

SAMPLE COLLECTION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims the benefit of US Provisional Application Serial No. 63/368320, filed July 13, 2022, incorporated by reference in its entirety herein.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates to devices for collecting biological samples.

BACKGROUND

[0003] Blood used for diagnostic testing is most often extracted from a patient with a hypodermic needle and collected in a test tube. The collected blood is then packaged for shipment to a remote lab where various diagnostic tests are performed. However, many diagnostic tests require significantly less volume than the actual collected sample. Separation of cellular components from the sample is also needed for some tests.

[0004] Many tests only require small blood samples, where a finger stick rather than a hypodermic needle can produce enough blood. But this small amount of blood cannot be easily transported to a remote lab. If the testing method cannot be immediately used at the same time the blood is extracted, convenient and reliable methods of collecting, prepping, and preserving small amounts of blood are still needed.

[0005] US Patent Publication US2014/0050620A1, assigned to Boston Microfluidics, Inc., describes several ways to implement a portable, user-friendly device for collecting a biological fluid sample and stabilizing it for transport to a remote lab. The devices include a small, hand-held housing that provides a chamber for collecting a fluid sample. Movement of the housing itself, and/or mechanisms located within the housing, initiate collection of a predetermined, metered to volume of a fluid sample. The devices may also stabilize the collected sample and/or seal the sample in the chamber. Other mechanisms in the device may mix the collected sample with a reagent.

SUMMARY

[0006] Applicants have recognized systems and methods of collecting a biological sample may facilitate analysis of target analytes in individuals and among groups of individuals. Applicants have further recognized systems and methods of collecting a biological sample from a location remote to analysis, while ensuring the integrity of the assay, such as by preventing oxidation of the sample. A simple to use, portable sample collection apparatus may facilitate

acquisition of a biological sample for an analysis of target analytes present in a biological sample.

[0007] Aspects disclosed herein provide a fluid sample collection device comprising: a housing configured to move from a first position to a second position; a sample collection well for collecting fluid; one or more capillaries arranged to draw in fluid from the sample collection well; a membrane; one or more plungers disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the first position to the second position, wherein the device is configured to prevent oxidation of a sample stored within the device when the device is in the second position.

[0008] Embodiments of the device include the following, alone or in any combination.

[0009] The device may comprise an oxygen absorber or a plurality of oxygen absorbers and an optional antioxidant or reducing agent disposed within the housing.

[0010] The oxygen absorber may be contained in a sachet, a packet, an air permeable pouch, or other air permeable packaging.

[0011] The oxygen absorber may comprise silica gel, iron powder, carbon, charcoal, calcium sulfate, calcium chloride, zeolites, a mixture of iron powder and sodium chloride, ascorbate with NaHCO_3 , an oxygen scavenging polymer, ferrous carbonate with a metal halide catalyst, an oxygen scavenging packet, pyrogallol acid, an oxygen scavenger sachet, or combinations thereof.

[0012] The antioxidant or reducing agent may comprise L-ascorbic acid, sodium L-ascorbate, calcium L-ascorbate, 6-o-palmitoyl-L-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA), or a combination thereof.

[0013] The housing may comprise a gasket configured to seal the membrane from the surrounding environment when the housing is in the second position. The gasket may be provided on a mating surface between a first portion of the housing and a second portion of the housing. The housing may form a substantially airtight seal defining an enclosed space within the housing. The enclosed space within the housing may comprise the membrane. The enclosed space may be in contact with the membrane and the oxygen absorber. The enclosed space may be about 1 to about 50 mL in volume; or about 1 to about 10 mL in volume; or the enclosed space may be 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 mL in volume.

[0014] The membrane may be a testing strip. The membrane may be a lateral flow strip.

[0015] The device may, or may not, comprise a desiccant within the housing. The housing may additionally include a desiccant region adjacent the membrane. A desiccant tablet may be located within the desiccant region. The desiccant tablet may comprise desiccant and the oxygen absorber. The device may additionally comprise a support structure for holding the desiccant tablet adjacent the membrane. The support structure may further hold the oxygen absorber. The desiccant tablet may further comprise an inert layer between the desiccant and the oxygen absorber.

[0016] The membrane may comprise the oxygen absorber. the membrane may comprise an oxygen absorbent region comprising the oxygen absorber. The oxygen absorber may be impregnated into the membrane. The membrane may comprise an antioxidant or a reducing agent.

[0017] The device may comprise a reagent, such as wherein the reagent is configured to prevent oxidation of the sample. One or more of the capillaries may be coated with the reagent. The reagent may comprise the oxygen absorber. The reagent may comprise an antioxidant.

[0018] The device may comprise an antioxidant coating on the device, on a portion thereof which contacts the sample, or on a component thereof. an antioxidant coating on a funnel clip, gasket, capillary tube, pore plug, the port or outlet, or the membrane. The antioxidant coating may be applied through dip coating, spray coating, during the plastic injection molding process, or other means. The device may comprise an antioxidant coating on a removable funnel clip configured to prevent accidental actuation of the device and to funnel a sample into the collection well, on a capillary tube, on the sample collection well, or combinations thereof.

[0019] The device may be configured to prevent oxidation of a sample stored within the device, such as to preserve the sample for subsequent analysis in a subsequent assay. The subsequent assay may comprise an Essential & Metabolic Fatty Acids Analysis (EMFA), a lipid panel, a fatty acid test, a free fatty acid test, a fatty acid profile, a fatty acid panel, an oxidized low-density lipoprotein (OxLDL) assay, an assay measuring oxidation of a component within a blood sample, a complete metabolic panel, a complete blood count, a basic metabolic panel, a liver panel, a prothrombin time assay, a hemoglobin A1c assay, a thyroid stimulating hormone assay, or combinations thereof.

[0020] The device may be configured to extend the amount of time that a sample can be stored within the device, such as prior to analysis in a subsequent assay. The device may be configured to permit the sample to be stored within the device for 5, 7, 10, 14, 15, 20, 21, 25, 28, 30, 35, 40,

45, 50, 55, 60, 65, 70, 75, 80, 85, or 90 days while preserving the sample for analysis in a subsequent assay.

[0021] Moving the device from the first position to the second position may comprise forming an airtight seal defining a volume of air within the device, or wherein moving the device from the first position to the second position comprises forming a hermetic seal defining a volume of air within the device.

[0022] The device may be configured to separate a blood sample into a plasma component, and a cellular component, wherein the device is configured to prevent oxidation of the plasma component and the cellular component with the oxygen absorber.

[0023] The oxygen absorber or the membrane may comprise an antioxidant or a reducing agent concentration of about 0.5 mg/mL to about 20 mg/mL.

[0024] The device may be configured to collect a biological sample, the device comprising: a housing having a sample collection well to receive the biological sample; the housing configured to move from a first position to a second position; a conduit comprising the one or more capillaries, disposed within the housing, the conduit having openings at a first end and a second end, with the opening at the first end configured to receive the biological sample from the sample interface collection well; a sample storage chamber, disposed within the housing, and configured to receive the biological sample from the conduit; and a mechanical actuator; wherein the first position provides an opening to the sample collection well, and the second position restricts access to the sample collection well, and wherein the mechanical actuator is configured to dispense a predetermined amount of the biological sample from the second end of the conduit into the sample storage chamber via mechanical force when the housing is moved from the first position to the second position and the second position and comprises an airtight seal defining a volume of air within the device when the device is in the second position.

[0025] The mechanical actuator may be further configured to control a plunger disposed within the conduit to dispense the biological sample into the sample storage chamber.

[0026] The housing may comprise first and second portions slidably engaged to each other and configured to be pressed towards each other to configure the device from the first position to the second position.

[0027] The biological sample may comprise blood.

[0028] Aspects disclosed herein provide a method of storing a sample for subsequent analysis

comprising: inserting a sample in the sample collection well of a device described above, including any of the embodiments above, alone or in any combination; moving the housing from the first position to the second position; forming an airtight seal within the housing defining an enclosed airspace; and removing oxygen from the enclosed airspace.

[0029] Embodiments of the method include the following, alone or in any combination.

