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Abstract: Disclosed are compositions that contain an alginate and natural rubber resins. Also disclosed are simulated anatomical structures and assemblies of simulated anatomical structures, including a torso model, prepared from such compositions. Also disclosed herein are methods of making and using such compositions, simulated anatomical structures, and assemblies.
MODELS IMITATING INTERNAL ORGANS AND THE REAL ANATOMY

BACKGROUND

Among the recent advancements in healthcare, the use of medical techniques involving endoscopy has constantly grown in popularity. Endoscopy entails the use of a small video camera, called an endoscope, which is inserted into a patient through an opening or narrow incision. The endoscope allows a physician to view the patient’s internal anatomy by displaying video images on a monitor. Typically, endoscopy also involves the use of other surgical instruments that are inserted into the patient through one or more additional openings or narrow incisions. The physician manipulates the surgical instruments inside the patient to perform a medical procedure while observing video images of the procedure with the endoscope. Because such endoscopic surgical procedures generally cost less than open surgery, result in fewer complications with less postoperative pain, produce smaller scars, and allow patients a faster recovery, endoscopy is rapidly becoming the medical technique of choice for many surgical procedures.

Despite the advantages and growing popularity of endoscopy, performing endoscopic techniques can be challenging, and there is a demand for physicians who have received adequate training and mastered such skills. With endoscopic surgical procedures, a physician is required to precisely control the three-dimensional movements of surgical instruments inside a patient while observing two-dimensional images from the endoscope on a monitor. Such movements can be quite demanding due to problems with orientation and hand-eye coordination. Further, a lack of normal tactile sensation, the surgical instruments’ restricted range of movement, and a limited visual field contributes to the difficulty of endoscopic surgical procedures.

Consequently, it is critical that physicians receive adequate training in endoscopic skills so that endoscopic surgical procedures can be preformed safely and without causing unnecessary damage to surrounding tissues.

Usually, physicians receive training in endoscopic techniques by practicing
on animal models. Such methods are disadvantageous, however, because animal models are expensive, and practicing on animals generally requires an operating room, surgical and anesthetic equipment, and the appropriate certificates and registrations. Moreover, using animals to practice surgical skills is ethically debatable and it does not provide an accurate environment for practicing human surgical techniques.

Other endoscopic training methods involve the use of cadavers. However, like animal models, the use of cadavers can be expensive. Further, the properties of cadaver tissue differ from those of living tissue, for example, the absence of bleeding in cadaver tissue. Thus, practicing some endoscopic surgical procedures on cadavers can be unrealistic.

Still other endoscopic training methods involve the use of training devices that consist of box-like structures with various devices or simulated organs placed inside. While these devices provide some opportunity to practice a few basic endoscopic movements and skills, they do not provide a realistic environment in which to practice more complex endoscopic surgical procedures.

Therefore, in light of increasing significance of endoscopic surgical procedures and the need for physicians to receive adequate training in endoscopic techniques, there is currently a need for materials, compositions, devices, and methods for training physicians and medical students in endoscopic techniques that offer a realistic training experience and that is cost effective.

**SUMMARY**

In accordance with the purposes of the disclosed materials, compositions, devices, and methods, as embodied and broadly described herein, in one aspect, the disclosed subject matter relates to a composition comprising an alginate and rubber resin. In another aspect, the disclosed matter relates to simulated anatomical structures and assemblies of simulated anatomical structures, including a torso model, prepared from such compositions. Also, described herein are methods of
making and using such compositions, simulated anatomical structures, and assemblies.

Additional advantages will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the aspects described below. The advantages described below will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims. It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several aspects described below.

Figure 1 is a photograph showing the exterior of a prototype model torso of the present invention imitating the real anatomy.

Figure 2 is a photograph showing the interior of a prototype model of the present invention with simulated internal female genital organs.

Figure 3 is a photograph showing the interior of a prototype model of the present invention with a simulated bladder exposed under a simulated peritoneum.

DETAILED DESCRIPTION

The disclosed materials, compositions, and methods may be understood more readily by reference to the following detailed description of specific aspects of the materials, compositions, devices, and methods and the Examples included therein and to the Figures and their previous and following description.

Before the present materials, compositions, devices, and methods are disclosed and described, it is to be understood that the aspects described below are not limited to specific synthetic methods or specific reagents, as such may, of
course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular aspects only and is not intended to be limiting.

Disclosed are materials, compositions, and components that can be used for, can be used in conjunction with, can be used in preparation for, or are products of the disclosed method and compositions. These and other materials are disclosed herein, and it is understood that when combinations, subsets, interactions, groups, etc. of these materials are disclosed that while specific reference of each various individual and collective combinations and permutation of these compounds may not be explicitly disclosed, each is specifically contemplated and described herein.

For example, if a module simulating an anatomical region is disclosed and discussed and a number of modifications that can be made to a number of anatomical structures are discussed, each and every combination and permutation of the module simulating an anatomical region and the modifications to its simulated anatomical structures that are possible are specifically contemplated unless specifically indicated to the contrary. Thus, if a class of substituents A, B, and C are disclosed as well as a class of substituents D, E, and F and an example of a combination molecule, A-D is disclosed, then even if each is not individually recited, each is individually and collectively contemplated. Thus, in this example, each of the combinations A-E, A-F, B-D, B-E, B-F, C-D, C-E, and C-F are specifically contemplated and should be considered disclosed from disclosure of A, B, and C; D, E, and F; and the example combination A-D. Likewise, any subset or combination of these is also specifically contemplated and disclosed. Thus, for example, the sub-group of A-E, B-F, and C-E are specifically contemplated and should be considered disclosed from disclosure of A, B, and C; D, E, and F; and the example combination A-D. This concept applies to all aspects of this disclosure including, but not limited to, steps in methods of making and using the disclosed compositions. Thus, if there are a variety of additional steps that can be performed it is understood that each of these additional steps can be performed with any specific
embodiment or combination of embodiments of the disclosed methods, and that each such combination is specifically contemplated and should be considered disclosed.

