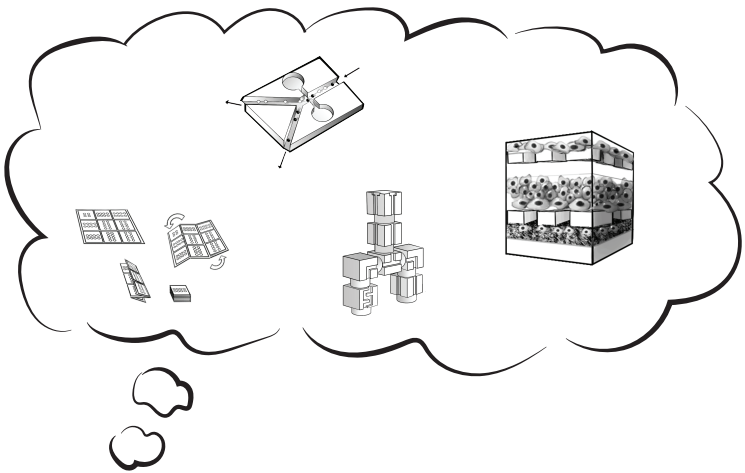
Microfluidic Design Strategies For Inspiring Ideas



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Microfluidic Design Strategies For Inspiring Ideas

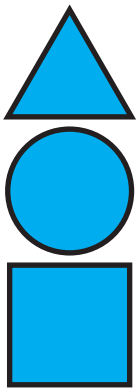
Microfluidic Design Strategies are prompts that encourage exploration of possible solutions in concept generation. They aid designers to consider non-obvious, novel ideas that are different from one another. Also, they can help designers to become "unstuck" when they struggle to generate different ideas.

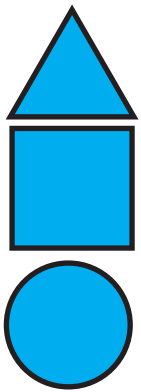
Microfluidic Design Strategies are a result from a research study that extracted characteristics from patented microfluidic devices (Lee, Daly, Huang-Saad, Seifert, & Lutz, 2018). After analyzing 235 patents over a 2-year period, we identified 36 distinct design strategies in microfluidic devices. Each card includes a description of the strategy, an abstract image demonstrating the strategy, and two sketches that show how the strategy is evident in microfluidic devices.

Lee, J. W., Daly S. R., Huang-Saad, A. Y., Seifert, C. M., Lutz, J. (2018) Using design strategies from microfluidic device patents to support idea generation. Microfluidics and Nanofluidics, 22(70)

Add modularity

1

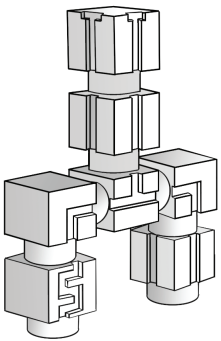




Design a device comprising of multiple components that can be arranged in multiple layouts and is easily replaced. This can allow for rapid prototyping.

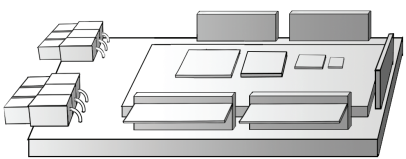
Add modularity

1



This device is made up of multiple modules to control fluid flow.

This is a multidimensional modular microfluidic system that consists of a motherboard, fitting components, and microchannel inserts with different configurations.



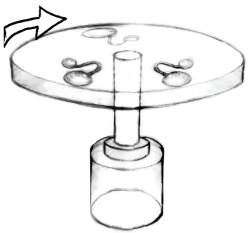
Add motion

2

Apply motion as part of the device's function. This can improve function or change user interaction.

Add motion

2

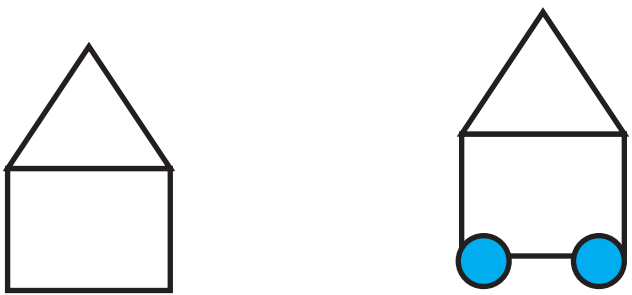


The platform of this device is capable of rotating to improve fluid movement and separation.

A suspended microchannel resonator (SMR) measures particles' masses as they flow through a narrow channel. The original mass sensor consists of a fluid-filled microchannel etched in a tiny silicon cantilever that vibrates inside a vacuum cavity.

Add to existing product

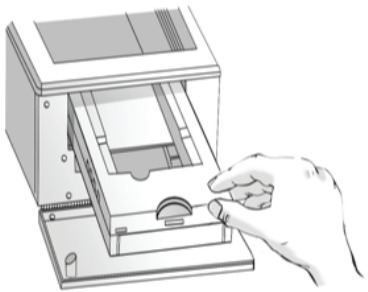
3



Use an existing item as part of the product's function. Consider attaching components or defining relationships between objects. This can reduce material and cost, or improve efficiency.

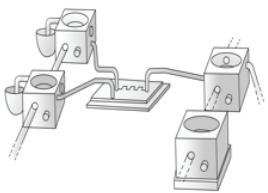
Add to existing product

3



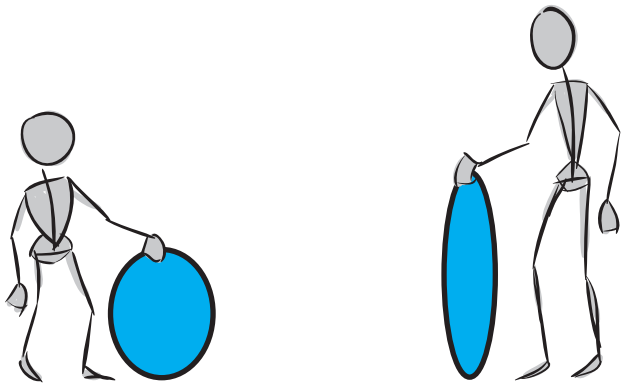
This device reads fluorescent signals from a microfluidic assay that has already completed its reaction(s).

Two independent microfluidic systems are connected together through the mixing chamber.



Adjust functions for specific users

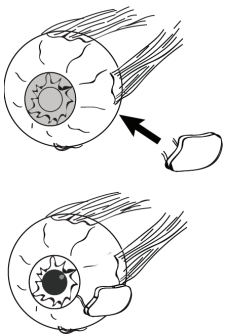
4



Design the functions of the device with target user characteristics in mind. This can improve device performance.

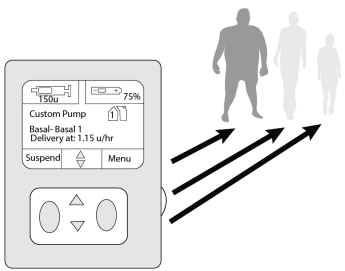
Adjust functions for specific users

4



This is a regulator of intra-ocular pressure that is inserted into patients with glaucoma. The amount of vitreous humor that needs to be removed is specific to each patient.

