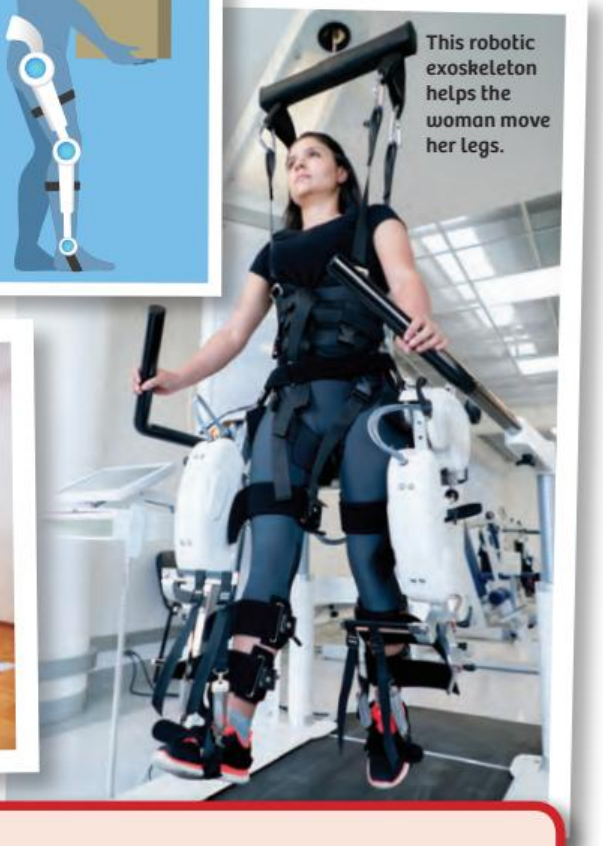
ACTUATORS

Just as is true of the materials needed to build an exoskeleton, the actuators that are needed must be lightweight and powerful, but they must also be precise in their movements. You have seen from the robotic arm models how you are not able to easily control the degree with which the grabber closes. One possibility to overcome this is through the use of pneumatic artificial muscles. Pneumatic artificial muscles are pressurized air bladders that are able to contract and shorten, or relax and lengthen, mimicking the action of real muscles.



Robotic exoskeleton legs could help you lift heavier objects.

A boy uses a robotic machine for walking therapy.



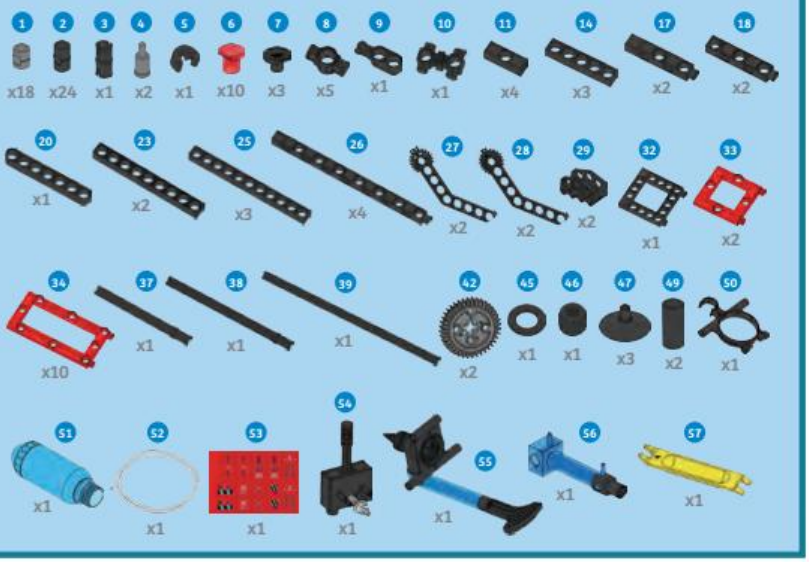
This robotic exoskeleton helps the woman move her legs.

POWER

Another challenge is that there are currently few power sources that have enough energy to power an exoskeleton for more than a few hours. Non-rechargeable batteries have more energy but require transporting, storing, and replacement. On the other hand, rechargeable batteries require a system to recharge the battery. Most current prototype exoskeletons are tethered to a separate power source, which may be sufficient if the exoskeleton is used in a limited range, such as a home or factory. However, this would not work if the exoskeleton is required to go to locations that do not have access to a power source.

