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Lee

(54) SURGICAL INSTRUMENT

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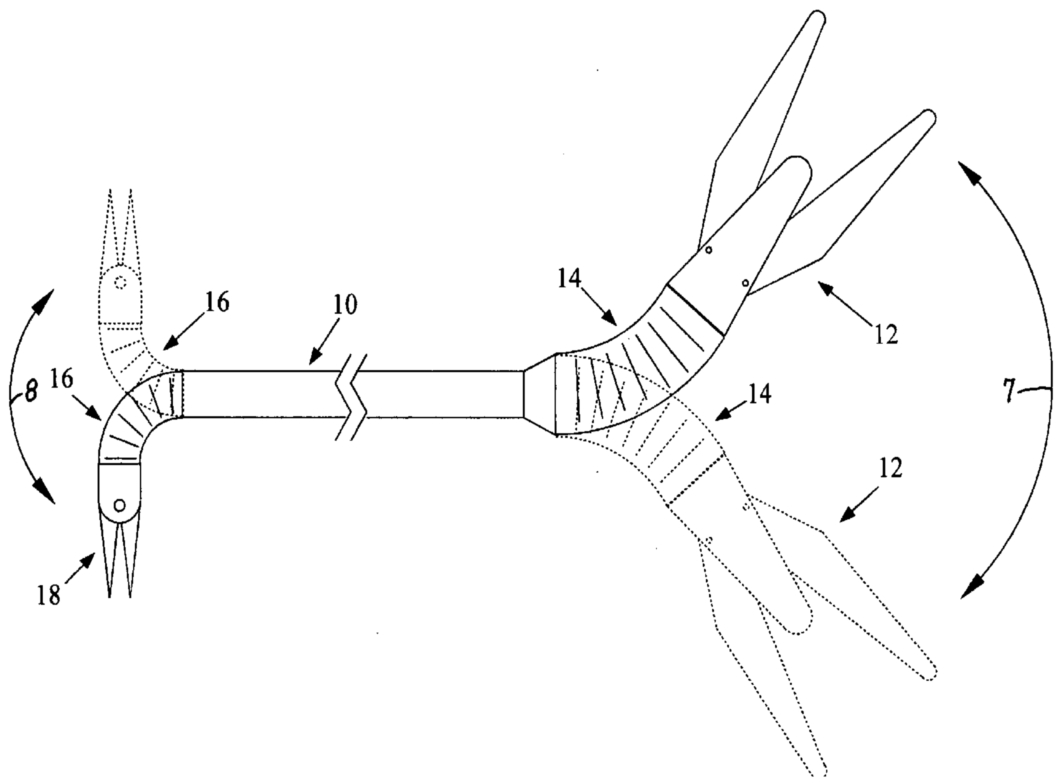
(57) **ABSTRACT**

An endoscopic or laparoscopic instrument includes a distal tool, a rigid or flexible elongated shaft that supports the distal tool, and a proximal handle or control member, where the tool and the handle are coupled to the respective distal and proximal ends of the elongated shaft via bendable motion members. The tool and the tool motion member are coupled to the handle and the handle motion member via cables and a push rod in such a way that the movement of the handle with respect to the elongated shaft in any direction is replicated by the tool at the distal end of the shaft. The magnitude of the tool motion with respect to the handle motion may be scaled depending on the size of the handle motion member with respect to that of the tool motion member.



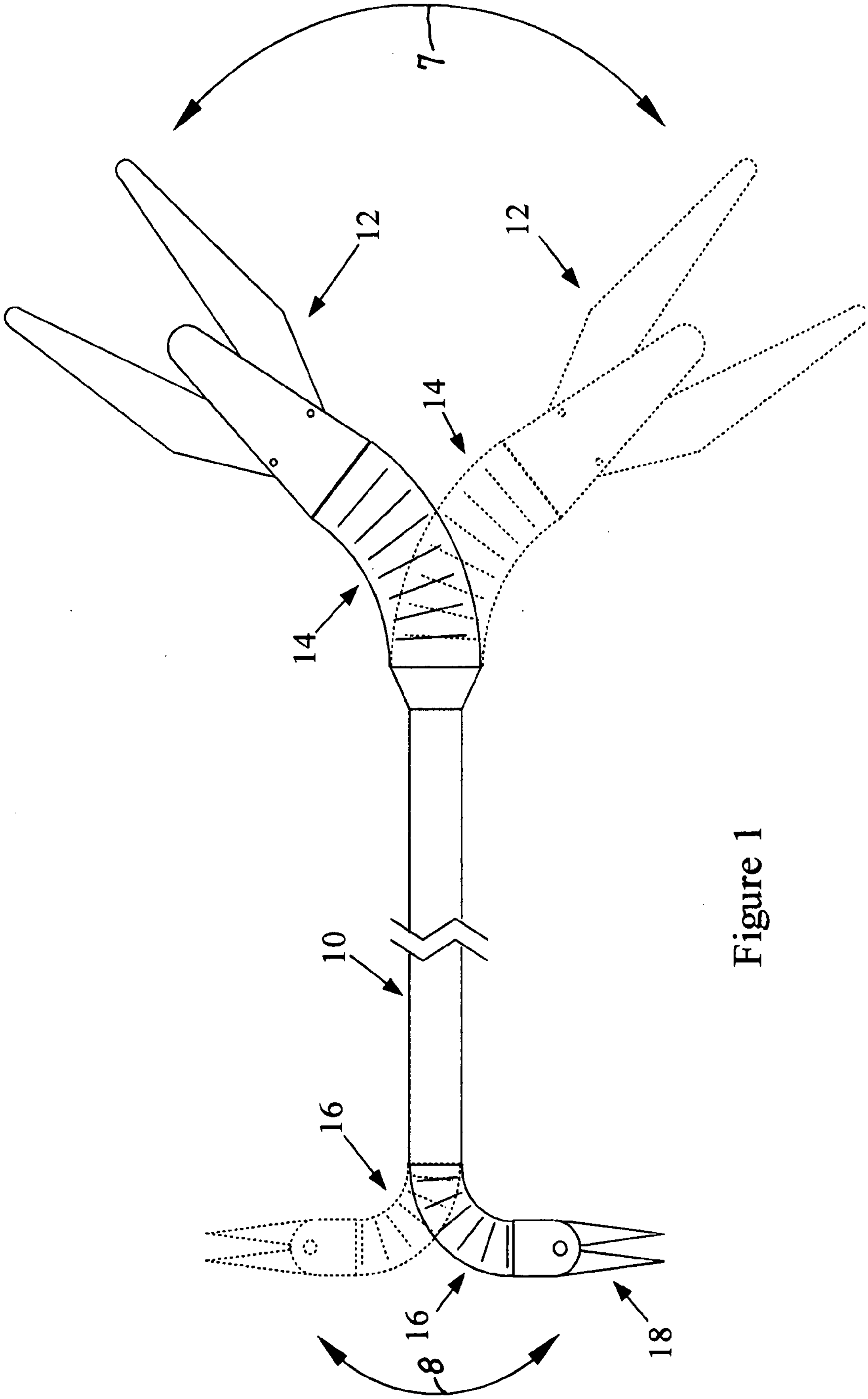
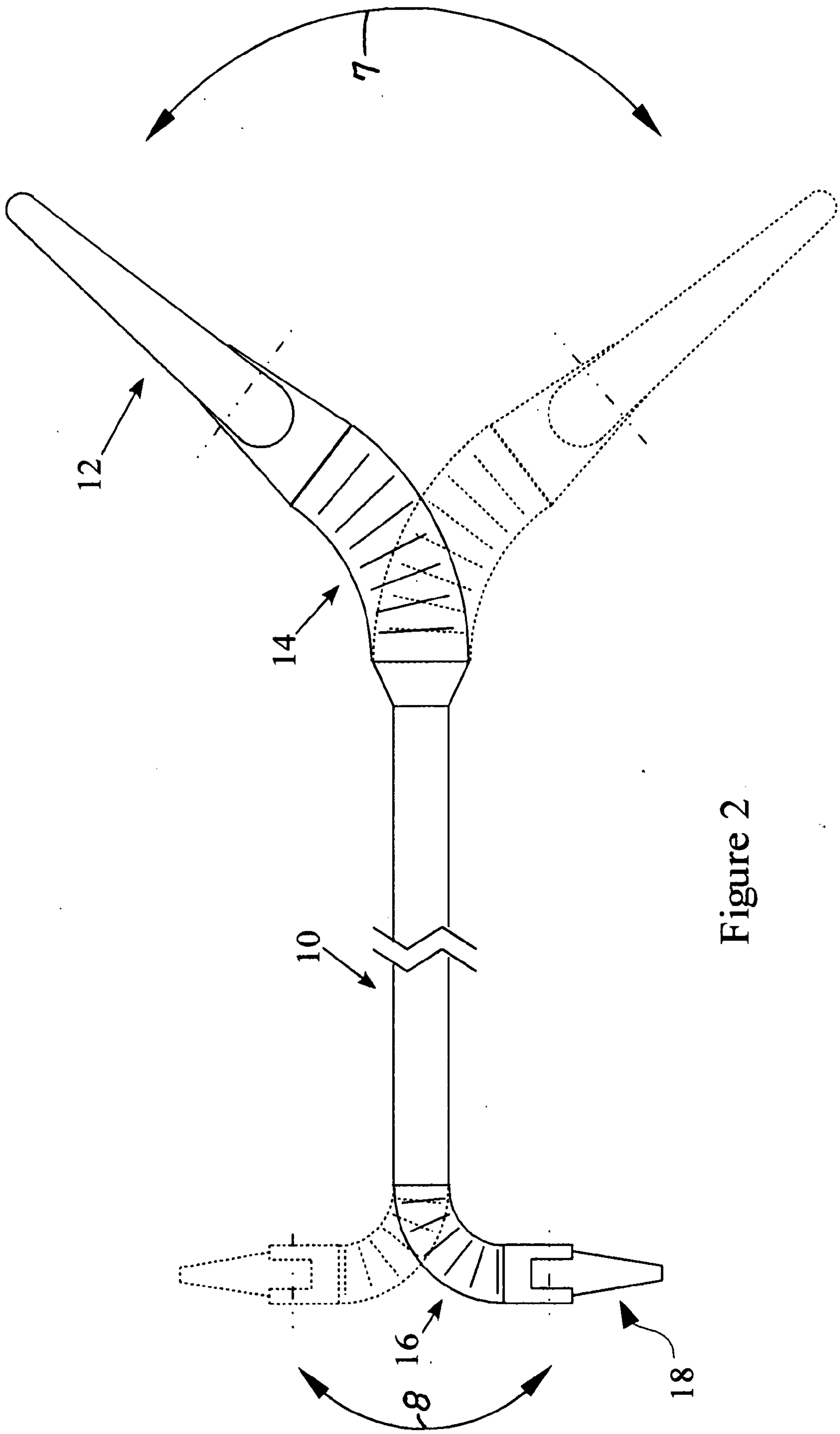



Figure 1

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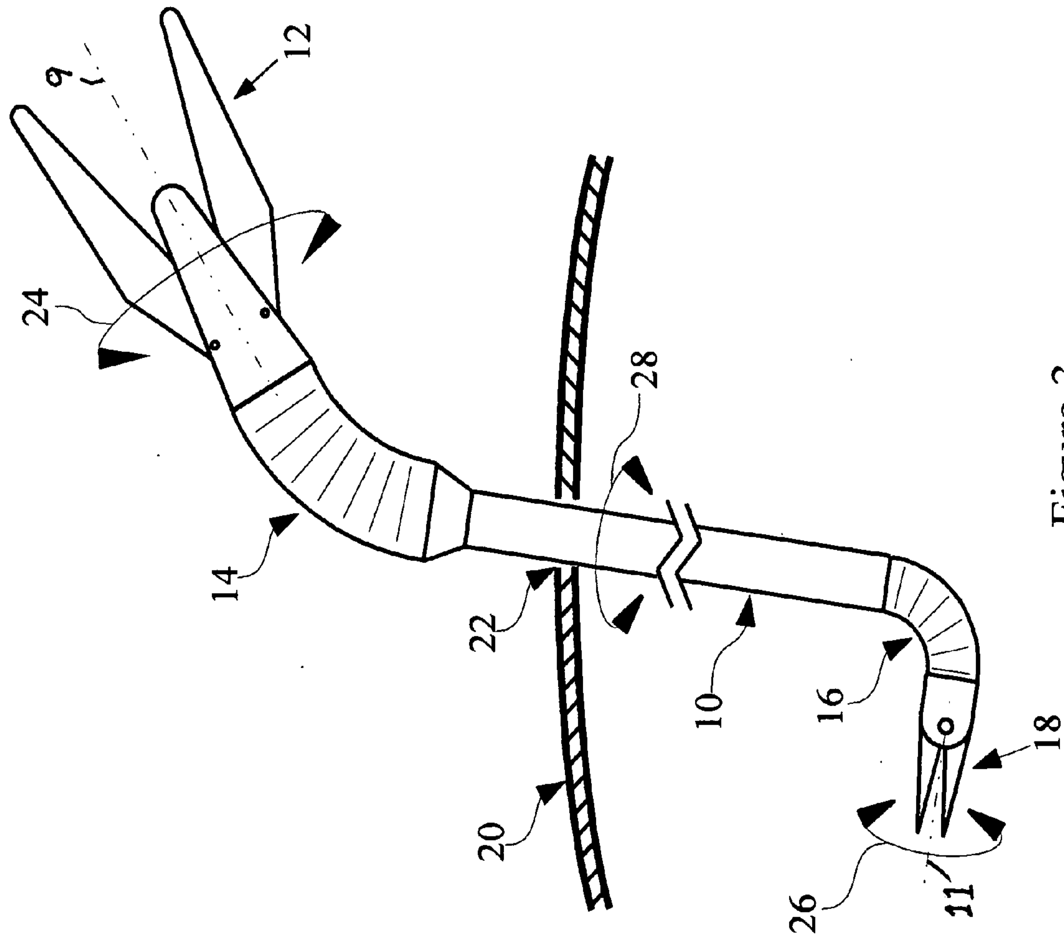



