

# **NUMERACY THROUGH PROBLEM SOLVING**

Shell Centre for Mathematical Education/Joint Matriculation Board

## **BE A PAPER ENGINEER**

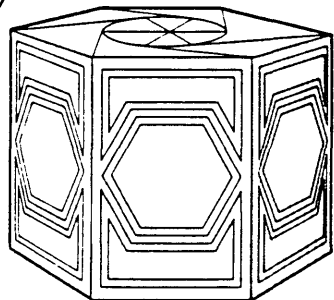
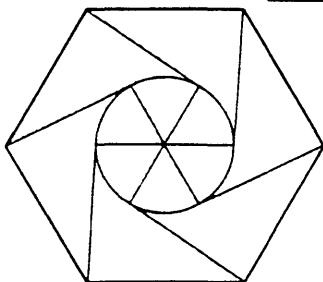
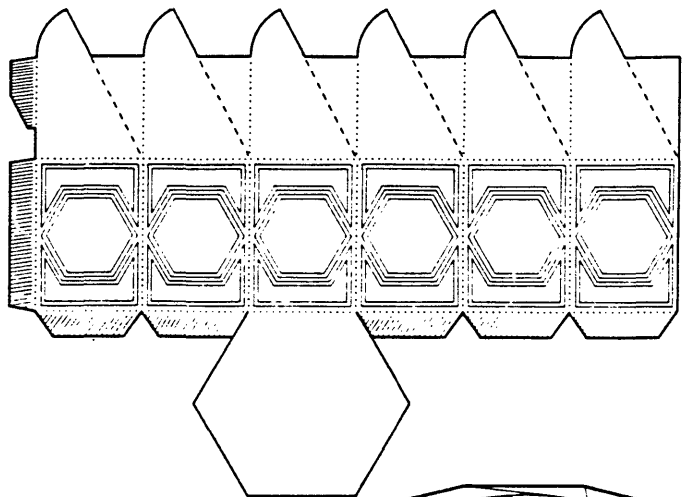
### **Contents of Box**

- 1 Teacher's Guide
- 25 Student's Booklets
- 1 pack of Masters for Photocopying



NUMERACY ▶ THROUGH ▶ PROBLEM ▶ SOLVING

# Be a Paper Engineer



Shell Centre for Mathematical Education

Joint Matriculation Board



MASTERS FOR PHOTOCOPYING

# Masters for Photocopying

Except where indicated, these Masters are designed to produce single-sided, reusable worksheets. Masters for consumable sheets are labelled (c). Masters for double-sided sheets are labelled \*.

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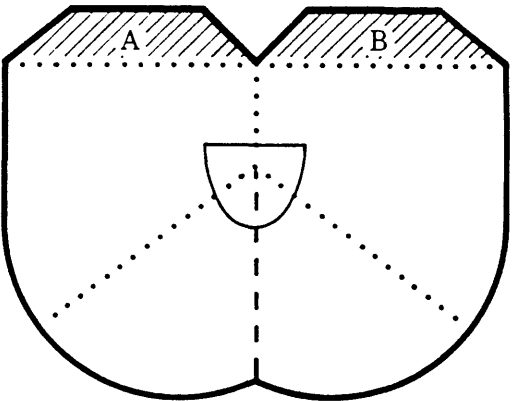
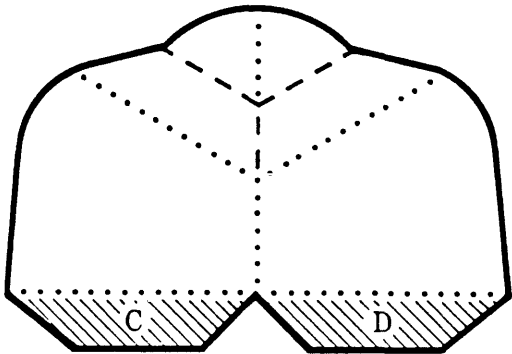
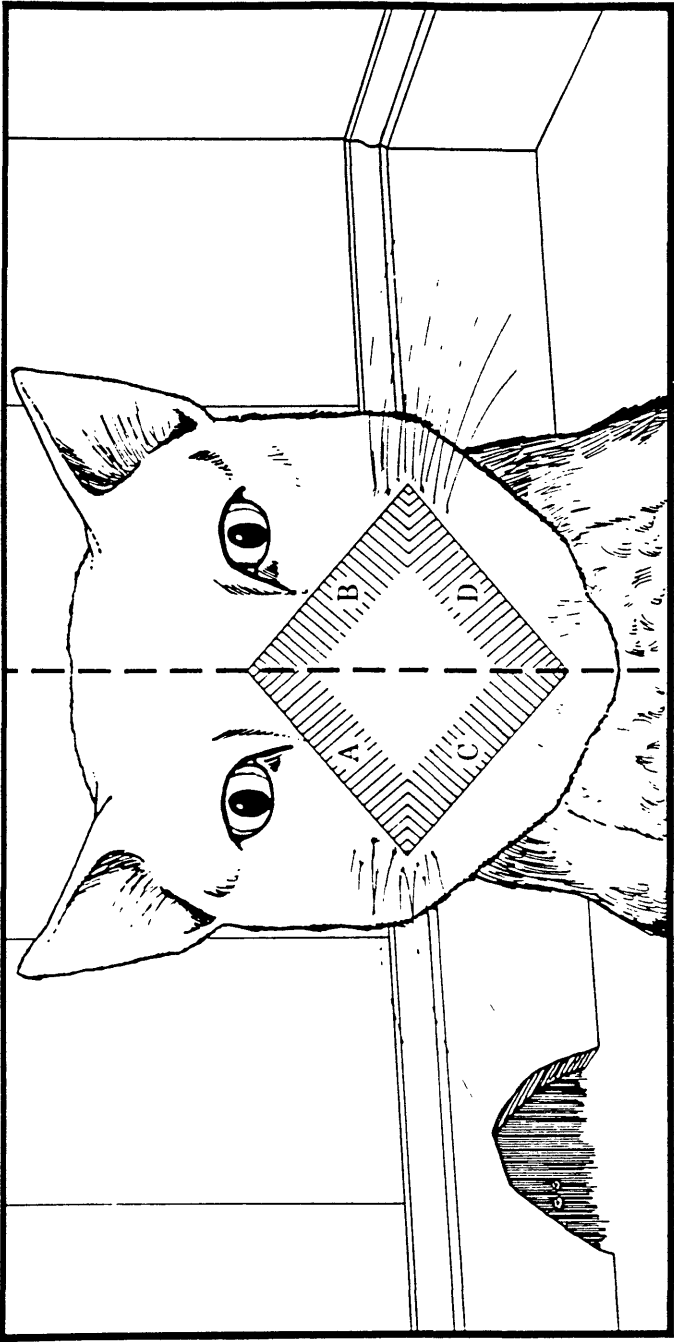
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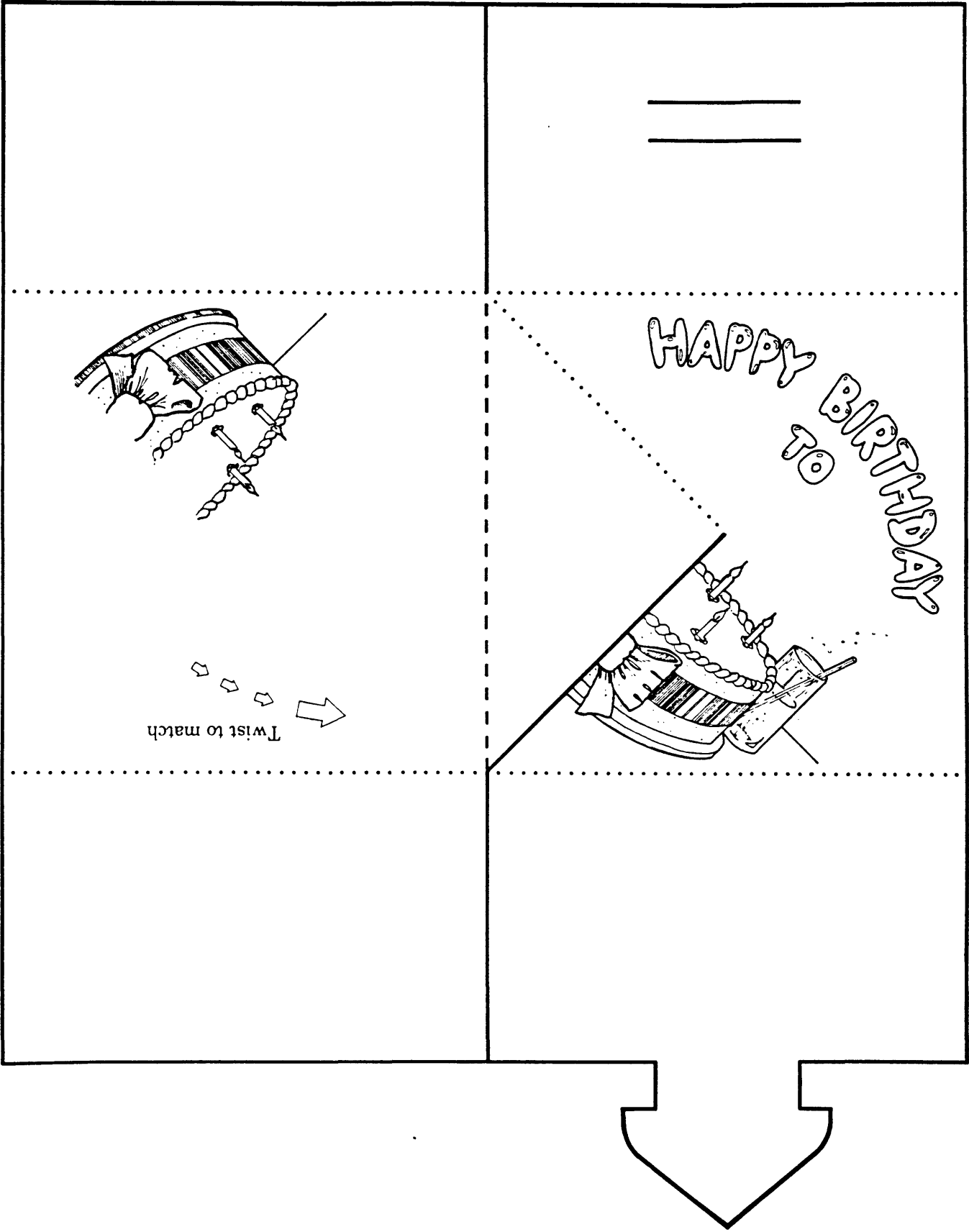
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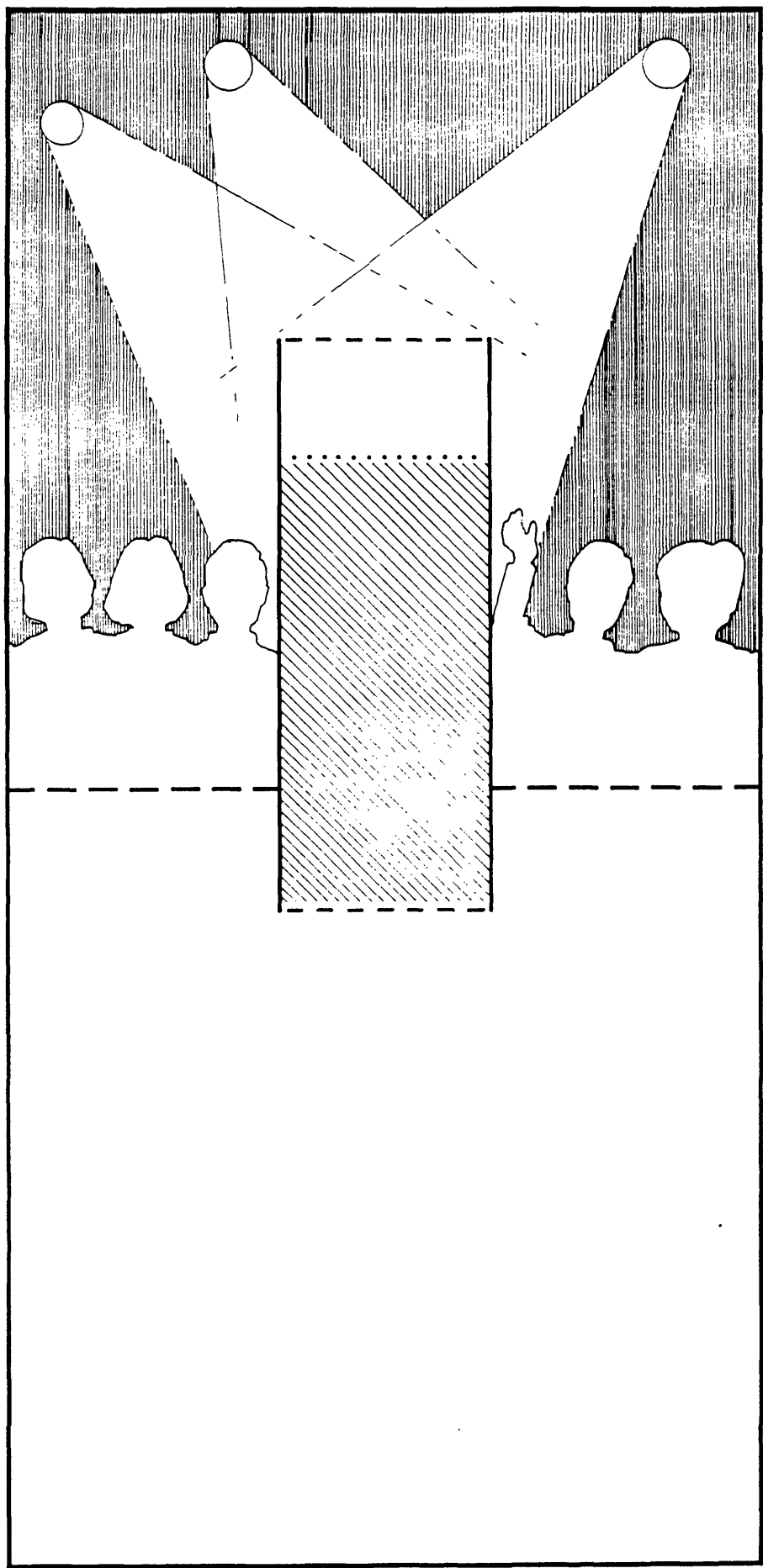
# 1. The Cat



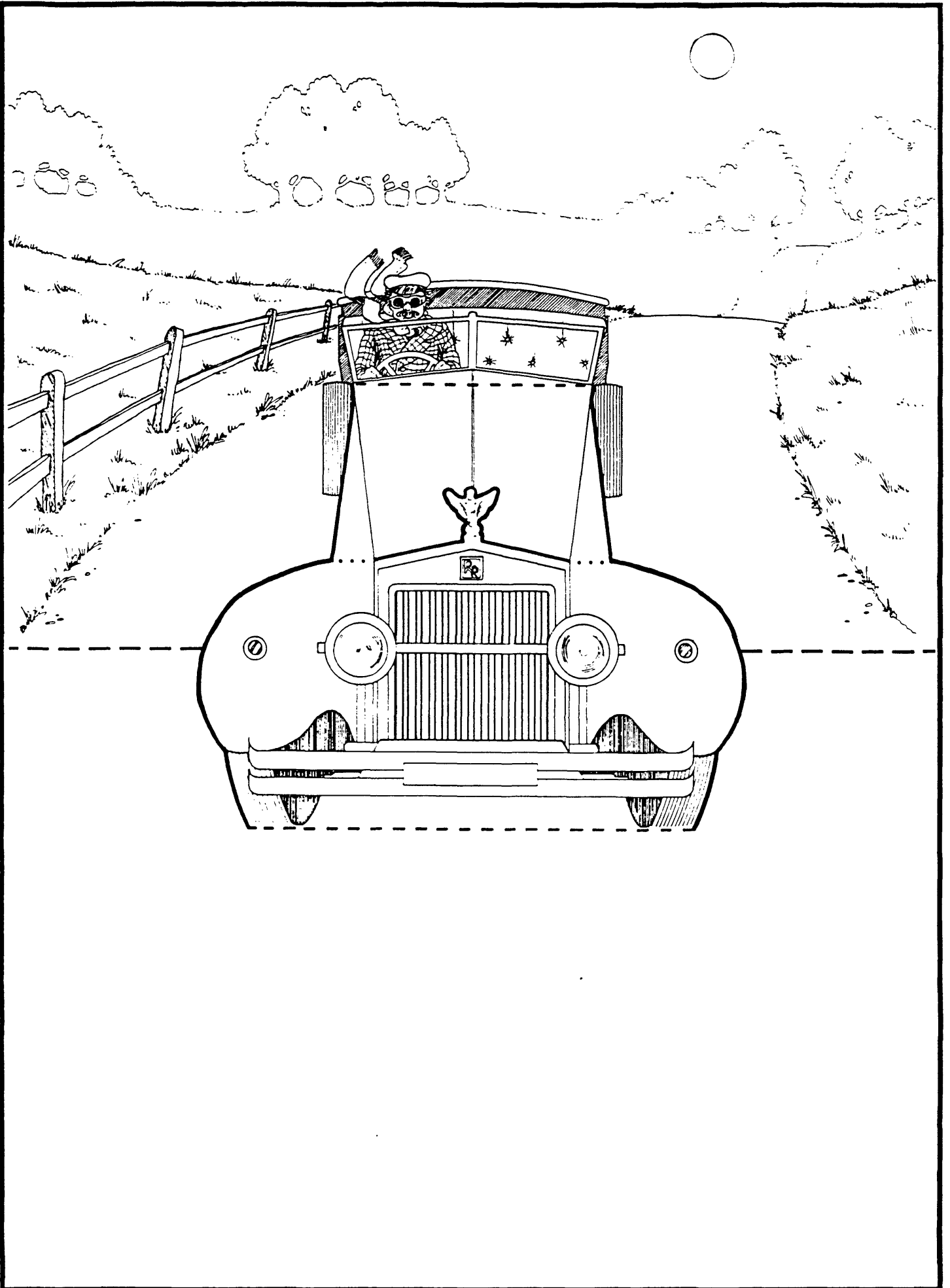
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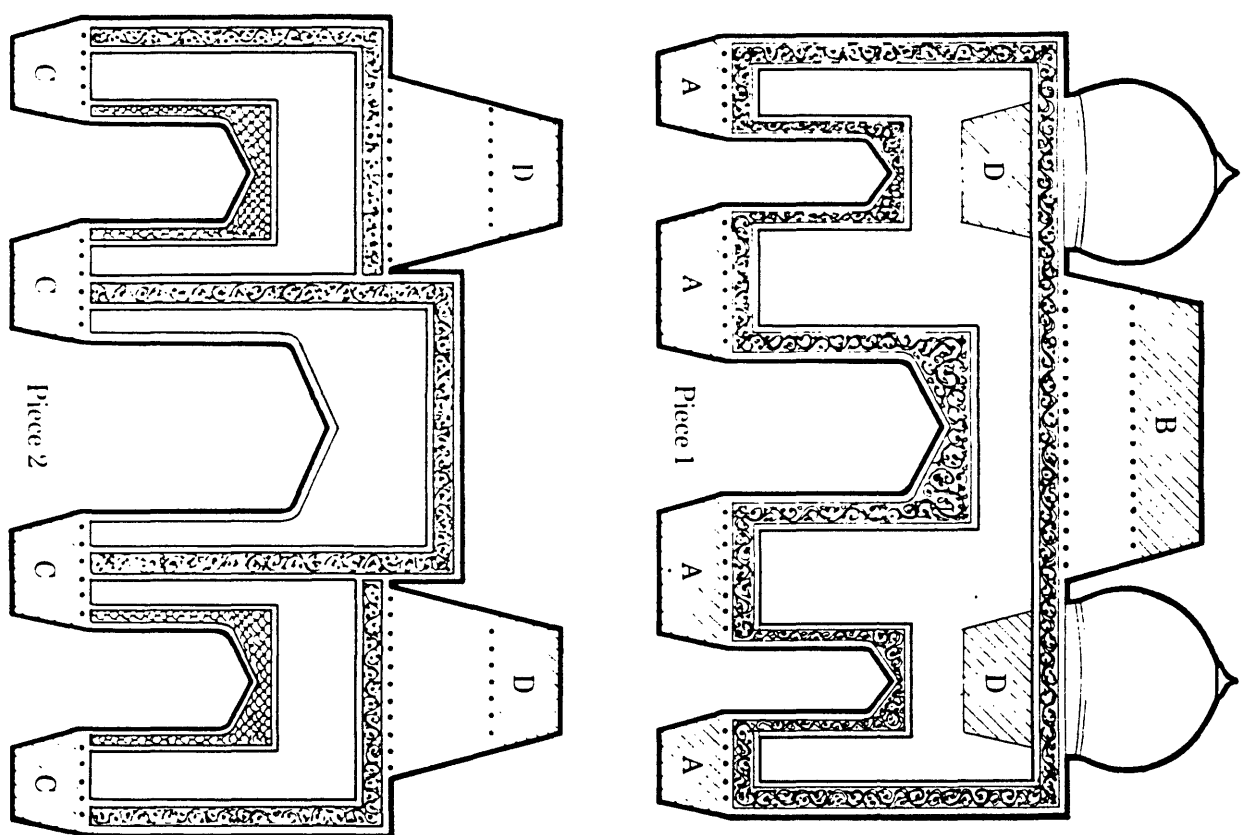
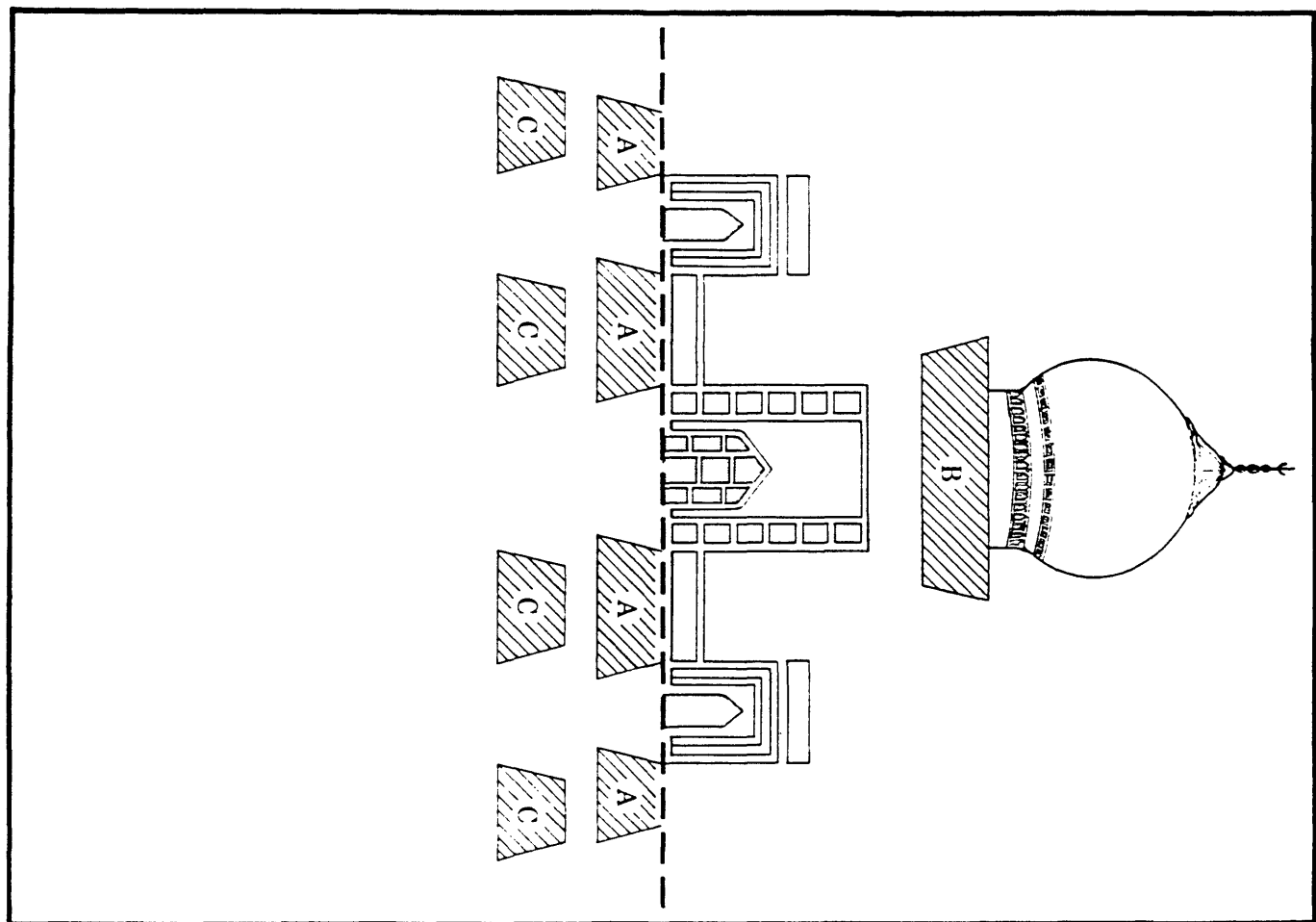


## 4. The Rolls Royce

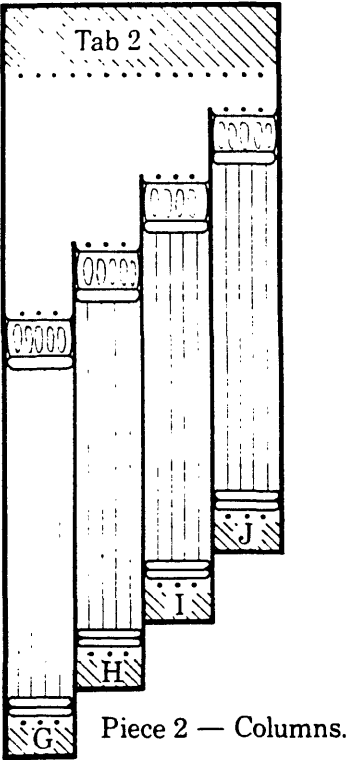
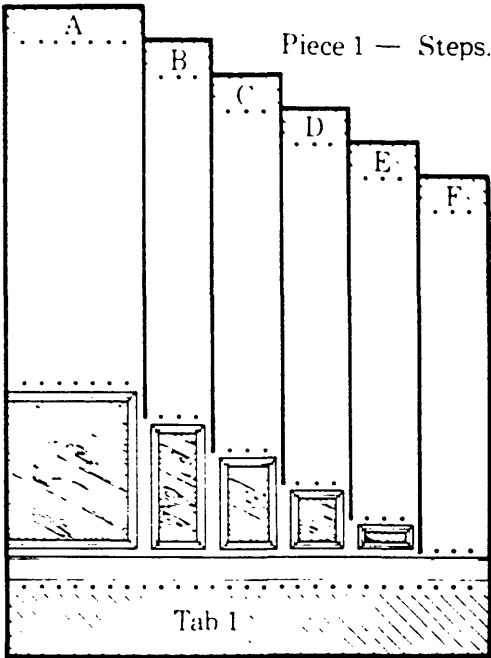
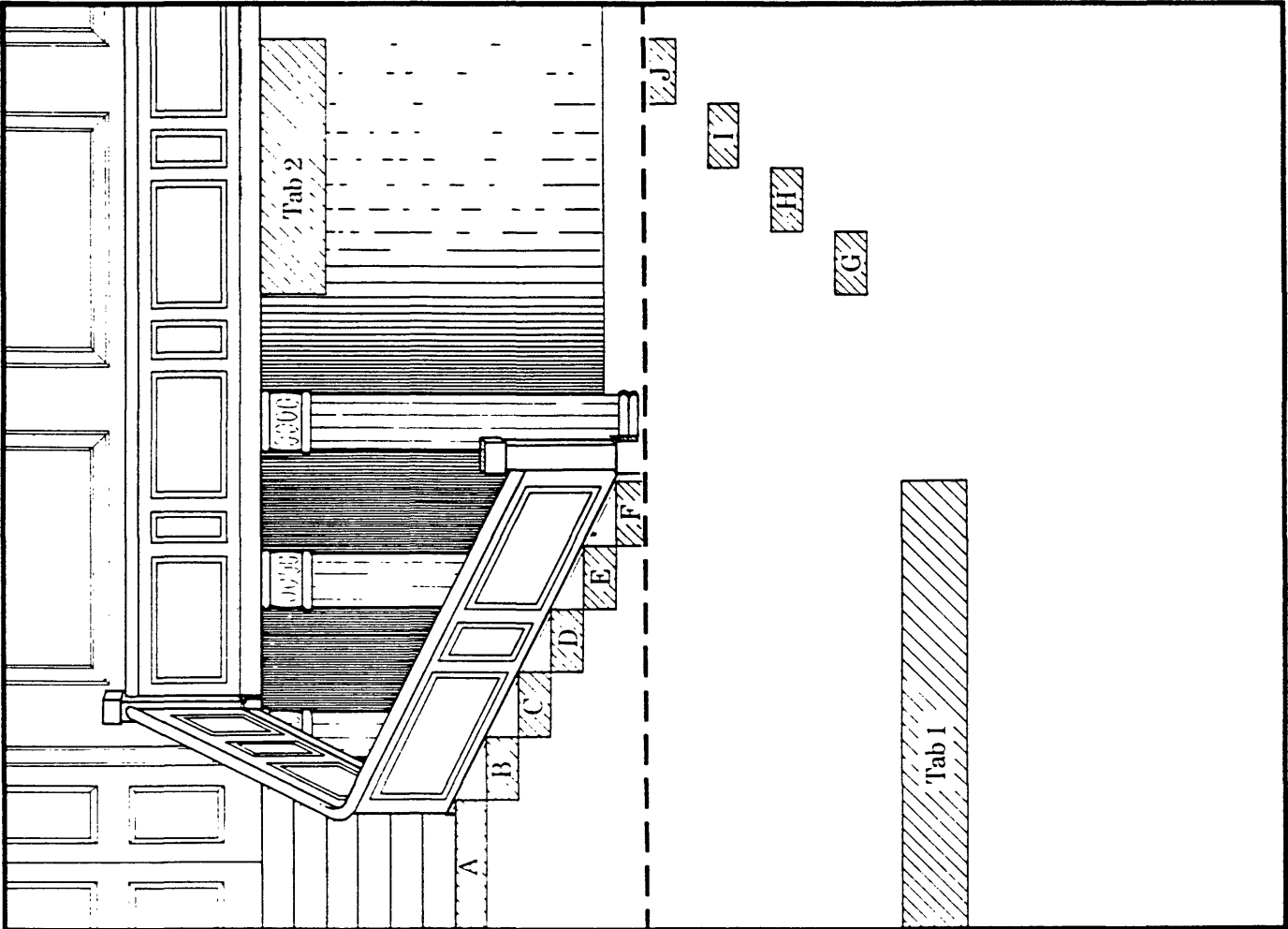




