SSPC
SYNTHESIS AND SOLID STATE PHARMACEUTICAL CENTRE
Innovation Through Collaboration

Supermarket Science

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The purpose of this short article is to provide some short, practical ideas for fun inquiry-based activities utilising everyday items from the home. These experiments can be carried out in school or at home, but the key is to remember that you do not have to be in a laboratory with top of the range equipment to do science. Many of these experiments illustrate and provide a framework for learning some fundamental concepts in all areas of science, while also developing a range of skills.
The first experiment we will look at is on which explores the concept of density, a core concept at Junior Cycle.

Introduction:

Topic area: Density, mass, volume

Apparatus:
- Unopened cans of coca-cola (diet, regular, and zero)
- Large glass trough (big enough to allow the three cans to float in it at the same time)

What to do:
- Pass the cans of coca-cola around the room. Have each pupil examine them carefully and ask them to make careful observations about what they see.
- Ask the pupils to name as many similarities as they can about the 3 cans of coke. Make a list on the board. Either you or two pupils can make these lists for the whole class on the board.
- Ask the pupils to list as many differences as they can about the 2 cans. Make a list of differences on the board. Some answers they may come up with:

Similarities	Differences
They are made by the same company	One can is regular, one is diet and one is zero
They have the same shape	The cans are different colours
The cans are all made of aluminium	They have different amounts of sugar
The cans are all sealed shut	
have the same amount of liquid - 12 fl oz	
They have similar weights	
They all contain water	
They contain carbon dioxide	
They contain caffeine	

- Ask the (in pairs or groups) to develop ideas to investigate these products. If this is to open ended, ask them to develop plans to investigate specific physical properties (mass, weight, volume, density)
- To examine the density the pupils should place the three cans in the water trough (which should be filled with water) and note what happens.

To guide the pupils in this use the following:
- First observe what happens.
- Then try and explain what happens – why do they behave differently?
- Discuss possible answers to the problem.
- How could you check your answer?

Notes/Tips:
The regular Coca-cola is denser than diet coca-cola or Coke zero.
These differences in density can be explained by the differences in amounts and types of ingredients.
Specifically, the density of sugar (sucrose) (which is in the Coca-cola) is different to the density of aspartame (which is the sweetener in diet Coca-cola).

Alternatively you can use a probing question to initially guide the pupils' inquiry, as they predict and test assumptions:
Question I: Diet Coke cans and bottles are lighter than cans and bottles of normal Coke. Why is that?

Assumption 1: It is because of the sugar. Diet Coke does not contain sugar, which makes normal Coke heavier.
Assumption 2: If sugar is the reason then equal volumes of Coke Zero (follows A 1) and Diet Coke should not have different masses, because both contain no sugar.

Instructions for testing the assumptions
- First make a specific amount of defined sugar solutions and determine their densities:
- Determine the median mass of sugar cubes. In 9 beakers (400 ml), dissolve 0 to 15 sugar cubes in exactly 250 ml water. Determine the volume of the solutions. The density can now be calculated by dividing the mass by the volume.
- Plotting the density values (x-axis) against the number of sugar cubes (y-axis) forms a calibration curve.
- Determine the mass of 250 ml each of Coke, Diet Coke and Coke Zero, and calculate the density. Comparing the values with the calibration curve can yield the approximate amount of sugar contained in each solution.

Results:

Beaker Number									
Sugar Cubes Amount									
Mass of sugar [g]									
Mass of solution [g]									
Volume of solution [cm^3]									
Density [g/cm^3]									

Title: Dancing Raisins

Introduction: Fizzy drinks contain carbon dioxide, what happens to this carbon dioxide when we open a bottle containing a fizzy drink?

Level: Junior Certificate Science
Topic area: Gases, density

Apparatus:
- Bottle of soda water/fizzy water
- Raisins

Procedure:
1. Open the bottle of water, note what happens when the bottle is opened.
2. Drop 6 or 7 raisins into the bottle. Watch the raisins for a few seconds. Describe what is happening to the raisins. Do they sink or float? Keep watching; what happens in the next several minutes?
3. Close the lid of the bottle, keep watching the raising. Note what happens.