Figure 3

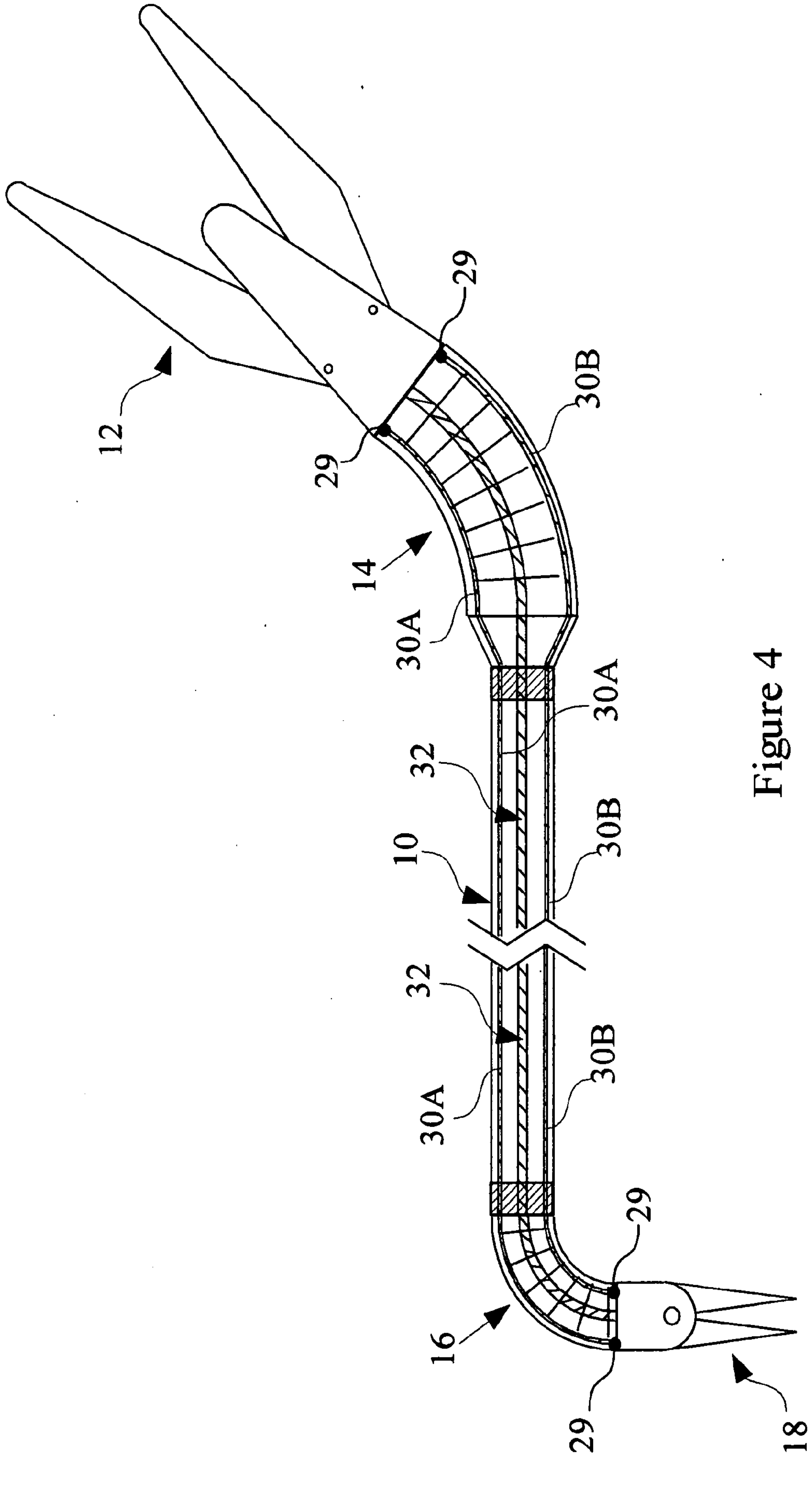



Figure 4

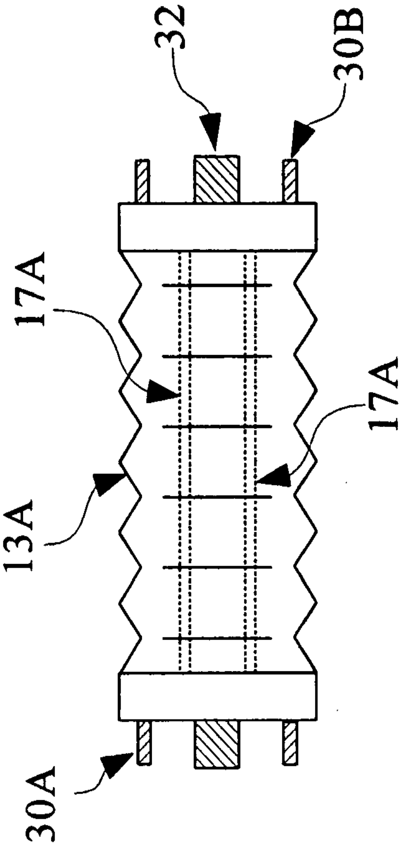



Figure 5B

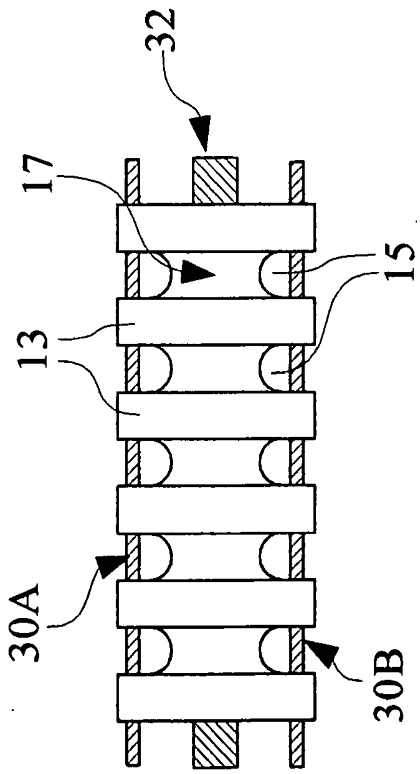



Figure 5A

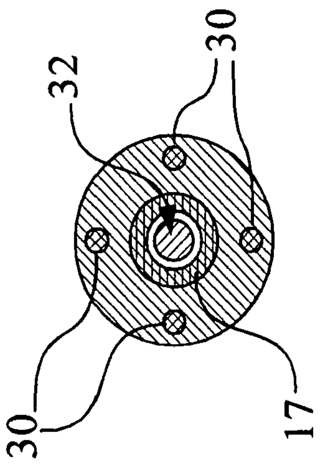



Figure 5C

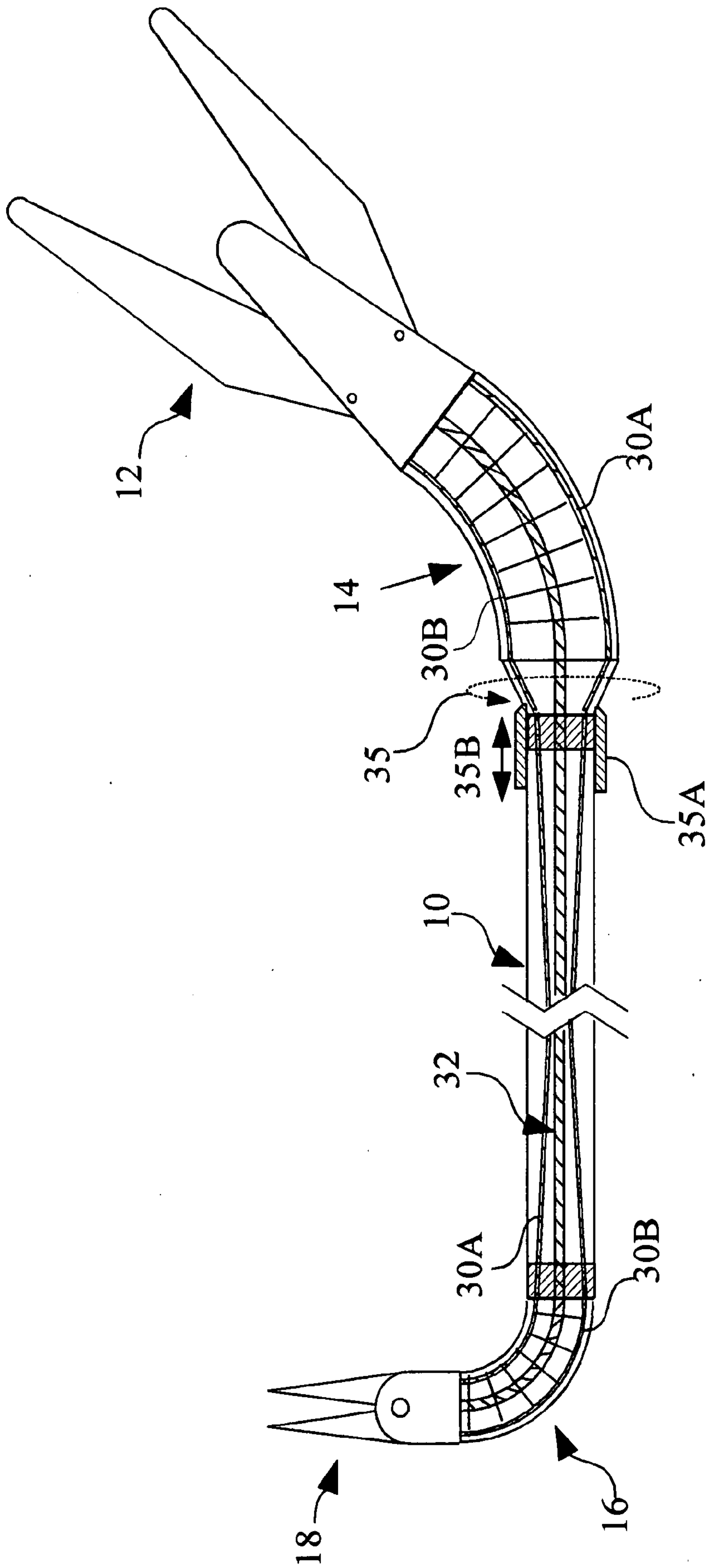



Figure 6

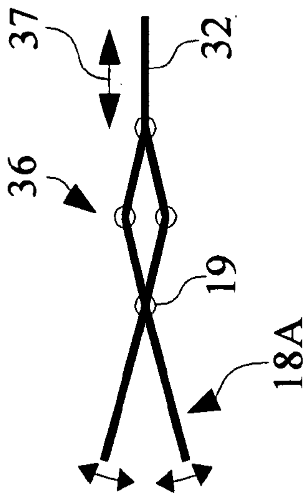



Figure 7A

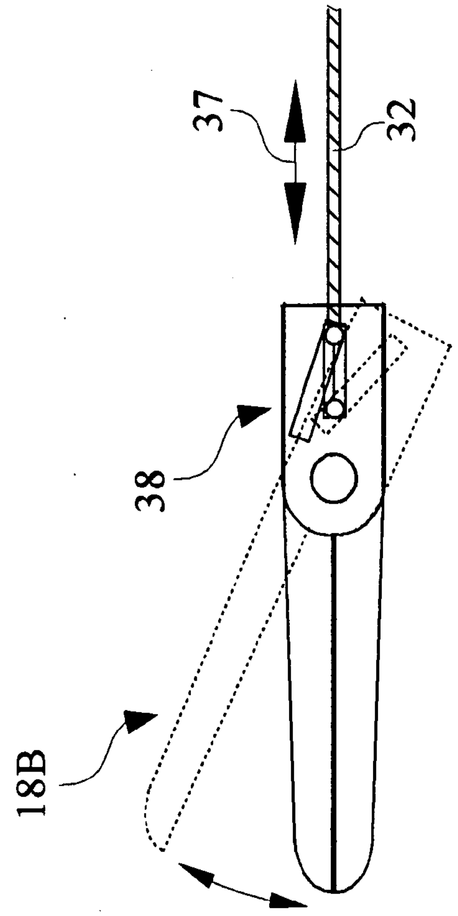



Figure 7B

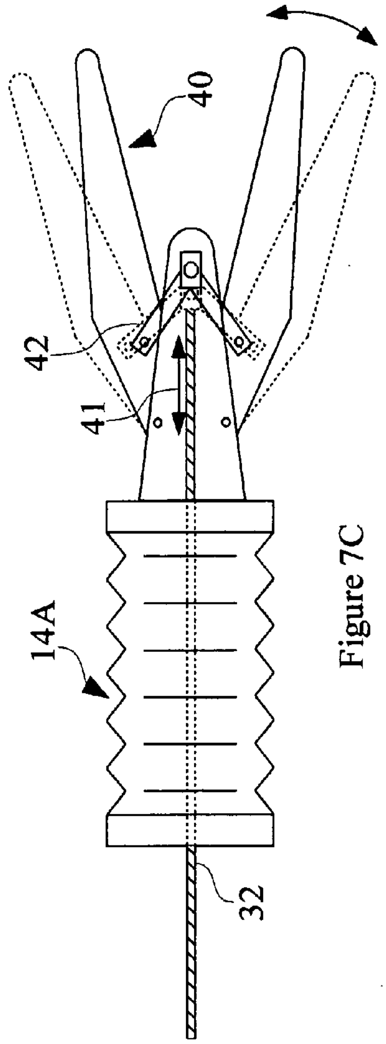



Figure 7C

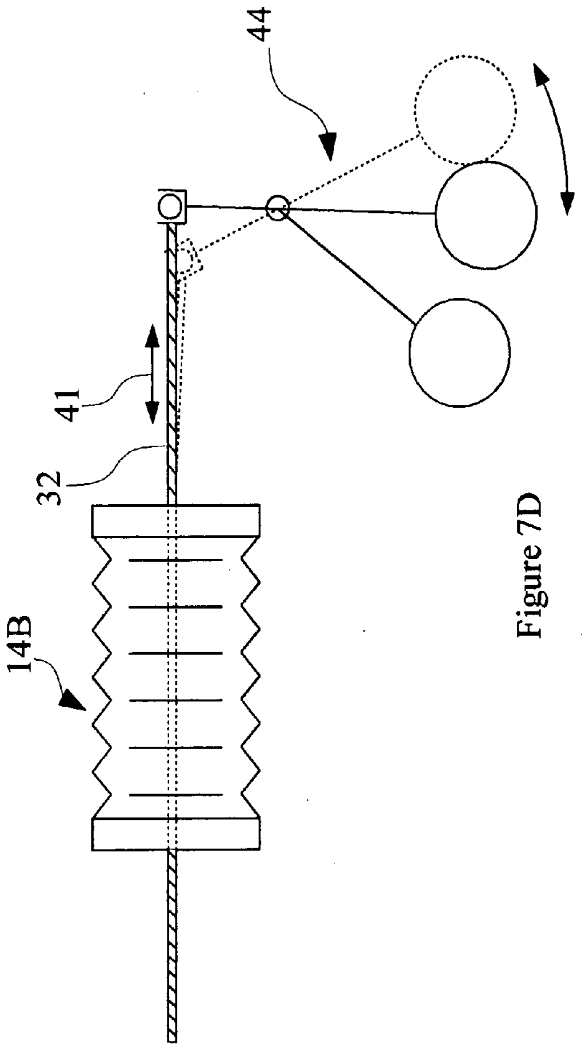



Figure 7D

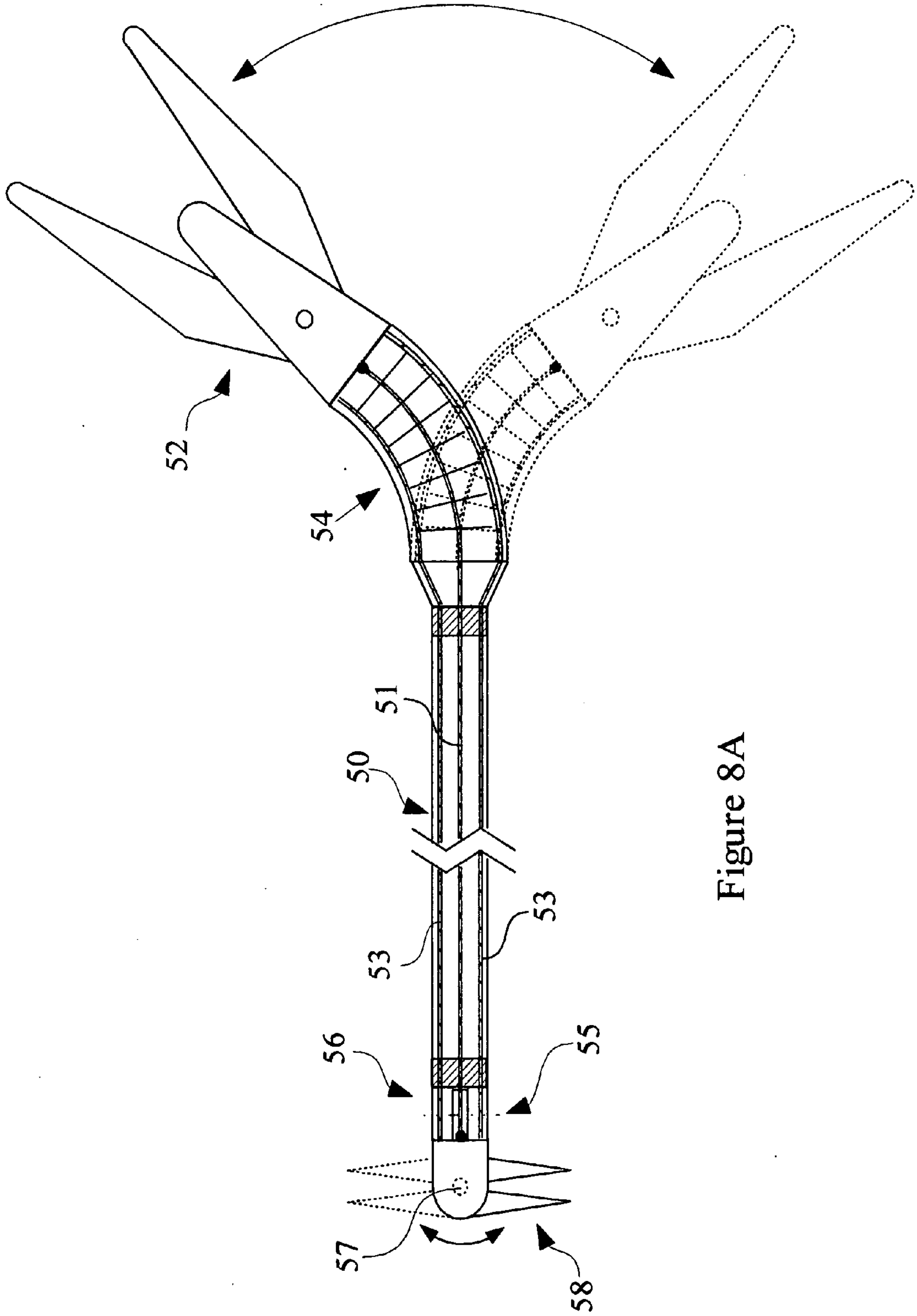



Figure 8A

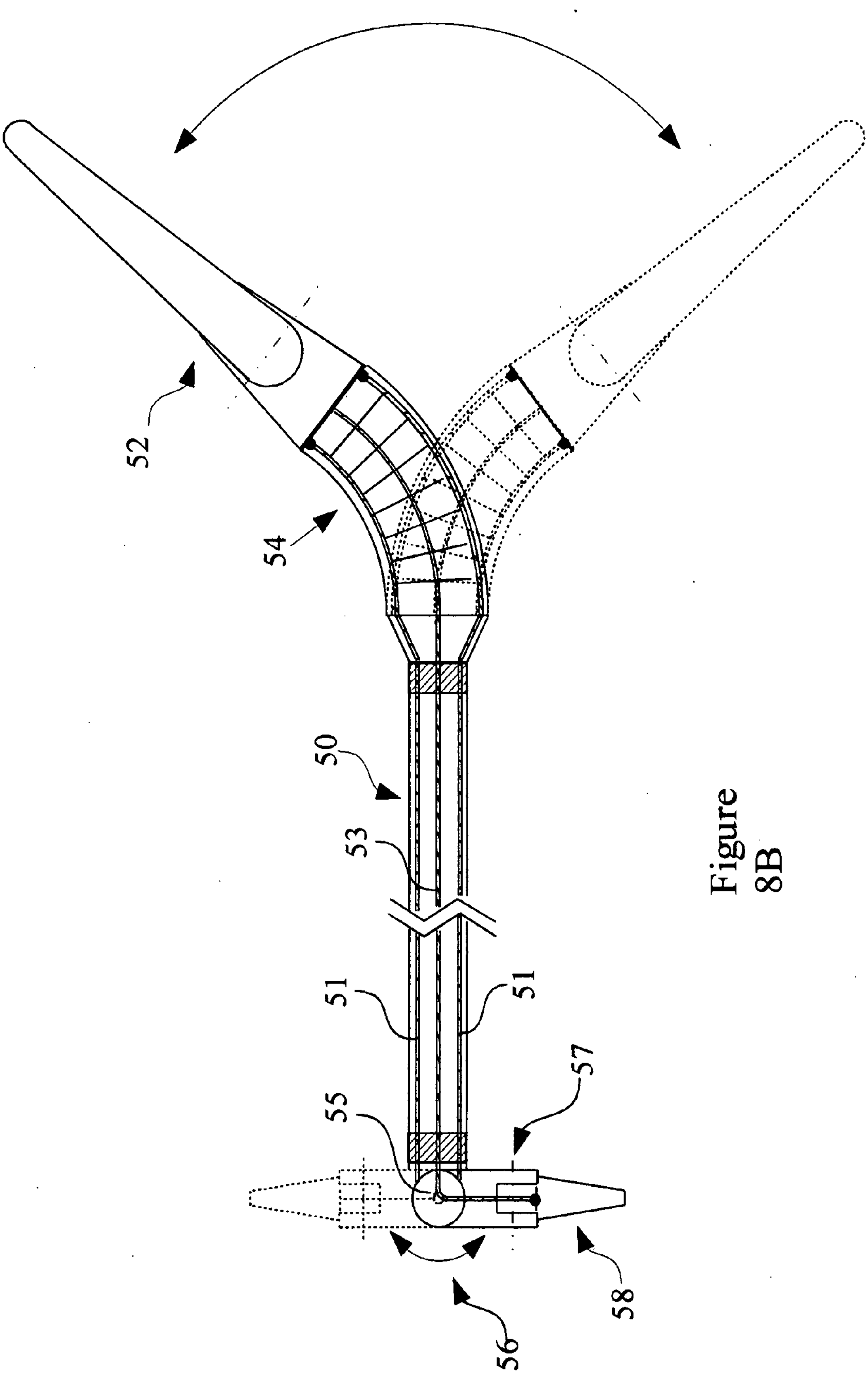
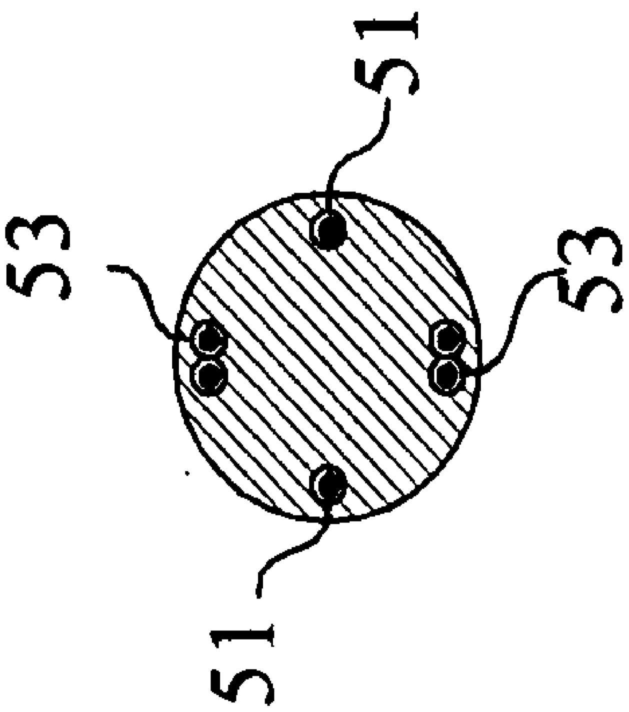



Figure 8B

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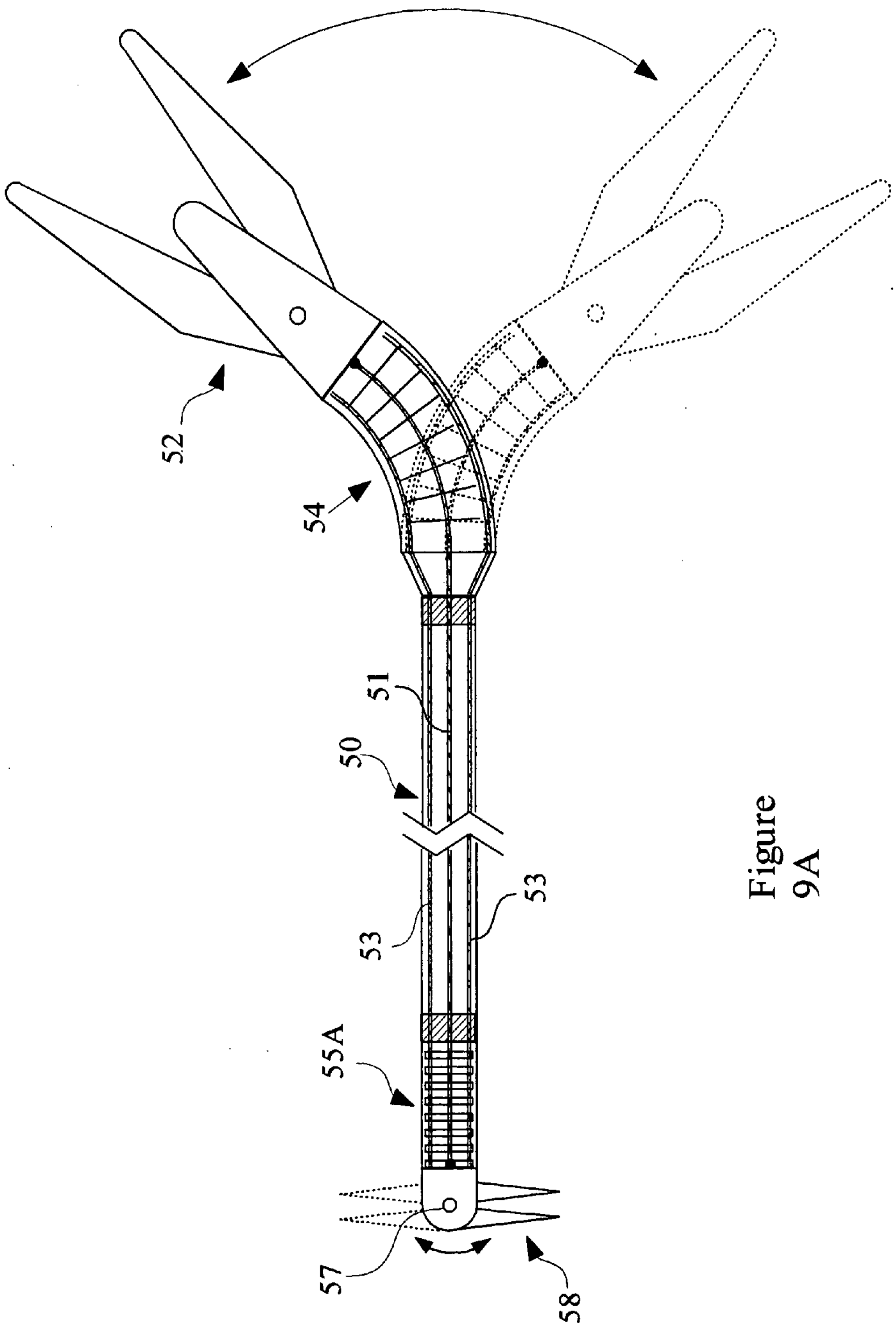


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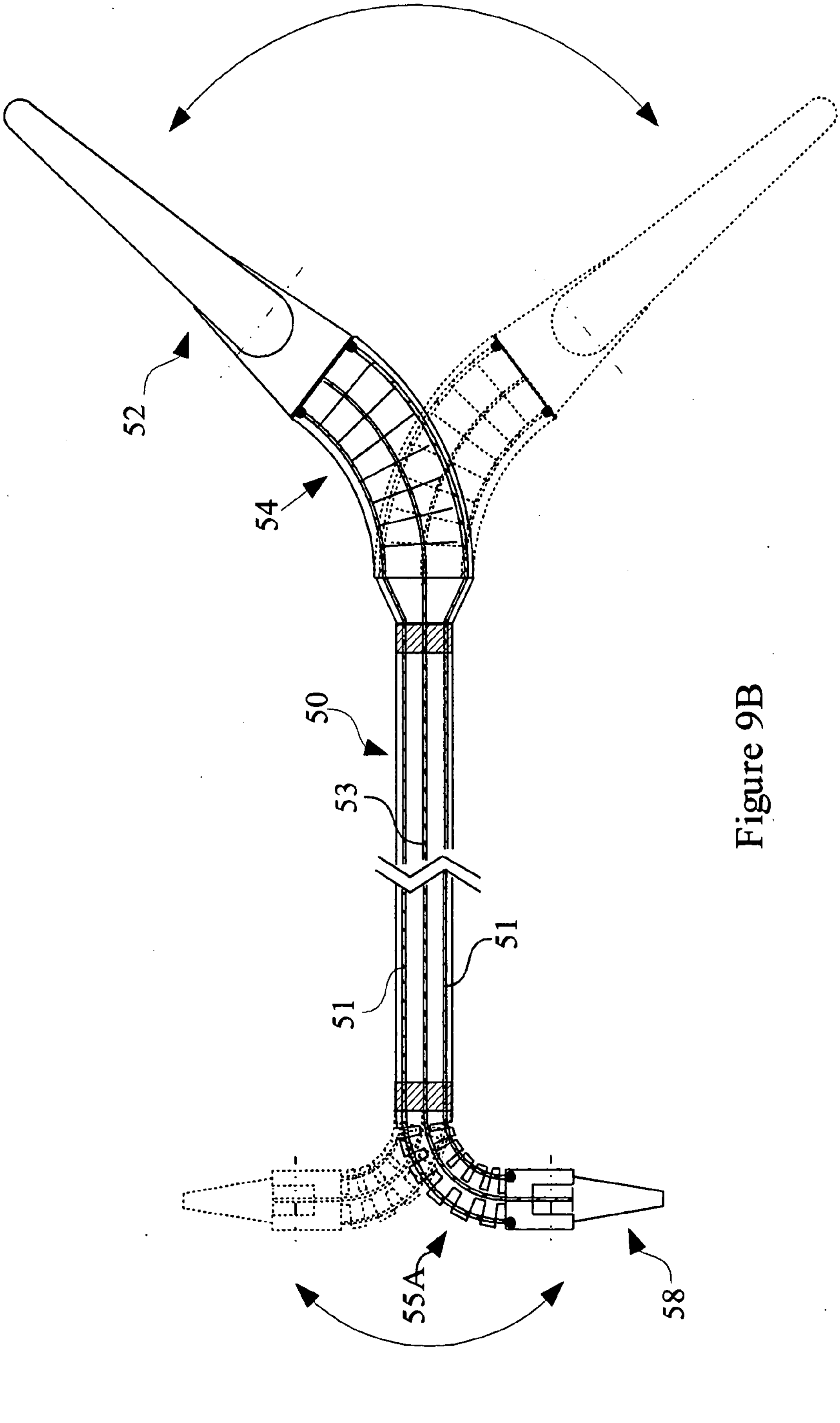