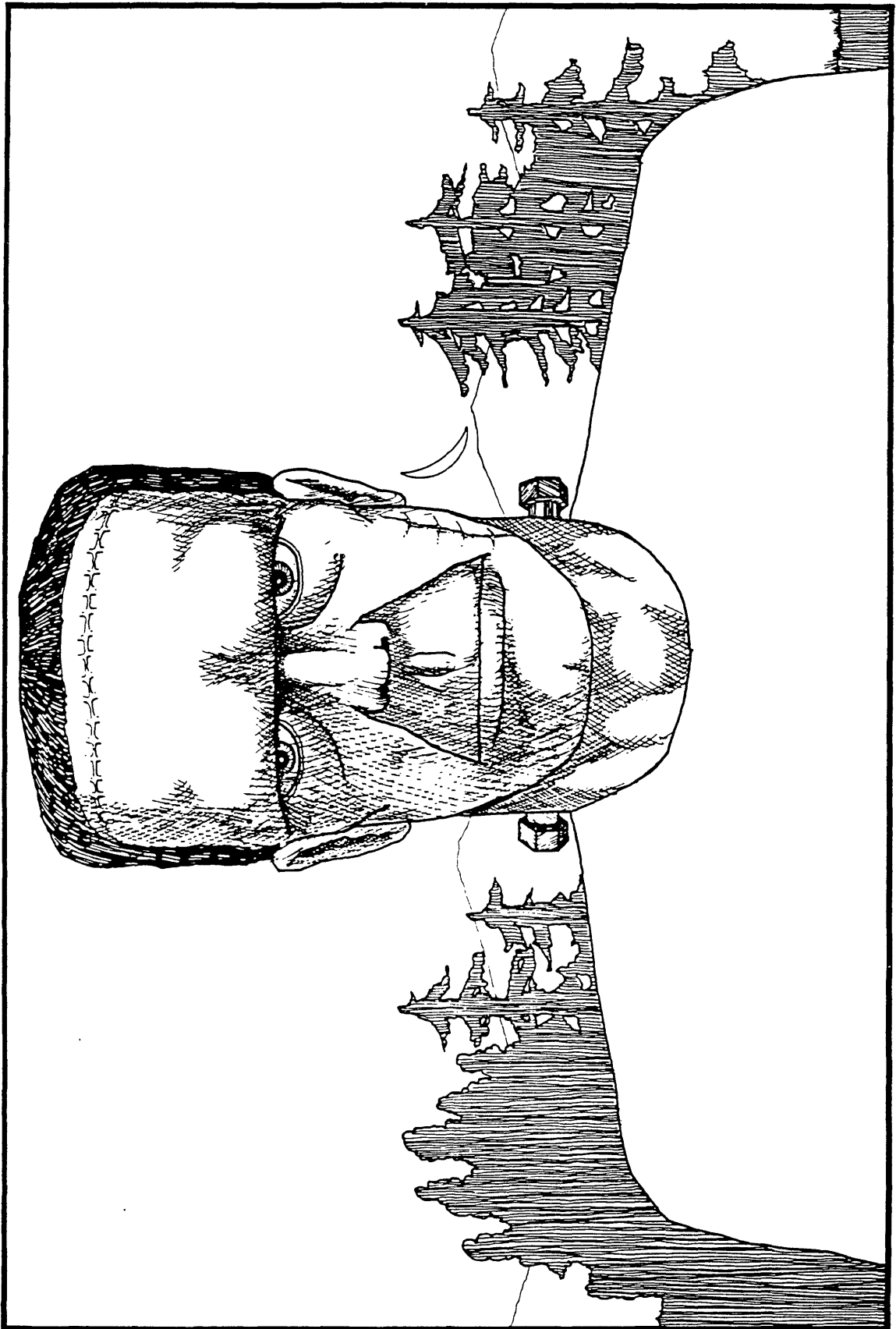
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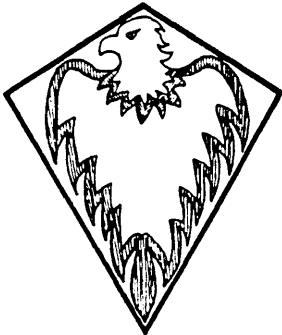
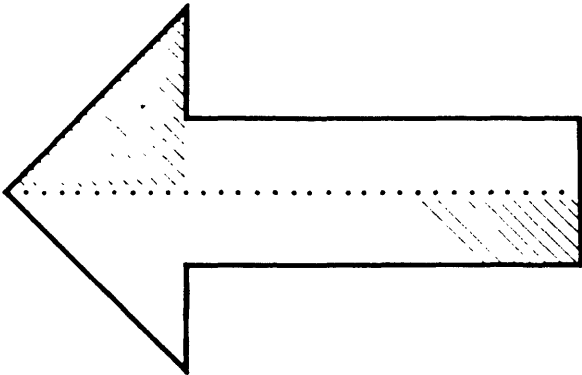
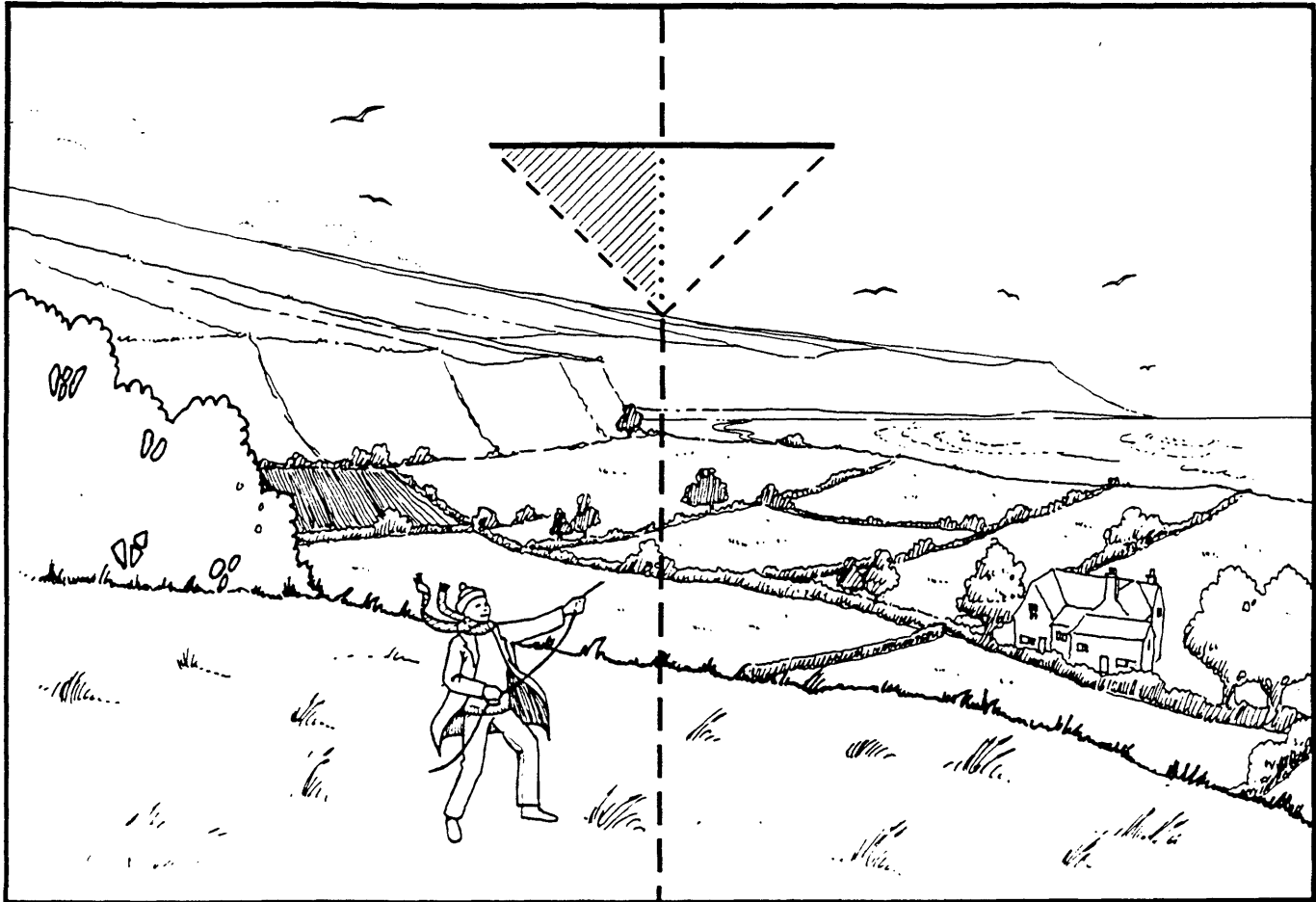
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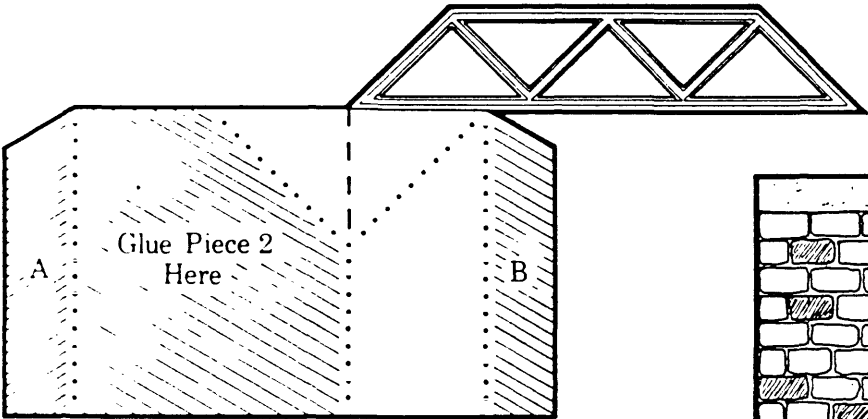
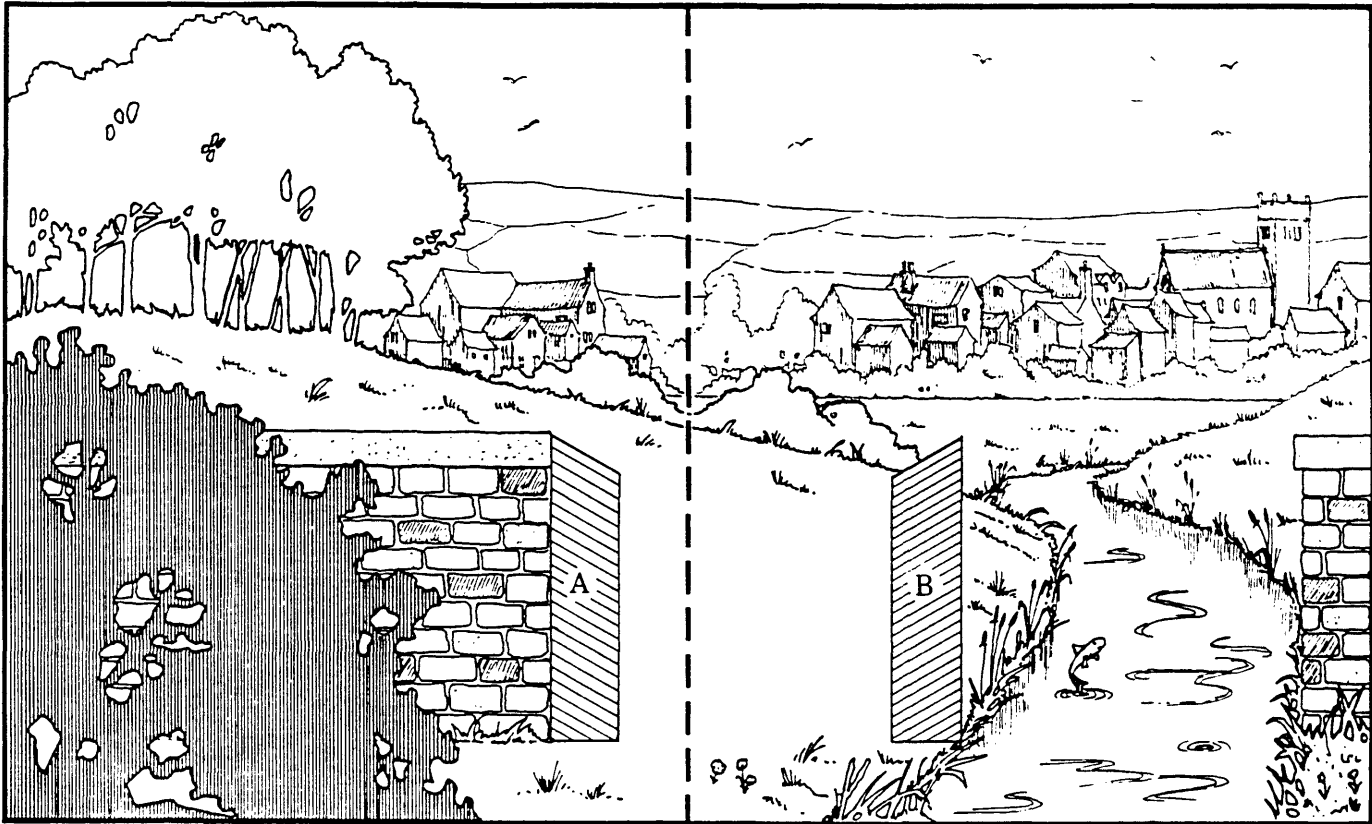
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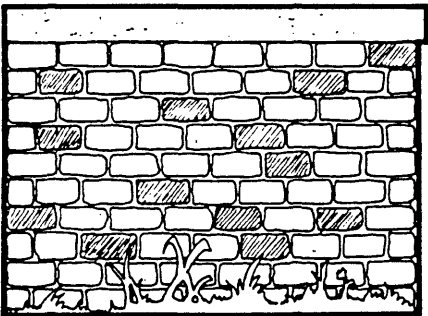
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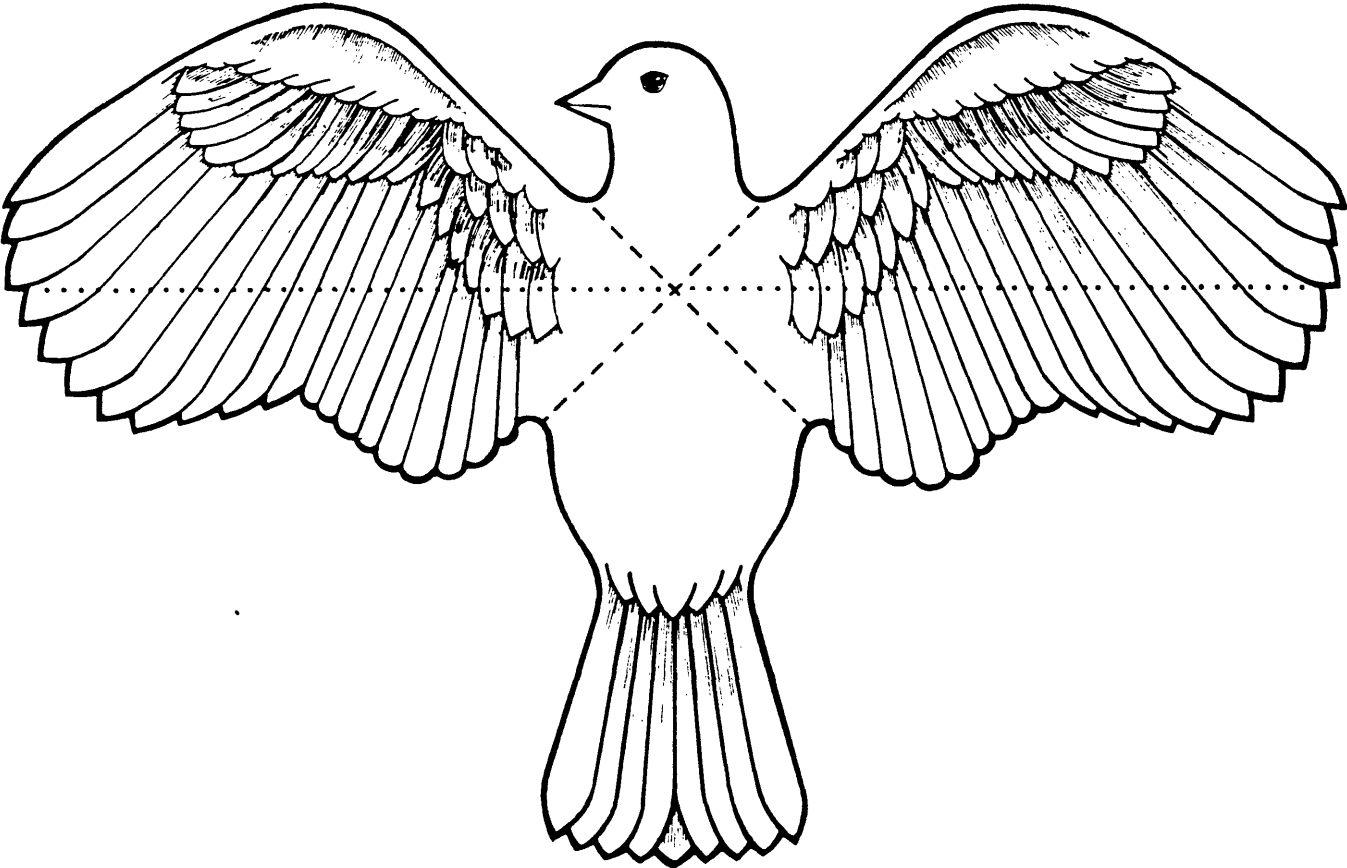
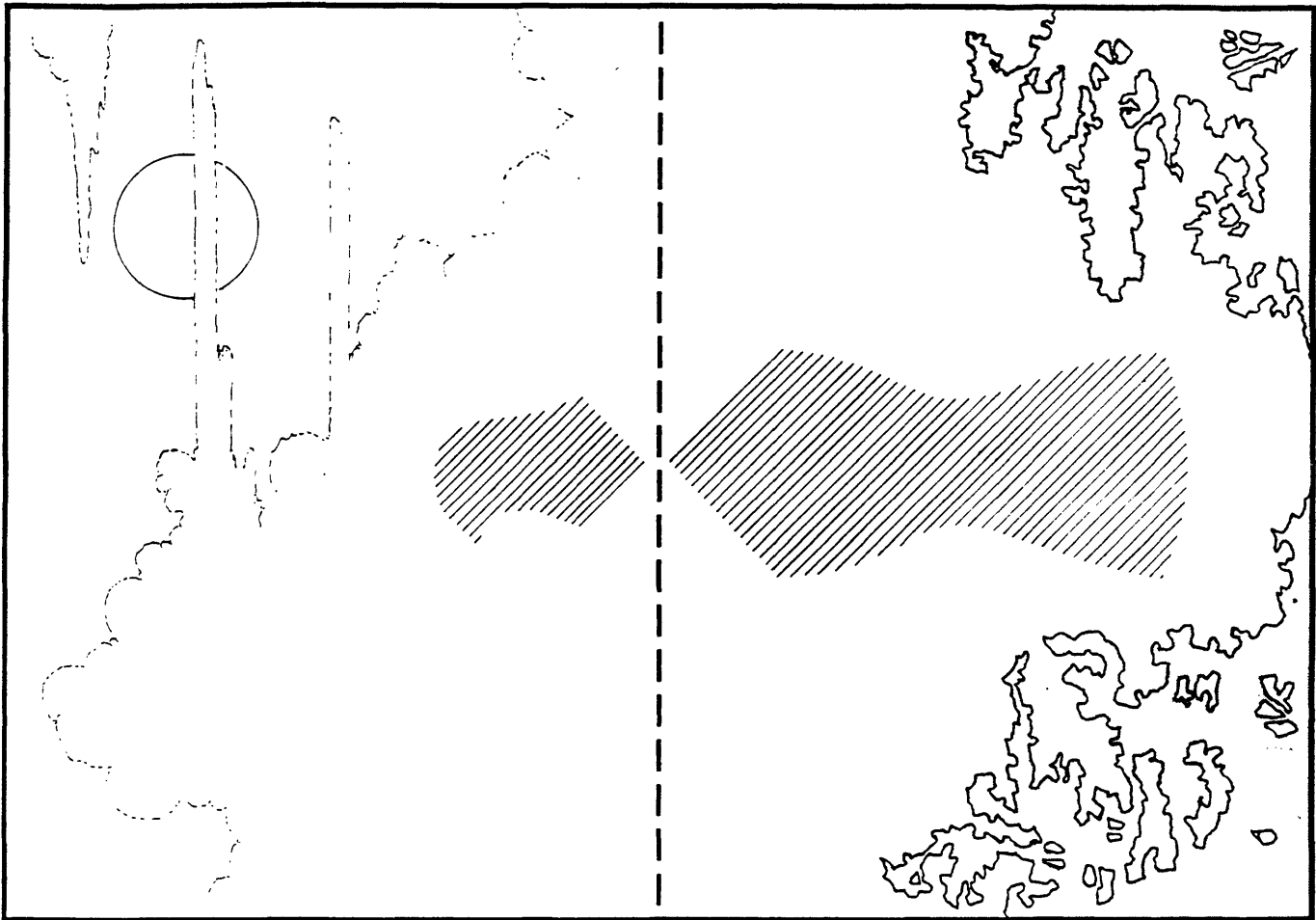


Piece 1.

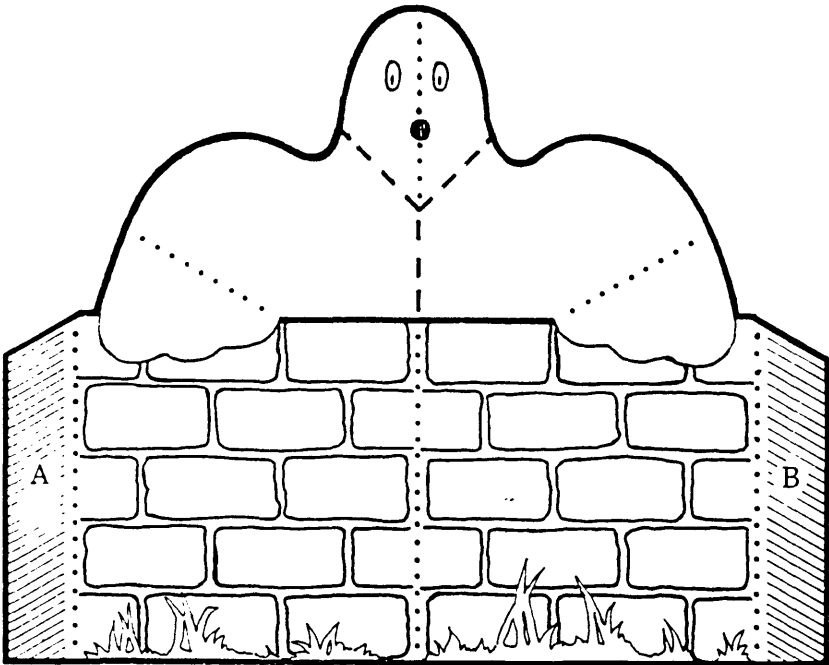
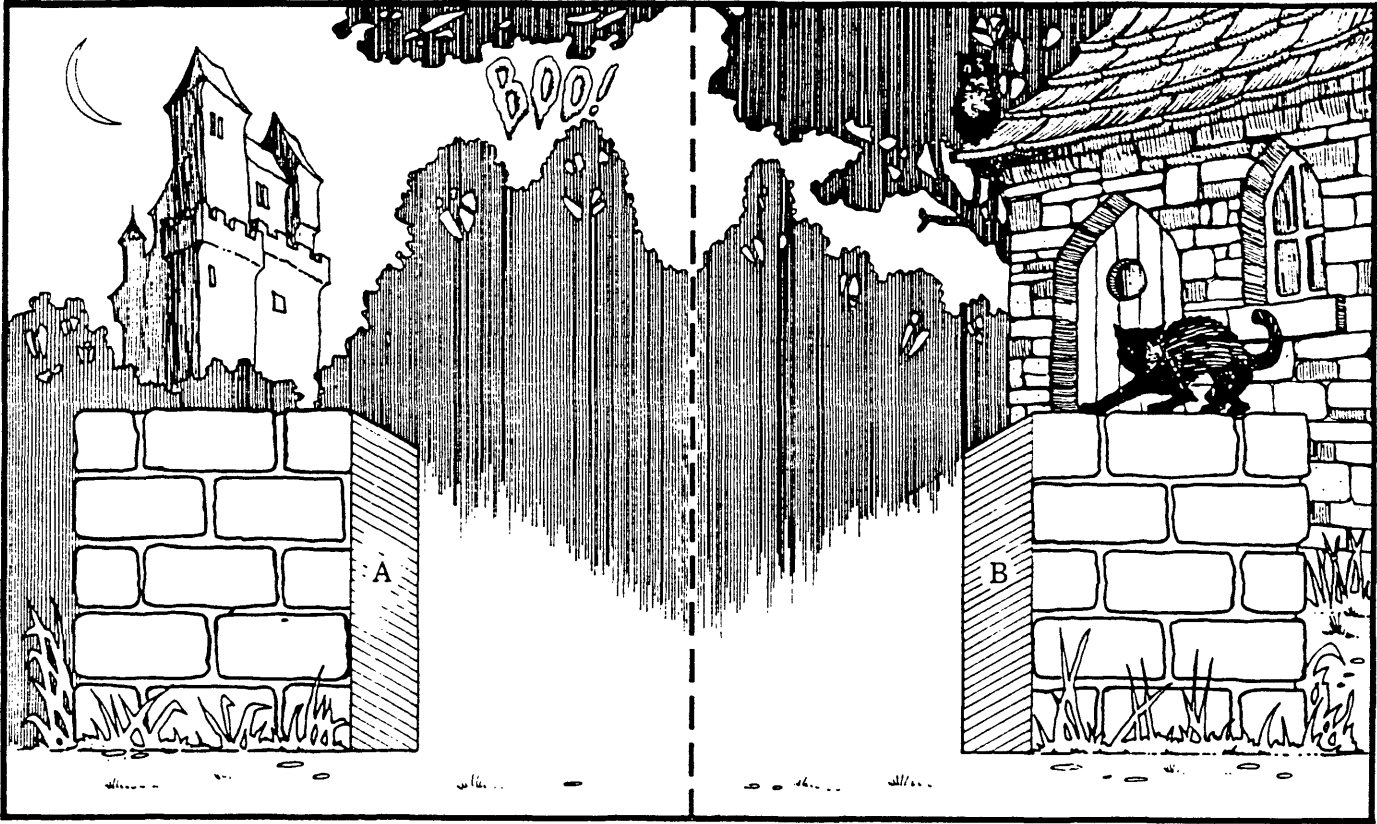


Piece 2.

# 11. The Dove of Peace

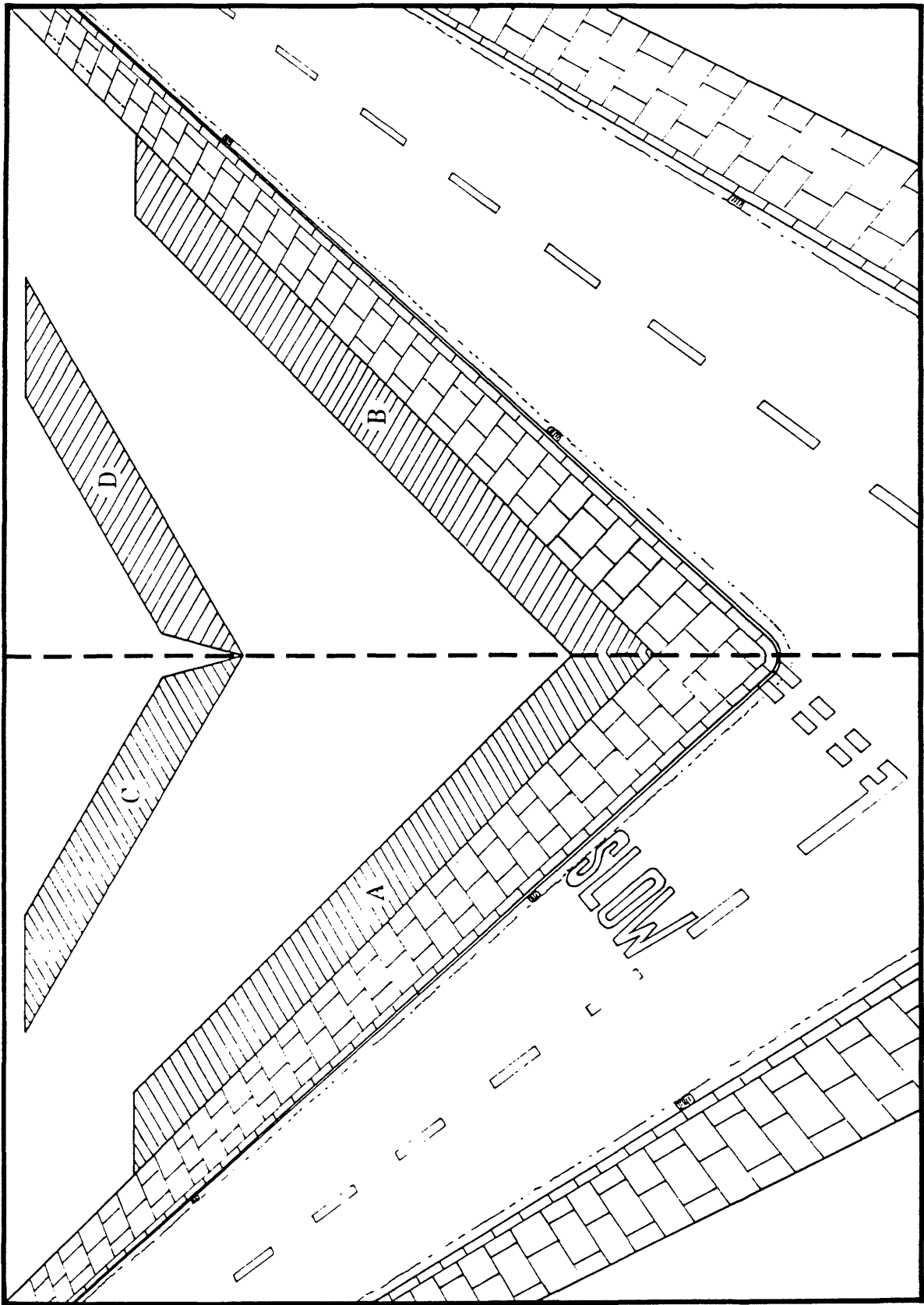


12. The Ghost

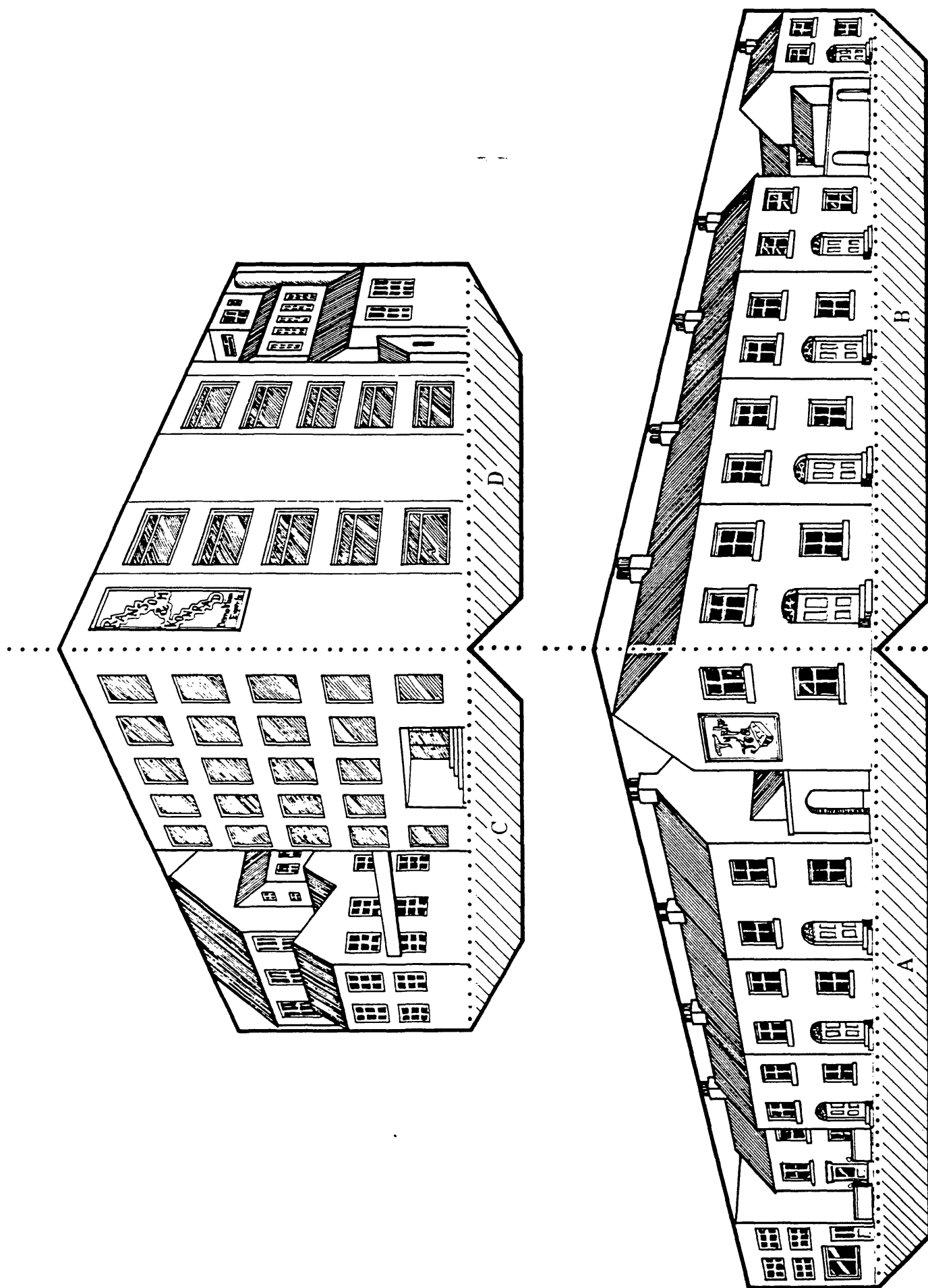




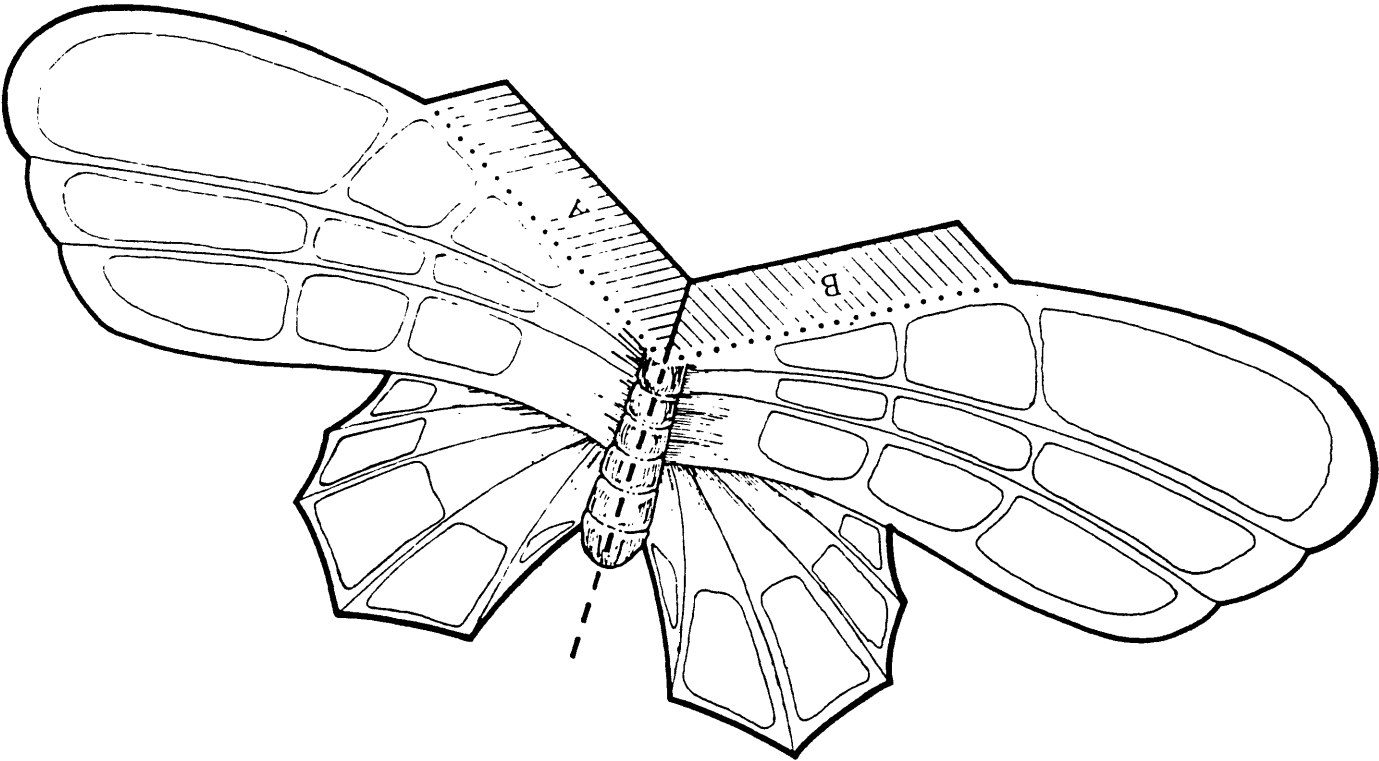
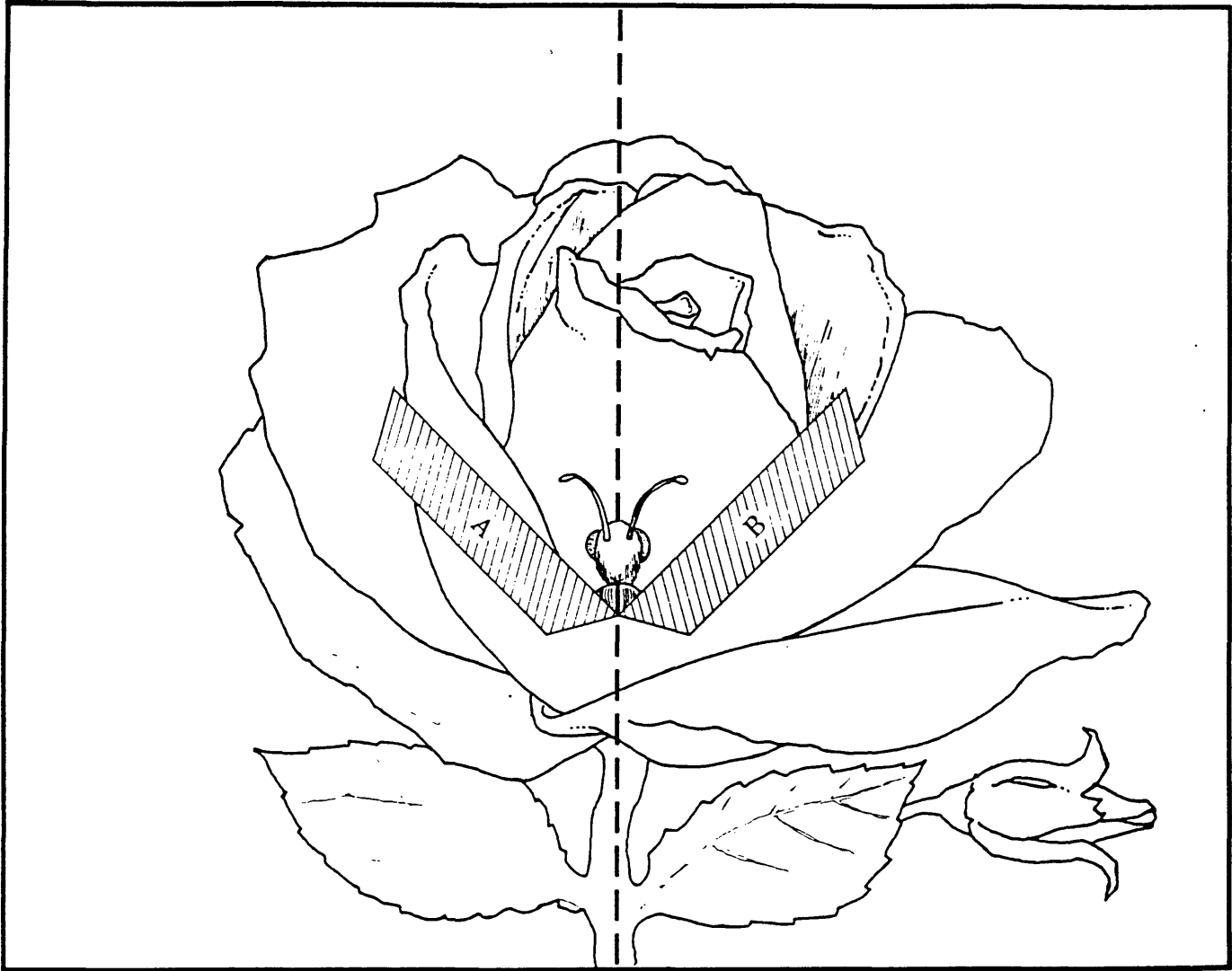
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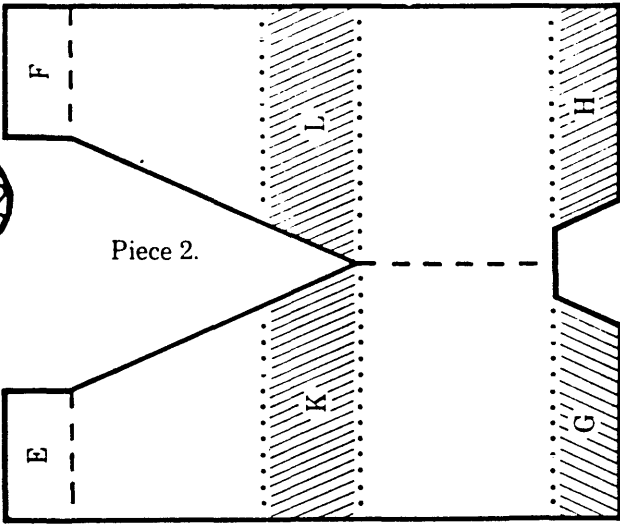
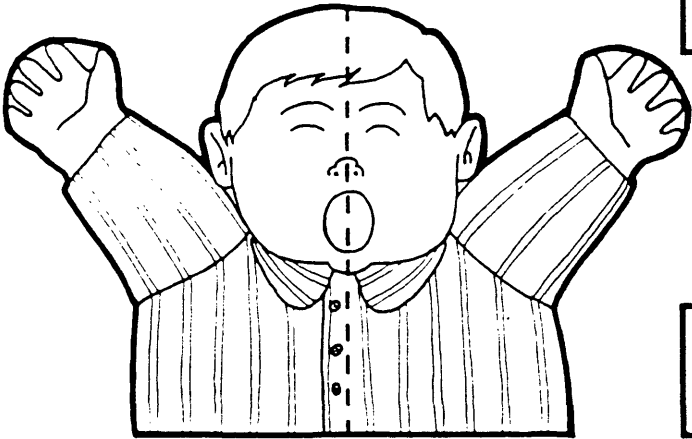
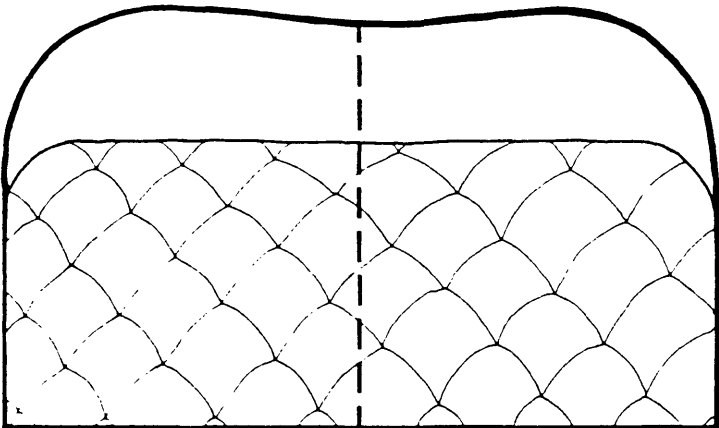
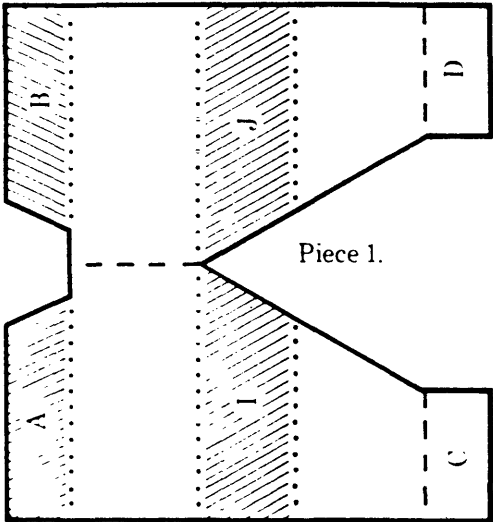
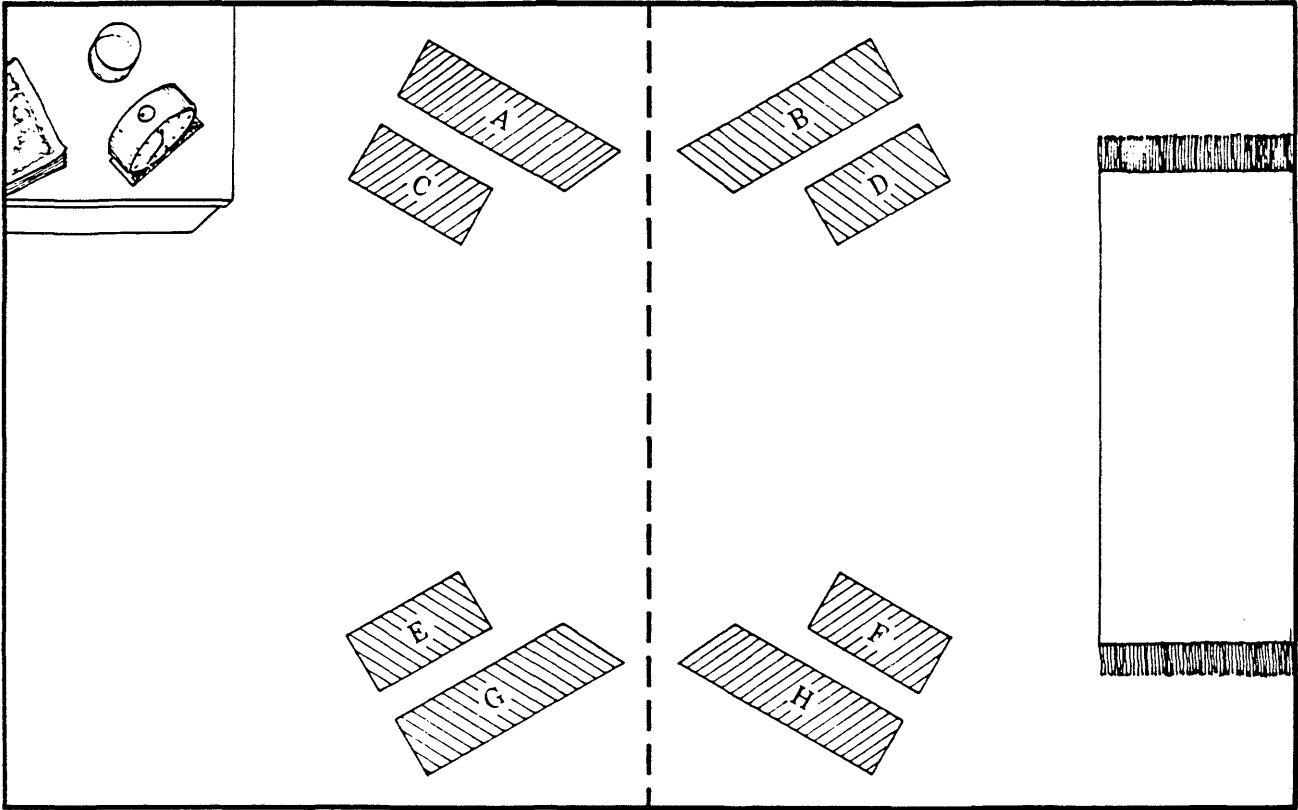
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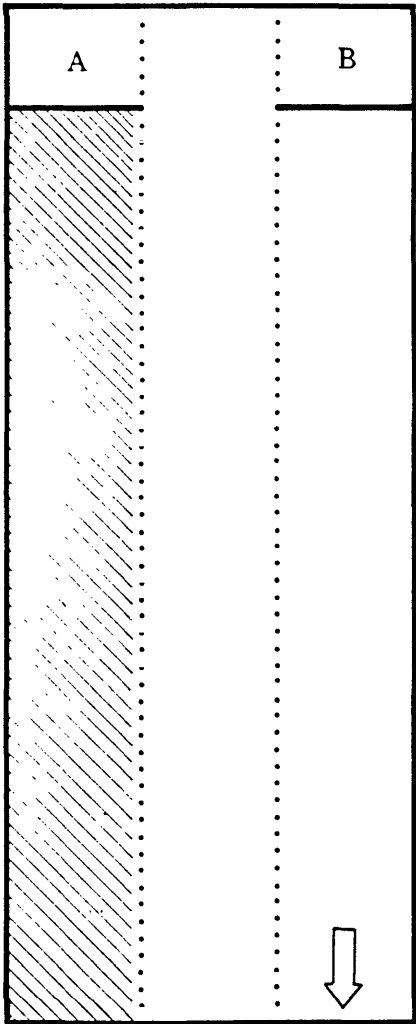
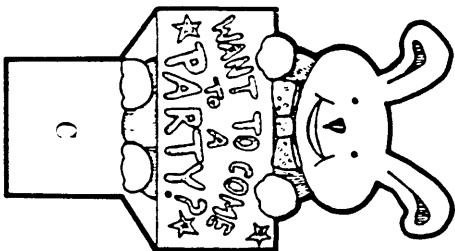
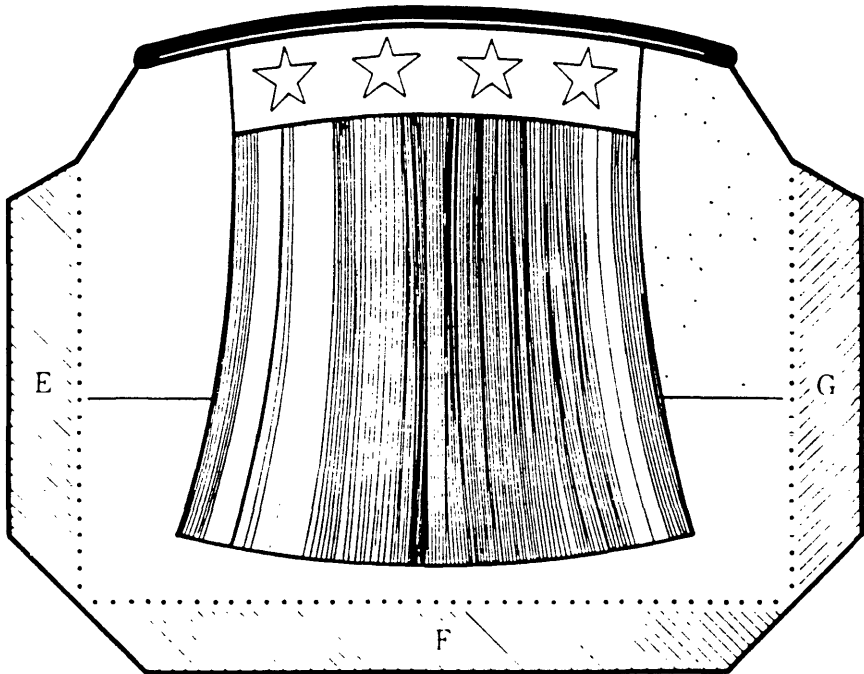
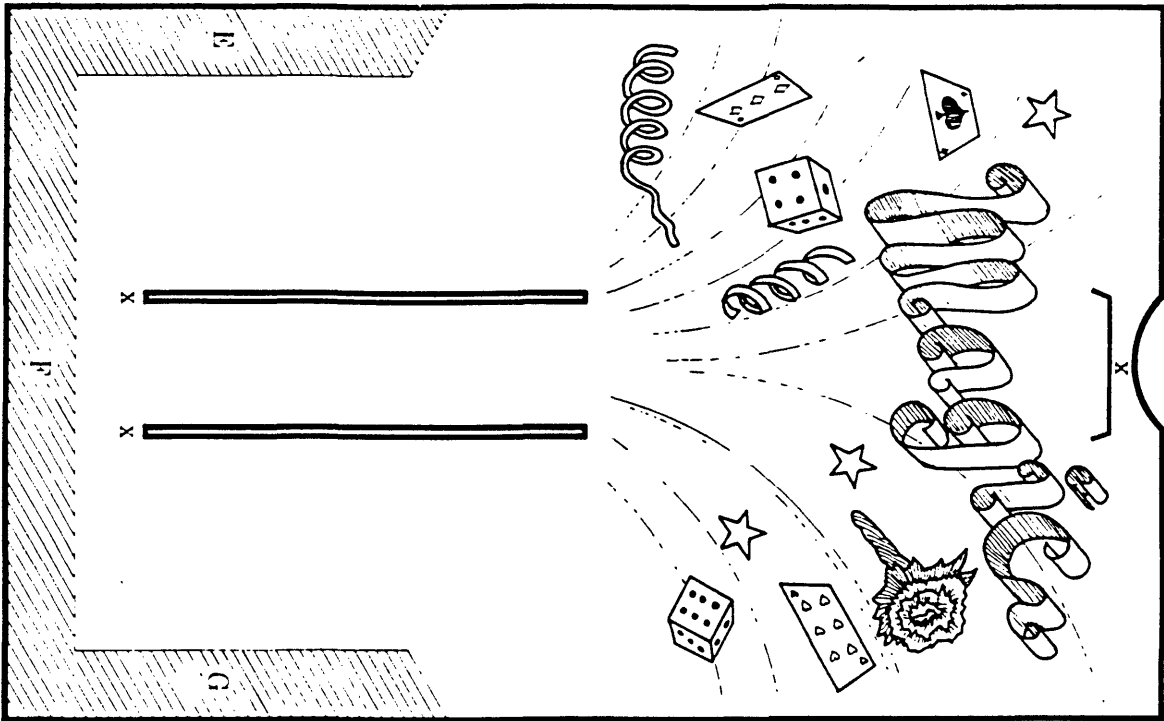
# 14. The Settling Butterfly