This is an insulin pump that can be programmed to deliver a specific amount of insulin depending on the user.



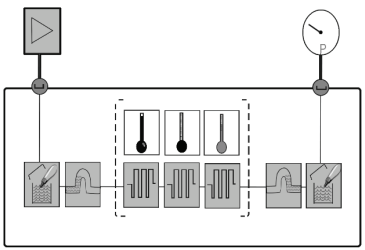
Adjust temperature

5

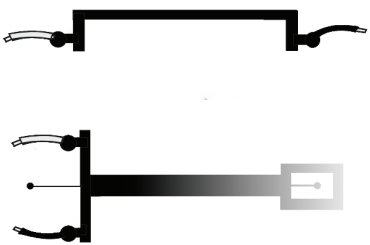
Alter the typical or expected temperature of the device's material or sample.

Adjust temperature

5

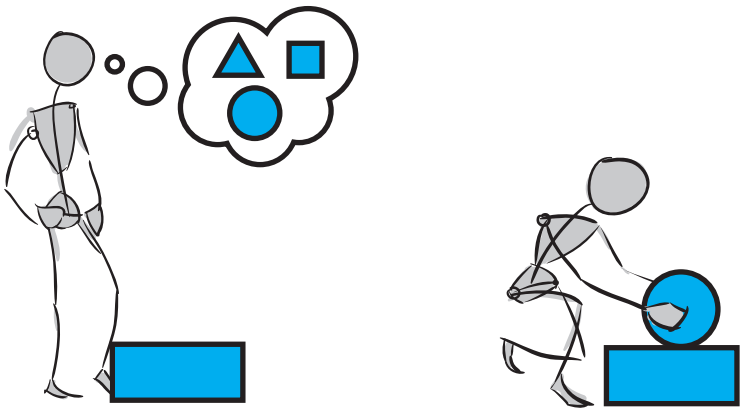


The temperature can be controlled within this microlfuidic device through the applied voltage.



Allow user to customize

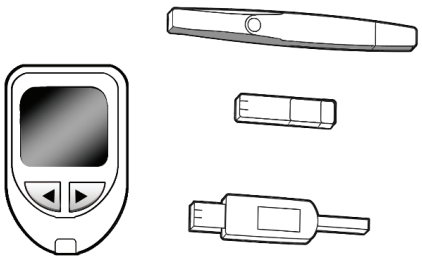
6



Give the user customizable options to best fit their needs and preferences. The final product is developed for each user based on their choices. This can allow the user to use multiple experimental procedures with only one device.

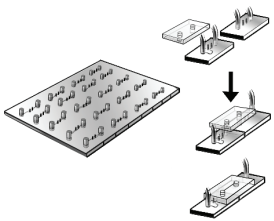
Allow user to customize

6



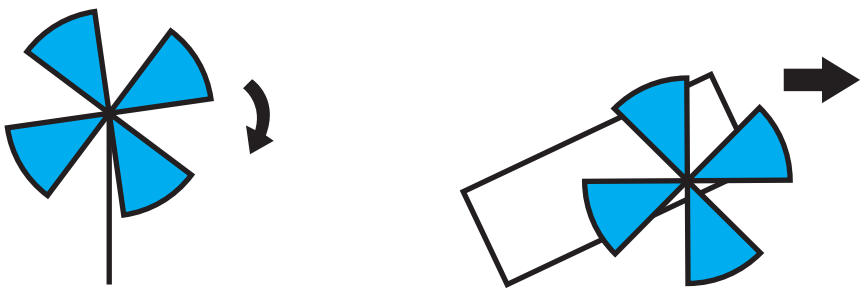
This breath sensor is capable of performing multiple functions by using different mouthpieces.

Human organ-on-a-chip systems for drug screening that can be customized to perform various functions that users require.



Apply an existing mechanism in a new way

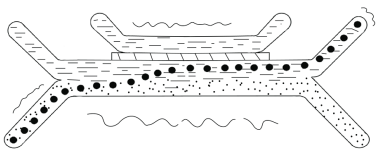
7



Consider whether existing devices or their components can fulfill the desired function. This can facilitate reuse of existing devices, make the design process more efficient, and expand the pool of options.

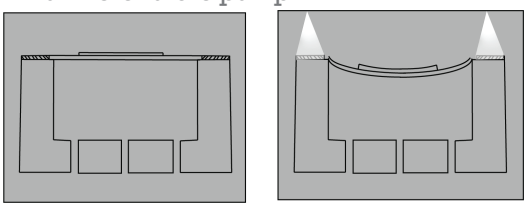
Apply an existing mechanism in a new way

7



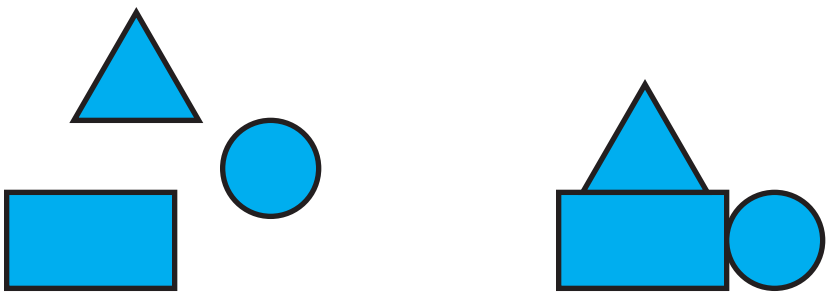
This microfluidic device uses ultra-sound to separate particles.

This is a retinal prosthesis device that uses a light-powered microactuator as a microfluidic pump.



Attach independent functional components

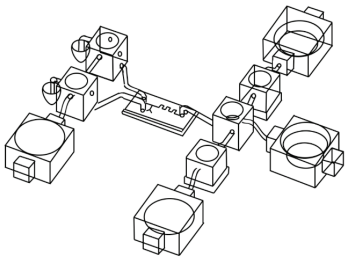
8



Identify different parts or systems with distinct functions, assign a form to each, and add a connection between them. This can increase product efficiency, reduce material, facilitate compactness, and unite separate functions.

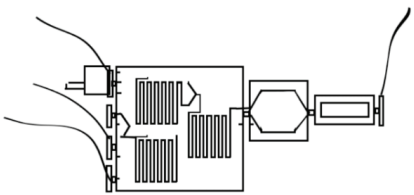
Attach independent functional components

8



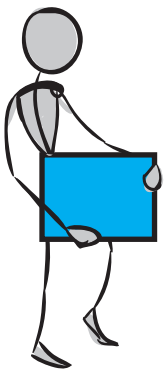
This is a PCR microfluidic system connected by multiple modules.

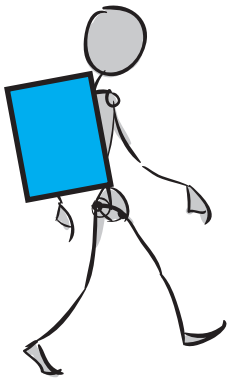
This is a modular microfluidic device with different modules, each serving one specific function like mixing or a reaction chamber.