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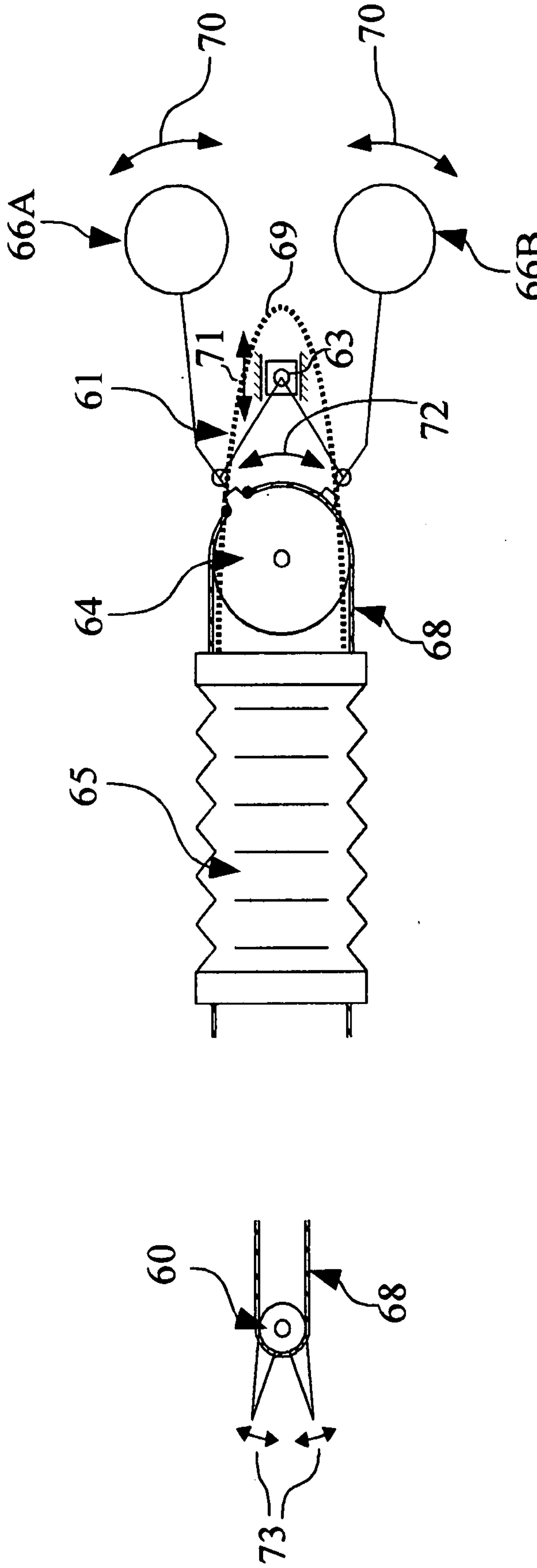
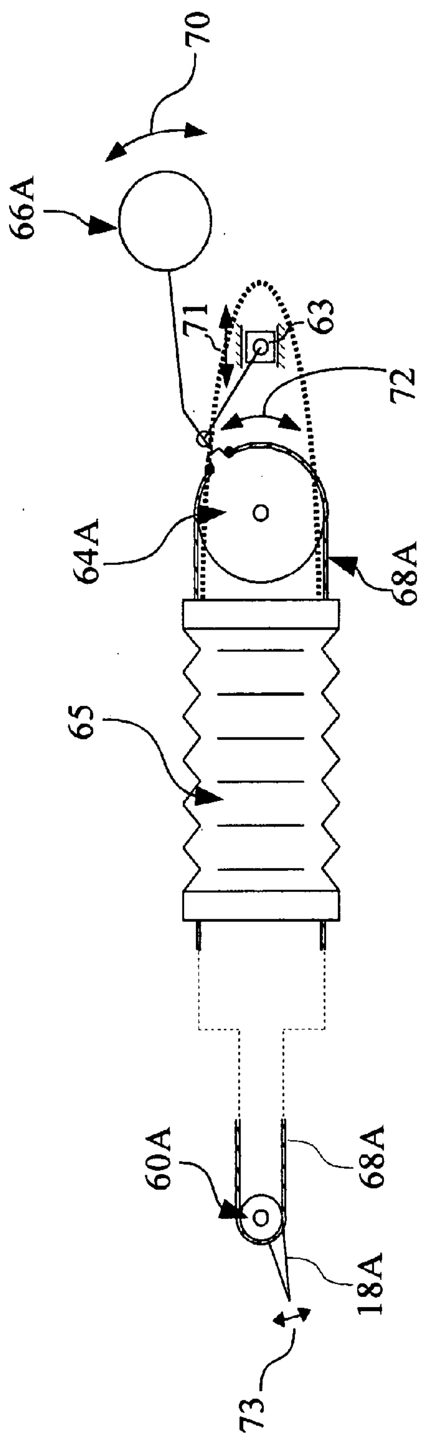



Figure 10A

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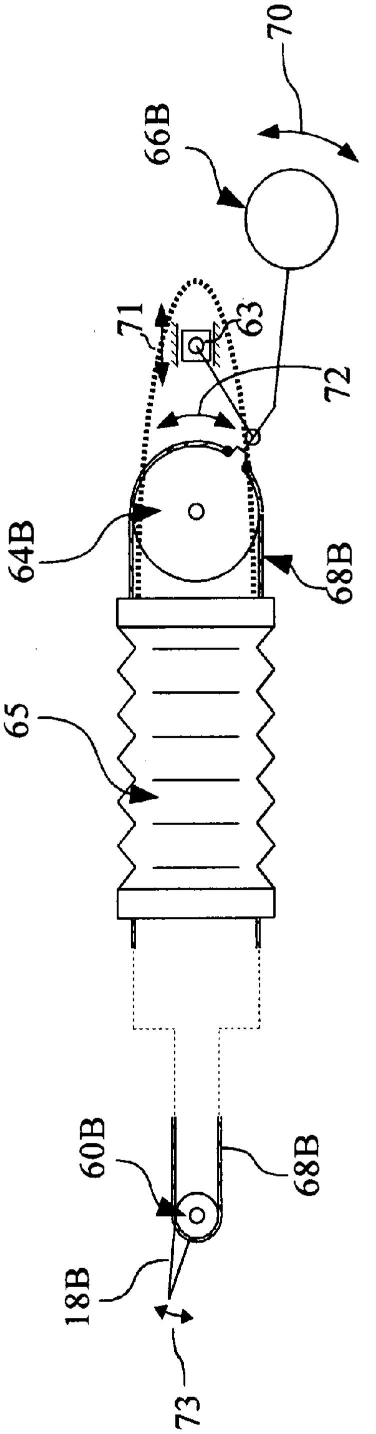


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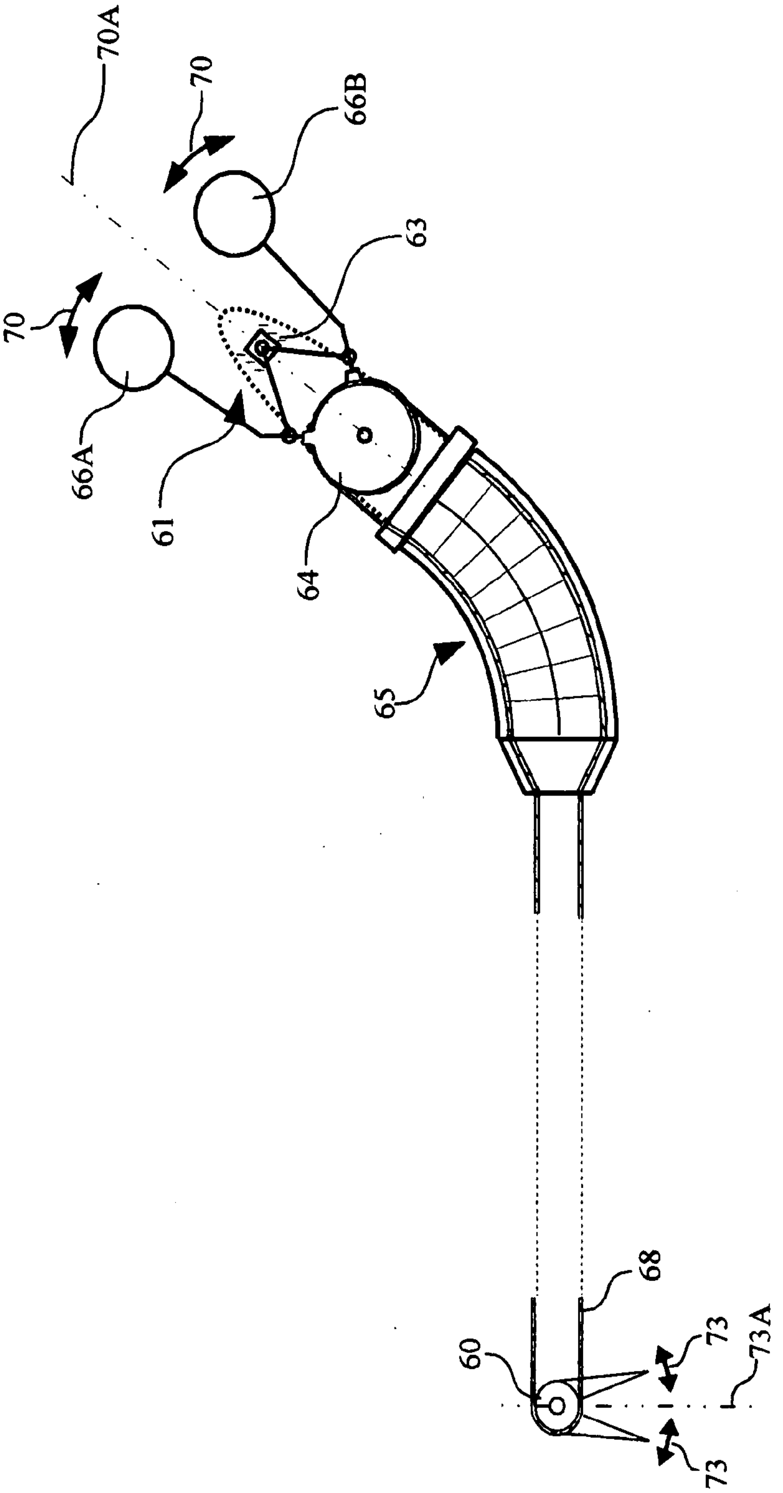


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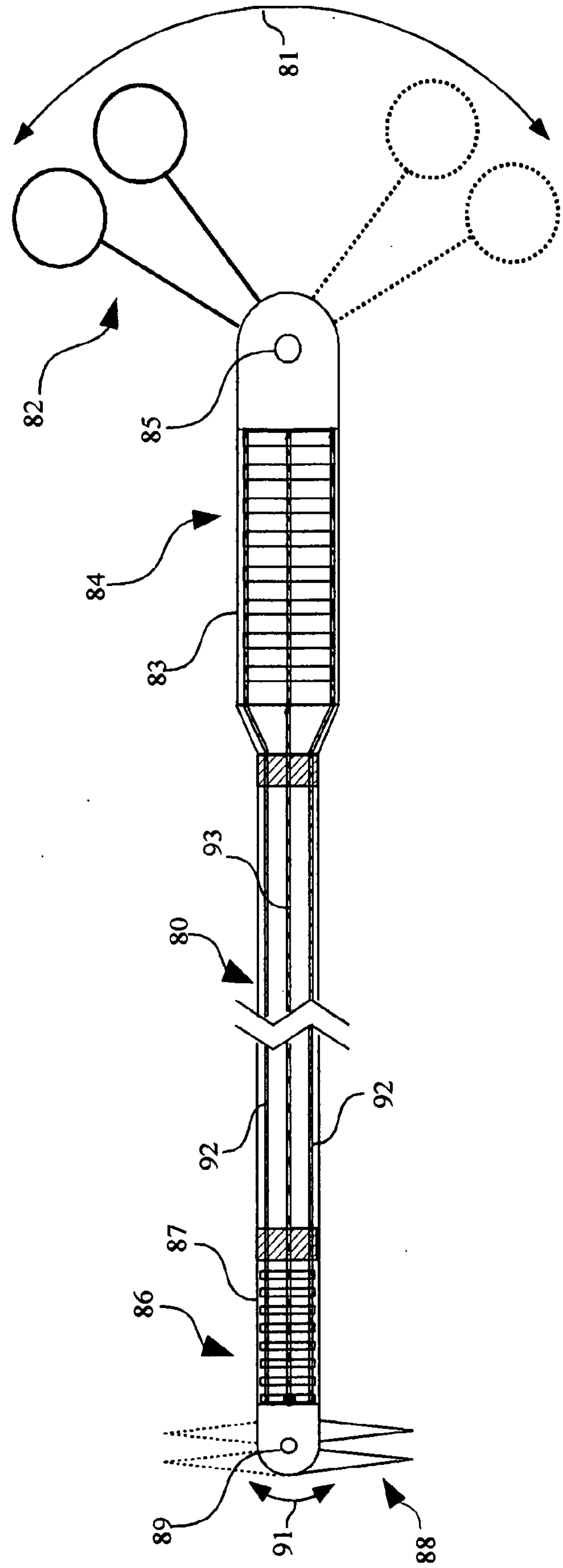



Figure 11A

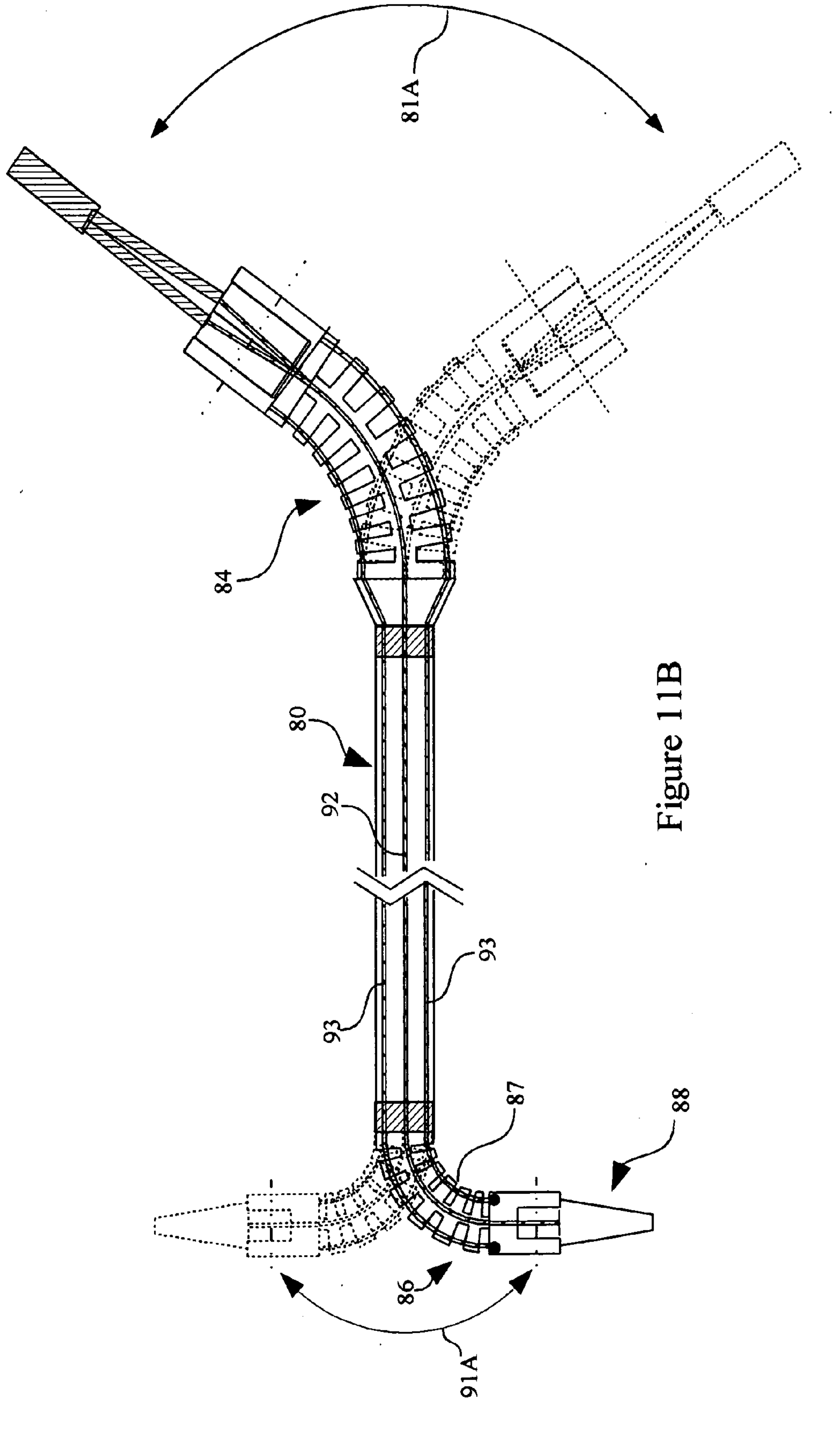
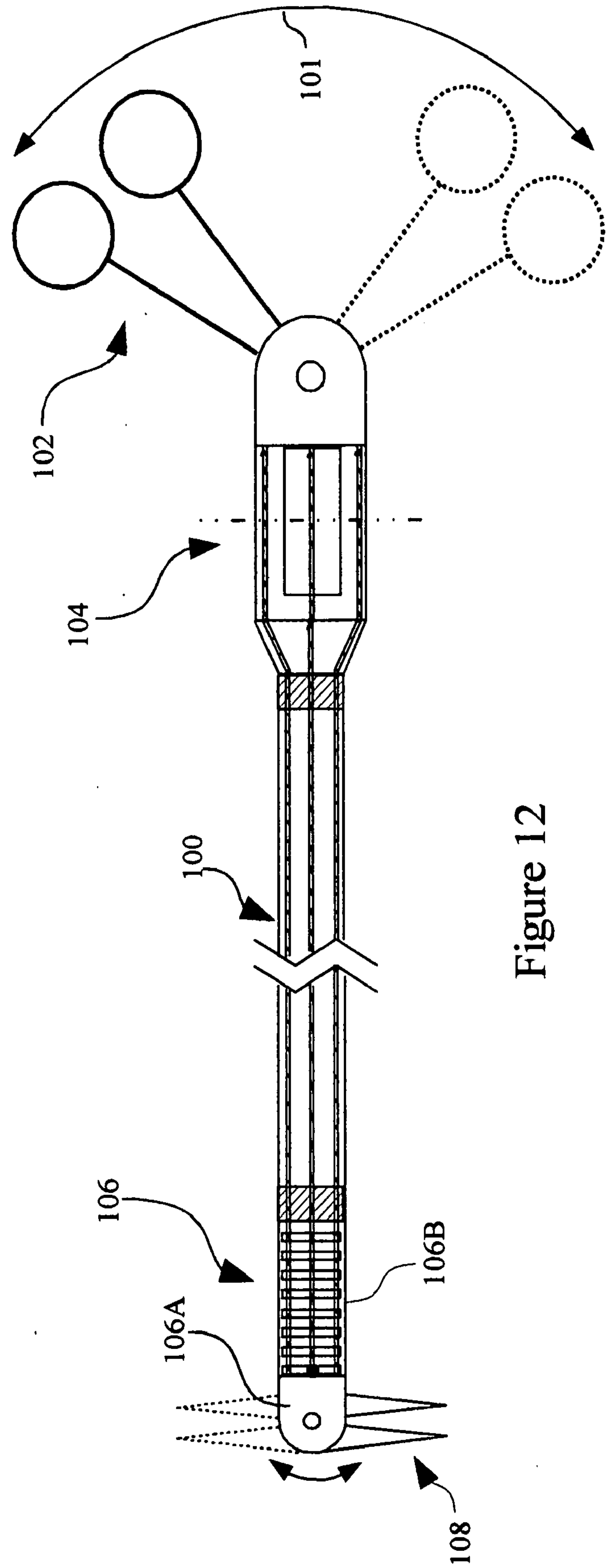



Figure 11B

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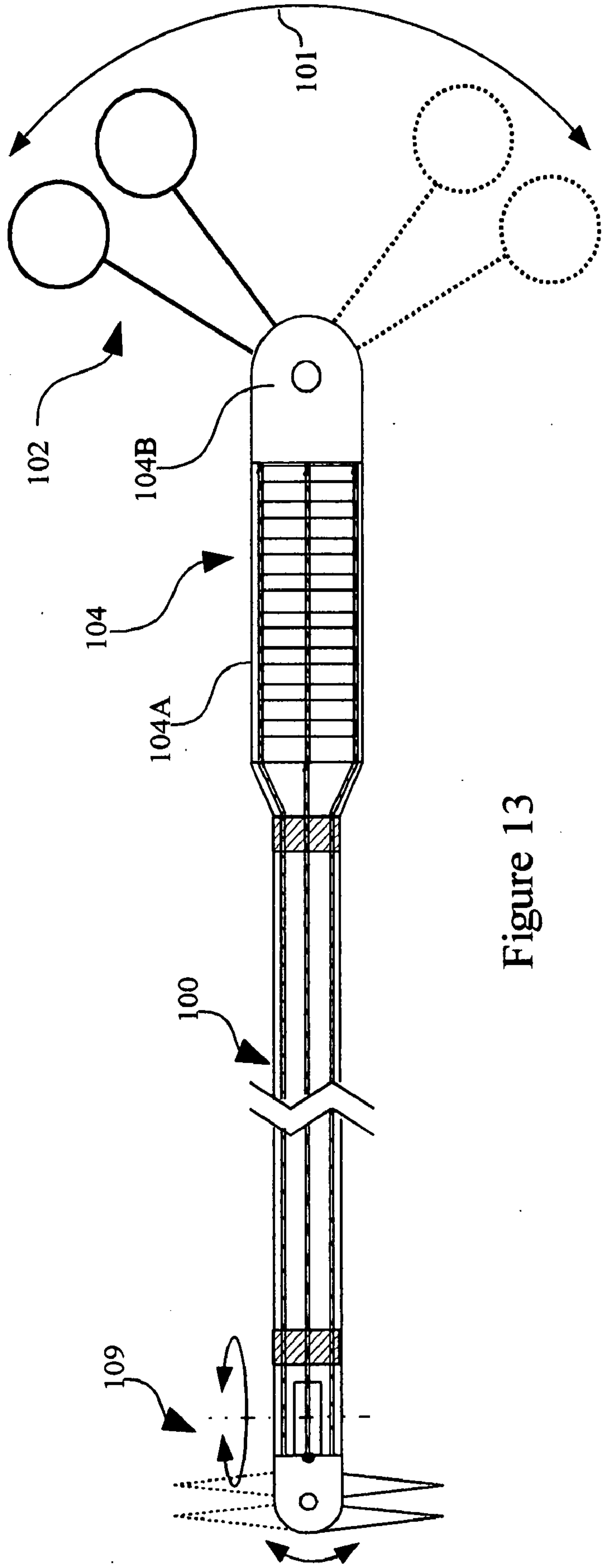


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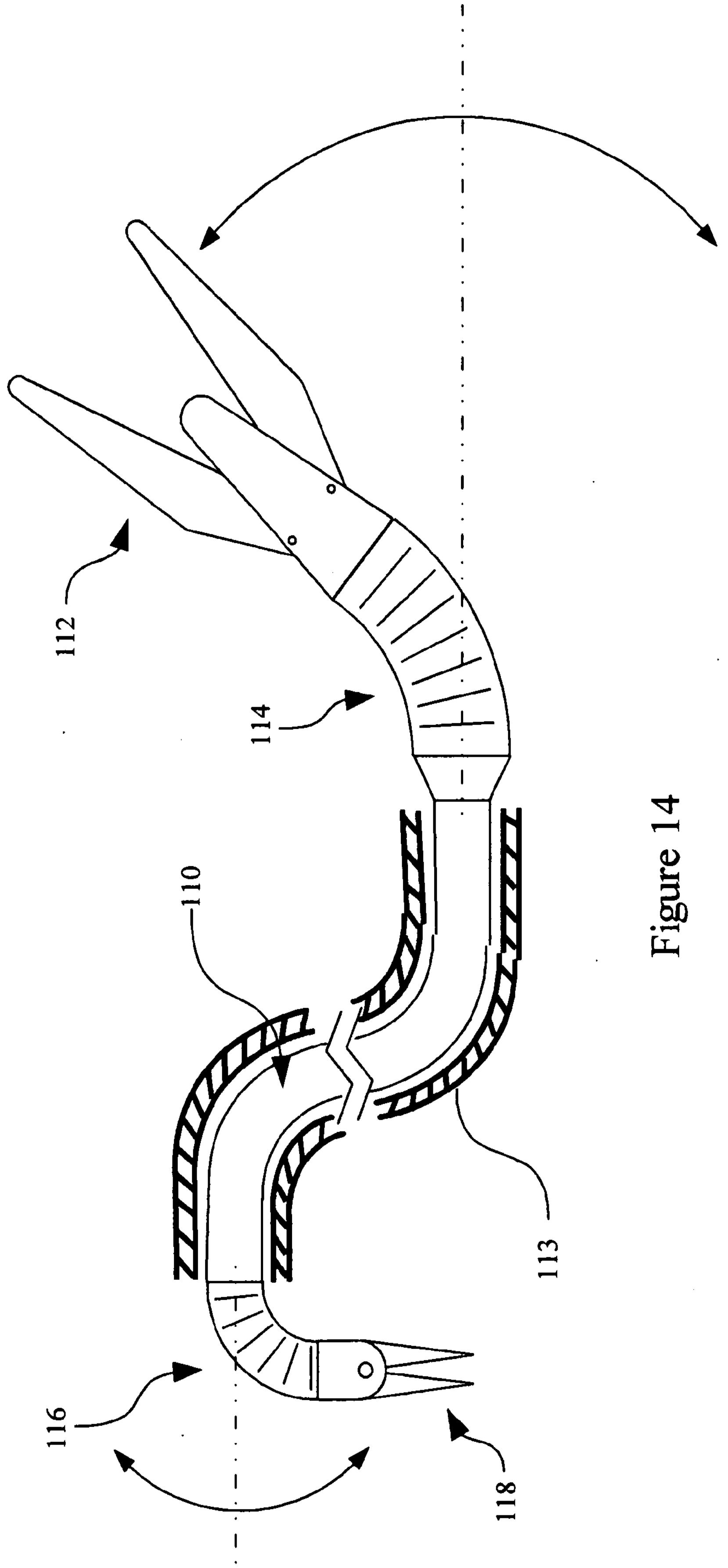