Exoskeleton Arms Model 5

Parts Needed



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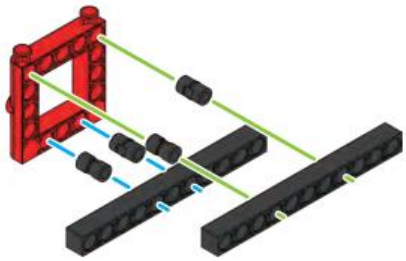

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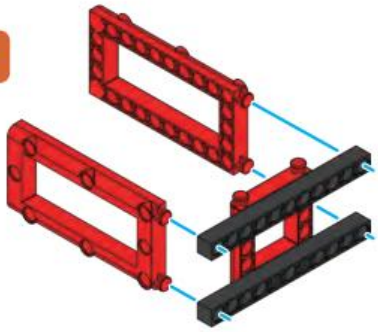

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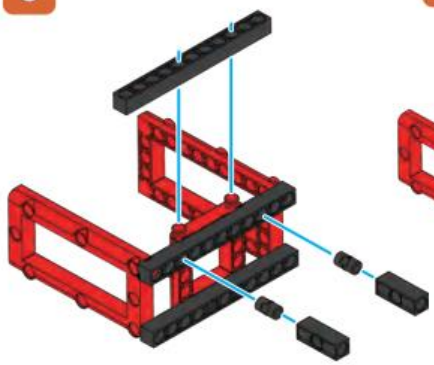

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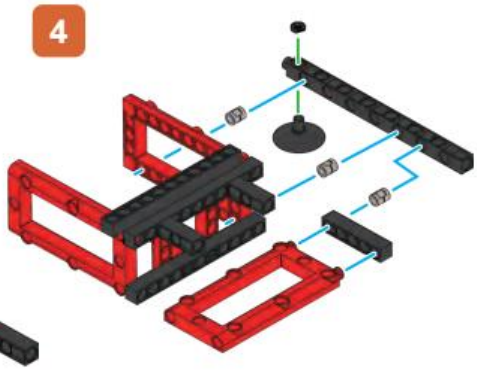

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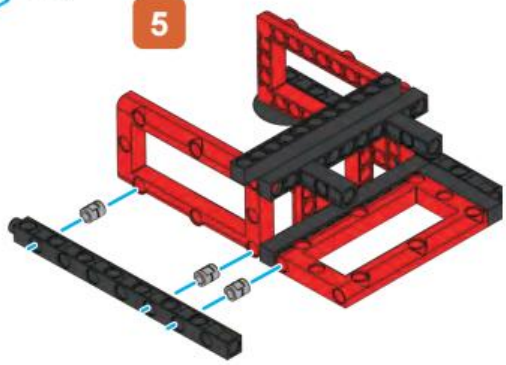

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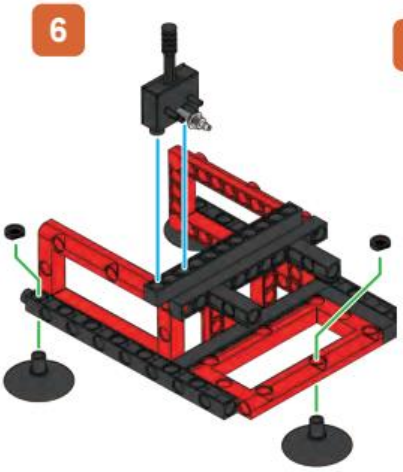

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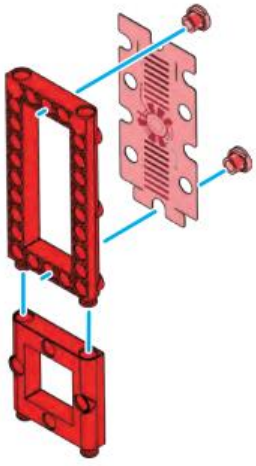

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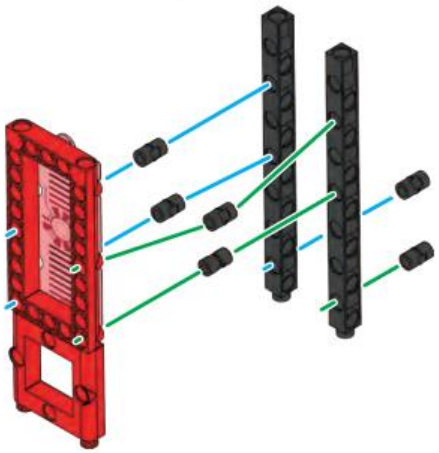