**General Definitions**

In this specification and in the claims which follow, reference will be made to a number of terms which shall be defined to have the following meanings:

As used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a rubber resin” includes mixtures of rubber resins, reference to “an alginate” includes mixtures of two or more such alginates, and the like.

“Optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where the event or circumstance occurs and instances where it does not. For example, the phrase “optionally comprising a salt solution” means that salt solution can or cannot be present in the composition and that the description includes both compositions without salt solution and compositions where there is salt solution.

Ranges may be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another aspect includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent “about,” it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

References in the specification and concluding claims to parts by weight, of a particular element or component in a composition or article, denote the weight relationship between the element or component and any other elements or components in the composition or article for which a part by weight is expressed. Thus, in a compound containing 2 parts by weight of component X and 5 parts by
weight component Y, X and Y are present at a weight ratio of 2:5, and are present in such ratio regardless of whether additional components are contained in the compound.

A weight percent of a component, unless specifically stated to the contrary, is based on the total weight of the formulation or composition in which the component is included.

"Endoscopy" or "endoscopic" is used herein to refer to a medical procedure or technique that involves the use of an "endoscope." An "endoscope" as used herein refers to a small video camera that can be inserted into a patient and that can provide video images of the internal anatomy of the patient. Typically, an endoscope uses an integral system of viewing lenses, fiberoptic illumination, and a video camera attached to a light source and video monitor. As used herein, an "endoscope" can be inserted into a patient through a natural opening, such as the esophagus, sinus, anus, urethra, or vagina, or through an incision. The terms "endoscopy" and "endoscopic" are also meant to include the many specialized types of medical procedures that utilize an endoscope but which have specific names depending on the part of the anatomy the endoscope is used. Typically, these specialized types of procedures are named by inserting the appropriate term before the suffix "scopy." For example, "arthroscopy" is endoscopy of the joints, "cystoscopy" is endoscopy of the bladder, "hysteroscopy" is endoscopy of the uterine cavity, "laparoscopy" is endoscopy of the abdominal cavity, and so forth; these various terms are used interchangeably herein, unless context clearly indicates otherwise. Likewise, the endoscope used in such specialized procedures can be similarly named, e.g., an arthroscope, cystoscope, hysteroscope, laparoscope, and so forth.

Reference will now be made in detail to specific aspects of the disclosed materials, compounds, compositions, components, and methods, some examples of which are illustrated in the accompanying drawings.
Compositions

In one aspect, described herein is a composition that comprises an alginate and rubber resin. In another aspect, described herein is a composition that comprises an alginate, rubber resin, and a salt solution. Still further, described herein is a composition that comprises an alginate, rubber resin, a salt solution, and microspheres.

**Alginates:**

"Alginate," as used herein, is the general name given to salts of alginic acid, which is a linear heteropolysaccharide containing units of β-D-mannosyluronic (mannuronic) and α-L-gulopyranosyluronic (guluronic) acid residues. These saccharide-based residues can be arranged in various configurations in the alginate polymer. For example, alginates can contain homopolymeric sequences of mannuronic acid residues, known as M blocks, homopolymeric sequences of guluronic acid residues, known as G blocks, and mixed sequences of mannuronic and guluronic acid residues, known as MG blocks or alternating blocks. Usually, alginates contain all three different blocks and each block contains from about three to about twenty mannuronic and/or guluronic acid residues.

Alginates that have a high proportion of guluronic acid residues (and, hence, a low proportion of mannuronic acid residues) are known as high G alginates (or low M alginates). Correspondingly, alginates that have a low proportion of guluronic acid residues (and, hence, a high proportion of mannuronic acid residues) are known as low G alginates (or high M alginates). In one aspect, high G alginates can have about 60 to about 80% by weight guluronic acid residues. In another aspect, low G alginates can have about 60 to about 80% by weight mannuronic acid residues. Both high G and low G alginates (low M and high M alginates, respectively) are suitable for use in the compositions and methods described herein.

In one aspect, alginates suitable for the compositions and methods described herein can have a mannuronic to guluronic acid residue ratio of from about 1:10
(i.e., about 1 mannanuronic acid residue to about 10 guluronic acid residues) to about 10:1 (i.e., about 10 mannanuronic acid residues to about 1 guluronic acid residue). In still another aspect, suitable alginates can have mannanuronic to guluronic acid residue ratios of about 1:10, 1:9, 1:8, 1:7, 1:6, 1:5, 1:4, 1:3, 1:2, 1:1, 2:1, 3:1, 4:1, 5:1, 6:1, 7:1, 8:1, 9:1, or 10:1.

In another aspect, suitable alginates can be water soluble or water-insoluble gels. “Water soluble” as used herein defines a solubility sufficient to allow production of an aqueous solution of alginate having a concentration of at least about 0.1 mM. “Water insoluble” as used herein defines a solubility insufficient to allow production of an aqueous solution of alginate having a concentration of at least about 0.1 mM.

Suitable water-soluble alginates include, but are not limited to, sodium alginate, potassium alginate, lithium alginate, ammonium alginate, and magnesium alginate.

Water-insoluble alginate gels are typically formed by the chemical conversion of water-soluble alginates, in an aqueous solution, into water-insoluble alginates. This conversion usually is accomplished by the reaction of a water-soluble alginate with an insolubilizing salt that contains a polyvalent cation and one or more soluble anions, such as chlorides, sulphates, nitrates, glucuronates, and the like. Polyvalent cations capable of forming water-insoluble alginate gels include, for example, calcium and zinc cations. While not wishing to be bound by theory, it is believed that the role of the polyvalent cations is to react with and, in some cases, crosslink the alginate polymer. As the polyvalent cation content in solution is increased, thickening, gelation, and finally precipitation of the alginate occurs.