[0030] Oxygen may be removed from the enclosed airspace with an oxygen absorber, or an oxygen scavenger. The method may further comprise removing moisture from the airspace, such as with a desiccant.

[0031] The method may extend the amount of time a sample can be stored prior to a subsequent analysis. The subsequent analysis may comprises an assay, such as an Essential & Metabolic Fatty Acids Analysis (EMFA), a lipid panel, a fatty acid test, a free fatty acid test, a fatty acid profile, a fatty acid panel, an oxidized low-density lipoprotein (OxLDL) assay, an assay measuring oxidation of a component within a blood sample, a complete metabolic panel, a complete blood count, a basic metabolic panel, a liver panel, a prothrombin time assay, a hemoglobin A1c assay, a thyroid stimulating hormone assay, or combinations thereof.

[0032] The oxygen absorber or the oxygen scavenger may =comprises an antioxidant or reducing agent comprising: l-ascorbic acid, sodium l- ascorbate, calcium l-ascorbate, 6-o-palmitoyl-l-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA), or a combination thereof.

[0033] The oxygen absorber may comprise an antioxidant concentration of about 0.5 mg/mL to about 20 mg/mL.

[0034] Another aspect disclosed herein provides a kit comprising a fluid sample collection device as described above, including the embodiments above, alone or in any combination; an airtight packaging; and an oxygen absorbent packet, a desiccant, a molecular sieve, or combinations thereof.

[0035] Embodiments of the kit include the device described above, including the embodiments disclosed above, alone or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0037] FIG. 1 depicts a biological sample collection apparatus in an open position, according to some embodiments;

[0038] FIG. 2 depicts a biological sample collection apparatus in a closed position, according to some embodiments;

[0039] FIGS. 3A depicts an exploded view of a biological sample collection apparatus, according to some embodiments;

[0040] FIG. 3B depicts an exploded view of a biological sample collection apparatus, according to some embodiments;

[0041] FIGS. 4A–4D depict a sample medium of a biological sample collection apparatus, according to some embodiments;

[0042] FIG. 5 depicts a sample medium of the biological sample collection apparatus, according to some embodiments;

[0043] FIG. 6 depicts a biological sample collection apparatus, according to some embodiments;

[0044] FIGS. 7–13 depict components of a biological sample collection apparatus, according to some embodiments;

[0045] FIG. 14 depicts a biological sample collection apparatus, according to some embodiments;

[0046] FIG. 15 depicts a biological sample collection apparatus, according to some embodiments;

[0047] FIG. 16 depicts a biological sample collection apparatus, according to some embodiments;

[0048] FIGS. 17A–17C depict implementation of an oxygen absorber within a biological sample collection apparatus, according to some embodiments; and

[0049] FIGS. 18A–18B depict implementation of an optional removable extension for the

biological sample collection apparatus, according to some embodiments.

DETAILED DESCRIPTION

[0050] A sample collection device can be used to collect, meter, and store a body fluid sample for a subsequent assay. Fluid collected from a patient is first introduced into the device via a sample port, such as by directing blood droplets from a fingertip into a well. In some configurations, metering capillaries then extract blood from the sample port and deposit it onto a storage medium via capillary action. In addition, one or more plungers, coupled to a closeable housing, may further encourage dispensing fluid from the metering capillaries and onto the storage medium. The plungers may be attached to one or more movable housing pieces, such that when the housing is moved from an open to a closed position, the plungers are forced through the capillaries.

[0051] In some arrangements, an assay region may also be located between the capillaries and the membrane, such that the stored reagent is mixed with the fluid when the housing is moved from the open position to the closed position.

[0052] A raised ridge portion may be provided adjacent the well. The ridge provides a convenient place to wipe a patient's finger to encourage blood droplets to better flow.

[0053] The housing may also include one or more windows positioned on the housing in a location such that at least a portion of the capillaries and/or sample media are visible through the window.

[0054] A first housing section and second housing section may engage and slide along a center support section, to allow moving the housing from the open position to the closed position, and thus push the plungers through the capillaries. In that configuration, the center support section may include an opening for the insert element that defines the sample well.

[0055] The sample well may be defined by an inlay element disposed within the housing. In that case, the inlay may also provide the raised ridge portion. The inlay typically further includes one or more thru holes, each for holding a respective one of capillaries in a defined position. The inlay piece can also be used to retain at least one capillary in alignment with at least one of the plungers as the housing is moved from the open position to the closed position.

[0056] The inlay element may also include a slot disposed at an exit port of the one or more capillaries. The slot provides a directed path for blood exiting the capillaries onto the storage media.

[0057] The capillaries and/or an inlay part that provides the sample well and supports the capillaries may also be wholly or partially transparent. These design feature can provide further visible confirmation that a sample of blood fluid is properly collected and/or stored.

[0058] The plungers can be connected to a tab attachment on an end distal from the capillaries. The tab can be disposed adjacent one of the housing pieces, so that the plungers are forced into the capillaries as the housing is closed.

[0059] A ratcheting mechanism may be located at one end of the backbone, to further assist with holding the housing in the closed position during transit. That mechanism may be engaged when the housing is moved from the open to the closed position. In some embodiments, access holes are provided at one end of the housing, a tool to disengage the ratcheting mechanism more easily, and pry open the housing to gain access to the stored blood sample.

[0060] The storage medium may take different forms. For example, it may be a substrate having a pair of engagement tabs therein and spaced apart from one another. The blood sample collection storage medium is then disposed on the substrate and sized to fit between the engagement tabs.

[0061] FIG. 1 is an isometric view of an example fluid collection device 100. The device 100 includes a two-piece housing 101 that supports and encloses a fluid sample port 102. The housing 101 includes a first housing piece 101-A and second housing piece 101-B. In this view, the housing is in the open position with the two housing pieces 101-A, 101-B spaced apart from one another, to provide access to the sample port 102. A sample collection well 104 and one or more capillaries 105 located adjacent the sample port 102 are partially visible in this figure. A window 150 in the housing permits a user to confirm the status of one or more portions of a fluid sample in the process of being collected and/or stored within the device 100.

[0062] In some embodiments (not shown), the device may comprise a removable cap or a pore plug to cover the sample collection well and hold the two housing pieces apart to prevent accidental activation of the device before the sample is collected. In embodiments, the cap may comprise a funnel as shown in Figs. 17A, 18A and 18B, described below. In embodiments, the pore plug may comprise die-cut filter material shaped to cover the sample collection well.

[0063] In some embodiments, the sample is a biological sample. In some embodiments, the sample is a fluid biological sample. In some embodiments, the sample is a blood sample.

[0064] While embodiments herein may refer to use of a biological sample collection device for

collection of a blood sample, it should be readily understood that the collection device may be modified or adapted to collect various biological samples such as saliva, stool, urine, hair, skin tissue, or other sample containing biological material.

[0065] FIG. 2 is a similar isometric view of the device 100. In this view, a blood sample has been taken via the sample port 102, and the two housing pieces 101-A and 101-B have been pushed together to place the device 100 in a second or closed position. In this closed position, the window 150 still provides access to the blood collection status.

[0066] The device 100 is typically used to collect a blood sample as follows. The device 100 is initially presented in its open position, as per FIG. 1, to provide access to the well 104. A user, such as a patient herself or a health care professional, then uses a lancet to produce a blood sample such as from a fingertip. Drops of whole blood are then taken with the finger positioned near to, above, adjacent to, or even in contact with the well 104 or other parts of the sample port 102 to minimize blood spillage.

[0067] Blood is then eventually drawn into the rest of the device 100 in one or more different ways. As will be explained in more detail below for one embodiment, blood flows and/or is first drawn from the well 104 by one or more collection capillaries 105 adjacent the sample port via capillary action. Three capillaries are shown in this embodiment, but fewer or more capillaries may be embodied. The capillaries may be visibly transparent so that the user can confirm that blood is being properly drawn into the device 100. The capillaries 105 can optionally be pre-coated with reagents such as heparin and/or EDTA for subsequent stabilization and preservation of the sample. The capillaries 105 can also have a known and predetermined volume, in which case the incoming sample is precisely metered. The collection capillaries 105 then direct the metered sample to media inside the device housing 101.

