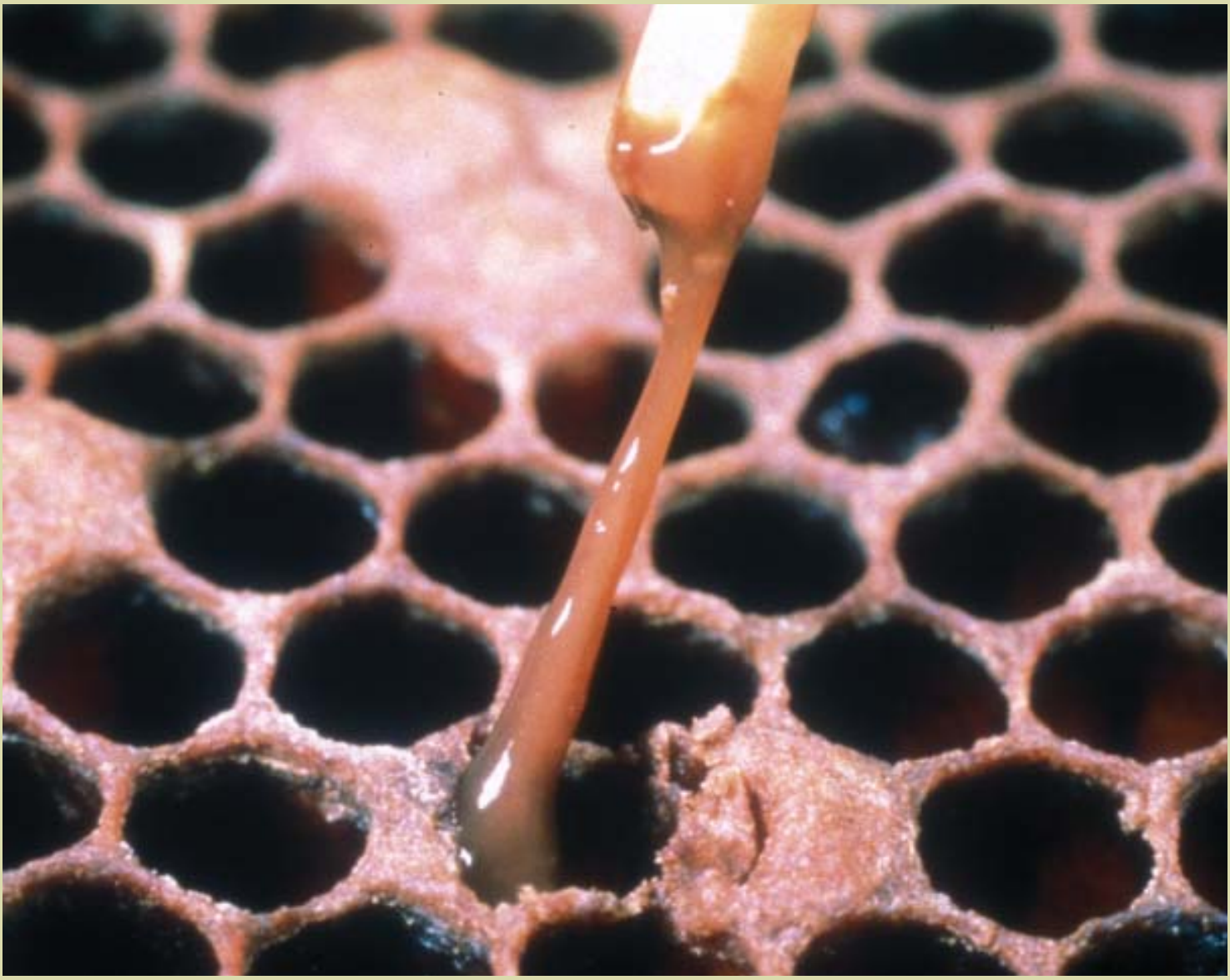
Foul brood disease of honey bees: recognition and control



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Pollinating animals provide almost incalculable economic and ecological benefits to humans, flowering plants and wildlife. Pollination by bees and other insects is the first step in the flowering/fruiting process resulting in the production of vegetables and fruits. This essential nutrition comprises approximately 35% of the human diet.

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About this leaflet

Foul brood disease of honey bees: recognition and control

Honey bee colonies are subject to a number of diseases that affect their brood. This leaflet describes the recognition and control of the two most serious of these, American foul brood and European foul brood (which are subject to statutory control) along with other common but less serious brood disorders.

Contents

Honey bees and disease

Honey bees, as they forage for nectar and pollen, play a vital role in the environment and in preserving biodiversity by pollinating both wild flowers and many agricultural crops. The economic value of pollination of such crops is estimated at £120m-£200m annually – and this is in addition to the production of honey, beeswax and other hive products. The essential and valuable activities of bees depend upon beekeepers maintaining a healthy population of honey bees.

Fig 1: Honey bee colonies pollinating Apple Blossom and Oil Seed Rape

As with other forms of livestock, honey bees are subject to a range of harmful diseases. Some of these affect adult bees, others affect immature stages of the bees' development (larvae and pupae) and these are referred to as brood diseases. There are several such brood diseases that affect honey bee colonies in the UK. These include the two extremely serious and infectious foul brood diseases, which are subject to statutory control, together with a range of common and less harmful disorders.

Foul brood

The term 'foul brood' covers two diseases of the honey bee larvae, one known as American foul brood (AFB), and the other European foul brood (EFB). The names bear no relation to the geographical distribution of the diseases: both occur in Great Britain and the economic damage done by them annually to our beekeeping industry is considerable. American foul brood is considered the most destructive brood disease in Great Britain. However, European foul brood is currently the most widespread, and where it occurs it often spreads rapidly and is difficult to eradicate unless prompt measures are taken.

Minor brood diseases

There are several other brood diseases and disorders that, although much less serious than foul brood, are extremely widespread. It is essential that beekeepers are able to recognise these and distinguish them from foul brood.

Varroosis and exotic pests

Infestation of honey bee colonies by the parasitic mite *Varroa destructor* is the subject of a separate CSL/Defra leaflet, *Managing Varroa*. The two exotic notifiable pests are covered in the following leaflets: *Small hive beetle, a serious new threat to European Apiculture* (full leaflet and fact sheet) and in *Tropilaelaps; parasitic mites of honey bees*.

All the leaflets are available on line through the National Bee Unit (NBU) website (www.nationalbeeunit.com), direct from your local Bee Inspector, or from the NBU main office at:

CSL
Sand Hutton
York
YO41 1LZ.

UK bee disease legislation

Both AFB and EFB are subject to statutory controls in the UK. The Bee Diseases and Pests Control (England) Order 2006 (SI 2006 No 342), empowers the Department for Environment, Food and Rural Affairs (Defra) to take measures to control both diseases in England. There are separate Orders in Wales, Scotland and Northern Ireland. Beekeepers should be familiar with the provisions of the Order. Copies are available on line from the Office of Public Sector Information (OPSI) website www.opsi.gov.uk/

Any beekeeper in England or Wales who suspects the presence of either AFB or EFB in a colony for which they are responsible is **legally required** either to contact the Central Science Laboratory (CSL) NBU in order to have the colony officially examined by a CSL Bee Inspector, or to submit a suspect disease sample for analysis to CSL. Beekeepers should also place the apiary from which the sample is taken under "self-imposed" standstill. Beekeepers elsewhere in the UK who suspect the presence of AFB or EFB should contact the local office of the relevant Government Agriculture Department for advice.

The NBU operates a statutory apiary inspection and surveillance programme in England and Wales. CSL Bee Inspectors inspect bee colonies for foul brood, free of charge. When foul brood disease is suspected, a sample is tested using a rapid diagnostic field test kit known as a Lateral Flow Device (LFD). Sometimes samples are taken for laboratory analysis. If disease is confirmed a Standstill Notice is issued, prohibiting the removal of bees and equipment from the apiary. The inspector will then carry out the necessary disease control measures. Further details about the NBU and its advisory and training services are given at the end of this leaflet.

Fig 2: CSL Bee Inspectors and NBU staff at work

Statutory inspection of colonies for pests and diseases

Beekeeper responsibility

- All colonies in the UK are at risk of contracting foul brood. If disease occurs but is not detected and controlled, the infection will normally spread quickly through the apiary and into adjacent apiaries belonging to other beekeepers. However, if the infection is spotted at an early stage and action is taken to tackle it, no further or only limited spread should occur.
- Good husbandry should be a starting point for control of foul brood. Keep a close eye on the health of your bees, and in particular make sure you can recognise the signs of foul brood infection and any abnormalities in the brood.
- Maintain apiaries to minimise the effects of robbing and drifting.
- Aim to keep strong vigorous colonies and try to select hygienic strains of bees that do not suffer from disease.
- As part of routine good husbandry practice aim regularly to replace old comb. Many beekeepers replace a minimum of four combs per brood box each year. Others replace all the combs in the brood chambers each year as the colony expands in the spring.
- Beekeepers, as keepers of livestock that contribute enormously to agriculture and the environment, have a responsibility to ensure that their bees are healthy and that they are not unwittingly spreading any infection through their beekeeping practices.
- You should be familiar with the signs and causes of the diseases that may affect your bees, the action to take if foul brood is suspected, and the measures you should take to help keep your colonies healthy and productive.
- The Bee Inspectors from the CSL's NBU cannot examine all colonies of bees each year, and it is therefore essential in the control of foul brood for you regularly to inspect your own colonies for signs of brood disease. Vigilance is the key; you must spot the signs of infection **early**.
- If you suspect foul brood, you must contact the NBU for assistance. It is also very good practice to inform other local beekeepers of the problem so that they can quickly check for signs of disease in their own bees.

Figure 3: Migratory beekeeping has the potential to spread pests and diseases long distance. It is essential to check before moving that your colonies are healthy

10 Rules for Foul Brood Control

1. Make sure you are familiar with the signs and causes of foul brood and other brood disorders.
2. Inspect your colonies at the very least every spring and autumn, **specifically** to check for brood disease. If you are unsure, seek expert advice.
3. Never transfer combs between colonies, or divide colonies, without first checking for signs of brood disease.
4. Never bring colonies, combs or beekeeping equipment into the apiary unless you are sure that they come from a disease-free source.
5. Never buy old combs. Always sterilise second-hand hives by thoroughly scorching them with a blow lamp before use.
6. Control robbing in the apiary. Never leave combs or honey exposed to robbing bees. Never feed honey from another source to your bees.
7. If a colony of bees dies out at any time, seal the hive to prevent the remaining stores being robbed out, pending examination of the brood combs for signs of disease.
8. If any colony appears not to be thriving, and the reason is not already known, examine the brood for signs of disease.
9. Be suspicious of stray swarms. Hive them on foundation rather than drawn comb, keep them "isolated" from the rest of the apiary as the colony expands and inspect them for disease once they have become established.
10. Regularly and systematically replace old brood combs in the apiary by melting them down and replacing them with frames fitted with foundation.

Figure 4: Bee disease recognition training

Healthy Brood

All beekeepers should be familiar with the appearance of healthy worker brood, so that they can recognise any abnormalities immediately which may indicate the presence of foul brood or other brood diseases.