One of ordinary skill in the art will understand that the properties of alginate gels and solutions are influenced by the mannanuronic and guluronic acid residue ratio, the type and amount of monovalent salts in the solution, the type and amount of polyvalent cation, temperature, and degree of polymerization. Thus, based upon the
desired properties for a particular application, it is possible to select alginates that have or can produce an alginate gel or solution with desired properties. For example, high G alginates can be used to produce strong, brittle gels that are heat stable, while high M alginates can be used to produce weaker, more elastic gels that have less heat stability, but more freeze/thaw stability.

Suitable alginates can be found in and isolated from various species, such as from algae belonging to the order Phaeophyceae, soil bacteria such as Azotobacter vinelandii and Azotobacter crococcum, and from several strains of Pseudomonas bacteria, as described in, for example, U.S. Pat. No. 4,235,966, which is incorporated by reference herein for its teaching of alginate sources. Common commercial sources of alginates include, but are not limited to, horsetail kelp (Laminaria digitata), Ecklonia maxima, giant brown seaweed (Macrocystis pyrifera), Lessonia nigrescens, Ascophyllum nodosum, Laminaria japonica, Durvillea antarctica, Durvillea potatorum, sugar kelp (Laminaria saccharina), and Laminaria hyperborea.

Supplies of alginates suitable for the compositions and methods described herein, such as those described above, can be obtained from, for example, Pronova Biopolymer (Portsmouth, NH), Kelco, a Division of Merck & Co., Inc. (San Diego, Calif.), and Protan Ltd. (Drammen, Norway). For example, naturally derived sodium alginates can be purchased under the trademarks KELTEX, KELGIN, and KELTONE from Kelco. Also, high G alginate can be obtained from, for example, Laminaria hyperborea, and is commercially available as, for example, LF 10/60 from Protan Ltd. Low G alginate can be obtained from, for example, Ascophyllum nodosum, and is commercially available as, for example, LAMITEX (Protan Ltd.) and MANUCOL DM (Kelco). Depending on the source and supplier, alginates can vary in the distribution of the M, G, and MG blocks, the relative manuronic and guluronic acid content, molecular weight, particle form, viscosity, and mesh size.
Other alginates suitable for the compositions and methods described herein are described in detail by I.W. Cottrell and P. Kovacs in "Alginates," Chapter 2 of Davidson, ed., Handbook of Water-Soluble Gums and Resins (1980). Still other suitable alginates and their method of isolation and modification are disclosed in U.S. Patent Nos. 6,695,307, 6,274,174, 5,976,439, and 5,563,186. These four U.S. patents and Chapter 2 of the Handbook of Water Soluble Gums and Resins are incorporated by reference herein for their teachings of alginates and methods for their isolation and modification.

In one aspect, the composition described herein has from about 40 wt. % to about 80 wt. % alginate, based on the total weight of the composition. In another aspect, the alginate can be present in the composition at from about 50 wt. % to about 70 wt. %, based on the total weight of the composition. In still another aspect, the alginate can be present in the composition at about 60 wt. %, based on the total weight of the composition. In the composition described herein, the alginate can be present in an amount of from about 40, 45, 50, 55, 60, 65, 70, 75, or 80 wt. %, based on the total weight of the composition, where any of the stated values can form an upper and/or lower endpoint when appropriate.

*Rubber Resin:*

The materials, compositions, devices and methods described herein, in one aspect, relate to a composition that comprises an alginate and a rubber resin. Rubber resin, as used herein, can be a natural rubber resin, a synthetic rubber resin, or a combination thereof. For example, in one aspect, the composition can comprise one or more natural rubber resins. In another aspect, the composition can comprise one or more synthetic rubber resins. In a further aspect, the composition can comprise one or more natural rubber resins and one or more synthetic rubber resins.

*Natural Rubber Resin:*

Natural rubber resins are latex compositions that are derived from the *hevea braziliensis* rubber tree. These compositions comprise natural rubber particles
dispersed in a continuous phase. The natural rubber is a polymer made up of repeating units of isoprene, i.e., cis-1,4-polyisoprene. The continuous phase of natural rubber resins is generally aqueous and, depending on the type of resin and how it is processed, can contain various additional components, such as proteins, nucleic acids, lipids, and/or salts.

There are several types of natural rubber resin suitable for use in the compositions and methods described herein. The types differ in how the natural rubber resin is processed. One type of natural rubber resin, known as standard grade, is subject to the requirements of international standards. HA (high-ammonia) resin is another type of natural rubber resin and has been preserved with greater than about 0.6% ammonia, based on the total weight of latex. LA-TZ (low ammonia) resin has been preserved with about 0.2% ammonia and of not more than about 0.1% of tetramethyl-thiuramdisulphide (TMTD)/ZnO, based on the total weight of the latex. Double centrifuged (DC) resin is a purified latex concentrate prepared by centrifuging the latex, diluting, and then re-centrifuging. With DC resins, the non-rubber constituents of the resin are further reduced. Articles prepared from DC resin generally exhibit good clarity, low water absorption, and high dielectric properties. Other types of natural rubber resins that can be used in the composition and methods described herein include, but are not limited to, High Dry Rubber Content (DRC) resin, Pre-vulcanized (PV) resin, and creamed and evaporated resin. One of ordinary skill in the art will readily understand the general types of available natural rubber resins and the methods for their procurement, handling, storage, use, and disposal.