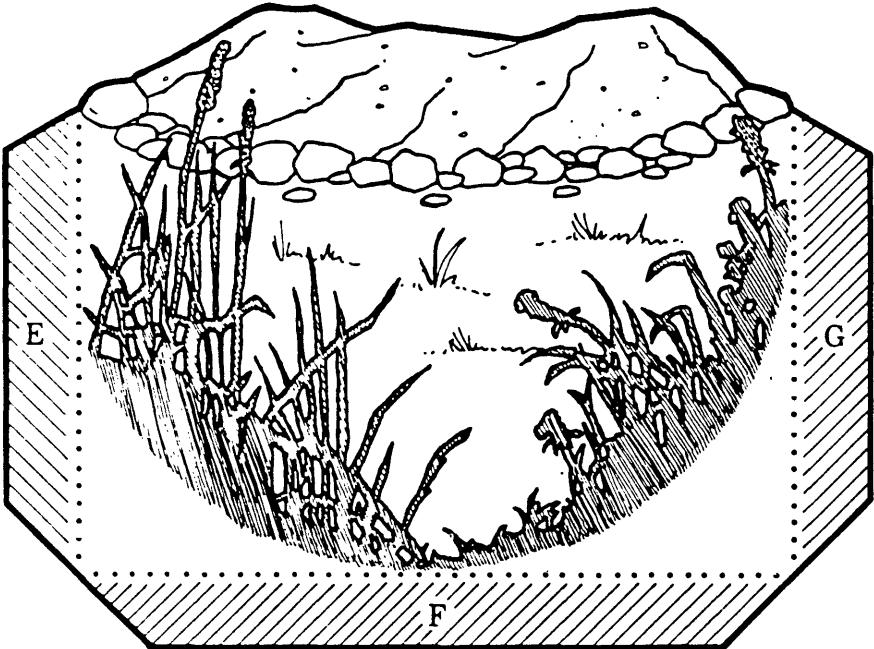
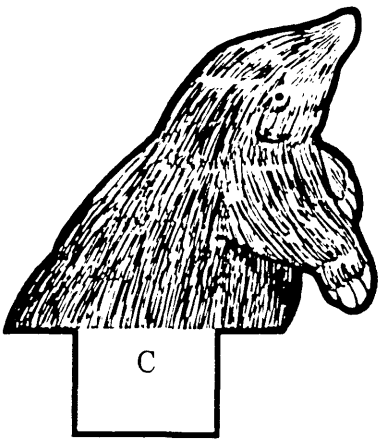
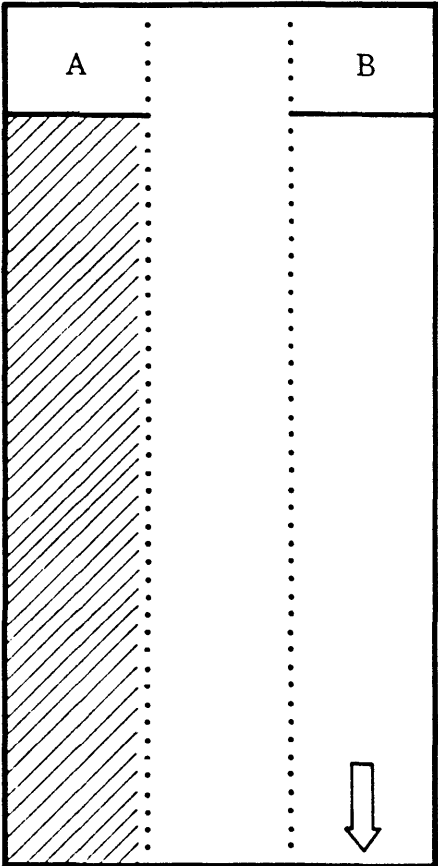
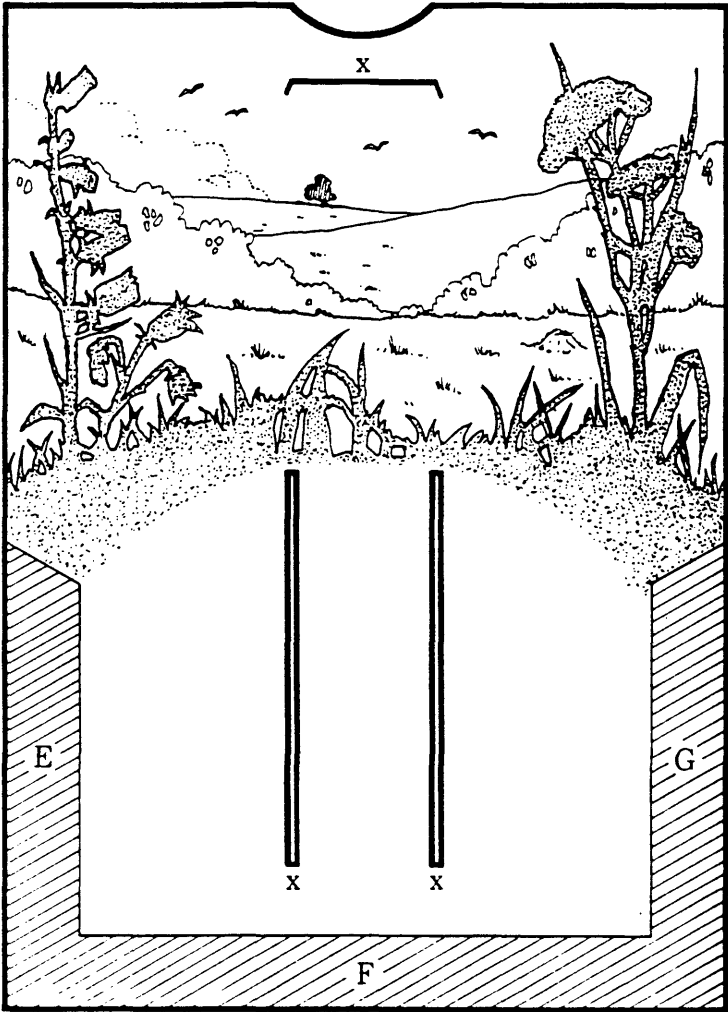
15. "Rise and Shine!"



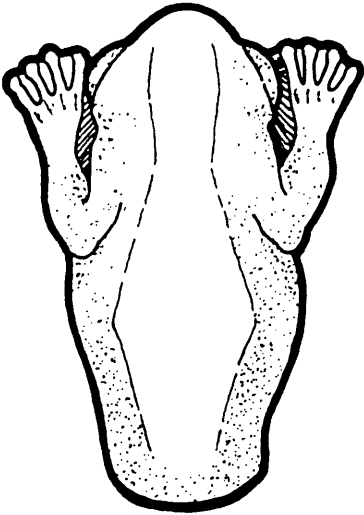
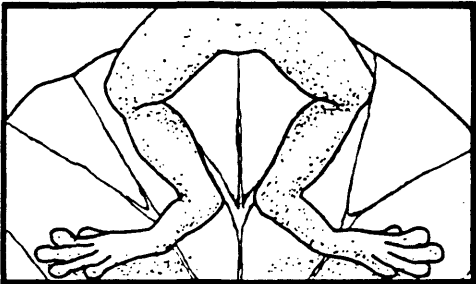
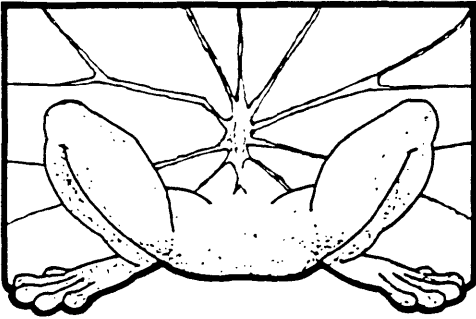
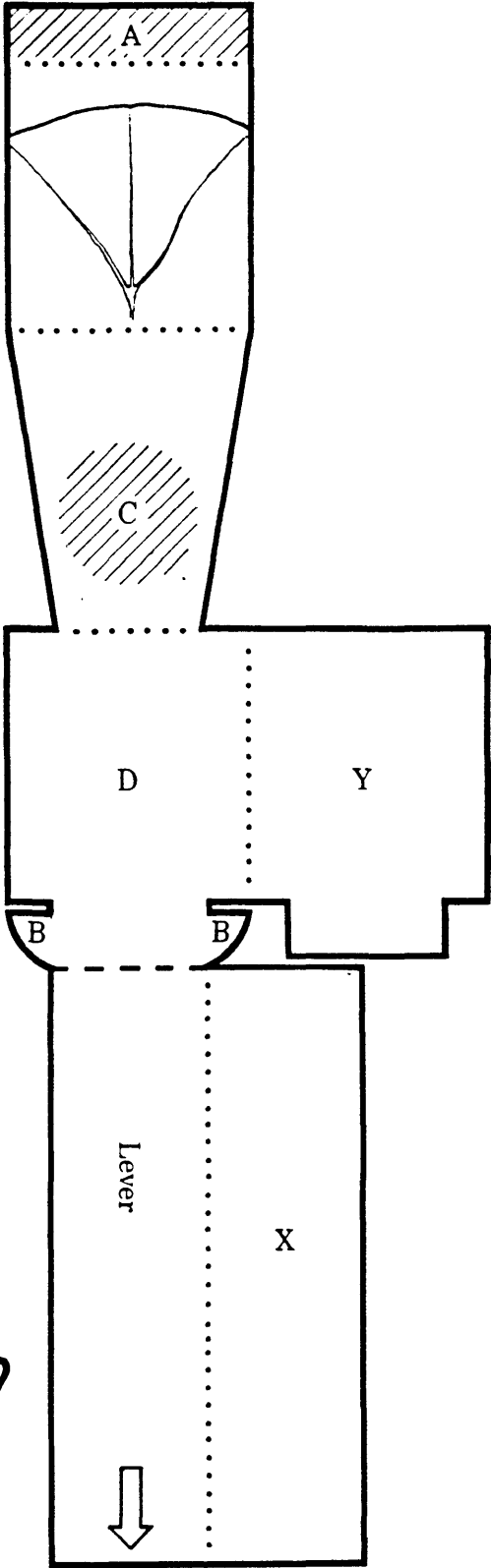
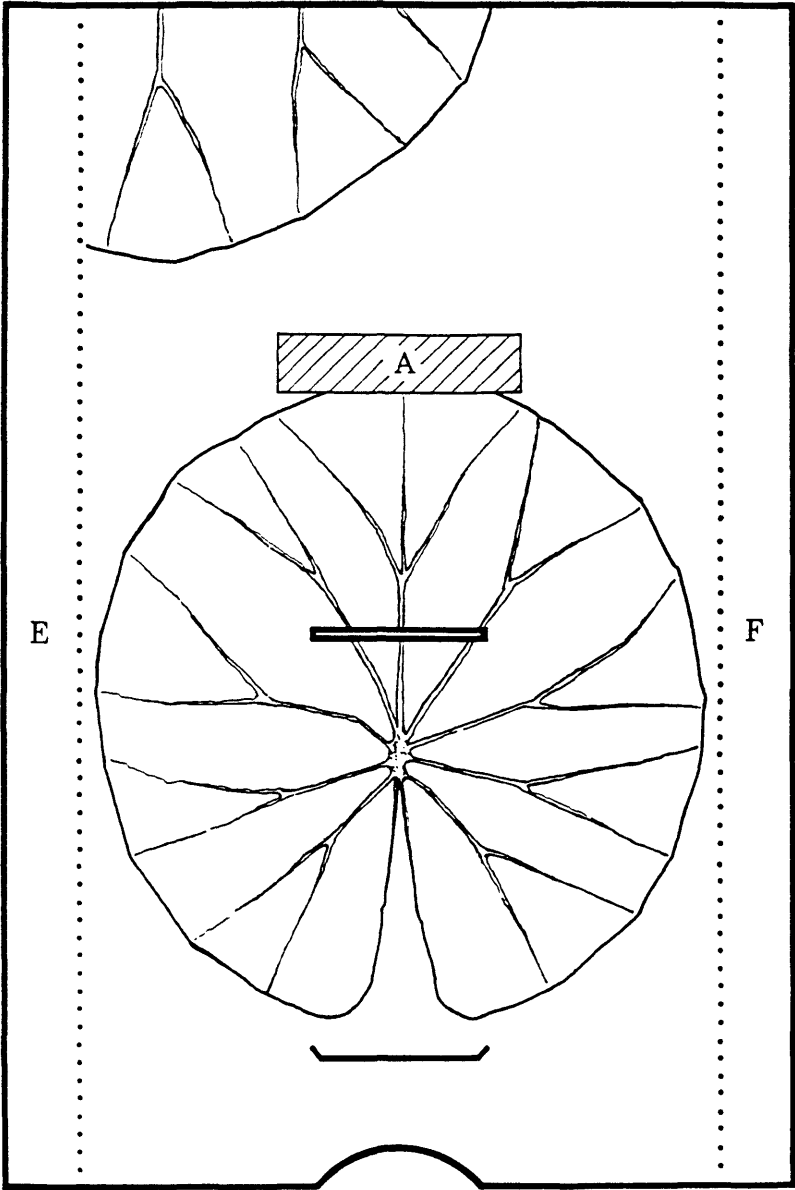
16. The Magic Rabbit



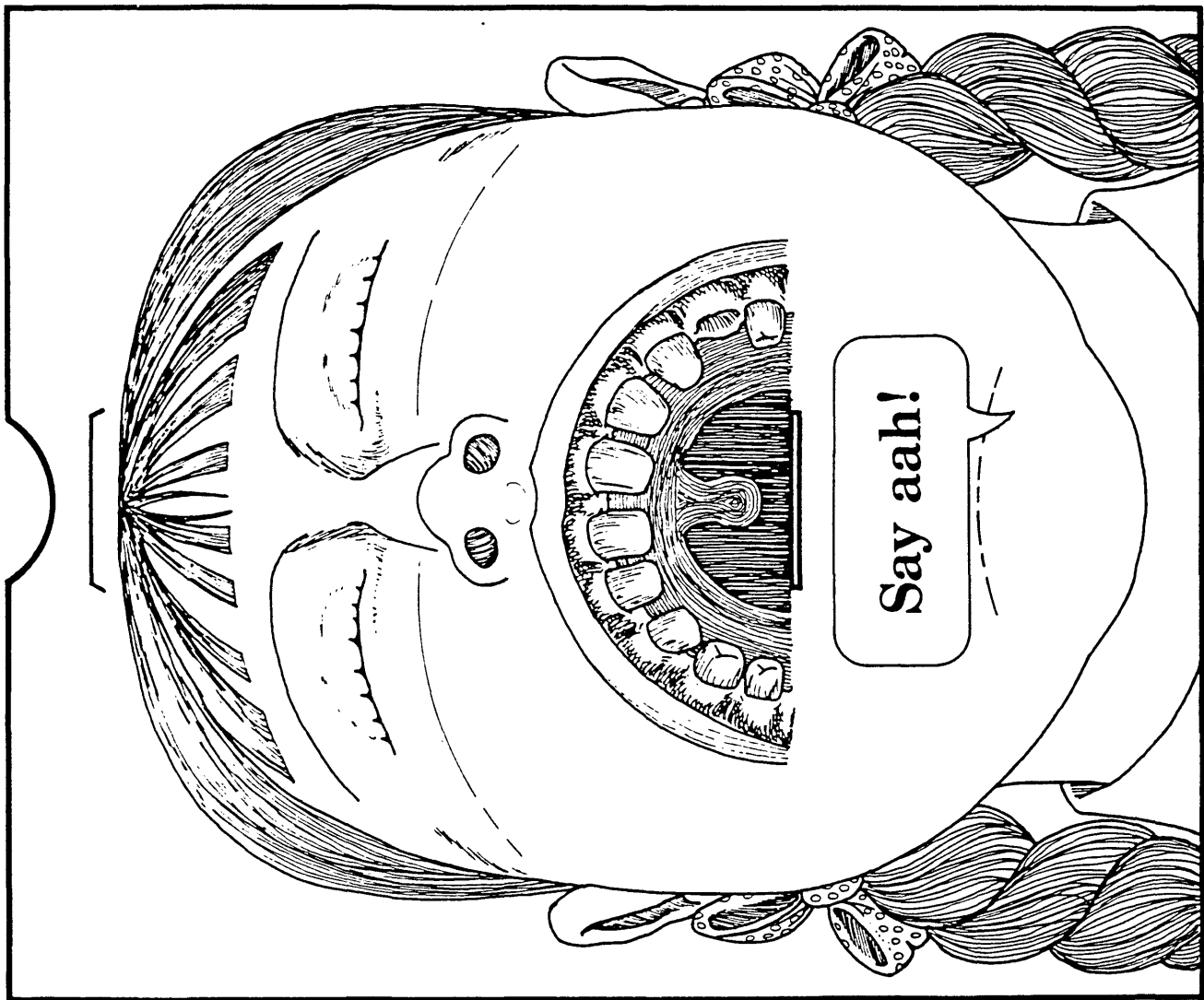
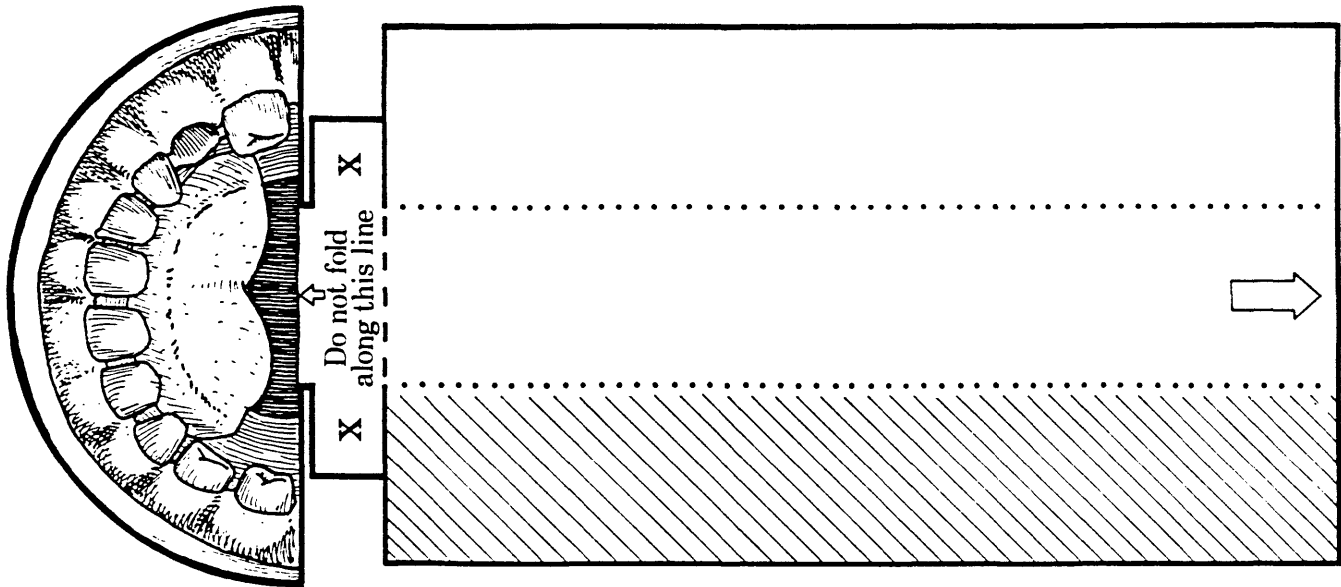
17. The Mole



# 18. The Frog

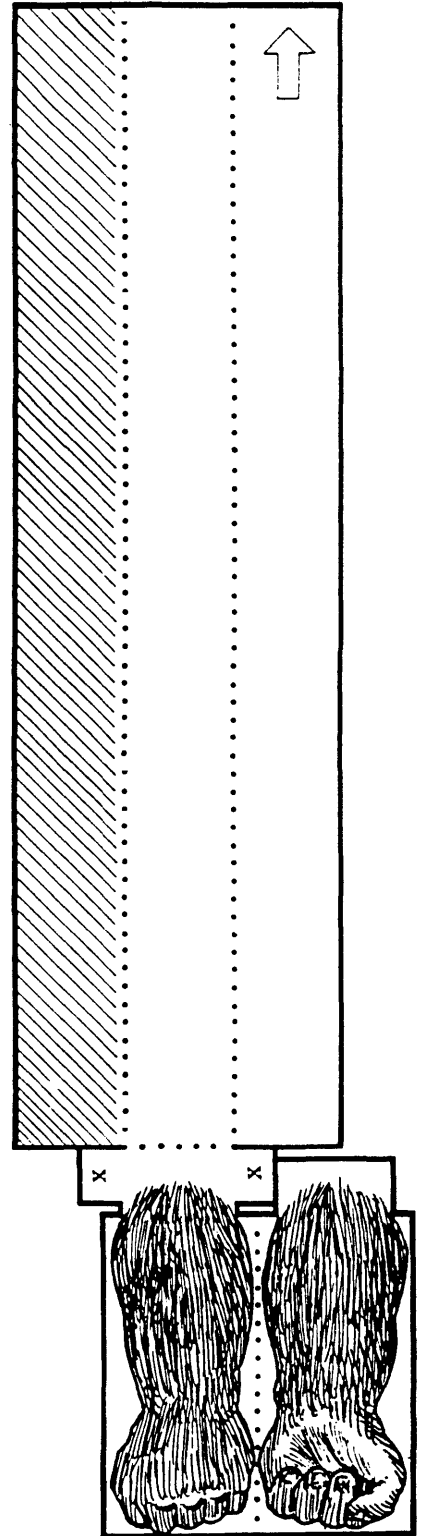
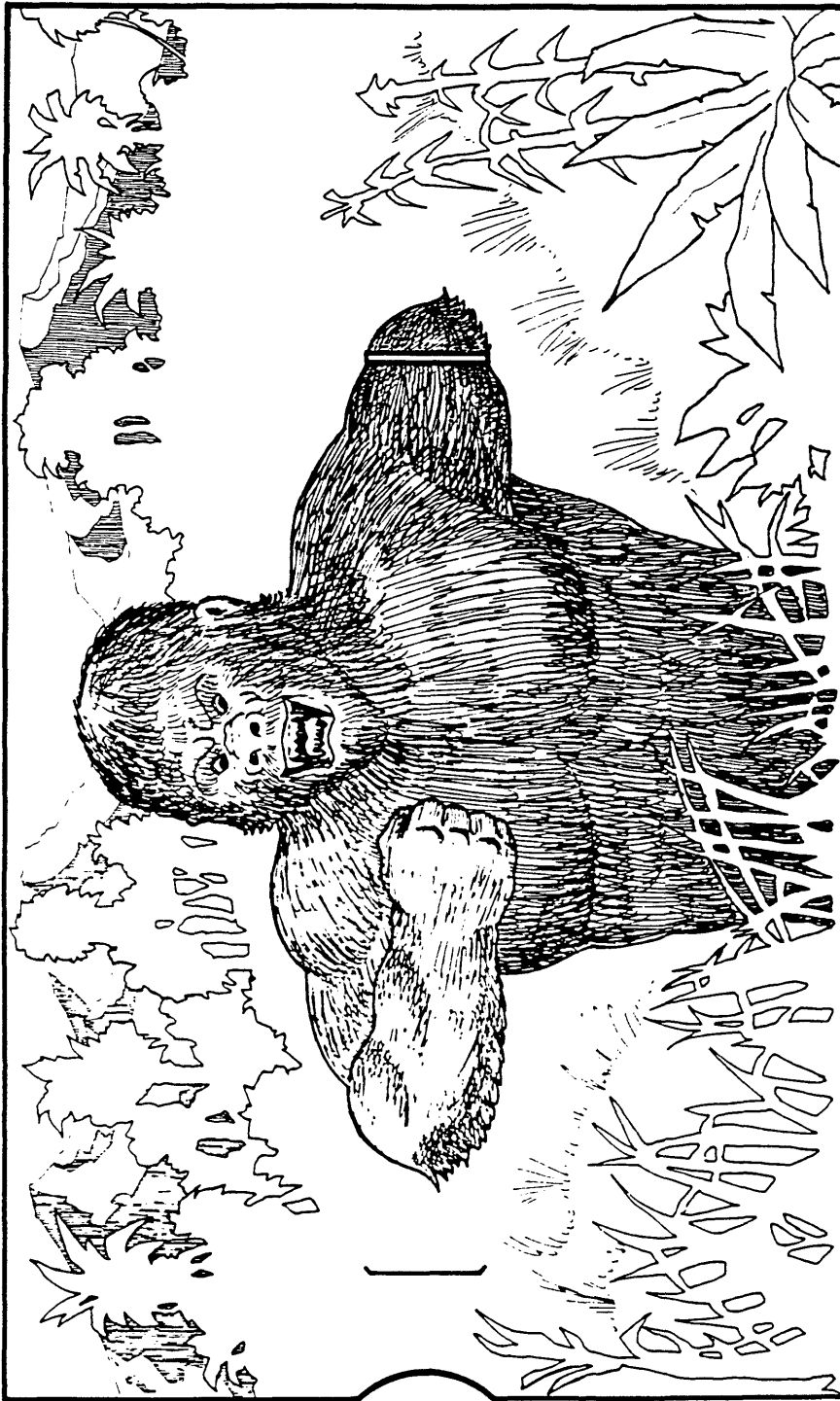


19. "Say aah!"

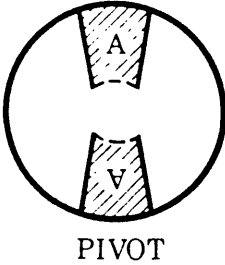
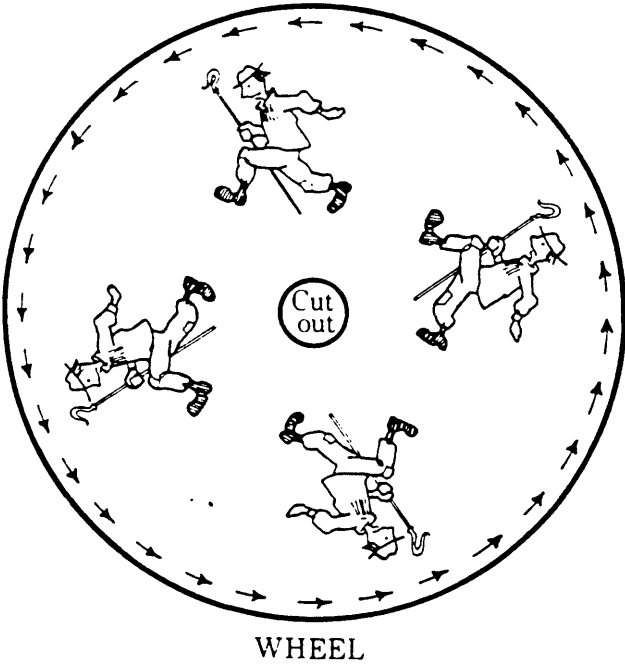
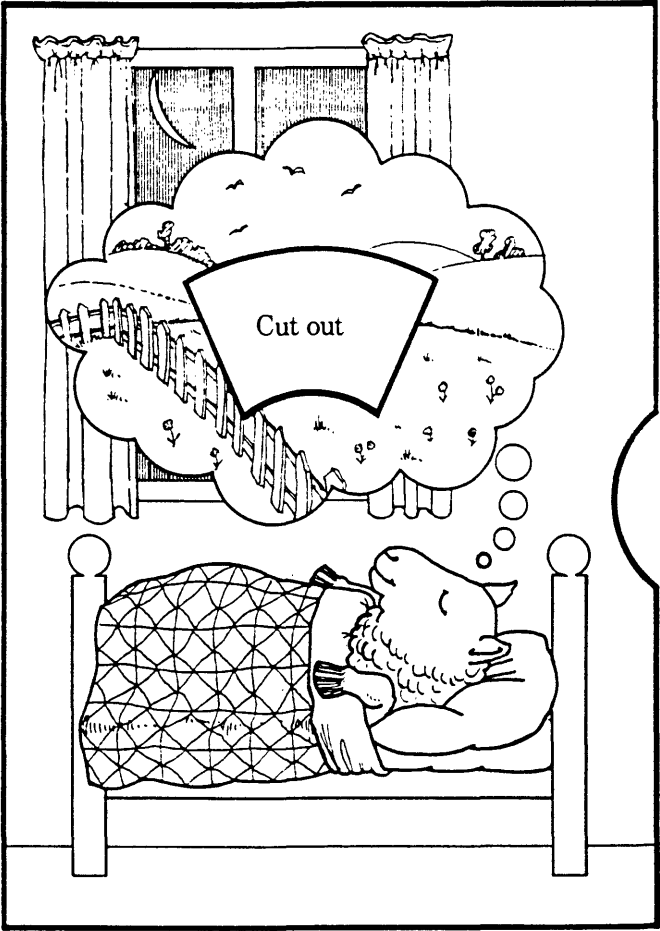
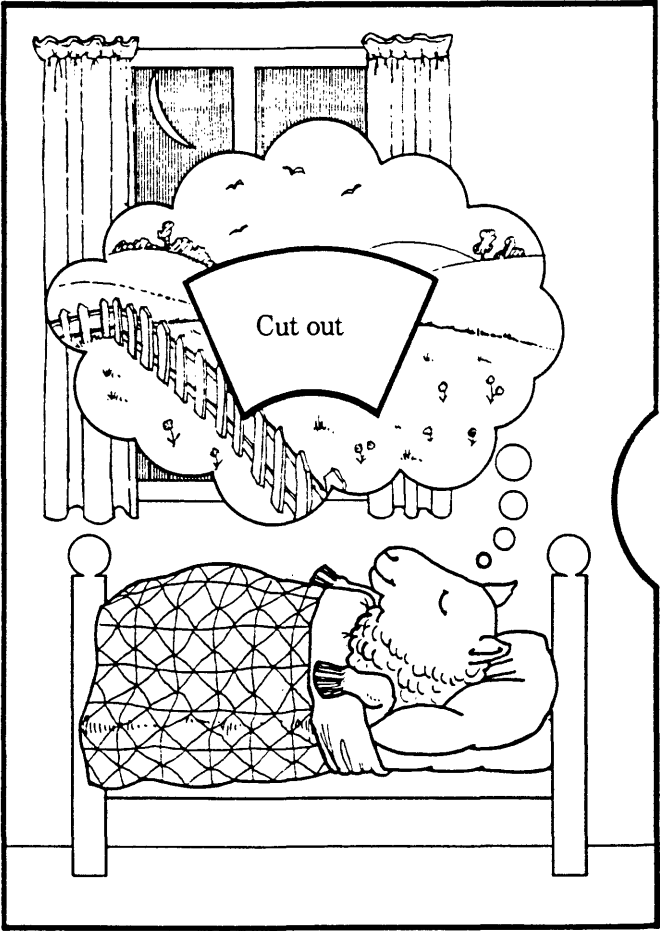
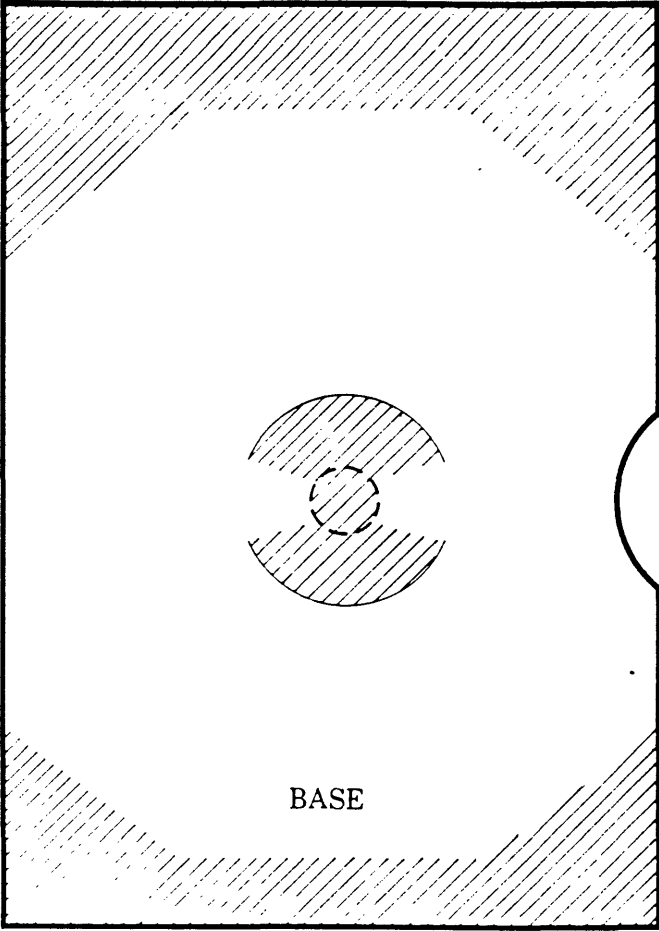




