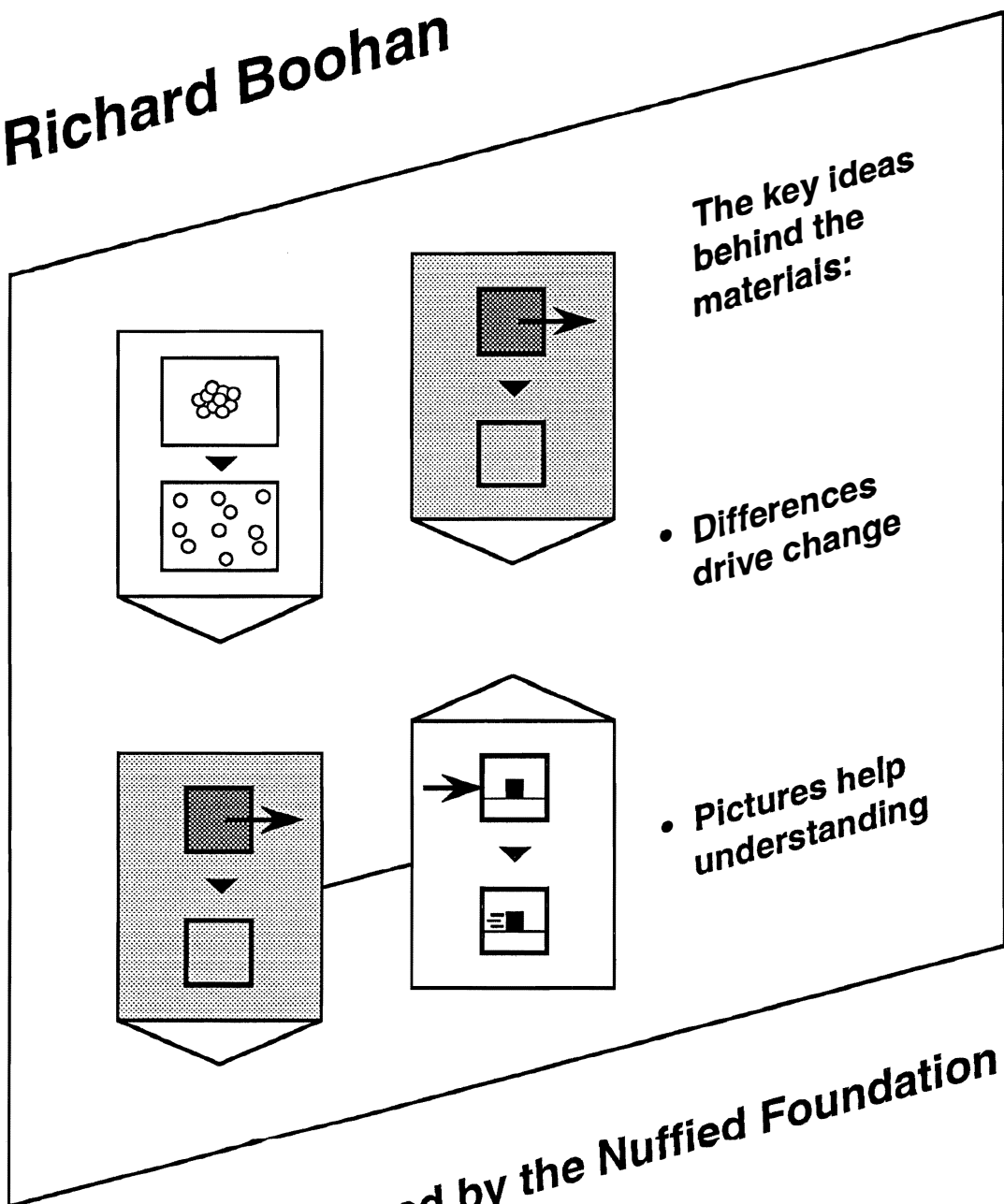


# ENERGY AND CHANGE

## Support materials

Richard Boohan



A project sponsored by the Nuffield Foundation

## Acknowledgements

I should like to thank the many teachers and others who have helped during the project and offered very valuable advice and insights. Particular thanks should go to Jon Ogborn who co-directed the project, to Charlotte René for her support during the school development work, and to Fani Stylianidou for carrying out a major part of the evaluation. I should also like to thank Janet Maxwell for the illustrations used in the activities and Mike Drew for his assistance in producing the molecular pictures. I am grateful to all of those who have assisted in the school trials and given helpful feedback, including Karen Burrows, Deidre Canavan, Hester Greenstock, Jo Lang, Louise McCulloch, Mac McKenzie, Angela Mngaza, Cath Mitchinson, Gary Phillips, Inder Sharma, Keith Strachan, Keith Wiseman and to the pupils of South Camden Community School, Christ Church Secondary School, Lancaster Girls' Grammar School, Maria Fidelis Convent School, North London Collegiate School, Parliament Hill School, St Richard of Chichester School and William Ellis School.

The approach and the materials were developed during the project 'Teaching about why things change' (1992-1995). We gratefully acknowledge the support of the Nuffield Foundation who funded this project.

*The material in this pack may be reproduced without infringing copyright provided the reproduction is for use by teachers or students within the purchasing organisation. The permission of the publishers must be obtained before reproducing the material for any other purpose.*

*This pack provides a set of support materials for the publication 'Energy and change' by Richard Boohan and Jon Ogborn, which is published by the Association for Science Education, College Lane, Hatfield, Herts AL10 9AA.*

First published 1996  
University of London Institute of Education,  
20 Bedford Way,  
London WC1H 0AL.

© 1996 University of London Institute of Education

ISBN 0 85473 463 5

# **Contents**

## **Introduction and INSET materials**

<b>Theme A</b>	<b>Mixing and 'unmixing'</b>
<b>Theme B</b>	<b>Hot and cold</b>
<b>Theme C</b>	<b>Solids, liquids, gases</b>
<b>Theme D</b>	<b>Living things</b>
<b>Theme E</b>	<b>Energy from hot to cold</b>
<b>Theme F</b>	<b>Particles and change</b>
<b>Theme G</b>	<b>Up and down in complexity</b>
<b>Theme H</b>	<b>Fuels and food</b>
<b>Theme I</b>	<b>How much energy?</b>
<b>Theme J</b>	<b>Flows of matter and energy</b>

# **Energy and change**

**A project funded by the Nuffield Foundation**

## **Introduction and INSET materials**

## Introduction

Increasing emphasis in science education has been placed on making fundamental and everyday issues, from pollution to global warming, accessible to a wider range of pupils. The National Curriculum contains many such examples. Essentially, pupils are expected to make sense of *processes of change*. Despite being of central importance to science, teachers and textbooks lack a way of explaining change that makes sense for this purpose. Essentially, what is needed are simple, everyday and coherent ways of talking about thermodynamic ideas which are accessible to school pupils.

'Energy and change' is a set of materials outlining a new approach which starts from commonsense ways of explaining why things happen. In developing these materials we have had three important criteria in mind, namely, that the approach should be *intelligible* to pupils, *useful* to teachers and scientifically *consistent*. So the approach is useful to *all* pupils in helping them to understand the world, while those who later specialise in science can build on the ideas in a natural way.

Our central idea is that change is caused by *differences*, for example, differences in temperature or in concentration. To make these ideas intelligible to pupils we have developed a range of *abstract pictures*, examples of which can be found throughout this pack. Some of these pictures may appear somewhat daunting at first, but we have found that pupils are quickly able to become familiar with them, and are stimulated into a good level of discussion.

It is all too easy to offer advice about ways *not* to talk about energy and change, but this only leads to a feeling of paralysis. What we are hoping to do is to offer to teachers a new and constructive way of talking about these ideas with pupils.

### The materials

- *Energy and change: Introducing a new approach*
- *Energy and change: Activities in the classroom*
- *Energy and change: Background stories for teachers*

The ideas behind the approach are introduced in these booklets which are published separately by the Association for Science Education.