In one aspect, the natural rubber resin can be obtained commercially from hobby or arts supply companies. For example, natural rubber resin suitable for use in the compositions and methods described herein can be obtained from Cementex, (New York, NY).
In one aspect, the composition described herein has from about 20 wt. % to about 60 wt. % natural rubber resin. In another aspect, the natural rubber resin can be present in the composition at from about 30 wt. % to about 50 wt. %, based on the total weight of the composition. In still another aspect, the natural rubber resin can be present in the composition at about 40 wt. %, based on the total weight of the composition. In the composition described herein, the natural rubber resin can be present in an amount of from about 20, 25, 30, 35, 40, 45, 50, 55, or 60 wt. %, based on the total weight of the composition, where any of the stated values can form an upper and/or lower endpoint when appropriate.

**Synthetic Rubber Resin:**

Synthetic rubber resins are latex compositions that are not derived from the *hevea brasiliensis* rubber tree. These compositions comprise synthetic rubber particles dispersed in a continuous phase. The continuous phase of synthetic rubber resins is generally aqueous.

Suitable synthetic rubber includes, but is not limited to, polyurethane, silicone rubber, RTV silicone rubber, polysulfide rubber, polyester, polyethylene, polyvinyl alcohol, acrylonitrile-butadiene rubber, butadiene-styrene rubber, ABS rubber, and neoprene rubber.

Suitable synthetic rubber resins that can be used in the compositions and methods described herein can be obtained from commercial supplies such as Synair (Chattanooga, TN), Smooth-On, Inc. (Easton, PA), Alumilite Corp. (Kalamazoo, MI), BJB Enterprises, Inc. (Tustin, CA), Goldenwest Manufacturing, Inc. (Cedar Ridge, CA), Silcones, Inc. (High Point, NC), POLYTEK Development Corp. (Easton, PA), Douglas and Sturgess (San Francisco, CA), Burman Industries (Van Nuys, CA), and Chicago Latex Products (Chicago, IL).

In one aspect, the composition described herein has from about 20 wt. % to about 60 wt. % synthetic rubber resin. In another aspect, the synthetic rubber resin can be present in the composition at from about 30 wt. % to about 50 wt. %, based
on the total weight of the composition. In still another aspect, the synthetic rubber resin can be present in the composition at about 40 wt. %, based on the total weight of the composition. In the composition described herein, the synthetic rubber resin can be present in an amount of from about 20, 25, 30, 35, 40, 45, 50, 55, or 60 wt. %, based on the total weight of the composition, where any of the stated values can form an upper and/or lower endpoint when appropriate.

Salts Solution:

In one aspect, the compositions described herein can further comprise a salt solution. While the use of a salt solution is optional in the compositions described herein, its use can allow various properties of the composition to be tailored to provide a composition with certain desired characteristics.

Suitable salt solutions can be aqueous, i.e., containing water. In one aspect, the aqueous salt solution further contains other water-miscible solvents, such as dioxane, N,N-dimethylformamide (DMF), dimethylsulfoxide (DMSO), acetonitrile, acetone, acetic acid, including mixtures thereof.

Suitable salts that can be present in the salt solution include, but are not limited to, ammonium chloride, lithium chloride, sodium chloride, potassium chloride, magnesium chloride, calcium chloride, zinc chloride, ammonium bromide, lithium bromide, sodium bromide, potassium bromide, magnesium bromide, calcium bromide, zinc bromide, ammonium hydroxide, lithium hydroxide, sodium hydroxide, potassium hydroxide, magnesium hydroxide, calcium hydroxide, zinc hydroxide, ammonium sulfate, lithium sulfate, sodium sulfate, potassium sulfate, magnesium sulfate, calcium sulfate, zinc sulfate, ammonium nitrate, lithium nitrate, sodium nitrate, potassium nitrate, magnesium nitrate, calcium nitrate, and zinc nitrate.

In one specific aspect, the salt solution can be about a 0.1 M salt solution. In other aspects, the salt solution can be about a 0.01, 0.05, 0.1, 0.15, 0.2, 0.25, 0.5,
1.0, or 1.5 M salt solution, where any of the stated values can form an upper and/or lower endpoint when appropriate.

In one aspect, the composition described herein has from about 1 wt. % to about 40 wt. % salt solution. In another aspect, the salt solution can be present in the composition at from about 10 wt. % to about 30 wt. %, based on the total weight of the composition. In still another aspect, the salt solution can be present in the composition at about 20 wt. %, based on the total weight of the composition. In the composition described herein, the salt solution can be present in an amount of from about 1, 5, 10, 15, 20, 25, 30, 35, or 40 wt. %, based on the total weight of the composition, where any of the stated values can form an upper and/or lower endpoint when appropriate.

*Additional Components:*

The compositions described herein can optionally contain additional components. For example, the compositions can additionally contain stabilizers, preservatives, emulsifiers, surfactants, dyes, pigments, inks, colorants, thickeners, thinners, metal ions, and the like.

In one aspect, the described composition can contain within its matrix microspheres or microcapsules. The preparation of microspheres or microcapsules is known to those of ordinary skill in the art and can involve methods such as interfacial polycondensation, spray drying, hot melt microencapsulation, and phase separation techniques like solvent removal and solvent evaporation. One suitable method for synthesizing microspheres suitable for use herein is disclosed in K. J. Lui *et al.*, *Biophys. J.*, 67, 896-901, 1994, which is incorporated by reference herein in its entirety.

In one aspect, the suitable microspheres or microcapsules that can be used in the compositions described herein can have an average particle size of between about 10 nanometers and about 1000 micrometers. The average particle size, of course, may be adjusted within this range, for example to between about 100
nanometers and about 100 micrometers or between about 1 micrometer and about 10 micrometers.

In another aspect, the microspheres or microcapsules can encapsulate various components such as dyes, pigments, inks, or colorants. When a composition contains such microspheres or microcapsules, cutting, abrading, or puncturing the composition can cause the microspheres contained therein to release their encapsulated contents. In this way, for example, cutting the composition with microspheres having a red dye can resemble bleeding.