[0068] The user, who can be the patient himself/herself or a healthcare professional, then manually closes the device 100 by pushing the two housing pieces 101-A, 101-B together, resulting in the housing position shown in FIG. 2. As more fully explained below, the motion associated with closing the housing may then optionally enact one or more mechanisms that further process the sample, and to securely store it inside the device 100.

[0069] The window 150 may include a transparent piece of material that enables the user to view the state of the sample port 102, the well 104, and/or collection capillaries 105. In that way, an indication of whether a sufficient sample of blood is being drawn into the device 100 (when the

housing 101 is in the open position of FIG. 1) or was drawn into the device (when the housing 101 is in the closed position as in FIG. 2).

[0070] FIG. 3A is a more detailed, exploded view of the components of the device 100. The first housing piece 101-A consists of a top case 201-A-1 and bottom case 201-A-2, and second housing piece 101-B consists of a top case 201-B-1 and bottom case 201-B-2.

[0071] A backbone structure 203 provides a support for the two housing pieces 101-A, 101-B. The inside vertical walls of the housing pieces 201-A, 201-B may engage elongated slots or other structures formed in the backbone 203, thus enabling at least second housing piece 101-B to slide back and forth along the backbone, and to thus move the housing into the open or closed position. In one arrangement, first housing piece 101-A remains fixed in position on backbone 203. However other embodiments are possible where first housing piece 101-A slides on backbone 203 and second housing piece 101-B remains fixed, or where both housing pieces 101-A, 101-B can slide with respect to one another.

[0072] The backbone 203 also supports other components of the device 100. For example, the backbone 203 provides a location for the sample collection port 102, as formed from an inlay part (also referred to as a capillary support element) 252. A rack of plungers 202 is also supported by the backbone 203. For illustration but not limitation, three plungers are shown. The backbone 203 may further include a ribbed section 230 to support a desiccant tablet (not shown in FIG. 3) to further dry the collected sample. The backbone 203 may also have tines at an end that provide a ratcheting closure 240, which is activated when the two housing pieces 101-A, 101-B are pushed together.

[0073] Capillaries 204 (also referred to with reference number 105 in other figures) are inserted into and held in place by longitudinal holes (not shown in FIG. 3) formed in the inlay 252. The capillaries may be formed as a rigid tube of precisely defined volume, in which case they also serve a metering function. The capillaries 204 extract a defined quantity of blood by engagement with the blood in the sample collection port 102 through capillary action. The inlay 252 may fit into a hole 221 in backbone 203. As explained in further detail below, the inlay 252 defines the location of a well 104 into which the patient's blood is introduced.

[0074] The capillaries 204 can optionally be pre-coated with reagents, heparin, EDTA, or other substances including antioxidants.

[0075] One or more capillaries 204 may also store a predetermined amount of a liquid reagent.

Such a reagent may then be dispensed together or in parallel with the blood sample when the housing is moved from the open (first) to the closed (second) position. However, reagents of other types may also in a storage region within the housing. The storage region (not designated in the figures), may hold a first type of reagent such as a solid surface or substrate, and a second type being a liquid storage chamber, each of which are placed in the path of the blood sample collected by the device 100.

[0076] In one arrangement, the one or more plungers 202 firmly engage with the inner diameter of the capillaries 204, creating a shutoff that blocks off any excess blood sample while also pushing the metered sample volume to the subsequent downstream processing steps.

[0077] A base 206 may also fit into the backbone 203 to provide additional mechanical support for a blood collection element 250. The collection element 250 may consist of a sample medium (also called a membrane herein) 209 that is supported and/or held in place by other components that assist with handling the sample medium 209 when it is removed from the device 101 for processing by a laboratory. These other parts of the collection element 250 may include the base 206, a top frame 208, media support 210, and bottom frame 211. The top 208 and bottom 211 frame may have extensions 222-A, 222-B on an outboard end. The extensions 222 further assist with handling the collection element 250 during and after its removal from the housing 101.

[0078] The sample medium 209 may be a plasma separation membrane or filter of various types located at or near an exit port of the capillaries 105. For example, a mixed-cellulose ester membrane such as the Pall Vivid Plasma Separation available from Pall™ Corporation. The membrane 209 may also be an LF1 glass fiber membrane (sold by General Electric™ Company) or other media designed to receive serum or whole blood which it then separates into a blood portion and a plasma portion. A medium such as LF1 paper has a fibrous structure that causes differential migration of the sample, with a slower rate for red cells, resulting in a gradual separation of plasma sample as it migrates down the paper. The membrane 209 can optionally be previously impregnated with heparin, EDTA, sugars, oxygen absorber, antioxidant or other stabilization agents. LF1 paper, which separates plasma from red blood cells through a fiber matrix, is preferred in some embodiments, because it causes a slower migration rate for the blood cells. However other types of separation membranes for blood either liquid or dried may be used.

[0079] Plasma separation may also be achieved through non-membrane microstructures that exclude red cells by size. For example, plasma separation can be achieved or enhanced by

selectively binding red cells as well. Binding agents are typically coated on a membrane or microstructure but could also be deposited in a channel.

[0080] The sample medium 209 can also be coated with various chemicals to perform a test, such as an assay, on the collected sample. Thus, an immunoassay strip can be substituted for all, or for part of, or together with the sample medium 209. When device 100 is closed, the sample is delivered to a sample pad area on the immunoassay strip. The window 150 may also allow for visual inspection of color change results of the immunoassay or other test.

[0081] FIG. 3B is an exploded view of one such example device 100, similar to FIG. 3A. However, this device 100 has both a collection membrane 209 and an immunoassay strip 309. The membrane 209 and strip 309 may be arranged in parallel. The collection membrane 209 receives and stores a blood sample from some capillaries, and the immunoassay (or other test) strip 309 may receive and process a blood sample from other capillaries.

[0082] Alternatively, the sample could be delivered to an assay region within the housing 101 where capture molecules are exposed to the sample and bind analytes. These analytes could then be bound by a conjugate making them detectable. The bound analytes may also modify the optical or electrical properties of the surface they are bound to, making them detectable directly.

[0083] It can now be appreciated that the action of closing the housing pieces together causes the blood sample to be drawn from the well 104, to be drawn into the capillaries 105 via both capillary action and mechanical force, exiting the capillaries to be deposited onto the sample medium 209. In particular, the plungers 202 are engaged by housing piece 201-A, and the capillary tubes 105 are in turn held in place within the inlay 252. Thus, as the housing sections are closed together, the plungers 202 are forced into the capillaries 105, which in turn force blood to exit onto the membrane 209.

[0084] In some implementations, the material used to fabricate one or more sections or parts of the inlay piece 252 may have an elasticity that is sufficient to hold the capillary tubes 105 in place while the plungers 202 are forced into them. The elasticity of inlay 252 may also be chosen to seal and/or prevent at least some blood from flowing around, rather than flowing through, the capillary tubes 105.

[0085] The closed housing 101 also creates a small and isolated internal air space above the sample medium 209. The sample can be further encouraged to dry with the aid of one or more desiccant tablets (not shown) located in this air space. For example, a desiccant may be supported

by the backbone 203 adjacent where the sample medium 209 sits when the housing is in the closed position.

[0086] During or after the housing is closed, a ratcheting mechanism provided by the far end of the backbone 203 encourage the housing to remain shut. For example, the tines 240 may act as a ratcheting pawl and engage small holes 245 or other features in the end of housing piece 101-A (See FIG. 1) when the housing is pushed shut. The tines 240 may be shaped to permit opening of the housing only with a pinching tool that accesses small holes 245 in the side of the housing piece 101-B to release the ratchet pawl, e.g., by pinching the tines 240. Thus, once the device 100 is closed by pushing the housing pieces 101-A, 101-B together, the blood sample remains enclosed within, and ready for transport to a remote lab.

[0087] FIGS. 4A and 4B are respective top and side views of one way to implement the sample medium 209 and media support 210. FIG. 4C is a top view of the medium 209 and FIG. 4D a top view of the support 210.