Model 5 Exoskeleton Arms

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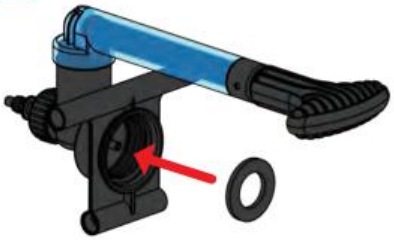

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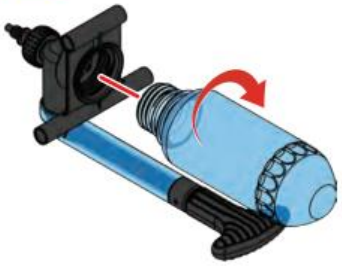

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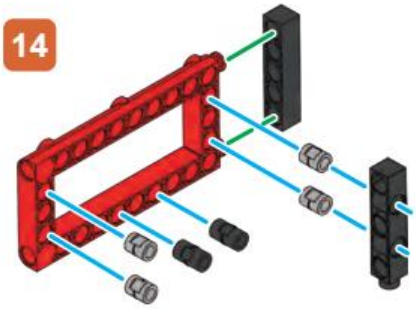

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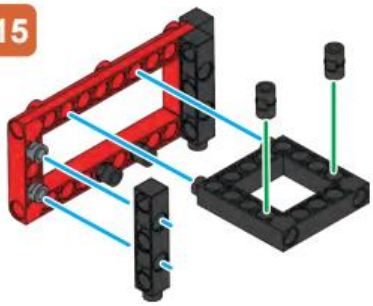

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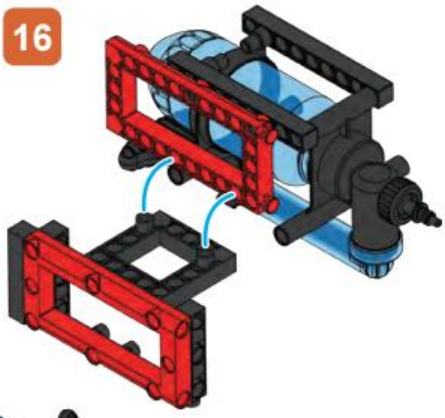

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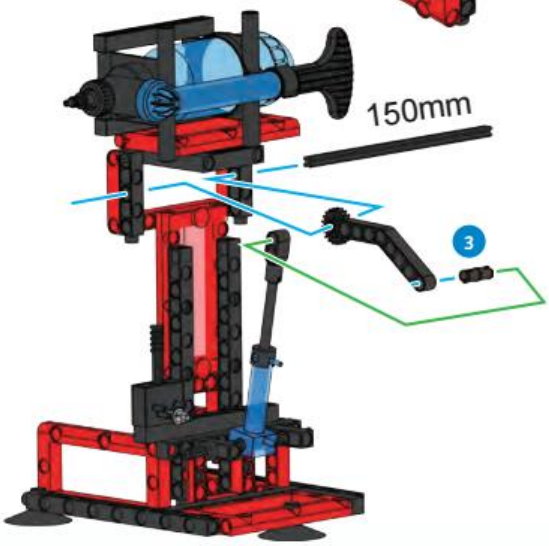

Exoskeleton Arms Model 5

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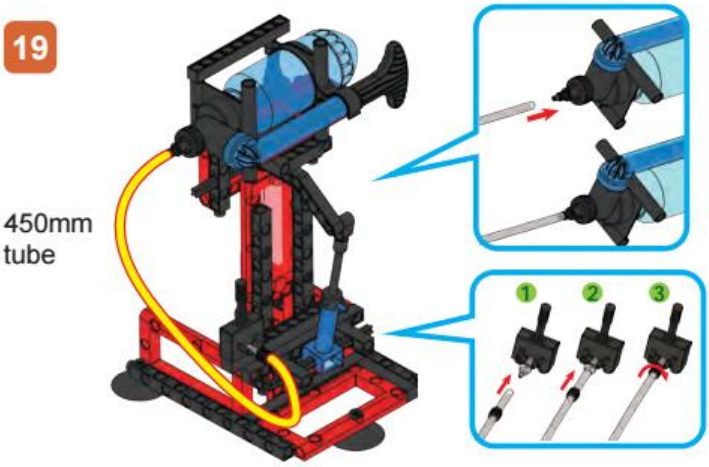