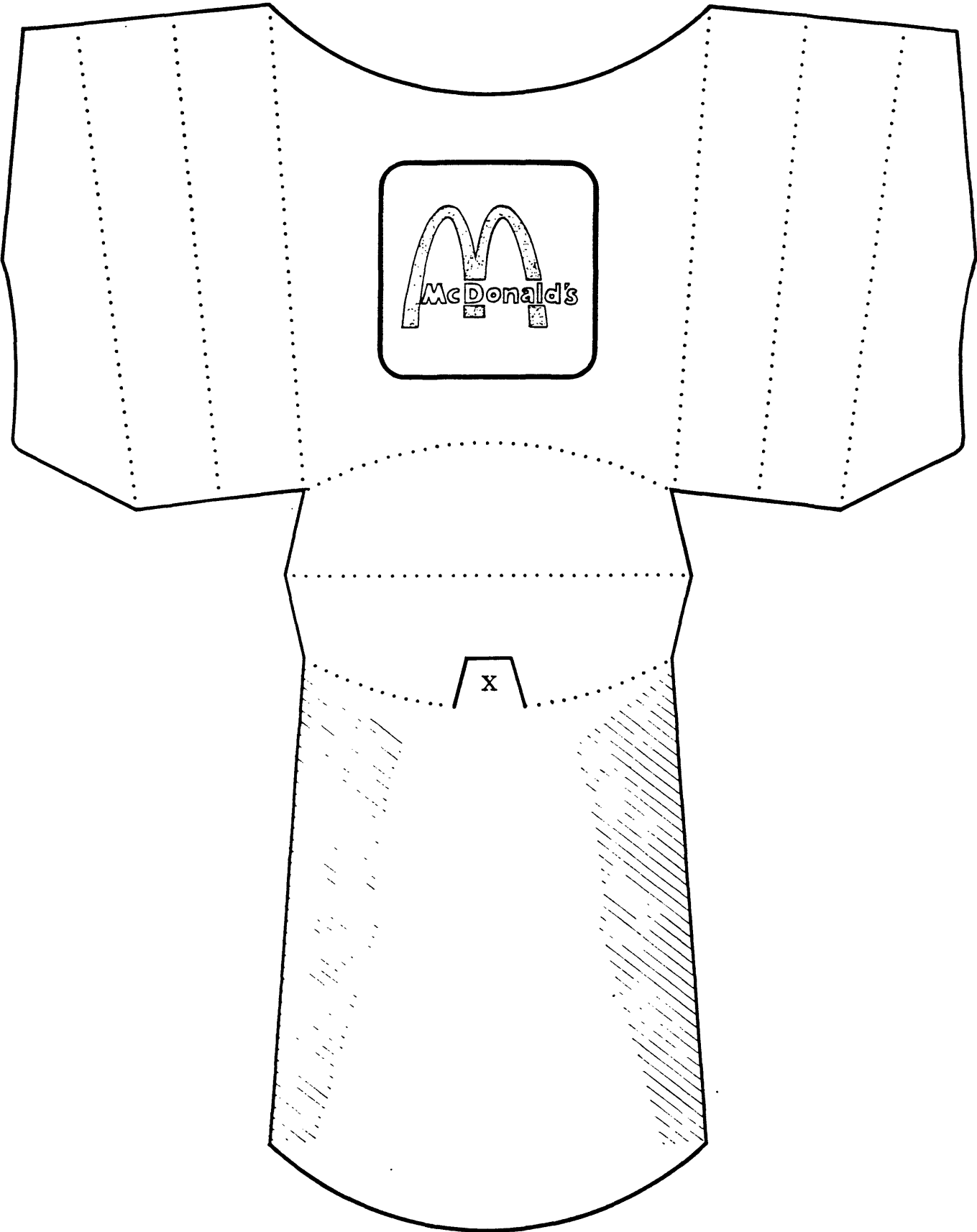
## 20. The Gorilla



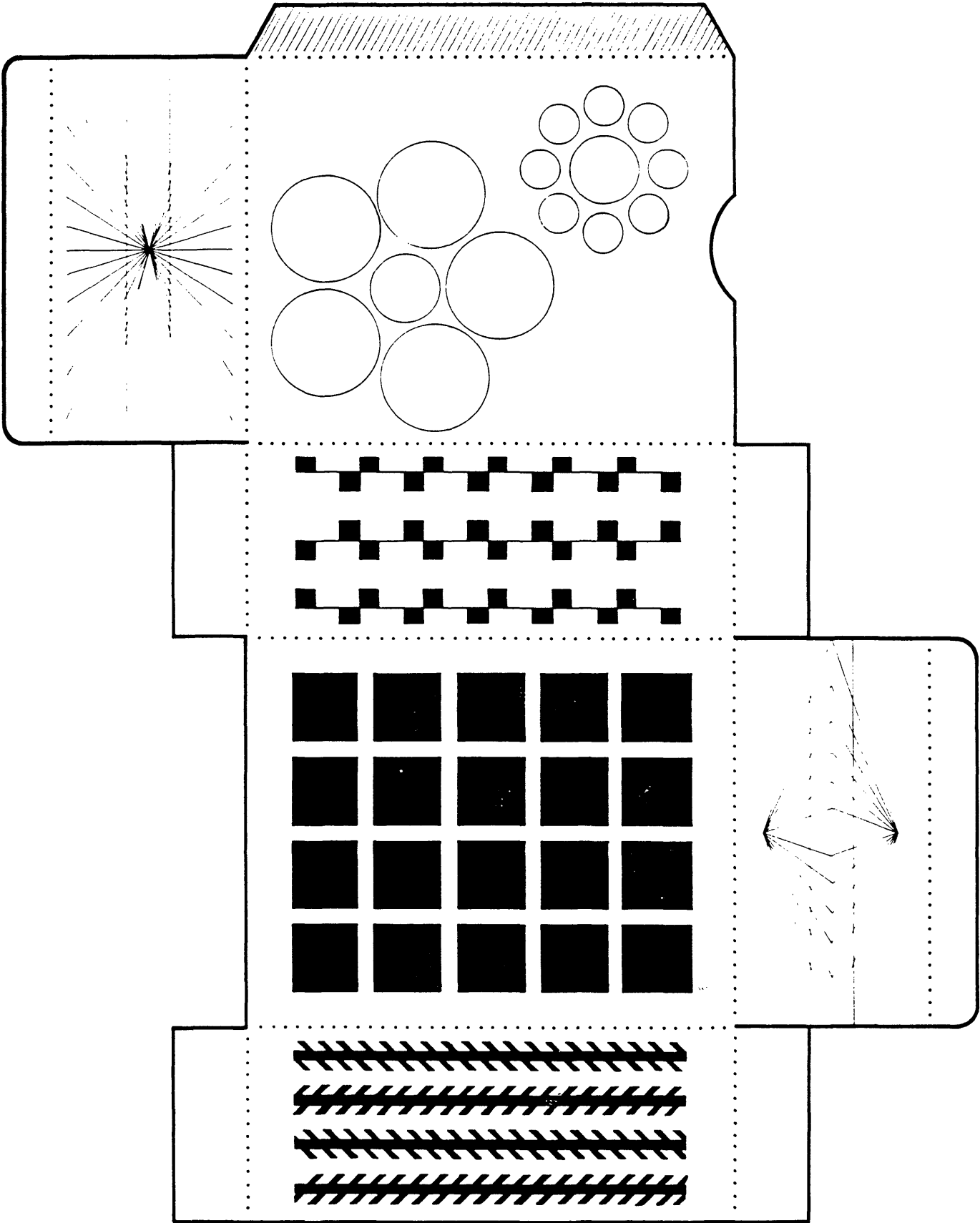
# 21. The Sleeping Sheep



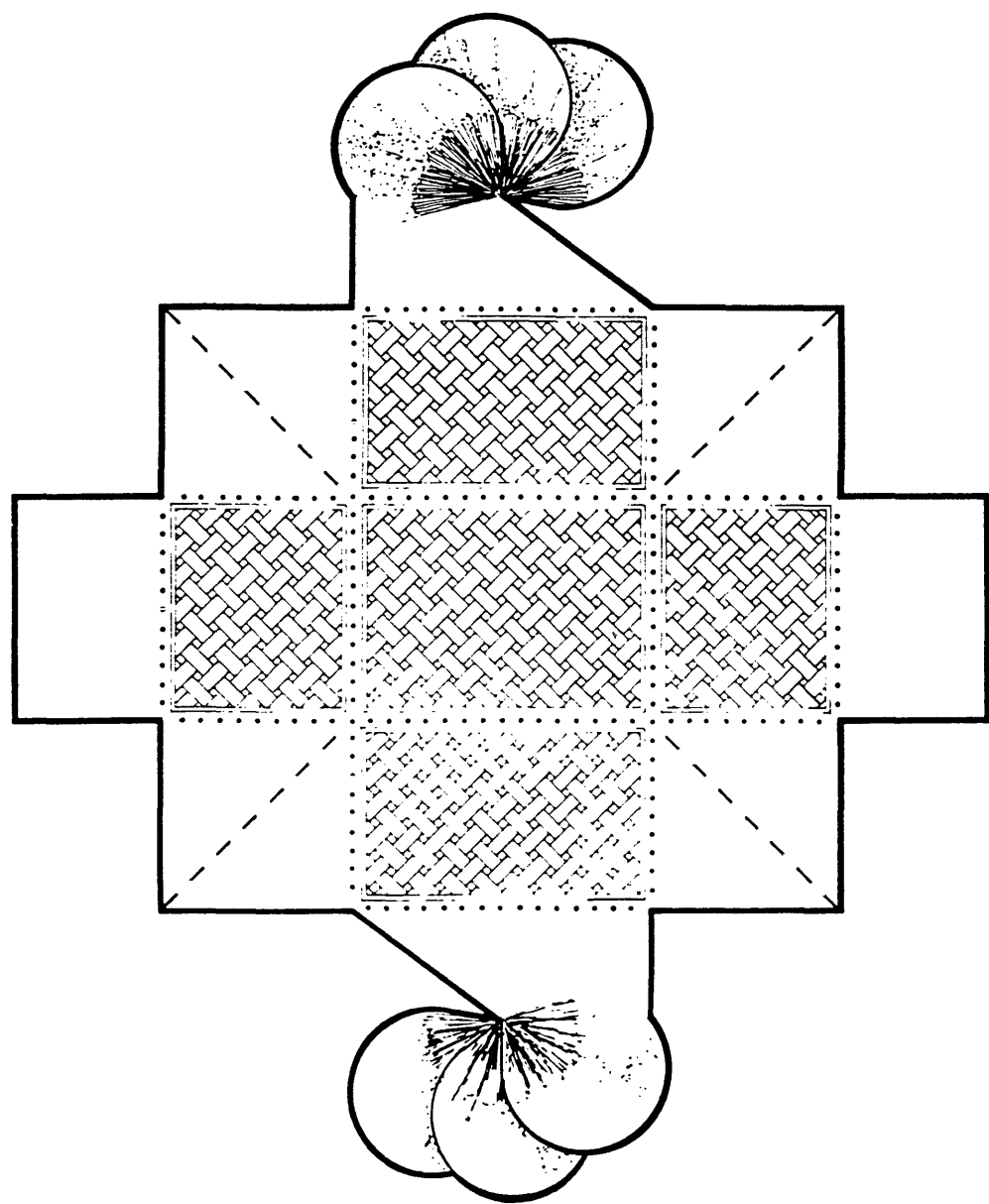
# 22. The French Fries Container



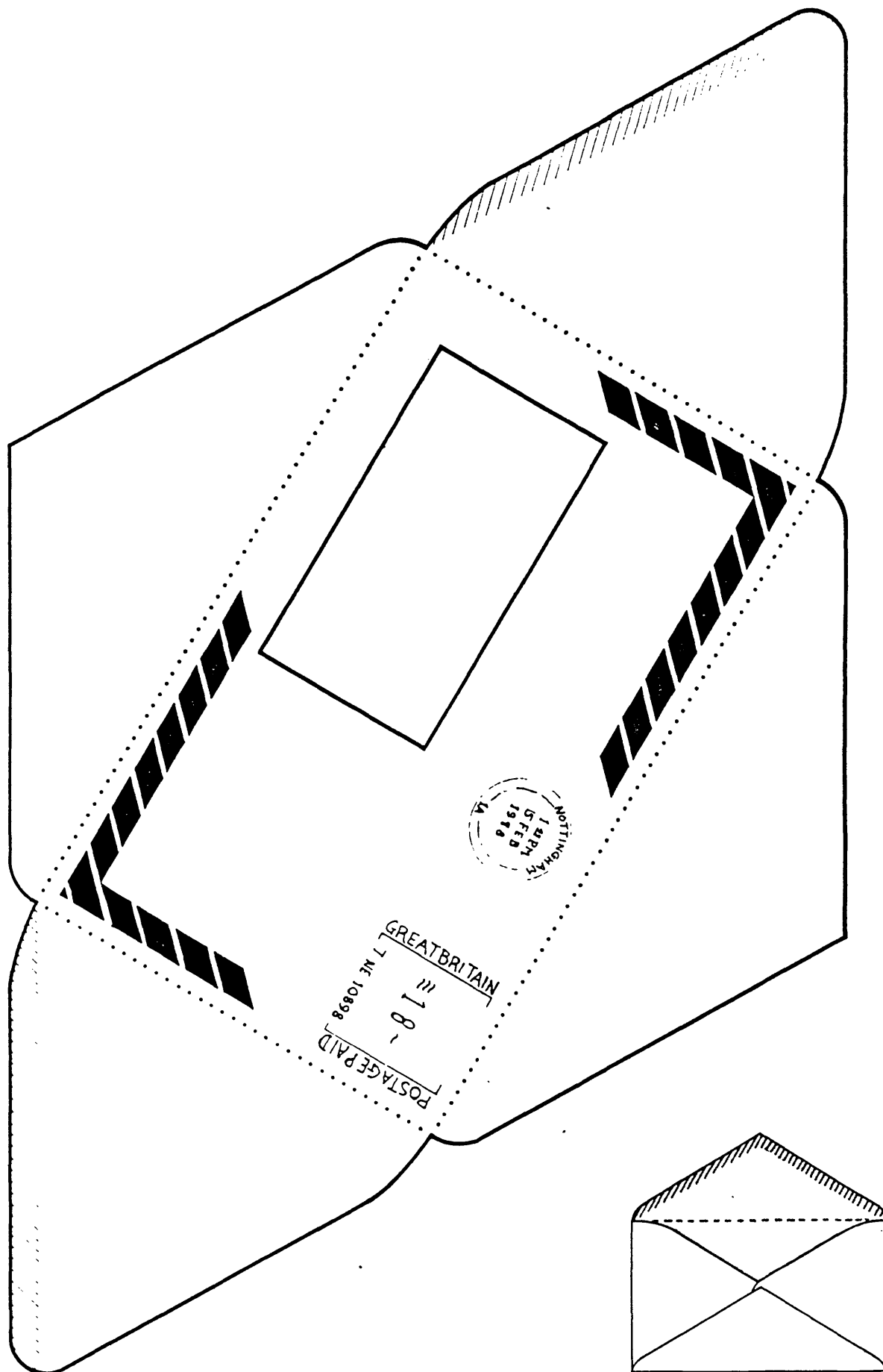
23. The Box of Tricks



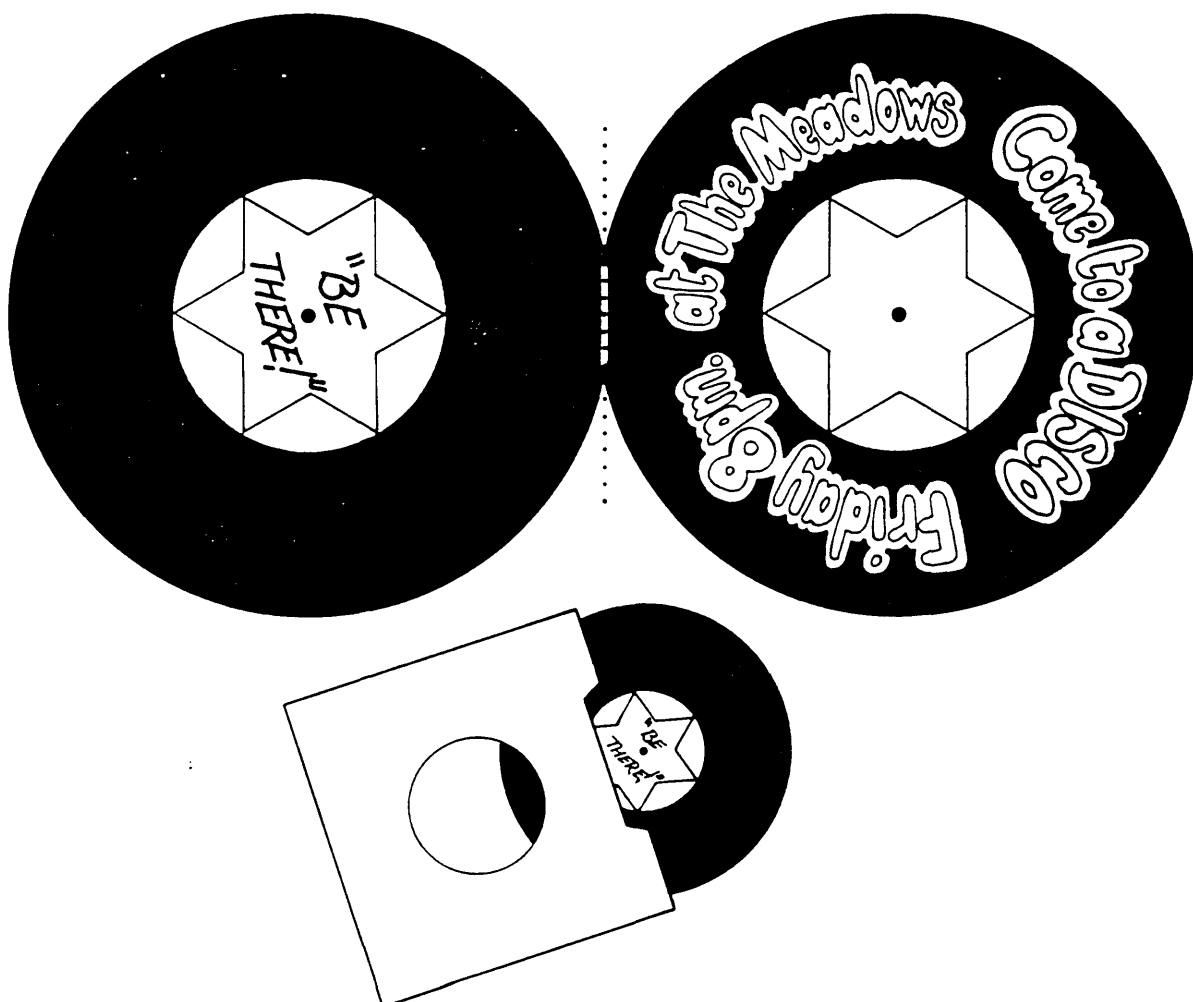
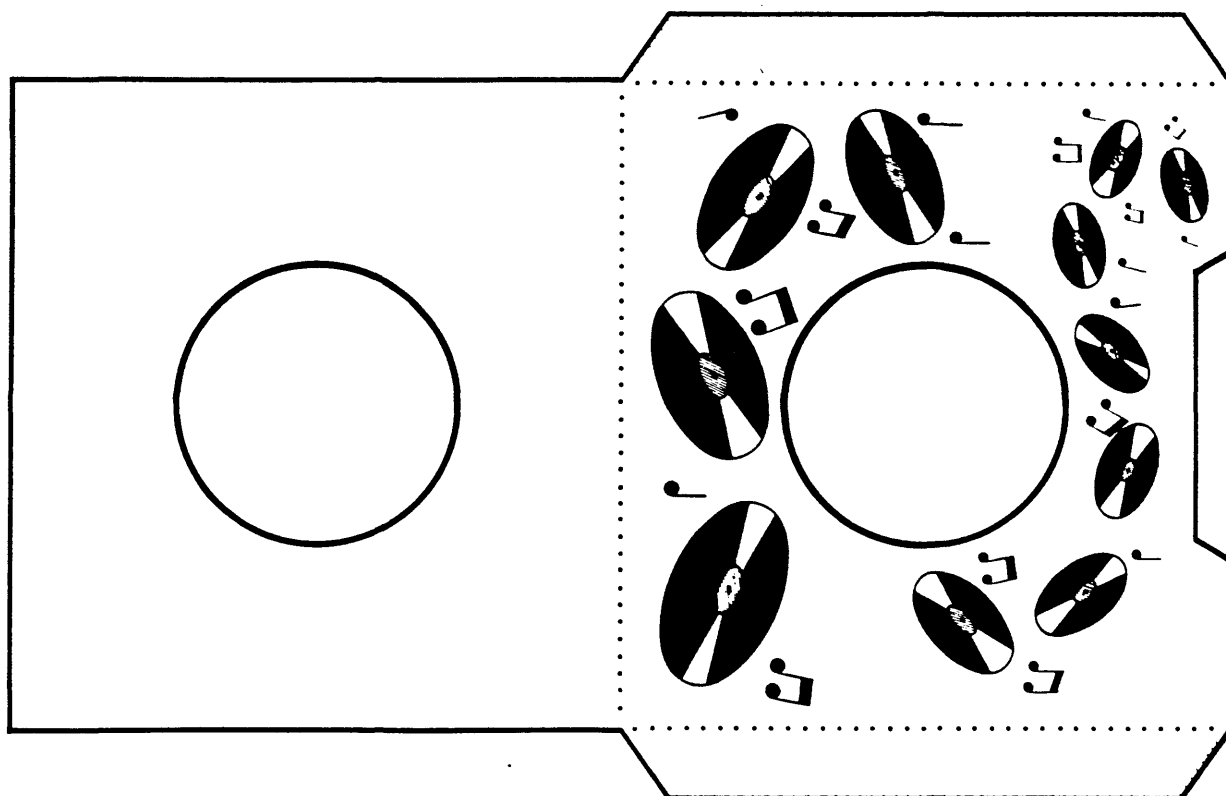
# 24. The Flower Box



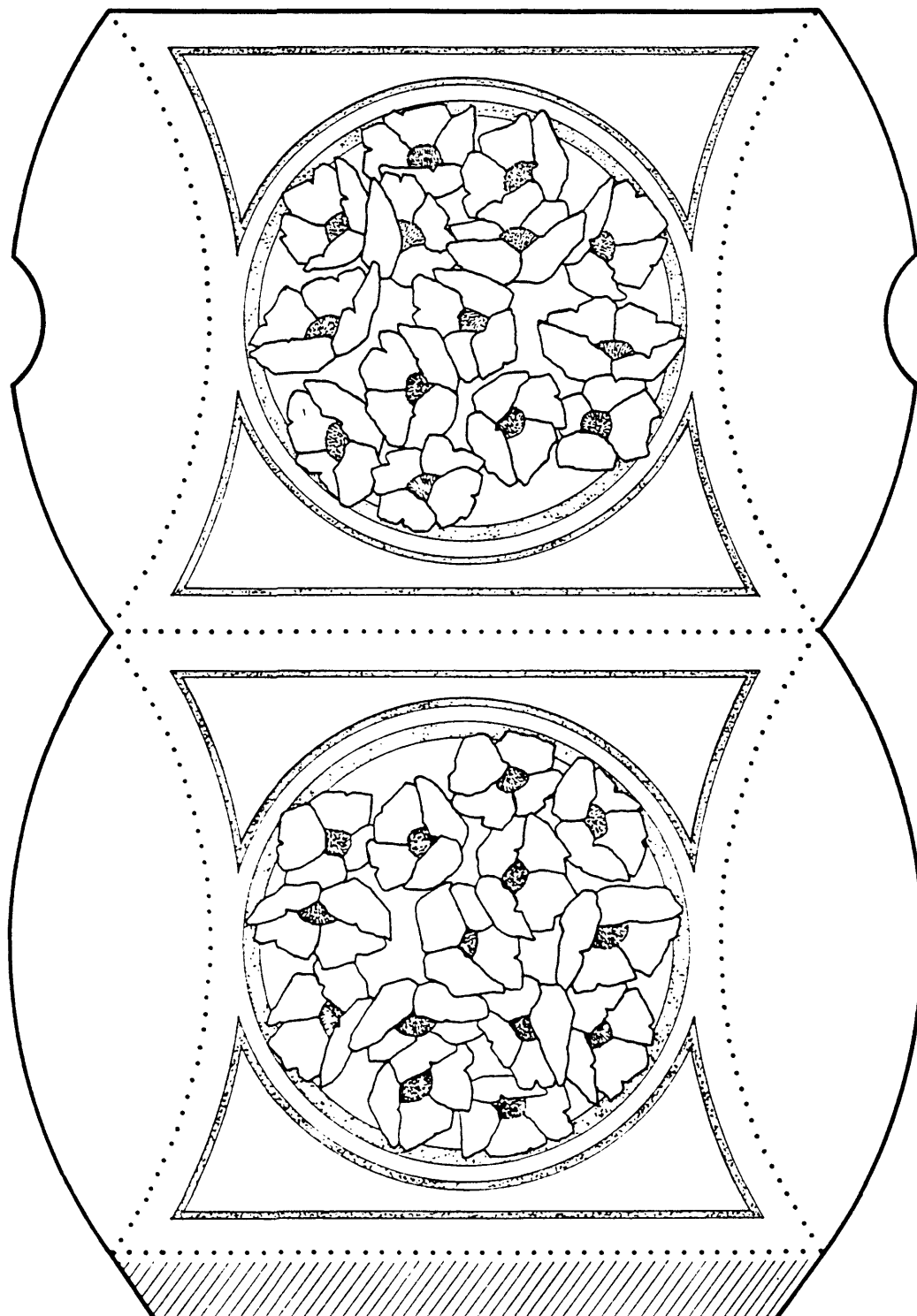
## 25. The Window Envelope



## 26. A Disco Invitation

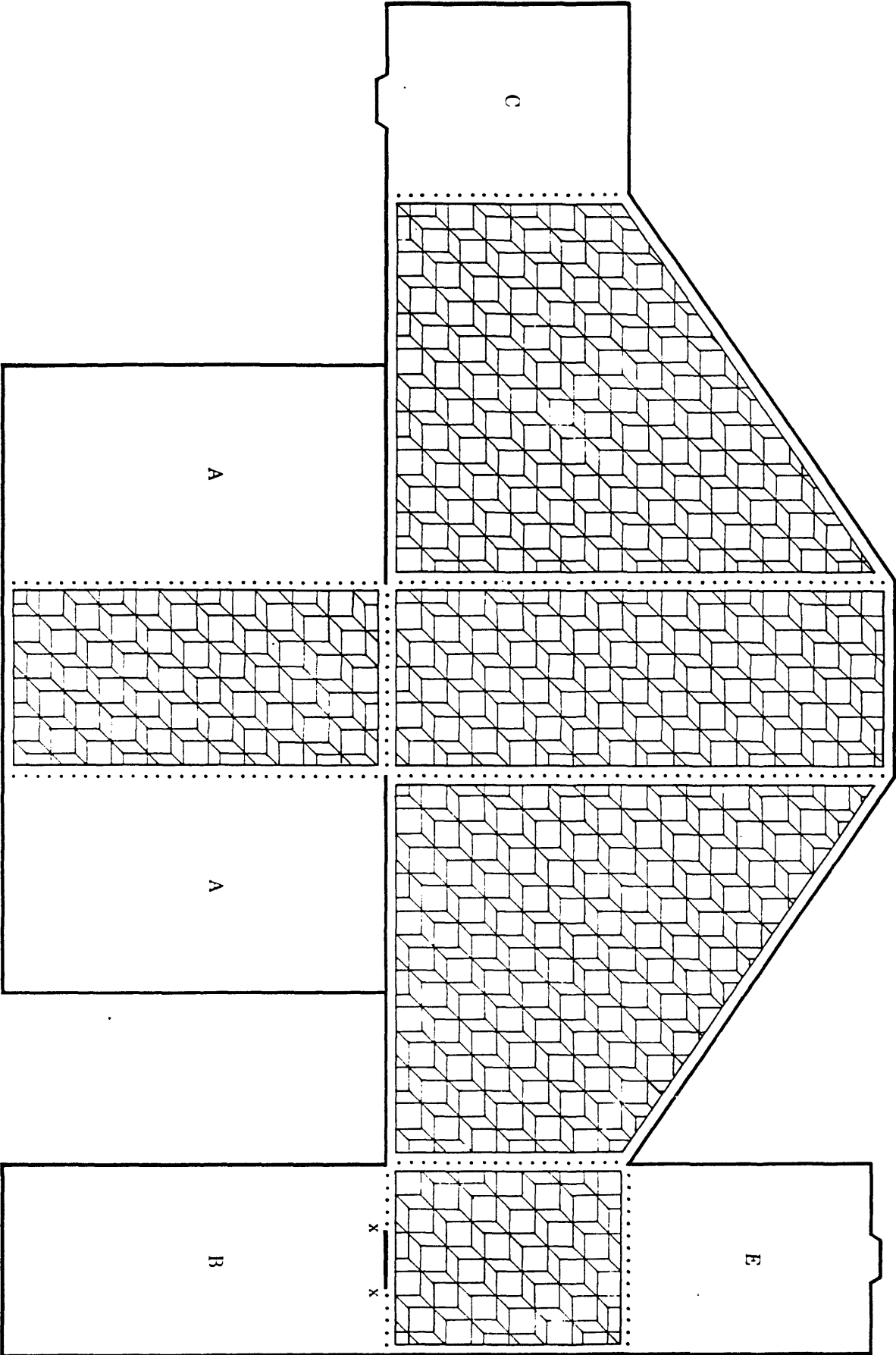


# 27. The Pillow Box

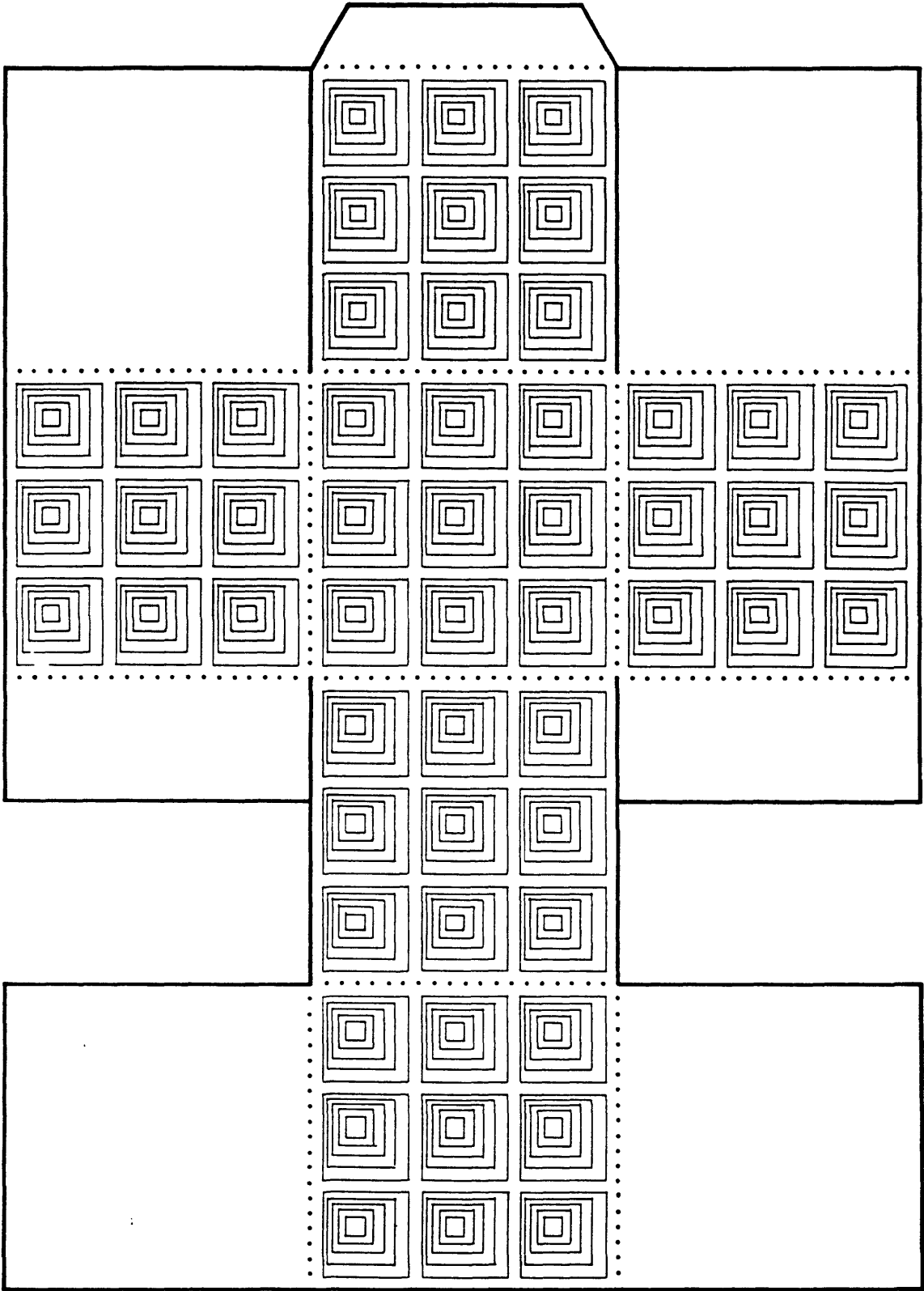




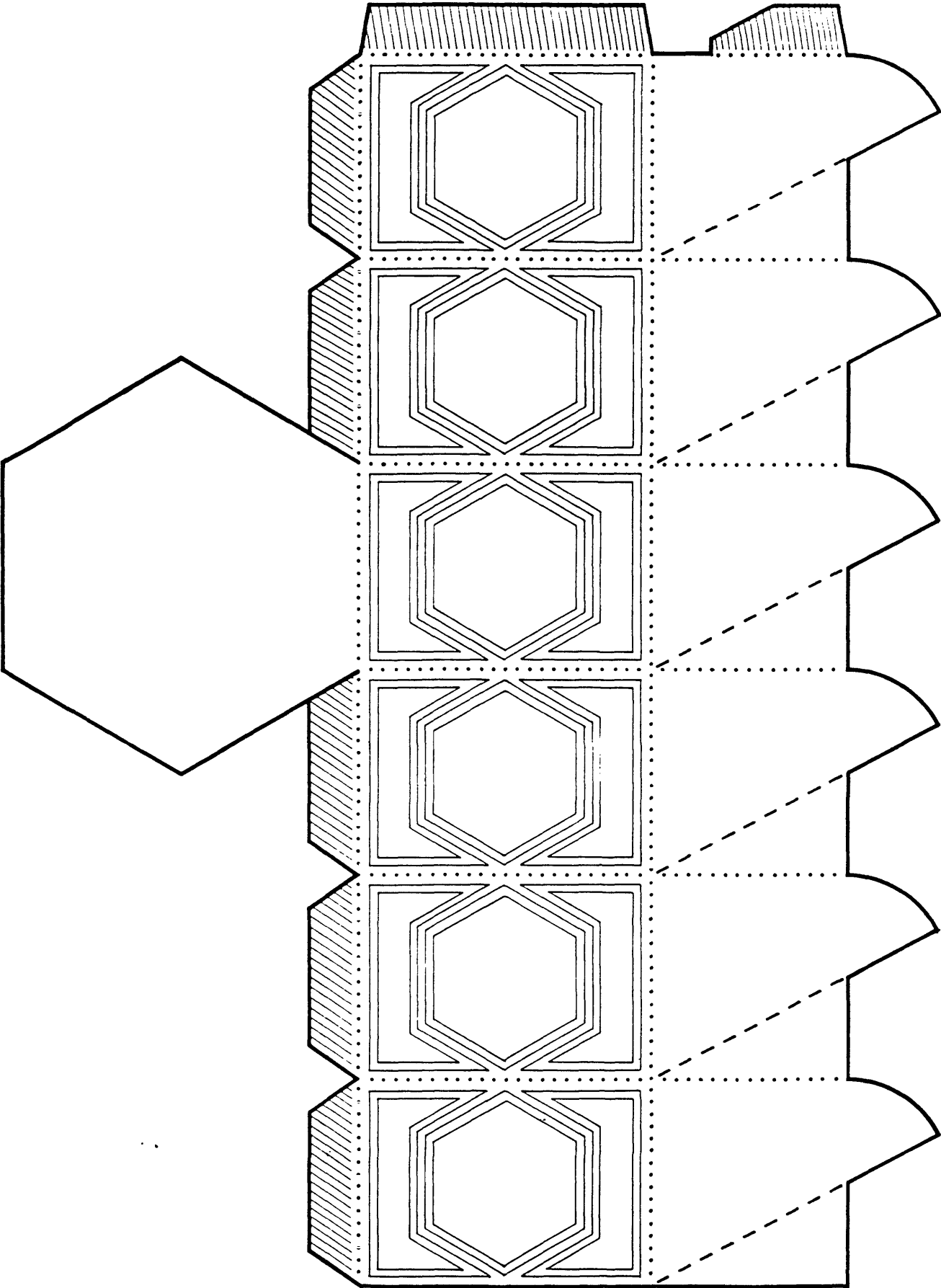
28. The Library Box



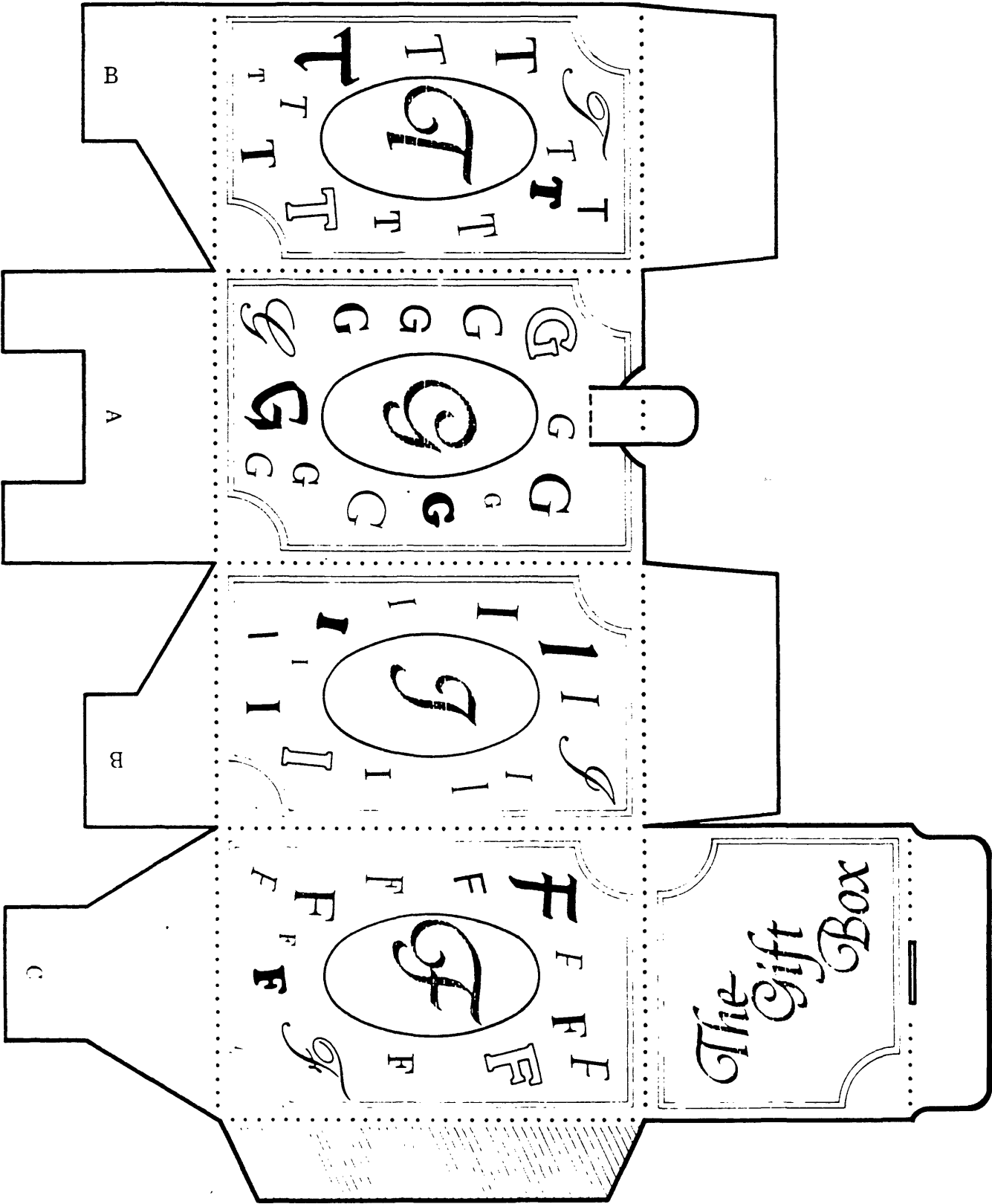
29. A Cube



30. A Hexagonal Box



31. The Gift Box





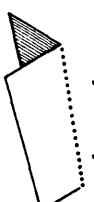



# Stage 1 Instructions pack

This pack contains all the instructions on how to make the cards, boxes and envelopes.

## Contents

- |                            |                                |
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| 1. The Cat*                | 17. The Mole                   |
| 2. The Birthday Envelope*  | 18. The Frog                   |
| 3. The Pop Star            | 19. "Say aah!"                 |
| 4. The Rolls Royce         | 20. The Gorilla                |
| 5. The Indian Palace       | 21. The Sleeping Sheep         |
| 6. Staircase and Pillars   | 22. The French Fries Container |
| 7. Frankenstein            | 23. The Box of Tricks          |
| 8. A Barbecue Invitation   | 24. The Flower Box             |
| 9. The Flying Kite         | 25. The Window Envelope        |
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| 11. The Dove of Peace      | 27. The Pillow Box             |
| 12. The Ghost              | 28. The Library Box            |
| 13. A Street Scene         | 29. A Cube                     |
| 14. The Settling Butterfly | 30. A Hexagonal Box            |
| 15. "Rise and Shine!"      | 31. The Gift Box               |
| 16. The Magic Rabbit       |                                |

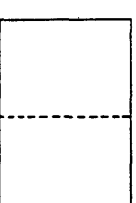
\* Instructions for the Cat and the Birthday Envelope are in the Student's Booklet on pages 4 and 5.

	Cutting line	You should only cut along thick black lines
	Hill fold	Fold away from you: 
	Valley fold	Fold towards you: 
	Glue	Put glue only on parts that are shaded.

## Some useful words:

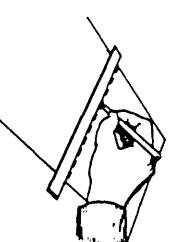
**"Base"** – this means the bottom of the box, or the back of the card. (It's usually the part that lies on the desk while you're making it.)

**"Centre-fold"** – this is the name given to the main fold line down the middle of a card.



**"Score"** – this means draw over the fold lines with a blunt point like a ballpoint pen. This makes the paper easier to fold. Use a ruler to keep your scoring straight.

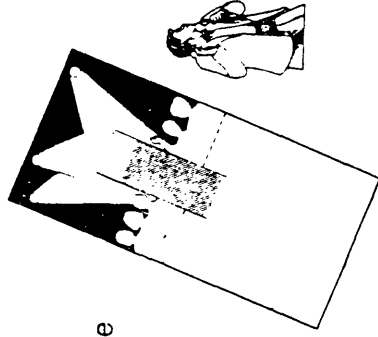
Always press your folds to make sharp creases.