*Properties:*

The compositions described herein can have, although not required (*i.e.*, optionally), one or more properties that make them particularly amenable for use in simulated anatomical structures, surgical training models, and devices. That is, by preparing compositions according to the present invention, the compositions will have one or more properties that simulate one or more anatomical structures. For example, the compositions described herein can possess one or more of a color, texture, rigidity, thickness, density, and/or toughness of real animal tissue. Also, by varying the conditions used when preparing the described compositions, the properties of the compositions can be altered or modified. Such an ability to vary the properties of the disclosed compositions is useful since many anatomical structures and tissues have different properties and characteristics. Thus, the compositions described herein can be used to simulate a multitude of different anatomical structures and tissues.

In one aspect, the compositions described herein have a color that simulates a real animal tissue or organ. The color of the composition can be varied by methods known in the art, such as by adding dye, ink, or pigment to the composition or to the alginate, natural rubber resins, and/or salt solution of the composition. Also, the composition can be colored or painted after it has been formed into a simulated
anatomical structure. By providing a realistic color appearance, the described compositions can be beneficial in creating a realistic surgical training environment.

In another aspect, the compositions described herein have a texture, rigidity, thickness, and density that cooperatively mimic real animal tissue. In this way, the compositions can provide a similar sensation to real animal tissue when the composition is cut, dissected, punctured, sutured, clamped, and the like. By providing realistic sensations, the described compositions can be beneficial in creating a realistic surgical training environment.

The texture of the compositions described herein can be varied by methods known to those of ordinary skill in the art. For example, when the composition is poured into a mold to form a particular a simulated anatomical structure, the mold can be fashioned in such a way that the surface of the simulated anatomical structure produced from the mold will have a particular characteristic, e.g., the mold can produce a surface that is rough, pitted, smooth, and the like. Another way to vary the texture of the composition described herein is by varying the type and amount of alginates, natural rubber resins, and/or salt solution in the composition.

Rigidity is another property of the disclosed compositions that renders them useful for surgical training models and devices. Because many real tissues have different rigidity, it may be desirable to vary the rigidity of the compositions disclosed herein to simulate the various real tissues. For example, the rigidity of muscle tissue is higher than that of fat tissue. And the rigidity of tendon is higher than the rigidity of connective tissue. The rigidity of the compositions described herein can be controlled by varying the amount of salt solution and/or the concentration of salt solution in the composition. For example, to increase the rigidity of the described compositions, a lesser amount of salt solution can be used. Alternatively, to increase the rigidity of the described compositions, a more concentrated salt solution can be used.
Another particular property of the disclosed compositions that renders them useful for surgical training models and devices is their shear strength. Many tissues found in real animals can have different shear strength. For example, connective tissue has a relatively low shear strength and is readily incised and severable.

Conversely, muscle has a relatively high shear strength. The shear strength of the compositions described herein can be varied by controlling the amounts of the natural rubber resins in the composition. For example, to increase the shear strength of the composition, more natural rubber resins can be present in the composition. Similarly, to decrease the shear strength of the composition, less natural rubber resins can be present. In one aspect, the composition described herein has a shear strength that allows the composition to be sutured without tearing through.

A still further property of the compositions described herein is their ability to be electrocoated. Since many endoscopic surgical procedures require incision and dissection of tissue using electrocoaterization, the ability to practice such procedures with a composition that responds to electrocoaterity in a realistic way can be beneficial.

**Methods of Making Composition**

The disclosed compositions can be made by techniques generally known to those of skill in the art. The starting materials and reagents used in preparing these compounds are either available from commercial suppliers such as Aldrich Chemical Co., (Milwaukee, Wis.), Acros Organics (Morris Plains, N.J.), Fisher Scientific (Pittsburgh, Pa.), Sigma (St. Louis, Mo.), Pronova Biopolymer (Portsmouth, NH), Kelco, a Division of Merck & Co., Inc. (San Diego, Calif.), and Protan Ltd. (Drammen, Norway) or are prepared by methods known to those skilled in the art following procedures set forth in references such as Fieser and Fieser's Reagents for Organic Synthesis, Volumes 1-17 (John Wiley and Sons, 1991); Rodd's Chemistry of Carbon Compounds, Volumes 1-5 and Supplementals (Elsevier Science Publishers, 1989); Organic Reactions, Volumes 1-40 (John Wiley and Sons,

In one aspect, the disclosed composition is prepared by combining an alginate with natural rubber resins. This combination can occur in any order. That is, neat or diluted alginate can be added to neat or diluted natural rubber resins. Or, alternatively, neat or diluted natural rubber resins can be added to neat or diluted alginate. Still further, the two components can be combined simultaneously.

**Article: Simulated Anatomical Structure**

The compositions described herein can be used to prepare a simulated anatomical structure, such as an organ or tissue, which closely resembles or mimics a real anatomical structure.

In one aspect, the simulated anatomical structure can include, but is not limited to, a simulated esophagus, stomach, intestine, colon, liver, kidney, bladder, appendix, lung, heart, gall bladder, spleen, prostate, uterus, fetus, ovary, testes, muscle, tendon, cartilage, ligament, artery, vein, connective tissue, peritoneum, and the like.

In another aspect, the simulated anatomical structure can contain microspheres or microcapsules. Suitable microspheres or microcapsules are described above and can have, for example, dye, ink, pigment, or colorants encapsulated within the microsphere or microcapsule.

**Method of Making Article**

Disclosed herein is a method of making simulated anatomical structures comprising the steps of (a) preparing a mold of an anatomical structure, (b) preparing a cast from the mold, (c) adding a composition as described herein to the cast and allowing it to set, and (d) removing the set composition from the cast. Also, described herein is a method of making layered anatomical structures, further comprising the steps of (e) contacting the composition removed from the cast with a
basic solution to provide a base treated composition, (f) washing the base treated composition with water to provide a washed composition, (g) placing the washed composition into a cast, (h) adding a composition as described herein into the cast with the washed composition and allowing the composition to set, thereby forming a layered composition, and (i) removing the layered composition from the cast.