- *Energy and change: Support materials*

This pack provides support for using the ideas in the classroom, and consists of ten Themes, each containing about eight pupil activities with accompanying teachers' notes. Earlier themes are aimed at Key Stage 3, while later themes have material suitable for Key Stage 4. In addition, this pack contains INSET materials to support the introduction of the approach to teachers.

## About the approach

In these materials, we address the fundamental question 'why do things change?'. Our aim is to provide a coherent framework within which many important scientific concepts can be developed.

The key idea in our approach is to pay attention to the differences which drive change. For example, air in a balloon tends to leak out because of a *pressure difference*. Pollution spreads out and mixes with the air in the atmosphere because of a *concentration difference*. Hot coffee cools because of a *temperature difference*. These differences tend to disappear because matter or energy or both become more spread out. This essentially simple idea is also powerful. We can use it to make sense of a wide range of phenomena from a hot cup of tea cooling, to the direction of chemical reactions and even to the complexity of life.

Though energy is an important part of this story, teaching about why things change is not something which can be confined to a topic called 'energy'. The activities in this pack relate to many areas of the science curriculum and can be developed across the whole age range. Here are a few examples of areas in which these ideas could be used:

dissolving	respiration
pollution	energy efficiency
evaporation	weathering of buildings and rocks
separating and purifying mixtures	metal extraction and corrosion
chemical change in everyday materials	microbes and decay
meaning of hot and cold	cost of energy used by domestic appliances
energy transfers	cycling of materials in ecosystems
weather and the water cycle	energy transfers in ecosystems
burning fuel and the release of energy	the atmosphere
energy resources	maintaining the internal environment of plants and animals
photosynthesis	enzymes and the synthesis of biological molecules

In understanding such a wide range of different kinds of processes, we need to help pupils to see that many changes are essentially similar, even though, superficially, they appear to be very different. Thus, dissolving is rather like evaporation in that particles spread out, though there are also important differences. Respiration is in some ways like burning. A human being can be understood as being a 'steady state system' rather like a central heating system. Making such abstractions is not easy, and it is for this reason that we have developed a range of pictorial representations which help pupils to do this.

The scientific ideas behind the approach, and the way this story can be told in abstract pictures, are discussed in the separate booklet 'Energy and change: Introducing a new approach'.

## **The Themes**

This pack is divided into ten Themes, each containing about eight pupil activities with accompanying teachers' notes. Earlier themes are aimed at Key Stage 3, while later themes have material suitable for Key Stage 4.

### **Theme A    Mixing and 'unmixing'**

Simple changes to substances, e.g. dissolving and mixing, purifying and separating mixtures.

### **Theme B    Hot and cold**

Temperatures differences, warming and cooling, ways of making things hot, introducing energy.

### **Theme C    Solids, liquids, gases**

More changes to substances, e.g. smells and air pollution, evaporation and other changes of state.

### **Theme D    Living things**

Processes of life, e.g. how living things obtain and get rid of substances from their surroundings.

### **Theme E    Energy from hot to cold**

Pictures of temperature differences and energy flow, e.g. Sun/Earth, human body, insulation, burning.

### **Theme F    Particles and change**

Pictures of physical and chemical changes, e.g. melting, combustion, corrosion, metal extraction.

### **Theme G    Up and down in complexity**

Building up and breaking down molecules, e.g. fermentation, photosynthesis, decay, polymerisation.

### **Theme H    Fuels and food**

Storing, transferring, releasing energy, e.g. engines, fuels, electrical cells, photosynthesis, respiration.

### **Theme I    How much energy?**

Quantitative activities on energy, e.g. simple 'ladders' of energy, efficiency, costs of domestic fuels.

### **Theme J    Flows of matter and energy**

Keeping things in balance, e.g. weather, organisms, food chains, carbon cycle, ecosystems.

An overview of the way in which the ideas of the approach can be developed in the curriculum can be found in the separate booklet 'Energy and change: Activities in the classroom'.

## Using the materials for INSET

Though activities can be introduced in an *ad hoc* basis by individual teachers into existing schemes of work, the approach will clearly be of more value if it is adopted in a more co-ordinated way by a whole science department, so delivery of INSET is an issue which needs to be addressed. These notes outline how the materials in this pack and in the three booklets from the ASE may be used for INSET. The sections are:

- 1 Planning a session
- 2 Background to the approach
- 3 Pupil activities
- 4 Pupil discussion
- 5 Background stories

### 1 Planning a session

Our experience suggests that in introducing this approach to teachers it is important to illustrate how it can form the basis of simple classroom activities, while at the same time indicating what the essential features of the approach are and where it is leading. Thus, included in this section are overhead transparency masters to introduce the abstract picture language, suggestions about a suitable selection of pupil activities and some examples of pupils discussing these activities. The way in which the materials have been structured in the booklets 'Introducing a new approach' and 'Activities in the classroom' have also been designed to support this. The largest sections in each of these booklets ('Telling the story in pictures' and 'Ideas and activities') follow a similar progression of ideas and use the same headings, thus making it easier to relate the two.

The selection of material which could be used during INSET depends of course on the time available. We have worked with a number of different groups of teachers, over periods ranging from a single session to a whole day, and below are examples of the kind of work which we have done with these groups.

#### Example 1 - A single session

- Brief overview of the approach based on the Preface and Introduction from the booklet 'Introducing a new approach'.
- Looking at some examples of early activities which do not use abstract pictures (for example, A1 and C5).
- Introducing the abstract pictures using overhead transparencies INSET/1 - INSET/4 (see section 2 'Background to the approach' below).
- Small group work on an early pupil activity which uses abstract pictures, for example, E6 (see section 3 'Pupil activities' below).
- Small group work on pupil discussion about this activity using INSET/14 (see section 4 'Pupil discussion' below).



- Looking at later pupil activities which require some experience of using the abstract pictures, for example, H1 and H5 (see section 3 'Pupil activities' below).
- Discussion of how the fundamental set of pictures (INSET/13) can be used to represent various different kinds of changes (see the booklet 'Introducing a new approach' pp. 39-42).
- Evaluation of the approach - how may it be used in our existing curriculum?

## **Example 2 - A whole day**

### **PART 1**

- Brief overview of the approach based on the Preface and Introduction from the booklet 'Introducing a new approach'.
- Looking at some examples of early activities which do not use abstract pictures (for example, A1, B2 and C5).
- Introducing the abstract pictures using overhead transparencies INSET/1 - INSET/5 (see section 2 'Background to the approach' below).
- Small group work on early pupil activities which use abstract pictures, for example, A2, E6 and F2 (see section 3 'Pupil activities' below).
- Small group work on pupil discussion about one of these activities, using INSET/14 or INSET/15 (see section 4 'Pupil discussion' below).

### **PART 2**

- Continuing the introduction to the abstract pictures using INSET/6 - INSET/10 (see section 2 'Background to the approach' below).
- Small group work on later pupil activities which require some experience of using the abstract pictures, for example, H1, H5 and J5 (see section 3 'Pupil activities' below).
- Small group work on pupil discussion about one of these activities, using INSET/16 or INSET/17 (see section 4 'Pupil discussion' below).

### **PART 3**

- Discussion of how the fundamental set of pictures (INSET/13) can be used to represent various different kinds of changes (see the booklet 'Introducing a new approach' pp. 39-42).
- Small group work on the 'Background stories' and how the fundamental set of pictures can help in understanding (see section 5 'Background stories').
- Evaluation of the approach - how may it be used in our existing curriculum?

## 2 Background to the approach

The way in which the picture language can be used to understand the nature of change is described in the booklet 'Introducing a new approach'. The set of figures used to tell the story in the booklet have been reproduced in this section as A4 sheets which can be used to prepare overhead transparencies (INSET/1 - INSET/13). Some brief notes are given below; more details are given in the booklet.

### INSET/1 - Backwards and forwards

Why do things change? Fundamental to this question is why things tend to happen in *one direction* and *not the other*. The story developed in this approach is based on the idea that *differences drive change*. Differences tend to disappear because matter or energy or both become *more spread out*.