[0088] The medium 209 may be a generally rectangular, thin sheet or membrane, paper or fibrous, that slips under or fits into tabs 401, 402. Tabs 401, 402 may be cut into or formed as part of support 410 to hold medium 209 in place. The support 210 may also have a handle portion 410. The handle 410 may conform to extensions 222 in the frame pieces 208, 211. The handle 410 and makes it easier to handle the collection medium 209 when it is removed from the housing 101. The handle 410 may also have other features such as shaped peripheral edges 412 to provide a more secure fit of the support 410 (and/or frame pieces 208, 211) within the housing.

[0089] FIG. 5 is a plan view of a collection element 250 sometime after a blood sample has been taken and after it has been removed from the housing 101. Note a blood loading location 500 that was located adjacent the sample port 102 when the sample was taken. A first region 501 of the sample medium 209 contains filtered red blood cells (RBCs). However other portions of the blood sample have diffused through the medium 209, to provide a sample separation region 502 and a purified plasma region 503.

[0090] FIG. 6 is a view of the device 100 with both top housing covers 201-A-1 and 201-B-1 removed. The backbone 203 is seen to now include not just an area to support the inlay 252 that defines the well 104, but also a plunger support area 611 to the left of the well 104, and a sample medium area 612. A ribbed section 614 on the right-hand side may support one or more tablets of desiccant 630 in FIG. 6 over the sample medium area 612. Three plungers 202 are shown on the

left-hand side retained in position by a pair of supports 616, 617 in the lower left housing piece 201-A-2. As explained in more detail below, each of the plungers 202 is aligned with a corresponding one of the capillary tubes 204.

[0091] FIG. 7 shows the plunger support area 611 and inlay piece 252 in more detail. The left ends of the plungers 202 are connected to a tab 619 that rests against an inside edge 620 of the lower housing piece 201-A-2. In this way, the plungers 202 are forced into the capillaries 105 as the housing is closed shut. Note that the right-hand sides of the plungers 202 are inserted into corresponding holes (not shown in FIG. 7) formed in the inlay 252 which are in turn aligned with an inlet of the capillary tubes 204.

[0092] FIG. 8 is a partial view of the bottom of part of the support member 203 with the bottom housing covers 201-A-2, 201-B-2 now also removed. Collection medium 209 and support 210 have been removed for the sake of illustration in this figure. Ribs 801 on the left end of the support 203 may further assist with guiding the plungers 202 into the inlay 252. Also note a lateral slot 803 is formed on the right-hand side of the inlay 252 adjacent the outlet of the capillary tubes 105. The slot 803 provides an exit path from the capillaries for the collected blood. One or more ridges 820 adjacent slot 803 may further encourage blood exiting the tubes 204 to travel to the lateral slot 803.

[0093] FIG. 9 is a partial view of the backside of the inlay 252 similar to FIG. 8, but now with collection element 250 inserted into backbone 203. Note that the position of collection element 250, including frames 208 (and 211, not shown in FIG. 9) hold collection medium 209 adjacent the exit path from the capillaries 105 and lateral slot 803.

[0094] FIG. 10 is an exploded view showing more detail of the components of one example implementation of an inlay 252.

[0095] FIG. 11 is a cutaway view of the inlay 252.

[0096] FIG. 12 is a resilient insert part 1030 of the inlay 252. In this implementation the inlay 252 comprises three parts, a well piece 1010, a capillary support 1020, and a resilient insert 1030. The well piece 1010 and capillary support 1020 may be formed of a rigid, visually transparent plastic. The inlay 252 may be assembled by engaging pins 1040 on the well piece 1010 into corresponding holes 1050 in the capillary support 1020. The well piece 1010 generally serves to define the well 104 as a depression or bowl into which the blood sample is initially introduced by the patient. Longitudinal holes 1015 in the well piece 1010 provide guidance for plungers (not shown in FIG. 10).

[0097] The capillary support 1020 has longitudinal holes 1060 with a diameter appropriate for firmly holding the capillary tubes 105 in alignment with the plungers (not shown in FIG. 10). Here, three capillaries 105 are supported by the inlay 252, but it is possible to have fewer or a greater number of capillaries 105. Although not seen in this view, capillary support 1020 also defines, in whole or in part, the lateral slot 803 at the exit end of the capillaries.

[0098] The insert 1030 is formed of a resilient plastic or rubber. It is disposed between the well piece 1010 and capillary support 1020. The insert 1030 also has a number of holes 1035 formed therein to permit a corresponding number of the capillaries 105 to be inserted through it. Having a generally rectangular shape, insert 1030 preferably has an upper curved ridge 1210. Note the upper ridge on the piece 1101 now provides an edge adjacent the well on which the patient (or a caregiver) can swipe the fingertip to encourage filling the well 1010 with blood. The ridge on piece 1101 may be treated, coated, or formed of a hydrophobic material, to facilitate blood not sticking thereto and instead being directed to the sample well.

[0099] FIG. 13 is a perspective view of an alternate implementation of the inlay 252, here formed from a single piece of resilient material, such as injection molded silicone. This version 1300 of the inlay otherwise has the same features as the inlay 252 version shown in FIG. 10, including at least a sample well 1301, finger swipe ridge 130, and lateral slot 1320.

FIG. 14 is a view of the backbone 203 with housing covers removed, showing one possible location of a desiccant 1402 in tablet form. Note the tablet 1402 is held in place above the sample medium 209 such as near the exit end of the capillaries (not shown in FIG. 14). Although only one desiccant tablet 1402 is shown, certainly more than one may be provided. In embodiments, the tablet may further comprise an oxygen absorber. The tablet may comprise a desiccant region and an oxygen absorbing region. The tablet may further comprise an inert layer between the desiccant and the oxygen absorber.

[0100] Also note here that one corner 1450 of one or more of the housing pieces, for example, housing piece 201-B-2, may have a shape that is different from the other corners of the other housing pieces 101. For example, corner 1450 may be chamfered while the other corners are rounded. Corner 1450, having a different shape, may assist with registration of the device 100 with automated handling or processing equipment.

[0101] FIG. 15 is a close-up view of the plungers 202, illustrating that the ends 1501 thereof may be ribbed or castellated, to further promote blood flow into and through the capillaries 105.

[0102] FIG. 16 is a detailed view of one way to further hold the collection element 250 within backbone 203, via one or more spring clips 1601. The clips 1601 may engage or press against one end of the media support 210. The clips 1601 may also engage other corresponding features in the backbone 203 or housing pieces 201-B-2 (not shown). Note that a barcode 1600 or other identifying indicia such as a QR code, or reference number, may be printed on or on a label affixed to a back side of the collection element 250.

[0103] In use, the device 100 is a very convenient way to collect blood expressed by a patient after using a lancet on one of his/her fingers. Commercially-available lancets may be used, and it generally is the choice of the user to select the type of lancet. Once a drop of blood has been expressed on the finger, the patient skims the drop into a well 104 in the sample collection port 102 by gliding the finger across the protruding resilient edge 1030. The blood drop, through gravitational force and surface forces, proceeds to the bottom of the well 104 where it encounters openings in the collection (metering) capillaries 105. From there, blood is further drawn into the collection element 250 including the sample storage medium 209, further encouraged by plungers that force blood out of the capillaries as the two housing pieces are closed together.

[0104] The closed device 100 then creates a small and isolated internal air space which can be quickly dried with the aid of desiccant tablets contained in an internal pocket. In its current form, use of LF1 paper as a collection medium creates spots of red-cell free plasma as well as plasma-depleted whole blood. The LF1 paper's structure causes differential migration, with a slower rate for red cells, resulting in a gradual separation of plasma sample the further down the paper the sample migrates. Plasma is far better for any quantitative blood test, eliminating red cells, which tend to interfere with many analyte assays.

[0105] The device 100 therefore offers substantially better opportunity for high-quality quantitative assays as compared to standard dried blood spots. Furthermore, infectious disease tests can still be done on the red cell portion of the dried sample—though plasma-depleted, it is still adequate for accurate detection of infectious agents.