In one aspect, the simulated anatomical structures described herein can be prepared by first preparing a mold of the anatomical structure to be simulated. The mold should have characteristic such as size and shape that closely resemble the characteristics of a real anatomical structure. Also, the mold can be made from a formable material such as clay. One of ordinary skill in the art will understand the techniques and materials used in preparing such molds.

A cast can then be prepared from the mold. Typically, such casts are made from a material that can harden, such as plaster or latex rubber. One of ordinary skill in the art will know how to procure and use a suitable plaster material, or a suitable alternative, for preparing a cast from a mold.

Typically, after the cast has hardened, the compositions described herein can be added to the cast and allowed to set. Addition of the composition to the cast can be accomplished by, for example, pouring, injecting, or spraying the composition into the cast. Alternatively, the cast can be dipped into the composition. The amount of the composition that should be added will, of course, depend on the size of the cast. After the composition has been added to the cast it can be allowed to set. Once the composition has set, it can then be removed from the cast.

In another aspect, the simulated anatomical structure can contain one or more layers of the compositions described herein. Having layers can allow the simulated anatomical structure to more closely resemble certain real anatomical tissues and organs since many real organs and tissues are themselves made up of various layers. For example, real organs like a uterus or stomach can have a membrane layer, a muscle layer, an inner lining, and so forth. Each of these layers can differ in
thickness, rigidity, density, texture, and the like. Thus, to more accurately simulate, for example, a uterus, multiple layers of the described compositions, each having properties simulating a different layer of a real uterus, can be used.

To prepare a simulated anatomical structure with various layers of the compositions described herein, the procedure described above can be used. However, after the composition has been allowed to set and removed from the cast, it can be contacted with a basic solution. Suitable basic solutions include, but are not limited to, 1N sodium hydroxide. Contacting the set composition with the basic solution can be performed by, for example, removing the composition from the cast and brushing it with or immersing it into a basic solution.

After the set composition has been contacted with a basic solution, the base treated composition can then be washed with water. Washing can be performed by immersion, spraying, or contacting the composition with water. The washed composition can then be placed back into the original cast or into a different cast, depending on the particular simulated anatomical structure and the layer to be formed. Once the washed composition is in the cast, a second composition can be added to the cast and allowed to set. The process of adding the composition into the cast, setting, contacting the set composition with basic solution, washing, and adding another composition can be repeated depending on the number of desired layers.

**Assembly of Articles**

Also disclosed herein is a module that simulates an anatomical region of an animal. The module can simulate various anatomical regions of an animal, such as a pelvic region, an abdominal region, a genital region, a thoracic region, a head region, and the like, or mixtures thereof. For example, in one aspect, the module can simulate an abdominal-pelvic region of an animal. As used herein, "animal" includes, but is not limited to, mammals (e.g., primate, human, etc.), domesticated animals (e.g., cats, dogs, etc.), livestock (e.g., cattle, horses, pigs, sheep, goats, etc.), laboratory animals (e.g., mouse, rabbit, rat, guinea pig, etc.) and birds. In one
aspect, the animal is a mammal. In another aspect, the animal is a primate. In a further aspect, the animal is a human.

In one aspect, the module comprises a substantially air tight container that simulates an anatomical region of an animal. The air tight container can have an exterior surface and an interior cavity, and at least one simulated anatomical structure in the interior cavity of the container. By “substantially air tight” is meant that the interior cavity of container can be filled with a gas to a particular pressure and have no or minimal reduction of gas pressure over time. For example, the container can be inflated to a pressure of about 2 atm and not see a significant reduction over a period of 2 hours, or over a period of 6 hours, or over a period of 12 hours. The air tight container can be made of, for example, polyurethane, polystyrene, polyethylene, polyethylene terephthalate, and the like.

In another aspect, the interior cavity of the container can contain at least one simulated anatomical structure. In still another aspect, the interior cavity of the container can contain a plurality of simulated anatomical structures. For example, the interior cavity of the container can contain one or more of a simulated esophagus, stomach, intestine, colon, liver, kidney, bladder, appendix, lung, heart, gall bladder, spleen, prostate, uterus, fetus, ovary, testes, muscle, tendon, cartilage, ligament, artery, vein, connective tissue, peritoneum, and the like.

The at least one simulated anatomical structure can be positioned in the interior cavity of the container in an anatomically correct manner. For example, the simulated anatomical structures can be positioned in the container in the same or similar fashion as is found in a real animal. That is, the positional relationship between two or more simulated anatomical structures in the interior cavity resembles the positional relationship of real anatomical structures in a real animal.

In one aspect, the exterior surface of the container can simulate body tissue. For example, the external surface can have the same or similar appearance, texture, color, thickness, density, or tactile characteristics of real tissue. In one aspect, the
exterior surface of the container can simulate skin. Simulated skin can be made from silicone rubber and/or urethane foam. In another aspect, the exterior surface of the container can comprise a simulated peritoneum.

In one aspect, the module can further comprise synthetic blood.

In another aspect, the module is disposable.

**Method of Making Assembly of Articles:**

The module simulating an anatomical region of an animal can be prepared by methods known in the art. For example, the module can be prepared by placing one or more simulated anatomical structures in an anatomically accurate position in the interior cavity of the module. The simulated anatomical structures can, optionally, be fixed into position by methods known in the art. For example, the simulated anatomical structures can be fixed into position with glue, resin, adhesive, cement, and the like. Other means for fixing simulated anatomical structures in the interior cavity of the module include, but are not limited to, pins, zippers, Velcro, snaps, straps, and the like; however, these means may detract from the ability of the module to realistically simulate an anatomical region of an animal.