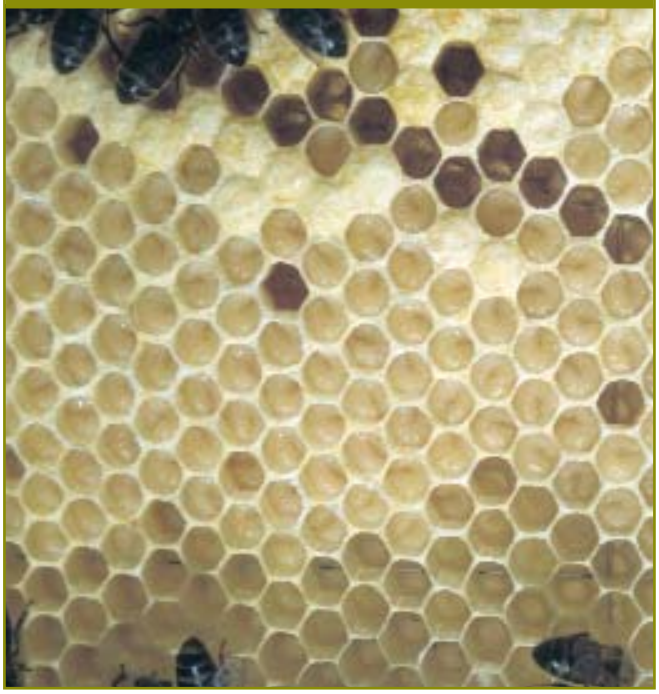
The queen lays eggs at the base of cells in the brood nest. These hatch after three days and develop into tiny translucent larvae lying at the base of the cell in a bed of milky brood food.

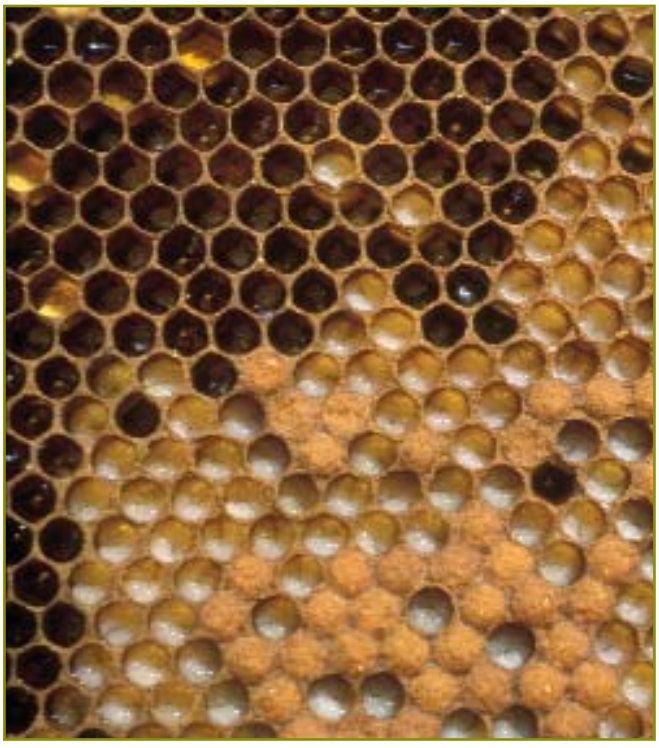
Figure 7: An even pattern of eggs

Figure 8: Young healthy worker bee larvae and eggs

After six further days of development, the larvae have increased in size to almost fill the base of the cell. Healthy larvae are **pearly-white** in colour. They lie in a distinct **'C' shape**, with the head and tail curled towards one another. The body of the larva can be seen to be divided along its length into a series of segments.

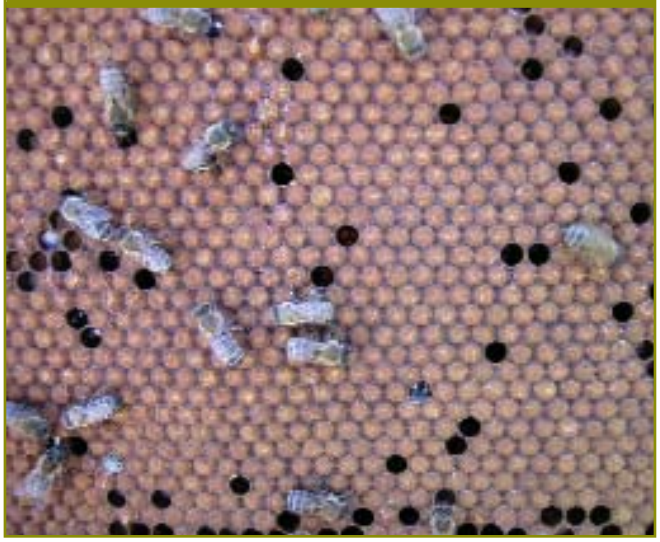
Figure 9: Healthy larvae shortly before sealing





When the larvae are nine days old, the cell opening is sealed by adult bees with a cap of wax, and development into an adult bee occurs inside the sealed cell completing metamorphosis. The wax cappings on healthy worker brood vary in colour from very light to dark brown (often referred to as digestive biscuit colour), and they are dry looking and slightly convex. Drone brood can be distinguished from worker brood by its larger cells and domed cappings.

Figure 10: Sealed healthy brood



A good even brood pattern (refered to by beekeepers as wall to wall), with very few empty cells within patches of brood suggests that the queen is laying well and nearly all the larvae are developing normally. Even where the brood pattern is more haphazard, as results from an old or failing queen for instance, the individual larvae and cell cappings should still have a normal appearance.

Figure 11: Healthy capped brood produced in a productive healthy colony

Sources of spread of foul brood	
Sources of infection	**Means of spread**
Infected combs, brood combs	Transfer of combs between colonies
Super combs	Robbing
Honey	Drifting
Beekeeping equipment	Swarming
	The beekeeper through management practices

How to examine a honey bee colony for brood disease

- Wear full protective clothing and have a smoker well lit.
- Keep the colony subdued with smoke.
- Remove the hive roof and place it on the ground by the hive (to the side of the hive or behind away from the hive entrance).
- If there are supers on the hive, remove them and place them on the upturned roof, keeping them covered to prevent robbing.
- Remove any queen excluder and examine the underside for the queen. If she is present return her to the colony. Place the excluder on the ground next to the roof.

Figure 12: Opening the hive for disease inspection

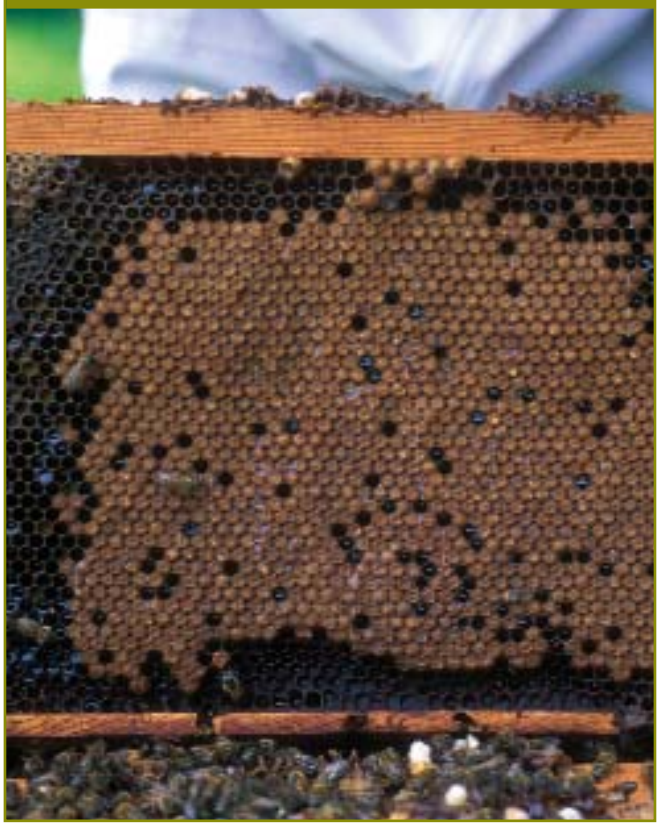
- Where two boxes are used for the brood nest examine the bottom one first.
- Remove the outside comb, which is unlikely to contain brood, and lean it against a front corner of the hive – you will then have room to work.
- Take each comb in turn, and holding it by the lugs within the brood chamber, give it a sharp shake. This will deposit the bees on the bottom of the hive without harming them, the queen or brood.

Figure 13: With the adult bees on the comb you can not clearly see the brood

Figure 14: Shaking adult bees from the comb into the hive

- Any bees on a comb may be concealing infected brood from the beekeeper's view. On combs free from bees, any abnormality is easily spotted.
- Examine the brood, both sealed and unsealed, quickly but carefully, for any signs of abnormality – such as discoloured larvae or perforated cappings.
- Look for AFB scales (see page 14) by holding the combs towards the light and scanning the bottom walls of any open cells.

Figure 15: With the bees removed the brood is clearly visible



- Look inside any sealed cells with abnormal looking cappings after opening the cell with a corner of the hive tool, matchstick or suitable implement.
- To establish the consistency of any dead remains present, probe these with a matchstick. Dispose of the used matchstick in the smoker.
- Continue until you have examined all the brood combs; then reassemble the hive.
- **If you suspect EFB or AFB may be present, you must contact the NBU immediately for assistance** (see key contacts information at the end of the leaflet for details).

Figure 16: Examining comb for scales

American Foul Brood

Cause

American foul brood is caused by a spore-forming bacterium called *Paenibacillus larvae.* Young honey bee larvae become infected when they consume *P. larvae* spores in their food. The spores germinate in the gut; bacteria then move into the tissues, where they multiply enormously in number. Infected larvae normally die after their cell is sealed, and millions of infective spores are formed in their remains. These remains dry to form 'scales' which adhere closely to the cell wall and cannot easily be removed by bees. Consequently brood combs from infected colonies are inevitably severely contaminated with bacterial spores. If the scales are not spotted and infected combs are subsequently used and distributed or moved from colony to colony during routine beekeeping management then infection has the potential to spread quickly.

The spores are very resistant to extremes of heat and cold, and to disinfectants. They retain their powers of germination for many years in honey, in old combs kept in store, or in derelict hives, skeps or boxes.

Once a colony is infected the disease will usually progress until most of the brood is affected. The colony then becomes unable to replace the ageing adult bee population, causing it to become weakened, and finally to die out. The disease may develop for months before the colony succumbs, and death may occur at any time of the year.

Spread

The beekeeper is the chief spreading agent of the disease. If combs, honey or hive equipment are transferred from an AFB-infected colony to a healthy colony, it becomes infected. Bees robbing honey from infected colonies also transmit the disease. Swarms from infected colonies may also carry infection with them and become diseased after they are hived.

Control

AFB is a notifiable disease under the Bee Diseases and Pests Control (England) Order 2006 and is subject to official control by a programme of apiary inspections carried out by the NBU. Control of the disease is through compulsory destruction of infected colonies, which is a very effective measure. This eradication policy has been highly effective since the 1940s when first introduced, bringing the incidence of foul brood down from several thousand infected colonies per year to about 60 in 2006 the lowest level ever recorded. In recent years disease incidence has been characterized by sporadic but large outbreaks which have been rapidly brought under control by the inspectors and beekeepers working together. Methods of control of AFB using antibiotics that are used in some overseas countries are not effective, as they only serve to suppress signs of the disease without eradicating it and through frequent use allow the development of resistant bacterial strains. **The use of antibiotics to control AFB is not permitted in the UK**.

Diagnosis

For confirmation of AFB, a suspect sample is tested using a LFD field kit. Sometimes brood combs (or suspect larvae in plastic tubes) are sent to the NBU laboratory where larval remains are examined for the presence of the causative bacteria.

Infected colonies are destroyed by burning under the supervision of a Bee Inspector. The bees are killed, and together with the combs are safely burned in a deep pit (fig 17).

Hives and appliances can be sterilised by thoroughly scorching them with a blow lamp (Fig 18). Gloves, overalls, footwear and the smoker are then washed thoroughly in washing soda or hot soapy water.