Questions/Problems for the pupils to discuss and develop an argument for:
- Why do the raisins sink to the bottom?
- Why do the raisins rise to the surface?
- What does this tell us about gases?
- What happens if you put the lid back on the bottle? Why?
- What other objects/foods exhibit this behaviour? Will this work with grapes? Uncooked pasta?

Notes/tips:
Raisins are denser than the liquid in the soda, so initially they sink to the bottom of the glass. The carbonated drink releases carbon dioxide bubbles. Carbonated water contains dissolved carbon dioxide gas. This gas will collect on the uneven surfaces on the raisins. When enough gas has collected, it will actually lift the raisins to the surface (kind of like little tiny parachutes). When the raisin reaches the surface the bubbles pop, and the carbon dioxide gas escapes into the air. With the gas now gone, the raisins will sink back to the bottom where the process begins again. This causes the raisin to lose buoyancy and sink. When the lid of the bottle is closed again, the carbon dioxide has nowhere to go and the raisins all sink to the bottom until the lid is opened again and the cycle continues. This rising and sinking of the raisins continues until most of the carbon dioxide has escaped, and the soda water goes flat.

If you put the raisins directly in the bottle and replace the cap, eventually the raisins will stop dancing. This is because carbon dioxide gas is prevented from leaving the bottle. As a result, pressure builds up in the space above the fluid. This pressure is transmitted throughout the fluid, and the bubbles cannot grow as large. The volume of the raisins cannot increase enough to lower their density to the point where they will rise. When the cap of the bottle is removed, the bubbles grow larger, and the raisins resume the cycle of their "dance."
The same scientific principles are at work when a child uses a set of inflated "arm-bands" or an inflatable ring at the swimming pool. The volume of the arm-bands increases the child's volume considerably. The mass of the arm-bands, however, is very small. The overall effect is to lower the density of the child wearing the arm-bands to less than that of the pool water, so that the child can float. Deflating the arm-bands (don't try this with someone who can't swim!) would reverse the process and cause the person to sink.

Carbonated beverages are prepared by putting the beverage into a can under high pressure of carbon dioxide gas. This high pressure causes the carbon dioxide gas to dissolve in the liquid. When you open a can of fizzy drink, the noise you hear is produced by the carbon dioxide gas as it rushes out of the can. When the can is opened, the decreased pressure allows some of the carbon dioxide gas dissolved in the liquid to escape. This is what makes the bubbles in a soft drink.

Another way to do this experiment is to generate the carbon dioxide gas using the reaction of baking soda and vinegar. Fill your glass about 1/2 full with water. Add one teaspoon of baking soda and stir until it is dissolved in the water. Add 6 or 7 raisins to the glass. SLOWLY pour in vinegar until the glass is about 3/4 full. The vinegar and baking soda react to form carbon dioxide bubbles, and the raisins will dance just as in the soft drink!

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Title: Flaming Wool!

Introduction: The iron in the steel wool is finely divided and therefore it burns more readily than a block of iron.

Level: Junior Cycle Science and Senior Cycle Chemistry

Topic area: Combustion, electricity, particulate nature of matter, chemical reactions, effect of surface area on rates of reaction

HEALTH & SAFETY: Wear eye protection

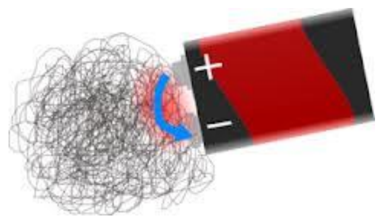
Take care with the sparks, and ensure that this is conducted on a white tile or non-flammable substance. Ensure that all flammable substances are not near the demonstration.

Waste disposal:
The battery can be recycled and the iron wool can be thrown into the waste.

Apparatus:
- Eye protection
- Iron wool
- 9V Battery

Procedure:
1. Get the mass of a clump of iron wool the size of your fist on a scale. Record this mass.
2. Will the mass of this clump of iron wool be greater or less after being burned?
3. Place the clump of iron wool in a ceramic or Pyrex container or on a large ceramic white tile in a well-ventilated area
4. Touch the terminals of the 9V battery to a few strands of the iron wool. It should start to glow.
5. Blow on the burning iron wool to make sure that the entire clump has burned (this enables oxygen to get to all the nooks and crannies of the clump).
6. Let the iron wool cool.
7. Collect all the bits and pieces of burned steel wool and take its mass again. Record this mass.