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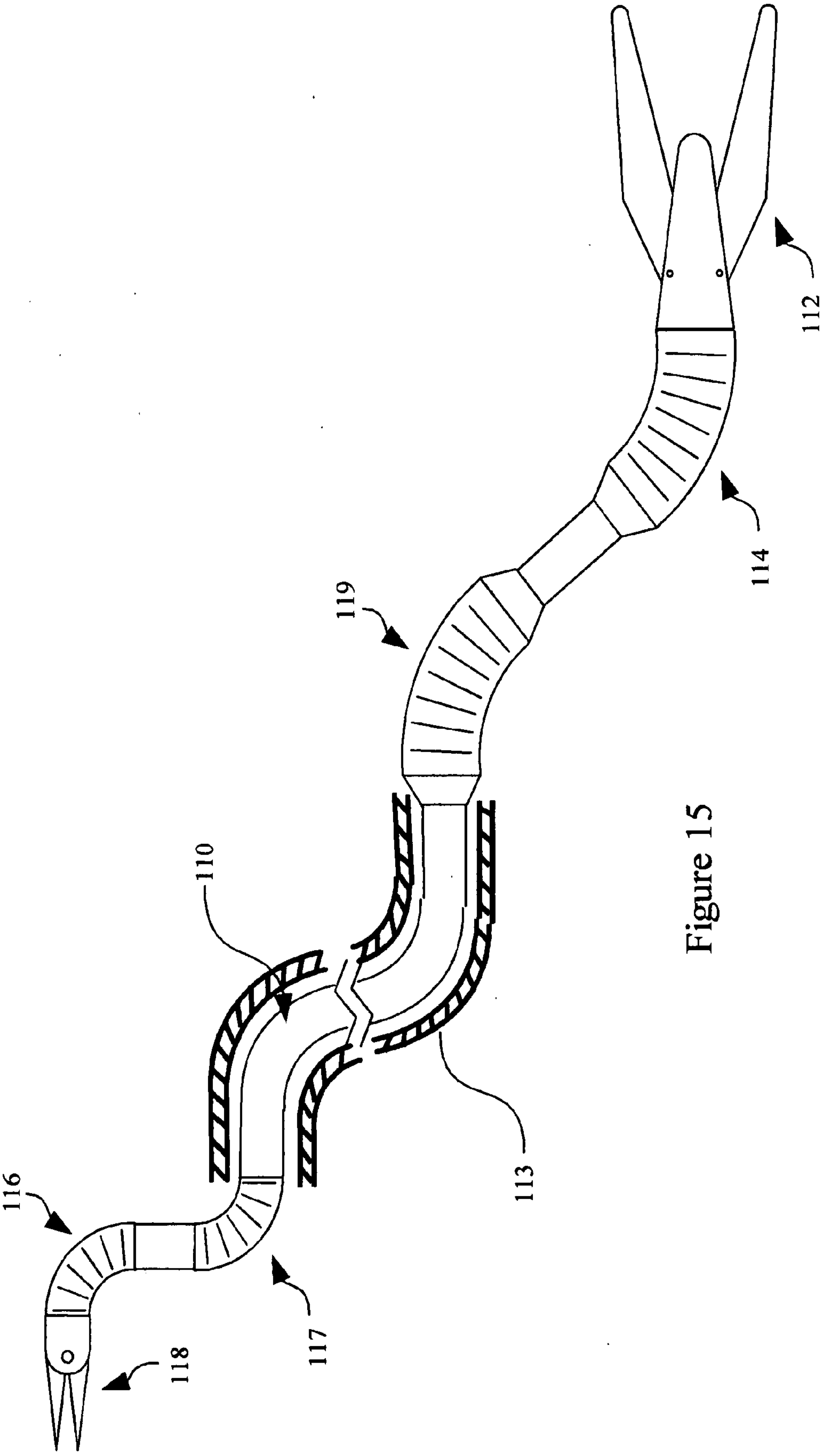


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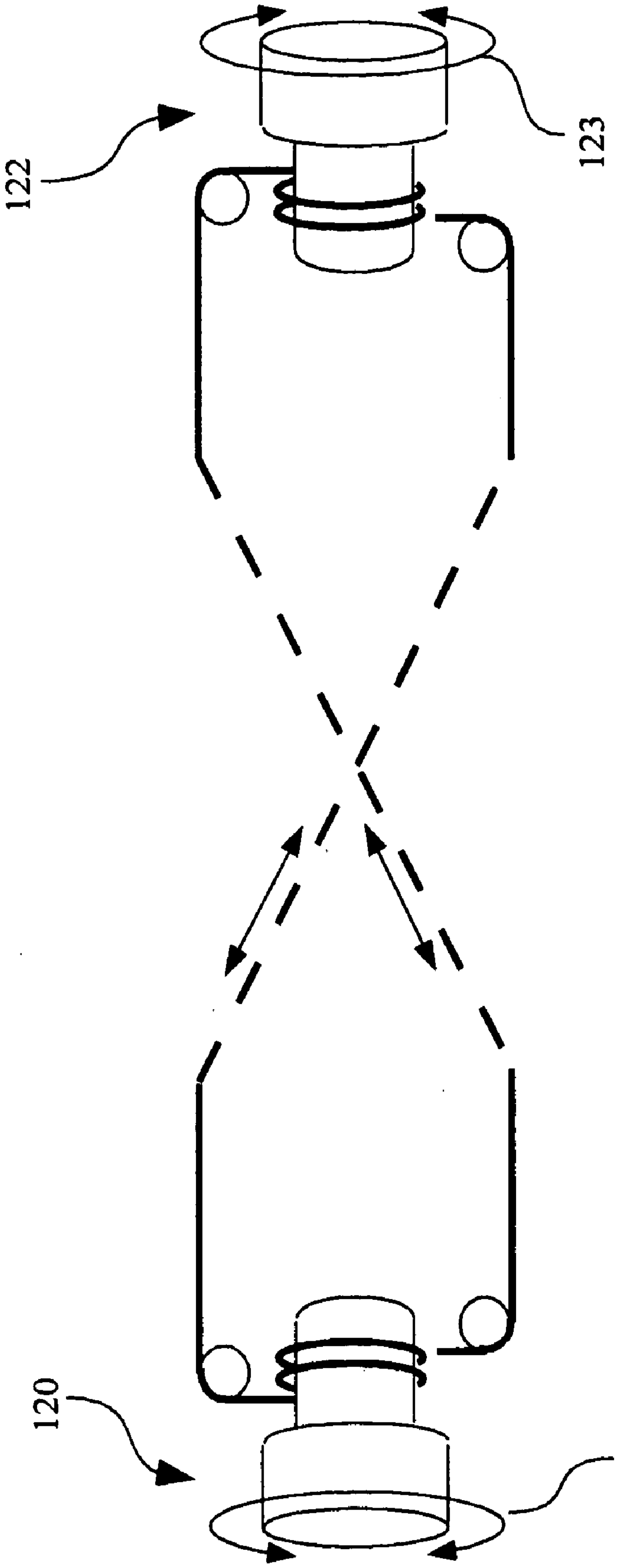


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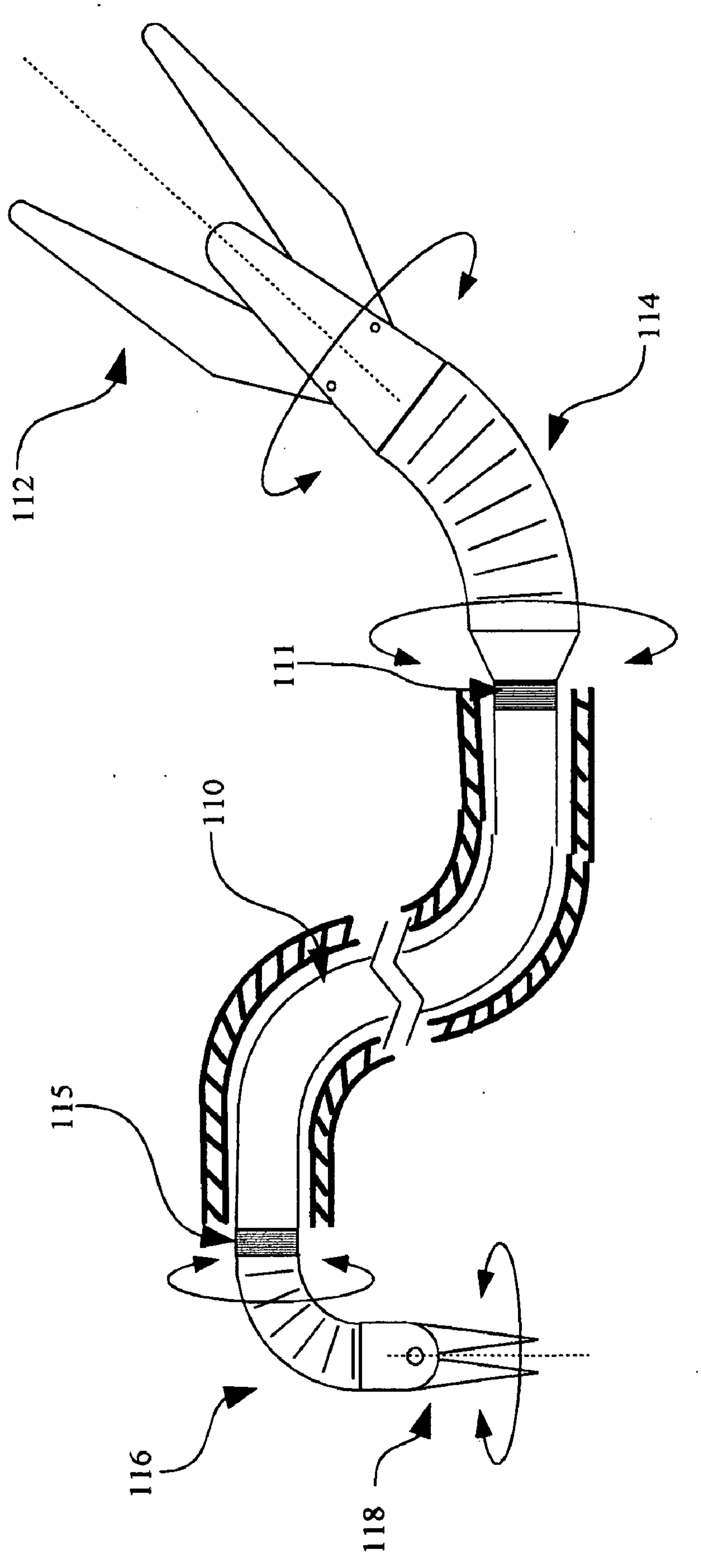



Figure 17A

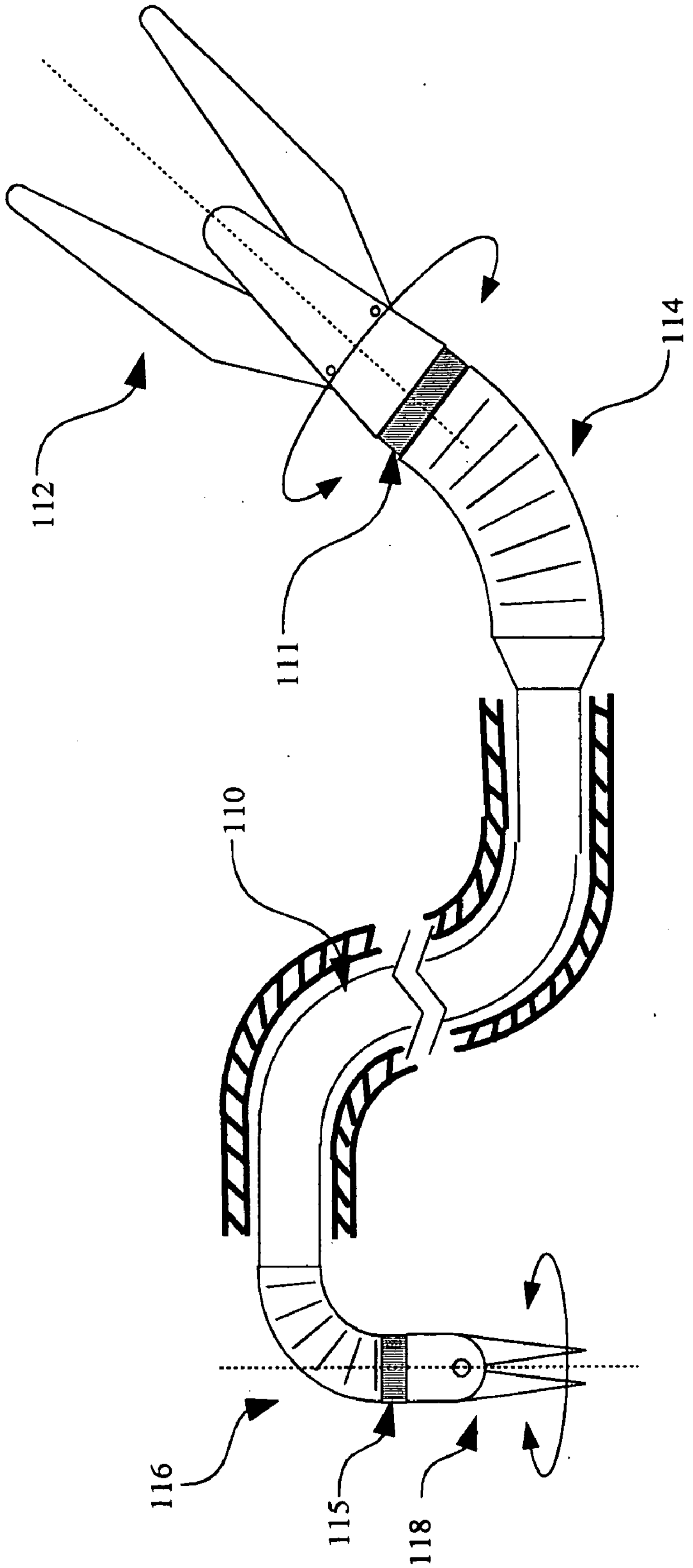
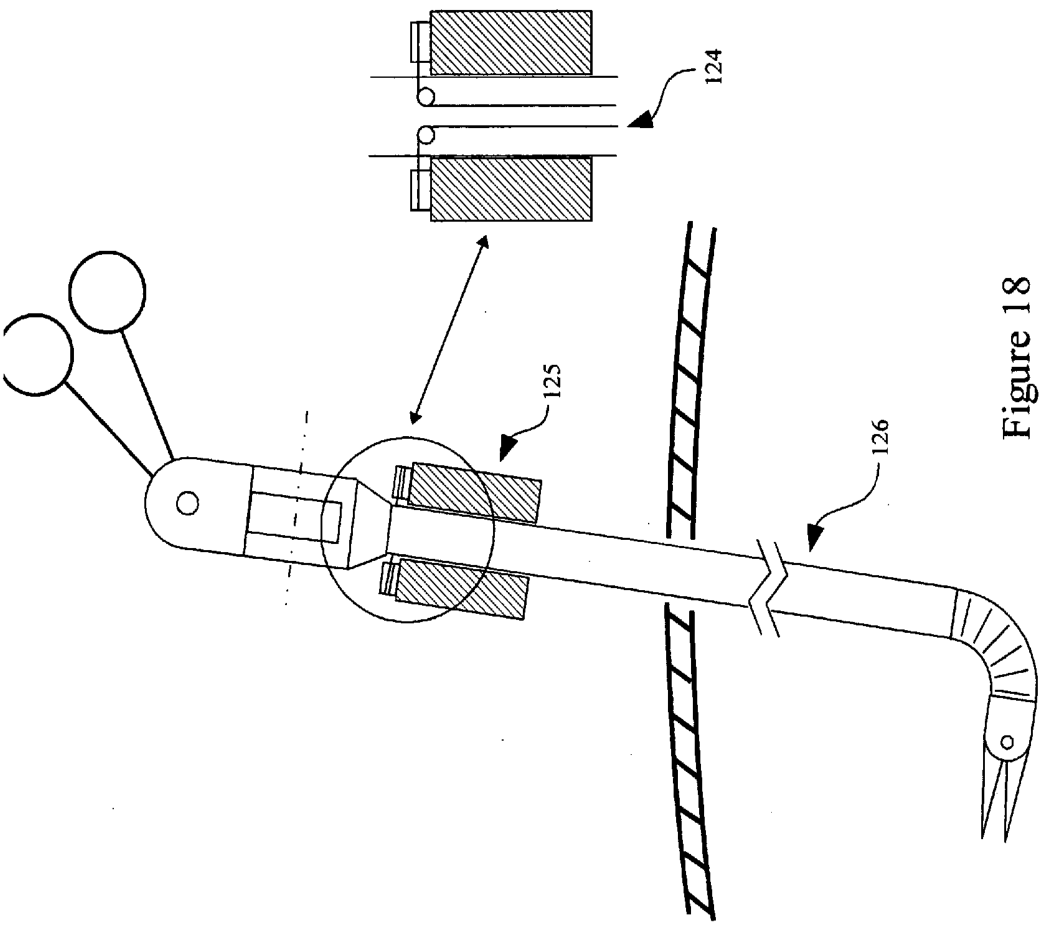



Figure 17B

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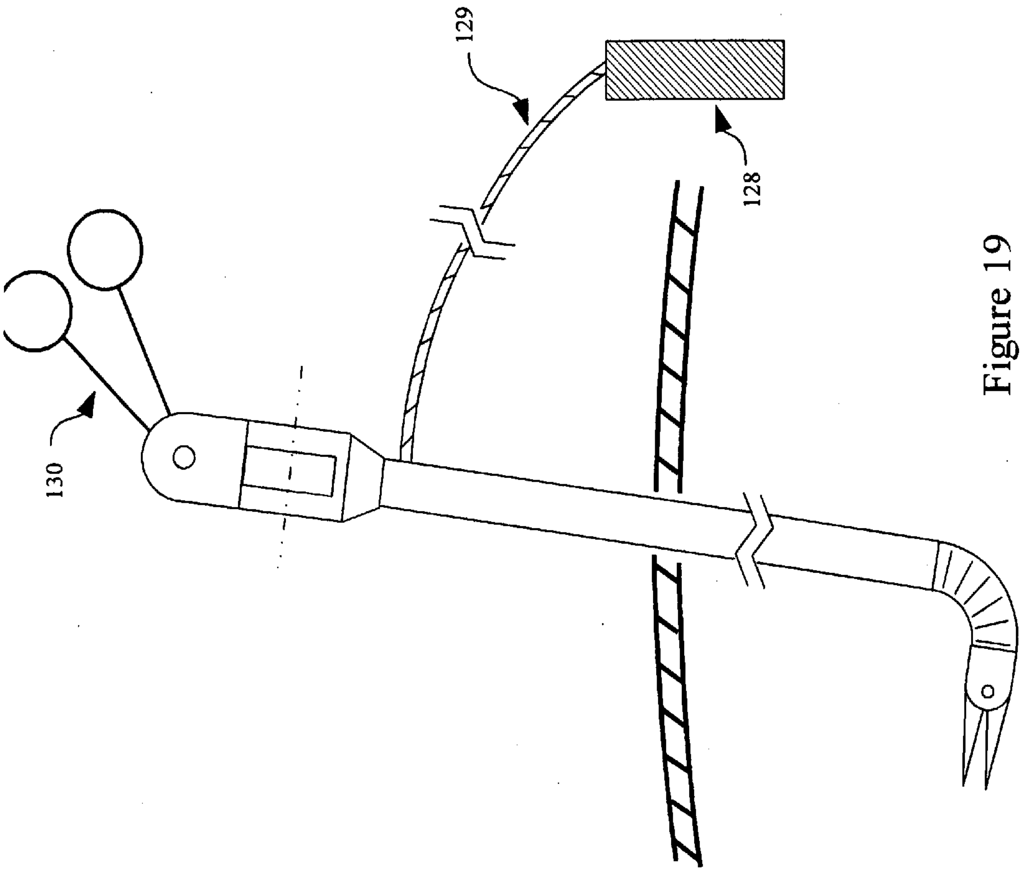


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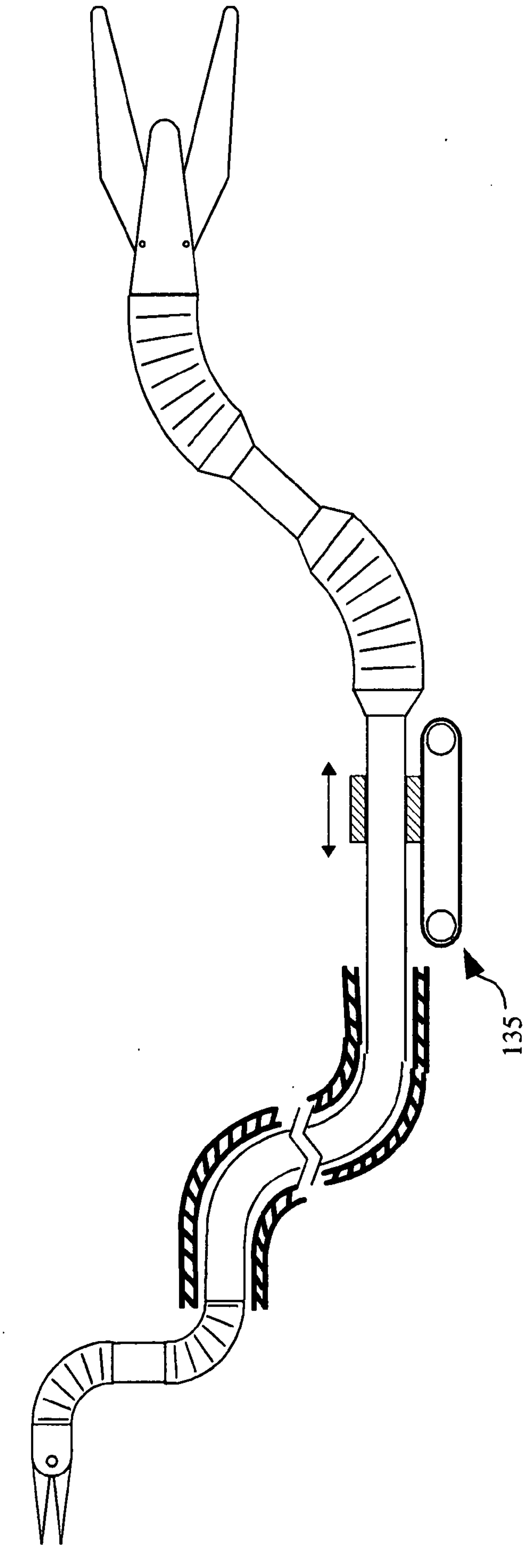