Figure 17: Destruction of an AFB infected colony

Figure 18: Sterilisation of hive boxes with a powerful blow lamp

Signs of American foul brood

- AFB generally affects only sealed brood. When infected larvae die within the sealed cell, the appearance of the cell cappings changes. A good way of remembering is that AFB = ***A*** (after sealing of the cell).
- Wax cappings become sunken and perforated when adult bees nibble holes in them to try to remove the infected larva within. These perforations tend to be jagged and irregular in shape.
- Some cappings may become moist or greasy looking and slightly darker in colour than other cells.

Figure 19: AFB – perforated and sunken cappings

- At first only very few cells may show signs of disease, and the colony will appear normal in other respects.
- Eventually much of the sealed brood will become affected by the disease, causing a patchy or 'pepper pot' brood pattern.
- There may then be an unpleasant smell associated with decomposition.
- At the sunken capping stage the dead larval remains are light to dark brown in colour, and have a slimy consistency.

Figure 20: AFB – "pepper pot" brood

- If a matchstick is inserted and slowly withdrawn, the remains can be drawn out in a brown, mucus-like thread or 'rope' 10-30mm long. This is called the **'ropiness'** test and is a reliable test for the presence of AFB.
- The ropy condition is followed by a tacky stage as the larval remains in the cell gradually dry up and the colour changes to dark brown.
- The proboscis of dead pupae may sometimes remain intact, protruding upwards from the bottom edge of the cell (fig 23).

Figure 21: AFB ropiness test

- Further drying leads to the final stage, which is a very dark brown, rather rough scale lying on the lower side of the cell and extending from just behind the mouth of the cell right back to the base.
- The scales can be detected if the comb is held facing the light: they reflect the light from their rough surfaces and can easily be seen, even when their colour is almost the same as the comb itself.

Figure 22: AFB scales in comb

Figure 23: AFB pupal tongue stage

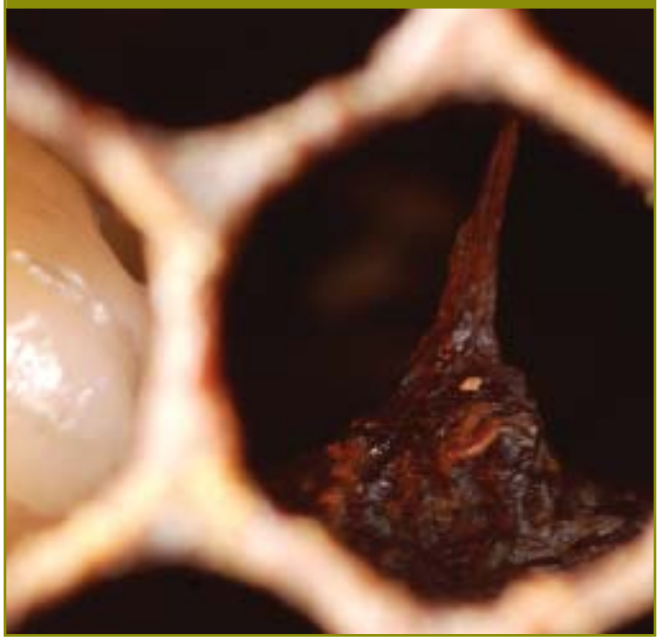
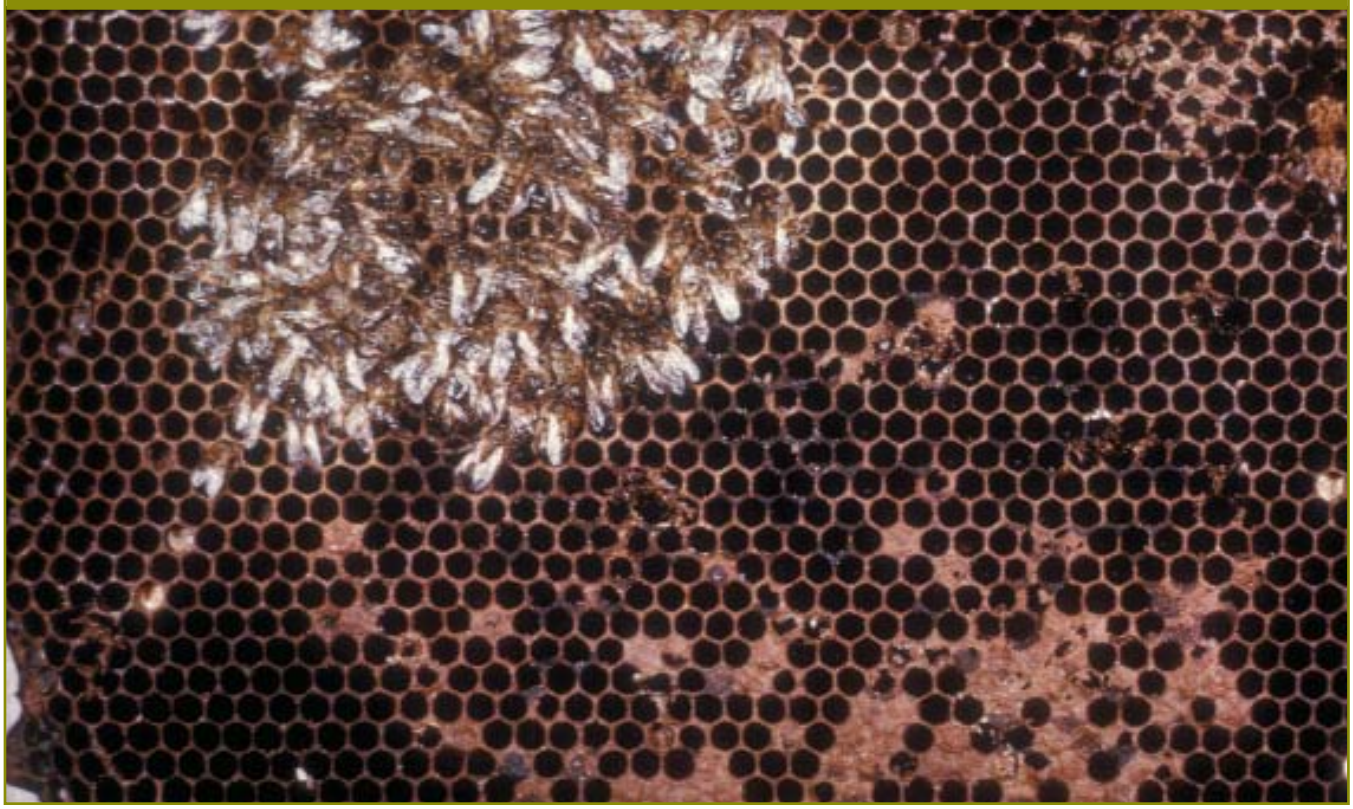


Figure 24: Can you spot the abnormality?

Figure 25: What happened to this colony?



Answers

Figure 24: AFB Scales are visible if you look carefully

Figure 25: This colony died of starvation and a heavy infection of American foul brood.

European Foul Brood

Cause

European foul brood is caused by the bacterium called *Melissococcus plutonius*. The bacteria multiply in the mid-gut of an infected larva, competing with the larva for its food. They remain in the gut and do not invade the larval tissue; larvae that die from the disease do so because they have been starved of food. This normally occurs shortly before their cells are due to be sealed. Subsequently other species of bacteria may multiply in the remains of dead larvae as 'secondary invaders', such as *Paenibacillus alvei, Enterococcus faecalis, Brevibacillus laterosporus*, and *Lactobacillus eurydice.*

Progression of the disease

The development of the disease within a colony is complex, and still not fully understood. It appears that infection can develop over a period of months or years, debilitating but not killing the colony. During this time, signs of the disease may become more or less severe, or disappear altogether. Frequently there is a seasonal pattern, with signs becoming most obvious in late spring. This is thought to be because when there are many larvae relative to the number of nurse bees, larvae tend to receive less brood food overall, and those infected with EFB are more likely to suffer from starvation. At other times, larvae that are infected but receive an abundance of brood food may survive the infection, and develop into healthy adult bees. However, when such larvae pupate, they void their gut contents into the cell, contaminating the comb with millions of infective bacteria. Eventually the disease is likely to reach the stage where a high proportion of the brood is affected and the colony will be weakened and ultimately killed.

Spread

The beekeeper is the chief spreading agent of the disease. If combs, honey or hive equipment are transferred from an EFB infected colony to a healthy colony, it is likely to become infected. Bees robbing honey from infected colonies also transmit the disease. Swarms from infected colonies may also carry infection with them and become diseased after they are hived.

Migratory beekeeping – moving infected or healthy colonies into close proximity of infected apiaries-can also spread disease.

Diagnosis

European foul brood cannot be reliably identified visually, as the disease signs can easily be confused with various other brood abnormalities. Suspect infections are confirmed in the field by CSL Bee Inspectors using Lateral Flow Devices. Occasionally sample brood combs (or suspect larvae in plastic tubes) are sent to the NBU laboratory where larval gut contents are examined for the presence of the causative bacteria.

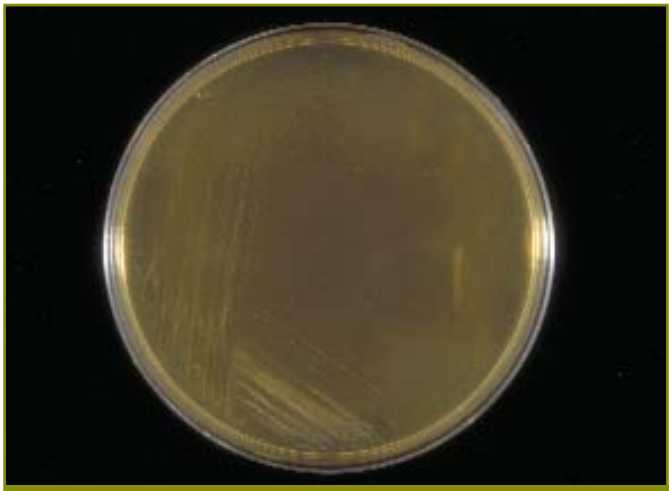
Control

EFB is a notifiable disease under the Bee Diseases and Pests Control (England) Order 2006 and is subject to official control by the examination of colonies for signs of disease and compulsory treatment or destruction of diseased colonies. Weak colonies and colonies with a high proportion of diseased brood are destroyed, as with American foul brood, but lightly diseased colonies may be treated with an antibiotic. Treatment must be carried out only by an Appointed Officer under the Order, using drugs officially dispensed following confirmation of European foul brood in a disease sample submitted for diagnosis at an approved laboratory or by LFD. Treatment is prescribed by the designated Veterinary Laboratories Agency (VLA).

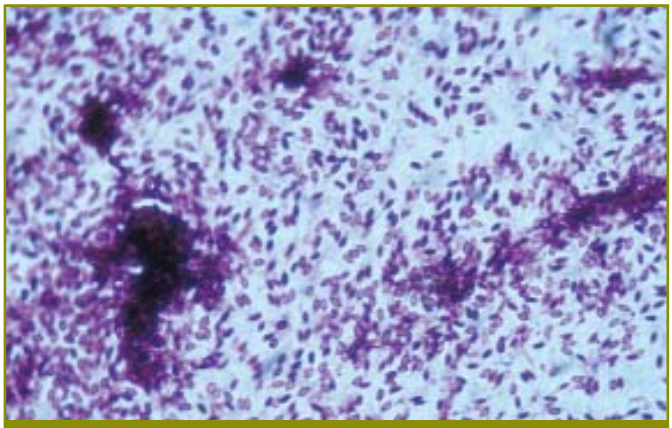
Control of the disease by a husbandry method known as the *"shook swarm"* has also been shown to be effective and is an option available to beekeepers (see pages 21-22 and 25).