Questions:
- Why does the iron wool ignite?
- What effect does spreading out the strands have?
- What would happen if the strands were very tightly clumped together?
- Is there a difference in mass before and after the burning?
- Did you expect there to be a difference? Why? Why not?



Celebrate Science

Notes/tips:
The strands in the wool are made of iron. These iron strands are surrounded by pockets of oxygen unlike a solid block of iron. This allows it to combust/burn very easily. To prevent this iron from rusting, iron wool is usually coated with an oil based coating. When the iron wool is heated, this coating is burned off. The heat and large amount of surface area allows the iron in the steel wool to burn or combine with the oxygen in the air.
The iron strands short circuit the battery, allowing a large current to flow, which heats up the strands in the iron wool. The iron then combusts to form iron oxide (rust). The reaction is vigorous, which causes the sparks.
There is typically an increase in mass after the iron wool is burned. This tends to be anti-intuitive for pupils.
When iron becomes iron oxide (through reacting with oxygen), it usually forms the compound Fe2O3. Since oxygen atoms have mass and are joined to the iron atoms, the resultant compound weighs more. If you were able to do this activity under perfect conditions, your clump of steel wool would weigh 30% more than its original mass.

$Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$

Balanced equation: $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

Touching the 9-volt battery to the steel wool will make the metal strands glow red-hot and melt. This is because the resistance of the narrow strands or wires is too great for the flow of electrons. The internal friction caused by this electrical overload causes the steel wool to heat up.

References:
http://www.exo.net/~emuller/activities/Fast_Rusting.doc.pdf
http://www.scienceonstage.ie/resources/SOS_steel_wool.pdf

Title: The Milky Way – using milk to demonstrate the Tyndall effect

Introduction: This demonstration is a nice introduction to the scattering of light. It also includes many links to other physics concepts including wavelength of light. Ask the pupils to guess why the sky is red in colour as the sun sets.

Topic area: Light

Apparatus:
- a transparent container with flat parallel sides (a 10-liter [2½-gallon] aquarium is ideal)
- A flashlight
- 250 mL of milk

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Procedure:

1. Set the container on a table where you can view it from all sides. Fill it ¾ full with water.
2. Light the flashlight and hold it against the side of the container so its beam shines through the water. Try to see the beam as it shines through the water.
3. Add about 60 mL of milk to the water and stir it.
4. Hold the flashlight to the side of the container, as before. [Notice that the beam of light is now easily visible as it passes through the water]
5. Add another 60 mL of milk to the water and stir it. [Now the beam of light looks even bluer from the side and more yellow, perhaps even orange, from the end.]
6. Add the rest of the milk to the water and stir the mixture. [Now the beam looks even bluer, and from the end, it looks quite orange. Furthermore, the beam seems to spread more now than it did before; it is not quite as narrow.]

Questions:

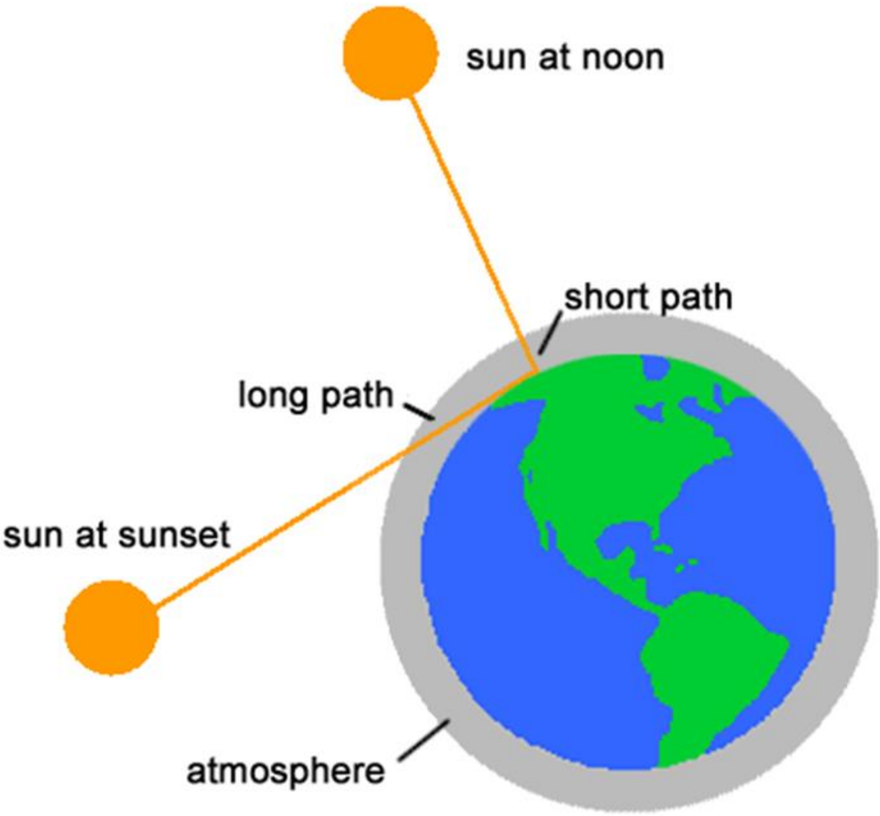
- Why do you think the milk helps us see the beam of light travelling through the container?
- Describe the colour of the beam of light as it passes through the milk solution. Why do you think this is?
- What causes the beam of light from the flashlight to look blue from the side and orange when viewed head on?
- What does this experiment have to do with blue sky and orange sunsets?
- What causes the sun to appear deep orange or even red at sunset or sunrise?

Notes/tips:

Light usually travels in straight lines, unless it encounters the edges of some material. When the beam of a flashlight travels through air, we cannot see the beam from the side because the air is uniform, and the light from the flashlight travels in a straight line. The same is true when the beam travels through water, as in this experiment. The water is uniform, and the beam travels in a straight line. However, if there should be some dust in the air or water, then we can catch a glimpse of the beam where the light is scattered by the edges of the dust particles.
Milk contains many tiny particles of protein and fat suspended in water. These particles scatter the light and make the beam of the flashlight visible from the side. Different colours of light are scattered by different amounts. Blue light is scattered much more than orange or red light. Because we see the scattered light from the side of the beam, and blue light is scattered more, the beam appears blue from the side. Because the orange and red light is scattered less, more orange and red light travels in a straight line from the flashlight. When you look directly into the beam of the flashlight, it looks orange or red.
light you see when you look at the sky is sunlight that is scattered by particles of dust in the atmosphere. If there were no scattering, and all of the light travelled straight from the sun to the earth, the sky would look dark as it does at night. The sunlight is scattered by the dust particles in the same way as the light from the flashlight is scattered by particles in milk in this experiment.

Looking at the sky is like looking at the flashlight beam from the side: you're looking at scattered light that is blue. When you look at the setting sun, it's like looking directly into the beam from the flashlight: you're seeing the light that isn't scattered, namely orange and red.

At sunset or sunrise, the sunlight we observe has travelled a longer path through the atmosphere than the sunlight we see at noon. Therefore, there is more scattering, and nearly all of the light direct from the sun is red.



Skittles Scientific Method

Level: Junior Cycle to introduce the scientific method
Topic: n/a

Introduction question: Is there a dominant colour in a bag of skittles?

In this activity we will be reviewing the scientific method while actually using it! We will be working through the scientific method step by step, using skittles. The purpose of the experiment will be to figure out if one colour skittle is more dominant (occurs the most) in a bag of skittles.

1. Define the problem
2. Collect information
3. Form a hypothesis
4. Test your hypothesis
5. Observe

Colour of Skittle	Number at table (your group)	Total in class

6. Draw a conclusion

Alternative Scientific Method Scenarios

Give the pupils the following scenario and then ask them to answer the following questions based on the experiment:

Susie wondered if the height of a hole punched in the side of a quart-sized milk carton would affect how far from the container a liquid would spurt when the carton was full of the liquid.

- She used 4 identical cartons and punched the same size hole in each.
- The hole was placed at a different height on one side of each of the containers.
- The height of the holes varied in increments of 5 cm, ranging from 5 cm to 20 cm from the base of the carton.
- She covered the holes and filled the carton to a height of 25 cm with water.