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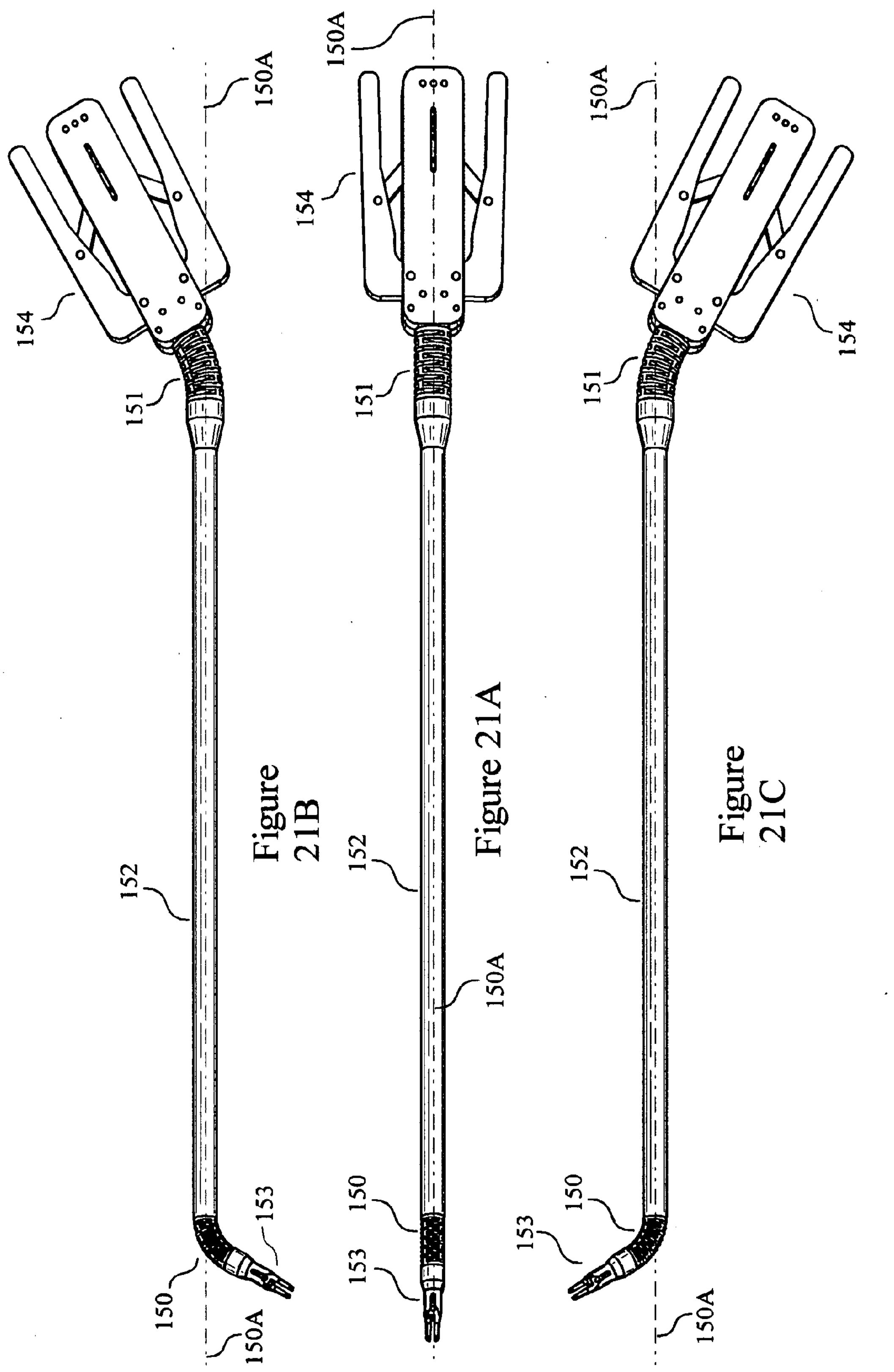


Figure 21B

Figure 21A

Figure 21C

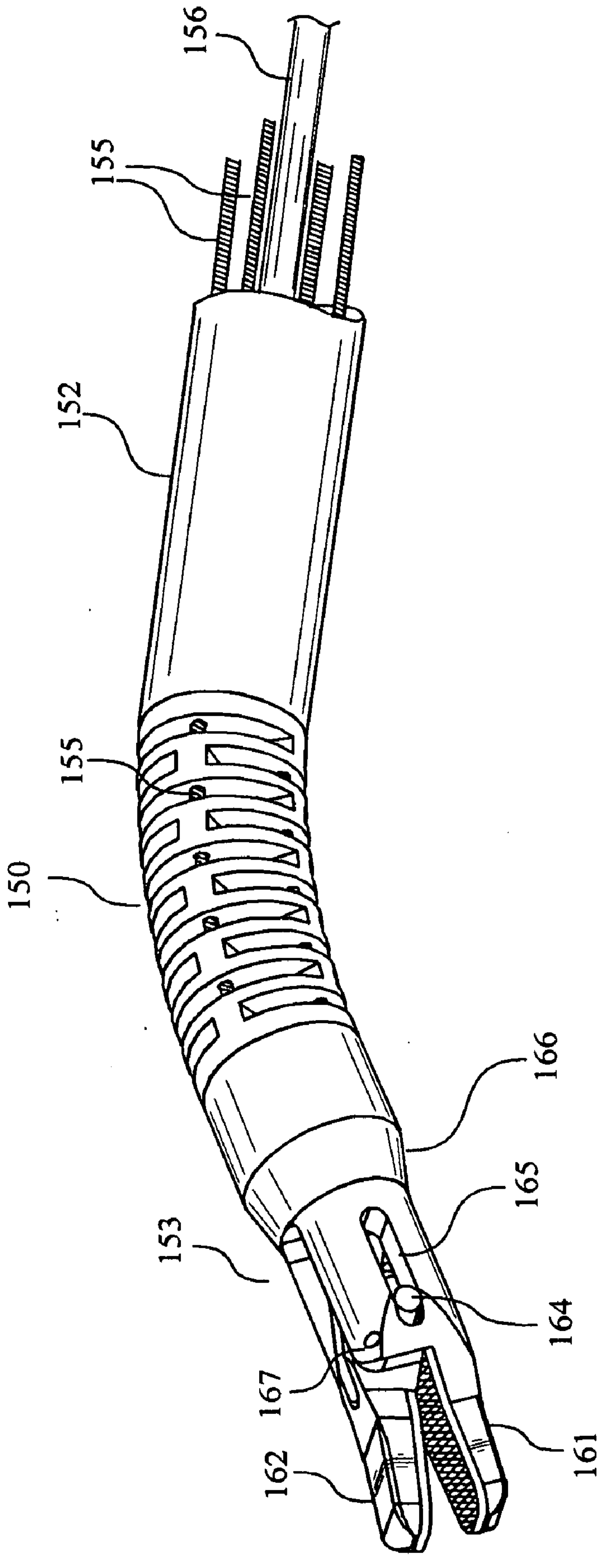


Figure 22A

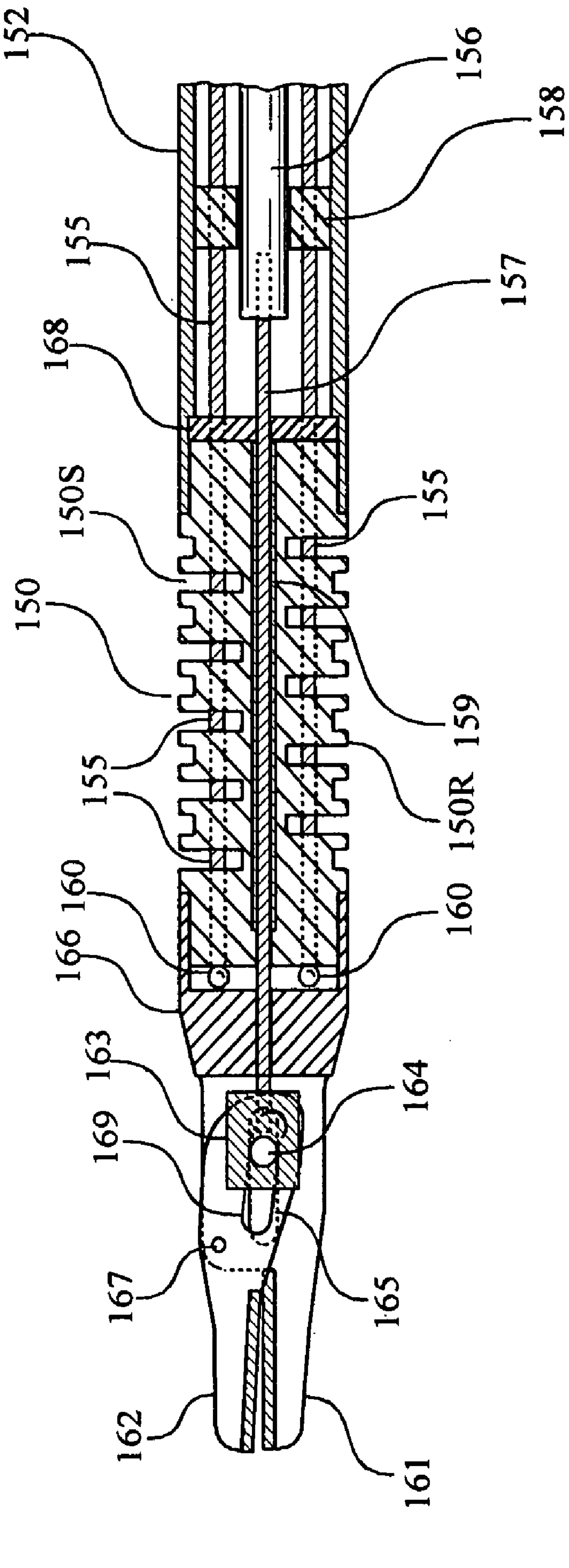
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Figure 22B

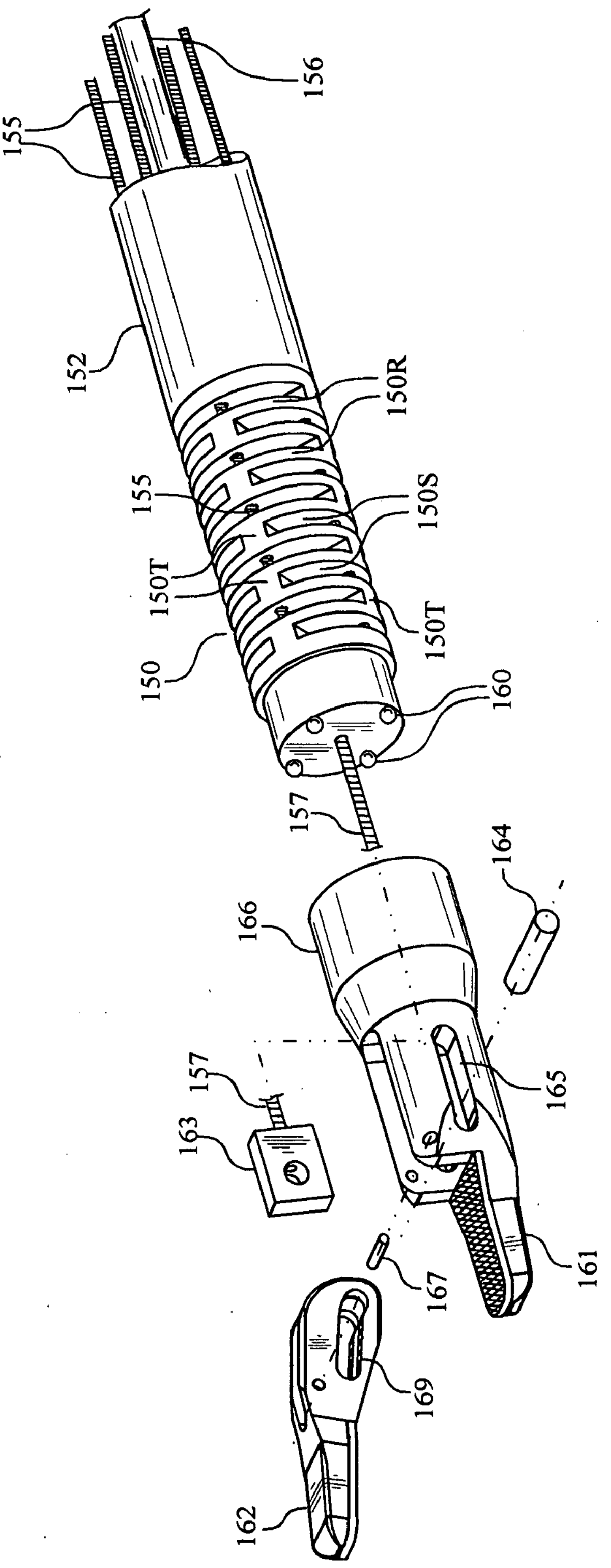
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Figure 22C

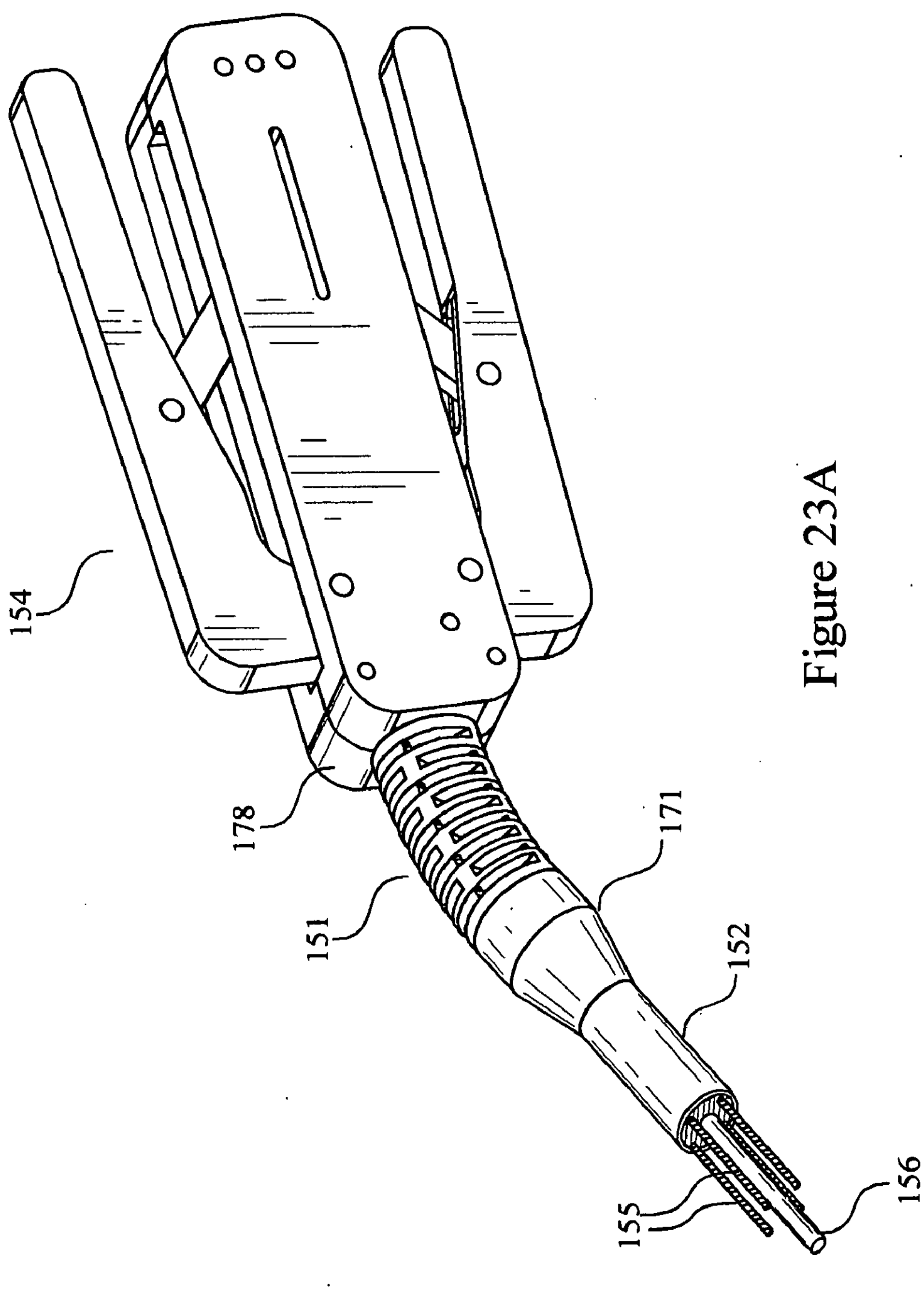


Figure 23A

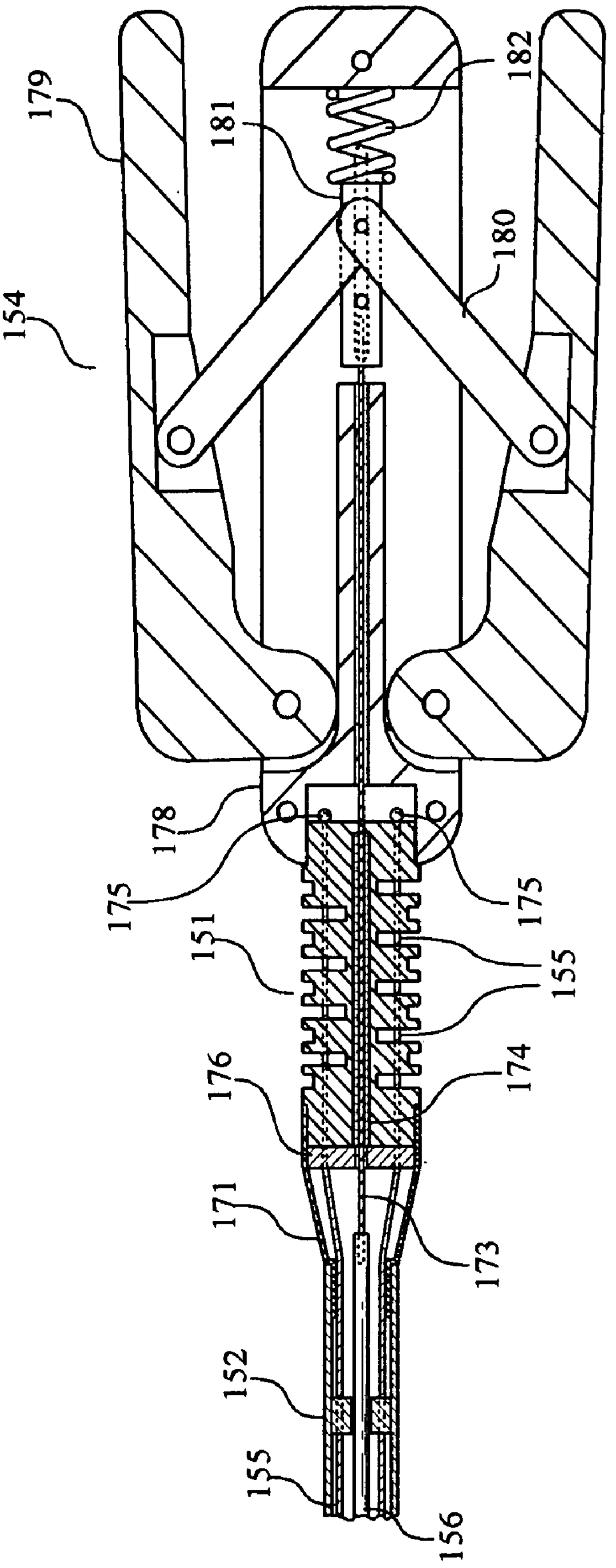
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Figure 23B