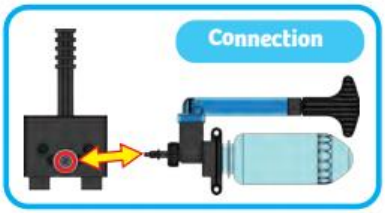

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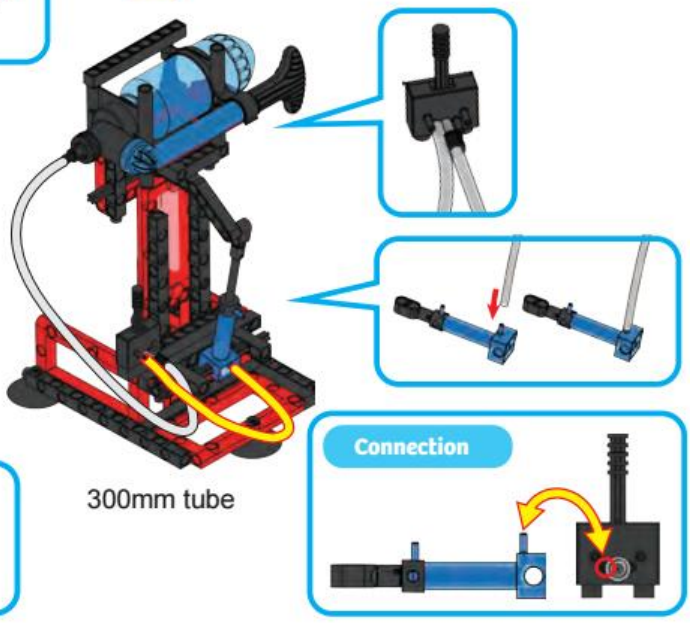

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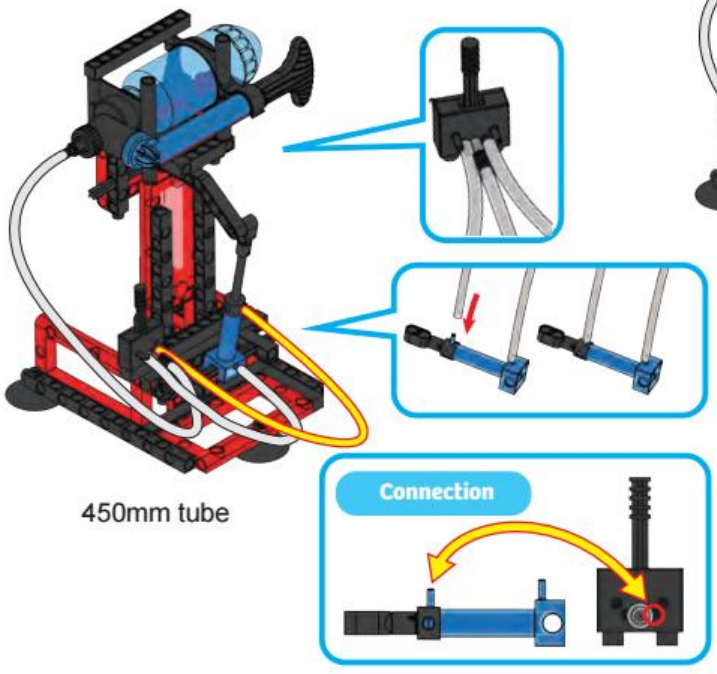

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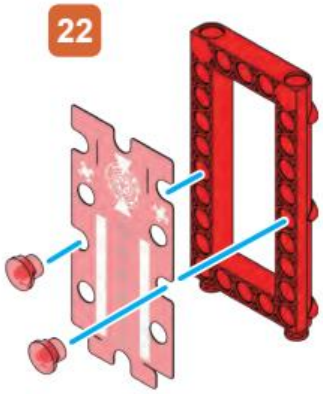