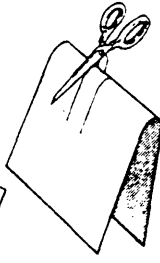
### 3. The Pop Star

Cut out the base of the card and the figure of the singer.

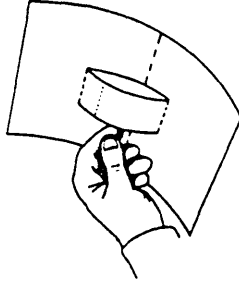
Score along each of the fold lines.



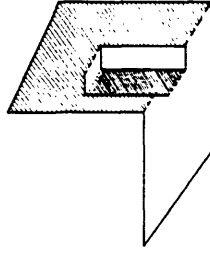
Make the two cuts in the middle of the base.



Lift the middle of the card with your finger and press along all the fold lines.

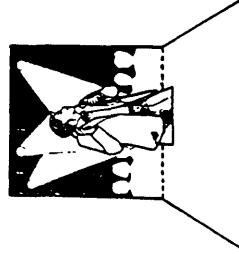


Now close the card and press it flat.

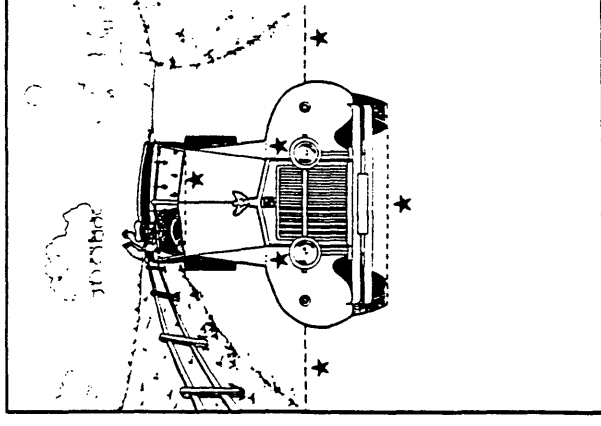


Open it out and glue the figure onto the shaded area.

As you open the card, the singer should pop-up!



### 4. The Rolls Royce



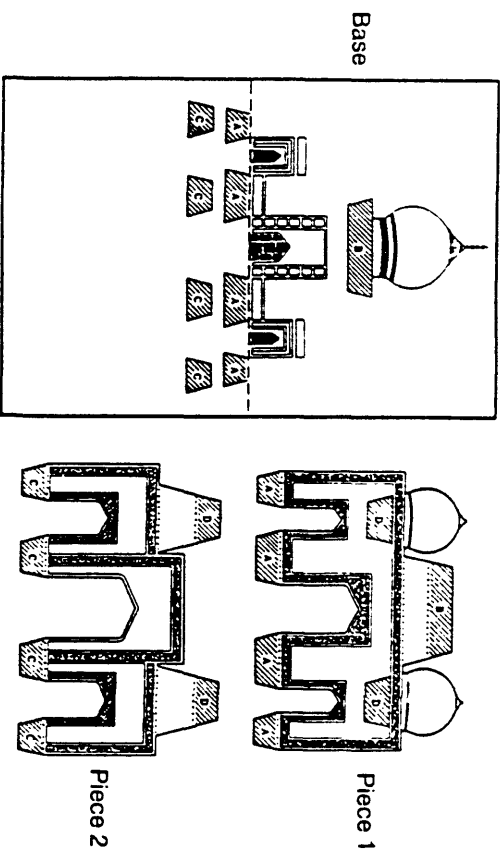
Cut out the base.

Score along the six fold lines marked\*.

Cut along the sides of the car and along the top of the bonnet.

Lift out the middle and fold the card in half to make the car stand out.

## 5. The Indian Palace



Cut out the base, fold it in half, and open it up again.

Cut out piece 1 and make the six hill folds.

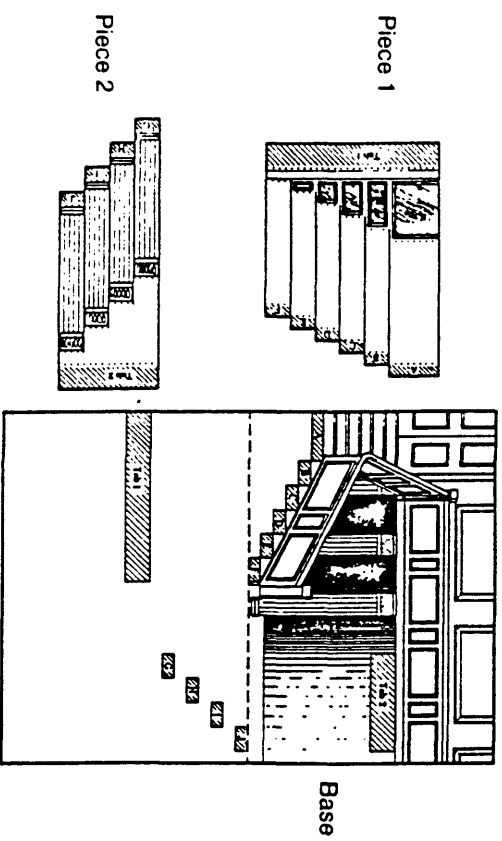
Match up tabs A and B to the base and glue them in place.

Close the card so that the piece folds forward. Press it flat and then open it again to check that it works.

Cut out piece 2, fold, match up tabs C and D and glue them in place.

Close the card and press it flat.

## 6. Staircase and Pillars



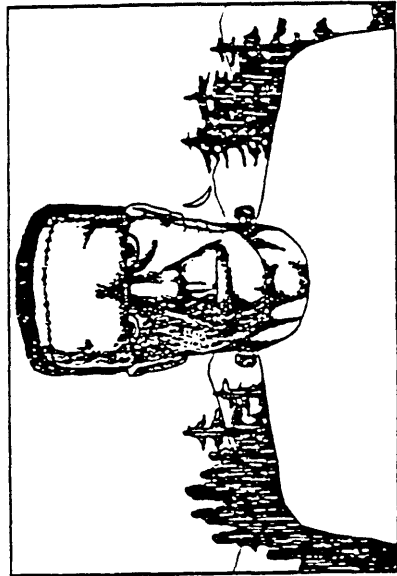
Cut out the base, fold it in half, and open it up again.

Cut out pieces 1 and 2. Make sure that you cut between *all* the steps and columns.

Make the folds and match the tabs to the base. Glue them in place.

Close the card so that both pieces fold forward. Press it flat.

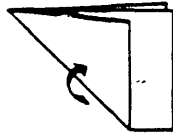
## 7. Frankenstein



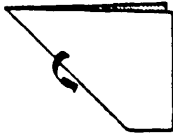
Cut round the base, then .....



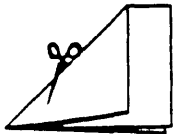
1. Fold it in half.



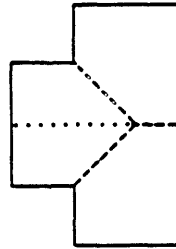
2. Fold corner forwards.



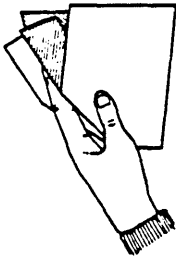
3. Fold corner backwards.



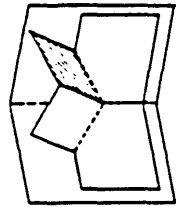
4. Cut corner off halfway down triangle.



5. Open out.

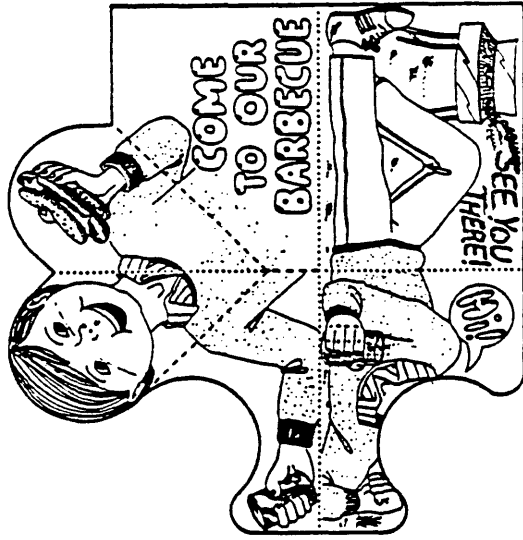


6. Push forward from behind.



7. Glue on to backing sheet.

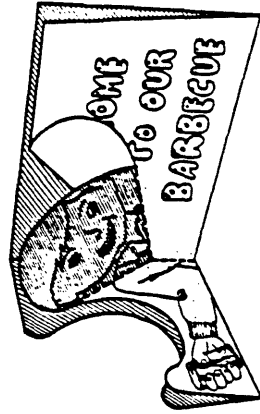
## 8. A Barbecue Invitation



Cut round the outline of the card.

Score along the fold lines.

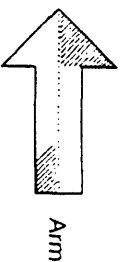
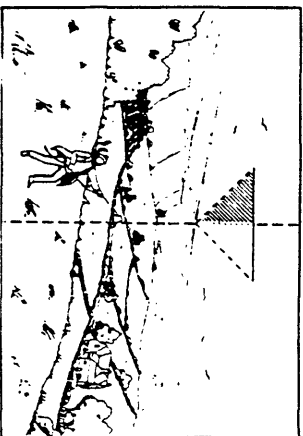
Fold along the fold lines, and then try to make the hill and valley folds go the right ways:





## 9. The Flying Kite

Base



Arm



Kite

Cut out the base and fold it in half.

Make the cut across the centre-fold and make the hill and valley folds on the base.

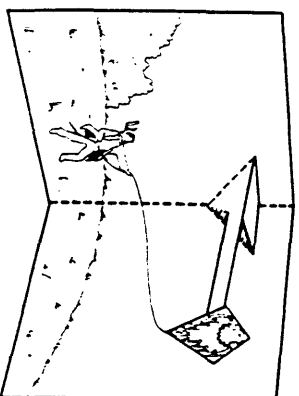
Cut out the arm, fold and glue both halves together. This makes the arm strong.

Glue the back of the triangle on the arm to the shaded area on the base.

Cut out the kite and glue to the end of the arm.

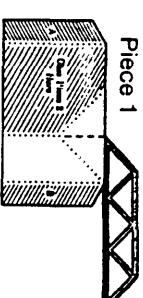
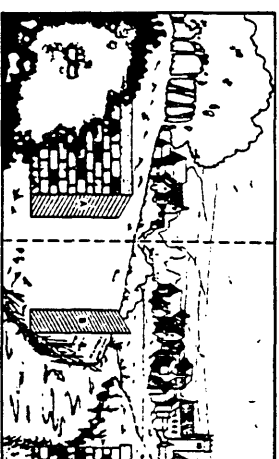
Use sticky tape to fix a piece of thread to the end of the kite.

Put the other end of the thread through a hole in the boy's hand and fix it behind the base of the card.



## 10. The Swing Bridge

Base



Piece 1



Piece 2

Cut out the base and fold it in half.

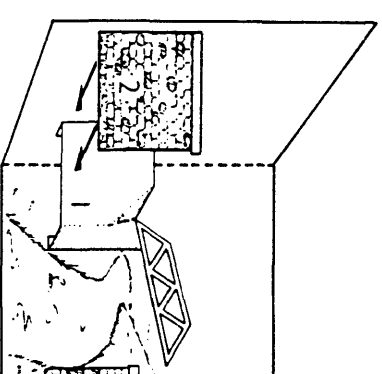
Cut out, then score and fold piece 1.

Make sure you make the hill and valley folds correctly.

Match the tabs to the base and glue into place.

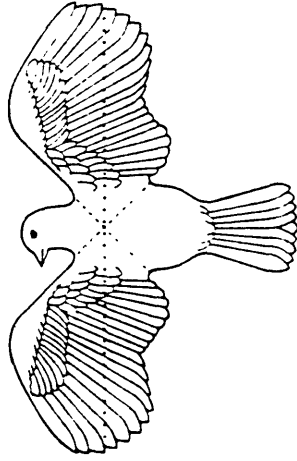
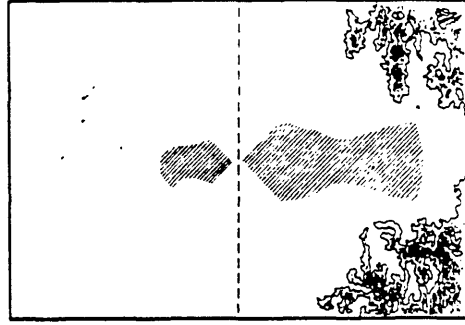
Close the card to check that the bridge swings up.

Cut out piece 2 and glue it in place as shown.



## 11. The Dove of Peace

Base



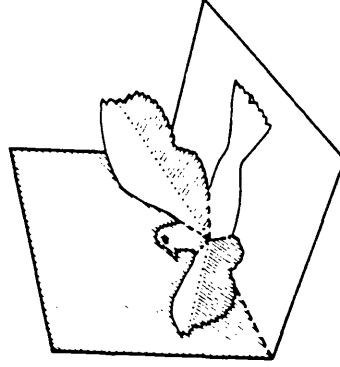
Cut out the base and fold it in half.

Cut out the dove and score along the three fold lines.

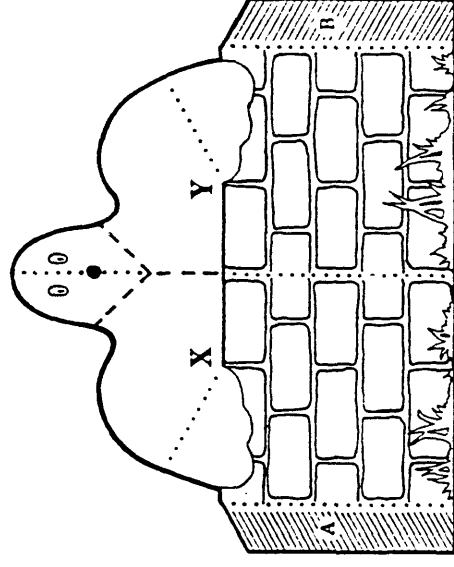
There are hill and valley folds. Make sure that you fold them the right way.

Glue just the head and tail of the dove to the shaded area on the base.

Check that as you open and close the card, the dove opens and closes its wings.



## 12. The Ghost

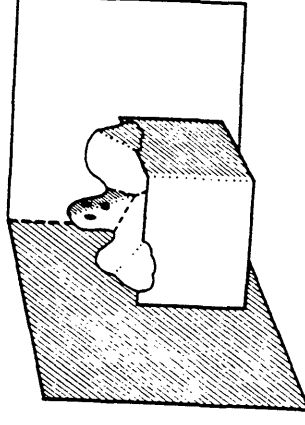


Cut out the base and fold it in half.

Cut out the "ghost" piece. Remember to cut along the top of the wall between the fold lines. (From X to Y in the above diagram.)

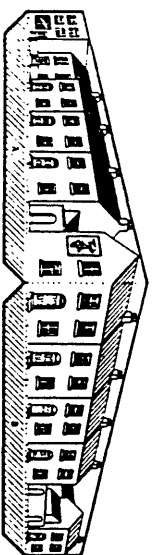
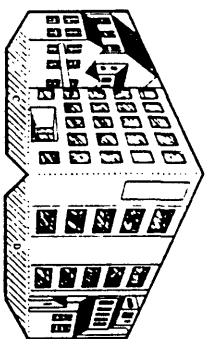
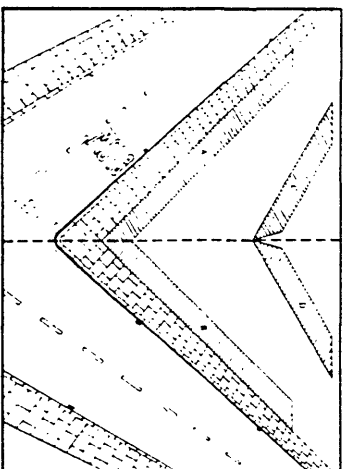
Score then make the fold lines. Be careful with the hill and valley folds.

Match tabs A and B to the base and glue in place.



Now open the card and watch the ghost rise!

### 13. A Street Scene



You will need *two* sheets for this card, 13a and 13b.

Cut out the three pieces.

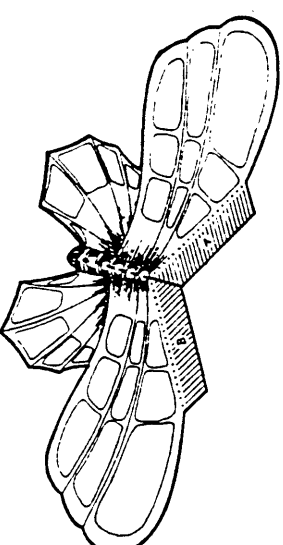
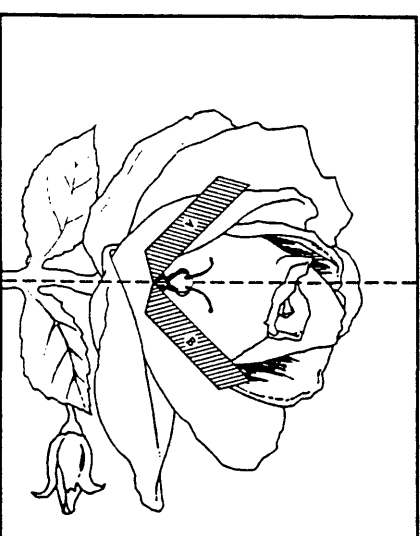
Score and make the folds.

The base has a valley fold, all the others are hill folds.  
Match the tabs and glue them into place.

Close the card and press it firmly.

Check that the buildings pop-up as it opens.

### 14. The Settling Butterfly



Cut out the base and fold it in half.

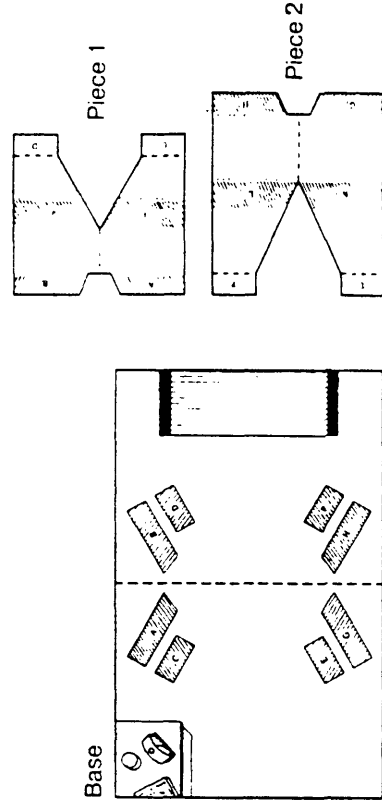
Cut out the butterfly.

Score along the three fold lines.

Fold back the tabs and fold *up* the wings.

Glue the butterfly to the base, carefully matching the tabs.

## 15. "Rise and Shine!"

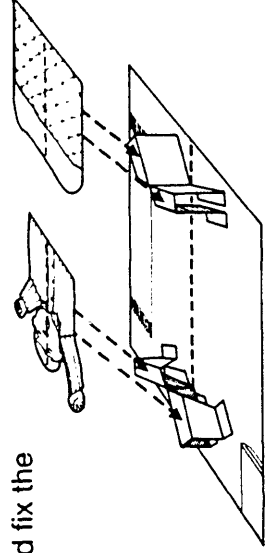


Cut out the base, fold it in half and open it up again. Cut out piece 1, score and make the folds. Match the tabs to the base and glue them in place. (You will need to put glue underneath tabs C and D.)

Similarly, cut out and fix piece 2 in place.

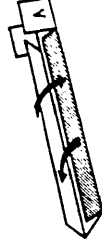
Cut out the boy and fold him in half. Lay his arms along tabs I and J, lining up the centre folds, and glue in place.

Similarly, cut out and fix the bed to K and L.

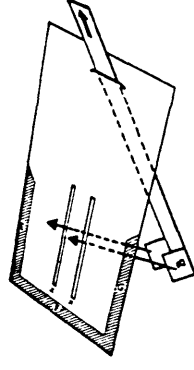


## 16. The Magic Rabbit

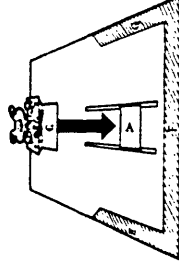
Cut out the slide, fold and glue so that the arrow piece is on top.



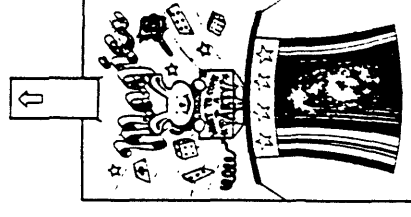
Cut out the 'Magic' base. Cut out the three slots, marked X.



Push tabs A and B through the long slots, and feed the slide through the top slot. Fold the tabs over and glue tab A on top of tab B.



Cut out the rabbit. Glue the back of C on top of tab A. Make the rabbit slide up and down.

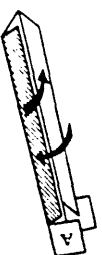


Cut out the hat piece, and fold back tabs E, F and G. Match the hat piece to the base so that you can make the rabbit pop in and out.

Glue E, F and G in place and test again.

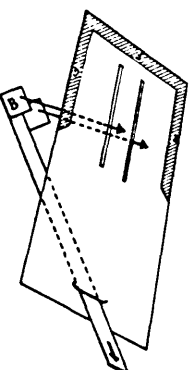
## 17. The Mole

Cut out the slide, fold and glue, so that the arrow piece is on top.

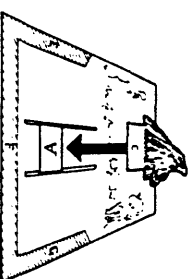


Cut out the base. Cut the three slots, marked X.

Push tabs A and B through the long slots, and feed the slide through the top slot. Fold the tabs over and glue tab A on top of tab B.



Cut out the mole. Glue *the back* of tab C on top of tab A. Make the mole slide up and down.



Cut out the remaining piece and fold back tabs E, F and G. Match it to the base so that you can make the mole pop in and out.

Glue E, F and G in place and test again.



## 18. The Frog

*The base*

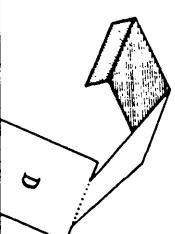
Cut out the base and cut the two slots. Fold back the strips E and F and stick them underneath. This will give extra strength to the base.

*The lever*

Cut out the lever.

Fold X and Y underneath, and glue them to give extra thickness to parts of the lever.

Thread the lever down through the centre slot, including tabs B, then up through the end slot. Open tabs B out again.



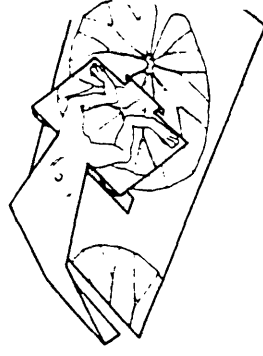
Pull the lever so that the end lies flat.

These instructions are continued on the next sheet . . .

## 18. The Frog (continued)

### *The jumping legs*

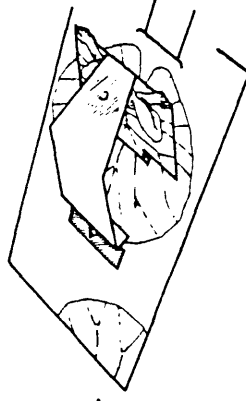
Cut out the jumping legs rectangle. Matching the veins on the leaf, glue the legs onto D.



### *The sitting legs*

Cut out the sitting legs piece.

Push in the lever so that it flips over showing Y. Match up the piece and glue to Y. This will put it on the back of the jumping legs.

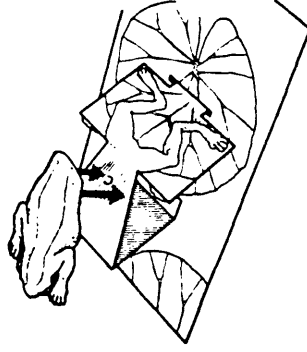


Glue tab A in place and make the lever work.

### *The body*

Cut out the frog's body

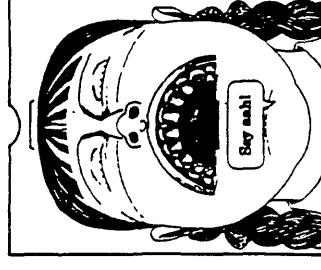
Push the lever in and match up to C. Glue in place.



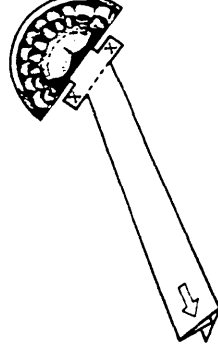
Now you can make the frog jump off the lily-pad!

## 19. "Say aah!"

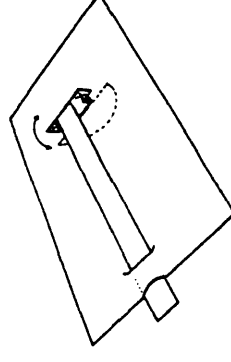
Cut out the base. Cut the two slots (above hair and just below the mouth).



Cut out the lever, fold the two sides underneath and glue. This treble thickness will make the lever more rigid. Push the lever, including part x x, through the mouth slot.



Open out the part x x again and feed the lever through the hair slot.

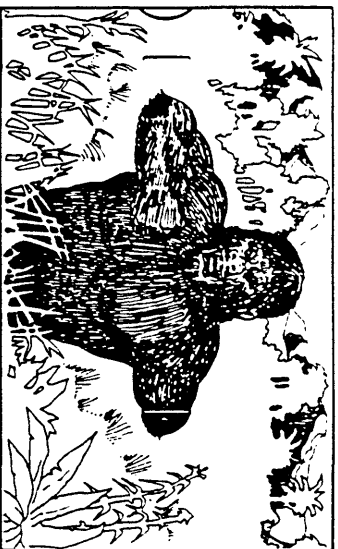


Underneath  
view

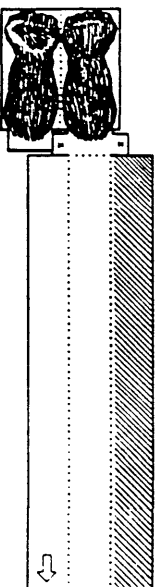
Push and pull the lever to open and shut the mouth.

## 20. The Gorilla

Base



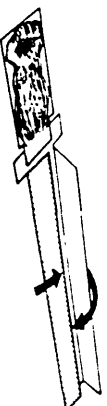
Arm lever



Cut out the base.

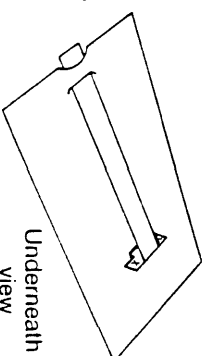
Cut the two slots (at the elbow and side).

Cut out the arm lever, fold the two sides over and glue them down. This will give the lever extra strength.



Push the lever, including the part labelled x x, through the elbow slot.

Open out the part x x again and feed the lever through the end slot.



Push and pull the lever to make the gorilla beat his chest.

## 21. The Sleeping Sheep

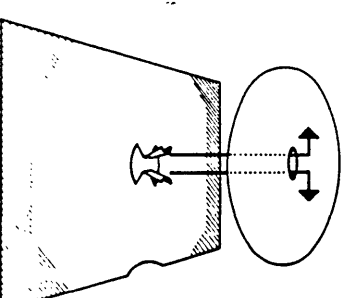
Cut out the four pieces.

Cut out the window in the top sheet and the hole in the wheel.

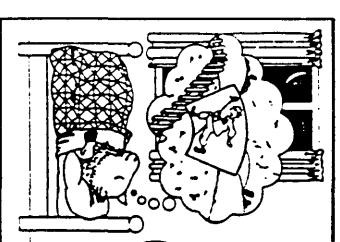
Fold up the tabs marked A on the pivot. Glue the back of the unshaded part of the pivot to the shaded centre on the base.



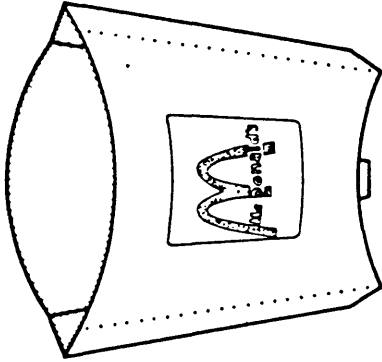
Feed the tabs A through the centre of the wheel.  
Fold back the tabs and test out the wheel.



Keeping glue away from the wheel, put glue on tabs A and on the shaded edge of the base. Put the top sheet in place. Test the wheel again.



## 22. The French Fries Container



Cut out the box. Remember the foot marked x as this will help the box to stand up.

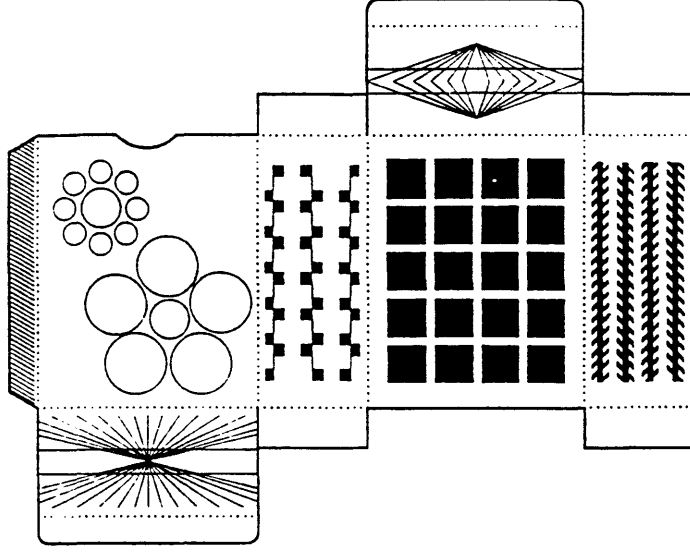
Score and crease all the fold lines. Take care round the curves.

Lay the box face down and fold the bottom half up. Fold the sides over and onto the shaded areas. Glue the sides in place.

Open the box, making sure that the foot does not bend. Push the bottom up along the curved folds to hold the box open.

The box design is reproduced with kind permission from McDonald's Hamburgers Ltd.

## 23. The Box of Tricks



Cut out the box and score along all the fold lines.

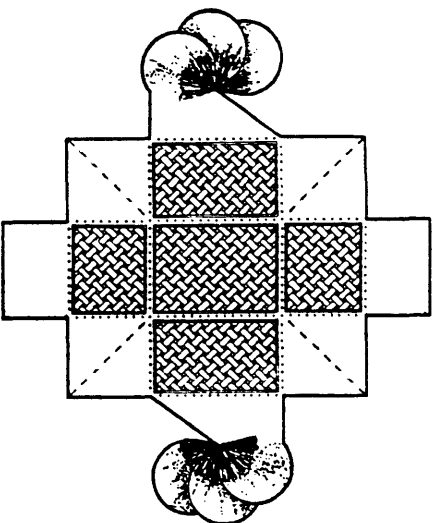
Make the folds. They are all hill folds.

Put glue along the shaded tab and join the edges together.

Fold over the side tabs and tuck in the lid and base. These do not need to be glued into place.

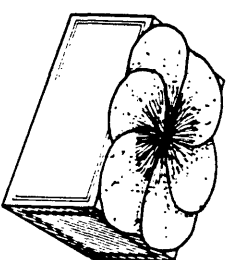
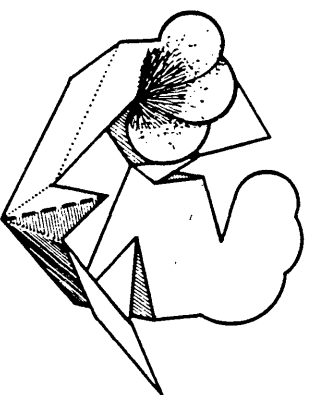


## 24. The Flower Box



No glue is needed for this box. Score along all the fold lines. Make the folds, but be careful with the hill and valley folds.

The two halves of the flower slot together.

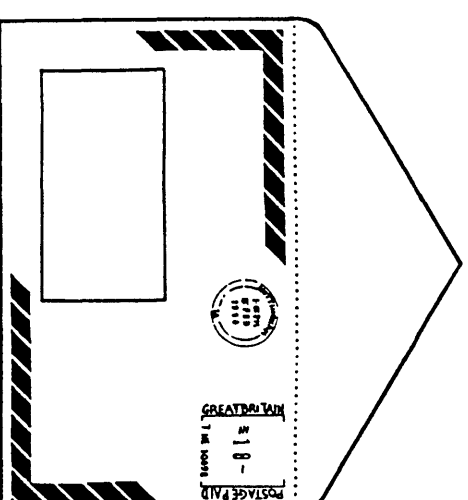


The design is adapted from the 'Sweet box' in 'Wrap it up' – a collection of packaging activities from Maths in Work, by Mary Harris, University of London Institute of Education.

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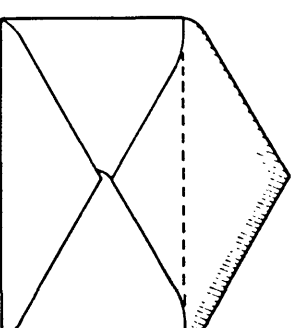
© Shell Centre for Mathematical Education/Joint Matriculation Board 1988

## 25. The Window Envelope



This envelope allows the name and address on the letter to be clearly seen through the window.

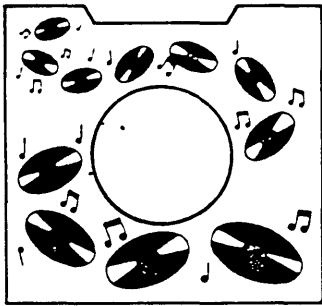
Cut round the envelope. Cut out the window. Score and fold. Put glue on the two shaded edges and fold the bottom flap over to hold the envelope together.



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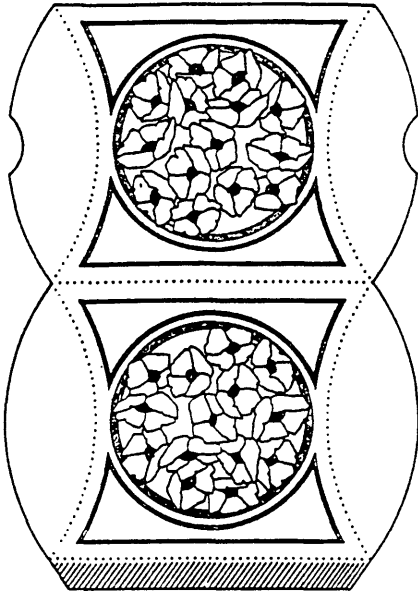
© Shell Centre for Mathematical Education/Joint Matriculation Board 1988

26. A Disco Invitation

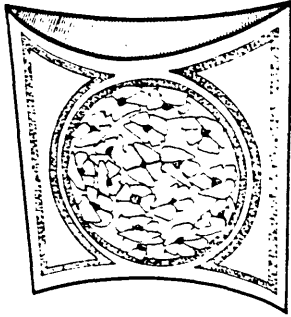


- Cut out the record sleeve and the record. Cut out the two centres on the sleeve.
- Score along the fold lines, then make the folds.
- Put glue on the shaded areas and stick the two halves of the sleeve together.
- Glue the two halves of the record back to back.
- Put the record into the sleeve.

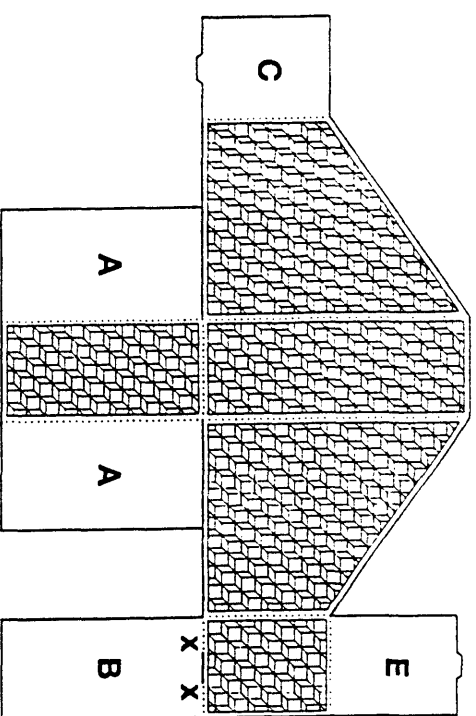
27. The Pillow Box



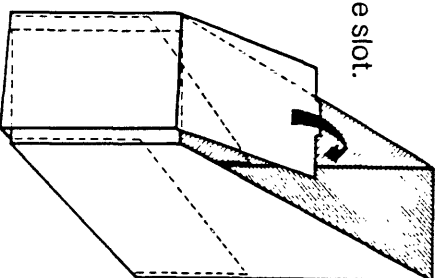
- Cut out the box.
- Score along the fold lines taking special care round the curves.
- Make the folds.
- Put glue on the shaded edge of the box, and stick the two sides together.
- Now push in the ends.
- The ends with thumb holes should go in first. (Why?)



## 28. The Library Box



Cut the box out then make the slot marked x x.  
Score and crease all the folds.  
Swing the base and the flaps marked A up.  
Wrap the front round and lay flap B along the inside of the base.  
Feed flap C behind the front face.  
Make the notch fit the slot.  
Fold flap E inside and fit the notch in the slot.

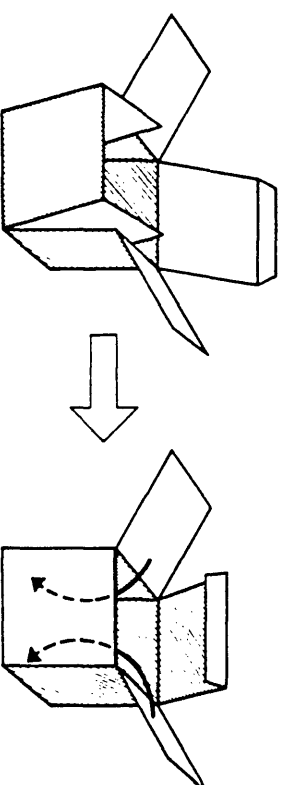
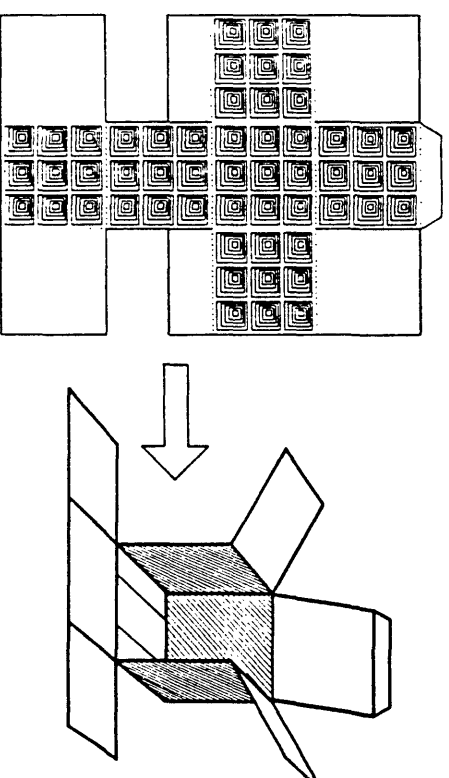


The box design is reproduced with kind permission from Lawtons Ltd, Liverpool.

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## 29. A Cube

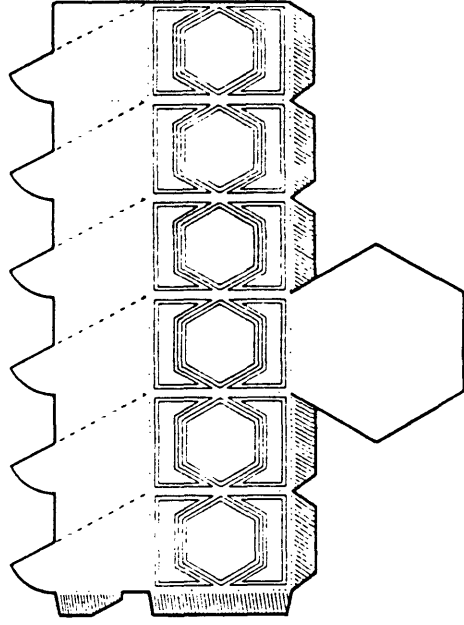


No glue is needed.