**Surgical Trainer**

Another aspect of the materials, compositions, and devices disclosed herein is a surgical trainer. The surgical trainer can be used by medical students, veterinary students, physicians, and the like, to receive training in and to practice various surgical procedures.

In one aspect, the surgical trainer can comprise a simulated animal torso with an anatomical region cavity and a module simulating an anatomical region. In one aspect, the simulated torso mimics or resembles all or a portion of the torso area of an animal in size, shape, and appearance. The simulated torso can be made from materials such as polyurethane, polystyrene, polyethylene, polyethylene terephthalate, and the like. In a further aspect, the simulated torso has an anatomical
region cavity, which is an opening in the torso which can accept one or more modules simulating an anatomical region.

In one aspect, the surgical trainer can simulate various portions of an animal's anatomy. For example, the surgical trainer can simulate a whole body of an animal, e.g., a simulated animal torso including appendages, or a portion of an animal, like the upper torso and head. The animal includes, but is not limited to, mammals (e.g., primate, human, etc.), domesticated animals (e.g., cats, dogs, etc.), livestock (e.g., cattle, horses, pigs, sheep, goats, etc.), laboratory animals (e.g., mouse, rabbit, rat, guinea pig, etc.) and birds. In one aspect, the animal is a mammal. In another aspect, the animal is a primate. In a further aspect, the animal is a human.

In one aspect, the anatomical region cavity is a cavity in the pelvic region, abdominal region, genital region, thoracic region, head region, and the like, or mixtures thereof. For example, in one aspect, the anatomical region cavity can be an abdominal-pelvic region cavity. The particular module placed in the anatomical region cavity will depend on the particular anatomical region cavity. For example, a module simulating an abdominal region will fit into an abdominal region cavity, and a module simulating an abdominal-pelvic region will fit into an abdominal-pelvic region cavity, and a module simulating a thoracic region will fit into a thoracic region cavity, and so forth.

The module simulating an anatomical region can fit into the anatomical region cavity of the simulated animal torso. The module can be secured to the simulated animal torso with means known in the art, such as with an adhesive, pins, zippers, Velcro, snaps, straps, and the like. In one aspect, the module is removable. In one aspect, the module sits in the anatomical region cavity.

In another aspect, the module is removable. That is, the module simulating an anatomical region can be placed inside the anatomical region cavity for a training exercise and then be removed. In this way, the removed module simulating an
anatomical region can be examined or analyzed by the trainer, or it can be discarded.

In yet another aspect, the surgical train can be air tight and hold insufflation inside its exterior or anatomical region cavity to provide students with a realistic surgical experience.

A photograph of the exterior of a surgical trainer of one aspect of the invention is shown in Figure 1. Photographs of the interior portions of two aspects of the trainer of the invention are shown in Figures 2 and 3. The trainer’s dimensions in these figures are 21” length, 12” width and 9” height. Such dimensions can, of course, be varied to more accurately simulate various animal’s body types and age groups. The thin, single layer, rubber abdominal covering shown in Figure 1 can be replaced by a more anatomically correct substitute that consists of an outer skin layer, a musculo-cutaneous middle layer, and an inner fascial layer. Such a substitute exterior can be chosen by selecting materials that have the desirable mechanical characteristics to simulate the resistance to passage of instruments experienced in actual live endoscopy.

Method of Using Surgical Trainer

Also described herein is a method for training surgical techniques, comprising the steps of: providing a surgical trainer; and performing a surgical technique on the surgical trainer. The surgical technique can involve the use of an endoscope or specific types of endoscopes, such as a laproscope. In one aspect, the surgical trainer can be used to practice various endoscopic techniques, such as formation of pneumoperitoneum, insertion of trocars, sharp and cautery dissection, irrigation, cutting, intra- and extra-corporeal suturing, stapling, bagging and aspiration of cysts, clamping, and morcelation of tumors and the like. In another aspect, the surgical trainer can be used to practice any endoscopic surgical procedure. Examples of endoscopic surgical procedures suitable for the methods described herein can involve diagnostic procedures, operative procedures, exploratory procedures, therapeutic trauma treatments, visceral repair, visceral
removal, and the like. Some specific examples of such endoscopic surgical
techniques include, but are not limited to, diagnostic and operative laparoscopy such
as laparoscopic hysterectomy or adnexectomy, lapro-endoscopy such as
laparoscopic cholecystectomy, and diagnostic and operative hysteroscopy such as
polypectomy or endometrial ablation.

**EXAMPLES**

The following examples are put forth so as to provide those of ordinary skill
in the art with a complete disclosure and description of how the compounds,
compositions, articles, devices, and/or methods described and claimed herein are
made and evaluated, and are intended to be purely exemplary and are not intended to
limit the scope of what the inventors regard as their invention. Efforts have been
made to ensure accuracy with respect to numbers (e.g., amounts, temperature, etc.)
but some errors and deviations should be accounted for. Unless indicated otherwise,
parts are parts by weight, temperature is in °C or is at ambient temperature, and
pressure is at or near atmospheric. There are numerous variations and combinations
of reaction conditions, e.g., component concentrations, desired solvents, solvent
mixtures, temperatures, pressures and other reaction ranges and conditions that can
be used to optimize the product purity and yield obtained from the described
process. Only reasonable and routine experimentation will be required to optimize
such process conditions.

**Example 1: Preparation of a Composition**

To a vessel containing thirty (30) cubic centimeters of alginate powder was
added twenty-two (22) cubic centimeters of 1M saline salt solution and twenty-two
(22) cubic centimeters of natural rubber resin. The composition was stirred by
mechanical stirring for 30 seconds at room temperature. A composition of the
invention was thereby formed.

**Example 2: Preparation of a simulated anatomical structure**
To a plaster cast of an anatomical structure was added the composition of Example 1. The composition was allowed to harden overnight and then removed from the cast. A simulated anatomical structure of the invention was thereby formed.