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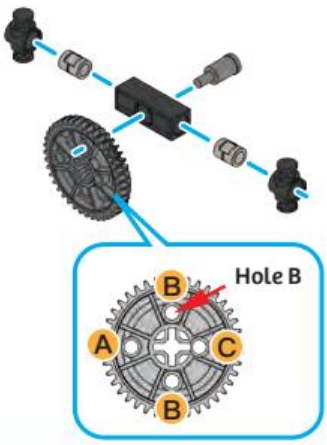
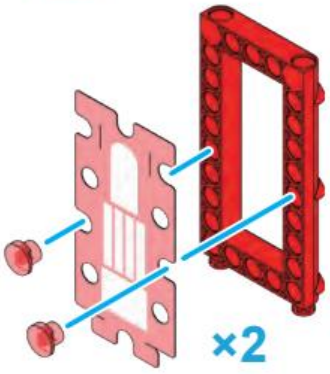


24 ×2

Model 5 Exoskeleton Arms

25



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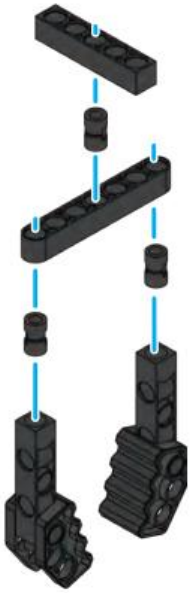

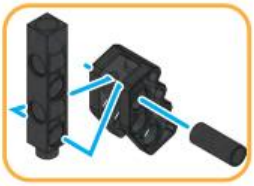

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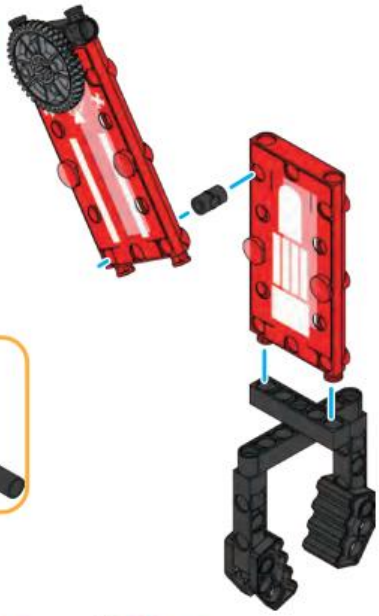

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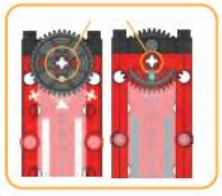
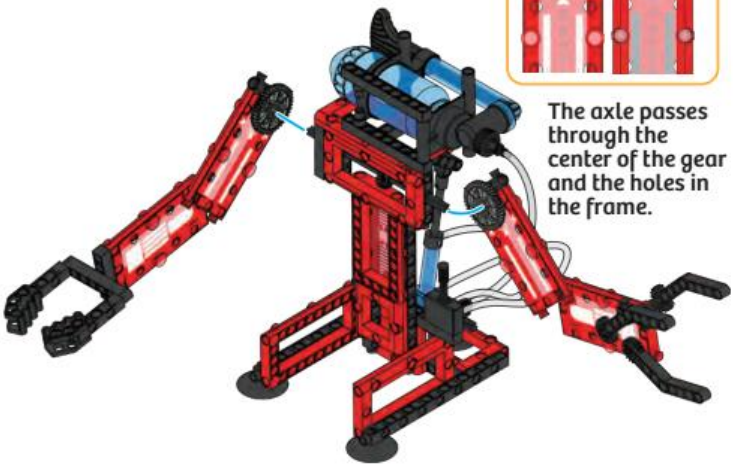


The axle passes through the center of the gear and the holes in the frame.



32

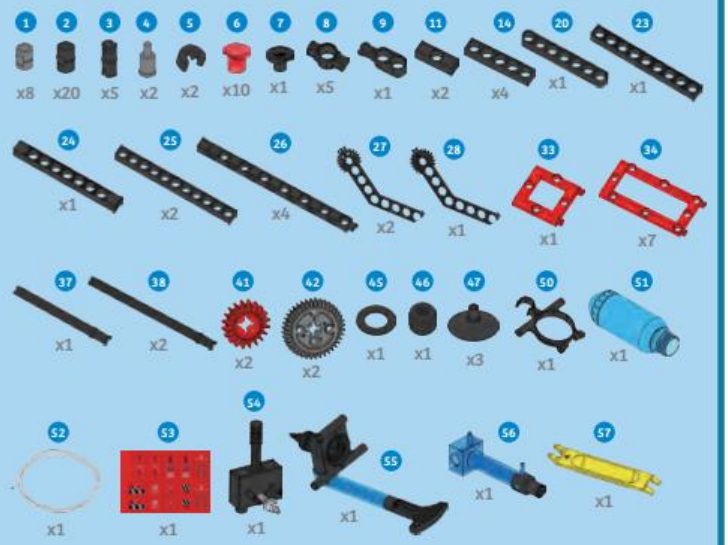
Done!

