

THE EXPERIMENTAL PRODUCTION OF FOOT INFECTIONS IN BIRDS;
OBSERVATIONS ON CAUSES AND CURE

L. G. Swartz
Biological Sciences Department
University of Alaska, College, Alaska

Introduction

The published information on the affliction commonly called "bumblefoot" embodies a curiously varied set of opinions on cause, cure, and prevention, often quite firmly and oppositely expressed. This is certainly due to the fact that the body of knowledge about it has been acquired gradually in a more or less accidental way as individual falconers have come to unhappy conclusions about probable causes and have tried the best they knew how to cure individual cases. A systematic research program has obviously been needed and while the present work does not pretend to be extensive or intensive enough to provide final answers, it may be a start.

My own interest in the subject began, naturally, when I became the horrified owner of a case of bumblefoot. This experience with both feet of a tiercel peregrine lasted for 21 months and resulted in about 130 closely written pages of notes on treatment. The notes and efforts to cure the bird ended only when I lost the bird while flying. A second case appeared later in a peregrine falcon and was caught at a very early stage. Observations on these cases will be given later but each stimulated the reasoning which led to experimental attempts to produce the affliction, the first step in developing a rationale about both disease and cure.

Experimental Production of Foot Infections

It is clear that any foot problem which logically could be called bumblefoot is really better described as a foot infection. This was aptly pointed out by Mavrogordato (A Hawk for the Bush, 1960). I think that the point is important because the term "bumblefoot" tends to conjure up a narrower form of thinking. Since any microbial infection depends upon a breach in the body defenses, the skin in this case, for entry of the causative organisms, artificially producing the breach and introducing microorganisms to be found in the environment of the bird should result in typical foot infections.

Operating on this assumption, I set up an experiment using ten near-adult leghorn chickens. The chickens were segregated into three groups and treated as indicated below. The right foot was used in each chicken as the experimental foot and the left as the untreated control.

Group A. Three chickens were each injected with a suspension of peregrine feces in 0.9% saline solution in the "ball" of the foot. The chickens were placed and maintained in a cage with a wire floor.

Group B. The ball of the foot of three chickens was incised with a scalpel and the birds were placed in a cage with a solid floor having abundant chicken feces so that contamination with "chicken microorganisms" would occur.

Group C. The ball of the foot of four chickens was incised with a scalpel and a suspension of peregrine feces was rubbed into the wound with a cotton swab. The chickens were placed in a cage with a wire floor.

In six days signs of infection were present in the treated foot of all chickens although Group B showed less swelling than the others. The chickens in Group C, which had received peregrine feces rubbed into the wound were the most swollen.

The same general picture prevailed until the experiment was terminated on the 45th day except that the swelling, which reached a maximum at about the thirtieth day, began to diminish (see Figs. 1, 2, 3, 4) in all groups. By the end of the experiment the black scab which has often been described as typical of "bumblefoot" had developed in all of the incised feet but much more markedly in those which had received peregrine feces rubbed in (see Figs. 3 and 4). It is possible that this difference was due to greater virulence of "peregrine microorganisms" to the chickens but also may have been due to variations in the depth to which the feet were incised. The birds which had been injected with a suspension of peregrine feces did not show the black scab, probably because the infection had been contained within the substance of the foot; the injection hole, having been made with a thin sterile needle, healed very quickly. Whether or not a surface lesion would have formed in time is a moot point. The chickens in Group A were showing indications of self-cure by the forty-fifth day which probably would have prevented what I feel is a normal course of the infection in falcons, i.e. formation of a persistent lesion reaching the surface. Hypothetically, it seems likely that gallinaceous birds with greater masses of connective tissue in the feet, an adaptation to walking on the ground, are better able to cope with a hazard which must appear normally in their lives more often than in falcons. The birds in all groups were showing some indications of self-cure in that the swelling was diminishing which may further imply some differences in the usual course of infections in the two kinds of birds.