Throughout this application, various publications are referenced. The disclosures of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the compounds, compositions and methods described herein.

Various modifications and variations can be made to the compounds, compositions and methods described herein. Other aspects of the compounds, compositions and methods described herein will be apparent from consideration of the specification and practice of the compounds, compositions and methods disclosed herein. It is intended that the specification and examples be considered as exemplary.
What is claimed is:

1. A composition, comprising:
   a. an alginate; and
   b. rubber resin.

2. The composition of claim 1, wherein the alginate is water insoluble.

3. The composition of claim 1, wherein the rubber resin is a natural rubber resin.

4. The composition of claim 1, wherein the rubber resin is a synthetic rubber resin.

5. The composition of claim 1, further comprising a salt solution.

6. The composition of claim 5, wherein the salt solution comprises one or more of ammonium, sodium, potassium, calcium, magnesium, zinc, chloride, bromide, hydroxide, sulfate, or nitrate ions.

7. The composition of claim 1, wherein the composition comprises from about 40 to about 80 wt. % alginate and from about 20 to about 60 wt. % rubber resin based on the total weight of the composition.

8. The composition of claim 7, wherein the composition further comprises from about 1 to about 40 wt. % salt solution based on the total weight of the composition.

9. The composition of claim 1, wherein the composition has a color, texture, rigidity, thickness, density, and toughness of real animal tissue.

10. The composition of claim 1, further comprising microspheres having dye.

11. The product made by the process of mixing an alginate and rubber resin.

12. A simulated anatomical structure comprising the composition of claim 1.
13. The simulated anatomical structure of claim 12, wherein the simulated anatomical structure comprises one or more of a simulated esophagus, stomach, intestine, colon, liver, kidney, bladder, appendix, lung, heart, gall bladder, spleen, prostate, uterus, fetus, ovary, testes, muscle, tendon, cartilage, ligament, artery, vein, connective tissue, or peritoneum.

14. The simulated anatomical structure of claim 12, further comprising microspheres having dye.

15. A method of making the simulated anatomical structure of claim 12, comprising the steps of:
   a. preparing a mold of an anatomical structure;
   b. preparing a cast from the mold;
   c. adding the composition of claim 1 to the cast and allowing it to set; and
   d. removing the set composition from the cast,
thereby providing a simulated anatomical structure.

16. The method of claim 15, further comprising the steps of:
   e. contacting the composition removed from the cast with a basic solution to provide a base treated composition;
   f. washing the base treated composition with water to provide a washed composition;
   g. placing the washed composition into a cast;
   h. adding a composition of claim 1 into the cast with the washed composition and allowing the composition to set, thereby forming a layered composition; and
   i. removing the layered composition from the cast,
thereby providing a simulated anatomical structure.

17. A module simulating an anatomical region of an animal, comprising:
   a. a substantially air tight container simulating an anatomical region of an animal and having an exterior surface and an interior cavity; and
   b. at least one simulated anatomical structure of claim 12,

   wherein the at least one simulated anatomical structure is in the interior cavity of the container.

18. The module of claim 17, wherein the module simulates a pelvic region, an abdominal region, a genital region, a thoracic region, a head region, or mixture thereof, of the animal.

19. The module of claim 17, wherein the module simulates an abdominal-pelvic region.

20. The module of claim 17, wherein the at least one simulated anatomical structure is a plurality of simulated anatomical structures.

21. The module of claim 17, wherein the at least one simulated anatomical structure comprises one or more of a simulated esophagus, stomach, intestine, colon, liver, kidney, bladder, appendix, lung, heart, gall bladder, spleen, prostate, uterus, fetus, ovary, testes, muscle, tendon, cartilage, ligament, artery, vein, connective tissue, or peritoneum.

22. The module of claim 17, wherein the at least one simulated anatomical structure is positioned in the interior cavity in an anatomically correct manner.

23. The module of claim 17, wherein the exterior surface of the container is a simulated body tissue.

24. The module of claim 17, wherein the exterior surface of the container comprises a simulated peritoneum.
25. The module of claim 17, further comprising synthetic blood.

26. The module of claim 17, wherein the animal is a human.

27. A surgical trainer, comprising:
   a. a simulated torso with an anatomical region cavity; and
   b. the module of claim 17,

   wherein the module is in the anatomical region cavity.

28. The surgical trainer of claim 27, wherein the module is removable.

29. The surgical trainer of claim 27, wherein the anatomical region cavity is an abdominal-pelvic region cavity and the module simulates an abdominal-pelvic region.

30. A method for training surgical techniques, comprising the steps of:
   a. providing the surgical trainer of claim 27; and
   b. performing a surgical technique on the surgical trainer.

31. The method of claim 29, wherein the surgical technique uses an endoscope, laparoscope or hysteroscope.

32. The method of claim 29, wherein the surgical technique is selected from one or more of a diagnostic laparoscopy, operative laparoscopy, lapro-endoscopy, laparoscopic cholecystectomy, laparoscopic hysterectomy, diagnostic hysteroscopy, operative hysteroscopy, adnexectomy, polypectomy, or endometrial ablation.
Fig. 3
**INTERNATIONAL SEARCH REPORT**

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- Further documents are listed in the continuation of Box C. See patent family annex.
- Special categories of cited documents:
  - **"A"** document defining the general state of the art which is not considered to be of particular relevance
  - **"E"** earlier application or patent published on or after the international filing date
  - **"L"** document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - **"O"** document referring to an oral disclosure, use, exhibition or other means
  - **"P"** document published prior to the international filing date but later than the priority date claimed
  - **"I"** later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  - **"X"** document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  - **"Y"** document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  - **"&"** document member of the same patent family

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Form PCT/ISA/210 (second sheet) (January 2004)
C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US 4,260,574 A (MACOMSON) 07 April 1981.</td>
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