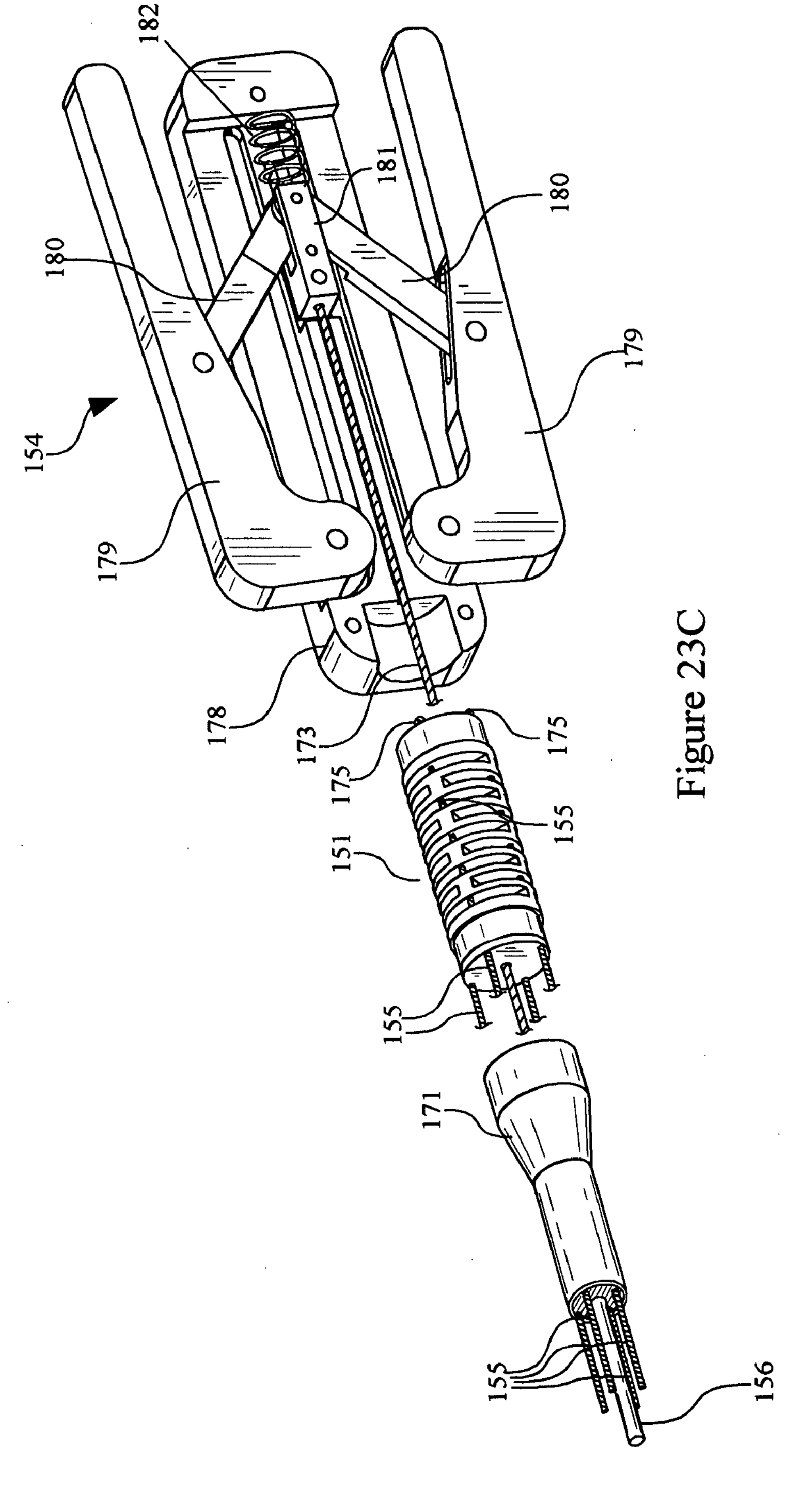

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Figure 23C

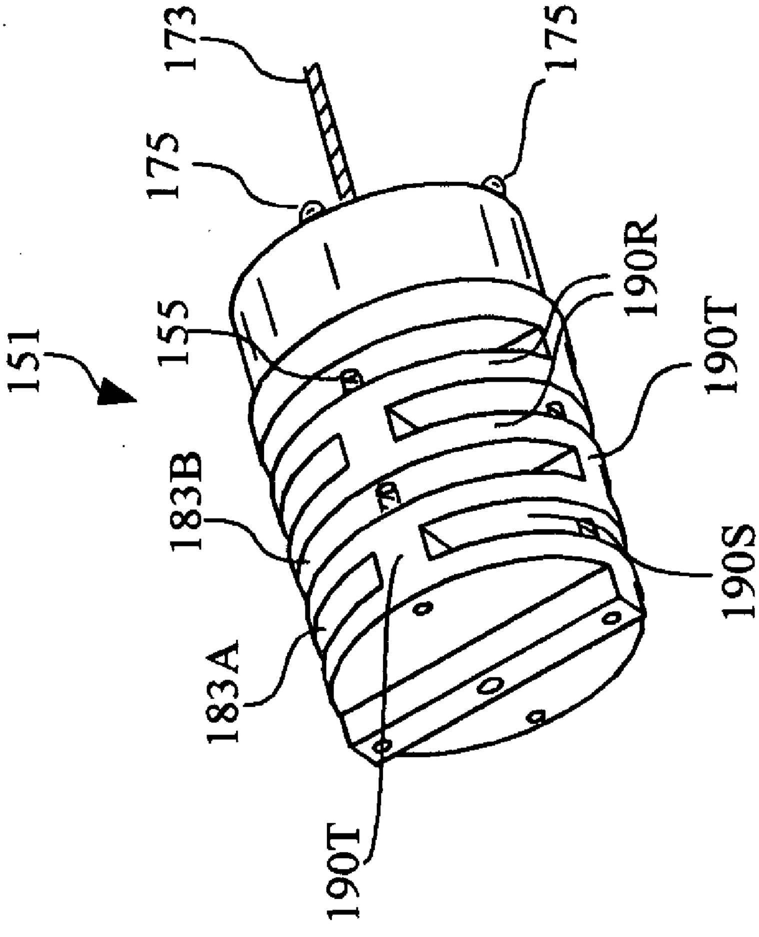


Figure 23D

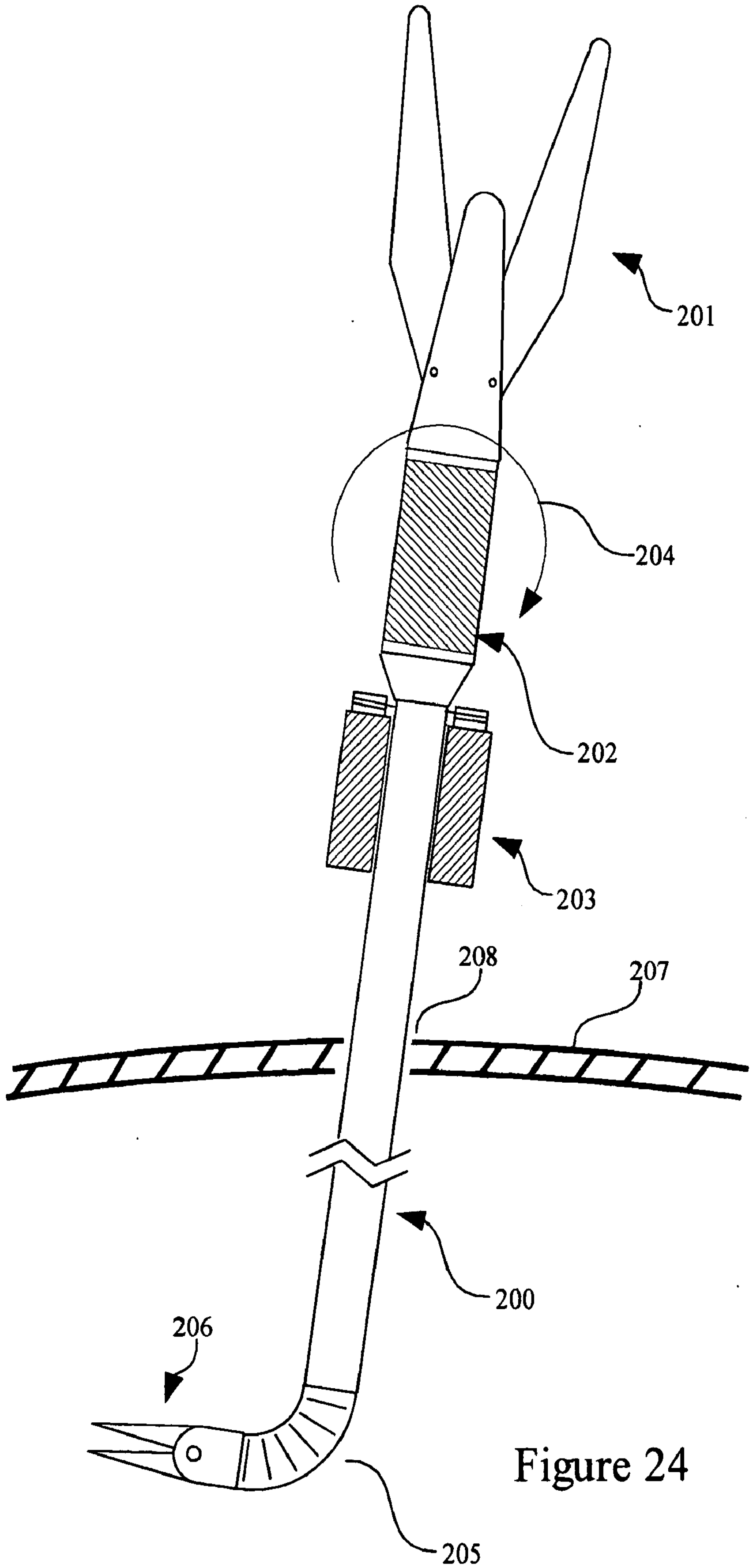


Figure 24

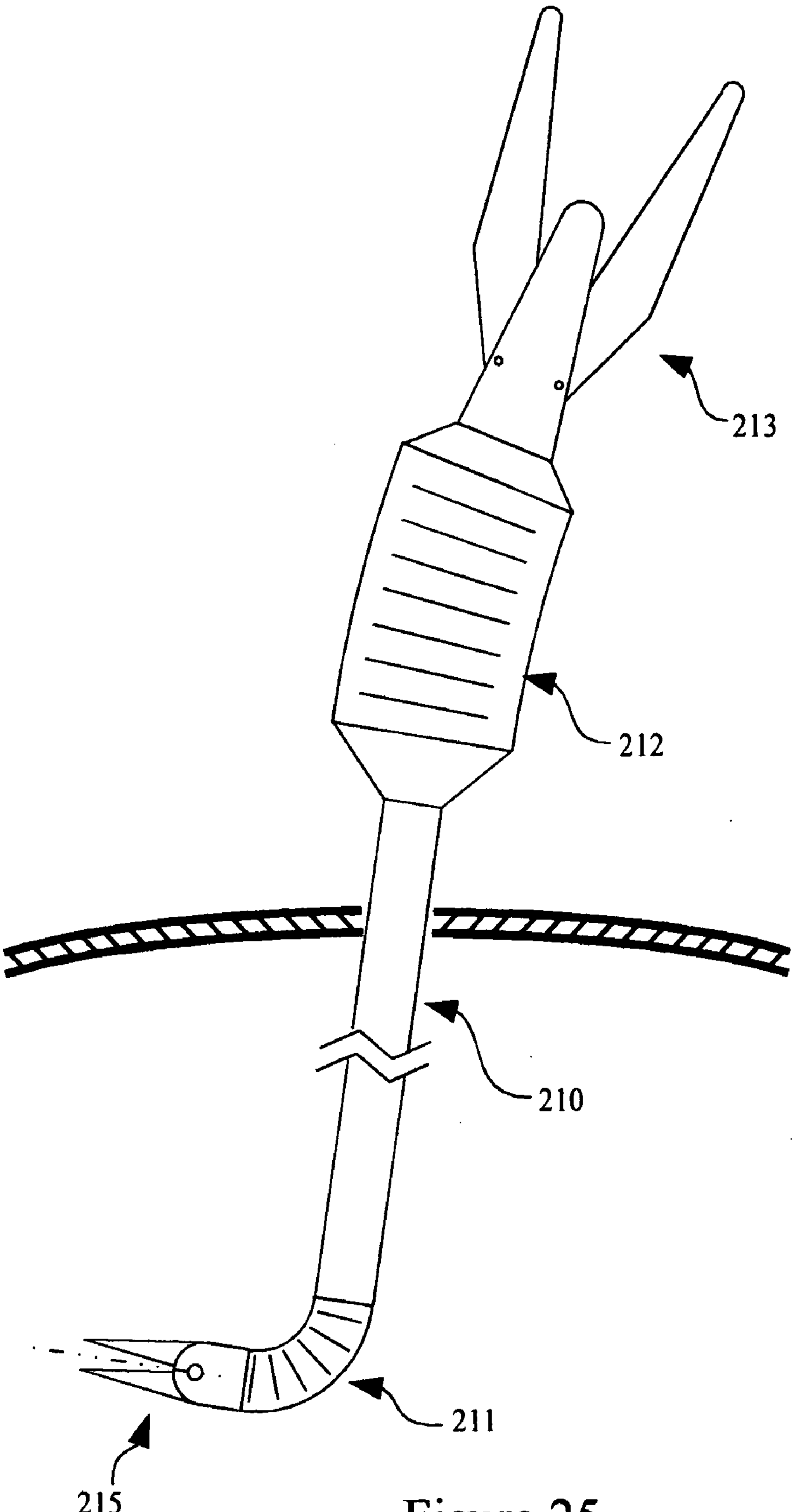


Figure 25

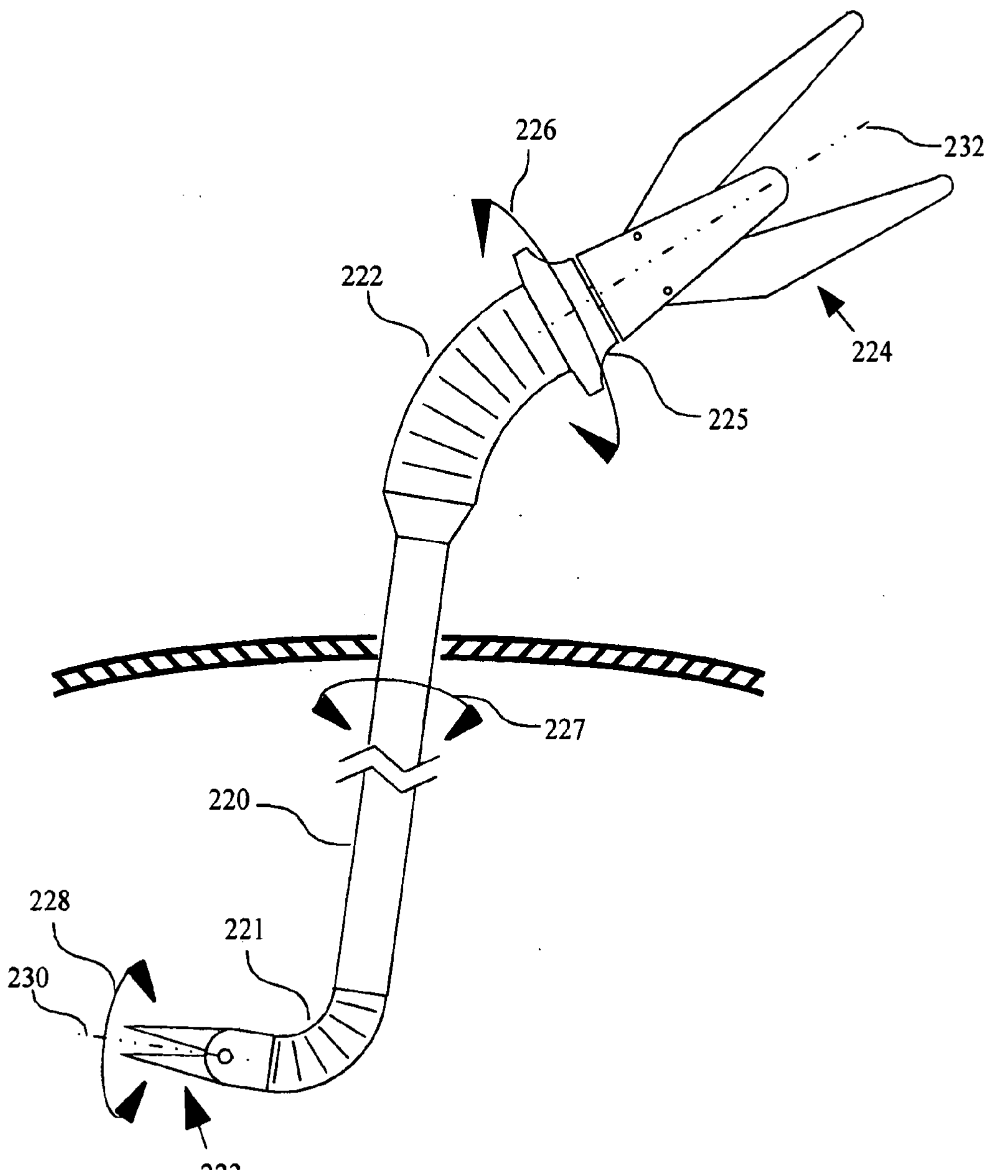


Figure 26

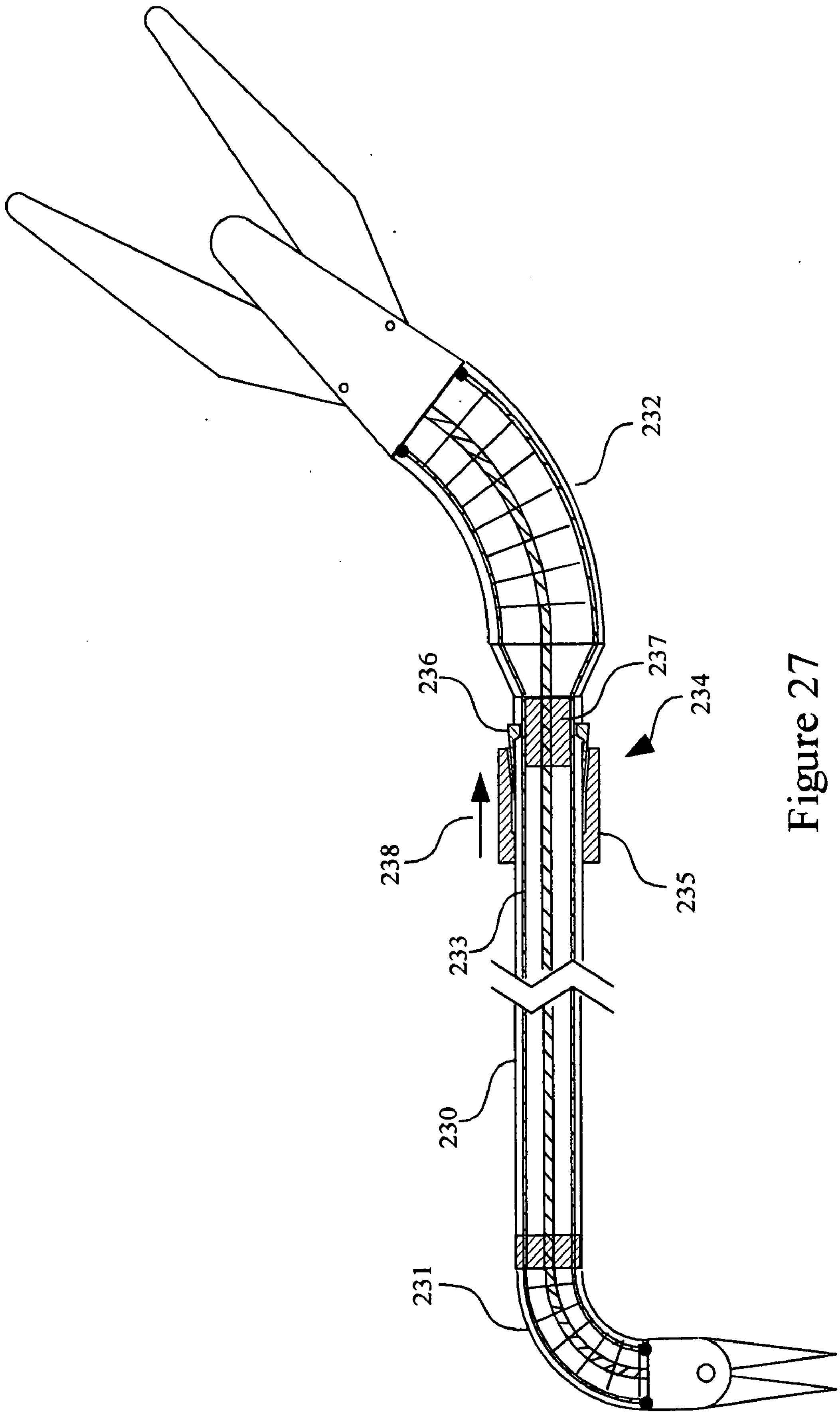


Figure 27

# SURGICAL INSTRUMENT

## BACKGROUND OF THE INVENTION

[0001] The present invention relates in general to surgical instruments, and more particularly to manually operated surgical instruments that are intended for use in minimally invasive surgery.

[0002] Endoscopic and laparoscopic instruments currently available in the market are extremely difficult to learn to operate and use, mainly due to a lack of dexterity in their use. For instance, when using a typical laparoscopic instrument during surgery, the orientation of the tool of the instrument is solely dictated by the locations of the target and the incision, which is often referred to as the fulcrum effect. As a result, common tasks such as suturing, knotting and fine dissection have become challenging to master. Various laparoscopic instruments have been developed over the years to overcome this deficiency, usually by providing an extra -articulation often controlled by a separately disposed knob. However, even with these modifications these instruments still do not provide enough dexterity to allow the surgeon to perform common tasks such as suturing at any arbitrarily selected orientation.

[0003] Accordingly, an object of the present invention is to provide a laparoscopic or endoscopic surgical instrument that allows the surgeon to manipulate the tool end of the surgical instrument with greater dexterity.

## SUMMARY OF THE INVENTION

[0004] In accordance with one aspect of the present invention there is provided an endoscopic or laparoscopic instrument that is comprised of a distal tool, a rigid or flexible elongated shaft that supports the distal tool, and a proximal handle or control member, where the tool and the handle are coupled to the respective distal and proximal ends of the elongated shaft via pivoted or bendable motion members. The tool and the tool motion member are coupled to the handle and the handle motion member via cables and a push rod in such a way that the movement of the handle with respect to the elongated shaft in any direction are replicated by the tool at the distal end of the shaft. The magnitude of the tool motion with respect to the handle motion may be scaled depending on the size of the handle motion member with respect to that of the tool motion member.

[0005] In the present invention one embodiment of the tool motion member is a bending section that is bendable in any arbitrary angle thereby providing two degrees of freedom, whereas in another embodiment, the tool motion member is comprised of the combination of a single plane bendable section and a pivotal joint. In still another embodiment, the motion member is comprised of two pivotal joints orientated orthogonal to each other. In addition to these embodiments where the motion member provides two degrees of freedom, in a situation where less dexterity is needed, the motion member can only be a one degree of freedom member, either pivotal or bendable.

[0006] In accordance with another aspect of the invention there is provided a manually operated surgical instrument primarily adapted for use in minimally invasive surgery. The instrument comprises an elongated instrument shaft having proximal and distal ends; a proximal turnable member; a control handle coupled to the proximal end of the elongated instrument shaft via the proximal turnable member; a distal turnable member; a surgical tool coupled to the distal end of the elongated instrument shaft via the distal turnable member; and a transmission element that intercouples between the proximal and distal turnable members so that a deflection of the control handle at the proximal turnable member causes a deflection of surgical tool via the distal turnable member.