Attach product to user

9

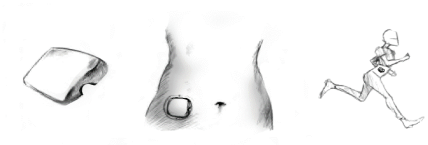




Design the device around the user by attaching it to the user's body, and redefine how the function is achieved. Consider attachments to a variety of body parts like the head, finger, back, and feet. This can increase device portability and efficiency.

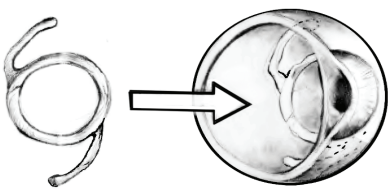
Attach product to user

9



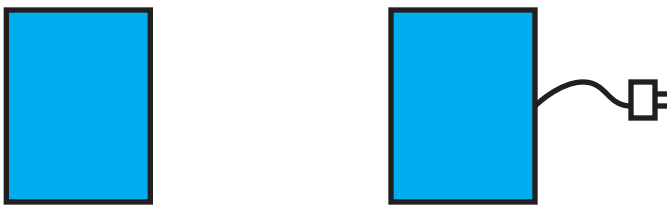
This device is a portable and water-proof insulin pump that can be attached to the user.

The embedded intraocular pressure sensor can be implanted into the eye of a patient with glaucoma during a routine cataract surgery or as a stand-alone implant.



Automate

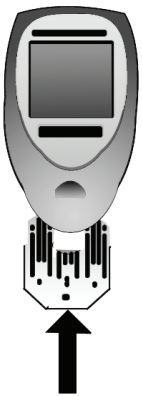
10



Make the device run with minimal user input. This can improve accuracy of results and usability of the device.

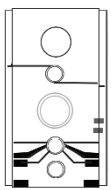
Automate

10

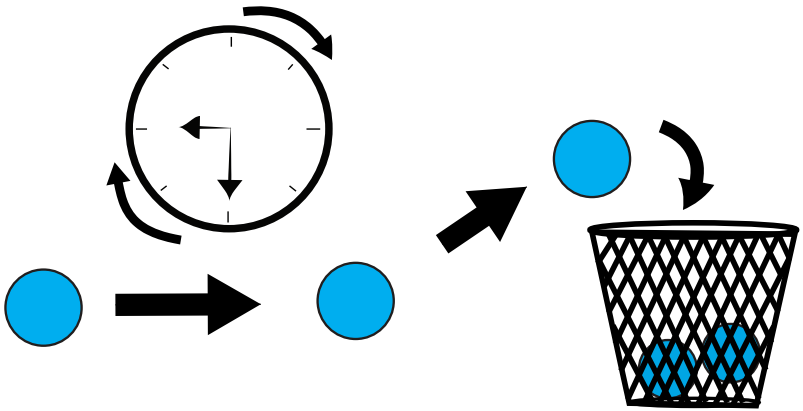


This device provides an automatic readout once a sample is inserted.

This is an automatic immunomagnetic device that is used for detecting DNA biomarkers.



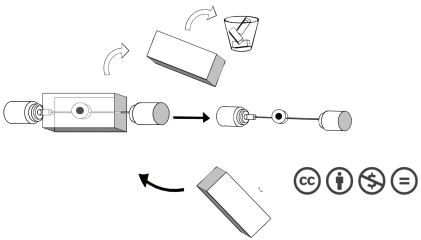
Change device and/or sample lifetime



Consider the assumed lifetime of a device or sample, and alter the number of times it can be used. For example, replace disposable components with reusable ones, or vice versa. This can optimize material use, allow environmentally friendly material use, and decrease waste.

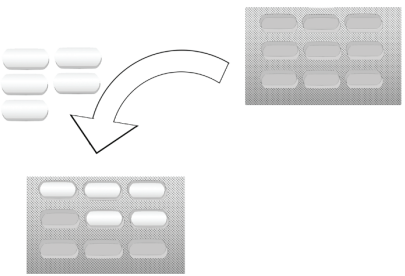
Change device and/or sample lifetime

11



This device can be stored packaged with filled reservoirs for 6-12 months. Also, some components can be reused.

Blist pouches are used for packaging purposes. Reagents can be stored and protected from UV exposure until required, extending the shelf life.



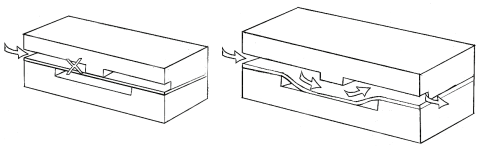
Change flexibility

12

Alter the typical or expected form of the device or its components while maintaining function. This can redefine user interactions, make the device more intuitive, and suggest new device functions.

Change flexibility

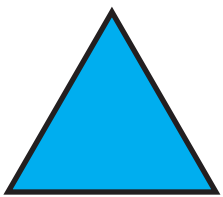
12

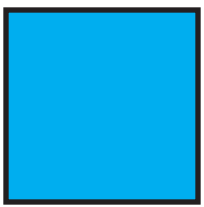


This device has a flexible membrane that can block the fluid flow.

This wearable microfluidic device has flexible sensors that can detect the change in pH.

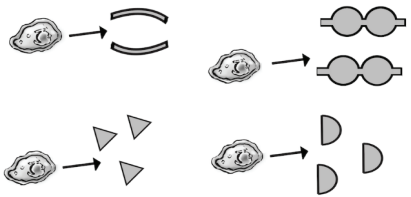
Change geometry





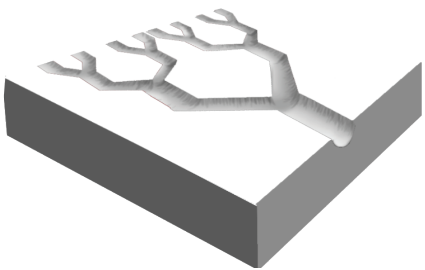
Alter the typical or expected geometric form of the device or its components while maintaining function. This can redefine user interactions, make the device more intuitive, and suggest new device functions.

Change geometry

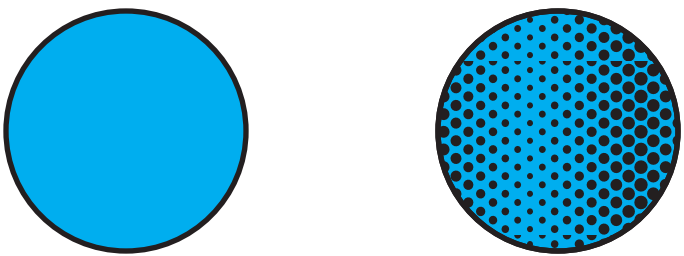


This device uses different surface shapes that affect how cells interact with it.

This device has the smooth, vascular-like geometry of microchannel networks in three dimensions.



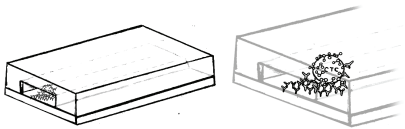
Change surface interactions



Highlight areas where the sample interacts with the device by changing hydrophobicity, changing surface tension, or coating it with binding molecules. This can improve existing function, and improve usability.