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## 30. A Hexagonal Box



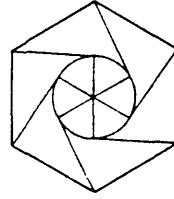
Cut out the box.

Score all fold lines and crease them well. This will make them easier to fold later on.

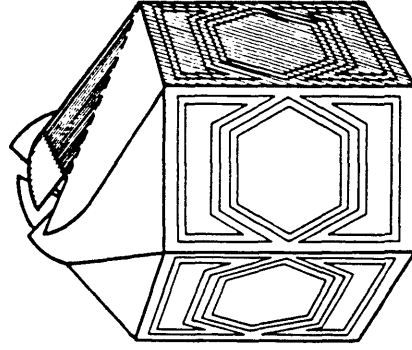
Glue each of the tabs to the base.

Glue the side edges together.

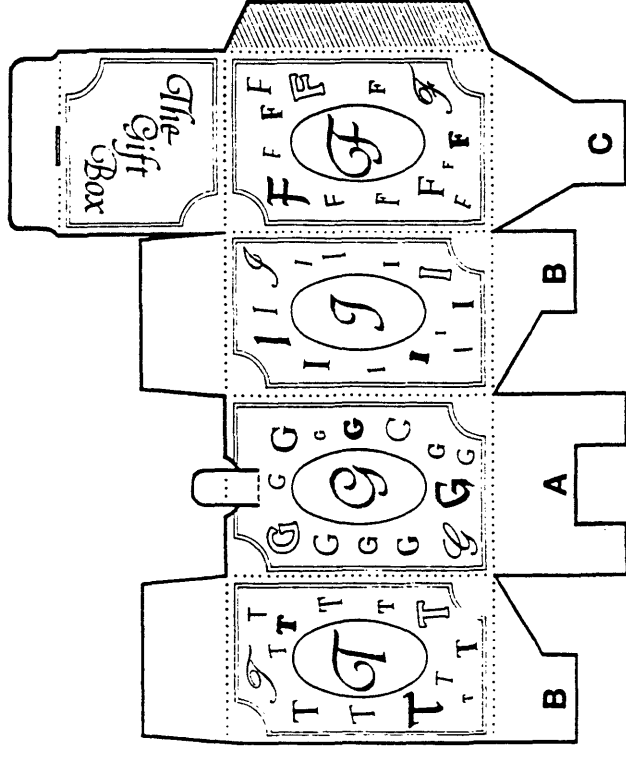
To close the top, fold each piece in turn so that they lie overlapping each other. When all the folds are made push down the centre to hold them in position.



Top view



## 31. The Gift Box

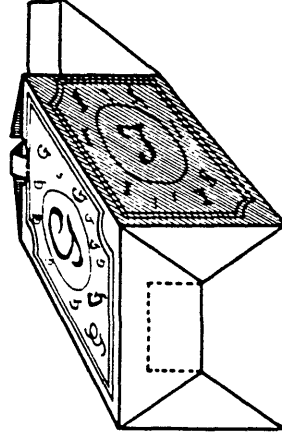


Cut out the box and make the slit in the lid.  
Score along all the fold lines.

Fold and glue the side edges together.






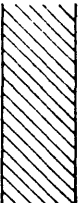
To fold the base:

- first fold flap A
- fold the B flaps on top
- thread C inside.



Fasten the lid and push the tab through the slot to hold it in place.

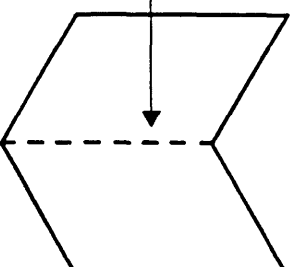
# Helpful Hints

	Cutting line	You should <i>only</i> cut along <i>thick</i> black lines
	Hill fold	Fold like this 
	Valley fold	Fold like this 
	Glue	Put glue <i>only</i> on things that are shaded

## Some useful words

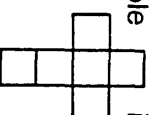
**“Base”** – this means the bottom of the box, or the back of the card. (It’s usually the part that lies on the desk while you are making it.)

**“Centre-fold”** – this is the name given to the main fold line down the middle of a card. \_\_\_\_\_



**“Score”** – this means draw over the fold lines with a blunt point like a ballpoint pen. This makes the paper easier to fold. Use a ruler to keep your scoring straight. Always press your folds to make sharp creases.

**“Net”** – this is the name given to a two-dimensional plan for making a box. (For example

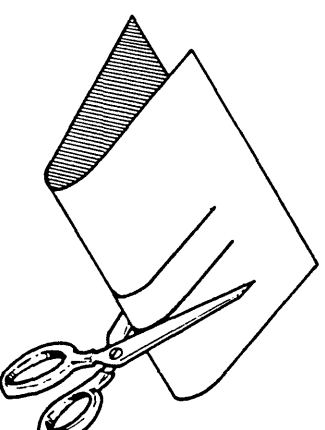


is a net for making a cube.)

## Some useful tips

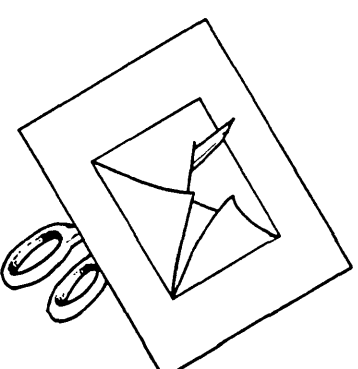
### Cutting slots

Curve the paper and snip the lines in the middle. Open the paper. Poke the scissor point in and finish the cut.



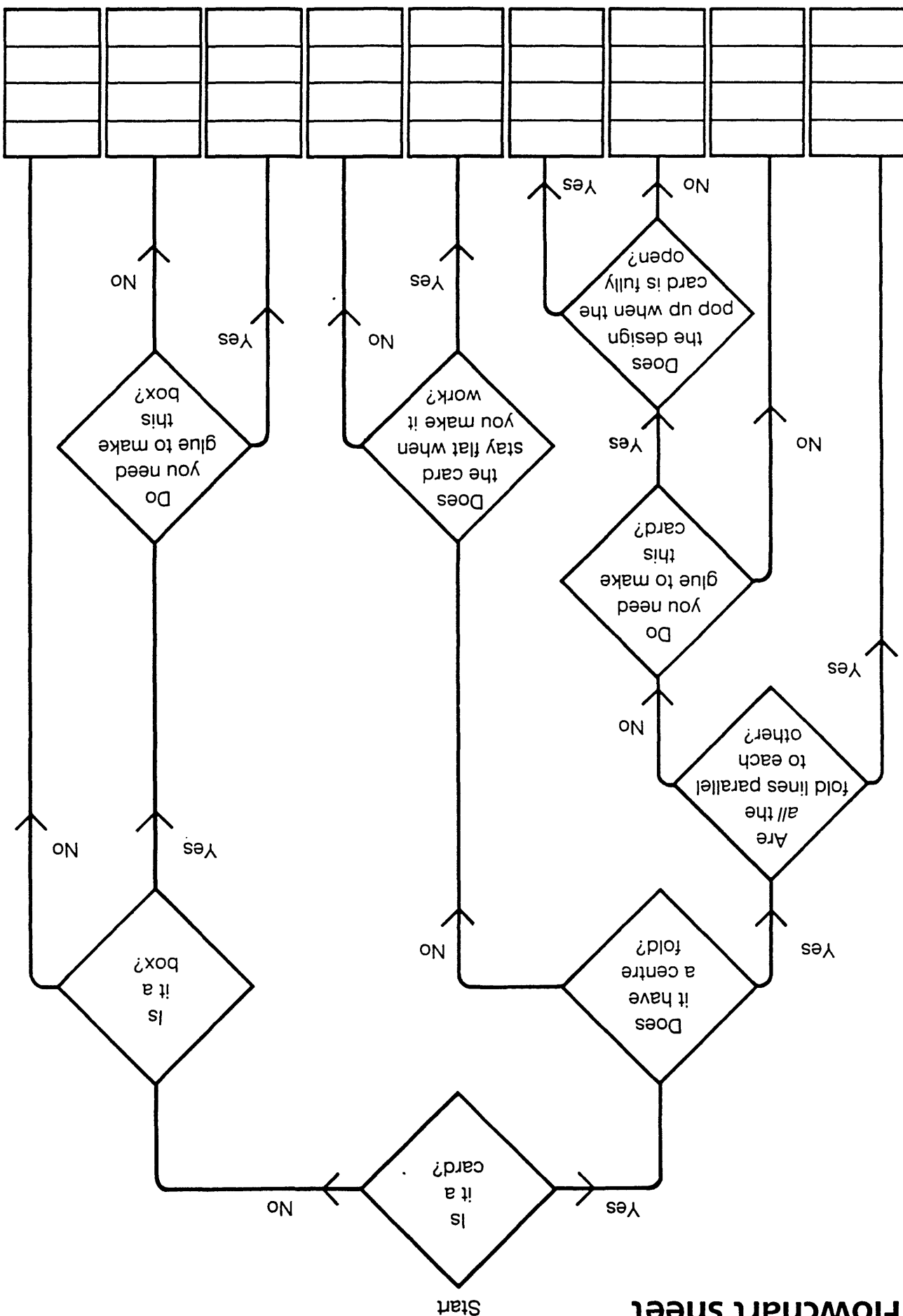
### Cutting windows and holes

Curve the paper and snip into the centre of the window. Open out and make several cuts to the edge of the cutting line. Trim round the cutting line.



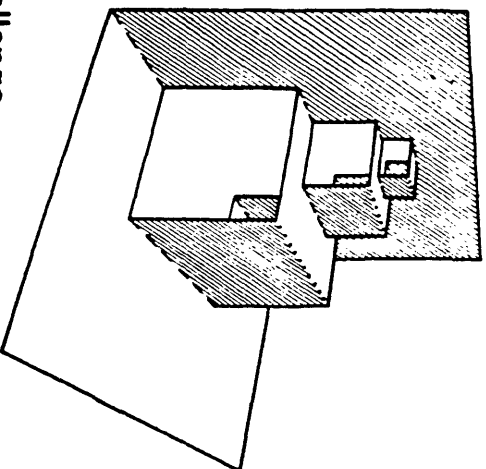
### Colouring

You may want to colour in your cards or boxes. Only use coloured pencils or crayons. *Warning: If you use felt-tipped pens, the paper may buckle and distort.*



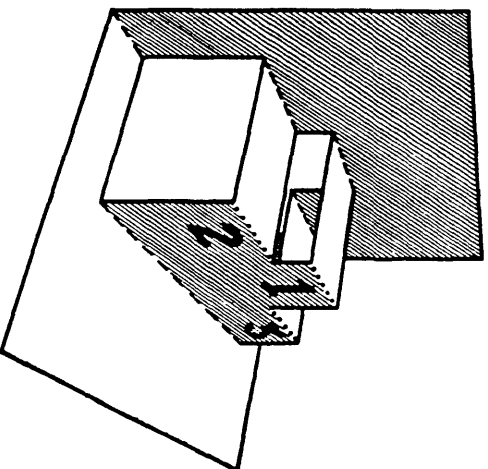
## Tower challenge

Try to make this pop-up tower from one sheet of paper without using any glue.



## Podium challenge

Make this Winners' podium from a single sheet, without using any glue.



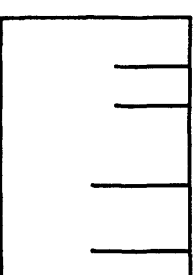
4

fold

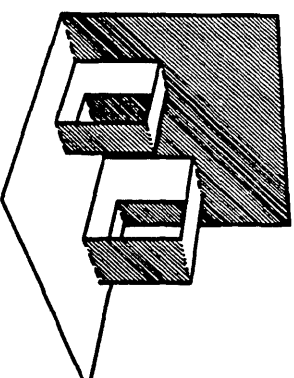
## Cards with parallel folds

(These are cards like 3. The Pop Star and 4. The Rolls Royce.)

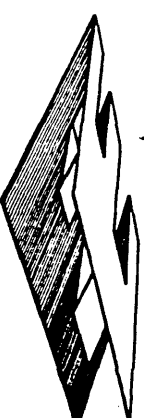
- Fold a piece of paper in half. Make pairs of equal cuts across the fold.



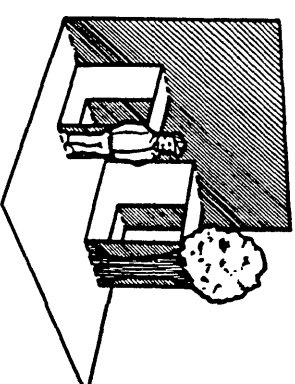
- Open the paper to an angle of 90°. Make the shapes stand out.



- Make the shapes fold flat when the paper is closed.



- Cut pictures out a magazine and stick them onto the vertical faces.



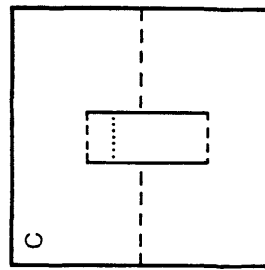
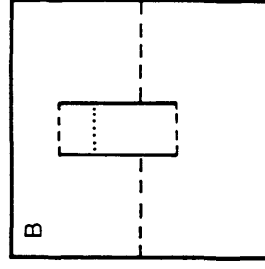
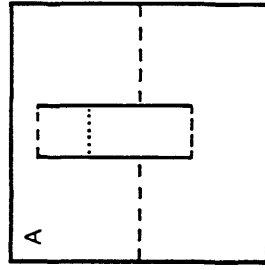
- Look at the card you have made. Does it work properly? Are the pictures completely hidden when the card is closed or do they stick out? Could you have forecast this before you made it? How?

1

# Cards with parallel folds (continued)

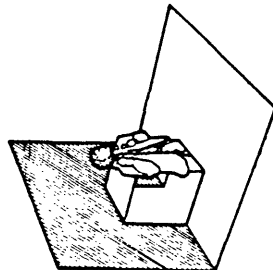
Try to make a pop-up card like the pop star card . . .

- Before you start, think carefully.

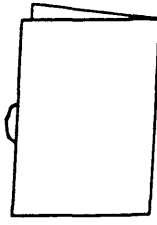


Only one of these three cards will work properly. Which is it? How can you tell? What is wrong with the other two?

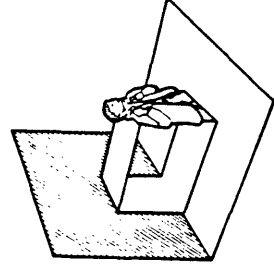
- Now make a card.
  - Make the cuts *before* you fold.
  - Paste on a picture.



- How can you be sure that the picture will *not* stick out of the card when it is shut?

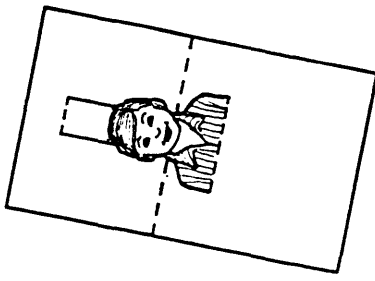


- How could you make the picture stand out *more* when the card is opened at 90°?



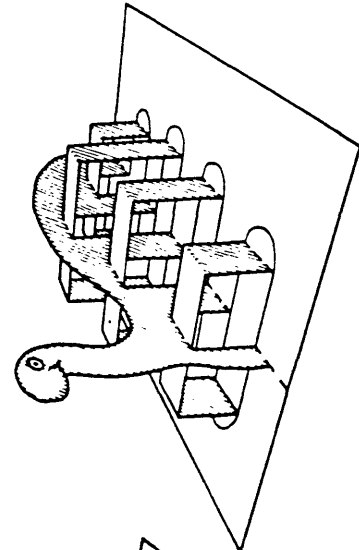
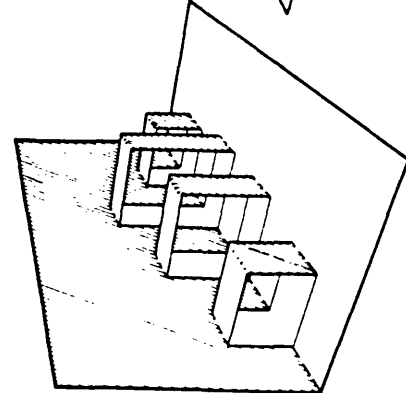
Try to make a pop-up card like the Rolls Royce . . . .

- Start by sticking a picture onto your flat card.
- Now think carefully . . .
  - how far should you cut round the outline?
  - where should you put the folds?
- Test your ideas to see if they work.



Glue two of these together, back to back . . . .

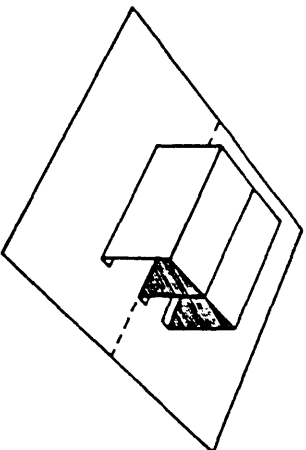
. . . and try to make this creature!



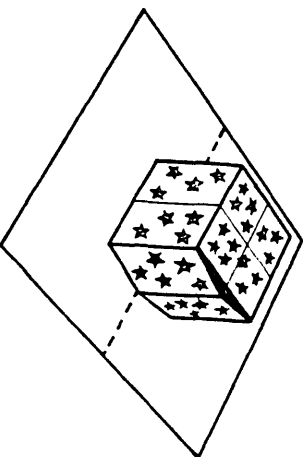


## A house or a parcel or ...

This box is like diagram H on page 3 of this leaflet.

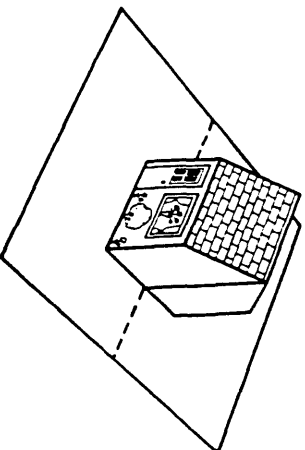


Try making it into a 'pop-up' parcel .....



This would make a good birthday card!

or a 'pop-up' house ...



or a pop-up 'birthday cake' or ... what?

Explore your own ideas.

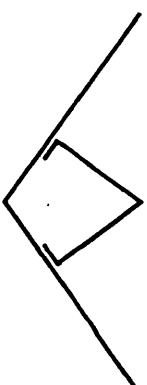
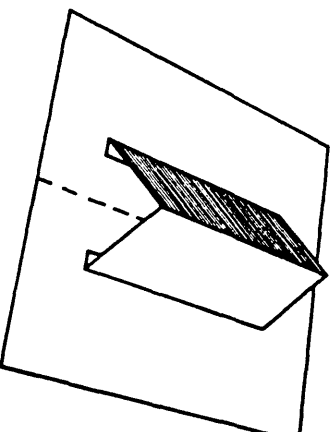
Try making something from diagram I on page 3.

4

fold

## Cards with parallel 'stick-ons'

(These are like 5. The Indian Palace and 6. Staircase and Pillars.)



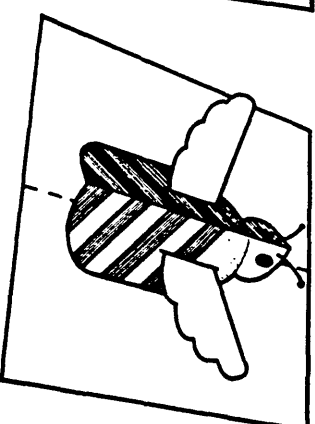
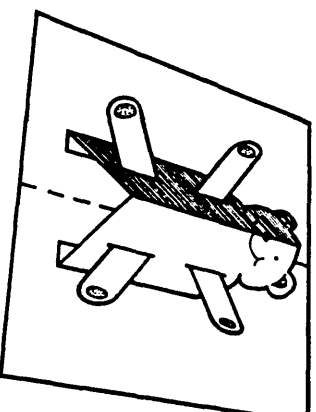
Side view

slots

Try making the basic tent shape.

Add slots and a strip of paper in the shape of wings, arms, legs ...

to make a teddy bear, an insect, an aeroplane or ...



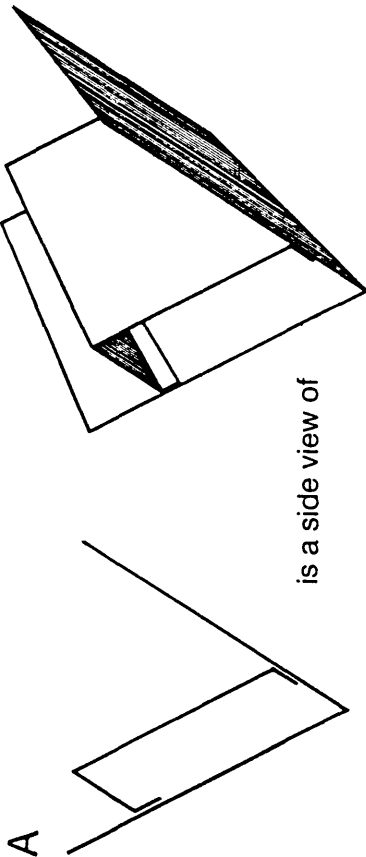
Explore your own ideas.

1

## Cards with parallel 'stick-ons' (continued)

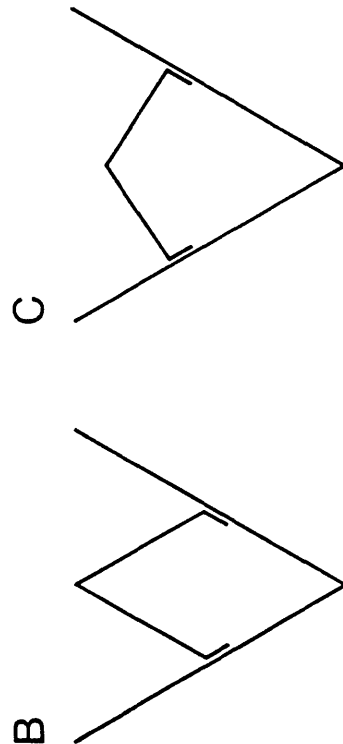
### A puzzle to think about

Below are some side views of different cards. For example,

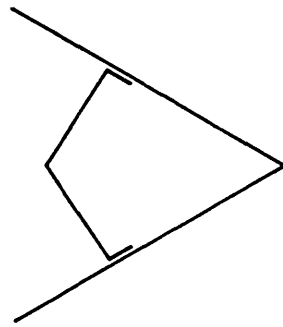


is a side view of

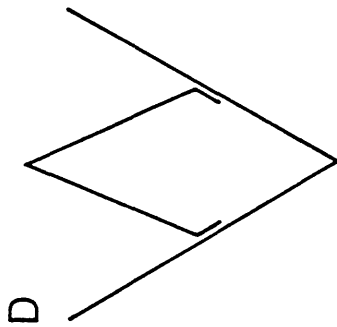
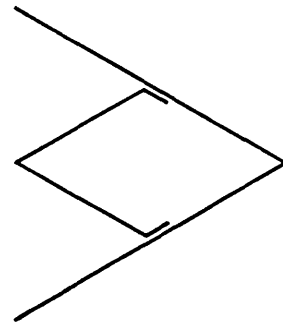
1. Which of the cards can be closed without creasing in the wrong place? Explain how you can tell without having to make the cards.
2. Which of the cards can be opened completely flat on the table without tearing? Again, explain how you can tell.



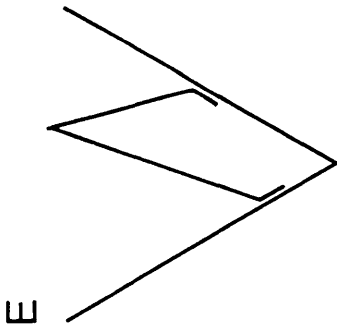
C



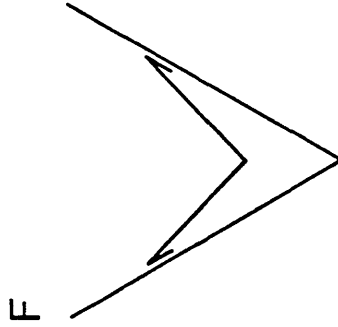
B



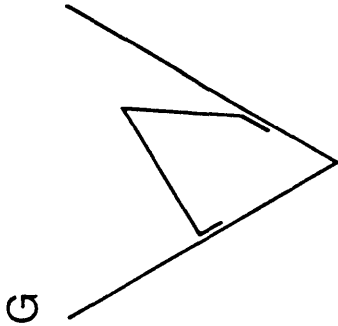
D



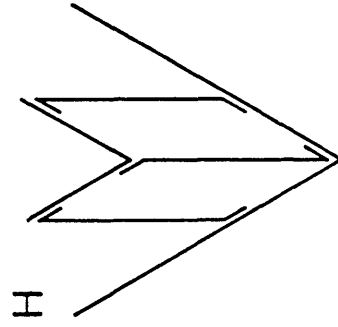
E



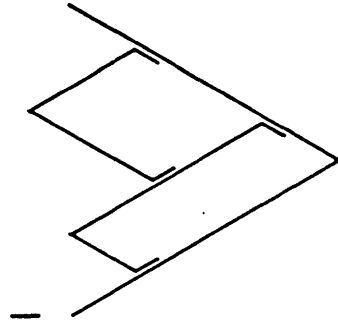
F



G



H

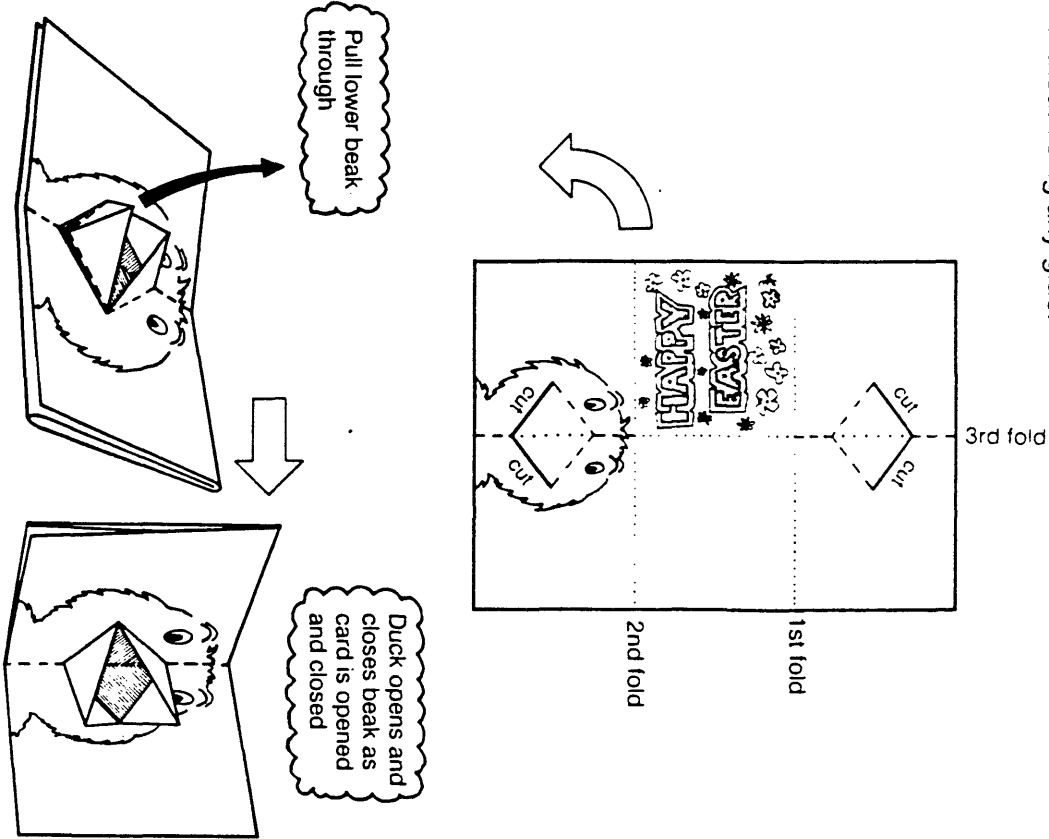


I

Now try making some, and see if you were right!

A Duck challenge

Try to make this Easter card from a single sheet of A4 paper, *without* using any glue.



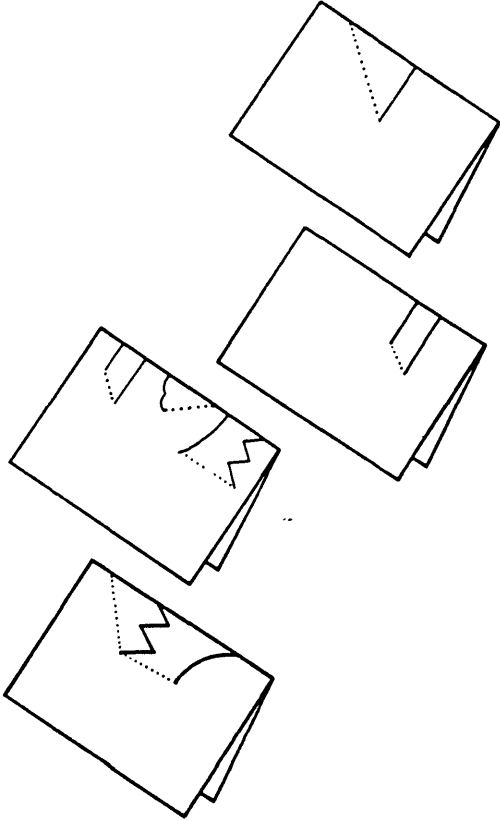
This sort of card only needs to be printed on one side of the paper. Look out for examples of this technique in the shops.

4

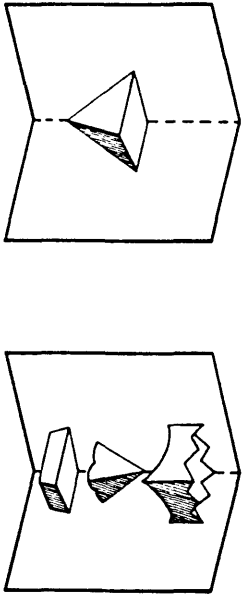
Cards with angled folds . . . part 1

(These are like 7. Frankenstein, 8. A Barbecue Invitation, 11. The Dove of Peace and 12. The Ghost.)

Fold a piece of paper in half.  
Try cutting and folding the paper in different ways.  
For example:



Now open the cards and make the shapes stand out.

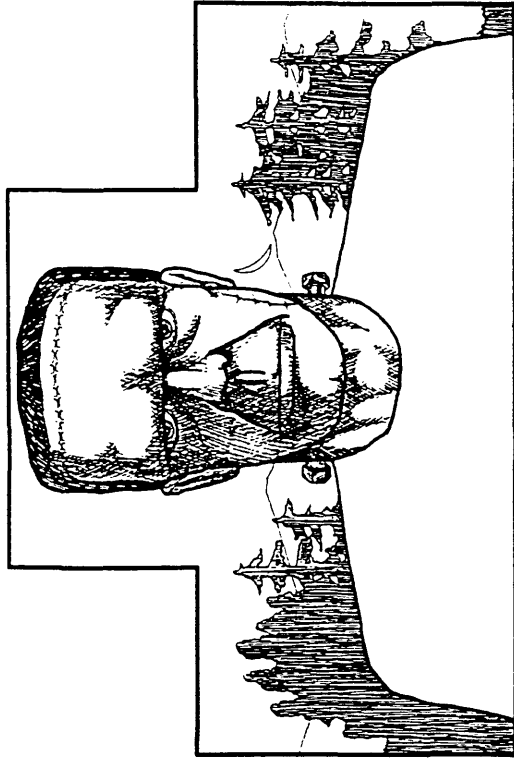


What happens?

1

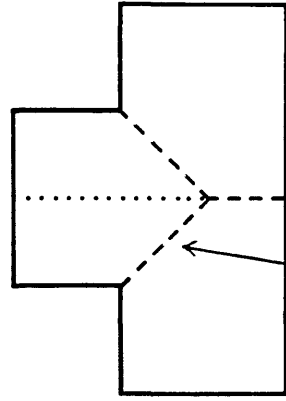
## Cards with angled folds (continued)

### Exploring Frankenstein



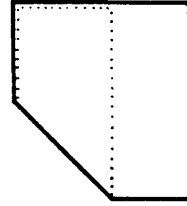
The two diagrams below show how the card folds flat.

Open Card



Fold lines

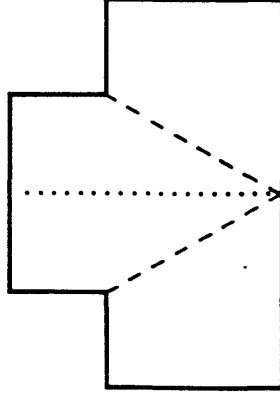
Folded card



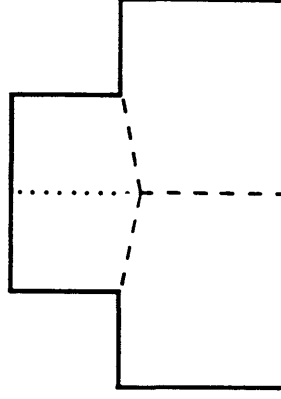
the dotted line shows how the inside folds down.

Using the same card (you don't need to keep making different ones) try changing the angle of fold and see what happens. Draw sketches to show the open card and folded card in each case.

For example:



draw a sketch of the folded card



draw a sketch of the folded card.

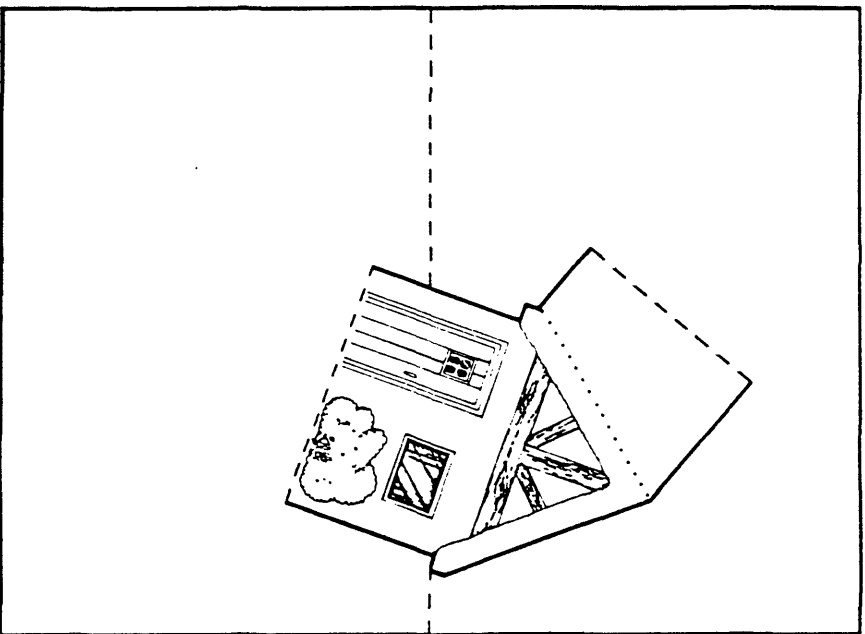
The Barbecue invitation uses the same idea, but you can see part of the inside of the card when it is shut. Try to think of other ways of using this idea.

## The 'Angled House'

(You should try page 3 before doing this page.)  
Try making a larger version of the pop-up card shown below.

If this card is to work properly, what can you say about

- the directions of the fold lines?
- the angles between the 4 fold lines?

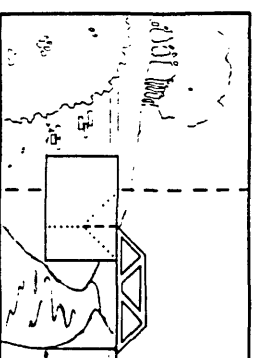
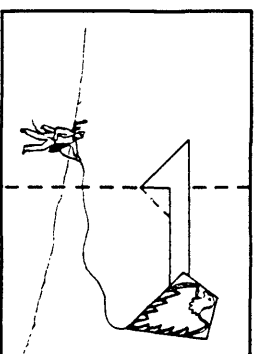


4 Can you make the house pop out at a different angle? How?

fold

## Cards with angled folds . . . part 2

(These are like 9. The Flying Kite and 10. The Swing Bridge.)

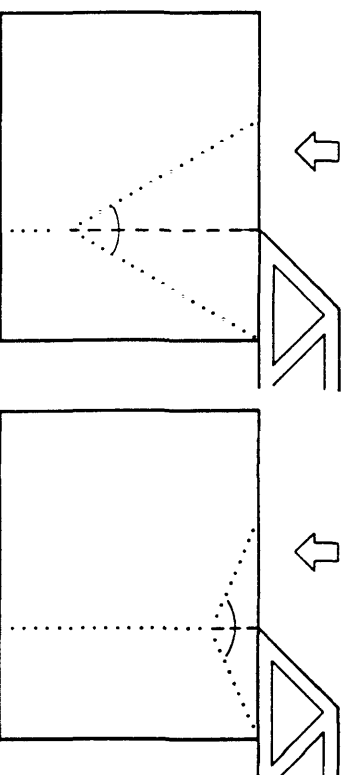


Compare these cards.

- In what ways are they similar?
- In what ways are they different?
- What angle does the bridge turn through as the card is closed?
- What happens if the V shaped folds are changed so that the angle between them . . .

. . . gets smaller?

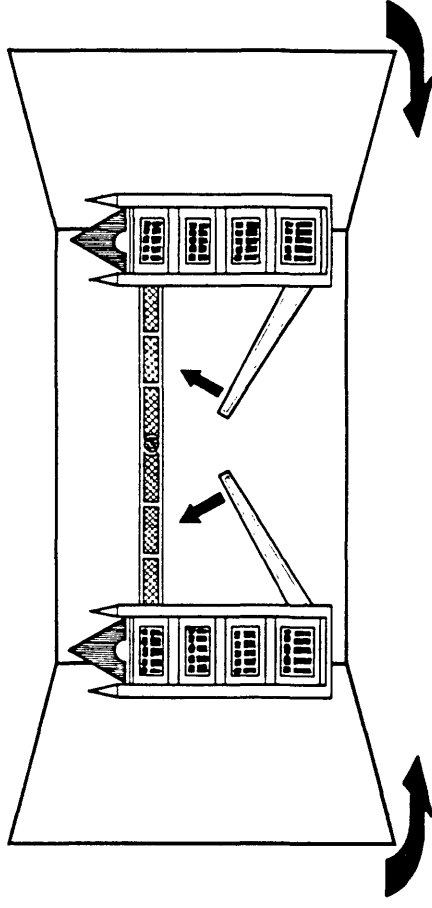
. . . gets larger?



## Cards with angled folds (continued)

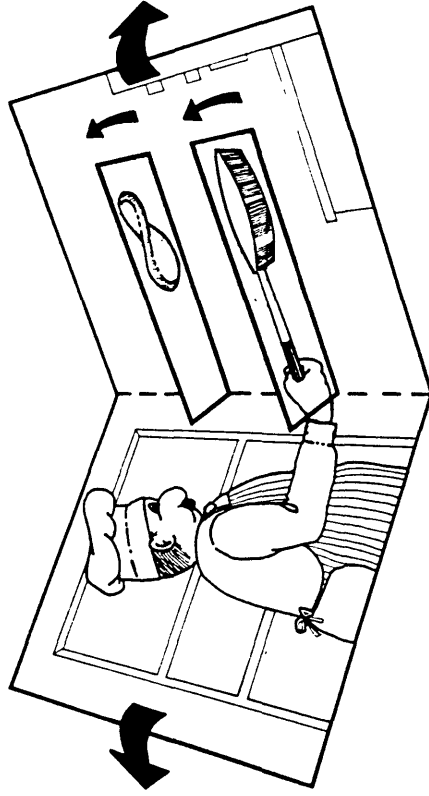
Try to make these cards . . .

### Tower Bridge card



As the card closes, the bridge is raised.

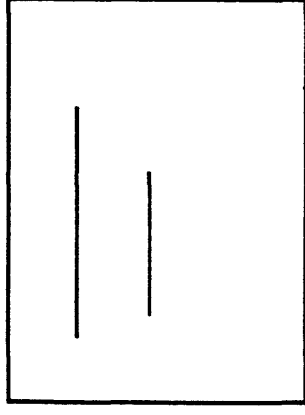
### Pancake party card



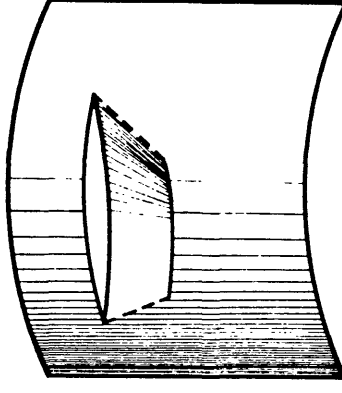
As the card is opened, the pan rises slowly, and the pancake rises quickly.