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1. What is the independent variable Susie is testing in this experiment ___________________
2. What would be a good hypothesis for Susie to make at the beginning of this experiment?
    a. 5 cm will work best
    b. All the holes will squirt out water the same distance.
    c. If the holes are higher, then the water will spurt out the farthest.

Notes/tips:

"I keep six honest serving men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who."

Rudyard Kipling

Scientific method you want to develop in your pupils:

- Define the Problem: Ask a Question you want to solve
- Do Background Research: List the Materials you will need.
- Construct a Hypothesis: " If [I do this] __________, then this_______ might/will happen"
- Test Your Hypothesis by Doing an Experiment:
    - Write a Procedure
    - Perform the Experiment
- Observations: Collect and Record Data, Analyse Your Data
- Draw a Conclusion and Communicate Your Results

Smartie Chromatography

Introduction:

Encourage the pupils to make small intense spots on the paper and to avoid smudging.

Some dyes will be found to produce only one spot further up the paper, whilst others will have spread into two or more areas of colour.

If appropriate pupils should be told that the relative distance travelled by each "spot" depends not only on its solubility in water but also on its attraction for the cellulose components of the paper.

It should be emphasised that each "spot" may well still be a mixture of dyes, and that a more effective separation might occur:

- if the distance travelled by the spots is increased, e.g. by using a taller cylinder in a taller beaker.
- with a different solvent, other than water
- with a different stationary phase (e.g. silica plates).

Apparatus:

- Several sheets of filter paper (15 – 20 cm in diameter)
- Tube of Smarties (various colours)
- Small cup of water
- Plate or flat dish

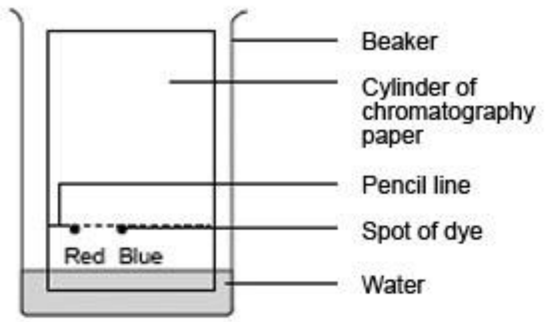
Procedure 1:

1. Place the filter paper on the plate or flat surface, making sure that the plate is fully dry. (Two or three sheets of filter paper can be placed on top of each other to give a number of replicas of the result)
2. Dip the Smartie in water and then place it on the centre of the filter paper. Then slowly allow drops of water to fall on the Smartie until a circle of water surrounds it (about 5cm diameter)
3. Leave aside in a safe place, occasionally allowing some drop to fall on the Smartie.
4. Separate out the sheets of filter paper and see the rings of colours that have emerged.

Alternative Procedure (to introduce idea of mobile phase)

1. Place the piece of chromatography paper on a clean flat surface, with the longer side horizontal and draw a horizontal line in pencil (not biro) about 1.5 cm from the base of the paper.
2. Use the dampened paint brush to remove the colour from one of the M&M'S® and paint this colour on the line about 2 cm from one end. Small spots are best.
3. Clean the brush in fresh running water and paint the colour of another M&M® on the line about 2 cm from the first spot.
4. Repeat this until all the colours are on the paper or until you have reached the other end.
5. Use a pencil (not a biro) to write the name of the colour next to the corresponding spot.
6. Roll the paper into a cylinder and hold this in place with the paper clips. Try to avoid any overlapping of the paper when you make the cylinder.

7. Put water into the beaker up to depth of about 1 cm.
8. Lower the paper cylinder into the beaker of water thus allowing the water to rise up the paper. Ensure that the water is below the level of the spots. Try to avoid moving the paper cylinder about once it is in position.
9. When the water approaches the top of the paper cylinder remove it from the water. Mark with a pencil the level of the water at the top of the filter paper.



10. Allow the paper cylinder to dry, perhaps by using a hairdryer if available or by clamping it and leaving it to dry overnight.
11. Unravel the paper cylinder and examine it carefully.