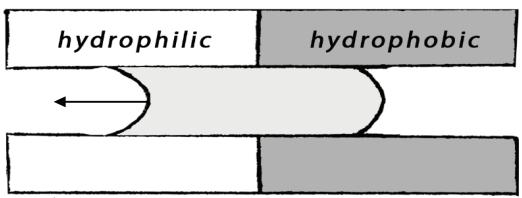
Change surface interactions

14



By having the chamber coated with a plurality of binding antibodies, this device can capture circulating tumor cells.

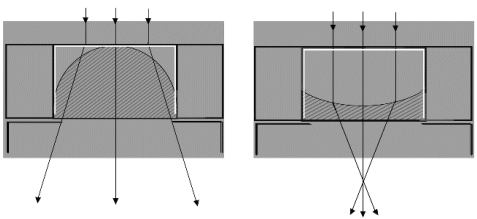
Droplets move due to a gradient in solid-liquid interfacial energy. A droplet straddling hydrophobic and hydrophilic surfaces can release stored interfacial energy by moving further into the hydrophilic region.



Change volume to surface area ratio

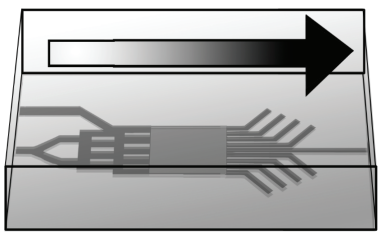
Highlight areas where the sample interfaces with the device. Altering the volume to surface area ratio can change how much the sample interacts with the surface of the device.

Change volume to surface area ratio

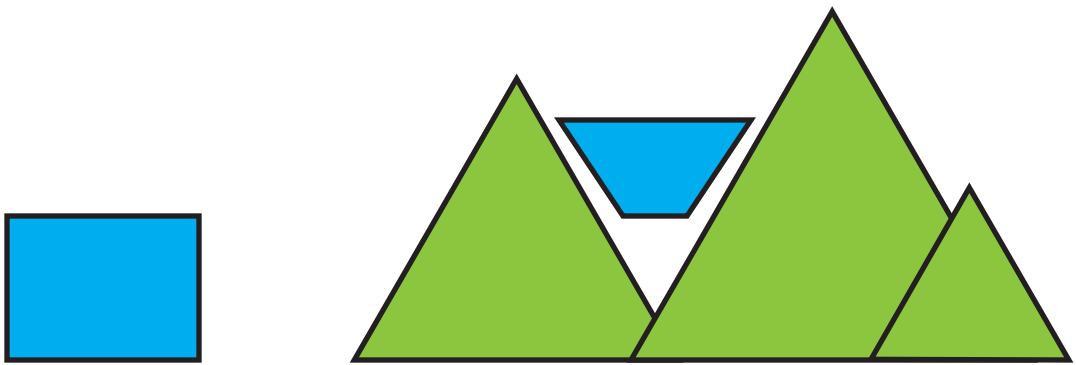


This is a microfluidic optical lens that is able to change the shape of its liquid lens by applying voltage.

The change in surface area affects how much the sample interacts with the surface of the device.

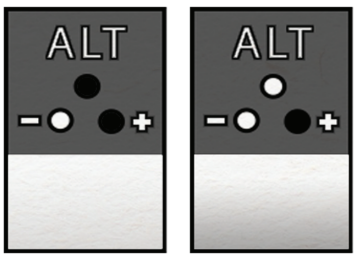


Contextualize



Envision the details of how and where the device will be used, and fit the device to this context. Alternatively, redesign the device to function in a new context. This can specialize the device to specific user groups and environments, including point-of-care testing and use in low-resource settings.

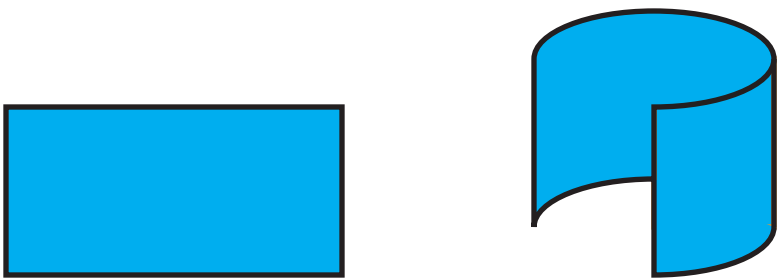
Contextualize



This paper-based microfluidic device is used to detect pathogens. Due to its low cost and easy setup, this device can be accessible to countries that lack the resources to detect pathogens.

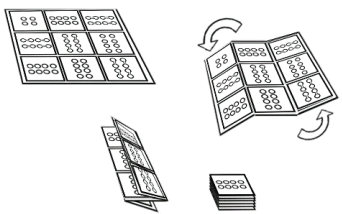
This $25 device is used to analyze blood samples or water supplies. The device is intended to diagnose cases of diabetes and malaria, as well as detect water pollutants.

Convert 2-D to 3-D



Create a three-dimensional object or environment that improves upon existing 2-D designs. This can provide more accurate modeling environments.

Convert 2-D to 3-D



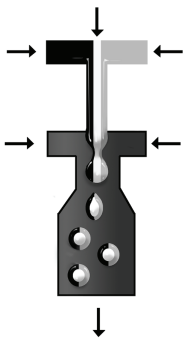
A 3D microfluidic device is fabricated by stacking layers of paper and double-sided adhesive tape impermeable to water, both patterned in ways that guide the flow of fluid within and between layers of paper.

This device mimics 3D cell culture conditions.

Create multi-phase system

Design a device that incorporates multiple phases or immiscible fluids. This can prevent unwanted false positives and cross-contamination/cross-talk.

Create multi-phase system



A microfluidic device forming aqueous droplets from three independent semi-dilute PNIPAm solutions.

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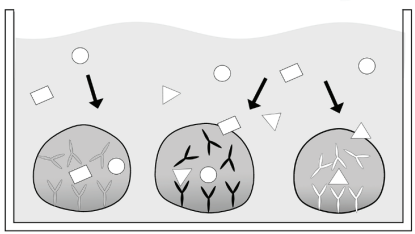
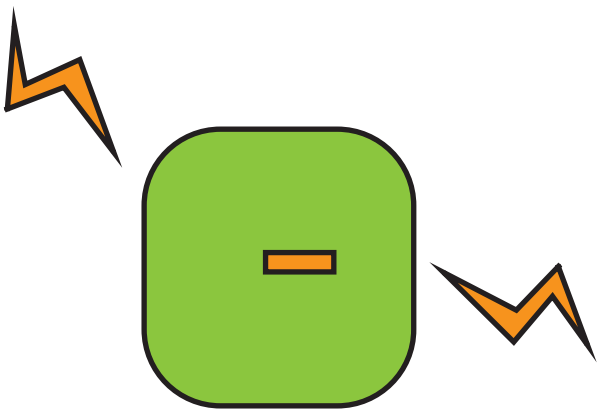
This is an aqueous 2-phase system that separates antibodies, minimizing cross contamination in multiplex assays.