How to use:

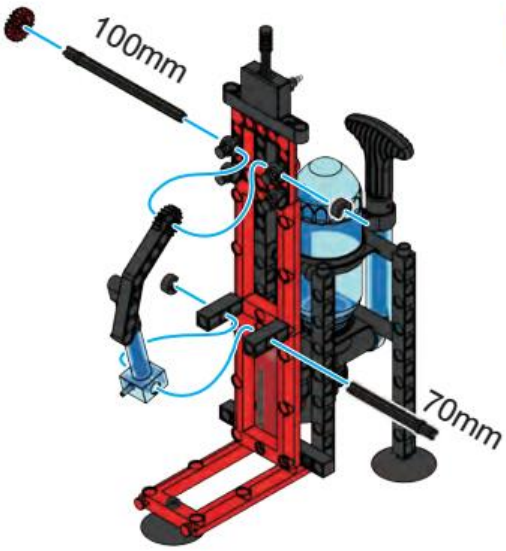
1. Put the switch lever in the center position.
2. Pump about 30 times.
3. The arms will move when you move the switch left and right.

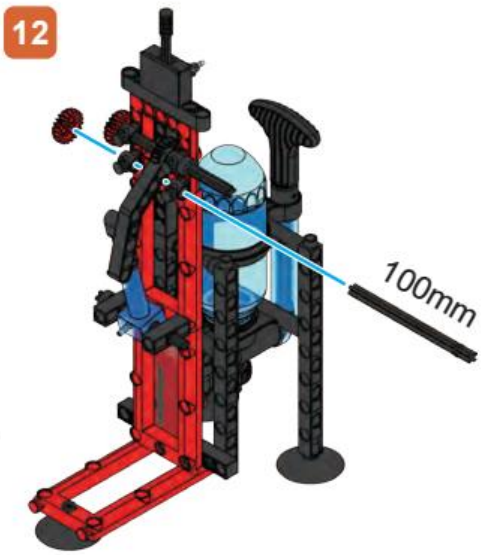
Exoskeleton Legs Model 6

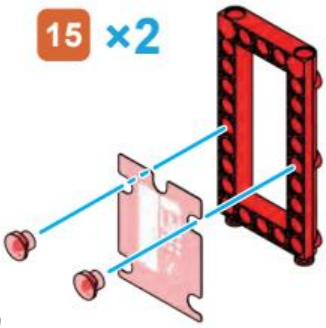
Parts Needed

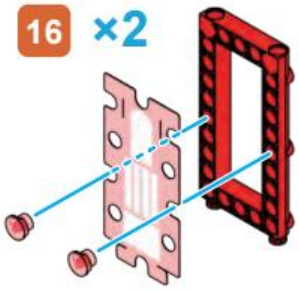


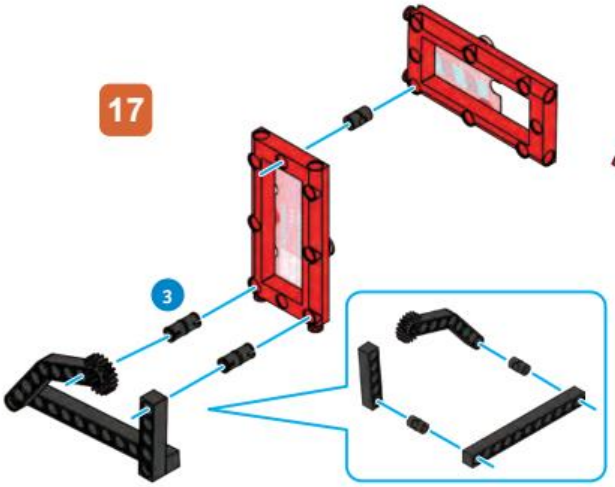
Model 6 Exoskeleton Legs