Results & Conclusions:
The colours of the Smartie have spread out along the filter paper, dividing into their composite colours. The hydrophilic molecules move further along the filter paper.
Tips:
- You can also use water soluble felt tip pens for this experiment.
- When black felt tip pens are from different manufacturers, you will find that they have different compositions – a nice little introduction into forensics etc.
- The chromatograph can be used to identify the ink and the pen.

Questions:
1. Why do you think some dyes separate out into different colours whilst others do not?
2. Why do you think some colours move further up the paper than others?
3. Can you think of any way of improving the separation between the different spots?
4. Look on the side of a Smarties® packet for a list of the coloured dyes used. Try to identify which dyes correspond to the spots on the chromatogram.

Ziploc chemistry

Introduction:
Alka-Seltzer is a combination of aspirin (acetylsalicylic acid), sodium hydrogencarbonate ($NaHCO_3$), and citric acid ($H_3C_6H_8O_7$), designed to treat pain and simultaneously neutralize excess stomach acid (the "Alka" being derived from the word "alkali").

Level: Junior and Senior cycle chemistry

Topics: Pressure, acid-base reactions, rate of reactions

Apparatus:
- Alka-seltzer
- Water
- Zip-loc bags/latex gloves/balloons
- 30mL red cabbage juice (indicator)
- Water ~ 30mLs per set-up

Procedure:
1. Place an alka-seltzer tablet into a Ziploc bag
2. Place a film canister full of water into the zip-loc bag
3. Carefully close the bag and allow the water to spill from the film canister onto the alka-seltzer
4. What happens?
5. Repeat this with the red cabbage juice/indicator
6. What happens? Are there any colour changes?

Questions:
- How could we speed this reaction up?
- What effect would changing the temperature of the water have?
- Classify each of these changes as chemical or physical. Use your observations to help you make your decisions.
- What did the indicator tell you about the observed reaction?
- What gas is being produced? How could you test this?
- Write an equation for any chemical changes that have taken place.
- Allow the pupils to suggest different ideas for altering the reaction, such as:

Particle size (2 halves of an alka-seltzer versus in quarters, versus crushing the whole tablet)
Temperature of water
Substance producing gas – vinegar and $NaHCO_3$
For senior chemistry classes this can become much more complex than just acknowledging that it is an acid base reaction and that CO_2 is produced. You can extend this to look at molarity, balancing equations, stoichiometry, and conservation of mass (volume and mass of bag before the reaction and after the reaction).

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Notes/tips:

The effervescent tablets are dissolved in a glass of water. As the tablets dissolve, the base (sodium hygrogencarbonate) and the acid (citric acid) react vigorously producing carbon dioxide gas (hence the "Seltzer").

This CO_2 builds up within the Ziploc bag, until there is no more space in the container for the gas, and at this point the pressure changes and the bag may explode. The indicator should show that the reaction occurring in the third bag is acidic. Cabbage juice will turn from red to blue in colour.

The gas that is produced is carbon dioxide (CO_2).

$$H_3C_6H_8O_{7(aq)} + 3NaHCO_{3(aq)} \rightarrow 3H_2O_{(l)} + 3CO_{2(g)} + Na_3C_6H_5O_{7(aq)}$$

Citric acid   Sodium hydrogencarbonate   water   carbon dioxide   sodium citrate

This illustrates a simple acid-base reaction which does not occur until water is added and the acid and base are brought into contact in solution.

These experiments can be done in a variety of different ways using various controls, or investigating things such as particle size (whole tablet versus crushed tablet), temperature (warm water versus hot water), and substance (vinegar CH_3COOH and baking soda $NaHCO_3$).

A burning splint would show that the gas extinguishes the flame. Some fire extinguishers use carbon dioxide for this reason.

About SSPC

The Synthesis and Solid State Pharmaceutical Centre (SSPC), a **Global Hub of Pharmaceutical Process Innovation and Advanced Manufacturing**, funded by Science Foundation Ireland (€30m) and industry (€10m), is a unique collaboration between 22 industry partners, 9 research performing organisations and12 international academic collaborators.

The SSPC transcends company and academic boundaries and is the **largest research collaboration in Ireland**, and one of the **largest globally**, within the pharmaceutical area. The role of the SSPC is to link experienced scientists and engineers in academia and the pharmaceutical industry, to **address critical research challenges**.

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