### INSET/2 - Spreading and mixing of matter

Randomly-moving particles tend to spread out from where they are concentrated to where they are less concentrated. With more than one kind of particle, they tend to mix until they are both spread evenly. These are changes that 'just happens by themselves'. Changes may be driven by differences in concentration or pressure which tend to disappear.

### INSET/3 - Energy flows and temperature differences

We can think of temperature as a measure of the *concentration of energy* - the greater the concentration of energy, the higher the temperature. As with matter, energy tends to go from where it is concentrated to where it is less concentrated (i.e. from hot to cold). This is a change that 'just happens by itself'. Changes may be driven by differences in temperature which tend to disappear.

### INSET/4 - Differences can create differences

Differences tend to disappear. But it is also possible to *create* differences, even though they do not appear from nowhere. You need a *difference* to create a *difference*. So, while changes in which differences appear do not 'just happen by themselves', this does not mean that they can never happen. Changes may be coupled together so that a change which 'just happens' drives a change which does not.

### INSET/5 - Moving things

In an idealised frictionless Universe, moving objects would always keep moving at the same speed. In the real Universe, things that move have a tendency to slow down. As a moving object slows down, the particles vibrate more and it becomes warmer, and energy spreads out as

it flows from the warmer object out into the surroundings. Such a change which 'just happens' may be used to drive some other change.

### **INSET/6 - Springy things**

We can store energy by creating a *potential energy difference* which can be used to drive other changes. When two ends of a spring are pulled apart, energy is stored; when it is released, the energy escapes and spreads out. A stretched spring could stay the same forever, but once released it 'just happens by itself'. This does not just apply to mechanical springs - we can also think of gravitational, electrostatic or magnetic 'springs'.

### **INSET/7 - Kinds of changes involving particles**

Because particles may move around randomly, differences in concentration tend to disappear. These differences drive change. But since particles are *attracted* to each other and tend to stick together, there is another kind of difference which can drive change - differences in *structure* or *complexity*. Changes in structure or complexity are always accompanied by *energy changes* as bonds are made or broken.

### **INSET/8 - Storing differences in 'chemical springs'**

Many simple changes occur because *either* matter *or* energy spreads out. In chemical reactions, however, we need to pay attention to what is happening both to matter *and* to energy. A spontaneous chemical change happens because matter or energy or both spread out. We can think of energy stored in a chemical system as a 'stretched chemical spring'. The idea that energy is stored when particles are pulled apart is fundamental to understanding chemical change.

### **INSET/9 - Kinds of chemical change**

Some chemical reactions are driven by the spreading of both energy and matter, while others do not 'just happen by themselves', because neither matter nor energy spreads out. Many chemical reactions, however, involve two competing tendencies. Matter may become more concentrated at the expense of energy spreading out, or vice versa.

### **INSET/10 - Steady states**

There is more than one way of staying the same. Things may stay the same because there are no differences to drive the change. Another reason is because the difference is maintained by 'walling it in'. But in many cases, *a difference is maintained by using a difference to keep it going*. Such steady states may be maintained by flows of energy or matter or both, which, like other non-spontaneous changes, need to be driven by a change which 'just happens'.

## **INSET/11 - Making measurements**

Energy measurements help give answers to two different kinds of question: about which way a change can go, and about how big a change can be. The language of differences driving change can help, because we can ask two different questions: what difference could drive a change from A to B, and how much energy has to be transferred to get from A to B?

## **INSET/12 - Entropy and potential difference**

It is possible to think of the pictures we use as terms to be added up in a calculation, either of a total potential difference or (equivalently) of entropy changes. The pictures are drawn to go down potential hills for spontaneous change. If thought of as representing entropy changes, the entropy must *increase* to go downhill. The pictures show two equivalent ways understanding equilibrium, in the simple case of water and ice.

## **INSET/13 - Fundamental kinds of change**

A number of different pictures have been introduced representing a wide variety of changes. These are summarised here, with pictures representing fundamental kinds of changes. On the left, are changes which 'just happen', and on the right, changes which do not 'just happen'. Using this restricted set of pictures is helpful in seeing the essential features of different kinds of phenomena, making clear the nature of the coupling between spontaneous and non-spontaneous changes.

## **3 Pupil activities**

We have found it important, for at least a few of the activities, that teachers should carry out the tasks as the pupils do them - cutting up slips of paper, making matches, discussing choices, and so on - in order to get an impression of the kind of demands made by this work. A selection of tasks providing a good introduction is shown below. They are of different levels of difficulty, requiring different amounts of background work from other activities in this pack, and cover a range of concepts.

### **Activity A2 Pictures of mixing**

This simple introductory activity illustrates a typical task for pupils in which they make matches of situations to abstract pictures. The situations are concerned with changes to matter, and the pictures represent matter as continuous. It is not necessary for pupils to have done any previous activity from the materials.

### **Activity E6 Examples of insulation**

This activity is concerned with energy flows from hot to cold. Later activities build on this convention as a way of understanding other kinds of energy flow. It requires some work from

previous activities to be done to introduce the conventions, though only a modest amount of time is necessary.

### **Activity F5 Everyday changes**

This activity is concerned with changes to matter. The abstract pictures represent matter as consisting of particles. It requires some work from previous activities to be done to introduce the conventions, though only a modest amount of time is necessary.

### **Activity H1 Things that just happen and things that don't**

This activity introduces the idea that some changes happen spontaneously, and they may be coupled to drive changes which are not spontaneous. It assumes rather more experience of the abstract pictures.

### **Activity H5 Fuels and food**

This builds on a wide range of different kinds of ideas that have been introduced in previous activities, in particular, the idea that we can think of energy being stored in a chemical system as a 'chemical spring' and the idea that changes can be coupled to each other.

### **Activity J5 Convection currents**

This is an example of a rather more demanding example of the use of abstract pictures to help in understanding a series of situations, and assumes the most background experience from previous activities.

## **4 Pupil discussion**

Teachers who use the abstract pictures are often surprised that pupils are able to understand and discuss them more easily than they had anticipated. At an INSET in which there are teachers who have not used the materials with pupils, it is useful to have examples of pupils' work from teachers who have. Examples of pupils' discussion are also useful, and four sheets are included in this pack (INSET/14 - INSET/17). The extracts from pupils' discussion shown here are selected to be typical of children of modest ability. A commentary on these extracts can be found on pages 49-56 of the booklet 'Activities in the classroom'.

### **INSET/14 - Examples of pupil discussion: Insulation (Activity E6)**

Children often tend to see insulation as something which actively keeps or makes things hot, and think of 'cold' as well as 'heat' as being something that flows from one place to another. The abstract pictures in this activity aim to encourage children to start thinking of insulation as a barrier to energy flow from a higher to a lower temperature. The extracts here are from Y8 groups.

### **INSET/15 - Examples of pupil discussion: Everyday changes (Activity F5)**

This activity introduces pupils to the use of particle pictures to represent physical and chemical changes, and encourages them to think about the nature of these changes, such as whether particles are staying the same or new particles are forming and whether substances are changing state. The extracts are from Y8 and Y9 groups.

### **INSET/16 - Examples of pupil discussion: Things that 'just happen' and things that don't (Activity H1)**

This activity introduces pupils to the fundamental notion that spontaneous changes can drive non-spontaneous changes. The situations in the activity are chosen to be as straightforward as possible, in order for pupils to be able to focus on understanding the conventions. Groups of Y9 pupils, over a month after they had done this activity and other activities using similar conventions, were shown some examples of these pictures and asked to explain in their own words what they understood by them.

### **INSET/17 - Examples of pupil discussion: Fuels and food (Activity H5)**

Perhaps the most difficult idea in all of the activities is the notion of a 'chemical spring'. The extracts below are from discussions of Y8 and Y9 pupils doing an activity in which they need to distinguish energy released from hot objects and from 'chemical springs' as well as understanding the idea of changes which 'just happen' and those that do not. All of the relevant work on using the abstract pictures had been done in only a few weeks prior to the activity.