[0007] In accordance with still another aspect of the invention there is provided a manually operated surgical instrument primarily adapted for use in minimally invasive surgery. The instrument comprises an elongated instrument shaft having proximal and distal ends; a tool disposed from the distal end of the instrument shaft; and a control handle disposed from the proximal end of the instrument shaft. The tool is coupled to the distal end of the elongated instrument shaft via a first movable member. The control handle is coupled to the proximal end of the elongated instrument shaft via a second movable member. The movement of the control handle with respect to the elongated instrument shaft via the second movable member causes attendant movement of the tool with respect to the elongated instrument shaft via the first movable member.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Numerous other objects, features and advantageous of the invention should now become apparent upon a reading of the following detailed description taken in conjunction with the accompanying drawings in which:

[0009] **FIG. 1** is a side view of a schematic diagram of a surgical instrument in accordance with the present invention;

[0010] **FIG. 2** is a plan view of the instrument shown in **FIG. 1**;

[0011] **FIG. 3** shows the instrument of **FIG. 1** illustrating the roll of the control handle and the attendant roll of the tool end;

[0012] **FIG. 4** is a view like that shown in **FIG. 1** and additionally illustrating a cabling scheme that can be used in the surgical instrument;

[0013] **FIG. 5A** schematically illustrates a bendable section of ribbed construction;

[0014] **FIG. 5B** schematically illustrates a bendable section of bellows construction;

[0015] **FIG. 5C** is a cross-sectional view through a tool motion member illustrating the motion control cables and the tool actuation push rod;

[0016] **FIG. 6** is a schematic diagram like that shown in **FIG. 1** but where the handle to tool motion is opposite to that illustrated in **FIG. 1**;

[0017] **FIG. 7A** is a schematic diagram of a tool push-pull arrangement that employs a four bar mechanism;

[0018] **FIG. 7B** is a schematic diagram of a tool push-pull arrangement that employs a camming slot mechanism;

[0019] **FIG. 7C** is a schematic diagram of a handle push-pull arrangement that employs a palm grip based upon a four bar mechanism;

[0020] **FIG. 7D** is a schematic diagram of a handle push-pull arrangement that employs a pistol grip handle;

[0021] **FIG. 8A** is a side view of a schematic diagram of a surgical instrument in accordance with another embodiment the present invention where the tool motion member is comprised of two pivotal joints orientated orthogonal to each other while the handle motion member is bendable in any directions, as in previously described embodiments;

[0022] **FIG. 8B** is a plan view of the instrument shown in **FIG. 8A**;

[0023] **FIG. 8C** is a cross-sectional view through the handle motion member of **FIG. 8A** illustrating the motion control cables and the tool actuation push rod;

[0024] **FIG. 9A** is a side view of a schematic diagram of a surgical instrument in accordance with still another embodiment the present invention where the tool motion member comprises a pivotal pitch joint as in the previous embodiment (**FIG. 8A**) but with a bendable section instead of the pivotal joint for the yaw motion;

[0025] **FIG. 9B** is a plan view of the instrument shown in **FIG. 9A**;

[0026] **FIG. 10A** is a schematic diagram of the pivotal pitch jaws and the control handle mechanism that may be used with the embodiments of **FIGS. 8A and 9A**;

[0027] **FIG. 10B** is a schematic diagram of the mechanism of **FIG. 10A** showing the upper handle controlling the lower jaw;

[0028] **FIG. 10C** is a schematic diagram of the mechanism of **FIG. 10A** showing the lower handle controlling the upper jaw;

[0029] **FIG. 10D** is a schematic diagram of the mechanism of **FIG. 10A** illustrating a midline axis of the jaws and the associated control by the bending of the handle motion member;

[0030] **FIG. 11A** is a schematic diagram showing an embodiment with yaw motion-only bending members for both the tool and handle motions where pivotal pitching motion of the handle controls pivotal pitching motion of the tool;

[0031] **FIG. 11B** is a plan view of the instrument shown in **FIG. 11A**;

[0032] **FIG. 12** is a schematic diagram showing an embodiment with one pivotal tool motion joint, one bendable tool motion section, and two pivotal handle motion joints;

[0033] **FIG. 13** is a schematic diagram showing an embodiment with two tool motion pivots, and with one bendable section and one pivotal handle motion member;

[0034] **FIG. 14** is a schematic diagram of a further embodiment of the invention in which the instrument shaft, between control and working ends of the instrument, is flexible so as to conform to the shape of an anatomic channel or lumen;

[0035] **FIG. 15** is a schematic diagram similar to that shown in **FIG. 14** where multiple motion members are placed along the length of the elongated instrument shaft for multi-modal controlled movement of the tool;

[0036] **FIG. 16** is a schematic diagram of another embodiment of the present invention in which an axial torque rotation and transmission mechanism is employed;

[0037] **FIGS. 17A and 17B** are schematic diagrams relating to **FIG. 16** showing alternate embodiments utilizing axial rotation joints at both control and tool ends of the instrument;

[0038] **FIG. 18** shows an embodiment in which the tool motion control cables and grip actuation rod are driven an by electrical motors mounted on the side of the proximal end of the elongated instrument shaft instead of being driven directly by the handle motion member and handle;

[0039] **FIG. 19** is a schematic diagram of an alternate embodiment related to **FIG. 18** and that illustrates an arrangement where the motors are situated away from the handle via mechanical cables traveling through the flexible conduit;

[0040] **FIG. 20** is a schematic diagram of another embodiment of the invention with multiple motion members, effectuating the forward/backward linear motion by means of a linear actuator to aid the forward/backward motion;

[0041] **FIGS. 21A, 21B** and **21**C are separate views showing a more detailed embodiment of the invention in different positions of the handle and tool;

[0042] **FIG. 22A** is a fragmentary perspective view of the tool end of the instrument illustrated in **FIG. 21**;

[0043] **FIG. 22B** is a longitudinal cross-sectional view of the tool end of the instrument as illustrated in **FIGS. 21 and** 22A;

[0044] **FIG. 22C** is an exploded perspective view of the instrument segment illustrated of **FIG. 22A**;

[0045] **FIG. 23A** is a fragmentary perspective view of the handle end of the instrument illustrated in **FIG. 21**;

[0046] **FIG. 23B** is a longitudinal cross-sectional view of the handle end of the instrument as illustrated in **FIGS. 21 and** 23A;

[0047] **FIG. 23C** is an exploded perspective view of the instrument segment illustrated of **FIG. 23A**;

[0048] **FIG. 23D** is a cutaway perspective view of the bendable section of the instrument at the handle end;

[0049] **FIG. 24** illustrates another embodiment of the present invention where the movement of the tool motion member is controlled by the torque applied at the handle motion member;

[0050] **FIG. 25** is still a further embodiment of the present invention relating to **FIG. 24**;

[0051] **FIG. 26** is a further embodiment of the present invention where ease of use of the instrument is further enhanced by making it simpler to roll the tool end about its axis, an essential motion in suturing at off-axis angle; and

[0052] **FIG. 27** illustrates still another embodiment of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0053] **FIGS. 1 and 2** show respective side and top views of one embodiment of the present invention. Both the tool and the handle motion members are bendable in any directions, and they are connected to each other via cables in such a way that the tool motion member bends in the opposite direction of the handle motion member, thereby creating a sensation that the tool always points in generally the same direction as the handle. Although **FIGS. 1 and 2** shows only the side and top views where only pitch and yaw motions are actuated, respectively, it should be noted that the handle motion member could be bent in any direction, actuating the tool motion member to bend in directly opposite directions, and in the same plane. Herein these motion members are also referred to as turnable members. In addition, unlike mechanisms that are comprised of pivotal joints, the bendable motion members can bend in any direction without any singularity. As a result, as shown in **FIG. 3**, the surgeon is be able to roll the instrument tool **18** about its longitudinal axis **11** at any orientation simply by rolling the handle, a desirable motion for suturing in off-axis.

**[0054]** Regarding **FIGS. 1-3**, there is disclosed an instrument that is comprised of an elongated instrument shaft **10** supporting, at its proximal end, the handle **12** connecting with the handle motion member **14**. At the distal end of the instrument shaft there is disposed the tool motion member **16** that couples to the tool or end effector **18**, shown in **FIG. 1** as a set of jaws. It is understood that other types of tools may also be substituted for the jaw set that is illustrated.

**[0055]** In **FIGS. 1 and 2** one position is shown in solid outline and an alternate position is shown in dotted outline. These two different positions are also illustrated by the double-headed motion arrow **7** indicating motion of the handle **12** and the double-headed motion arrow **8** indicating corresponding motion of the tool **18**.

**[0056]** In the descriptions set out herein the term "bendable section", "bendable segment", "bendable motion member"or "turnable member"refer to an element of the instrument that is controllably bendable in comparison to an element that is pivoted. The bendable elements of the present invention enable the fabrication of an instrument that can bend in any direction without any singularity, and that is further characterized by a ready capability to bend in any direction, all with a single unitary structure. A definition of these bendable motion members is—an instrument element, formed either as a controlling means or a controlled means, and that is capable of being constrained by tension or compression forces to deviate from a straight line to a curved configuration without any sharp breaks or angularity—.

**[0057]** **FIG. 3** also illustrates the roll of the instrument made possible by the interaction between the control handle **12** and tool **18**, and their respective motion members **14** and **16**. The instrument shaft is shown positioned through the incision or aperture **22** in the abdominal wall **20**.

**[0058]** This rolling action is also illustrated in **FIG. 3** by the series of circular arrows that include arrow **24** illustrating the rotation or rolling of the handle **12** about axis **9** to cause a corresponding rotation or rolling of the tool **18** about axis **11**, illustrated by the circular arrow **26**. Similarly, the instrument shaft **10** is rotated at the same time, as illustrated by the arrow **28** in **FIG. 3**.

**[0059]** Reference is now made to **FIG. 4** that illustrates the internal cabling scheme of the embodiment disclosed in **FIGS. 1-3**. In **FIG. 4** the same reference characters are used as in **FIGS. 1-3** to identify like elements. The control cables **30**A and **30**B run parallel to each other along the longitudinal direction of the instrument shaft **10** and they are terminated, respectively, at the proximal and distal ends of the handle and tool motion members. The termination is shown at each point **29** in **FIG. 4** and represents a location where the cable is fixed at each end thereof to the respective handle and tool structures. Although only two motion member control cables **30**A and **30**B are shown in the **FIG. 4**, it should be noted that three or more cables are preferred in order to actuate the tool motion member in any direction.

**[0060]** As illustrated in **FIG. 4**, as an example, when the handle **12** is tilted upwardly by bending the handle motion member **14** upwardly, the proximal end of the cable **30**B is pulled while the cable **30**A is relaxed. As a result, the distal end of the cable **30**B is shortened causing the tool motion member **16** to bend downwardly resulting in a pitching down motion of the tool **18**, as illustrated in **FIG. 4**.

**[0061]** In addition to the motion control cables **30**A and **30**B, **FIG. 4** also illustrates the tool actuating push rod **32** that runs through the center of the motion members **14**, **16** and the elongated shaft **10** so that the tool actuation is decoupled from the bending motions of the motion members. Since the sections of the push rod **32** that go through the tool and handle motion members **14**, **16** need to bend, the rod **32** needs to be somewhat flexible, and in order to prevent these sections from buckling, they are preferably confined in a conduit or a channel. See the more detailed embodiment in **FIGS. 21-23**. Alternatively, the section of push rod **32** that does not need to bend may be reinforced to prevent it from buckling. The proximal and distal ends of the push rod **32** are connected to the push-pull handle and jaw mechanisms, respectively (shown in **FIGS. 7A-7D**).

**[0062]** The bendable handle and tool motion members **14**, **16**, such as illustrated in **FIG. 4** can be constructed in many different embodiments. Refer, for example, to **FIGS. 5A and 5B** for an illustration of two possible embodiments showing two degrees of freedom (DOF) bending motion members. **FIG. 5A** shows a ribbed construction that includes alternating ribs **13** and slots **15** disposed about the center column **17**. The push rod **32** is disposed at the center of the center column **17**. The control cables **30**A, **30**B extend through the outer portions of the ribs **13**.

**[0063]** **FIG. 5B** shows a bellow construction **13**A including a center column **17**A which accommodates the push rod **32** at its center. The control cables **30**A, **30**B extend through the bellows construction **13**A. In both cases of **FIGS. 5A and 5B**, and, as shown in the cross-sectional view of **FIG. 5C**, the motion control cables **30** extend along the outer edge whereas the push rod **32** is centered along the center column **17**. The center column **17**, which acts as a conduit for the somewhat flexible push rod **32**, is relatively stiff longitudinally (high column strength) in order to maintain the overall length of the motion cable pathways constant, while maintaining lateral flexibility for bending. It should be noted that a variety of geometries may be employed for the bending motion member construction for improved lateral flexibility and column/torsion stiffness.

**[0064]** **FIG. 6** illustrates another embodiment of the present invention where the axial orientation of the handle with respect to the elongated instrument shaft is changed. In this embodiment, the surgeon, before or in the middle of the surgical procedure, may unlock, rotate axially and then lock back the handle onto the elongated instrument shaft. In **FIG. 6** the same reference characters are used as in **FIG. 4** to designate like elements. Regarding **FIG. 6**, there is disclosed an instrument that is comprised of an elongated instrument shaft **10** supporting, at its proximal end, the handle **12** connecting with the handle motion member **14**. At the distal end of the instrument shaft there is disposed the tool motion member **16** that couples to the tool or end effector **18**, shown as a set of jaws. In **FIG. 6**, because the handle has been rotated, the control cables **30**A and **30**B are shown in a crossed orientation. Also, terminations are used on the cable ends as shown before in **FIG. 4**.

[**0065**] As illustrated in **FIG. 6**, the handle motion member **14** may be axially rotatable 180 degrees from its normal orientation, such as was previously illustrated in **FIG. 4**. This is illustrated in **FIG. 6** by the rotation arrow **35** that is shown extending about the rotation and locking member **35**A, which slides in the direction of arrow **35**B to lock and unlock the axial orientation of the handle motion member **14** with respect to that of the elongated shaft **10**. As a result, when the handle is tilted upwardly, cable **30**A is pulled instead of cable **30**B, therefore, pitching the tool upwardly rather than downwardly, as shown in **FIG. 6**. This feature may be very useful when the surgeon's hand is in awkward position.

[**0066**] **FIGS. 7A-7D** illustrate some examples of push-pull jaw and handle mechanisms that may be employed with the present invention. For example, **FIGS. 7A and 7B** show two jaw constructions, one based on a four bar mechanism and the other based on a camming slot mechanism. It is noted that, in addition to the illustrated embodiments, a wide variety of similar push-pull or other mechanisms may be readily adapted to the tool end of the instrument of the present invention. For instance, one can adapt a stapler or clip applier tool to this invention. In addition to tool configurations described above, energy delivering tools such as monopolar, bipolar and electrocautery tools and non-actuated tools such as a scalpel or monopolar j-hook can be readily employed.

[**0067**] **FIG. 7A** schematically illustrates the four bar mechanism **36** operated from the push rod **32** and coupling to the jaws **18**A at the jaw axis **19**. **FIG. 7B** schematically illustrates the camming slot mechanism **38** operated from the push rod **32** and coupling to the jaw arrangement **18**B. In either case the linear translation of the push rod **32**, indicated by the double headed arrow **37**, controls the opening and closing of the jaws.

[**0068**] Similarly, **FIGS. 7C and 7D** show two examples of common push-pull handle designs; a palm grip in-line handle **40** including a bar mechanism **42** shown in **FIG. 7C**, and a pistol grip handle **44** shown in **FIG. 7D**. Again, a wide variety of similar push-pull handle designs may be employed. **FIG. 7C** illustrates the bar mechanism controlled from the handle **40** to actuate the push rod **32**. **FIG. 7D** illustrates the pistol grip handle **44** for controlling the push rod **32**. Double headed arrows **41** indicate the motion occasioned by the handle control on the push rod. **FIGS. 7C and 7D** also respectively show bellows type wrists **14**A and **14**B for facilitating corresponding tool motion.

[**0069**] **FIGS. 8A, 8B** and **8**C illustrate another embodiment of the present invention where the tool motion member is comprised of two pivotal joints (pitch and yaw axis) orientated orthogonal to each other while the handle motion member is bendable in any direction, as in previously described embodiments. This embodiment relies on independent pitch motions of each jaw of the tool to provide both the jaw grasping and pitch motion, and therefore, it uses two pairs of pitch motion control cables as shown in **FIG. 8C**. As in previous embodiments, tilting of the handle in the up/down directions causes respective pitching down/up of the tool (**FIG. 8A**), and the side-to-side motion of the handle results in yaw motion of the tool (**FIG. 8B**). The motion at any one point in time is usually a combination of pitch and yaw motions.

[**0070**] Regarding **FIGS. 8A-8C**, there is disclosed an instrument that is comprised of an elongated instrument shaft **50** supporting, at its proximal end, the handle **52** connecting with the handle motion member **54**. At the distal end of the instrument shaft there is disposed the tool motion member **56** that couples to the tool or end effector **58**, shown as a set of jaws. It is understood that other types of tools may also be substituted for the jaw set that is illustrated. The side view of **FIG. 8A** and the plan view of **FIG. 8B** illustrate the handle motion member as being bendable (a bendable section or segment), as in previous embodiments that have been described. However, the tool motion member **56** is comprised of two separate pivot joints orientated orthogonal to each other while the handle motion member is bendable in any direction. The yaw pivot joint is defined at yaw pivotal axis **55**, while the pitch pivot joint is defined at pitch pivotal axis **57**, one disposed orthogonal to the other. This embodiment uses two pairs of pitch motion control cables **53**, and one pair of yaw motion control cables **51**, as shown in the cross-sectional view of **FIG. 8C**.

[**0071**] **FIGS. 9A and 9B** show still another embodiment of the tool motion member with a pivotal pitch joint as in the previous embodiment (**FIGS. 8A-8C**) but with a bendable member **55**A instead of the pivotal joint for the yaw motion. As illustrated in **FIGS. 9A and 9B**, the bendable member **55**A bends only in a side-to-side plane (in the plane of the paper in **FIG. 9B**) providing only the yaw motion of the tool. The pitch motion control cables **53** extend through the central plane of the yaw motion bending section **55**A so that the pitch and grip motion of the jaws are decoupled from the yaw motion. The pitch motion control cables **53** control the pivoting at axis **57**.

[**0072**] **FIG. 10A** is a schematic diagram of the pivotal pitch jaws and the control handle mechanism that may be used with the embodiments of **FIGS. 8A and 9A**. **FIG. 10B** is a schematic diagram of the mechanism of **FIG. 10A** showing the upper handle controlling the lower jaw. **FIG. 10C** is a schematic diagram of the mechanism of **FIG. 10A** showing the lower handle controlling the upper jaw. **FIG. 10D** is a schematic diagram of the mechanism of **FIG. 10A** illustrating a midline axis of the jaws and the associated control by the bending of the handle motion member.

[**0073**] In **FIGS. 10A, 10B** and **10**C, there is described an example of a cabling/handle mechanism for a set of jaws, and in which the jaws have pivotal pitch motion, as in **FIGS. 8 and 9**. There are two jaw capstans **60** and two handle capstans **64** as shown in **FIGS. 10A-10C**. **FIG. 10B** illustrates the upper handle **66**A controlling the lower jaw **18**A via the capstan **64**A. Alternatively, **FIG. 10C** illustrates the lower handle **66**B controlling the upper jaw **18**B via the capstan **64**B. **FIGS. 10A-10C** also show the corresponding cable loops **68** one associated with each jaw. **FIG. 10B** depicts the cable loop **68**A extending about the capstan **64**A, through the bendable member **65** and to the jaw capstan **60**A for control thereof. **FIG. 10C** depicts the cable loop **68**B extending about the capstan **64**B, through the bendable member **65** and to the jaw capstan **60**B for control thereof.

**[0074]** The distal end of each of the pitch motion control cable loops **68**A, **68**B is terminated at the jaw capstan **60**A, **60**B, and the proximal end of each of the pitch motion control cable loops **68**A, **68**B is terminated at the handle capstan **64**A, **64**B. Each handle **66**A, **66**B is firmly attached to its associated handle capstan **64**A, **64**B, and the handle capstans are arranged to form a four bar mechanism **61** where the sliding member **63** thereof is constrained to a linear motion along the longitudinal axis of the base **69** of the handle. In **FIGS. 10A-10C** the various element motions are depicted by double headed arrows; arrows **70** depicting the handle motion; arrows **71** depicting the linear slider motion; arrows **72** depicting the capstan rotation motion; and arrows **73** depicting the jaw rotation occasioned by the jaw capstan rotation motion.

**[0075]** **FIG. 10D** illustrates the embodiment of **FIG. 10A**, the motion of the handles at their midline **70**A and the corresponding motion of the jaws at their midline **73**A. The pitching motion or rotation of the midline **73**A of the jaws is controlled by the bending up/down movement of the handle motion member **65**. The opening and closing of the handles **66**A, **66**B relative to midline **70**A controls the jaw opening and closing with respect to the jaws midline **73**A, as illustrated in **FIG. 10D**.

**[0076]** The embodiments described so far have employed a handle motion member arrangement that is bendable in any directions. However, just as a variety of tool motion members can be employed, other handle motion types can also be used. For example, **FIGS. 11A and 11B** show an embodiment with a yaw motion-only bending member for both the tool and handle motion members while pivotal pitching motion of the handles controls pivotal pitching motion of the tool.

**[0077]** **FIG. 11A** is a schematic diagram showing an embodiment with yaw motion-only bending members for both the tool and handle motions where pivotal pitching motion of the handles controls pivotal pitching motion of the tool. **FIG. 11B** is a plan view of the instrument shown in **FIG. 11A**. Regarding **FIGS. 11A and 11B**, there is disclosed an instrument that is comprised of an elongated instrument shaft **80** supporting, at its proximal end, a handle **82** connecting with a handle motion member **84**. The handle **82** is depicted as a hand-held scissors type handle that may be moved in the direction indicated by double headed arrow **81**. At the distal end of the instrument shaft **80** there is disposed a tool motion member **86** that couples to a tool or end effector **88**, shown in **FIG. 11A** as a set of jaws.

**[0078]** The handle motion member **84** may be considered as comprised of two components including a bendable segment **83** and a pivotal joint **85**. The bendable segment **83** is limited in motion so as to control only yaw motion of the handle. This yaw motion is illustrated by the double headed arrow **81**A in **FIG. 11B**. The pitch motion is defined as motion about pivotal joint **85**. This pitch motion is illustrated by the double headed arrow **81** in **FIG. 11A**. Similarly, at the distal end of the instrument the tool motion member **86** may be considered as comprised of two components including a bendable segment **87** and a pivotal joint **89**. The bendable segment or section **87** is limited in motion so as to control only yaw motion of the tool. This yaw motion is illustrated by the double headed arrow **91**A in **FIG. 11B**. The pitch motion is defined as motion about pivotal joint **89**. This pitch motion is illustrated by the double headed arrow **91** in **FIG. 11A**. **FIGS. 11A and 11B** also depict the control cables for both pitch and yaw. These are illustrated as pitch motion control cables **92** and yaw motion control cables **93**. There is preferably a pair of yaw motion control cables and two pairs of pitch motion control cables, one for each jaw.

**[0079]** Other tool and handle motion joint combinations can also be considered as illustrated in **FIGS. 12 and 13**. In these figures there is disclosed an instrument that is comprised of an elongated instrument shaft **100** supporting, at its proximal end, a handle **102** connecting with a handle motion member **104**. In both embodiments the handle **102** is depicted as a hand-held scissors type handle that may be moved in the direction indicated by double headed arrow **101**. At the distal end of the instrument shaft **100** there is disposed a tool motion member **106** that couples to a tool or end effector **108**, shown in **FIGS. 12-14** as a set of jaws.

**[0080]** **FIG. 12** shows an embodiment with the tool and handle motion members **106**,**104** comprised of one pivotal tool motion joint **106**A, one bendable section **106**B and two pivotal handle motion joints, respectively. **FIG. 13** illustrates an embodiment with two pivotal tool motion joints **109**, one bendable section **104**A at the handle, and one pivotal handle motion joint **104**B.

**[0081]** The embodiments described thus far have shown the elongated shaft to be rigid, however, in other embodiments of the invention the shaft may be an elongated flexible shaft. One such embodiment is shown in **FIG. 14**. The flexible elongated shaft section **110** is generally passive, conforming to the shape of an anatomic channel or body lumen, illustrated in **FIG. 14** at **113**. There is disclosed an instrument that is comprised of an elongated flexible instrument shaft **110** supporting, at its proximal end, the handle **112** connecting with the handle motion member **114**. At the distal end of the flexible instrument shaft **110** there is disposed the tool motion member **116** that couples to the tool or end effector **118**, shown in **FIG. 14** as a set of jaws.

**[0082]** In addition, one could also have embodiments where multiple motion members are placed along the length of the elongated shaft for multi-modal controlled movement of the tool, as illustrated in **FIG. 15**. In **FIG. 15** some of the same reference characters are used as used in **FIG. 14**. Thus, this embodiment includes an elongated flexible instrument shaft **110** supporting, at its proximal end, the handle **112** connecting with the handle motion member **114**. At the distal end of the instrument there is disposed the tool motion member **116** that couples to the tool or end effector **118**, shown in **FIG. 15** as a set of jaws. **FIG. 15** shows the added bendable sections, bendable segments or bendable motion members **117** and **119** directly at opposite ends of the flexible section **110**. The interconnection between the members **116** and **117** may also be a flexible section. Likewise, the interconnection between the members **114** and **119** may be a flexible section. The handle motion members **114** and

**119** may be cabled to control the motion of the tool motion members **116** and **117**, respectively, or vice versa.

[0083] In some applications such as in lower GI procedures, the elongated shaft may bend at multiple points, and transmitting axial rotational motion about the shaft may be difficult. In such cases, it is more effective to employ a torque transmission mechanism, as illustrated schematically in **FIG. 16**. **FIG. 16** schematically illustrates an axial rotation transmission mechanism that has a tool end **120** and a control handle end **122**. A rotation at the handle end **122** converts into a like rotation of the instrument at the tool end **120**. This rotation is indicated by the respective arrows **121** and **123**.