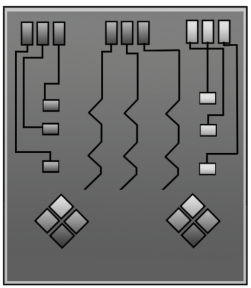
Embed electronics or electrodes

19



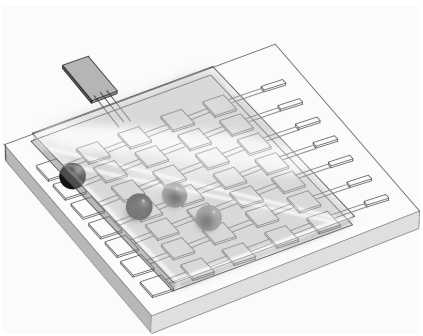
Design a device that has built-in electronics or electrodes. This can improve fluid control, increase functionality, and increase usability.

Embed electronics or electrodes



A portable whole-cell biochip used to monitor water geno-toxicity. The chip is controlled using external electric fields.

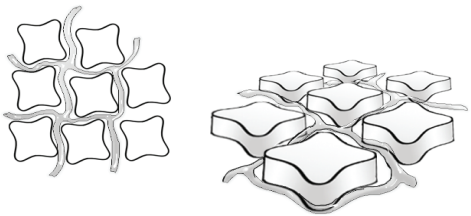
A microfluidic device that uses charged electrodes to control the motion and mixing of droplets.



Impede flow

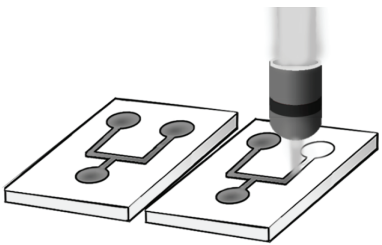
Explore ways to deviate flow from its preferred path. This can increase interactions between analytes and channel surfaces, and help regulate flow.

Impede flow



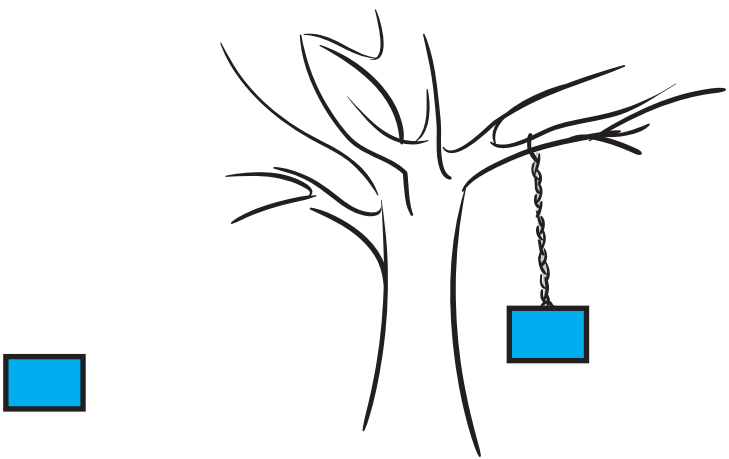
Concave posts in the device are angled to prevent hydrodynamic trapping of cells in concave sections and maximize fluid-structure interaction. This allows for higher interaction with post structures.

In this device, certain channels are heated using light to block the channel and thus, deviates flow into other channels.



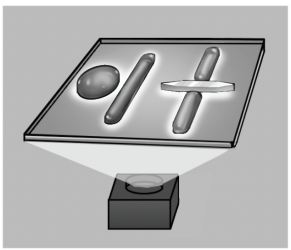
Incorporate environment

21



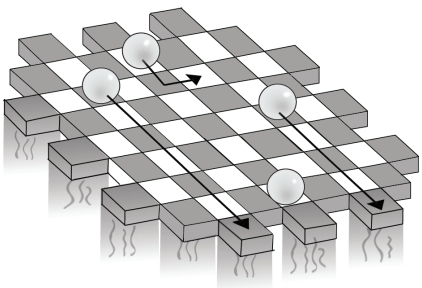
Use the surrounding environment (living or artificial) to perform a part of the product's function or serve as a product component. This can reduce material, create uniformity with the environment, and increase environmental awareness.

Incorporate environment



Light pattterns are used to elongate the droplet and move it across the surface. The droplet is sliced with an integrated Teflon blade on the light-actuated digital microfluidic platform.

Droplets are manipulated using different temperatures on the surface.



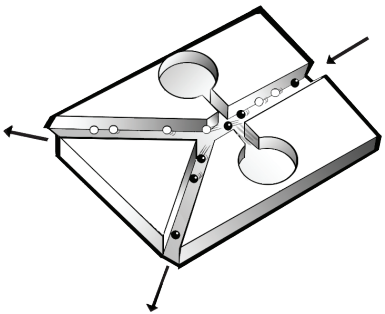
Incorporate filtration, separation, and/or sorting

22

Explore ways of deviating flow from its preferred path. This can increase interactions between analytes and channel surfaces and help regulate flow.

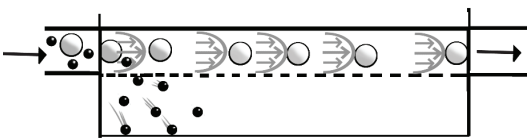
Incorporate filtration, separation, and/or sorting

22

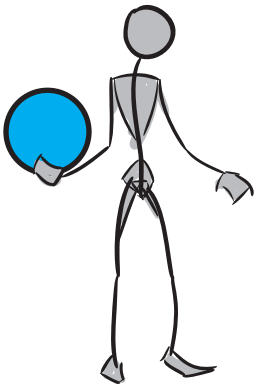


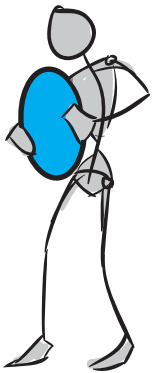
A particle-sorting module that helps to filter the cells of interest from the sample.

This device can filter the sample mixture based on their densities.



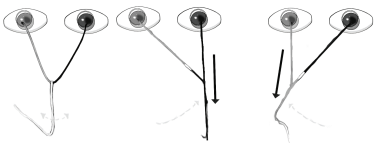
Incorporate user input





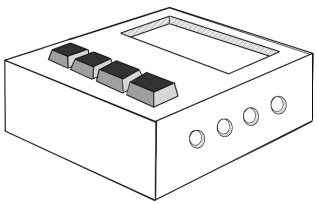
Identify product functions that are adjustable and allow users to make those changes through an interface control, using buttons, sliders, levers, dials, touch screens, etc. This can make the product adjustable to the user's needs.

Incorporate user input

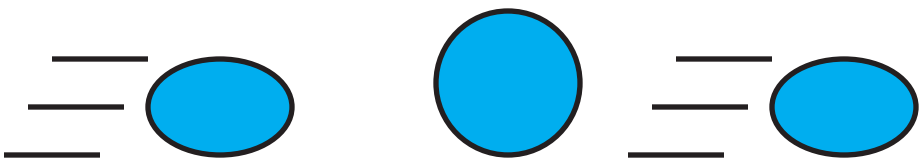


A micro-selector, with two inlets and a single outlet, allows a user to select which sample they wish to transport.

A portable glucose monitor that can analyze the blood sample for glucose levels, peak flow meter, etc., depending on the user's input.