## **5 Background stories**

For teachers to gain a deeper understanding than that aimed at in the pupil activities, the booklet 'Background stories for teachers' provides relevant material. In a workshop context, this may be used as a stimulus to discussion, by considering matches from the fundamental set of abstract pictures which are relevant to the changes described. The set of pictures should be reproduced and cut up, and the stories should be reproduced omitting the abstract pictures which are included in the booklet. A suitable range from which background stories could be selected is shown below.

**Frost and Flood** (melting and freezing pp. 12-13)

**Life Burns its Fingers** (the role of oxygen in living things and combustion pp. 18-19)

**Living off Sunlight** (photosynthesis pp. 20-21)

**Travel by Fire** (using temperature differences to drive an engine pp. 28-29)

**Think Electric!** (transmission of signals in nerve cells pp. 38-39)

## Backwards and forwards

**1A**  
a spontaneous or  
'downhill' change

a bottle  
falls off a  
shelf and  
breaks

a broken  
bottle  
'mends  
itself' and  
jumps onto  
a shelf

**1B**  
a non-spontaneous or  
'uphill' change

## Differences drive change and tend to disappear

**1C**  
matter spreads out  
due to a  
concentration  
difference

pollution  
spreads in  
the air

hot tea  
cools

**1D**  
energy spreads out  
due to a  
temperature  
difference

## It takes a difference to make a difference

**1E**  
a spontaneous  
change ...

petrol is  
burnt in a  
car engine

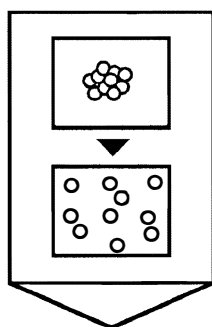
the car  
starts to  
move

... drives a  
non-spontaneous  
change

*Everything tends to go downhill.*

**Spreading and mixing of matter**

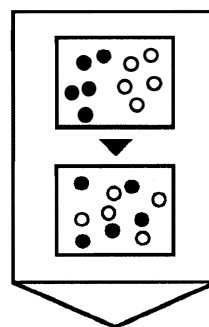
Changes which 'just happen by themselves'

**2A**

Before

After

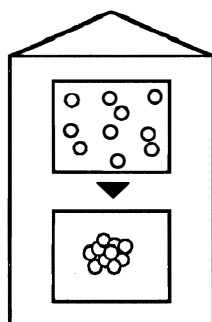
particles spreading out

**2B**

particles mixing

**Bunching together and 'unmixing'**

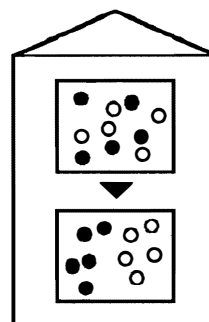
Changes which do not 'just happen by themselves'

**2C**

Before

After

particles bunching together

**2D**

particles 'unmixing'

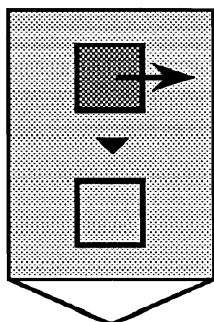
*Matter tends to go from where there's a lot to where there's not.*



# Energy flowing down a temperature gradient (from 'hot to cold')

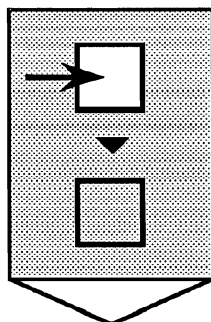
Changes which 'just happen by themselves'

3A



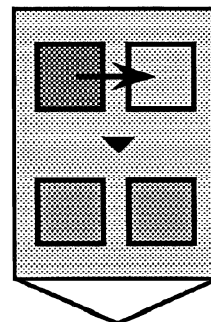
something cools to the temperature of the surroundings

3B



something warms to the temperature of the surroundings

3C

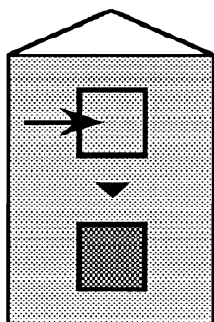


the temperatures of two things become the same

# Energy flowing up a temperature gradient (from 'cold to hot')

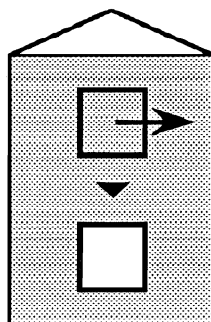
Changes which do not 'just happen by themselves'

3D



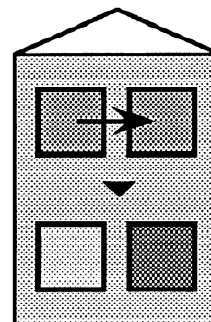
something becomes warmer than the temperature of the surroundings

3E



something becomes cooler than the temperature of the surroundings

3F

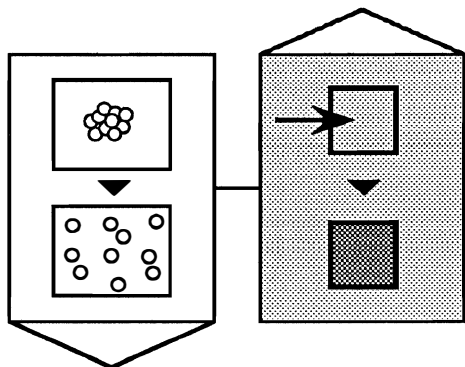


the temperatures of two things become different

*Energy tends to go from where it's hot to where it's not.*

### Concentration differences can drive changes

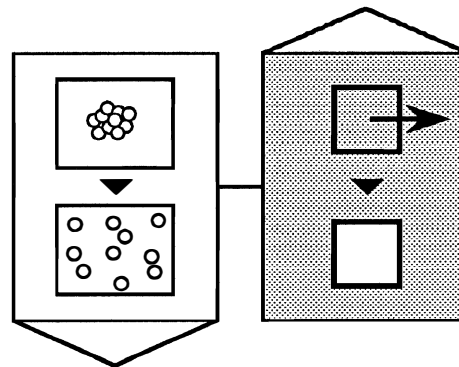
4A



concentration  
difference  
disappears

temperature  
difference  
created

4B

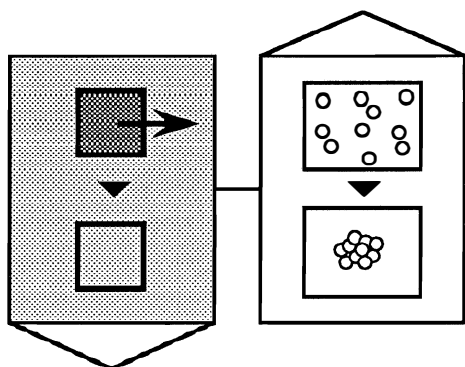


concentration  
difference  
disappears

temperature  
difference  
created

### Temperature differences can drive changes

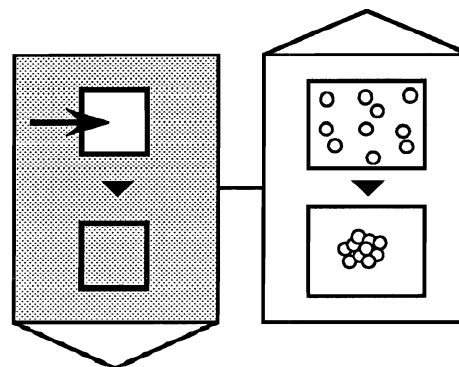
4C



temperature  
difference  
disappears

concentration  
difference  
created

4D



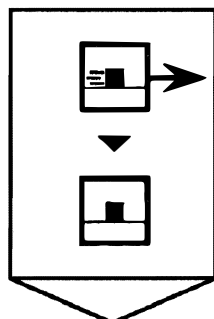
temperature  
difference  
disappears

concentration  
difference  
created

*Some changes will just happen and others won't.  
Those that do just happen can drive those that don't.*