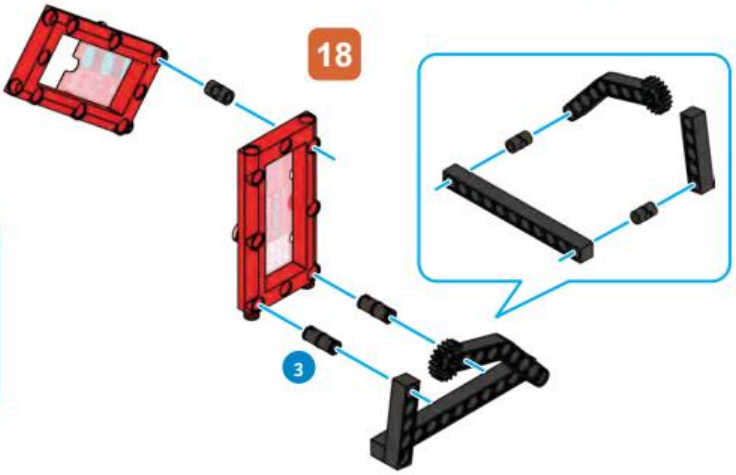












Exoskeleton Legs Model 6

19

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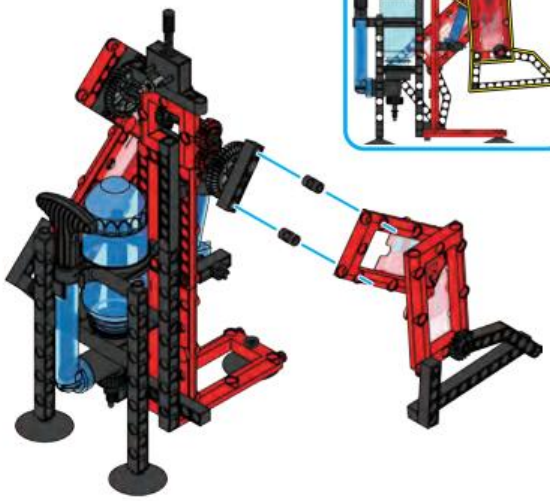
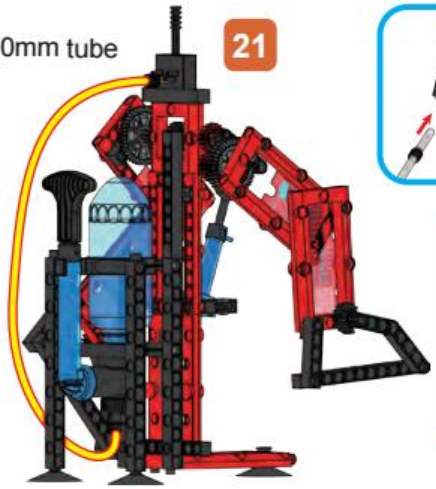
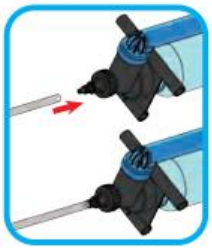
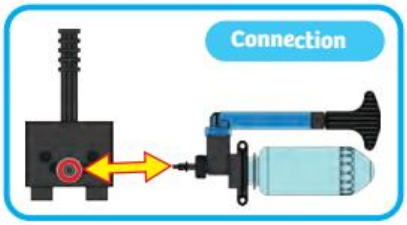


450mm tube

21







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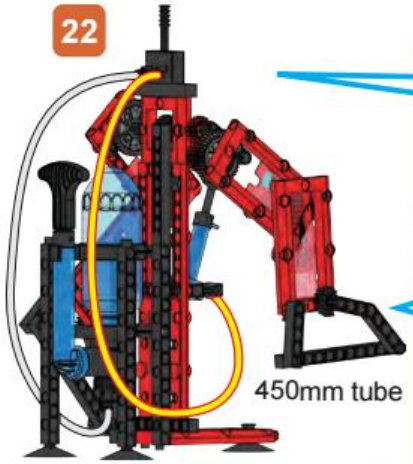