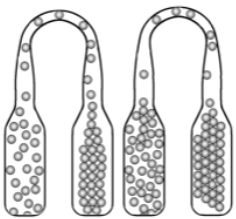


Incubate



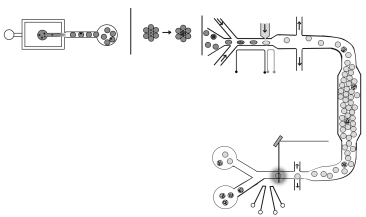
Store droplets or particles or increase the time it takes for them to move through channels. This can allow for processes that take longer than a few minutes to complete to be incorporated into a microfluidic assay.

Incubate



The bottleneck design allows more time for chemical reactions in the droplets to take place.

Droplets are incubated on-chip along a delay line and spaced with oil for fluorescence detection (i.e. enzymatic activity).

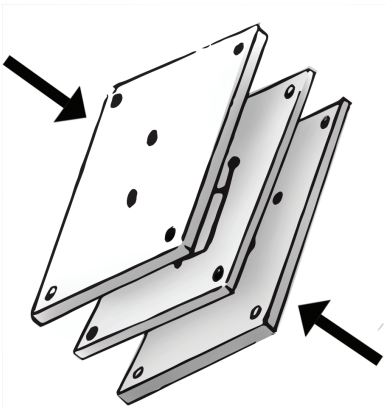


Layer

25

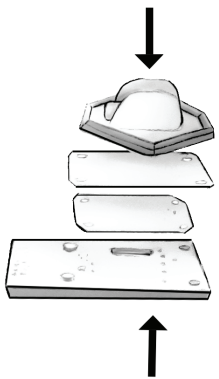
Build the device through a series of layers of similar or different materials. Different layers can provide a variety of functions and interest.

Layer

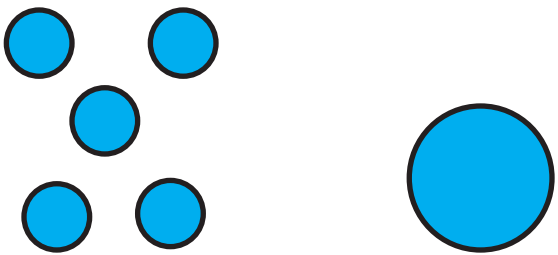


This device has three plastic layers with different channel designs for each layer, providing added functions.

This device is comprised of a diaphragm value with a fluidics layer, an actuation layer, and an elastic layer.

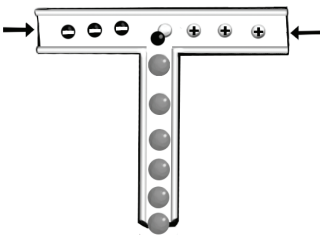


Merge droplets



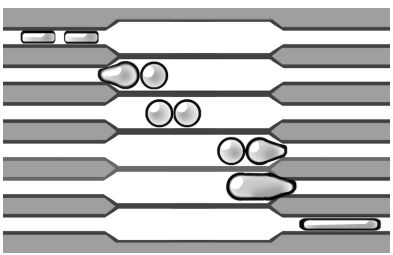
Consider incorporating droplets that converge. This can control mixing ratios and increase precision.

Merge droplets

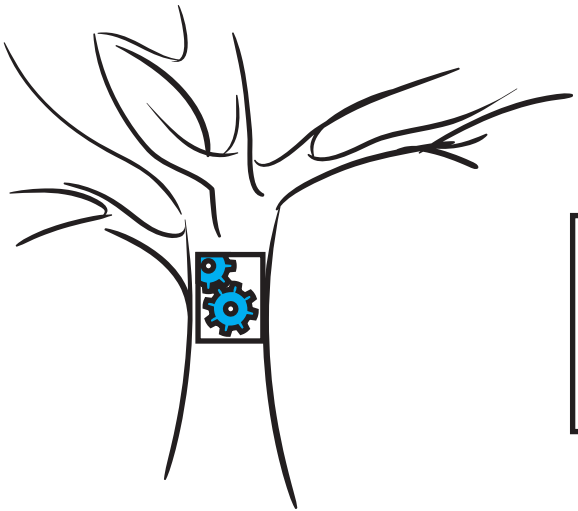


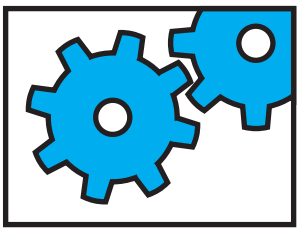
This device directs positively and negatively charged droplets toward each other to created fused droplets.

A pair of droplets collides and merges as a single droplet.



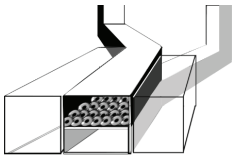
Mimic natural mechanisms





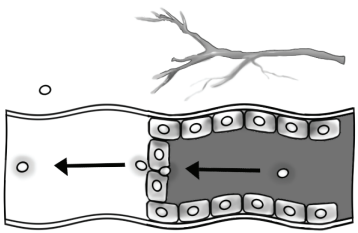
Imitate naturally occuring processes, mechanisms, or systems. This can provide efficiency.

Mimic natural mechanisms

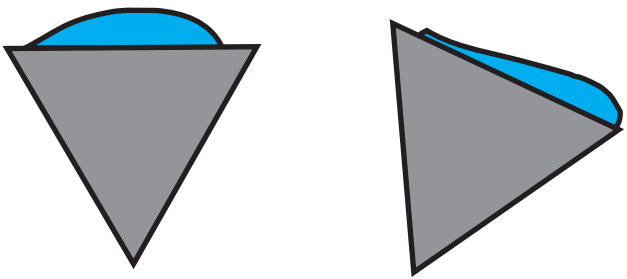


The gut-on-a-chip could be used to develop models of intestinal diseases or study absorption and toxicity of new drugs as it mimics the functions of the human intestine.

This device mimics the tumor environment to get a better understanding of how cancer cells interact with endothelial cells.

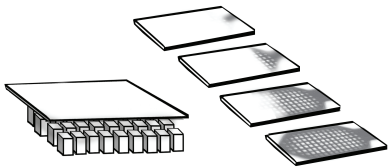


Run on passive flow



Allow the fluid to flow using passive methods, which include the gravitational force and capillary action. This can save energy, eliminate need for external equipment, and simplify the device.

Run on passive flow

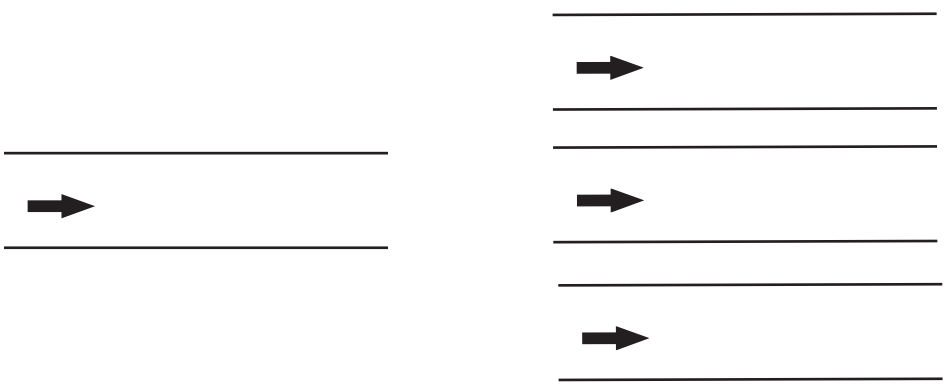


Snapshot images of capillary filling of air DBD processed microchannel containing micropillars.