Figure 26: Some of the options for laboratory diagnosis of foul brood

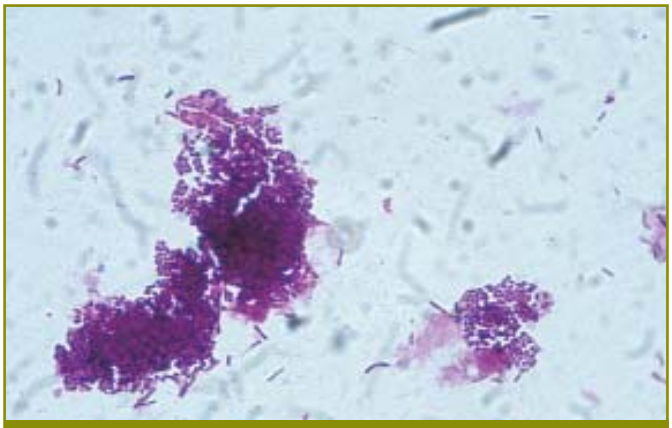
Real time Taq Man PCR (Molecular diagnosis)



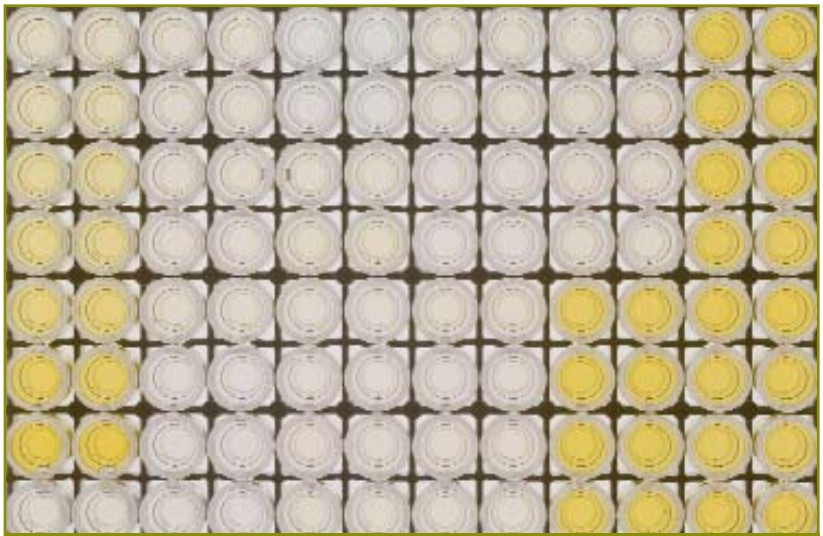
Microbiological identification



Microscopy and Staining techniques *Paenibacillus alvae* (associated with EFB)



Melissococcus plutonius (causative organism of EFB)



Detection of foul brood using ELISA (Enzyme-linked immunosorbent assay)

Identification of bacteria through light microscopy

Signs of European foul brood

- EFB affects mainly unsealed brood, killing larvae before they are sealed in their cells.
- An easy way to remember is that EFB = ***E*** (early infection before sealing of the cell).
- The EFB infected larva moves inside its cell instead of remaining in the normal coiled position characteristic of a healthy larva of the same age.
- When it dies it lies in an unnatural attitude – twisted spirally around the walls, across the mouth of the cell or stretched out lengthways from the mouth to the base.

Figure 27: EFB affected unsealed brood

The dead larva often collapses as though it had been melted, turning yellowish-brown and eventually drying up to form a loosely attached brown scale. (fig 30)

The gut of an infected larva may be visible through its translucent body wall. It has a creamy white colour caused by the mass of bacteria living within it. (fig 31)

Figure 28: EFB – twisted and discoloured larvae

When a high proportion of the larvae are being killed by EFB, the brood pattern will often appear patchy and erratic as dead brood is removed by the bees and the queen lays in the vacant cells.

A very unpleasant odour may sometimes accompany severe EFB infection, depending on the presence of certain other species of bacteria in the remains of dead larvae.

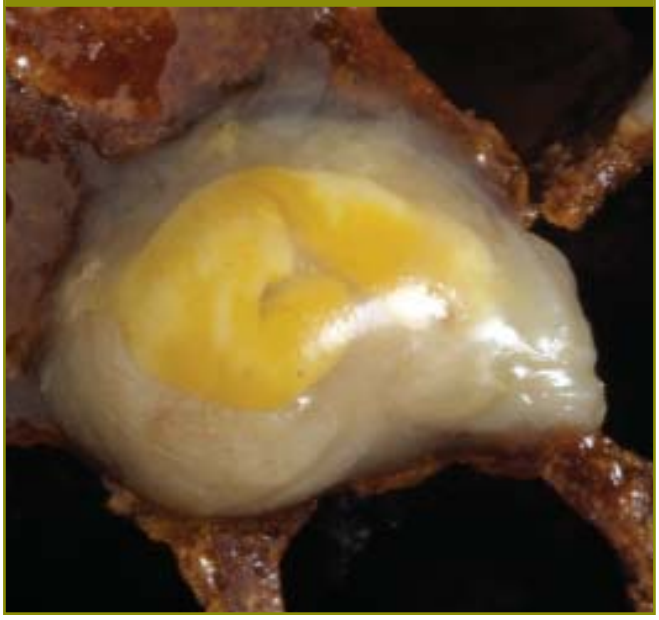
Figure 29: EFB – severe infection and patchy brood pattern

A minority of infected larvae may die after the cell is sealed. In such cases, there may be sunken perforated cappings resembling AFB infection. However, the cell contents although brown and sticky cannot be drawn into a 'rope' as with AFB.

Where larval remains dry to form scales, these are variable in colour, loose within the cell and somewhat "rubbery", unlike the hard black firmly attached scales of AFB.

Figure 30: EFB – dead brood with scales

Figure 31: EFB photograph showing yellow/white colour of infected larval gut



Controlling an outbreak of Foul Brood

If you keep bees for long enough, it is likely that you will someday have to deal with an outbreak of EFB or AFB in your colonies. When this happens, your Bee Inspector will visit you several times to help bring the infection under control – first inspecting your colonies for signs of disease, then treating or destroying infected colonies, and later returning to make sure that there has been no disease recurrence in the apiary. Bee Inspectors will work closely with you to bring the outbreak under control and provide advice on minimising recurrence. *Please see leaflet Statutory Procedures for Controlling Foul Brood*.

However, you have an equally important role in bringing the disease under control. This entails using some common-sense methods to avoid spreading the infection between colonies, and making sure that any new cases of disease are recognised before they can spread to other colonies.

Both EFB and AFB are infectious diseases, and can spread without the intervention of the beekeeper by the natural processes of robbing, drifting etc. Despite this, unfortunately in practice the main agent of spread is the beekeeper, as he/she moves combs, brood, bees and other disease carrying materials between colonies.

If careless, an infection that may only affect one colony in the apiary at the start of the beekeeping season may easily affect all the colonies by the end. Conversely, however, experience has shown that even very severe outbreaks of foul brood affecting many colonies in large beekeeping enterprises can be successfully brought under control so long as cases of foul brood are found and dealt with faster than new cases are allowed to develop.

Key strategies for controlling an outbreak of foul brood in your bees

1. Developing a keen eye: learning to recognise the signs of foul brood.

This is a skill that takes a little time and practice to acquire. Start by working with your Bee Inspector, as he/she inspects your bees. He/she will be glad to point out the signs that distinguish diseased and healthy brood. Then every time you inspect your bees, make a point of always checking the brood for signs of disease. **Your aim should be to spot one diseased larva in a comb of several thousand**. You can send individual suspect larvae to the NBU for diagnosis using larval tube sampling kits (available from your Bee Inspector).

2. Use quarantine systems to avoid spreading disease

When colonies with signs of foul brood have been found and dealt with, there is still a significant risk that other colonies may be infected but not yet showing signs of disease. Many beekeepers have found 'quarantine systems' to be very effective in minimising the spread of infection between colonies while a foul brood outbreak is brought after control. These will also help minimise the scale of any new outbreaks that may subsequently occur.

For instance:

Colony quarantine – avoid moving any combs, bees or equipment from one colony to another. It will be necessary to mark super frames and boxes so that they can be individually identified and returned to the same colonies after extraction. This is the most effective quarantine

system, and the most appropriate for colonies that are at particular risk – such as those that have been previously treated, and those that have had close contact with infected colonies – but involves significant effort to carry out on a large scale. This has worked very successfully to bring large outbreaks under control.

Apiary quarantine – avoid moving any bees, combs or equipment between apiaries, but allow some movement (e.g. super combs) within the apiary. This will not prevent spread within the apiary but involves less work than colony quarantine to implement on a large scale and helps prevent moving disease between apiaries.

Isolation apiaries – where an EFB outbreak extends between several apiaries managed by a single beekeeper, it can often be advantageous to move all known infected colonies, and other colonies believed to be at particular risk to a single apiary (under licence from the NBU inspectors). This keeps to a minimum any contact between diseased and healthy colonies, and makes it easier to operate quarantine systems appropriate to the level of risk in each apiary.

Disinfecting equipment – where it is necessary to move items between colonies, treat them to reduce the risk of spreading disease. Wooden hive parts can be made safe by scorching with a blowlamp. Hive tools, gloves, the smoker, etc. can be soaked in or scrubbed with a strong solution of washing soda. Irradiating equipment is another option (page 32).

Transfer colonies to new comb
The pathogens responsible for both AFB and EFB can exist in a colony's combs for long periods and remain capable of causing disease to develop. This is particularly true of colonies that have been treated against EFB with an antibiotic. A significant proportion of these colonies can suffer reccurrence of disease within a year or so as a result of live bacteria remaining in the colony after treatment. Any method that removes contaminated comb from colonies and replaces it with new comb will be helpful in reducing the risks of disease. The more rapid and complete the transfer, the more effective it will be.

Shook swarm
The 'Shook Swarm' method aims to remove completely contaminated comb by transferring the colony to entirely new combs in one operation. This is done by shaking the adult bees into a clean hive fitted with frames of foundation during the season. The removed combs are then destroyed by burning. Although this method can involve significant labour and expense, recent research at the NBU suggests that it is extremely effective at combating EFB and reducing subsequent recurrence of disease. Many beekeepers have found that colonies, when treated by shook swarm, are capable of quickly building up to gather a good crop of honey, and that the reduced risk of reccurrence of EFB makes it a sensible strategy for dealing with affected colonies, and other colonies thought to be at particular risk. For further details of methods that can be used to help control foul brood contact the NBU or your local Bee Inspector.

Integrated Pest Management

All of the above amount to integrated pest management, (usually abbreviated to 'IPM') which is a principal that has been widely used in agriculture, especially where it is desirable to keep chemical or medicinal inputs to a minimum. Significantly, no attempt is made to eradicate completely the pests or disease. Instead, the aim is to keep them below the level where they cause significant harm by using a combination of controls applied at different times of the year. More or fewer controls are employed depending on the levels of disease present. This is a much more effective approach than the alternative of waiting until pathogen numbers have reached a damaging level before applying controls, or applying the same controls each year regardless.

Figure 32: Shook Swarm Technique. The bees from infected colonies are 'shaken' from the combs one by one into a prepared sterilised brood chamber containing frames with foundation or with clean drawn comb as an alternative.

An IPM programme for foul brood control (with particular emphasis on EFB)

IPM is a principle that can be readily applied to control of many bee pests and diseases.