[0106] The device is also an ideal mechanism for blood sample preservation and transport. Once the device is closed, the blood sample is enclosed within, largely cut off from the external environment. Upon closing by the user, the device uses the ratcheting mechanism to ensure it remains locked and shut. It can be opened only with the use of a pinching tool that accesses the small holes 245 in the side of the housing 101 to releases the ratchet pawl.

[0107] A fluid sample collection device as disclosed herein may include a housing configurable from an open position to a closed position; a sample collection well for collecting fluid; one or more capillaries, arranged to draw in fluid from the sample collection well through capillary action, the capillaries having a predetermined volume; a membrane; one or more plungers, disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the open to the closed position; and a fluid stabilization agent, arranged to engage the fluid as the one or more plungers dispense fluid onto the membrane.

[0108] The stabilization agent may be heparin and/or EDTA, or coated onto an interior of at least one of the capillaries, or coated onto the membrane. A removable support element may be disposed within the housing, for supporting the membrane in place adjacent an exit port of the capillaries. The housing may additionally include a desiccant region adjacent the membrane. A desiccant may be a tablet; and a structure may hold the desiccant tablet adjacent the membrane. One or more of the capillaries may be coated with a reagent or hold a predetermined amount of a liquid reagent. The storage membrane may contain the reagent. The membrane may a testing strip in part or in whole, such an immunoassay strip. Such a test strip may be disposed in-line with an exit port of one of the capillaries. The test strip may be some other type of assay disposed on or adjacent to the whole blood collection membrane. A stored reagent may be mixed with the fluid when the housing is moved from the open position to the closed position. A ridge portion may be disposed adjacent the sample well. It may be hydrophobic. A collection element disposed within the housing may further include a depression formed therein to provide the sample well; and a raised ridge portion formed adjacent the depression and extending along only a portion an outer edge of the depression. The depression may be circular.

[0109] A fluid sample collection device may include a housing configurable from an open position to a closed position; a sample collection well, disposed within the housing, for collecting fluid; one or more capillaries, arranged to draw in fluid from the sample collection well through capillary action, the capillaries having a predetermined volume; a membrane; one or more plungers, disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the open to the closed position, and wherein the sample well is visible and exposed to receive the fluid when the housing is in the open position; wherein the housing at least partially encloses the sample well when the housing is in the closed position; and an optically transparent window, located within the housing, provides a view

of at least a portion of the sample well and/or at least one of the capillaries and/or the membrane when the housing is in either the open or the closed position. The window may be located adjacent the capillaries. The capillaries may be visibly transparent, so that when the housing is in the open position, the capillaries provide a visible indication that a sample of fluid is being collected by the device. In addition, when the housing is in the closed position, the optically transparent window may provide an indication whether a sufficient sample of fluid was drawn into the device. The device may include a first housing section and second housing section engaged and are slidable along a center support section, to allow moving the housing from the open position to the closed position. The center support section may include the sample well. In some arrangements, the first housing piece includes an optically transparent window arrange to provide a view of one or more capillaries when the housing is the closed position. The center support section may hold the capillaries in fixed alignment with the optically transparent window. In some configurations, the membrane provides one or more of a sample storage region or an assay region.

[0110] A fluid sample collection device may include a housing configurable from an open position to a closed position; a sample collection well, disposed within the housing, for collecting fluid; one or more capillaries, arranged to draw in fluid from the sample collection well through capillary action, the capillaries having a predetermined volume; a sample storage membrane; one or more plungers, disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the open to the closed position; and a support element or so-called “inlay” disposed within the housing to retain at least one capillary in alignment with at least one of the plungers as the housing is moved from the open position to the closed position. The support element may further include one or more thru holes, each for engaging a respective one of capillaries. All or part of the support element may be formed of a resilient material. The device may be configured such that two or more of the plungers are connected to a tab attachment on an end distal from the capillaries. The housing may comprise a first housing section and second housing section, with the housing being in the open position when the two sections are spaced apart from one another, and the housing being in the closed position when the two housing sections are moved adjacent one another. In certain configurations, a tab attachment is disposed in mechanical communication with the first housing section, such that as the two housing sections are moved adjacent one another, the plungers also move and force fluid through the capillary tubes. The support element may further comprise a slot disposed at an exit

port of the one or more capillaries. Such a slot may be disposed to further direct fluid from the capillaries towards the sample storage membrane. A lateral flange may be disposed adjacent the capillaries and the slot to further encourage fluid to pass to the lateral slot. In addition, the plungers may further each include a circumferential seal. The support element may be visually transparent.

[0111] In some embodiments, a fluid sample collection device includes a housing configurable from an open position to a closed position; a sample collection well for collecting fluid; one or more capillaries, arranged to draw in fluid from the sample collection well through capillary action, the capillaries having a predetermined volume; a membrane; one or more plungers, disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the open to the closed position; a removable support element disposed within the housing and providing support for the membrane; and an opening in the housing to enable access to the membrane. A fluid stabilization agent may be deposited in at least one of the capillaries or on the membrane. The removable support element may include a ratcheting mechanism that is engaged when the housing is moved from the open to the closed position. In such a case, the housing includes one or more access openings adjacent the ratcheting mechanism. Furthermore, the ratcheting mechanism may comprise a pawl that is releasable via the one or more access openings.

[0112] In some embodiments, a fluid sample collection assembly includes a substrate having a pair of engagement tabs therein and spaced apart from one another; and a blood sample collection region, located adjacent the substrate and sized to fit between the engagement tabs. The substrate may be formed of mylar. In some configurations, the engagement tabs are formed by cutting slots in the substrate. The membrane may be a strip of LF1 paper, Pall membrane, or a bound glass fiber filter, or other membrane to separate serum or whole blood into a blood portion and a plasma portion. The membrane can also be treated with heparin, EDTA, sugars, or other stabilization agents. Here, also, the housing can be re-configurable from an open position to a closed position, or have a sample collection well for collecting fluid; or include one or more capillaries, arranged to draw in fluid from the sample collection well through capillary action, the capillaries having a predetermined volume; or one or more plungers, disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the open to the closed position.

[0113] In some embodiments, a sample collection device comprises one or more components to prevent oxidation of a sample. In some embodiments, a sample medium or storage membrane comprises one or more reagents to prevent oxidation of a sample. In some embodiments, the sample collection device comprises one or more oxygen absorbers, oxygen scrubbers, or oxygen scavengers. In some embodiments, one or more one or more reagents to prevent oxidation of a sample comprise ascorbate, glutathione, ascorbate-glutathione, aloe vera, manganese, copper, iron, sodium chloride, carbon, activated carbon, sodium hydrogen carbonate, metaphosphoric acid, cysteine, pyrogallol, combinations thereof, and other substances which may prevent oxidization of the sample.

[0114] With reference to FIGS. 17A-17C, in some embodiments, an oxygen absorber 1705 is provided within a body of the sample collection device. In these Figures, the housing is shown partially disassembled to show the interior of the housing. In some embodiments, the oxygen absorber 1705 is retained by the backbone 1703 of the device. In some embodiments, the device comprises the oxygen absorber 1705 in addition to a desiccant tablet 1702. In the embodiment shown in FIG. 17A, the oxygen absorber 1705 is contained in a packet or sachet that can be inserted into the backbone 1703. FIG. 17B shows the desiccant tablet 1702 and the oxygen absorber packet inserted into the backbone 1703. FIG. 17C shows the backbone 1703, which has a ridge 1706 configured to hold the oxygen absorber packet above the membrane so it does not contact the membrane. In some embodiments, a seal, barrier, or coating is provided between the desiccant tablet and the oxygen absorber to prevent chemical interactions between the desiccant tablet and oxygen absorber. In some embodiments, the desiccant tablet is not provided within the housing and only an oxygen absorber is provided within the housing. In some embodiments, wherein the device is placed within a packaging for shipping, an oxygen absorber is provided within the packaging component for the device.