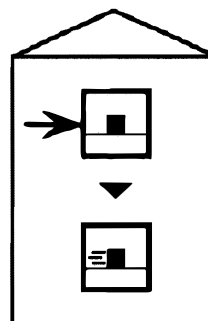
# Slowing down, speeding up and staying the same

5A



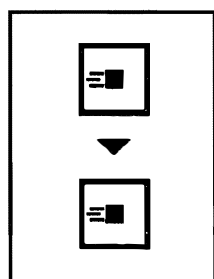
slowing  
down

5B



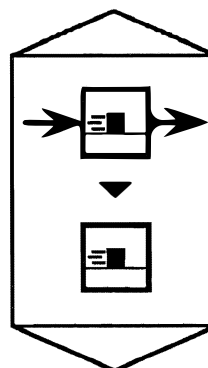
speeding  
up

5C



moving  
without  
friction

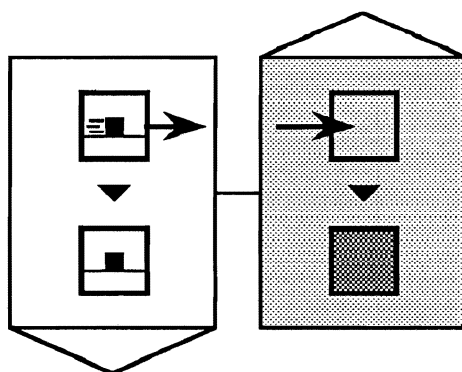
5D



being  
kept  
moving

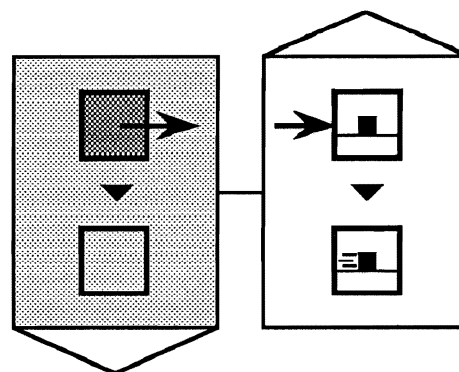
## Coupled changes

5E



creating a temperature difference

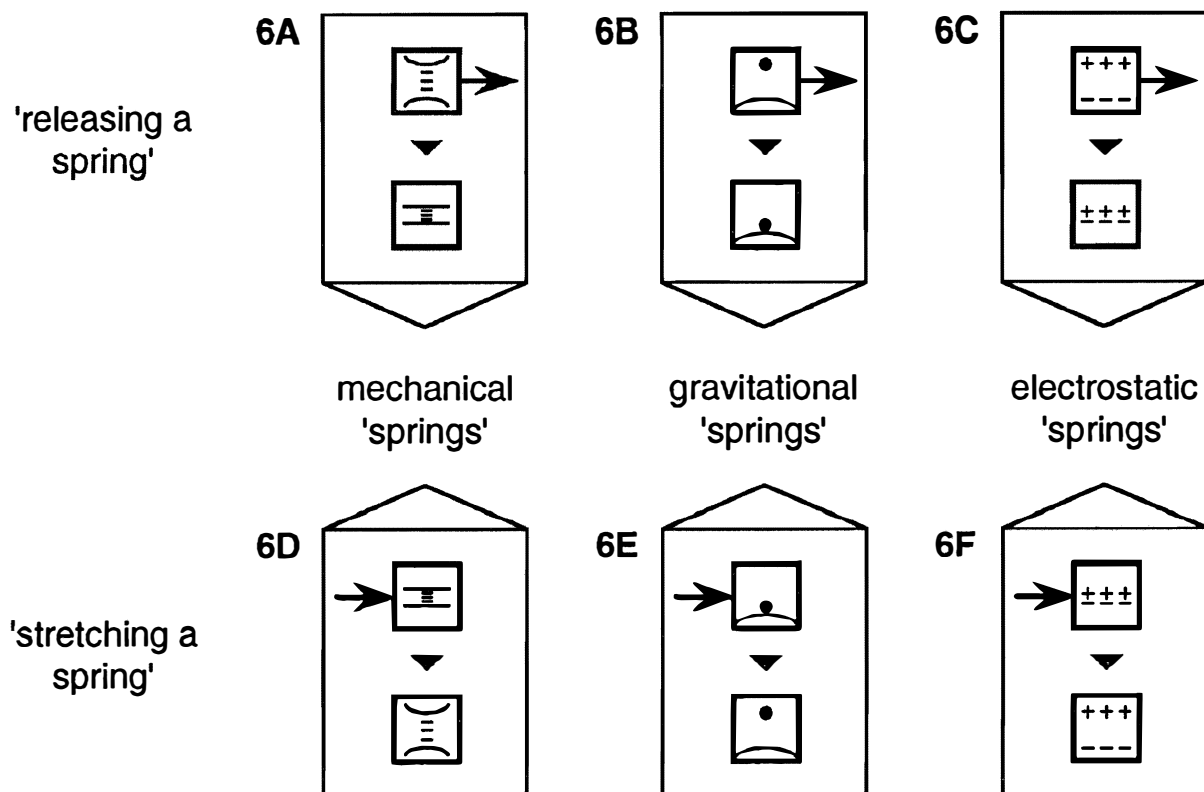
5E



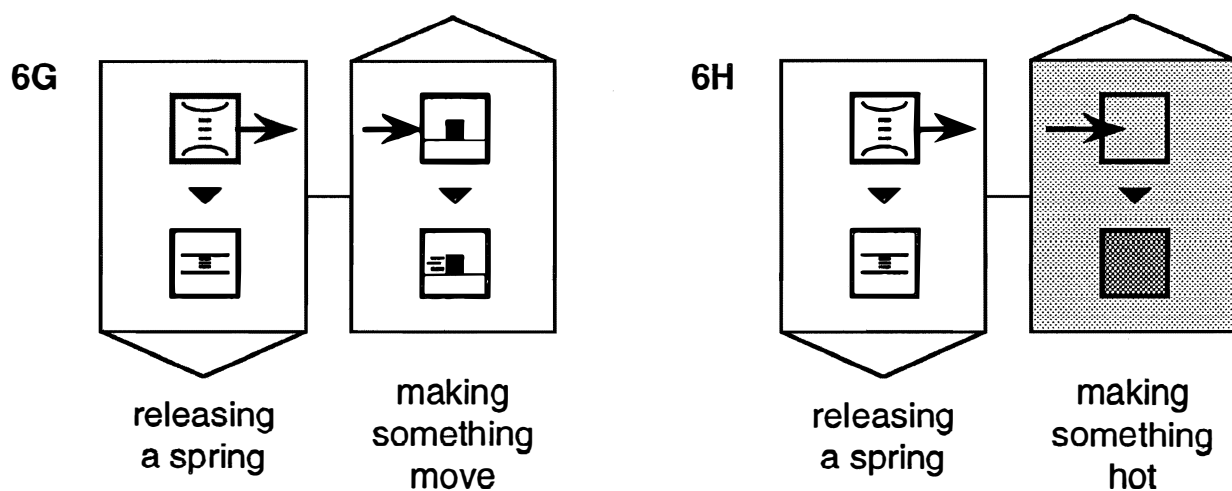
using a temperature difference

*Energy can be stored in hot things, moving things and pulled-out springs.*

## Springs and things

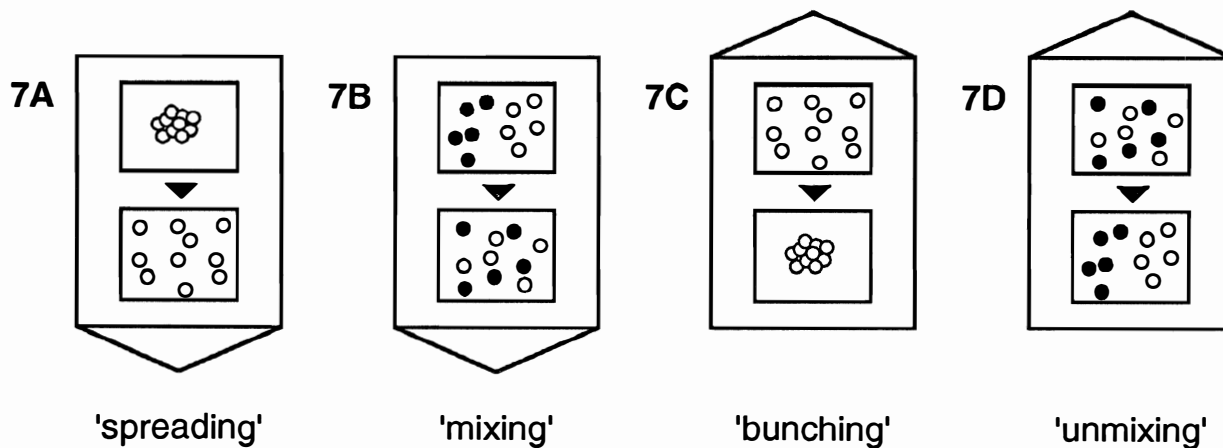


## Coupled changes

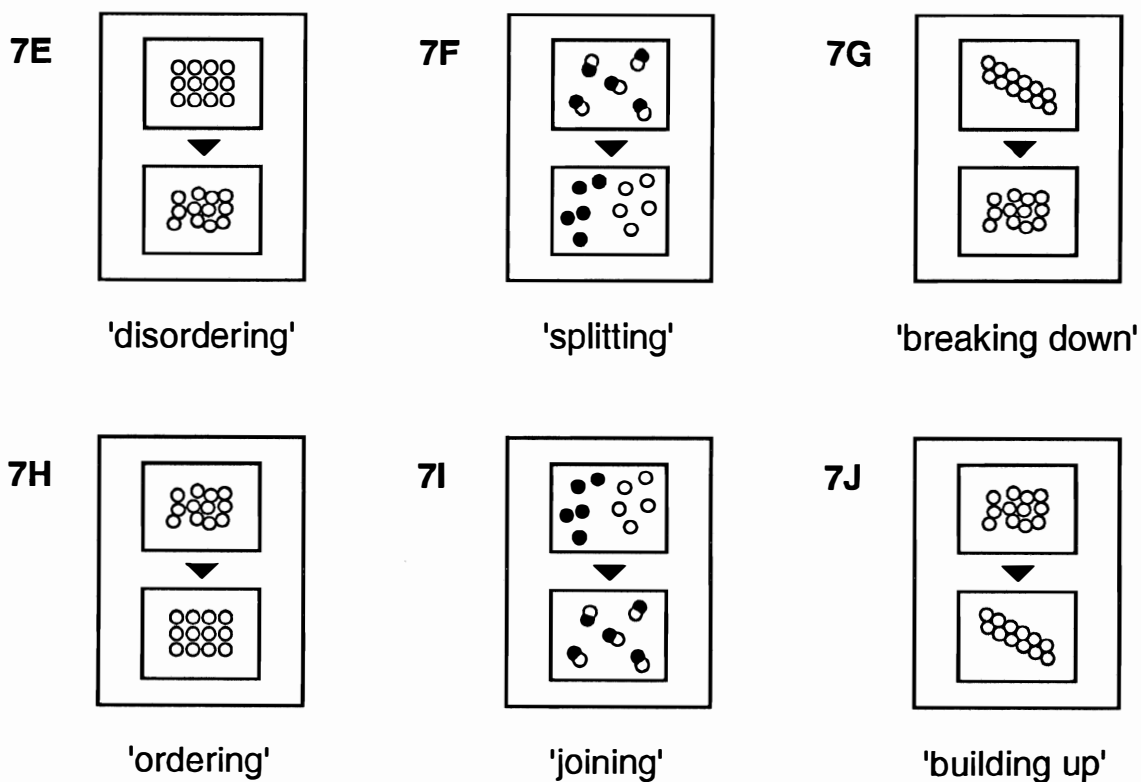


*Energy can be stored in hot things, moving things and pulled-out springs.*

**Particles with no attraction**



**Particles attracted to each other**

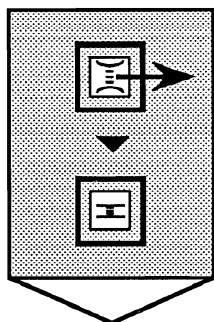