An IPM approach to foul brood control would aim to include:

- *A varied mix of controls working in different ways and at different times of year according to the level of risks (see Table 1 below and Figures 33 and 34)*
- *A mixture of prevention and intervention*
- *Graded response depending on level of problem*
- *Control at several points of the year makes it harder for the disease/pathogens to reach harmful levels or threshold levels.*
- *Use of management methods can reduce the need for antibiotic use.*
- *Control strategies can be easily altered to reflect changing circumstances, infection levels*

Table 1: Management action to take based on risk assessment

Low risk	Medium risk	High risk
Check for signs twice a year	Check several times a year	Check at each inspection
Basic apiary hygiene	Careful apiary hygiene	Strict apiary hygiene
Periodic comb change	Regular systematic comb replacement	Shook swarm/destroy infected colonies
Shook swarm/ destroy affected infected colonies	Shook swarm/ destroy infected colonies	Shook swarm contact colonies
	Apiary level quarantine	Colony level quarantine
		Maintain 'hospital' quarantine apiaries

This general approach can also be illustrated in the following Foul brood Control Calendar and Quad Chart (Fig 33 and 34)

Figure 33: Foul Brood Control Calendar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sterilise supers and combs. Replace old wax with foundation	■	■	■								■	■
Routine comb change (3-4 older combs per brood box)			■	■	■	■						
Mark supers placed on individual hives				■	■	■	■	■				
Monitor for disease signs				■	■	■	■	■	■			
Shook swarm				■	■	■	■	■				
Antibiotic treatment				■	■	■	■	■	■			
Biological control treatment				■	■	■	■					
Colony destruction	■	■	■	■	■	■	■	■	■	■	■	■
Apiary/colony quarantine (barrier management)	■	■	■	■	■	■	■	■	■	■	■	■
Control robbing							■	■	■			
Extraction hygiene					■	■	■	■	■	■		

Controlling an outbreak of Foul Brood

Figure 34: Control options for foul brood

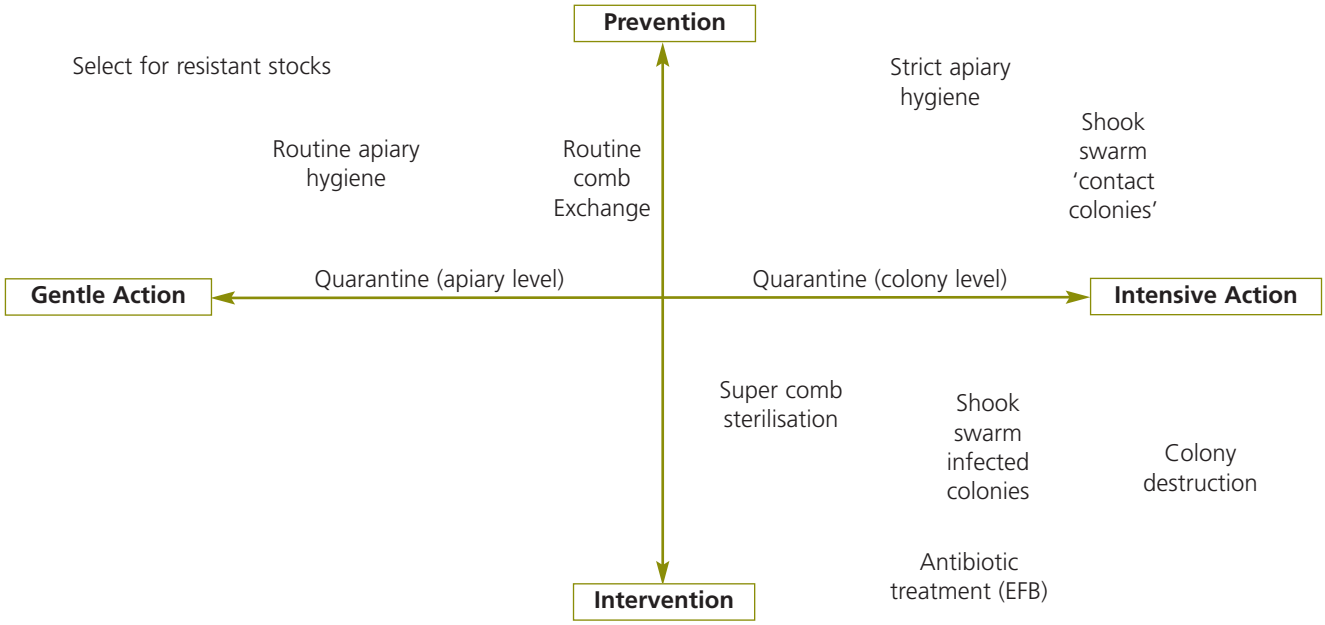
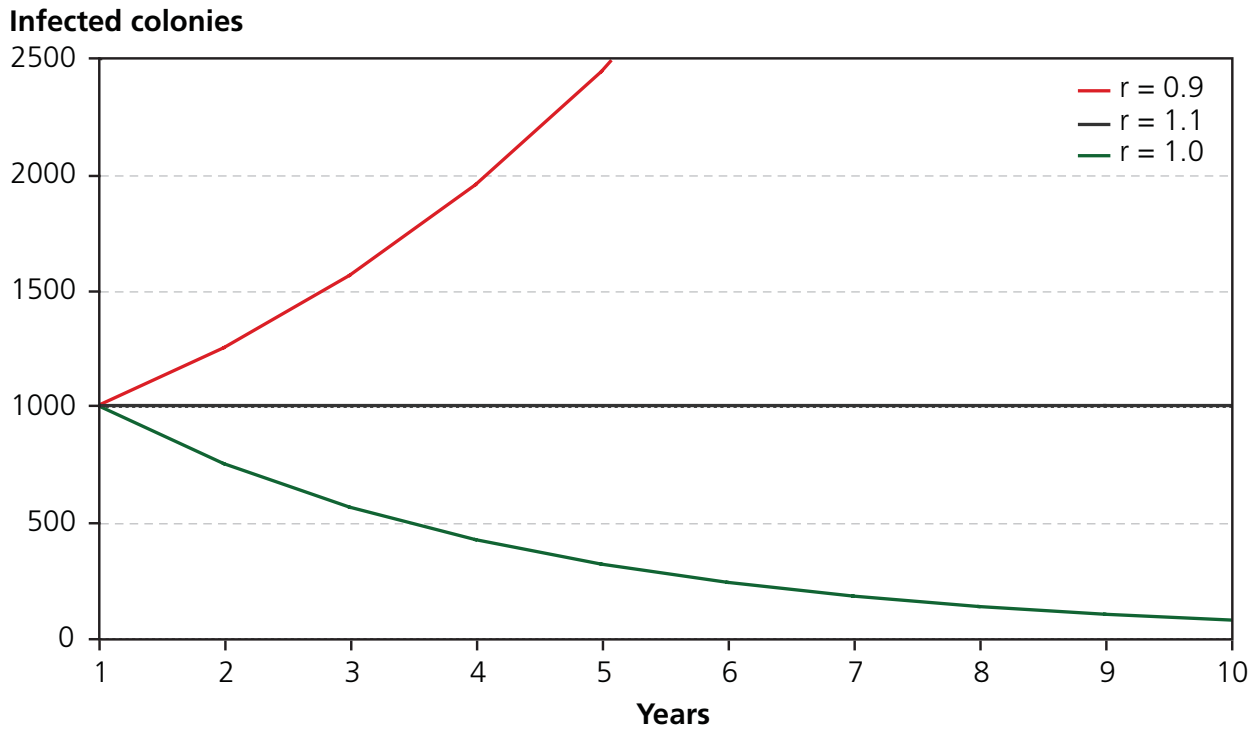


Figure 35: Influence of new infection rate on changes in disease levels

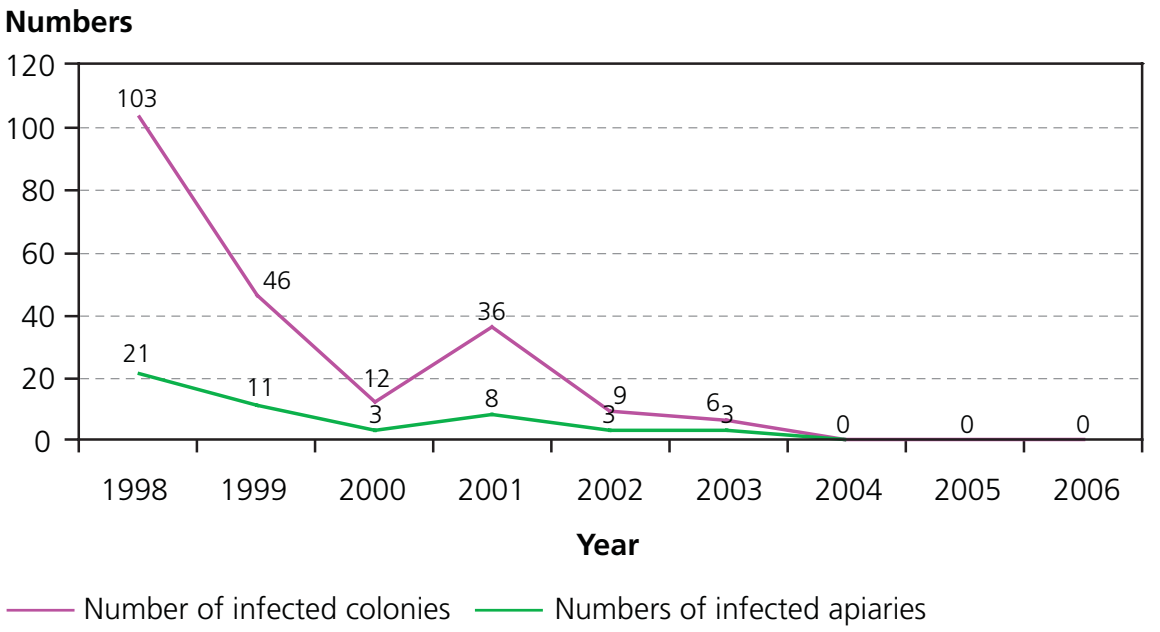


The conceptual graph above shows the big difference that small changes to "r" the reproductive rate of diseased colonies. (i.e. how many diseased colonies end the year compared with those at the beginning) can make to incidence of disease. Just a little below 1 and it dies away, just a little above 1 and it soars out of control.

By implementing the recommended means of control illustrated throughout this leaflet (IPM and good husbandry) r should be < 0.9 and this can be shown in detail with the case study opposite.

Case Study: Shook Swarm in practice

Figure 36: Reduction in Incidence of European foul brood 1998-2006



The graph shows a reduction in the incidence of EFB both in terms on the numbers of infected colonies and infected apiaries from a level of 25% (confirmed clinical cases) to zero in five years. This is an **actual** case involving a bee farm of 400 colonies in the south of England. This success is due to good husbandry, barrier management and an Integrated Pest Management (IPM) approach.

The beekeeper

- has learnt to recognise disease.
- sends off suspect tube samples to the NBU laboratory frequently.
- is willing to carry out shook swarms, even very early in the year or on small colonies and will follow up treatment with as much feeding as is required to build the colonies into usable units.
- is happy to shake good colonies onto clean comb.
- is happy to shook swarm whole apiaries to try to remove any latent EFB in colonies without clinical signs.
- does not like to burn colonies to eliminate infection but will do so with poor performing and susceptible colonies if considered necessary.
- removes all supers at the end of the season and takes them back to base.
- fumigates supers with acetic acid routinely.
- then has the frames/combs refitted and sterilised with acetic acid.
- sterilises all the boxes with a blowtorch.
- marks supers and returns them to the same colony and to the same apiary. The supers then stay with those colonies throughout the season.

Generally this means the beekeeper finds and deals with disease faster than it spreads. Therefore there is a general downward trend in disease incidence. With improved disease control it has been found that honey production has increased. It is worth mentioning that this case is especially impressive considering that EFB is generally prevalent in the area in which the bees are kept.

Common Brood Disorders

In addition to the foul brood diseases, there are honey bee brood disorders considered less serious such as sacbrood, chalkbrood, bald-brood, laying workers and drone-laying queens. It is important that beekeepers are able to distinguish between these and foul brood. These disorders will also affect colony productivity and can occassionally be serious problems for susceptible stocks of bees.