[0115] FIG. 17A also shows an optional removable cap, extension or funnel 1710 for fitting adjacent to the sample collection port when the housing is in the first position, wherein the removable extension provides a larger area for collecting the biological sample as compared to a collection area of the sample collection port, and wherein the removable extension is configured to prevent actuation of the mechanically actuated fluid controller when fitted adjacent to the sample collection port (see also Figs. 18A and 18B). The removable extension may further comprise one or more trenches extending from a top of the extension to an area adjacent the sample collection

port, wherein the trenches are shaped to encourage pulling the biological sample through capillary action. The removable extension is removably coupled to the housing such that after collecting a sample, it can be removed from the housing to allow the housing to be moved into the second position to enclose the sample. In the embodiment shown, the removable extension is a four-sided funnel, and the removable extension may further comprise a rounded off edge.

[0116] In some embodiments, the oxygen absorber is provided proximal to the membrane or sample medium. In some embodiments, to maximize the effect of the oxygen absorber, the device is sealed to be airtight. In some embodiments, the device creates an airtight seal when the device is in a closed position. In some embodiments, to create an airtight seal, a gasket is provided between the top case and the bottom case of a second housing piece (e.g., between 201-B1 and 201-B-2). In some embodiments, to create an airtight seal, a gasket is provided between the top case and the bottom case of a first housing piece (e.g., between 201-A and 201-A-2). In some embodiments, to create an airtight seal, a gasket is provided on a surface between the first housing piece and second housing piece (e.g., 101-A and 101-B) such that a seal is created at the mating interference between the first and second housing pieces when the device is in a closed position. A gasket may be disposed on an inner surface of the top of the first housing piece 101-A to engage the upper surface of the sample port 102 to cover the sample collection well 104 when the housing is in the second, closed position.

[0117] In some embodiments, the oxygen absorber comprises an antioxidant or reducing agent comprising: l-ascorbic acid, sodium l-ascorbate, calcium l-ascorbate, 6-o-palmitoyl-l-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) (2,6-di-tert-butyl-p-cresol), or a combination thereof.

[0118] In some embodiments, the oxygen absorber comprises an antioxidant concentration of about 0.5 mg/mL to about 20 mg/mL. In some embodiments, the oxygen absorber comprises an antioxidant concentration of about 0.5 mg/mL to about 1.5 mg/mL, about 0.5 mg/mL to about 2.5 mg/mL, about 0.5 mg/mL to about 5 mg/mL, about 0.5 mg/mL to about 7.5 mg/mL, about 0.5 mg/mL to about 10 mg/mL, about 0.5 mg/mL to about 20 mg/mL, about 1.5 mg/mL to about 2.5 mg/mL, about 1.5 mg/mL to about 5 mg/mL, about 1.5 mg/mL to about 7.5 mg/mL, about 1.5

mg/mL to about 10 mg/mL, about 1.5 mg/mL to about 20 mg/mL, about 2.5 mg/mL to about 5 mg/mL, about 2.5 mg/mL to about 7.5 mg/mL, about 2.5 mg/mL to about 10 mg/mL, about 2.5 mg/mL to about 20 mg/mL, about 5 mg/mL to about 7.5 mg/mL, about 5 mg/mL to about 10 mg/mL, about 5 mg/mL to about 20 mg/mL, about 7.5 mg/mL to about 10 mg/mL, about 7.5 mg/mL to about 20 mg/mL, or about 10 mg/mL to about 20 mg/mL. In some embodiments, the oxygen absorber comprises an antioxidant concentration of about 0.5 mg/mL, about 1.5 mg/mL, about 2.5 mg/mL, about 5 mg/mL, about 7.5 mg/mL, about 10 mg/mL, or about 20 mg/mL. In some embodiments, the oxygen absorber comprises an antioxidant concentration of at least about 0.5 mg/mL, about 1.5 mg/mL, about 2.5 mg/mL, about 5 mg/mL, about 7.5 mg/mL, or about 10 mg/mL. In some embodiments, the oxygen absorber comprises an antioxidant concentration of at most about 1.5 mg/mL, about 2.5 mg/mL, about 5 mg/mL, about 7.5 mg/mL, about 10 mg/mL, or about 20 mg/mL. In some embodiments, the device may reduce the presence of oxygen in the air during drying of the membrane after dosing. In some embodiments, the device may increase the oxygen scrubbing capacity within the return packaging; remove silica gel and molecular sieve (desiccants), increase oxygen absorber; comprise an additional oxygen scrubber in proximity to membrane; may comprise an antioxidant coating, or combinations thereof. In some embodiments, the antioxidant coating may be applied to components of the device, or to components of the device which contact blood. In some cases, the antioxidant coating may be applied to the funnel lock clip, the gasket, the capillary tubes, the pore plug (e.g. die cut filter material), the port or outlet, or the membrane. In some embodiments, the coating could be added through dip coating, spray coating, during the plastic injection molding process, or other means. In some embodiments, oxygen absorber may be comprised within a satchel or a packet, and may enclose or be wrapped around the membrane without touching the membrane. In some embodiments, a return kit may be provided with the device which includes an airtight package, oxygen absorbent packets, and a molecular sieve. In some cases, the antioxidant coating may be comprised by the membrane.

[0119] In some embodiments, the antioxidant coating comprises an antioxidant or reducing agent comprising: l-ascorbic acid, sodium l-ascorbate, calcium l-ascorbate, 6-o-palmitoyl-l-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA),

butylated hydroxytoluene (BHT) (2,6-di-tert-butyl-p-cresol), or a combination thereof.

[0120] In some embodiments, the membrane comprises an antioxidant agent or reducing agent. In some embodiments, the antioxidant agent or reducing agent is dispensed onto the membrane. In some embodiments the antioxidant agent or reducing agent is dispensed onto the membrane to form a coating. In some embodiments the antioxidant agent or reducing agent is comprised within the membrane. In some embodiments, application of an antioxidant onto the membrane increases analyte stability by approximately 20-30%. In some embodiments, application of an antioxidant onto the membrane increases analyte recovery by approximately 60%.

[0121] In some embodiments, an antioxidant solution is dispensed onto a portion of the membrane where the sample will be dispensed. In some embodiments, approximately 180 microliters (μL) of an antioxidant solution are dispensed onto a portion of the membrane where the sample will be dispensed. In some embodiments, approximately 90 microliters (μL) of an antioxidant solution are dispensed onto a portion of the membrane where the sample will be dispensed. In some embodiments, an antioxidant solution is dispensed onto the center of the membrane. In some embodiments, approximately 180 microliters (μL) of an antioxidant solution are dispensed onto the center of the membrane. In some embodiments, the membrane is dipped and fully saturated into the antioxidant solution. In some embodiments, the membrane with the antioxidant solution is allowed to dry for at least 1 hour prior to insertion within the device.

[0122] In some embodiments, the antioxidant solution is dispensed onto the membrane in an amount of about 20 μL to about 250 μL . In some embodiments, the antioxidant solution is dispensed onto the membrane in an amount of about 20 μL to about 50 μL , about 20 μL to about 90 μL , about 20 μL to about 120 μL , about 20 μL to about 150 μL , about 20 μL to about 180 μL , about 20 μL to about 210 μL , about 20 μL to about 250 μL , about 50 μL to about 90 μL , about 50 μL to about 120 μL , about 50 μL to about 150 μL , about 50 μL to about 180 μL , about 50 μL to about 210 μL , about 50 μL to about 250 μL , about 90 μL to about 120 μL , about 90 μL to about 150 μL , about 90 μL to about 180 μL , about 90 μL to about 210 μL , about 90 μL to about 250 μL , about 120 μL to about 150 μL , about 120 μL to about 180 μL , about 120 μL to about 210 μL , about 120 μL to about 250 μL , about 150 μL to about 180 μL , about 150 μL to about 210 μL , about 150 μL to about 250 μL , about 180 μL to about 210 μL , about 180 μL to about 250 μL , or about 210 μL to about 250 μL . In some embodiments, the antioxidant solution is dispensed onto the membrane in an amount of about 20 μL , about 50 μL , about 90 μL , about 120 μL , about 150 μL ,

about 180 μL , about 210 μL , or about 250 μL . In some embodiments, the antioxidant solution is dispensed onto the membrane in an amount of at least about 20 μL , about 50 μL , about 90 μL , about 120 μL , about 150 μL , about 180 μL , or about 210 μL . In some embodiments, the antioxidant solution is dispensed onto the membrane in an amount of at most about 50 μL , about 90 μL , about 120 μL , about 150 μL , about 180 μL , about 210 μL , or about 250 μL .