*Particles may spread or bunch - and stay unchanged.*

*Particles may split or join - and get re-arranged.*

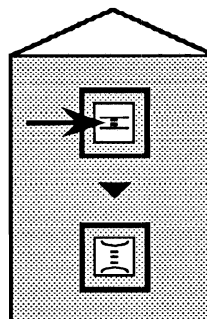
## Chemical springs

8A



releasing a  
chemical spring

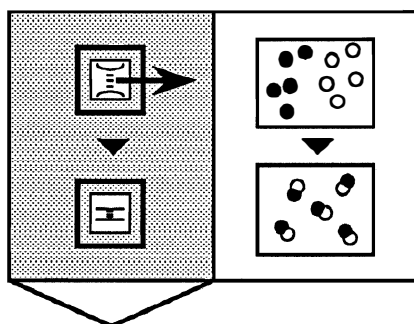
8B



stretching a  
chemical spring

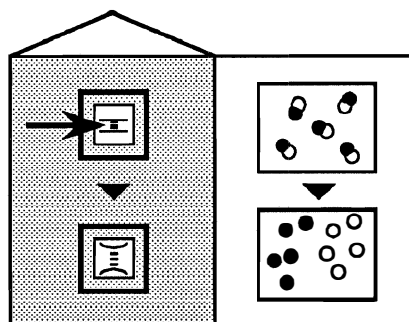
## Energy changes in 'splitting' and 'joining'

8C



energy spreads as  
particles join together

8D

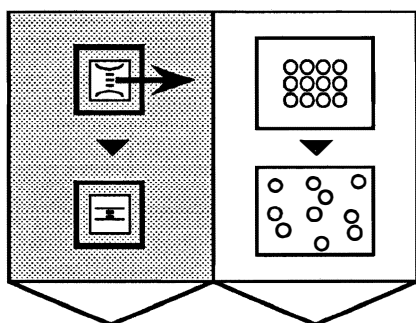


energy is stored as  
particles are pulled apart

*A fuel is half a 'chemical spring' which has been pulled apart.  
Energy spreads when the spring's released - with a push to make it start.*

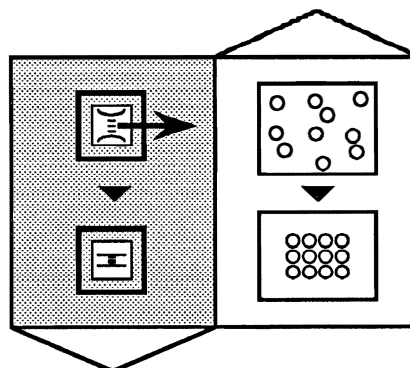
## Kinds of chemical change

9A



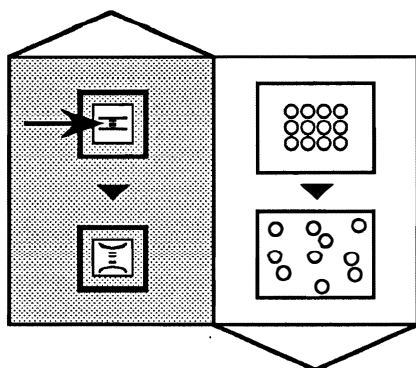
a chemical reaction which can  
'just happen' - driven by energy  
and matter spreading out  
(e.g. a candle burns)