[0084] **FIGS. 17A and 17B** show embodiment of the instrument of the present invention that utilize the schematic concepts of **FIG. 16**. In **FIG. 17** some of the same reference characters are used as used in **FIG. 14**. Thus, this embodiment includes an elongated flexible instrument shaft **110** supporting, at its proximal end, the handle **112** connecting with the handle motion member **114**. At the distal end of the instrument there is disposed the tool motion member **116** that couples to the tool or end effector **118**, shown in **FIGS. 17A and 17B** as a set of jaws. In the embodiment shown in **FIG. 17A**, there is an axial rotation joint **111** between the proximal end of section **110** and the handle motion member **114**, and likewise, there is an axial rotation joint **115** between the more distal end of the section **110** and the tool motion member **116**. On the other hand, in the embodiment shown in **FIG. 17B**, the axial rotation joint **111** is situated between the handle motion member **114** and the handle **112** whereas the axial rotation joint **115** is situated between the tool motion joint **116** and the tool **118**. In both cases, these axial rotation joints are interconnected so that rotation of joint **111** causes a corresponding rotation of joint **115**. The elongated flexible shaft **110** preferably does not rotate axially itself.

[0085] The motions of the tool and the actuation via the grip can also be controlled by actuators such as electrical motors as shown schematically in **FIGS. 18 and 19**. In the embodiment shown in **FIG. 18**, the tool motion control cables **124** and grip actuation rod are driven by electrical motors **125** mounted on the side of the proximal end of the elongated shaft **126**, instead of being driven directly by the handle motion member and associated handle. The pitch, yaw and roll motion of the handle is measured by respective rotational sensors such as potentiometers or encoders, and the on-board motion controller (not shown) sends appropriate commands to the motors based on the handle position information. In addition to the features of purely mechanical solutions, this embodiment provides additional benefits such as joint motion scaling, tremor reduction, etc.

[0086] As an alternate-embodiment, **FIG. 19** illustrates an arrangement where the motors **128** are situated away from the handle via the mechanical cables **129** traveling through a flexible conduit. The main benefit of this embodiment is lighter weight and the ability to plug in multiple kinds of instrument to a single bank of motors, thus reducing the cost.

[0087] Another potential usage of an actuator is shown in **FIG. 20**. In embodiments especially with multiple motion members, effectuating the forward/backward linear motion may be difficult as the handle motion members would tend to bend or rotate as well, and in such cases, a linear actuator **130** may be employed to aid the forward/backward motion. Various methods are possible for controlling the linear motion. A simple method could be using an input device such as a toggle switch or button. A somewhat more sophisticated method could be employing a force sensing element mounted on either the elongated shaft or the carriage of the linear actuator to detect the forward/backward force exerted by the surgeon. The force information would then be used by a motion controller to command the linear actuator appropriately.

[0088] **FIGS. 21 through 23** show detailed illustrations of the embodiment as described in **FIGS. 1 through 5**, where both the tool and the handle motion members **150**, **151** are bendable in any direction. The motion members **150** and **151** are connected to each other via cables extending through the elongated rigid shaft **152** in such a way that the tool motion member bends in the opposite direction of the handle motion member, as illustrated in **FIG. 21**. **FIGS. 21A, 21B** and **21C** are separate views showing the instrument in different positions of the handle and tool. **FIG. 21A** illustrates the handle and tool in line with each other and in line with the longitudinal axis **150A**. **FIGS. 21B and 21C** illustrate the off-axis motion of the handle and tool. **FIG. 21B** illustrates the handle **154** bendable upwardly while the corresponding tool bends downwardly relative to axis **150A**. **FIG. 21C** illustrates the handle **154** bendable downwardly while the corresponding tool bends upwardly relative to axis **150A**. Of course, in all of the views of **FIG. 21** motion can also occur in and out of the plane of the paper (both pitch and yaw).

[0089] In **FIG. 21**, although the end effector **153** in the illustration is a needle holder jaw set, it should be noted that other types of tools may be used. Similarly, although the in-line handle **154** is shown in the illustration, it could be easily substituted by other types of handles as well. Different types of handle could be with or without an opening spring, with or without the finger loops, with or without a lock, with one or two handle bars, or with a pistol-grip instead of an in-line grip, or various combinations thereof.

[0090] In **FIG. 21** it is noted that the handle motion member **151** is generally of larger diameter than the tool motion member **150**. Although this is a preferred arrangement, these diameters may be the same or have various other dimensional relationships therebetween. In the preferred embodiment the bendable sections **150** and **151** are illustrated as being slotted arrangements, however, they may also be of other form such as the bellows structure previously mentioned.

[0091] **FIGS. 22A, 22B** and **22**C further illustrate the tool or end effector **153** and the tool motion member **150** located at the distal end of the elongated rigid shaft **152**. **FIG. 22A** illustrates a perspective view of the tool section where the tool motion member **150** is bent slightly. The bendable motion member **150** and the distal end of the rigid shaft **152** are illustrated as receiving the motion control cables **155** and the tool actuating push rod **156**. The tool **153** is firmly fixed on the distal end of the tool motion member **150**, and likewise, the proximal end the tool motion member **150** is firmly fixed on the distal end of the rigid shaft **152**.

[0092] The needle holder (tool **153**) has only one jaw that opens in order to increase its grasping force, although the tool could also be provided with both jaws operable. The bottom jaw **161** is part of the jaw yoke **166**, and therefore it is not movable with respect to the yoke. The movement of the push rod **156** causes the pin **164** to move along the slot **165** in the yoke **166**, and as a result the top jaw **162** moves or pivots about the pin **167**.

[**0093**] Reference is now made to the cross-sectional view of the tool section, as illustrated in **FIG. 22B**. The push rod **156** is flexible at rod **157** in the portion that passes through the tool motion member **150** whereas the portion that is situated inside the rigid shaft **152** is preferably rigid. The flexible push rod **157** is fixedly coupled to the rigid push rod **156**. The motion control cables **155** and the rigid push rod **156** are guided by and through the spacer **158** along their paths, and the distal ends of the motion control cables **155** are terminated at **160**. The flexible portion of the push rod **157** passes through the center of the tool motion member **150** and the jaw yoke **166**, and it terminates by being fixedly coupled to the termination block **163**, which in turn carries the pin **164** that traverses along the camming slots **165** (jaw **161**) and **169** (jaw **162**).

[**0094**] In order to increase the column strength of the tool motion member, a reinforcement thin-walled tube **159** made of stiff material such as PEEK (a polyethylene plastic) is used. The end plate **168** is placed between the tool motion member **150** and shaft **152** to prevent the reinforcement tube **159** from sliding out. It should be noted that depending on the material and geometry of the tool motion member, it may not be necessary to employ such reinforcement tube.

[**0095**] **FIG. 22C** illustrates an exploded view of the tool section of **FIG. 22A**. As previously described, the motion control cables **155** are terminated at **160**. Forward and backward movement of the rigid push rod **156** moves the termination block **163** and the pin **164** along the slot **165** of the bottom jaw **161**. Since the pin **164** also rides in the slot **169** of the top jaw **162**, forward and backward motion of the pin **164** respectively opens and closes the top jaw. While the tool actuation rod **156** is disposed at the center of the bendable motion member, the four cables **155** are disposed in a diametric pattern so as to provide the all direction bending.

[**0096**] In **FIG. 22C** the tool motion member **150** is illustrated as being comprised of a series of ribs **150R** that define therebetween a series of slots **150S**, that together define alternating direction transverse slots. The ribs **150R** extend from a center support that carries the actuation rod **156** and tube **159**. The ribs **150R** provide a support structure for cables **155**. In the particular embodiment described in **FIG. 22C** between the ribs there is a pattern of staggered ridges **150T** disposed at 90 degree intervals about the member. The cables **155** pass through the area of the motion member **150** where these ridges **150T** are arranged.

[**0097**] **FIGS. 23A, 23B**, **23C** and **23D** illustrate in detail the handle section located at the proximal end of the elongated shaft **152**. **FIG. 23A** is a perspective view of the handle section where the handle motion member **151** is slightly bent. In **FIG. 23A** the same reference characters are used to identify like components previously described in connection with the tool end of the instrument. For example, four motion control cables **155** as well as the tool actuating push rod **156** travel through the handle motion member **151**. The cables **155** control bending motion at the tool motion member while rod **156** controls tool actuation. The distal end of the handle motion member **151** is fixedly connected to the proximal end of the elongated shaft **152** via the handle motion member coupler **171**, and similarly, the proximal end of the handle motion member **151** is fixedly mounted to the handle body **178** of handle **154**.

[**0098**] Reference is now made to the cross-section view of the handle section, as illustrated in **FIG. 23B**. As with the tool section, the tool actuating push rod **156** is flexible (flexible rod portion **173**) in the portion that passes through the handle motion member **151** whereas the portion that is situated inside the rigid shaft **152** is preferably rigid. The flexible portion **173** is fixedly coupled to the rigid push rod **156**. The motion control cables **155** travel through the outer edge of the handle motion member **151** and are terminated at **175**. The four cables **155** are disposed in the same pattern as discussed previously regarding the tool section (see **FIG. 22C**). The flexible push rod **173** travels through the center of the handle motion member **151** and is terminated at the sliding block **181**. Similarly to the tool motion member, a thin-walled reinforcement tube **174** is placed at the center lumen of the handle motion member **151** to increase the column strength of the handle motion member. An end plate **176** is placed between the coupler **171** and the handle motion member **151** to prevent the reinforcement tube **174** from sliding out. Depending on the material and geometry of the handle motion member, the reinforcement tube may not be necessary. Opening and closing of the handle bars **179** causes forward and backward movement of the sliding block **181** via the handle links **180**, which in turn, via the rods **156**, **157** and **173**, causes the jaw to respectively open and close. The handle spring **182** biases the handle to be open normally which is typical of needle holders. For other types of jaws, it may not be desirable to have the bias spring.

[**0099**] **FIG. 23C** further illustrates the handle section of the instrument. Note that the motion control cables **155** are situated on the outer edge of the handle motion member **151** and are terminated at **175**, whereas the flexible push rod **173** passes through the handle motion member **151** at its center and terminates at the sliding block **181**. The geometry of the handle motion member **151** in this embodiment is further illustrated in the cutaway view of the handle motion member, as shown in **FIG. 23D**. As discussed previously, the bendable tool and handle motion members can be constructed in many different embodiments such as a ribbed or bellowed construction. **FIG. 23D** illustrates the preferred embodiment of the handle motion member **151**. Substantially the same construction is shown herein for the tool motion member **150**.

[**0100**] In **FIG. 23D** the bendable motion section is illustrated as having alternating slots **183A** and **183B** extending in transverse directions for allowing the motion member to bend in any direction while maintaining a continuous center region for high column strength. **FIG. 23D** illustrates the motion member as being comprised of a series of ribs **190R** that define therebetween a series of slots **190S**. The ribs **190R** extend from a center support that carries the actuation rod **173** and tube **174**. The ribs **190R** provide a support structure for cables **155**. In the particular embodiment described in **FIG. 23D** between the ribs there is a pattern of staggered ridges **190T** that define the alternating slots and that are disposed at alternating 90 degree intervals about the member. The cables **155** pass through the area of the motion member **151** where these ridges **190T** are.

[**0101**] Reference has been made to the manner in which the instrument shown in **FIGS. 21-23** can be manipulated to perform a surgical task. For example, **FIG. 21** shows different positions of the instrument. These possible movements are brought about by the surgeon grasping the handle and bending or turning the handle virtually in any direction. For example, and in connection with **FIG. 21C**, the handle is illustrated as turned or tilted down with a corresponding turning or tilting of the tool section in an upward direction. In addition, by rotating the handle about the shaft the surgeon can tilt or turn the handle in and out of the plane depicted in **FIG. 21C**. Depending upon the direction of manipulation by the surgeon, the control cable **155** that is disposed closest in line to the direction of turning is loosened or slackened, and the opposite cable **155** is tightened. This action causes the opposite direction turning as depicted in **FIG. 21**. Essentially the tightened cable pulls the tool end in the opposite direction. By providing the four cable quadrant array of cables handle-to-tool action is in any direction.

[**0102**] Another embodiment of the present invention is illustrated in **FIG. 24** showing the instrument passing through an anatomic wall **207** at aperture **208**. In this embodiment the movement of the tool motion member **205** is controlled by the torque applied at the handle motion member **202** rather than the movement of the member itself. Due to the fulcrum effect as well as usage of long elongated instruments, the surgeon often has to move the instrument handle in a wide range of motion during a particular medical procedure in order to perform the surgical task at the intended target area. As a result, the surgeon is often forced into very awkward postures, and manipulating the instrument handle further to control the tool motion member in those circumstances can be extremely difficult.

[**0103**] In the embodiment of **FIG. 24**, the handle **201** is disposed at the proximal end of the elongated shaft **200** via the torque sensing member **202** which continuously measures the torque applied by the surgeon, as illustrated by the rotational torque arrow **204**. Based on the torque measurement, the on-board motion controller (not shown) sends appropriate commands to the motors **203** for controlling the tool motion member **205**. The torque sensing member **202** is preferably relatively stiff such that the movement of the handle **201** with respect to the elongated shaft **200** is minimal for reasons described above (to enhance surgeon manipulation). Tool actuation may be driven manually by the handle **201** itself as in **FIG. 4** or it could be driven electronically by the motor as in **FIG. 18**. The motors could also be placed remotely as in **FIG. 19**.

[**0104**] In the embodiment of **FIG. 24** the handle end of the instrument is manipulated in substantially the same way as in earlier embodiments that have been described herein. **FIG. 24** shows by arrow **204** the direction of motion at the handle end of the instrument, and the corresponding position of the tool **206**, bent to the left in **FIG. 24**. In **FIG. 24**, instead of the motion member **205** being directly cable driven from the handle member, it is driven by cabling that couples from the control motors **203**, which is in turn controlled from the torque sensing member **202**. A full range of motion can be obtained from the instrument shown in **FIG. 24** in all directions, as in earlier embodiments described herein.

[**0105**] In the embodiment shown in **FIG. 25**, the benefit of the previous embodiment shown in **FIG. 24** is, in essence, combined with the simplicity of the embodiment shown in **FIGS. 1-4**. As in the embodiment of **FIGS. 1-4**, the tool motion member **211** that couples to the tool **215** is disposed at the distal end of the instrument shaft **210**. The handle **213** is disposed at the proximal end of the instrument. The handle **213** couples to the shaft **210** via the handle motion member **212**, and both motion members **211** and **212** are bendable in any direction. In addition to what is illustrated in **FIGS. 1-4**, however, the embodiment in **FIG. 25** simulates the effect of torque sensing member **202** of **FIG. 24** by using a handle motion member **212** that is much larger in diameter and laterally stiffer than that of the tool motion member **211**. Due to large diameter ratio between the motion members **211** and **212**, small bending of the handle motion member **212** causes a substantial bending of the tool motion member **211**. At the same time, because the handle motion member **212** is substantially stiff laterally, the surgeon operating the tool has to apply a reasonable amount of torque to the handle to cause the desired movement at the tool motion member. Without such lateral stiffness at the handle motion member, the tool motion member may bend too freely and may thus be difficult to control.

[**0106**] Still another embodiment of the present invention is illustrated in **FIG. 26** where ease of use of the instrument is further enhanced by making it simpler to roll the tool end about its axis **230**, an important motion in suturing at an off-axis angle. Similar to the embodiment of **FIGS. 1-4**, **FIG. 26** shows an instrument with an instrument shaft **220** and with the tool **223** and the handle **224** disposed respectively at the distal and proximal ends of the shaft **220**, via motion members **221** and **222**. However, unlike the embodiment of **FIGS. 1-4**, in this embodiment, the handle motion member **222** has a rolling-motion wheel **225** fixedly mounted at its proximal end, which is able to axially rotate about axis **232** and relative to the handle **224** as shown by the double-headed arrow **226**. This action causes a corresponding rotation of the tool **223** about axis **230** and as illustrated by the double-headed arrow **228**. Therefore, the surgeon operating the instrument can roll the instrument tool **223** simply by rolling the rolling-motion wheel **225** with his or her thumb rather than rolling the whole handle **224**.

[**0107**] Yet another embodiment of the present invention that further enhances ease of use is illustrated in **FIG. 27**. In addition to the embodiment of **FIGS. 1-4**, **FIG. 27** also illustrates the motion member locking mechanism **234**. While performing the surgical procedure, the surgeon operating the instrument may desire to lock the orientations of the bendable motion members temporarily so that he or she would not need to continuously exert torque at the handle motion member in order to maintain the desired orientation. The motion member locking mechanism **234** may consist of the locking collar **235**, the locking wedge **236** and the cable guide **237**. When the surgeon desires to lock the orientation of the motion member, he or she simply slides the locking collar **235** in the direction shown by the arrow **238**, which then presses down the locking wedge **236** against the cable guide **237** with the control cables **233** pinched in between. Once pinched, the control cables **233** would not be able to move, and as a result, the orientations of the motion members **231** and **232** will be fixed. The motion member orientation lock can be released by sliding the locking collar **235** backward toward the instrument tip.

[0108] There are several improvements brought forth by employing bendable sections for the motion members as opposed to other mechanisms such as pivotal joints or ball-and-socketjoints.

[0109] A first important attribute of a bendable member is in its inherent lateral (bending) stiffness, especially when used for the proximal handle motion member. In a jointed arrangement the proximal joint is situated between the elongated shaft and the control handle, together with the fulcrum at the incision. This behaves as a "double-joint" and the instrument may have a serious tool stability issue if the joint is "free" to move. Suppose the operating surgeon slightly moves his/her wrist while holding the control handle of the instrument. If the joint is "free" to move without providing substantial support resistance, due to the fulcrum effect of the long elongated shaft passing through the incision, it will result in substantial, unintended swinging of the tool end of the instrument in opposite direction. In a typical laparoscopic or endoscopic procedures where the operating field is small, such instability of the tool will render the tool potentially dangerous and unusable. Unlike the pivotal or ball-and-socket joints that are "free" to move, a bendable member has inherent stiffness which acts to provide necessary support for stabilizing the operator hand's wrist movement, which in turn stabilizes the tool motion. By varying the material and geometry of the bendable member, the appropriate level of stability could be selected.

[0110] A second important attribute of the bendable member, especially for bending in two degrees of freedom, is its uniformity in bending. Because the bendable member can bend in any direction uniformly, it has no inherent singularity, and as the result, the operator can produce uniform rolling motion of the tool, an important motion for tasks such as suturing, simply by rolling the control handle. On the other hand, if the motion members are comprised of series of pivotal joints, not only may it bind due to singularities, but the rolling of the control handle will result in unwanted side motion of the tool as well, affecting its usability for surgical procedure.

[0111] A third attribute of the bendable member is its ability to transmit substantial torque axially. By selecting appropriate material and geometry, the bendable member can be constructed to transmit torque axially necessary to perform surgical procedure. On the other hand, the motion member comprised of ball-and-socket joints will not be able to transmit thye necessary torque from the handle to the tool end.

[0112] A fourth attribute of the bendable member is that it has no sharp bending point, location or pivot and thus this results in an increased life and higher performance. Either pivotal or ball-and-socket joints on the other hand have sharp corners which can increase friction, reduce life and decrease performance of the tool actuation push rod passing through.

[0113] A fifth attribute of the bendable member is in the reduction of manufacturing cost. The bendable motion member can be injection molded as a single body, thus significantly reducing the cost. Pivotal or ball-and-socket joints are comprised of more part and this results in a higher manufacturing cost.

[0114] Lastly, a sixth attribute of the bendable member is that it can be easily customized. By varying the stiffness at different points of the bendable member, one can optimize its bending shape for specific applications.

[0115] While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims. For example, the embodiments described herein have primarily used four control cables for providing all direction motion of the motion members. In alternate embodiments fewer or greater numbers of cables may be provided. In a most simplified version only two cables are used to provide single DOF action at the bendable motion member.

What is claimed is:

**1**. A surgical instrument comprising:

an elongated instrument shaft having proximal and distal ends;

a tool disposed from the distal end of the instrument shaft; and

a control handle disposed from the proximal end of the instrument shaft;

said tool being coupled to the distal end of said elongated instrument shaft via a first movable member;

said control handle coupled to the proximal end of said elongated instrument shaft via a second movable member;

whereby movement of said control handle with respect to said elongated instrument shaft via said second movable member causes attendant movement of said tool with respect to said elongated instrument shaft via said first movable member;

wherein at least one of said first and second members comprises a bendable motion member.

**2**. The surgical instrument of claim 1 further including a control element that intercouples between said first and second movable members so that a movement of the control handle at the second movable member causes a movement of tool via the first movable member.

**3**. The surgical instrument of claim 2 wherein said control element comprises a cable system that interconnects the first and second movable members, said cable system being actuated by the movement of the control handle to, in turn, move the tool.

**4**. The surgical instrument of claim 1 wherein each of the movable members have two degree of freedom to provide motion in all directions.

**5**. The surgical instrument of claim 1 wherein both of the movable members comprise a bendable motion member, each bendable motion member providing at least one degree of freedom and the bending stiffness of the second movable member is greater than the bending stiffness of the first movable member.

**6**. The surgical instrument of claim 5 wherein each of the bendable motion members have two degree of freedom to provide motion in all directions.

**7**. The surgical instrument of claim 5 wherein the control handle comprises a push-pull tool actuation arrangement.

**8**. The surgical instrument of claim 1 wherein the tool movement with respect to the distal end of the elongated shaft is in the opposite direction of the control handle movement with respect to the proximal end of the elongated shaft.

**9**. The surgical instrument of claim 1 wherein the tool movement with respect to the distal end of the elongated shaft is in the same direction of the control handle movement with respect to the proximal end of the elongated shaft.

**10**. The surgical instrument of claim 1 wherein the control handle comprises a pull-pull tool actuation arrangement.

**11**. The surgical instrument of claim 1 wherein the elongated instrument shaft includes at least a flexible segment thereof.

**12**. The surgical instrument of claim 1 wherein the tool is selected from a group comprising a jaw, gripper, clip applier, stapler, electrosurgery device, scalpel and scissors.

**13**. The surgical instrument of claim 1 further including another proximal movable member and another distal movable member for multi-modal controlled movement of the tool.

**14**. The surgical instrument of claim 1 wherein the second movable member is able to axially rotate about the control handle.

**15**. The surgical instrument of claim 1 further including a distal axial rotation joint for axially rotating the first movable member about the elongated shaft.

**16**. The surgical instrument of claim 1 further including a distal axial rotation joint for axially rotating the tool about the first movable member.

**17**. The surgical instrument of claim 1 further including distal and proximal rotation joints wherein the proximal axial rotation joint actuates the distal axial rotation joint.

**18**. The surgical instrument of claim 1 further including a motion member locking mechanism for releasably locking said movable members.

**19**. The surgical instrument of claim 1 further including an electromechanical actuator for driving at least one degree of freedom movement of the tool.

**20**. A surgical instrument comprising:

an elongated instrument shaft having proximal and distal ends;

a tool disposed from the distal end of the instrument shaft; and

a control handle disposed from the proximal end of the instrument shaft;

said tool being coupled to the distal end of said elongated instrument shaft via a movable member;

said control handle coupled to the proximal end of said elongated instrument shaft via a torque sensing member;

an electromechanical actuator coupled to said movable member;

wherein torque applied at said torque sensing member by the operator produces a proportional movement of said actuator, which in turn produces a movement of said tool with respect to said elongated instrument shaft via said movable member.

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摘要(译)

内窥镜或腹腔镜器械包括远侧工具，支撑远侧工具的刚性或柔性细长轴，以及近侧手柄或控制构件，其中工具和手柄通过细长轴的相应远端和近端连接。可弯曲的运动成员。工具和工具运动构件经由缆线和推杆联接到手柄和手柄运动构件，使得手柄在任何方向上相对于细长轴的运动由远处的工具复制。轴的末端。工具运动相对于手柄运动的大小可以根据手柄运动构件相对于工具运动构件的尺寸而缩放。