## A useful result

Make 2 slits, anywhere.



Bend the paper towards you.

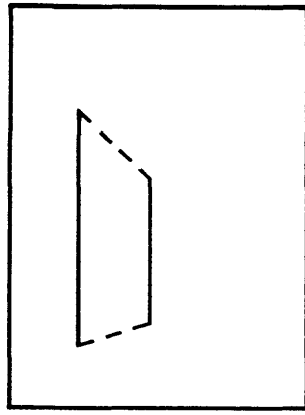


Open up your paper.  
There are four fold lines.  
What do you notice about

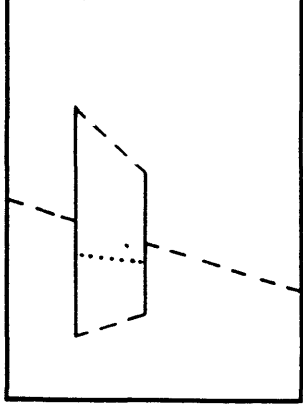
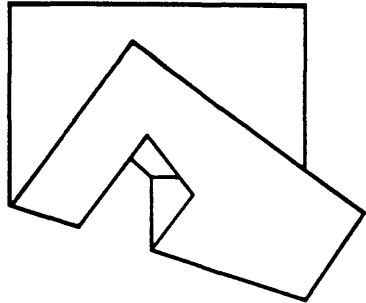
- the *directions* of these folds?
- the *angles* between these folds?

Will this always work? Why?

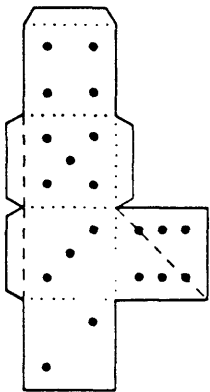
Make 2 valley folds between the ends of the slits.



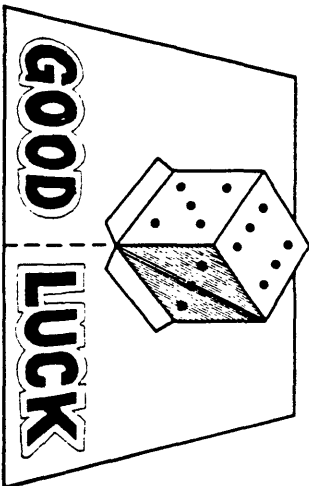
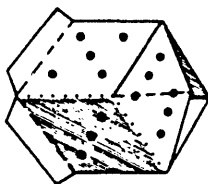
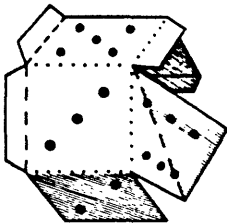
Fold flat and crease.



## Good Luck card



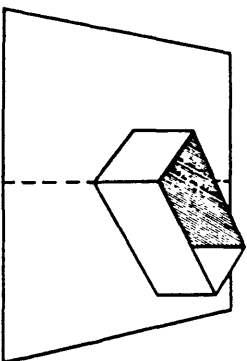
This is like a 'wall card' with a back and top. Notice that the back and top are not attached to the base.



Does the shape you paste on have to be a cube?

For example, is this open topped box possible?

Can it have a lid ... or a roof?



4

fold

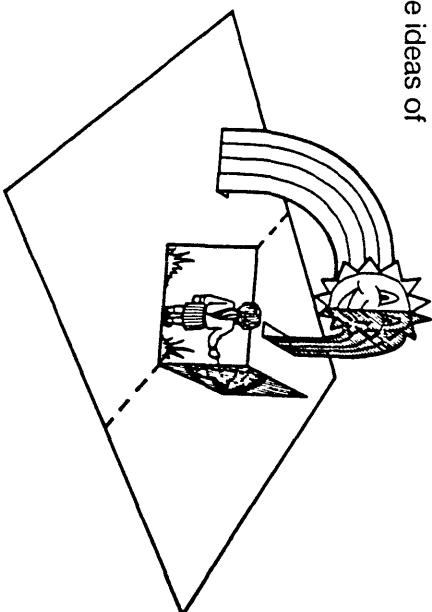
## Cards with angled 'stick-ons'

(These are like 1. The Cat, 13. A Street Scene, 14. The Setting Butterfly and 15. "Rise and Shine!")

### The Rainbow card

- Try making this rainbow card. (You can use the same idea to make bridges, doorways etc.)

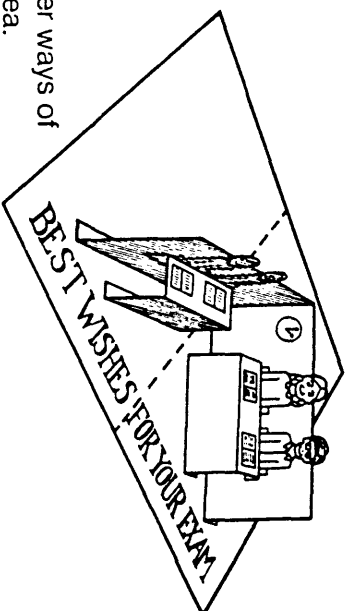
- Try out some ideas of your own.



### Exam card

- Try making this card.

(Notice how each half of the wall is like a separate pop-up card.)

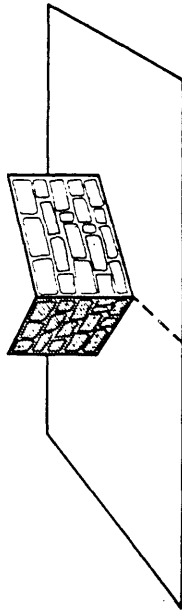


- Think of other ways of using this idea.

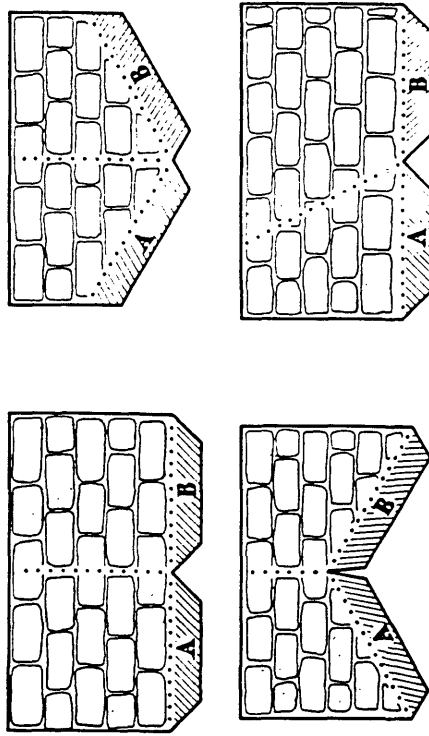
1

# Cards with angled 'stick-ons' (continued)

## Walls investigation



Cut out and fold some different walls like these . . .

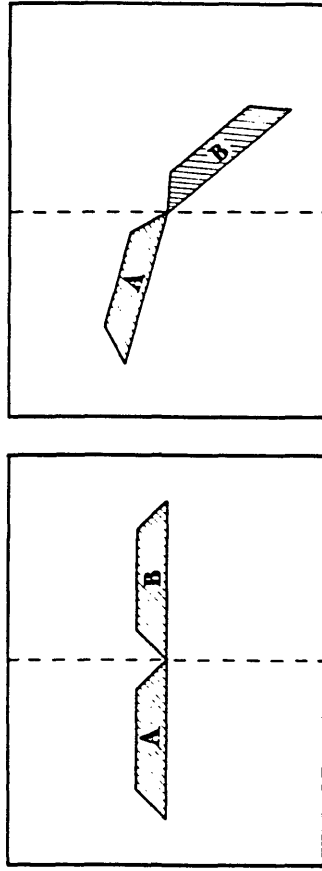
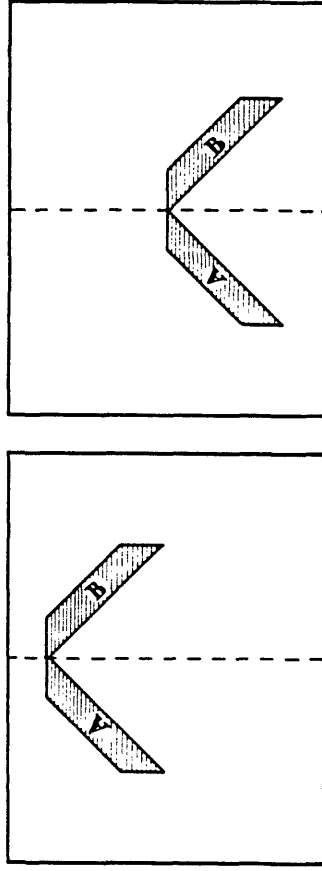


Try pasting them down onto the base sheets at different angles, and in different positions.

See the next page for examples

Try to make them work as pop-up cards.

Make sure they will close without creasing in the wrong place.



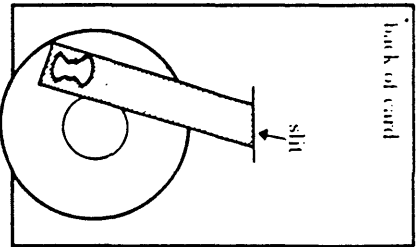
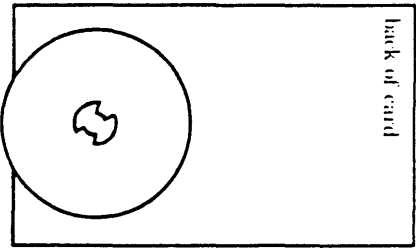
Write about what happens . . .

- How can you make a wall stand up vertically?
- How can you make a wall lean forwards or backwards or sideways?
- Do all the cards work properly? How can you tell if a card will work, without having to make it?
- Do any of the walls stick out of the cards when they are shut?
- How can you predict when this will happen?

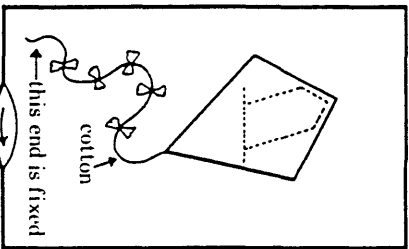
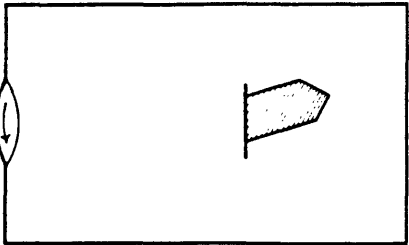


A Kite challenge

- 1. Make a wheel like you did for the 'Spiral' ....
- 2. Cover the pivot and attach an arm to the wheel with a second pivot ....



- 3. The front of the card should look like this ...
- 4. Stick a kite onto the top of the shaded arm.



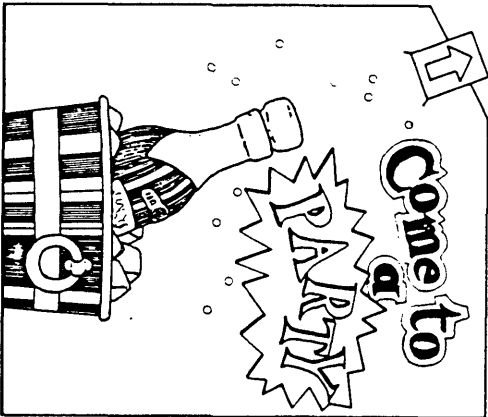
- 5. As the wheel is turned, the kite should move around the card in an interesting way.

Cards with slides and pivots

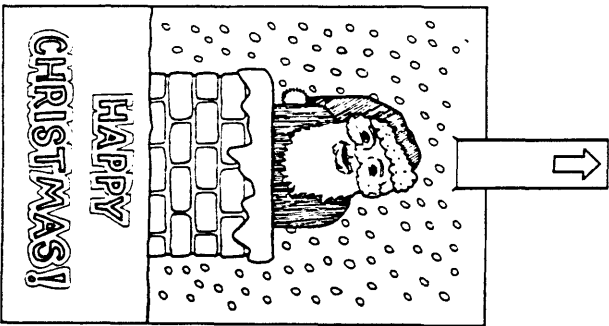
(These are like 16. The Magic Rabbit, 17. The Mole, 18. "Say aah!", 20. The Gorilla, 21. The Sleeping Sheep.)

A sliding challenge

Make one of these ... or invent an idea of your own.



You pull the tab and the cork explodes out of the bottle.



You pull the tab and Santa moves up and down the chimney!

# Cards with slides and pivots (continued)

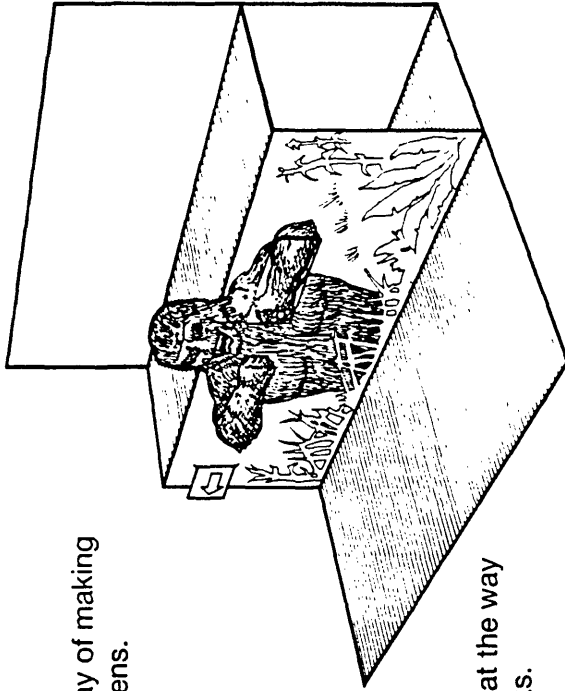
## A Gorilla challenge



Cards like this need some space behind them so that the hinge has room to turn.

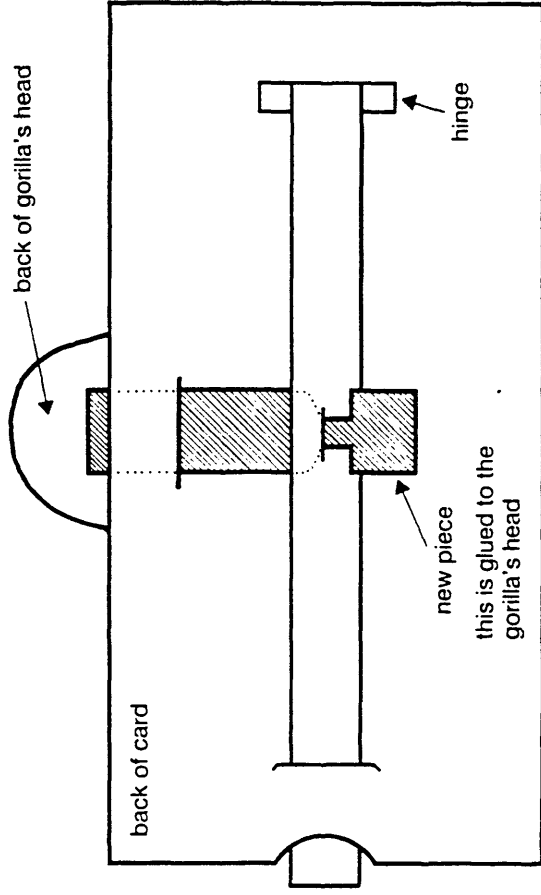
Here is one way of making sure this happens.

Try it!

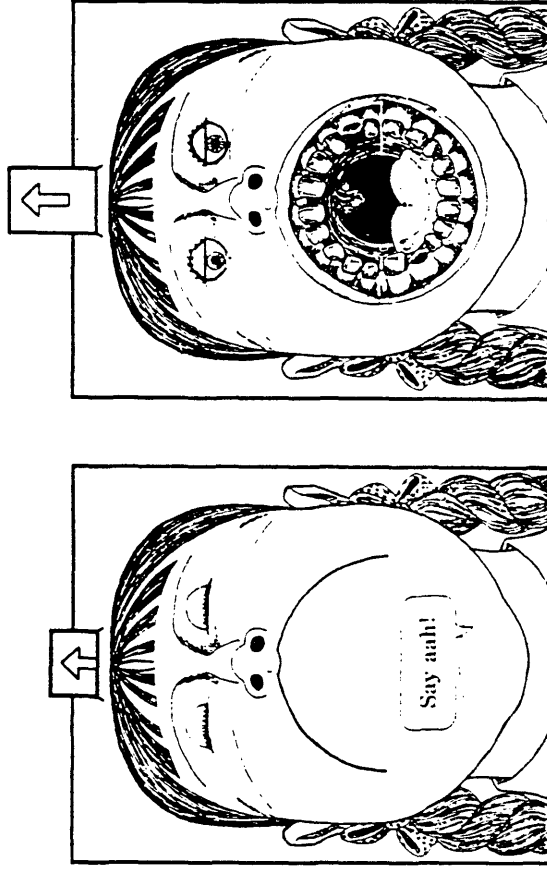


Look carefully at the way the hinge works.

Can you change this card so that the gorilla moves *both* of his arms when the tab is pulled?



- This diagram shows how you can also make the gorilla's head rock from side to side as the tab is pulled. Try to make it!
- You may also like to try making small changes to other cards. For example, try making the eyes open on the "Say aah!" card.

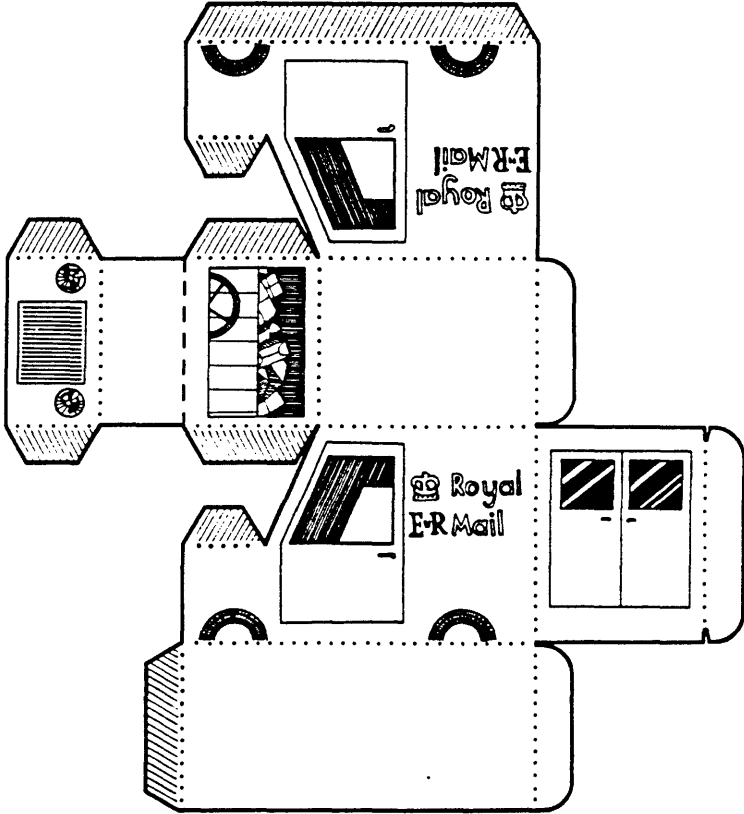


**A novelty box challenge**

Sometimes, sweet boxes, scent boxes, soap boxes, etc., are made into novel shapes.

(The example below shows a 'Post Office van' box. You might like to try making it.)

Try to design your own novelty box.

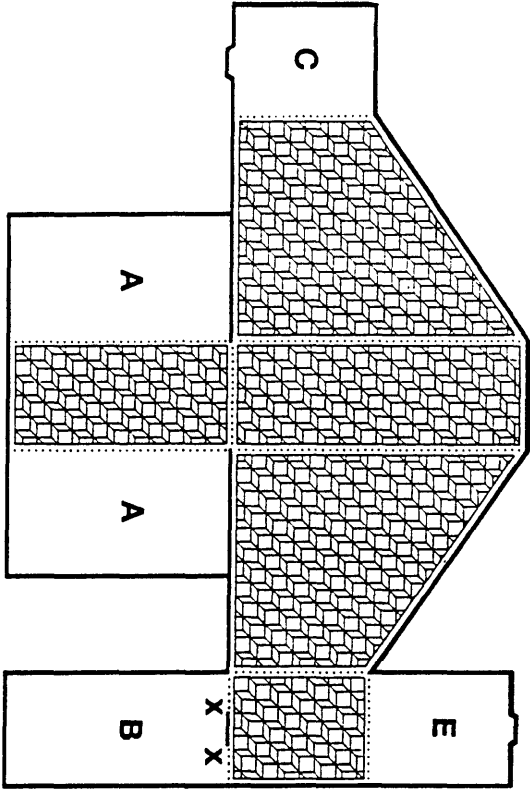


4

fold

**Boxes**

Look at 28. The Library Box from Stage 1.

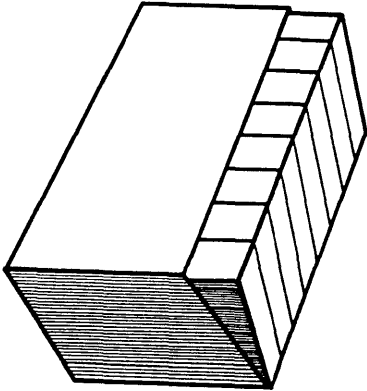


*Either*  
try to adapt the design to  
make a box for storing

- cassette tapes
- paperback novels
- or items of your own choice.

*Or*

try adapting other boxes from Stage 1, so that they fulfil a purpose.

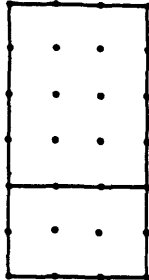


1

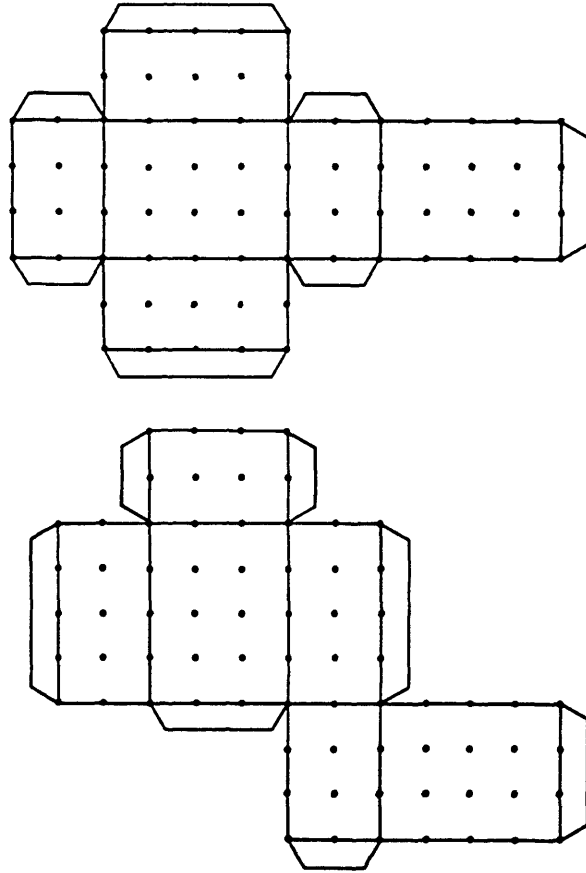
## Boxes (continued)

### Inventing nets for boxes

Here is a partly finished drawing of a net for a box.  
It will need to be glued together.  
(Dotty paper has been used to make the drawing easier.)



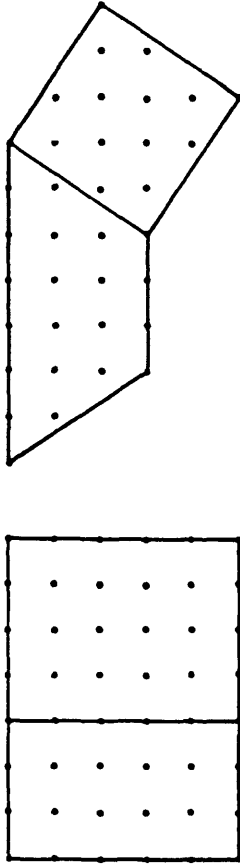
It can be completed in many different ways. For example:



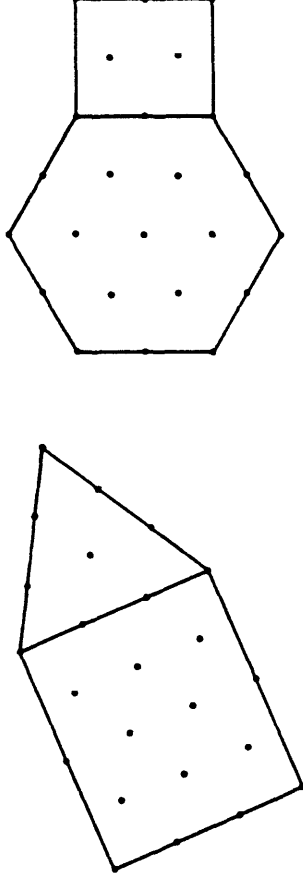
Think of a third way of completing the net, and draw it accurately on dotty paper.  
Put flaps on for gluing.  
Now make it.

Here are some other partly finished nets. Using dotty paper, try to finish them off. Add on flaps for gluing or fastening. Check that they work by making them.

Use square dotty paper for these two:



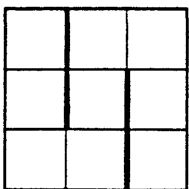
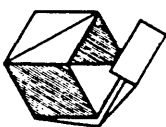
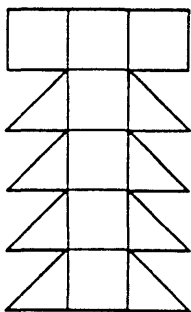
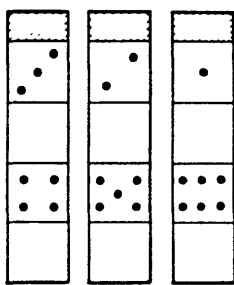
Use isometric dotty paper for these two:



Now invent some more of your own . . .

## Unusual methods . . .

Here are some more imaginative ways of making a cube . . . try some! Do they need extra flaps? Do they need glue?



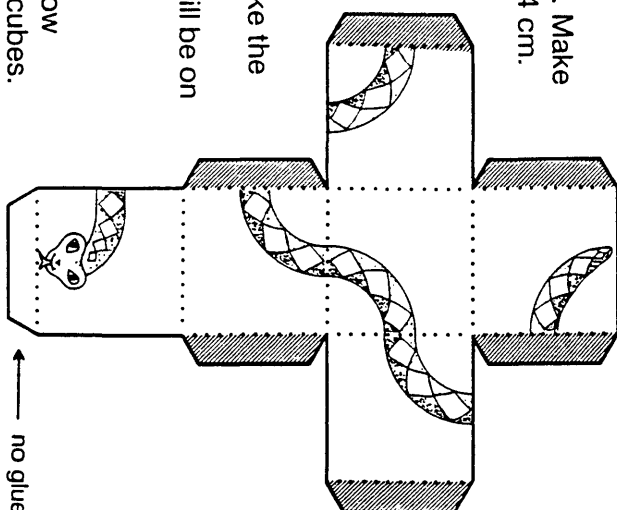
Can you find any other interesting ways?

4

## Cubes

### The Snake cube

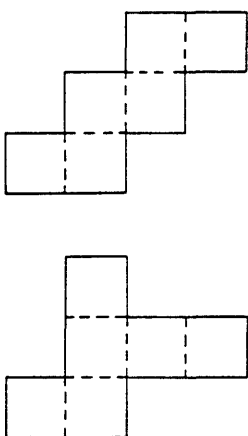
Draw this net accurately. Make all the squares 4 cm by 4 cm.



Copy the snake and make the cube.

The head of the snake will be on the lid of the box.

The two nets shown below will also fold up to form cubes.



Choose one, show how you would add glue flaps and a snake so that it will make another snake cube, exactly the same.

Now make it to see if you were right!

1



Brainstorming

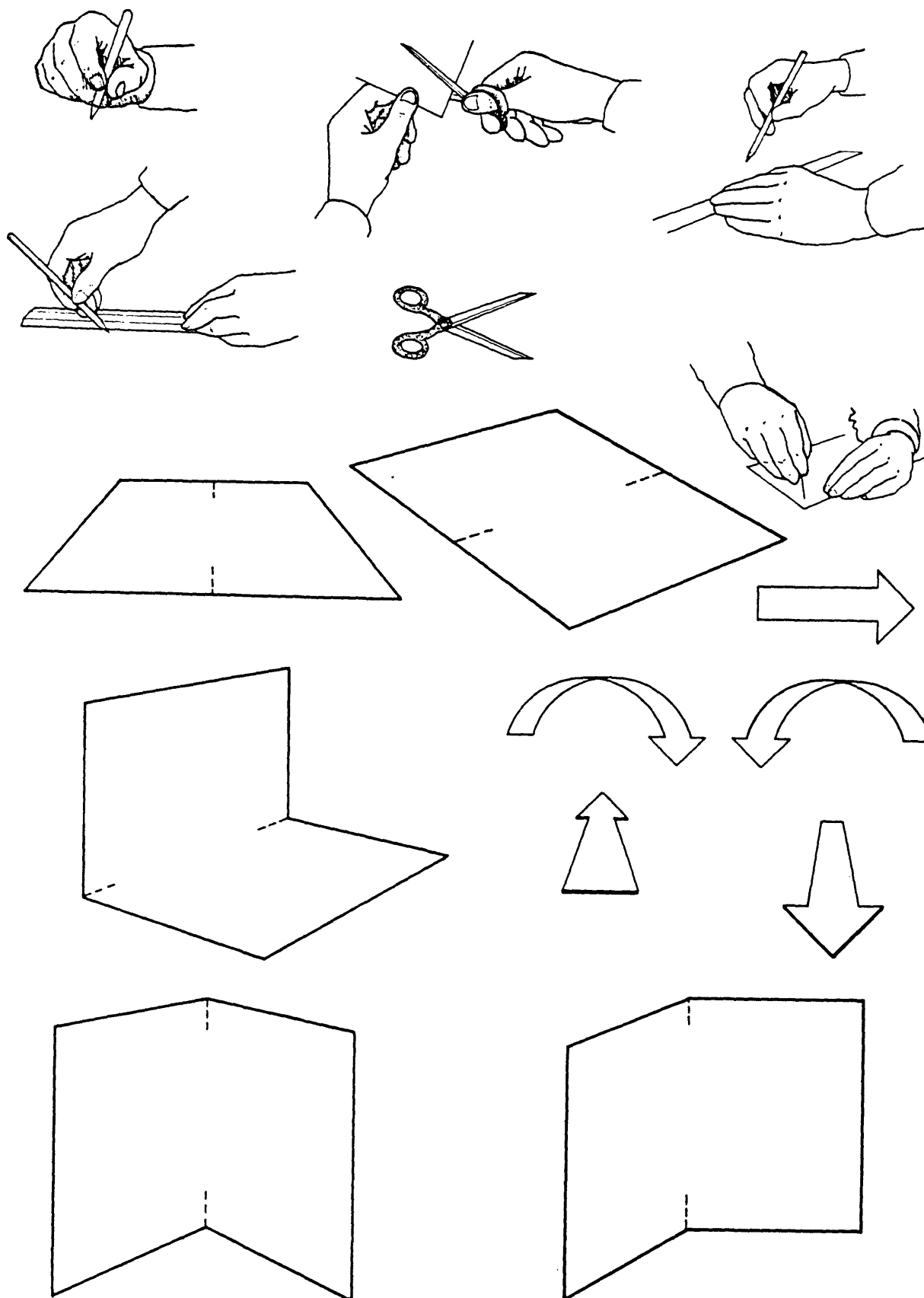
Name \_\_\_\_\_

Type of article (card, box, envelope...)	Theme	Special features	How it moves or works	Useful examples that we have already made

What I/we decided to make. (Draw a sketch on the other side of this sheet.)

## Cartoons for instructions

These may be photocopied and cut out to provide illustrations for the instructions for your own paper product in Stage 4.





## Discovering design principles

It is helpful to know if a design for a card will work, before you start to cut it out and assemble it. This can save a lot of time-consuming trial and error. This worksheet will help you to discover some design 'principles' for pop-up cards.

The diagrams below each show a different 'type' of card.

For each type, try to find out what *must* be true about

- distances between fold lines/gluing lines
- angles between fold lines/gluing lines,

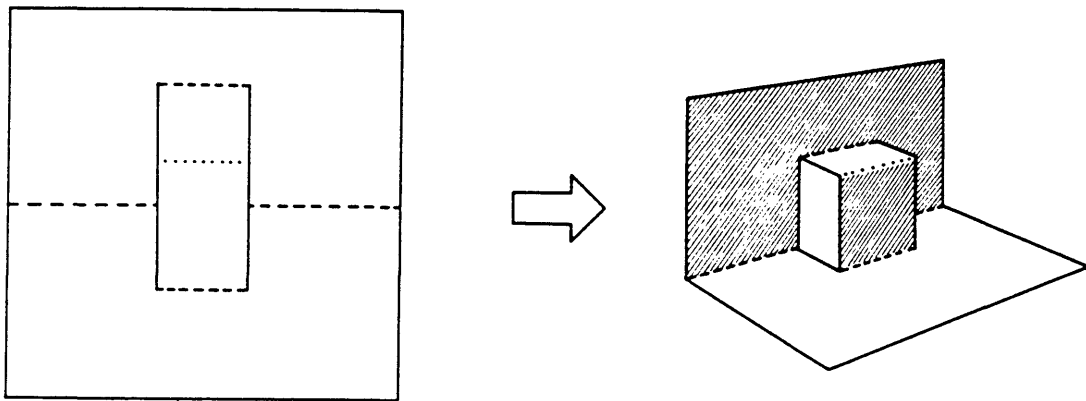
so that

- the cards will open and close through  $180^\circ$  without tearing or creasing in the wrong place,
- no parts will stick out beyond the base of the card when it is closed.

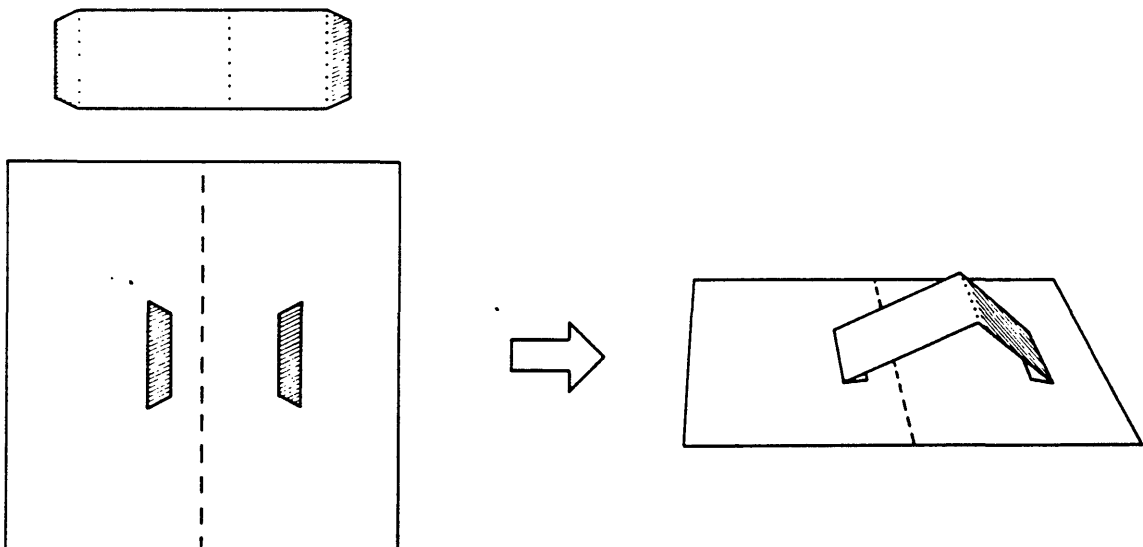
Check that your ideas work by making some models.

Try to prove that your ideas work.

### Type 1. Parallel folds – no glue.

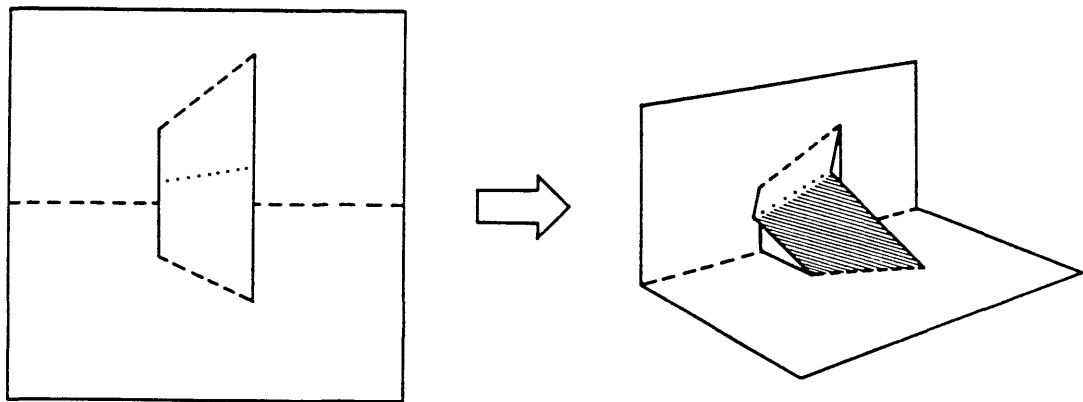


### Type 2. Parallel folds – with a piece stuck on.

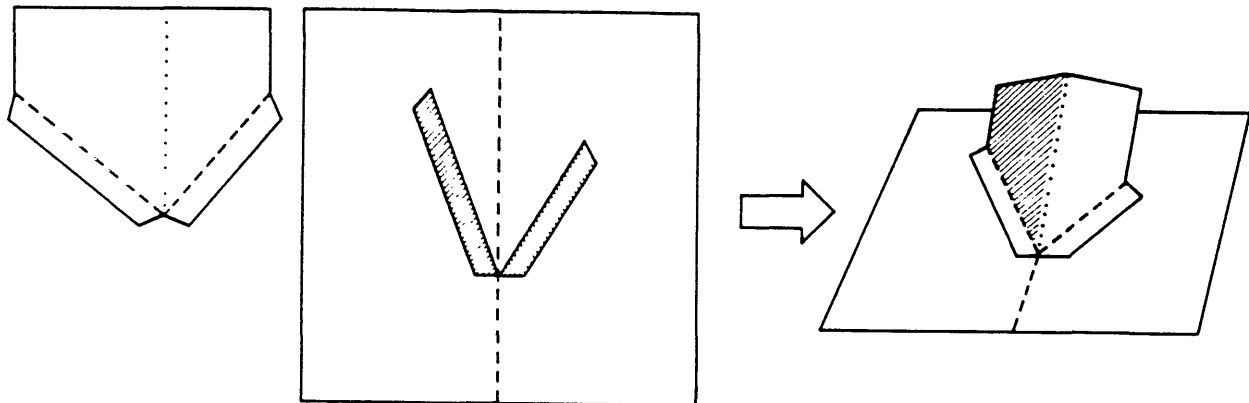


# Discovering design principles (continued)

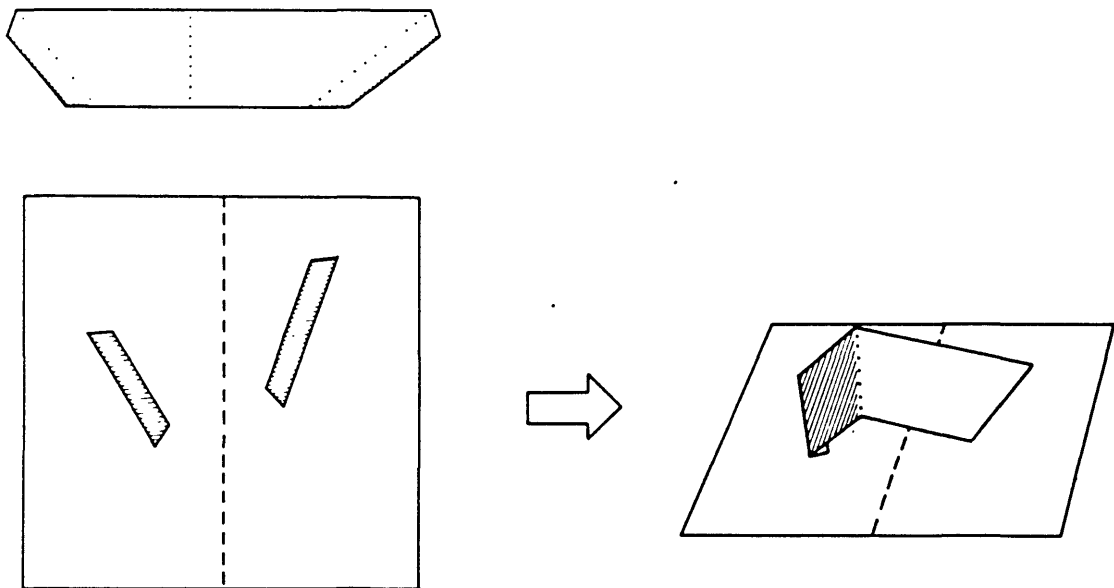
Type 3. Angled folds – no glue.