Sacbrood

Sacbrood is a very common virus disease affecting brood. In most diseased colonies relatively few larvae are visibly affected, and it rarely causes measurable harm to colonies. However, the signs can sometimes be mistaken for those of AFB.

Disease signs

Larvae that have died from sacbrood become like fluid-filled sacs, stretched on their backs with their heads towards the top of their cells. Adult worker bees eventually uncap them. Diseased larvae turn from the normal pearly-white colour to pale yellow and the head curls up as the body dries to a thin, dark brown scale lying along the bottom wall of the cell. These are often referred to as 'Chinese Slippers'

Figure 37: Sacbrood infected larva
(cell mouth enlarged for photograph)

The scale of a sacbrood infected larva has a distinctive gondola shape and is easily removed in one piece from its cell using a matchstick.

Treatment and control

There is no specific treatment for sacbrood. When much of the brood is obviously affected, the queen should be replaced by one from a colony showing no signs of the disease. Combs can be re-used; any sacbrood virus present on them becomes non-infectious within a few weeks.

Figure 38: Sacbrood
Top: "Chinese slipper"
Bottom: removed from cell for photograph

Varroosis

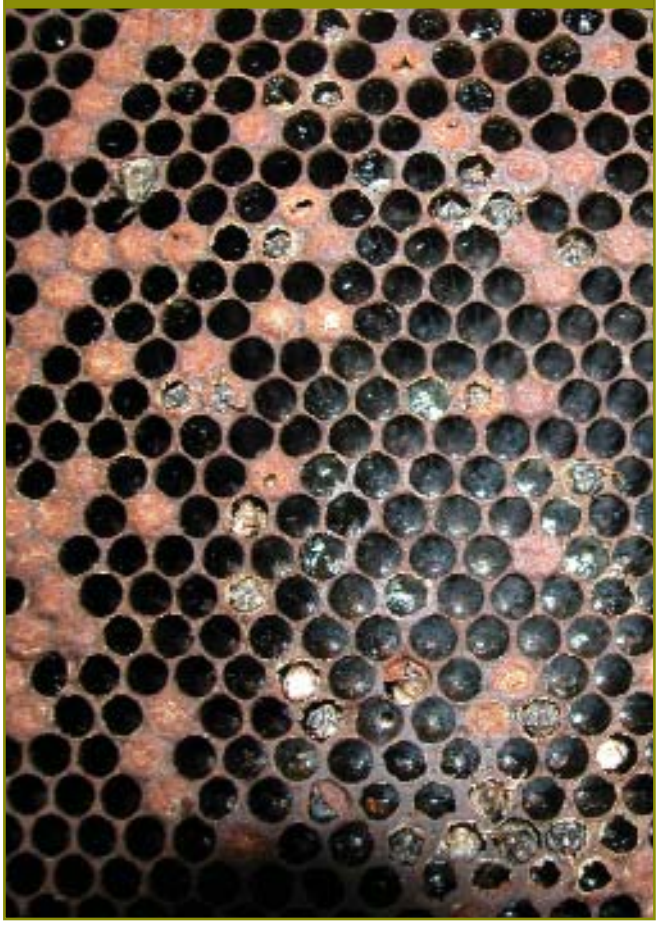
Colonies that are severely infested with varroa mites (*Varroa destructor*) frequently suffer from death of brood. This is normally most apparent in colonies that are very severely infested; especially those that are collapsing from the infestation in poorly treated or unmanaged colonies. The damage results not only from the mites themselves through feeding on the haemolymph and depriving the developing bee of vital nourishment, but also from viruses that are triggered by the infestation or, in the case of collapsing colonies, from the bees failing to care adequately for their brood.

Disease signs

Signs of damage to brood in varroa-infested colonies can be very variable. Most commonly sealed brood appears affected, with dead and discoloured brood in various stages below perforated cappings. The larval remains may be firm or watery, but never ropy (as with AFB). Close examination will reveal numerous varroa mites in floor debris, brood cells and on adult bees. (see CSL/Defra leaflet *Managing Varroa* for further details).

Figure 39: Varroa infested comb from collapsing colony

Figure 40: Varroa infested comb from collapsing colony



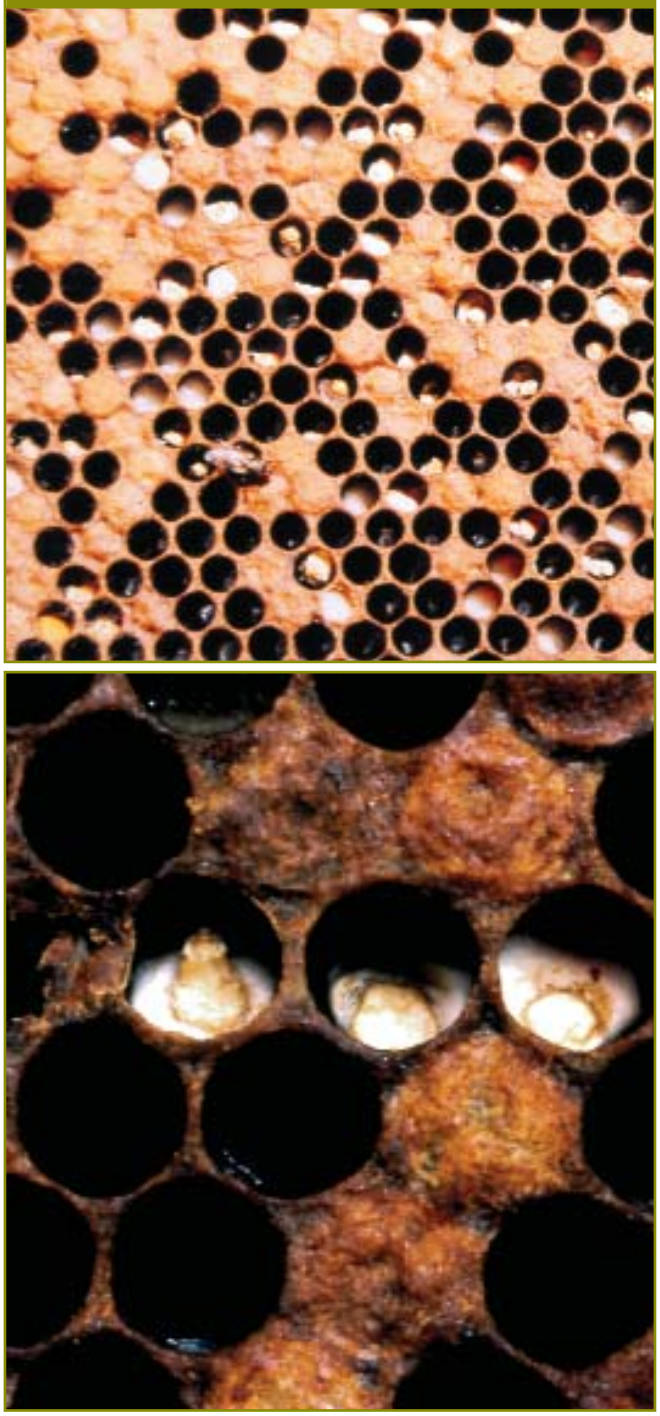
Chalkbrood

Chalkbrood is an extremely common brood disease caused by the fungus *Ascosphaera apis*. The thread-like, vegetative growths ('hyphae') of the fungus invade the body tissues of infected larvae, killing them after they have been capped over in their cells.

Disease signs

Adult bees usually tear down the brood cell cappings to remove the dead larvae. These appear as hard, chalky-white or mottled grey remains ('mummies') lying along the length of the cell. Infected larvae often take on the hexagonal shape of the cell itself before shrinking in size, at which point the bees are able to remove them from the comb. They are often noticeable on the hive floor or at the hive entrance.

Figure 41: Chalkbrood infected brood



The spread of chalkbrood

Larvae affected by chalkbrood may release millions of spores that all have a sticky coating, enabling them to adhere to combs and to adult bees. These are the dormant phase of the fungus and can remain infectious for three years or more.

Figure 42: Chalkbrood "mummies" on a hive floor

Both the transfer of combs by the beekeeper and the drifting of bees transmit chalkbrood spores between colonies. Signs of chalkbrood are probably present in the majority of colonies at some time, and spores of *A. apis* can be detected even in apparently unaffected colonies. However, it is rarely a serious disease, and the effect on most colonies is slight. Chalkbrood is most likely to be serious in colonies that are finding it difficult to care adequately for their brood, and is therefore most prevalent in weak colonies and during early spring.

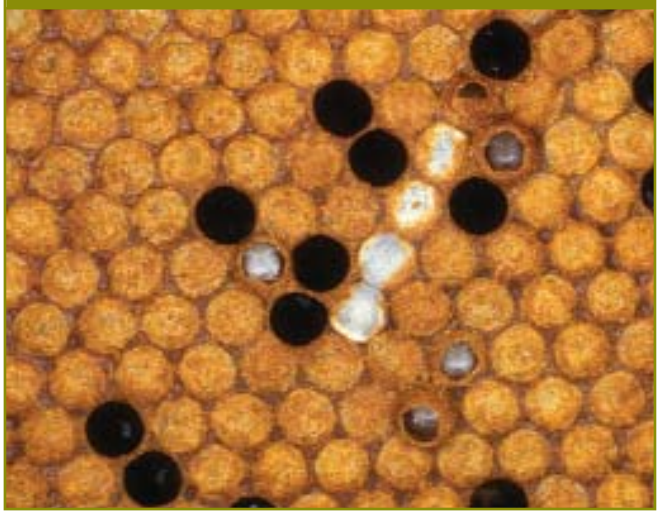
Treatment and control

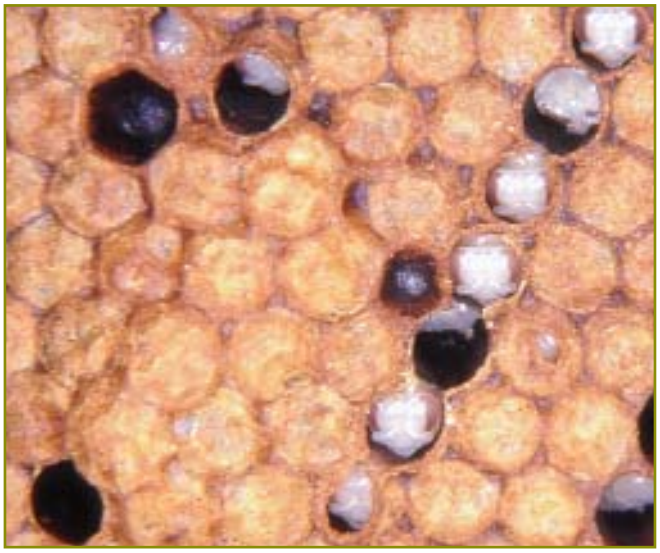
There are no specific treatments available on the market for chalkbrood. The most effective control results from avoiding the conditions favourable to its increase by maintaining strong and vigorous colonies, and bees that show marked hygienic behaviour. In severe cases, re-queening with a queen from a chalkbrood-free colony is recommended. It is reported that Apiguard (a varroacide treatment based on thymol) may assist in the control of this fungal infection.

Bald Brood

Normally pupae are sealed in their cells under wax cappings until they are ready to emerge as adults. Colonies with bald brood may have small patches of live and normal looking pupae in cells that are incompletely capped. The partial capping frequently has a raised lip that protrudes from the comb.

Figure 43: Bald brood





The cause of bald brood is not always clear; however, the most common reason is infestation of brood combs by wax moth larvae. These can often be found tunnelling below the surface of the comb close to patches of bald brood.