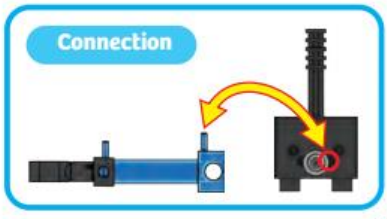

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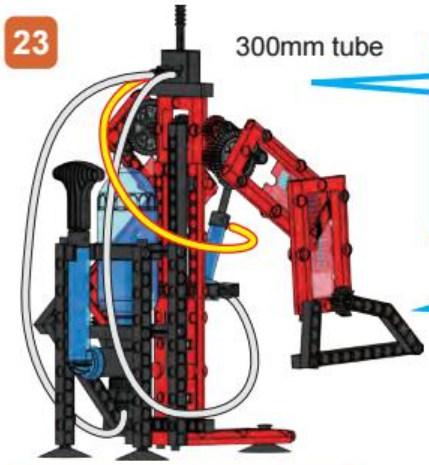
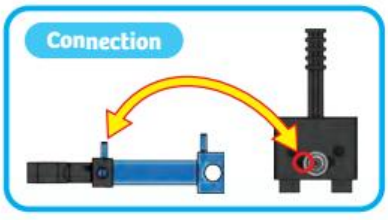
300mm tube





How to use:

1. Put the switch lever in the center position.
2. Pump about 30 times.
3. The arms will move when you move the switch left and right.

24

Done!

Please browse website

Gigo website

Gigo FB

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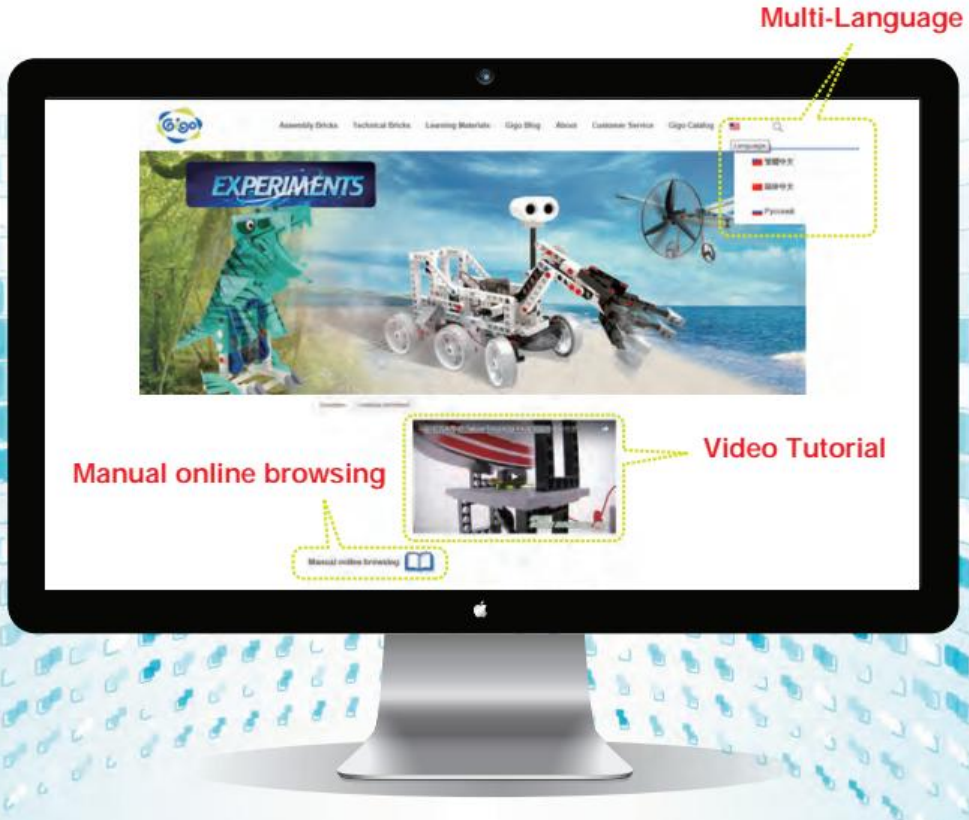
- Many brilliant videos for product introduction.
- Online product brochures to facilitate timely browse.



EXPERIMENTS

ELECTRICITY & MAGNETISM
#7065
10 Models to build
137 PCS

RC CUSTOM CARS
#7407
10 Models to build
260 PCS

CROSSBOWS & CATAPULTS
#7406
10 Models to build
110 PCS

ORNITHOPTER
#7405
4 Models to build
49 PCS

MINI GYRO
#7395
20 Models to build
88 PCS

GECKOBOT
#7409
7 Models to build
176 PCS

SOLAR POWER 2.0
#7303
10 Models to build
120 PCS

WATER POWER
#7323
15 Models to build
165 PCS

WIND TURBINE
#7400
5 Models to build
77 PCS

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