[0123] In some embodiments, the antioxidant solution comprises an antioxidant dissolved in a solvent. In some embodiments, the solvent is ethanol. In some embodiments, the solvent is 100% ethanol. In some embodiments, the solvent comprises ethanol, butyl carbitol, butyl cellosolve, glycol, glycerol, Propyl cellosolve, ethoxytriglycol, diethylene glycol monoethyl ether, or a combination thereof.

[0124] In some embodiments, the antioxidant solution comprises an antioxidant concentration of about 0.5 mg/mL to about 20 mg/mL. In some embodiments, the antioxidant solution comprises an antioxidant concentration of about 0.5 mg/mL to about 1.5 mg/mL, about 0.5 mg/mL to about 2.5 mg/mL, about 0.5 mg/mL to about 5 mg/mL, about 0.5 mg/mL to about 7.5 mg/mL, about 0.5 mg/mL to about 10 mg/mL, about 0.5 mg/mL to about 20 mg/mL, about 1.5 mg/mL to about 2.5 mg/mL, about 1.5 mg/mL to about 5 mg/mL, about 1.5 mg/mL to about 7.5 mg/mL, about 1.5 mg/mL to about 10 mg/mL, about 1.5 mg/mL to about 20 mg/mL, about 2.5 mg/mL to about 5 mg/mL, about 2.5 mg/mL to about 7.5 mg/mL, about 2.5 mg/mL to about 10 mg/mL, about 2.5 mg/mL to about 20 mg/mL, about 5 mg/mL to about 7.5 mg/mL, about 5 mg/mL to about 10 mg/mL, about 5 mg/mL to about 20 mg/mL, about 7.5 mg/mL to about 10 mg/mL, about 7.5 mg/mL to about 20 mg/mL, or about 10 mg/mL to about 20 mg/mL. In some embodiments, the antioxidant solution comprises an antioxidant concentration of about 0.5 mg/mL, about 1.5 mg/mL, about 2.5 mg/mL, about 5 mg/mL, about 7.5 mg/mL, about 10 mg/mL, or about 20 mg/mL. In some embodiments, the antioxidant solution comprises an antioxidant concentration of at least about 0.5 mg/mL, about 1.5 mg/mL, about 2.5 mg/mL, about 5 mg/mL, about 7.5 mg/mL, or about 10 mg/mL. In some embodiments, the antioxidant solution comprises an antioxidant concentration of at most about 1.5 mg/mL, about 2.5 mg/mL, about 5 mg/mL, about 7.5 mg/mL, about 10 mg/mL, or about 20 mg/mL.

[0125] Embodiments may also include the following.

[0126] A fluid sample collection device comprising: a housing configurable from a first position to a second position; a sample collection well for collecting fluid; one or more capillaries,

arranged to draw in fluid from the sample collection well; a membrane comprising a testing strip; one or more plungers, disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the first position to the second position; wherein moving the device from the first position to the second position comprises forming an airtight seal defining a volume of air within the device, wherein the device is configured to prevent oxidation of a sample stored within the device.

[0127] The device may comprise an oxygen absorber or antioxidant disposed within the housing.

[0128] The oxygen absorber may comprise silica gel, iron powder, carbon, charcoal, calcium sulfate, calcium chloride, zeolites, a mixture of iron powder and sodium chloride, ascorbate with NaHCO_3 , an oxygen scavenging polymer, ferrous carbonate with a metal halide catalyst, an oxygen scavenging packet, pyrogalllic acid, an oxygen scavenger sachet, or combinations thereof.

[0129] The antioxidant may comprises l-ascorbic acid, sodium l-ascorbate, calcium l-ascorbate, 6-o-palmitoyl-l-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA), or a combination thereof.

[0130] The housing may comprise a gasket configured to seal the membrane from the surrounding environment when the housing is in the second position.

[0131] The housing may form a substantially airtight seal defining an enclosed space within the housing when in the second position.

[0132] The enclosed space within the housing may be configured to enclose an air space in contact with the membrane and the oxygen absorber and optionally a desiccant.

[0133] The membrane may comprise the oxygen absorber.

[0134] The housing may additionally include a desiccant region adjacent the membrane.

[0135] A desiccant tablet may be located within the desiccant region.

[0136] The desiccant tablet may further comprise the oxygen absorber.

[0137] One or more of the capillaries may be coated with a reagent comprising the oxygen absorber or the antioxidant configured to prevent oxidation of the sample.

[0138] The membrane may comprise an oxygen absorbent region comprising the oxygen

absorber and optionally an antioxidant.

[0139] The device may be configured to prevent oxidation of a sample stored within the device to preserve the sample for a subsequent assay, wherein the subsequent assay comprises an Essential & Metabolic Fatty Acids Analysis (EMFA), a lipid panel, a fatty acid test, a free fatty acid test, a fatty acid profile, a fatty acid panel, an oxidized low-density lipoprotein (OxLDL) assay, an assay measuring oxidation of a component within a blood sample, a complete metabolic panel, a complete blood count, a basic metabolic panel, a liver panel, a prothrombin time assay, a hemoglobin A1c assay, a thyroid stimulating hormone assay, or combinations thereof.

[0140] The device may be configured to separate a blood sample into a plasma component and a cellular component, wherein the device is configured to prevent oxidation of the plasma component and the cellular component with the oxygen absorber.

[0141] The device may comprise an antioxidant coating on one of the funnel clip, the gasket, the capillary tubes, the pore plug, the port or outlet, or the membrane.

[0142] The oxygen absorber may enclose or wrap around the membrane without touching the membrane.

[0143] A method of storing a sample for subsequent analysis comprising inserting a sample in the sample collection well of a device as described above; moving the housing from the first position to the second position thereby forming an airtight seal within the housing defining an enclosed airspace; and removing oxygen from the enclosed airspace wherein oxygen is removed from the enclosed airspace with an oxygen absorber or an oxygen scavenger.

[0144] The method may further comprise removing moisture from the airspace with a desiccant.

[0145] A kit comprising the device as described above; and an oxygen absorbent packet, a desiccant, a molecular sieve, or combinations thereof contained within an airtight packaging.

[0146] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. Various alternatives to the specific embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents are covered thereby.

CLAIMS

1. A fluid sample collection device comprising: a housing configured to move from a first position to a second position; a sample collection well for collecting fluid; one or more capillaries arranged to draw in fluid from the sample collection well; a membrane; one or more plungers disposed in line with the capillaries and arranged to dispense fluid from the capillaries onto the membrane when the housing is moved from the first position to the second position, wherein the device is configured to prevent oxidation of a sample stored within the device when the device is in the second position.
2. The device of claim 1 comprising an oxygen absorber or a plurality of oxygen absorbers and an optional antioxidant disposed within the housing.
3. The device of claim 2, wherein the oxygen absorber is contained in a sachet, a packet, an air permeable pouch, or other air permeable packaging.
4. The device of claim 2 or claim 3, wherein the oxygen absorber comprises silica gel, iron powder, carbon, charcoal, calcium sulfate, calcium chloride, zeolites, a mixture of iron powder and sodium chloride, ascorbate with NaHCO_3 , an oxygen scavenging polymer, ferrous carbonate with a metal halide catalyst, an oxygen scavenging packet, pyrogallol acid, an oxygen scavenger sachet, or combinations thereof.
5. The device of any of claims 2, 3 or 4, wherein the antioxidant or reducing agent comprises l-ascorbic acid, sodium l-ascorbate, calcium l-ascorbate, 6-o-palmitoyl-l-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA), or a combination thereof.
6. The device of any of claims 1, 2, 3, 4 or 5, wherein the housing comprises a gasket configured to seal the membrane from the surrounding environment when the housing is in the second position.
7. The device of claim 6, wherein the gasket is provided on a mating surface between a first portion of the housing and a second portion of the housing.
8. The device of any of claims 1 through 7, wherein the housing forms a substantially airtight seal defining an enclosed space within the housing.
9. The device of claim 8, wherein the enclosed space within the housing comprises the membrane.