9B



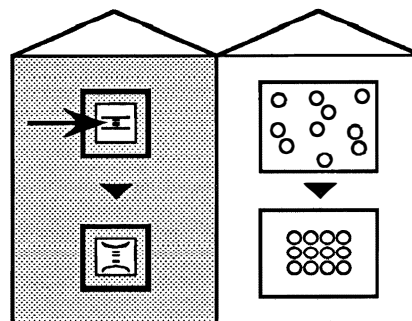
a chemical reaction which may  
'just happen' - driven by energy  
spreading out  
(e.g. magnesium burns)

9C



a chemical reaction which may 'just  
happen' - driven by matter  
spreading out  
(e.g. calcium carbonate decomposes)

9D

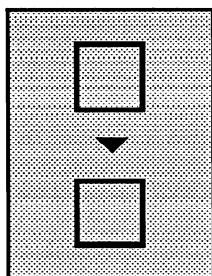


a chemical reaction which does  
not 'just happen' - neither energy  
nor matter spreads out  
(e.g. photosynthesis)

*A fuel is half a 'chemical spring' which has been pulled apart.  
Energy spreads when the spring's released - with a push to make it start.*

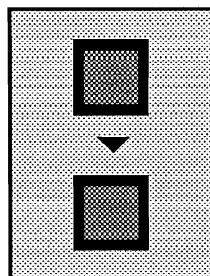
### Keeping things hot

10A



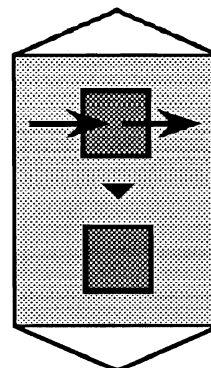
no change

10B



no change

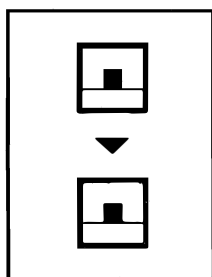
10C



steady state

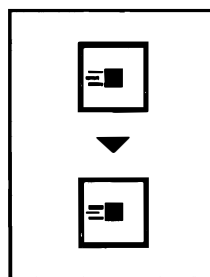
### Keeping things moving

10D



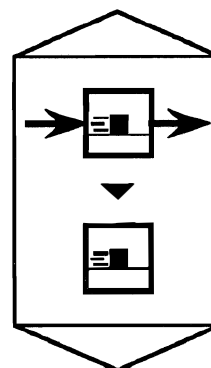
no change

10E



no change

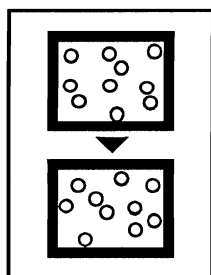
10F



steady state

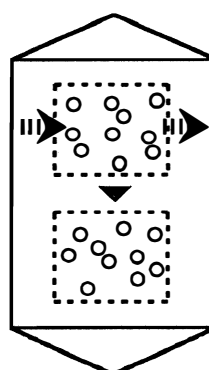
### Keeping things in one place

10G



no change

10H



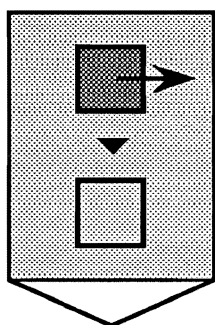
steady state

*You can stay where you are by standing still,  
But you need to keep running if you're sliding downhill.*



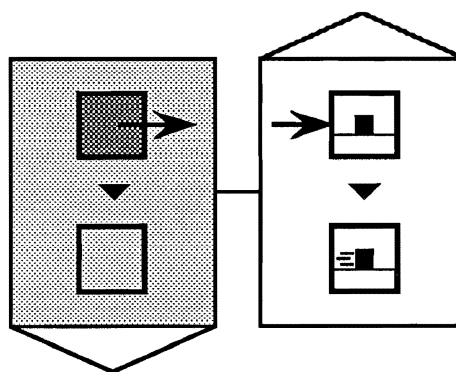
## Simple and coupled systems

11A



energy transfer measured  
from change in temperature

11B

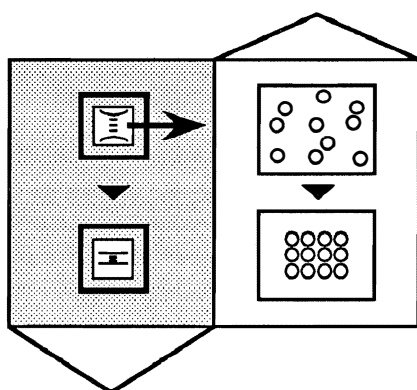


energy transfer measured  
as amount of work

## Competing tendencies in one system

11C

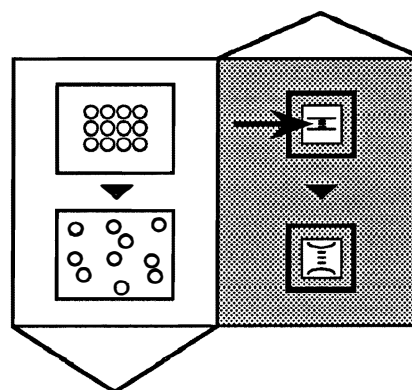
freezing



6000 J per mole  
250K

11D

melting



6000 J per mole  
300K

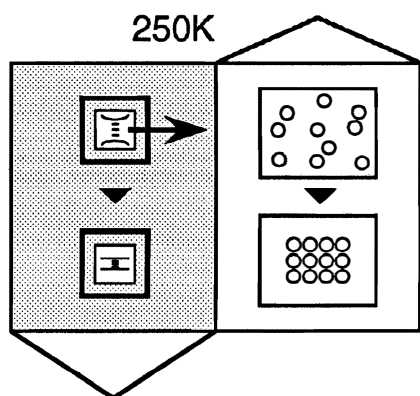
direction  
of change



*Differences cause changes*

## Ice and water: entropy point of view

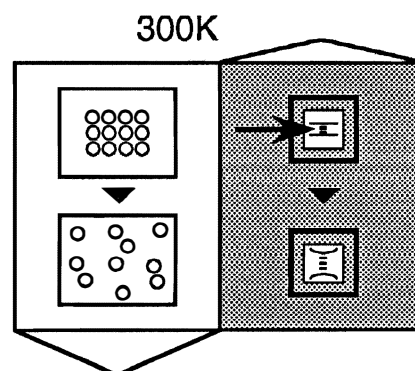
12A



$24 \text{ J K}^{-1} \text{ mol}^{-1}$   
DOWNHILL

$22 \text{ J K}^{-1} \text{ mol}^{-1}$   
UPHILL

12B



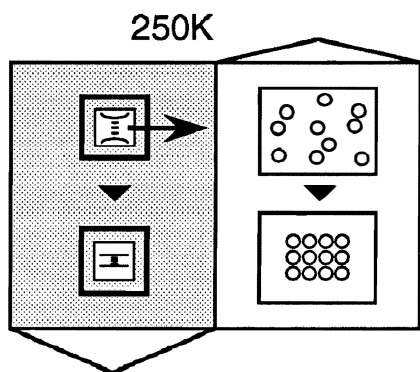
$22 \text{ J K}^{-1} \text{ mol}^{-1}$   
DOWNHILL