Drone Brood in Worker Cells

The characteristic domed cappings of sealed drone brood are present in virtually all colonies during the summer months on areas of drone comb, usually situated at the edge of the brood nest. However, there are common abnormalities that can cause drone brood to be reared in worker cells along with, or in place of, worker brood. Such drone brood is usually very irregular; capped pupae are interspersed with either vacant cells or cells containing larvae at every stage of development. There are two possible causes – a drone-laying queen or laying workers. Beekeepers often confuse these conditions with serious brood diseases.

Drone-laying queen

Worker bees develop from eggs that have been fertilised, before they are laid, by sperms stored in the queen's sperm sac (spermatheca). If the supply of sperm becomes exhausted (if the queen was poorly mated), only unfertilised eggs are laid, which develop into drone brood. Hence, queens may become drone-layers in later life or earlier if they have not properly mated. These should be replaced with queens of proven fertility.

Figure 44: Domed cappings of drone brood in worker cells

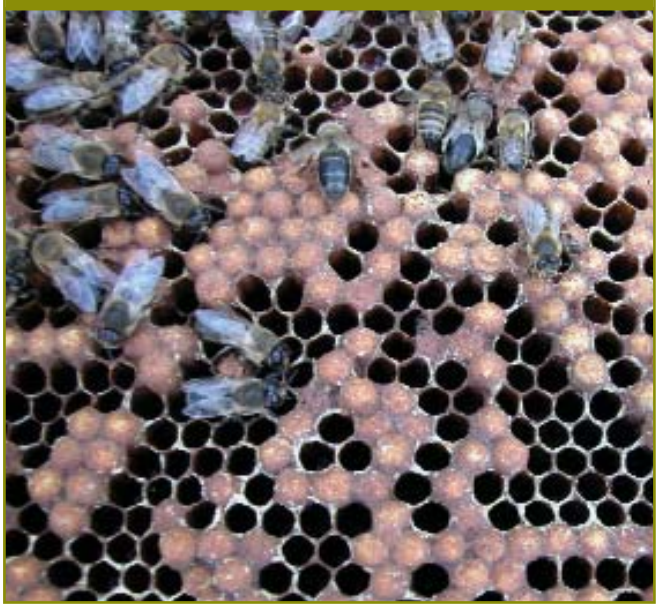
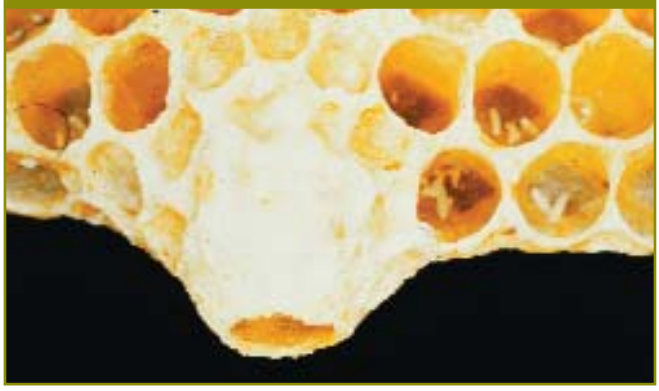


Figure 45: Typical comb showing signs of a failed queen or laying workers

Laying workers

When colonies lose their queen and have no young worker brood from which to rear a replacement, the workers may develop functional ovaries and begin to lay eggs. These eggs, being unfertilised, develop into drones; the signs are similar to those of the drone-laying queen, except that the brood pattern is often less compact. Also, there may be several eggs present in some cells, most often on the walls as well as at the bottom of the cell. Colonies with laying workers are very difficult to requeen, and are usually in poor condition. It is generally advisable to unite them with a strong colony, or to destroy them. Shake out the bees on the ground (on a sheet if wet) so that they return to other colonies in the apiary.

Figure 46: Signs of laying workers



Chilled brood

Sometimes relatively large areas of brood in all stages die at the same time and turn very dark in colour. This is usually diagnosed visually as 'chilled brood'. However, even young larvae can survive for several hours at temperatures well below the brood nest heat of 35°C. It is probable, therefore, that 'chilling' of brood is the result of brood becoming isolated from the adult bees and being neglected by them. As a result the brood dies from a combination of starvation and prolonged low temperatures.

Figure 47: Chilled brood

No pathogenic organism is responsible. Examining colonies in cold weather should not cause chilled brood. Keeping colonies in thriving condition with ample bees to cover and nurture the brood can prevent chilled brood.

Diseases of uncertain origin

Eggs, larvae and pupae sometimes die for reasons unconnected with infectious disease, and the cause of the death is often difficult to establish. A patchy brood pattern might be the result of poor egg-laying by the queen, or caused by a genetic defect in some of her eggs, preventing them from hatching or developing from larvae into adults or environmental contamination of some form or another. Usually the workers quickly remove the dead brood. Brood death of this kind may happen in many colonies, however, the numbers of abnormal eggs or larvae are probably so low that they are removed by the bees before the beekeeper even notices. If a genetic defect or a faulty queen appears to be the cause of a brood disorder then replacing the queen with another is the most effective course of action.

Summary of Brood Signs, Causes and Control

	Signs	Control
Normal brood	Uncapped: Pearly white, 'C' shaped larvae. Capped: Uniform brown colour, domed cappings.	None required
American foul brood *(Paenibacillus larvae)*	Affects only sealed brood sunken concave cappings, uneven brood pattern, 'pepper pot' or mosaic pattern, scales on bottom walls of open cells, brown decomposing larvae that 'rope' using matchstick test, moist dark perforated cappings.	**Notifiable disease** A CSL Bee Inspector burns infected colonies and the hives are sterilised by scorching.
European foul brood *(Melissococcus plutonius)*	Affects mainly unsealed brood. Infected larvae discoloured yellow-brown lying in abnormal positions in cell with 'melted' appearance. Some dark sunken cappings may be present, but cell contents will not form a 'rope'.	**Notifiable disease** Several choices are available to the beekeeper. Infected colonies can be: "Shook swarmed", a CSL Bee Inspector can treat lightly infected colonies with antibiotic and severe cases of EFB are destroyed as with AFB.
Chalkbrood *(Ascosphaera apis)*	Affects only sealed brood. Perforated cappings over cells containing hard white or mottled grey chalk like remains ('mummies').	No specific treatment. Keep strong colonies. Re-queen severely affected colonies.
Sacbrood *(Sacbrood virus SBV)*	Affects only sealed brood. Perforated cappings. Larvae become yellow-brown fluid filled sacs ('Chinese slipper'). Watery contents will not form 'rope'.	No specific treatment. Requeen severely affected colonies.
Bald brood	Abnormal cell cappings over sealed brood. Affected cells have round hole in capping sometimes with a slight protrusion. Pupae have normal appearance. Signs of wax moth larvae may be visible in comb.	No specific treatment. Control wax moth infestation.
Drone laying queen or laying workers	Domed drone cappings over worker cells. Abnormally small drone pupae within cells. May be multiple eggs per cell. Unsealed brood may be neglected and dying.	Replace drone laying queen. Unite colony with laying workers to another colony. Shake bees out in front of the hive so that they return to other colonies slowly.
Chilled brood	Dead brood usually present in all stages. Unsealed brood turns very dark brown or black in colour.	Avoid conditions that prevent bees being able to care for brood.
Varroa infestation *(Varroa destructor)*	Signs vary. Sealed brood may be partially uncapped, dead pupae discoloured brown or black, watery or firm, but never ropy.	Control varroa infestation to low levels using appropriate treatment. (see CSL/Defra *Managing Varroa* leaflet for details).

What to do if you suspect foul brood

1. Close the hive.
2. Reduce the size of the entrance and take any other steps necessary to prevent the hive being robbed by other colonies.
3. Disinfect gloves and other beekeeping equipment with a strong solution of washing soda before examining other colonies.

Either:

a) Contact the NBU to arrange a visit by your local Bee Inspector.

b) Send a whole comb containing diseased brood wrapped in several layers of paper and sealed in a cardboard box **so that it can not leak honey** in transit to the NBU, with a note stating your name and address, the location of the apiary and the identity of the affected hive. Alternatively, an infected larvae can be sent to the laboratory with all your details in a sample tube (such as an "Eppendorf" type tube). The NBU can provide samples to local associations and local bee health advisers.

4. You must not remove any hives, bees, or equipment from the apiary until the disease, if present, has been controlled. Place the apiary under **Standstill**.

Sterilising hives and equipment

It is very good practice to sterilise spare and empty hives routinely before re-use. This applies particularly to second-hand equipment and that which might have been associated with foul brood infection, but also will help to reduce the likelihood of transmitting foul brood or other diseases between colonies, if applied as part of normal apiary management.

Heat

Wooden hive parts can be sterilised by first scraping off brace comb and propolis, and then scorching with a blowlamp until the wood reaches a uniform coffee-brown colour. Particular attention needs to be paid to the corners and any cracks or crevices. Such treatment will destroy the infective stages of all the bee diseases. Alternatively, empty hive boxes and frames can be sterilised by immersion in molten paraffin wax heated to 150°C for 10 minutes.

Chemical sterilisation

There are no chemicals that have been shown to be fully effectve for the sterilisation of stored combs against foul brood. The spores of AFB in particular are strongly resistant to virtually all sterilising agents. Combs can, however, be sterilised to destroy the spores of chalkbrood (and Nosema disease of adult bees), using acetic acid vapour. In general it is better practice to melt down or burn old combs and replace them with new frames fitted with foundation.

Brood boxes, supers, queen excluders and other bee-keeping equipment, which has been thoroughly cleaned, of all wax and propolis can be effectively sterilized by using commercial disinfectants (e.g. bleach, Virkon S and others). It is important that the manufacturer's instructions are complied with.

Irradiation of equipment

Equipment such as stored supers and empty combs which may have been associated with colonies infected with foul brood, but do not show any disease signs, can be sterilised by gamma rays from a radioisotope of cobalt. This will kill the spores of the bacteria that cause disease without damage to equipment. Infected combs must not be irradiated if scales or other disease signs are present as these would remain indistinguishable visually from infectious untreated disease signs. Firms specialising in irradiation use 25 kiloGrays (kGy) to kill *Paenibacillus larvae* (AFB) and its spores on combs and hive equipment. Currently there is no recommendation for the treatment with irradiation for *Melissococcus plutonius* (EFB), but it is likely that 25 kGy is sufficient to kill *Melissococcus plutonius*.

How a Lateral Flow Device works

The routine diagnostic method used by the NBU to confirm the presence of foul brood is a field kit called a lateral flow device (or LFD). The term lateral flow refers to the suspect larval material flowing horizontally across the kit membrane into which specific antibodies have been incorporated. The kits were specifically developed to detect foul brood and work on the same principles as a human pregnancy test. They are based on specific monoclonal antibodies to AFB or EFB. There are two kits in use and each is specific for the foul brood disease in question.

The principle of the LFD relies upon the capture of target bacterium between an immobilised line of target specific (AFB or EFB) antibody on a nitrocellulose membrane (Test line) and a blue coloured latex-antibody conjugate to display a visible confirmation of target presence. A line of anti-species antibody is incorporated into the device to provide visual verification of latex flow (Control line), resulting in two lines as an indication of positive detection and a single line for a negative result.

Figure 5: The mechanics of the lateral flow device.