10. The device of claim 8, wherein the enclosed space is in contact with the membrane and the oxygen absorber.
11. The device of claim 8, wherein the enclosed space is in contact with the membrane, the oxygen absorber, and a desiccant.
12. The device of any of claims 8 through 11, wherein the enclosed space is from about 1 to about 50 mL in volume.
13. The device of any of claims 8 through 11, wherein the enclosed space is from about 1 to about 10 mL in volume.
14. The device of any of claims 8 through 11, wherein the enclosed space is 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 mL in volume.
15. The device of any of claims 1 through 14, wherein the membrane is a testing strip.
16. The device of any of claims 1 through 14, wherein the membrane is a lateral flow strip.
17. The device of any of claims 1 through 16, wherein the device does not comprise a desiccant within the housing.
18. The device of any of claims 1 through 16, wherein the housing additionally includes a desiccant region adjacent the membrane.
19. The device of claim 18, wherein a desiccant tablet is located within the desiccant region.
20. The device of claim 19 additionally comprising a support structure for holding the desiccant tablet adjacent the membrane.
21. The device of claim 20, wherein the support structure further holds the oxygen absorber.
22. The device of claim 21, wherein the oxygen absorber encloses or wraps around the membrane without touching the membrane.
23. The device of claim 19, wherein the desiccant tablet comprises desiccant and the oxygen absorber.
24. The device of claim 23, wherein the desiccant tablet further comprises an inert layer between the desiccant and the oxygen absorber.
25. The device of any of claims 1 through 16, wherein the membrane comprises the oxygen absorber.
26. The device of claim 25, wherein the membrane comprises an oxygen absorbent region comprising the oxygen absorber.
27. The device of claim 25 or claim 26, wherein the oxygen absorber is impregnated into the membrane.

28. The device of any of claims 25 through 27, wherein the membrane comprises an antioxidant or a reducing agent.
29. . The device of any of claims 1 through 28 further comprising a reagent.
30. The device of claim 29, wherein the reagent is configured to prevent oxidation of the sample.
31. The device of claim 29 or claim 30, wherein one or more of the capillaries are coated with the reagent.
32. The device of any of claims 29 through 31, wherein the reagent comprises the oxygen absorber.
33. The device of any of claims 29 through 31, wherein the reagent comprises an antioxidant.
34. The device of claim 33, wherein the device comprises an antioxidant coating on the device, on a portion thereof which contacts the sample, or on a component thereof.
35. The device of claim 34, wherein the device comprises an antioxidant coating on a funnel clip, gasket, capillary tube, pore plug, the port or outlet, or the membrane.
36. The device of claim 34 or claim 35, wherein the antioxidant coating is applied through dip coating, spray coating, during the plastic injection molding process, or other means.
37. The device of any of claims 34 through 36, wherein the device comprises an antioxidant coating on a removable funnel clip configured to prevent accidental actuation of the device and to funnel a sample into the collection well, on a capillary tube, on the sample collection well, or combinations thereof.
38. The device of any of claims 1 through 37, wherein the device is configured to prevent oxidation of a sample stored within the device to preserve the sample for subsequent analysis.
39. The device of claim 38, wherein the device is configured to prevent oxidation of a sample stored within the device to preserve the sample for a subsequent assay, wherein the subsequent assay comprises an Essential & Metabolic Fatty Acids Analysis (EMFA), a lipid panel, a fatty acid test, a free fatty acid test, a fatty acid profile, a fatty acid panel, an oxidized low-density lipoprotein (OxLDL) assay, an assay measuring oxidation of a component within a blood sample, a complete metabolic panel, a complete blood count, a basic metabolic panel, a liver panel, a prothrombin time assay, a hemoglobin A1c assay, a thyroid stimulating hormone assay, or combinations thereof.

40. The device of any of claims 1 through 39, wherein the device is configured to extend the amount of time that a sample can be stored within the device.
41. The device of claim 40, wherein the device is configured to extend the amount of time that a sample can be stored within the device prior to analysis in a subsequent assay.
42. The device of claim 40 or claim 41, wherein the device is configured to permit the sample to be stored within the device for 5, 7, 10, 14, 15, 20, 21, 25, 28, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, or 90 days while preserving the sample for analysis in a subsequent assay.
43. The device of any claims 1 through 42, wherein the device is configured to separate a blood sample into a plasma component and a cellular component, wherein the device is configured to prevent oxidation of the plasma component and the cellular component with the oxygen absorber.
44. The device of any of claims 1 through 43, wherein the oxygen absorber or the membrane comprises an antioxidant or a reducing agent concentration of about 0.5 mg/mL to about 20 mg/mL.
45. The device of any of claims 1 through 44 configured to collect a biological sample comprising:
- a housing having a sample collection well to receive the biological sample; the housing configured to move from a first position to a second position;
 - a conduit comprising the one or more capillaries, disposed within the housing, the conduit having openings at a first end and a second end, with the opening at the first end configured to receive the biological sample from the sample interface collection well;
 - a sample storage chamber, disposed within the housing, and configured to receive the biological sample from the conduit; and
 - a mechanical actuator; wherein the first position provides an opening to the sample collection well, and the second position restricts access to the sample collection well, and wherein the mechanical actuator is configured to dispense a predetermined amount of the biological sample from the second end of the conduit into the sample storage chamber via mechanical force when the housing is moved from the first position to the second position and the second position and comprises an airtight seal defining a volume of air within the device when the device is in the second position.

46. The device of claim 45, wherein the mechanical actuator is further configured to control a plunger disposed within the conduit to dispense the biological sample into the sample storage chamber.
47. The device of claim 45 or claim 46, wherein the housing comprises first and second portions slidably engaged to each other and configured to be pressed towards each other to configure the device from the first position to the second position.
48. The device of any of claims 45 through 47, wherein the biological sample comprises blood.
49. A method of storing a sample for subsequent analysis, the method comprising: inserting a sample in the sample collection well of a device of any of claims 1 through 48; moving the housing from the first position to the second position; forming an airtight seal within the housing defining an enclosed airspace; and removing oxygen from the enclosed airspace.
50. The method of claim 49, wherein oxygen is removed from the enclosed airspace with an oxygen absorber, or an oxygen scavenger.
51. The method of claim 49 or claim 50, wherein the method further comprises removing moisture from the airspace.
52. The method of claim 51, wherein moisture is removed from the enclosed airspace with a desiccant.
53. The method of any of claims 49 through 52, wherein the method extends the amount of time a sample can be stored prior to a subsequent analysis.
54. The method of claim 53, wherein the subsequent analysis comprises an assay, wherein the assay comprises an Essential & Metabolic Fatty Acids Analysis (EMFA), a lipid panel, a fatty acid test, a free fatty acid test, a fatty acid profile, a fatty acid panel, an oxidized low-density lipoprotein (OxLDL) assay, an assay measuring oxidation of a component within a blood sample, a complete metabolic panel, a complete blood count, a basic metabolic panel, a liver panel, a prothrombin time assay, a hemoglobin A1c assay, a thyroid stimulating hormone assay, or combinations thereof.
55. The method of any of claims 49 through 54, wherein the oxygen absorber or the oxygen scavenger comprises an antioxidant or reducing agent comprising: l-ascorbic acid, sodium l-ascorbate, calcium l-ascorbate, 6-o-palmitoyl-l-ascorbic acid (ascorbyl palmitate), extracts of natural origin rich in tocopherols, synthetic α -tocopherol, synthetic γ -tocopherol, synthetic δ -tocopherol, propyl gallate (propyl 3,4,5-trihydroxybenzoate), octyl gallate (octyl 3,4,5-trihydroxybenzoate), dodecyl gallate (dodecyl 3,4,5-

trihydroxybenzoate), erythorbic acid, sodium erythorbate, butylated hydroxyanisole (BHA), or a combination thereof.

56. The method of any of claims 49 through 55, wherein the oxygen absorber comprises an antioxidant concentration of about 0.5 mg/mL to about 20 mg/mL.
57. A kit comprising the device of any of claims 1 through 48; an airtight packaging; and an oxygen absorbent packet, a desiccant, a molecular sieve, or combinations thereof.