Capillary flow of blood and plasma through the tube. Due to lower velocity, the blood is no longer able to carry the plasma and they are separated out.

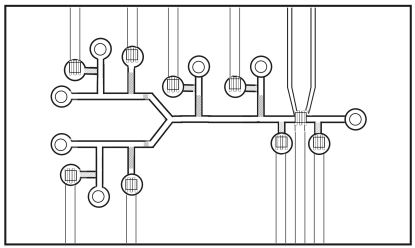
Run parallel operations

29



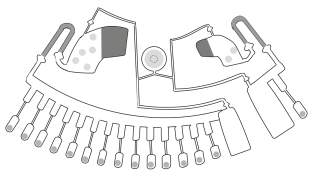
Consider making a device that can run similar operations simultaneously. This further increases throughput, and can decrease run time.

Run parallel operations

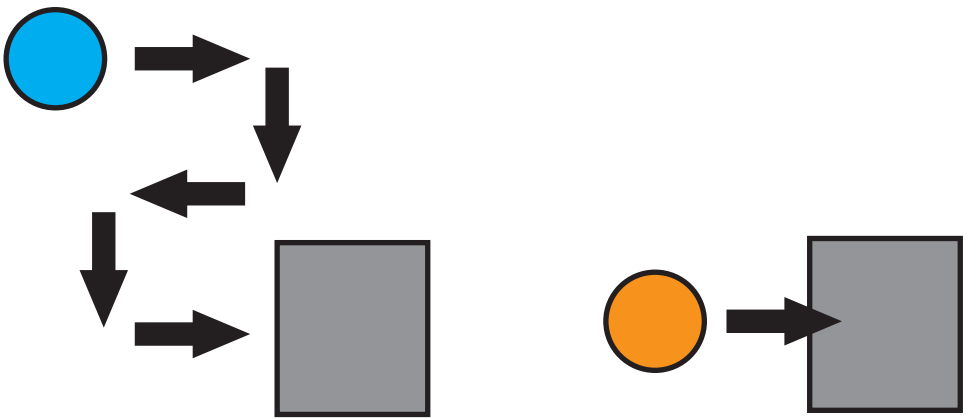


This is an integrated PDMS microfluidic system comprising of multiple modules. Several of these modules can operate in parallel.

A centrifugal microfluidic device for nested PCR. It is capable of executing multiple operations at the same time in parallel.



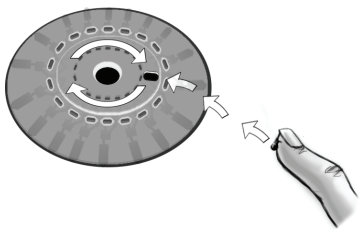
Simplify sample preparation



Consider treating the sample within the device. This can increase usability by reducing pretreatment steps.

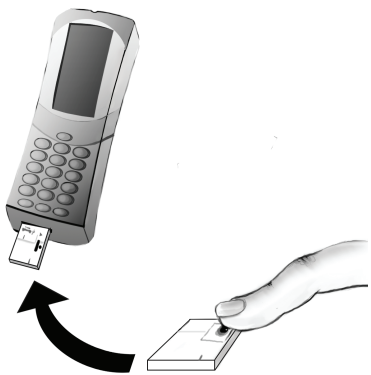
Simplify sample preparation

30

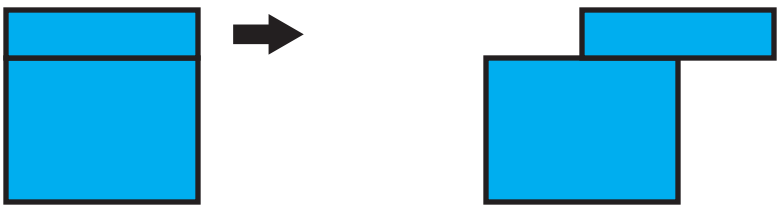


This device accepts a blood sample directly from the user without having to process the blood.

This is a blood analysis device; the user provides a blood sample and the device will provide a readout on the spot.



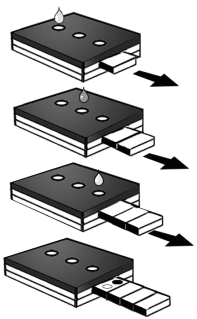
Slide



Move one component smoothly along a surface or another component. This can expose or cover surfaces, open or close spaces, and offer options to the user.

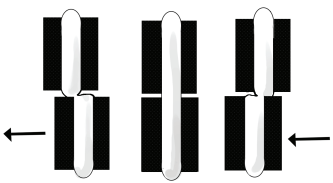
Slide

31



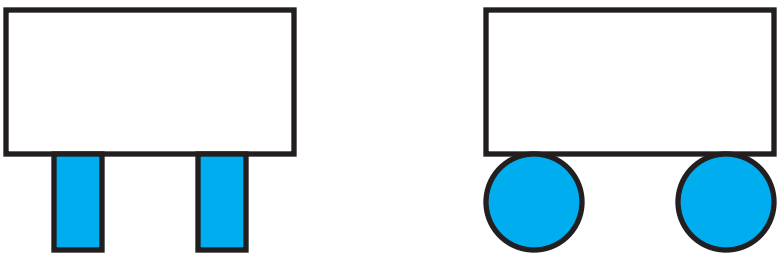
This is a 3D microfluidic paper-based analytical device used to conduct an ELISA. Running an ELISA involves adding a sample and water on the sliding strip.

This device controls the flow by sliding. When two channels are misaligned, the flow stops.



Substitute way of achieving function

32

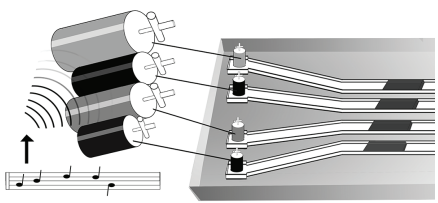


Replace one or more components with other designs that can achieve the same function. This can improve device performance, change device cost, and facilitate use of more readily available materials. This may include removing an important or costly piece of equipment, such as a thermal cycler for PCR.

Substitute way of achieving function

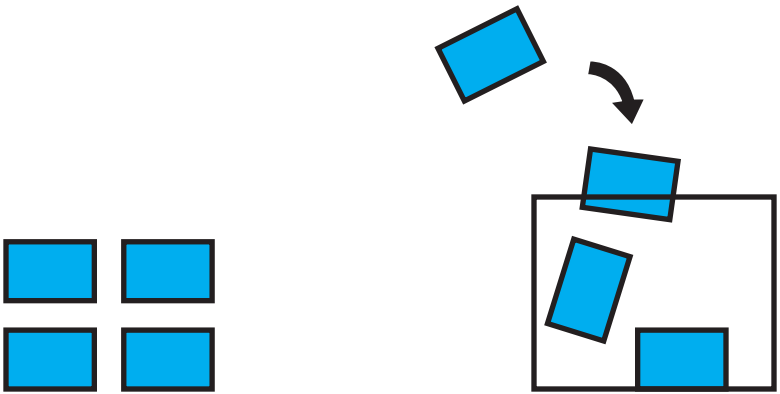
In this microfluidic device, light is used as a means to direct the flow of droplets. The droplets are transported by projected light patterns from a digital light projector.