Several conclusions seem warranted. Although the number of experimental animals is small, the uniformity of the results (almost identical within experimental groups) suggests that the results are valid. Further, although the results do not prove

that foot infections must always be contracted by gross breaches of the skin the condition obviously can be initiated by entry of microorganisms into the foot, probably irrespective of the mode of entry. It also seems likely that the presence of a black spot on the plantar surface of the foot may represent either an infection established on the surface working its way in or an internal infection manifesting itself on the surface. If a genuine corn forms in the same manner as a human corn, i.e. as a result of contact with an inappropriate surface (hypothesized by Beebe in Beebe and Webster, *North American Falconry and Hunting Hawks*, 1964), it is logical to expect infection of the foot to occur as it works itself deeper into the foot. I have not observed such a process, however, and cannot comment on the frequency of such a development. The formation of the "onion-like" nodule within the foot as described by K. W. Kost (*in* Woodford, *A Manual of Falconry*, 1960) and others, was in process in these chickens although it had not become as discrete and easily removed as in falcons (see Fig. 4). It might have become so in time although it is possible that the differing reactions of such widely disparate species as falcons and chickens may well dictate a different course of the disease. Obviously it is possible that the greatest benefit from this experiment may lie in the demonstration of an easy way to cause bumblefoot so that attempts at developing a good treatment may be conducted in the laboratory.

Observations on Foot Infections in Falcons

I have had personal experience with two cases, one in a peregrine tiercel and the other in a peregrine falcon. The former lasted for almost two years. At the end of my experiences with this bird, I still had some hope of recovery and in fact one of the two affected feet seemed to be near ultimate closure of the lesion. Over the long cyclic period of improvement followed by relapse, function of toes gradually became impaired as tendons were destroyed by the infection so that at last only the hind and inner toe on each foot were fully functional. I emerged from this experience with several convictions. One was that each conviction acquired during a new phase of the experience was only a little better than the previous. I am accordingly unsure of almost every generalization I make. But as regards diet and physical condition, neither is going to result in a "cure" of severe foot infections singly or together and the major effort must be medical. Certainly it is necessary, as always, to keep the bird in good condition but it seems quite clear that feeding certain items such as egg yolk, "cull" chicks, or vitamins is no cure. Eliminating such factors from the discussion as possibly significant but very difficult, at best, of analysis, I will present portions of these case histories and generalizations based on them.

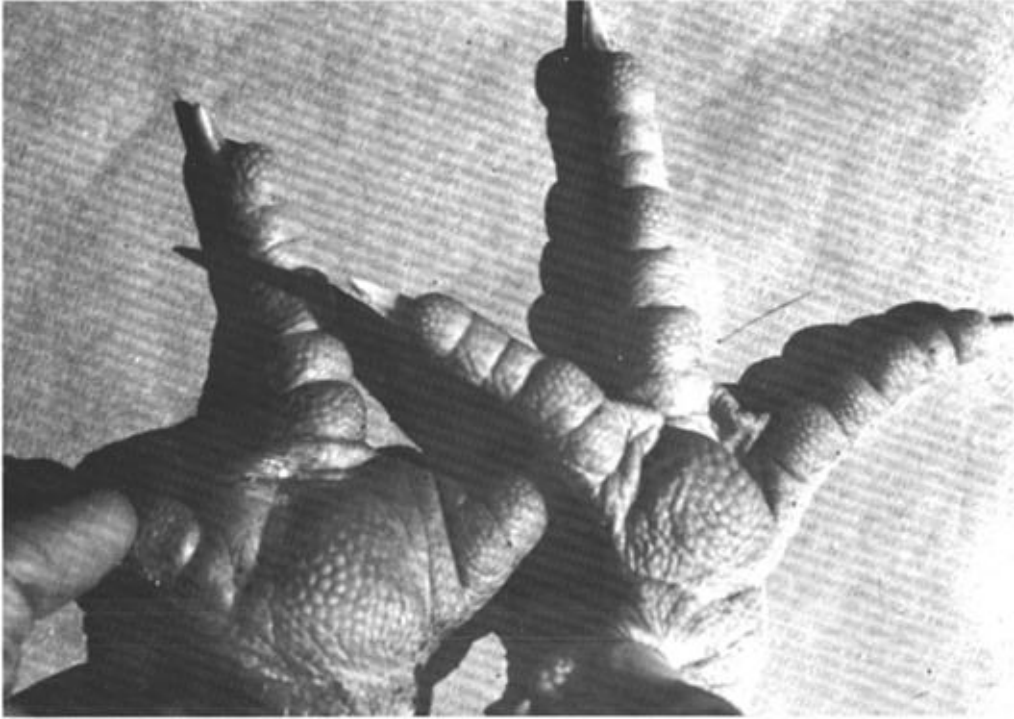


Figure 1. The experimental and control foot of Group A; injected with a suspension of peregrine feces in the ball of the foot.