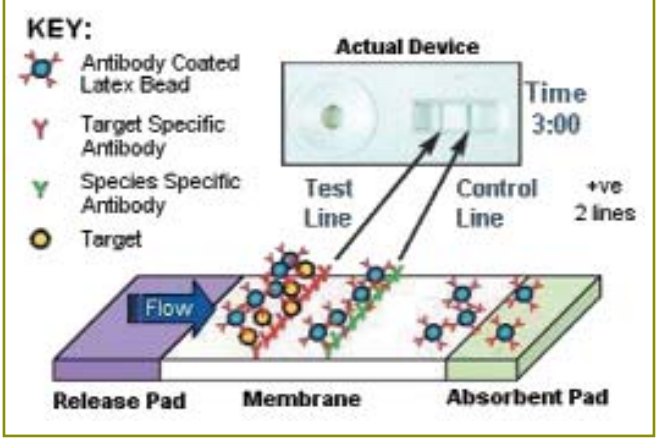
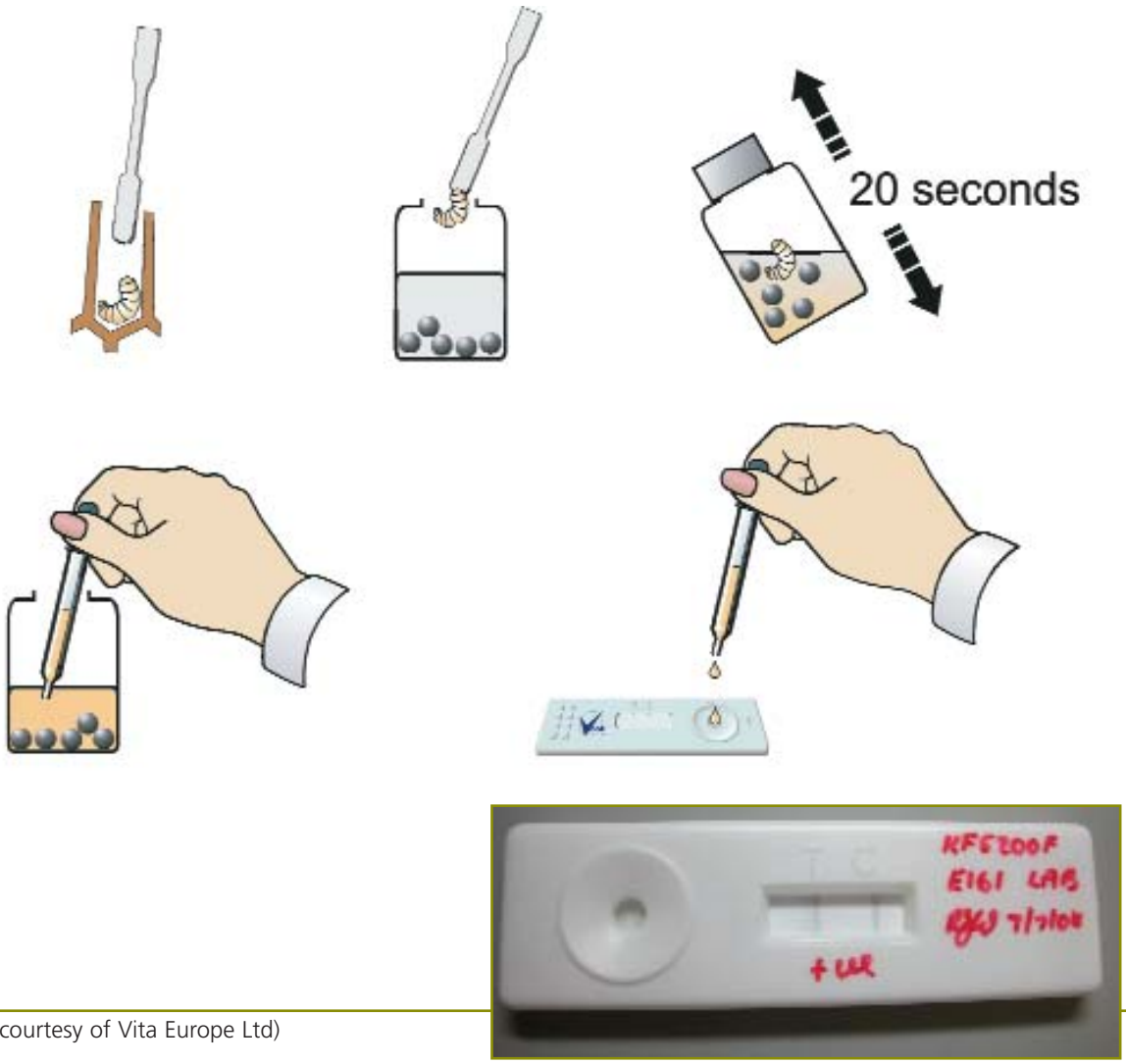


Figure 6: Using a Lateral Flow Device (LFD)
(These kits were developed by CSL on behalf of Vita Europe Ltd. Website: www.vita-europe.com)

Figure 6: Using a Lateral Flow Device (LFD) A sample of suspect infected larval material is placed in the buffer bottle and shaken for about 20 seconds. 2-3 drops of the resulting suspension are then placed on the lateral flow device. The blue lines at the C (Control) and T (Test) line indicate a positive result for foul brood infection.



(Diagram courtesy of Vita Europe Ltd)

The National Bee Unit (BeeBase http://beebase.csl.gov.uk)

The Central Science Laboratory National Bee Unit provides a statutory and advisory service to beekeepers in England and Wales. It provides diagnostic, consultancy and research services to Defra, Welsh Assembly Government, commerce and beekeepers. The Unit's laboratories are fully compliant with the international Good Laboratory Practice (GLP) quality scheme to ensure a high professional standard and uses as a base the Office International des Epizooties (OIE) Manuals of Standard Diagnostic tests for laboratory diagnosis. All staff are trained practical beekeepers as well as scientists, and are supported by teams of analytical chemists and agricultural specialists in the rest of CSL. (Website address http://www.csl.gov.uk)

Figure 47: Central Science Laboratory, Sand Hutton, York

Further help and advice

The NBU has a bee health support service, operating in England and Wales, comprising a regional network of inspectors. The Head of the Inspectorate is the National Bee Inspector (NBI). Regional Bee Inspectors (RBIs) reporting to the NBI manage teams of Seasonal Bee Inspectors (SBIs) throughout England and Wales. As well as the statutory inspection and apiary surveillance programme which includes the control of foul brood, Bee Inspectors provide advice and assistance to beekeepers on a range of bee health issues and run training courses for beekeepers on disease recognition and control, usually in conjunction with local beekeeping associations. NBU staff deliver around 700 training events per year.

Figure 48: An example Foul brood disease Incidence Map (2005)

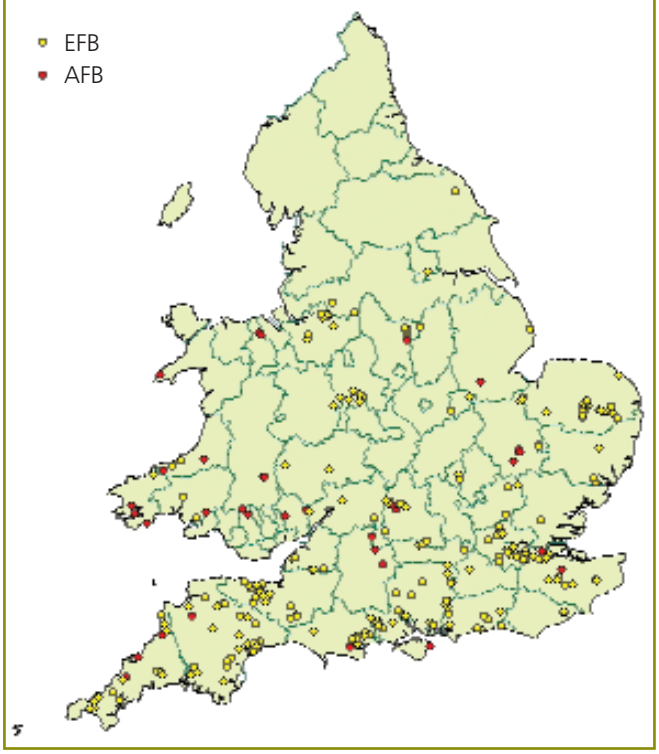


Fig 49: Disease control co-ordination from the NBU BeeBase on line

For further information see contacts information on this website (http://beebase.csl.gov.uk). In many areas, beekeeping associations operate local disease control schemes, and provide practical help and advice to members on bee disease recognition and control. Contact your local beekeeping association for details.

Bee Diseases Insurance Ltd

An insurance scheme to compensate against losses incurred through destruction of foul brood infected colonies is organised by Bee Diseases Insurance Ltd, a specialist insurance company operating with the aim of reducing the incidence of the foul brood diseases. Beekeepers can take out insurance either individually or through their local beekeeping association.

Acknowledgments

Leaflet written by Michael Brown and Richard Ball (with the assistance and technical expertise of James Morton and Selwyn Wilkins, Central Science Laboratory National Bee Unit), on behalf of Defra's Plant Health Division.

All photographs supplied by CSL National Bee Unit/CSL

Useful Addresses

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Fax: 01904 462240
Email: nbu@csl.gov.uk
Web: www.nationalbeeunit.com

Department for Environment, Food and Rural Affairs (Defra)
Plant Health Division, Foss House, King's Pool,
1-2 Peasholme Green, York, YO1 7PX
Tel: 01904 455182
Web: www.defra.gov.uk
Bee health pages:
www.defra.gov.uk/hort/bees.htm

Welsh Assembly Department for Environment Planning and the Countryside (DEPC) Animal Identification Branch
Penrallt, Caernarfon Divisional Office, Gwynedd,
Wales, LL55 1EP
Tel: 01286 662012 or 01286 662027
Web: www.wales.gov.uk

Scottish Executive Environment and Rural Affairs Department, (SEERAD)
Pentland House 47 Robb's Loan Edinburgh
Scotland EH14 1TY
Tel: 0131 2448400
Web: www.scotland.gov.uk/

Scottish Agricultural Science Agency
SASA, 82 Craigs Road East Craigs
Edinburgh EH12 8NJ
Tel: 0131 244 8890
Fax: 0131 244 8940
Email: info@sasa.gsi.gov.uk
Web: www.sasa.gov.uk

European Union
(website for details of European Community legislation in force)
Web: www.europa.eu.int/eur-lex/en

European Commission
Web: europa.eu.int/

Defra Veterinary Laboratories Agency
New Haw, Addlestone, Surrey, KT15 3NB
Tel: 01932 341111
Email: enquiries@vla.defra.gsi.gov.uk
Web: www.vla.gov.uk

Department of Agriculture & Rural Development, Northern Ireland (DARDNI)
Dundonald House, Belfast BT4 3SB,
Northern Ireland
Tel: 02890 525112
Web: www.dardni.gov.uk

Defra Veterinary Medicines Directorate (VMD)
Woodham Lane, New Haw, Addlestone,
Surrey KT15 3LS
Tel: 01932 336 911
Web: www.vmd.gov.uk

Office of Public Sector Information
(European Community and UK Legislation)
Web: www.opsi.gov.uk/

British Beekeepers' Association
(county and local beekeeping associations)
National Agricultural Centre, Stoneleigh
Warwickshire, CV8 2LZ
Tel: 01203 696679
Web: www.bbka.org.uk

Welsh Beekeepers' Association
(county and local beekeeping associations)
General Secretary, Pentrebwlen, Llanddewi brefi,
Tregaron, Ceredigion, SY25 6PA
Web: www.wbka.com/

Scottish Beekeepers' Association
Web: www.scottishbeekeepers.org.uk
Email: secretary@scottishbeekeepers.org.uk

Bee Farmers' Association of the United Kingdom
Web: www.beefarmers.co.uk

International Bee Research Association
(library and beekeeping information services)
18 North Road, Cardiff, Wales CF10 3DT
Tel: 02920 372409
Web: www.ibra.org.uk

Ulster Beekeepers' Association
Web: www.ubka.org

World Organisation for Animal health, Office International des Epizooties (OIE)
Web: www.oie.int

Bee Diseases Insurance Ltd (BDI)
Registered Office
National Beekeeping Centre, NAC
Stoneleigh, Warwickshire, CV8 2LG

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