Type 4. Angled folds – with a 'wall' stuck on.

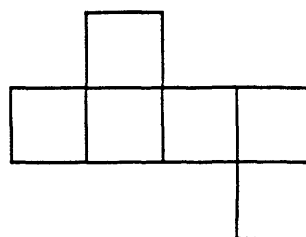
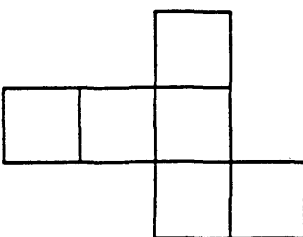
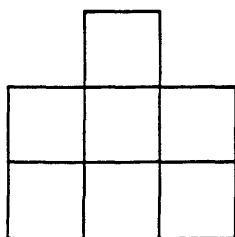
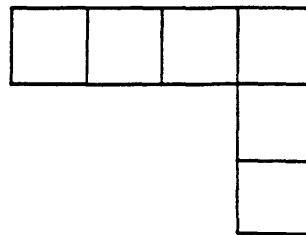
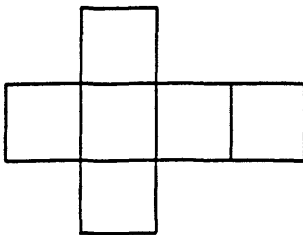
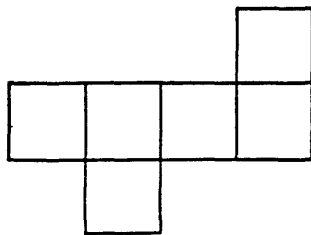


Type 5. Angled folds – with a piece stuck on.



## Designing nets for cubes

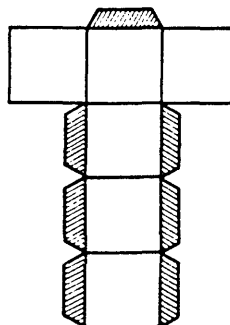
Here are six ways of joining six squares together, edge to edge:



- Which of these arrangements would you say are 'the same' as each other?
- Which *can* be folded up to form a cube?  
How can you tell, without having to make them?
- Which *cannot* be folded up to form a cube? Again, how can you tell?
- How many *different* nets of a cube are there?  
Draw them on dotted paper. How do you *know* that you have found them all?

If you want to make a cube from a net, you really need tabs as well.

- Choose any net.  
How many tabs do you need?  
Show how the tabs may be arranged.  
Now find some different ways of arranging them.  
How many different ways are there?
- Does the number of tabs needed depend on the particular net or arrangement you choose?  
Why?



## Design a shape sorter

Young children are often given 'shape sorters' to help them develop eye and hand co-ordination.

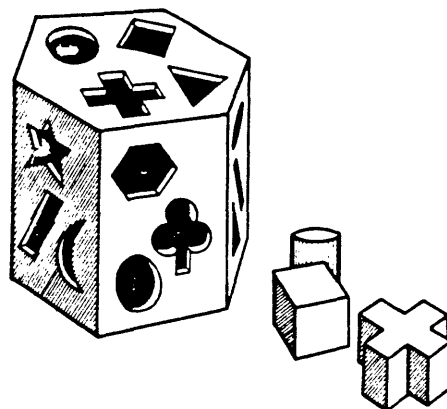
What do you think makes a 'good' shape sorter?

Write down a list of desirable features.

Design your own shapes and shape sorter and make them all out of cardboard.

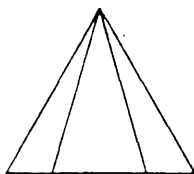
Write about how you designed it, and why you designed it like you did.

Give your shape sorter to young children and watch them play with it. Which shapes do they find easy to put in? Why? Which shapes are harder? Why?

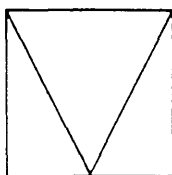


## Mystery box

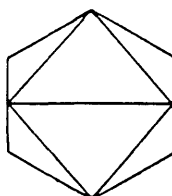
When the box is viewed from A, it looks like an equilateral triangle.



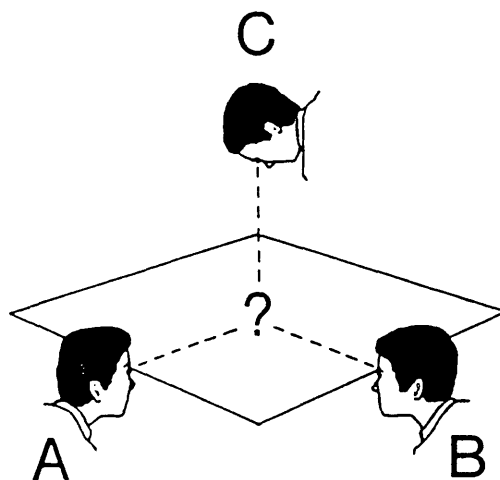
When the box is viewed from B, it looks like a square.



When the box is viewed from C, it looks like a regular hexagon.



Make the box!

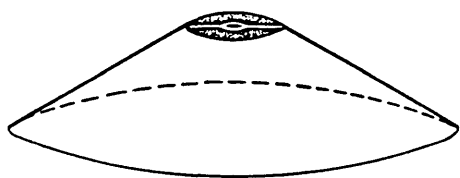


Now *you* write a worksheet like this for a box you have made.

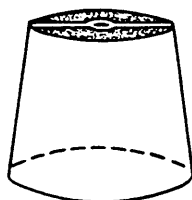
See if someone else can make the box from your worksheet.

# Design a lampshade

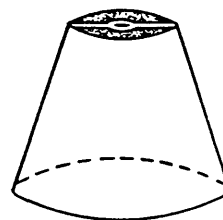
Lampshades come in all shapes and sizes, for example:



Coolie shape



Drum shape

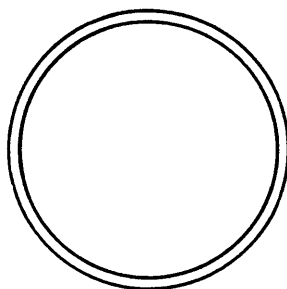


Empire shape

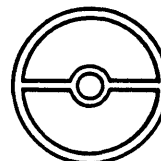
They are usually made from fabric, attached to wire frames.

The frames are designed so that the shades may either be hung from the ceiling or supported by a lampstand. Among the simplest lampshades to make are those with stiff-backed fabrics. All that is then needed for the frame are two rings, one for the top and one for the bottom. For example, you could have two rings like these:

bottom ring



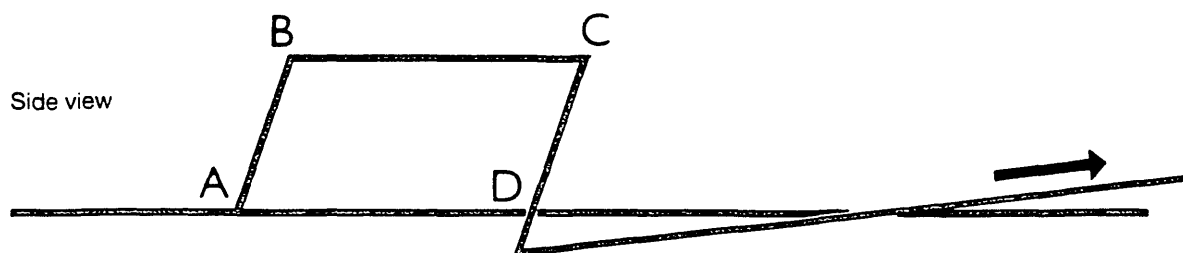
top ring



- If you can, obtain two rings from a shop or from an old lamp.
- Design and make a lampshade to fit these rings, from thin card.
- When you are happy with your design, buy some stiff-backed fabric and make the shade.

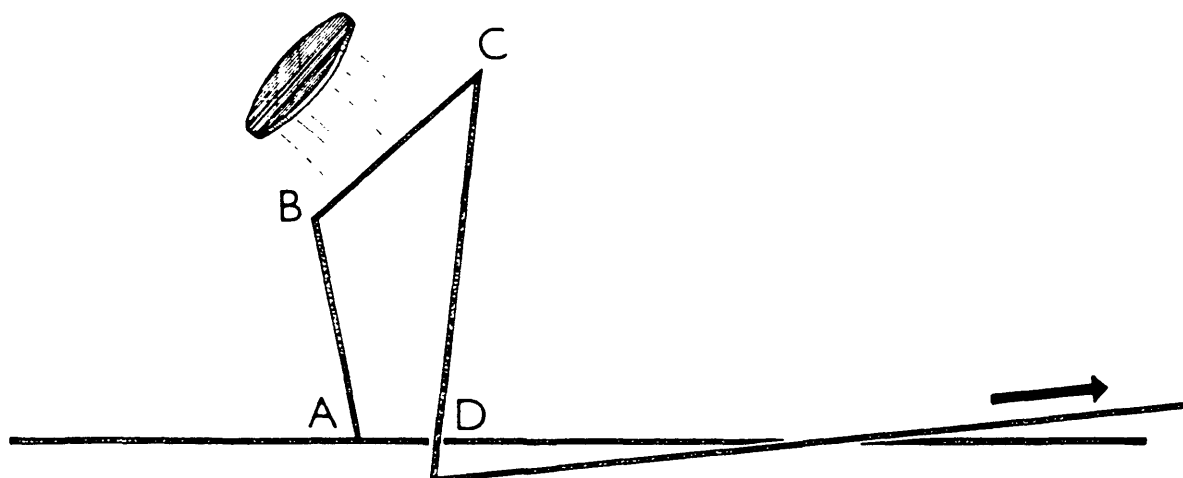
(When making your final design, prepare the frame by covering it with sticky-backed cotton tape. The fabric can be attached to the frame with clothes pegs, until it is positioned correctly, and then glued or sewn into place. A trimming may be added to make the edges neater.)

# Investigating the Frog linkage



The Frog card uses a parallelogram linkage, where  $AB = CD$  and  $BC = AD$ .

- Investigate what happens if  $AB \neq CD$ .
- Can you still make the card go flat when the lever is fully pushed in?  
Can you still make the card go flat when the lever is fully pulled out?  
What conditions must be satisfied?
- A student is designing a 'tiddlywinks' game which uses a linkage to toss the counters.



Can you make this linkage, which must satisfy the following conditions?

- (i)  $BC$  lies flat on the card when the lever is fully pushed in.  
(This ensures that it can be stored without breaking.)
- (ii) When the lever is fully pulled out and  $B$  touches the plane of the card,  $BC$  is vertical.

# Drawing in perspective

## Looking through windows



Look out of any window at nearby buildings.

Look for sets of parallel lines going away from you – roof lines, window frames, etc.

Imagine extending these lines into the distance. What do you notice?

Fix a transparent overhead projector film onto the window. Keeping your head as steady as possible shut one eye and draw what you see onto the film.

Remove the film and trace your picture. Extend sets of parallel lines.

The points where each set meets are called *vanishing points*.

Each set of receding lines has its own vanishing point. How many vanishing points can you find?

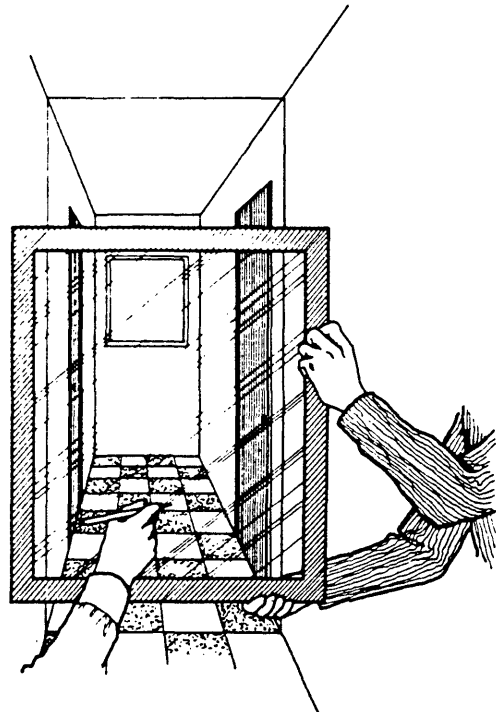
Draw additional lines through the vanishing points. Use them to insert new buildings or features into your picture.

Repeat the 'window' experiment, but this time get a friend to hold a piece of film vertically in front of you as you look through it down a corridor.

Keep your head steady and draw what you see onto the film.

Try again, with a different head position.

Investigate what happens when the film is not vertical.



## Drawing in perspective (continued)

### Looking at photographs

Look through some old magazines or colour supplements.

Find some pictures which contain lots of straight lines. Photographs of luxury kitchens are excellent – especially if they have tiled floors.

Extend all the lines and see what you find.

### Looking into mirrors

Fix a piece of transparent overhead projector film onto a mirror.

Put a box or any other object with parallel edges in front of the mirror.

Keeping your head steady, shut one eye and mark dots on the film to show the reflected corners of the box. (This is easier than trying to draw edges directly.) Remove the film and join up the dots with straight lines.

Extend all the edges in your picture. What do you find? Repeat for different mirror and head positions.

What happens to the vanishing points as you look down on something, horizontally at it, or up at it?

### Drawing a cube in perspective

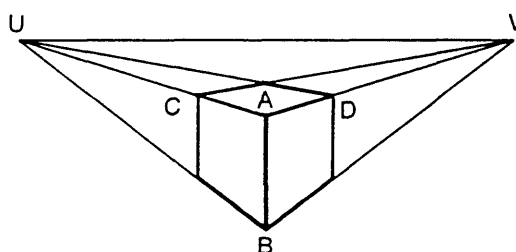
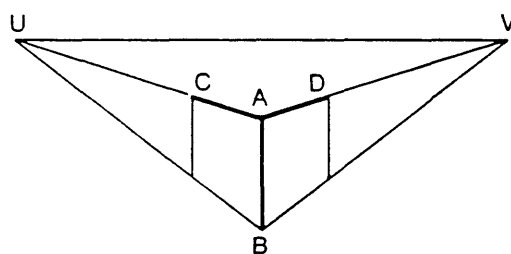
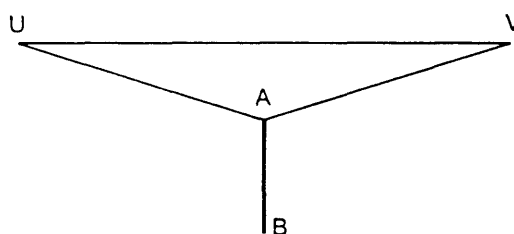
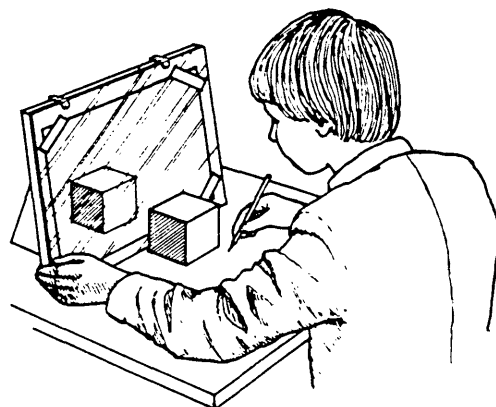
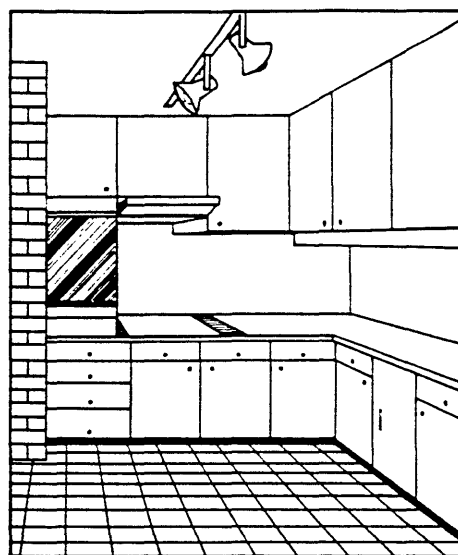
Imagine you are looking diagonally down on a cube on a table. In the diagram, AB is the front vertical edge of the cube. U and V are vanishing points for the horizontal edges.

Join up AU, AV, BU, BV. Mark in two other corners C and D as shown and draw vertical lines through C and D.

Join up CV and DU to complete the cube.

Repeat the drawing with AB in different positions – above UV, nearer U than V, at an angle. See what happens.

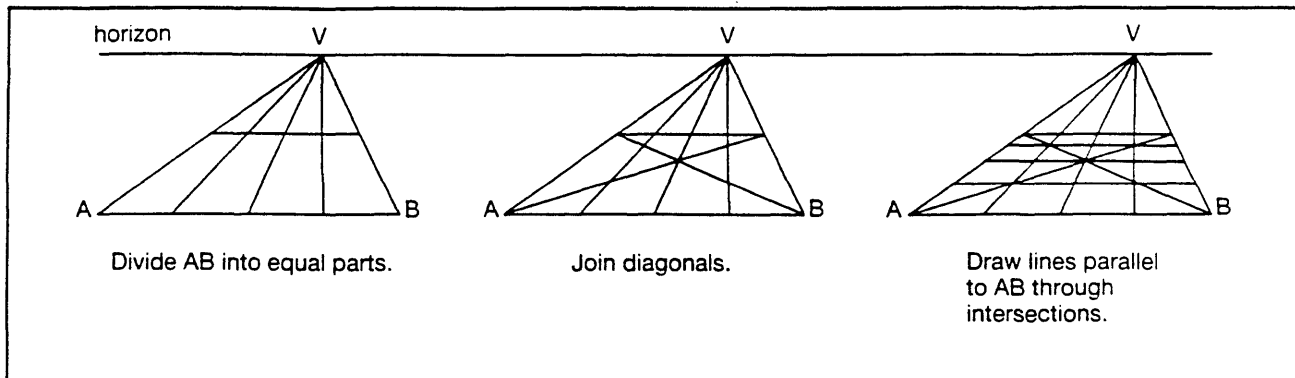
Repeat with U and V further apart and then closer together.





## Drawing in perspective (continued)

Try drawing a flat, square grid in perspective, using just one vanishing point:

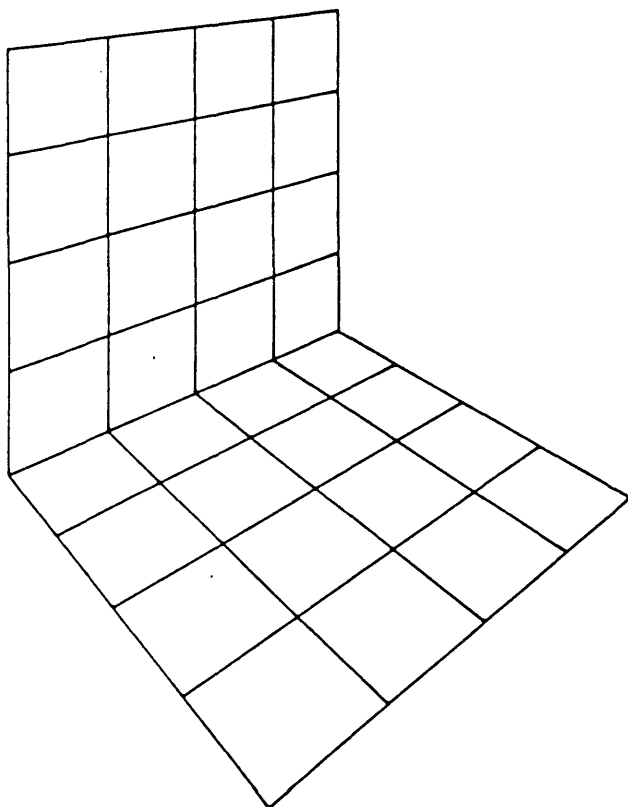
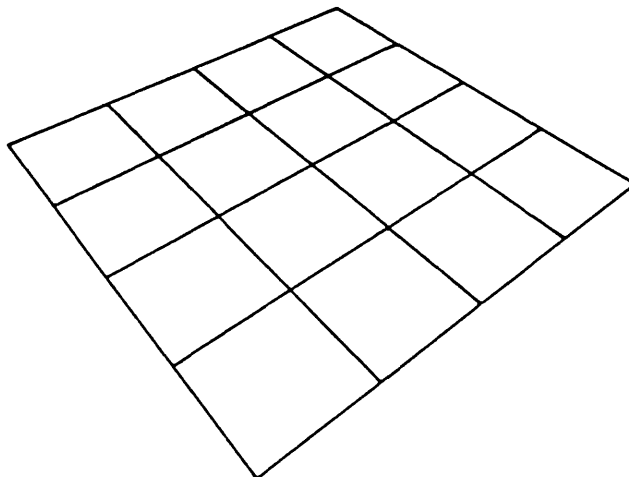


Draw in some other diagonals on your grid, and extend them.

See where they intersect.

Now try drawing a grid using two vanishing points.

Draw in diagonals and check that sets of parallel lines always intersect at vanishing points on the horizon.



Try adding a third dimension. (In the diagram, the vertical lines are all parallel, and there are still two vanishing points.)

Try drawing a perspective picture of a pop-up card or box using one or two vanishing points.

## Record sheet

## Criteria satisfied

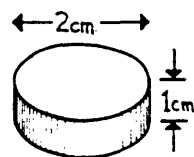
**A student has shown that he or she can:**

Name

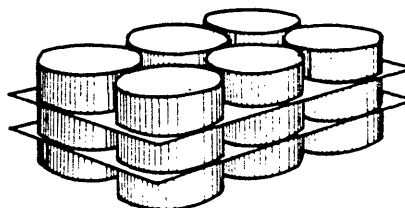
[illegible]

# Designing a box

Steve and Ann have made a large number of round peppermint sweets. Each sweet is 2cm diameter and 1cm thick.



They plan to sell them in boxes. Each box will hold 18 sweets, in layers of 6.

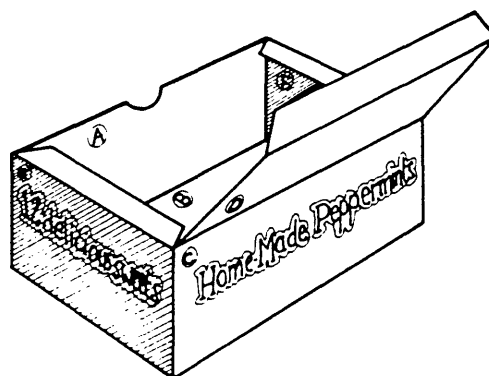
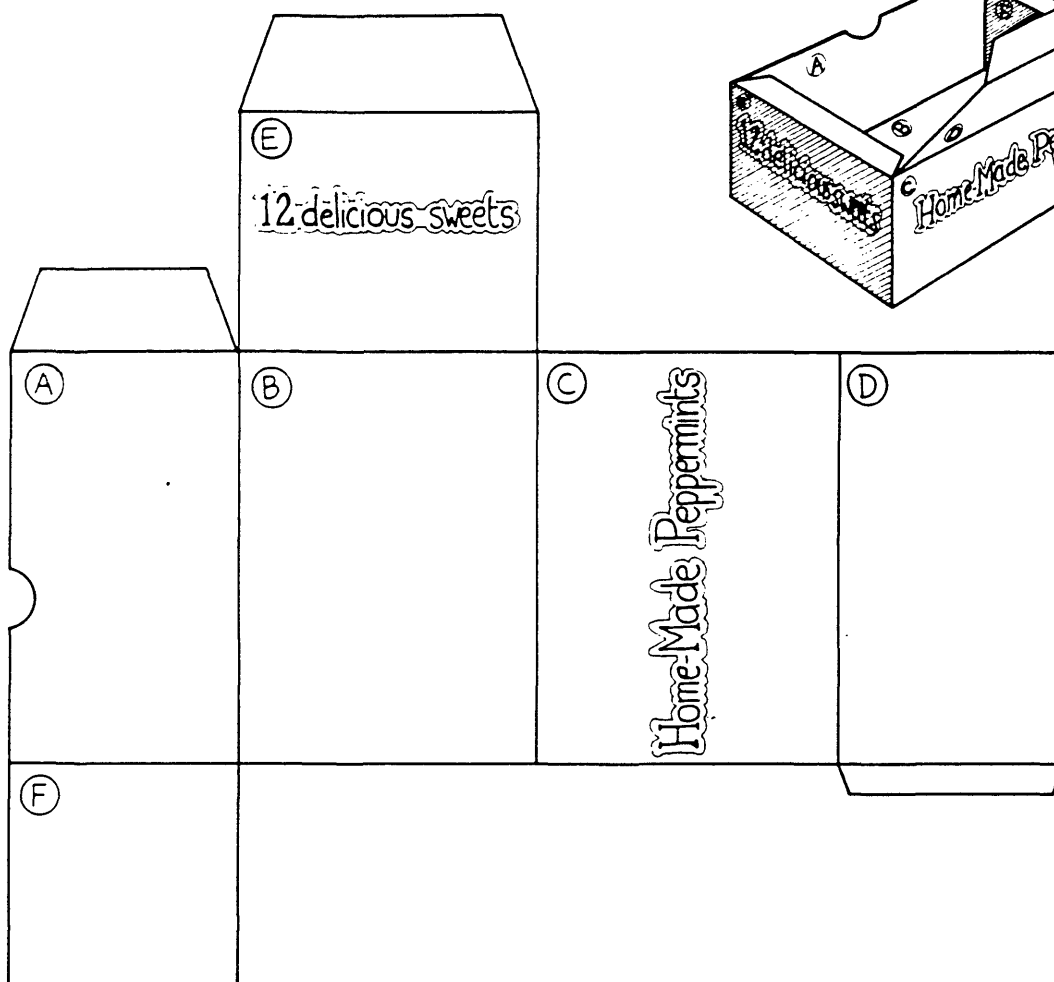


Below is their first design for a box. But . . . . .

It's no good!  
This won't even make a box!

- Using a copy of the design, cut out and try to make the box.

List as many mistakes in the design as you can. You can show them on the diagram below if you wish.

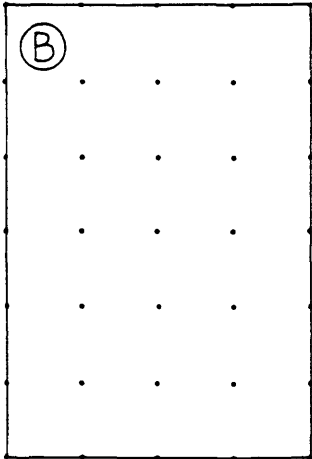


# Designing a box (continued)

We'll have to draw the design again

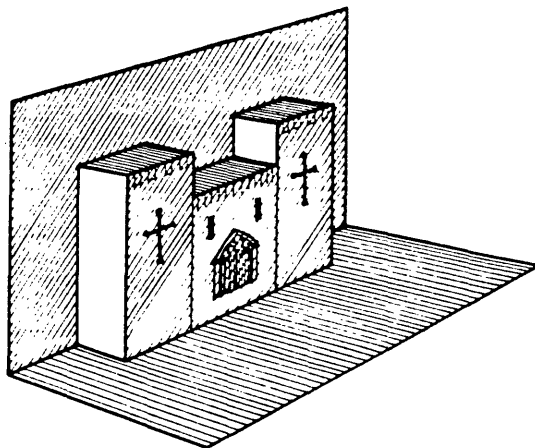
We must make it nice and strong.

2. Complete the correct design as accurately as you can.



# A Pop-up castle

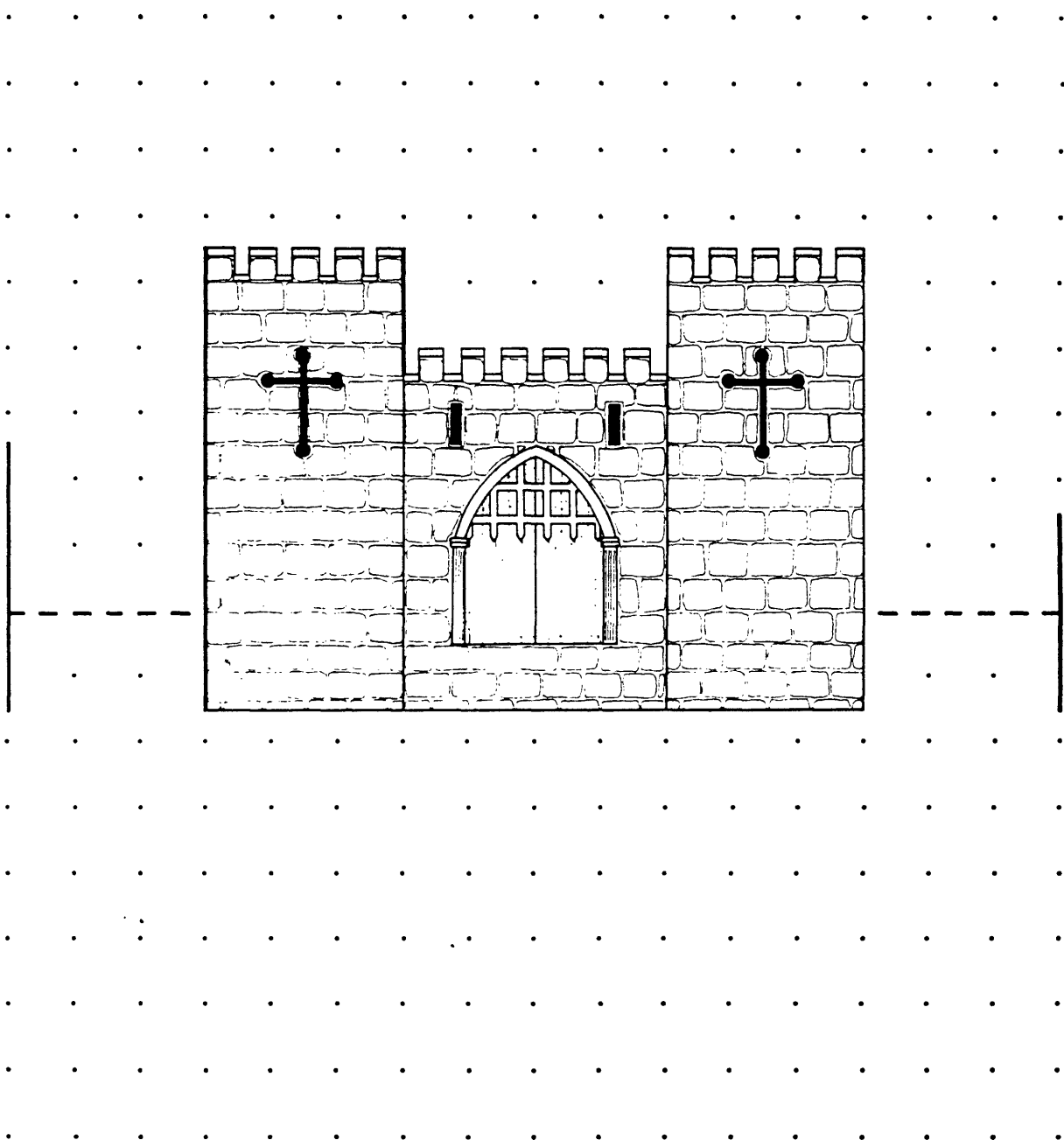
The picture shows a Castle pop-up card which Ann and Steve are making.



When the card is closed,

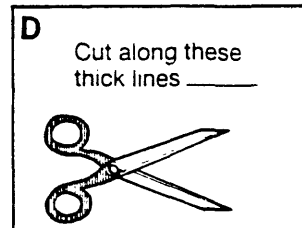
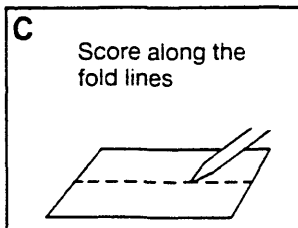
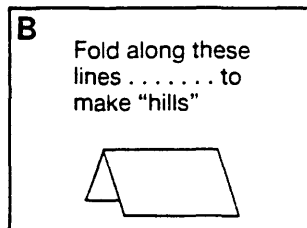
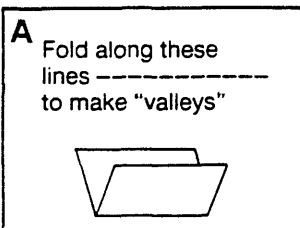
- the castle must not stick out beyond the edges of the card,
- the card must fit into an  $8\frac{1}{2}\text{cm}$  by  $16\frac{1}{2}\text{cm}$  envelope.

1. Using a copy of the design, cut out and make the card. Now complete the design for the card shown below as accurately as you can. (Use ——— for cut lines, . . . . . for hill folds, ———— for valley folds.)



# A Pop-up castle (continued)

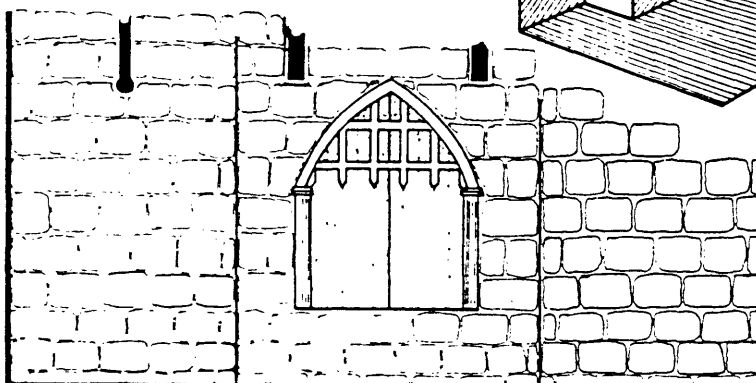
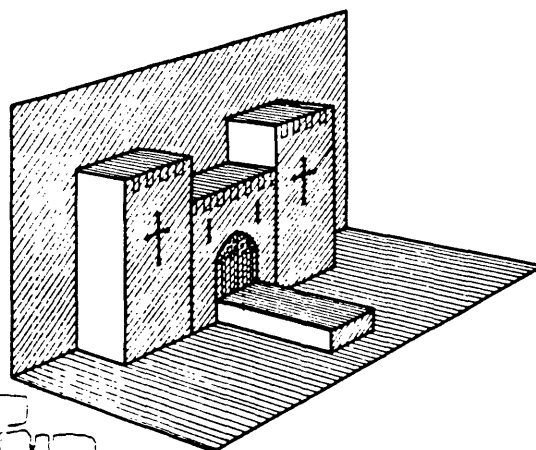
2. Here are four instructions (A, B, C, D) to help someone else make the card from the design:



In what order should the instructions be?

3. Anne and Steve decide to change their design by making a bridge which leads to the door. Add this bridge to the card you have already made.

Now show below, as accurately as you can, the extra cuts and folds that are needed on the design.

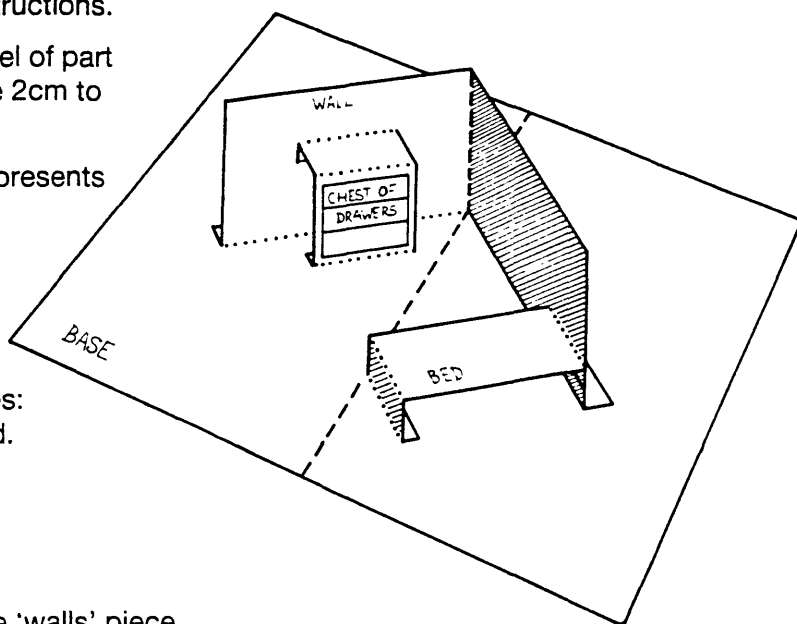


# A Pop-up bedroom card

Ann and Steve plan to produce an accurate design for the card, with assembly instructions.

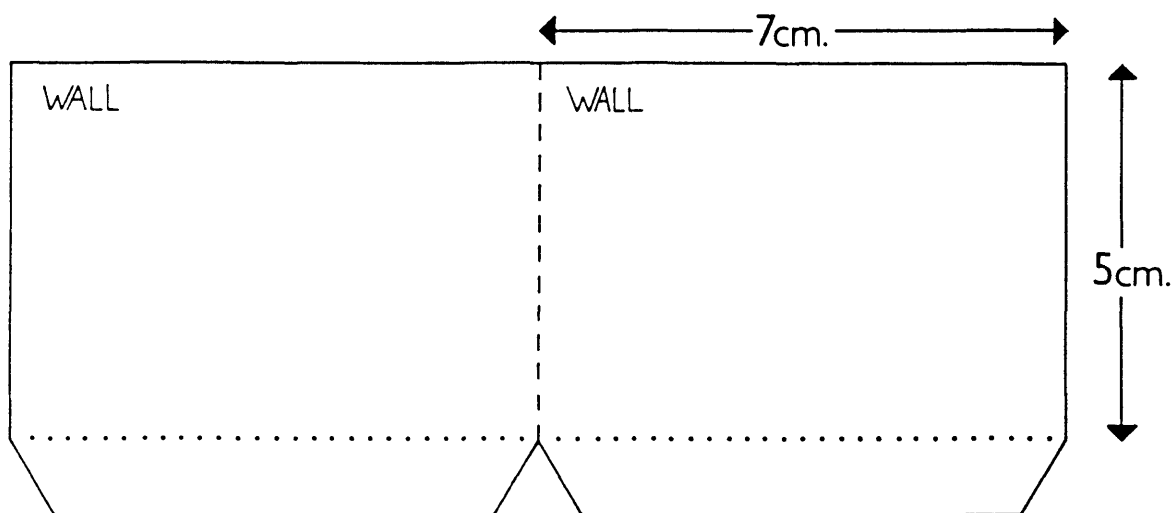
They want the card to be a scale model of part of a real bedroom. They decide to use 2cm to represent 1m.

So, for example, 10cm on the card represents 5m in the bedroom.



The card will be made from four pieces: Base, walls, chest of drawers and bed.

- Here is an accurate diagram for the 'walls' piece.  
What are the height and length of the wall in the real bedroom?



- Cut out the 'walls' piece from a copy of this sheet.  
Use it and some rough paper to make up the walls and base of the card.
- The chest of drawers is 1.5m wide by 0.7m deep by 0.9m high. On the card the pop-up chest will be fixed by glue to the wall and floor.  
Draw an accurate plan for this piece, including tabs for gluing.

## A Pop-up bedroom card (continued)

4. The card also includes a bed which is 4cm long and 1cm high. What is the greatest width the bed can have, so that the card will open and close properly? (Make sure it doesn't extend beyond the wall!)

Draw an accurate plan for this piece, including tabs for gluing.

5. When the card is closed, the pop-up parts should all be completely hidden.

At the same time, Ann and Steve want the base of the card to be as small as possible.

Draw an accurate plan for the base, showing clearly any fold lines and the exact positions where any tabs should be glued.

6. Give full instructions which explain clearly how to assembly an accurate version of the card, starting with the four pieces.