Acoustic signal is delivered to an array of resonance cavities to manipulate droplets. Droplets move in response to resonant musical tones supplied to the device.



Use a disposable cartridge

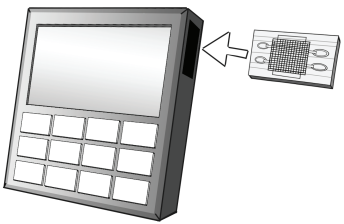
33



Consider using a small, removable component designed to be inserted into a device. This can reduce cost, increase usability, and increase variety of applications.

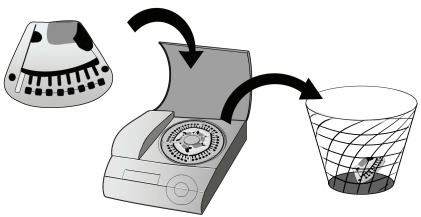
Use a disposable cartridge

33



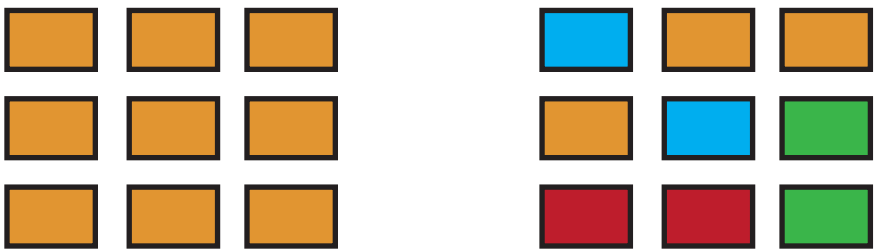
A droplet micro-actuator cartridge can be inserted into a portable electric device to be analyzed.

A centrifugal microfluidic platform can analyze cartridges.



Use colorimetric or fluorescent imaging

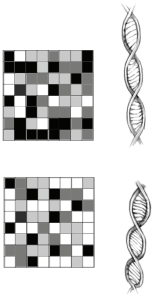
34



Utilize visual color changes or fluorescence to detect the status of the samples. This can improve detectability in devices and provide an easy way to visualize the reaction progress.

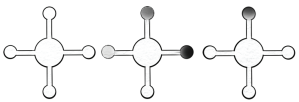
Use colorimetric or fluorescent imaging

34



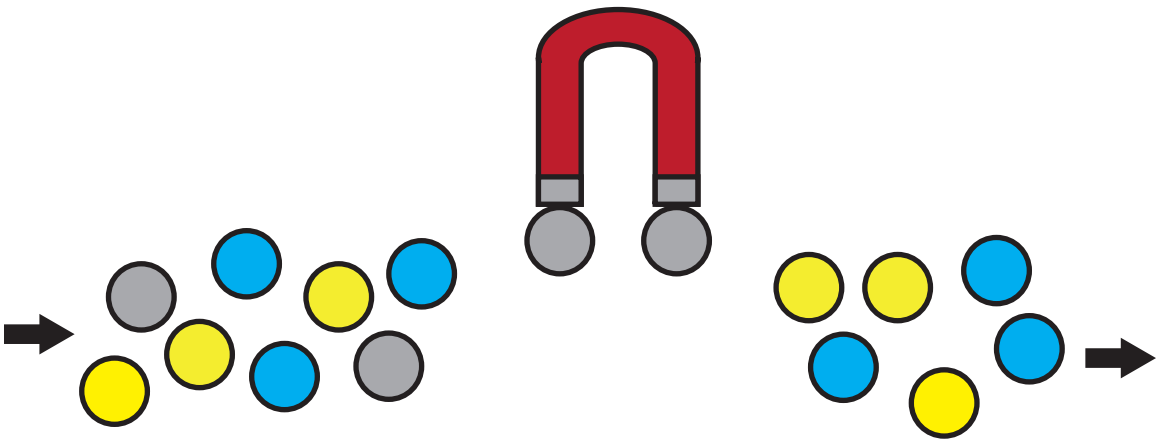
This is a microarray; a device used to analyze genes. Different colored fluorophores light up to indicate the presence of different types of genes.

These are paper-based microfluidic devices for monitoring glucose, protein, and nitrite in blood and urine. Different colors are used to indicate the presence of protein and nitrate.



Use magnets or a magnetic field

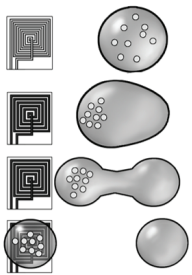
35



Consider incorporating magnets or using a magnetic field for proper device function. This can allow for better control of samples and analytes.

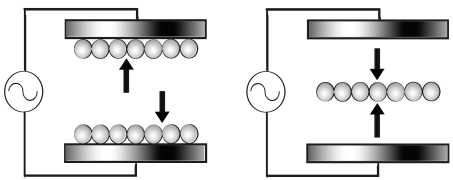
Use magnets or a magnetic field

35



This device uses magnetic beads to sort and manipulate droplets.

Dielectrophoretic separation uses a non-uniform electric field to either separate or merge particles by changing the direction of the electric field.



Utilize opposite surface

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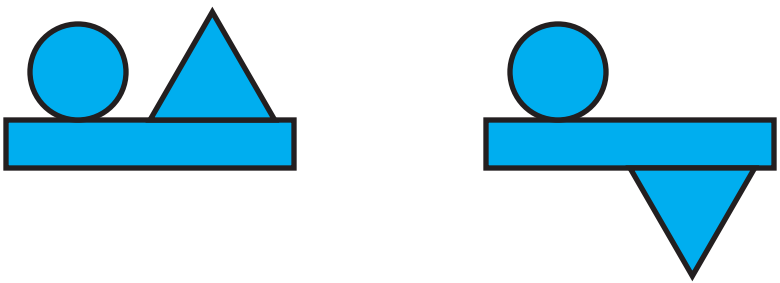
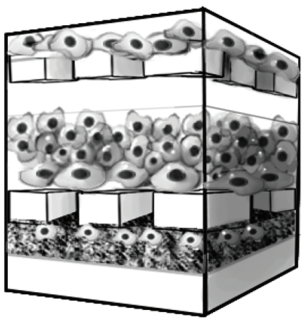


Create a distinction between exterior and interior, front and back, or bottom and top. Make use of both surfaces for complimentary or different functions. This can increase efficiency in the use of surfaces and materials, or facilitate a new way to achieve function.

Utilize opposite surface



This organ-on-chip device makes use of both surfaces for culturing different types of cells.

These PDMS microchannels incorporate a porous membrane in between the culture cells.