$20 \text{ J K}^{-1} \text{ mol}^{-1}$   
UPHILL

direction  
of change  
▽

## Ice and water: potential difference point of view

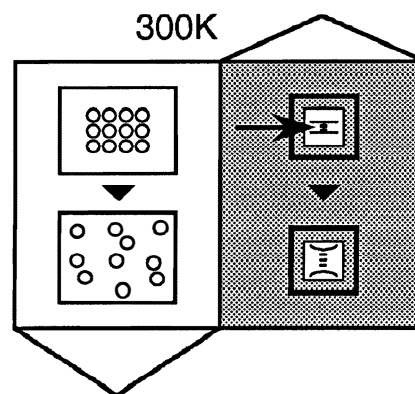
12C



$6000 \text{ J mol}^{-1}$   
DOWNHILL

$5500 \text{ J mol}^{-1}$   
UPHILL

12D

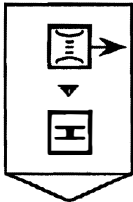
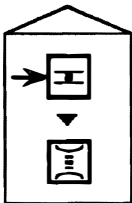
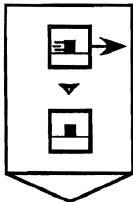
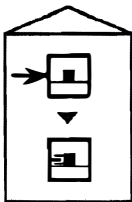
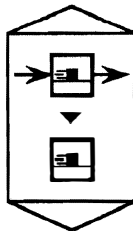
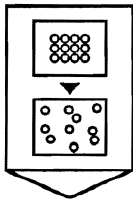
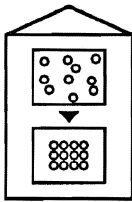
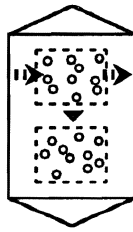
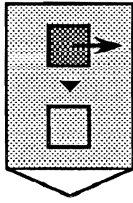
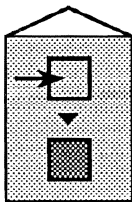
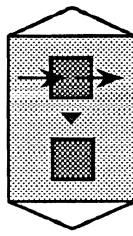
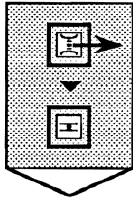
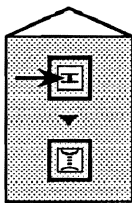


$6600 \text{ J mol}^{-1}$   
DOWNHILL

$6000 \text{ J mol}^{-1}$   
UPHILL

direction  
of change  
▽

*Two ways of looking at what decides the direction of change*

<p><b>'springs'</b> (mechanical, gravitational, electrostatic)</p>	<p><b>A1</b></p>  <p>spring relaxing</p>	<p><b>A2</b></p>  <p>spring stretching</p>
<p><b>moving objects</b></p>	<p><b>B1</b></p>  <p>slowing down</p>	<p><b>B2</b></p>  <p>speeding up</p> <p><b>B3</b></p>  <p>keeping moving</p>
<p><b>arrangements of particles</b></p>	<p><b>C1</b></p>  <p>spreading out</p>	<p><b>C2</b></p>  <p>bunching together</p> <p><b>C3</b></p>  <p>maintaining a structure</p>
<p><b>temperature differences</b></p>	<p><b>D1</b></p>  <p>temperature difference decreasing</p>	<p><b>D2</b></p>  <p>temperature difference increasing</p> <p><b>D3</b></p>  <p>temperature difference staying the same</p>
<p><b>'chemical springs'</b></p>	<p><b>E1</b></p>  <p>chemical spring relaxing</p>	<p><b>E2</b></p>  <p>chemical spring stretching</p>

## Examples of pupil discussion: Insulation (Activity E6)

### *Matching situations to abstract pictures*

#### *Hot chocolate:*

"The hot chocolate is hotter than the room temperature ... and when the hot chocolate is left in the room, 'cos the room is colder the energy goes out of it and the hot chocolate starts to get cold slowly."

#### *Frozen food:*

"Because the frozen food left on the table and the food is colder than the room and the room temperature melts the frozen food ... the energy is going into the food and makes it warmer."

#### *Frozen food:*

"The food is more colder so the room temperature will go into the food and the newspaper is not that powerful so the room temperature will slowly go into the newspaper wrapping the food."

#### *Hot chocolate:*

"The hot chocolate is hotter than the room temperature so this (*the central region in the representation*) is darker (*i.e. hotter with energy more concentrated*) and when the hot chocolate is left in the room, because the room is colder the energy goes out of it (*the chocolate*) and the hot chocolate starts to get colder slowly. This one in here (*in the vacuum flask*) - the hot chocolate is still hotter than the room so it's darker but it stays the same, as it's in the vacuum flask so no heat will come out and no heat will come in."

#### *Cold lemonade:*

##### *One choice of picture:*

"It's colder on the inside, and then the energy from the heat on the outside is going in making it warmer, and when it's in the vacuum flask the coldness just escapes making it warmer."

##### *A different choice of picture:*

"Mine's the same really but the cold doesn't escape - the insulation makes the lemonade warmer."

"That's what I meant - the insulation makes it warmer."

"No but that means if the insulation made it warmer the cold wouldn't go out but the heat would come in - so the heat goes in not comes out."

## Examples of pupil discussion: Everyday changes (Activity F5)

### *Matching situations to abstract pictures*

#### *Alka Seltzer in water:*

"Because that is solid and this is liquid and they react as gas and they ... "  
" ... they mix together, and that dissolves into the liquid and releases gas."

#### *Blood clotting:*

"Blood's a liquid first, red colour, and then it forms a clot and it changes colour. It goes to black doesn't it? And it becomes a solid afterwards."

#### *Using bleach on a stain:*

"Because you see the solid part with the dirt and the bleach, you mix it, then the dirt disappears, the stain disappears."

#### *Using rust remover:*

"Because it (*the abstract picture chosen by the pupil*) shows a gas mixing with a solid the solid changes colour ... the rust remover is the gas."  
"It might not be a gas - it might be in a bottle."  
"You don't see a spray can. It's rust remover ... it's a liquid."  
"As it sprays it's a gas and a liquid ..."  
"How is it a liquid?"  
"Because it is a liquid in a can and when you spray it is a gas."  
"Yeah, it's like shaving foam inside." (*They had recently discussed the nature of shaving foam.*)

#### *Spoon bending:*

"It's still the same substance but it changes. It just bended."

#### *Butter melting / Spoon bending:*

"That changes substance and that changes shape."

#### *Glue hardening:*

"Because it shows a liquid turning into a solid but it is the same substance."

#### *Using bleach on a stain:*

"The clothes is the black one and the dirt is the white one."

#### *Some wood burning:*

"It's a solid (wood) but I don't know what the fire is - is it a solid, liquid or a gas?"

## Examples of pupil discussion: Things that 'just happen' and things that don't (Activity H1)

### *Interpreting abstract pictures*

#### *Hot object spontaneously cools as energy flows from it to the cooler surroundings:*

"Something hot losing energy - getting cold."

"This is a room and this is a block and it is giving heat to the room and becoming the same temperature as the room."

"This happens usually, naturally."

"It just happens normally."

#### *The reverse change:*

"It's showing taking energy in."

"This is an example right. There is a glass of water and to make it hot just wouldn't happen."

"It does happen, but it is difficult to make it happen."

"It doesn't happen naturally but people ... You can make it happen."

#### *Objects slowing down and speeding up:*

"Something that is going fast and then slows down."

"Something starts moving."

"Natural and ... "

"One works - that one - and that one doesn't usually happen."

"Poltergeist!"

"Something that is moving and that is slowing down - stopping."

"Could be the wind that is pushing it or it just happens."

#### *Coupled changes:*

"This is the argument that it's possible, yeah? So you use something that is possible to make something that is impossible possible!"

"The 'down' one is something that happens and the 'up' one is - someone has to make it happen."

## Examples of pupil discussion: Fuels and food (Activity H5)

### *Matching situations to abstract pictures*

#### *Torch battery:*

"Like something happens by itself ... so ... it's from stored to released.

"Because energy was inside and it went outside."

#### *Bath cooling:*

"Because it goes from hot to cold, and it's heat and energy is being released."

#### *Petrol used in a car:*

"Because it's stored and then it's released which makes the car move."

#### *Light bulb:*

"Someone's driving that to get hot."

#### *Person running:*

"Number 6 then, because that's like pulling chemicals and things (6), and this is just cooling down (5)."

### *Finding similarities between situations matched to the same abstract picture*

#### *An electric light bulb gets hot / Using a kettle to boil some water:*

"Energy is being stored up "

"Something is driving the water, something has to drive the light bulb."

"It doesn't just happen by itself."

#### *Petrol is used in a car engine / A person uses up food running a race:*

"You gotta put energy in and then take it out - use it, burn it up, in other words."

"That is stored ... "

"That is driving that."

" ... but then it's released. It's stored then it's released, but then the person's running."