Figure 2. The experimental foot of a member of Group B; incised with a scalpel and placed on a substrate with abundant chicken feces.



Figure 3. The experimental and control foot of a member of Group C; incised with a scalpel, peregrine feces rubbed into the wound. Note the conspicuous development of the black "scab" typical of bad cases of plantar foot infections.

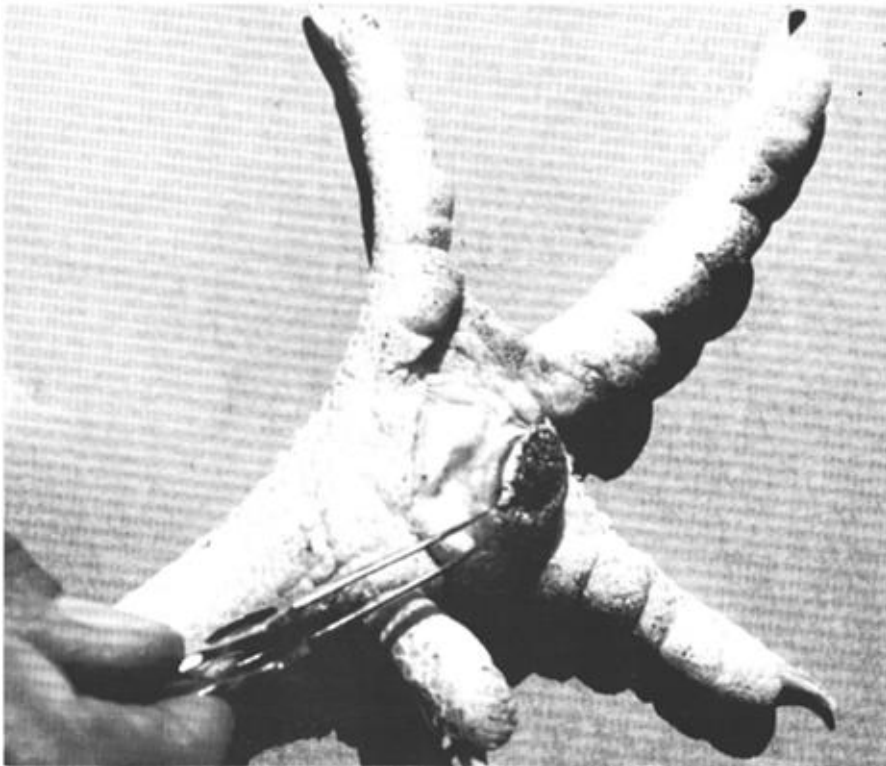


Figure 4. A dissection of the experimental foot shown in figure 3 showing the "nodule" capped with a firmly adherent "scab". The "scab" in this case, actually represents a dried portion of the nodule reaching the surface.

Case #1--Peregrine tiercel

Methods. The case in the tiercel was discovered when both feet had reached the stage in which a well developed plantar "scab" had formed and both were swollen. Surgery was attempted immediately. A caseous nodule was removed from both feet and aqueous procaine penicillin G was used abundantly in the cavity. Both were sutured, bandaged, and the bird put away in a light-tight closet with a padded floor. After ten days it was clear that the effort had failed; the lesions failed to heal and swelling was still present. Henceforth treatment included efforts to identify microorganisms and determine their drug sensitivities with six major surgical efforts on one foot and five on the other. Numerous occasions of minor surgery with no anaesthesia were performed to debride the lesions. For approximately a year and a half, efforts centered around attempts to secure sterility of the wounds and in the hope that once sterility was obtained the lesions would granulate up from the bottom. Sterility was obtained several times and maintained for varying periods but always with no evidence of healing and always terminated with new contamination. Microbiological assay was made by innoculating trypticase soy broth, thioglycollate broth, nutrient broth, nutrient agar and blood agar. Not all were used on each occasion but always more than one. Gram stains were made and examined under the microscope. Differential growth media were used as appropriate to the particular situation and normal procedures using sensitivity discs were used to determine drug sensitivities. The full gamut of techniques was not always used since a violent flare-up sometimes demanded very fast action and it was at least possible, if not best, to determine drug sensitivities of whole microbial populations without going to the trouble and time of isolating each element of a mixed population. Much of this I did myself but I very gratefully received aid from Dr. David Marrack and his colleagues at the M. D. Anderson Tumor Institute, Houston, Texas during a year I spent at Rice University on leave from the University of Alaska.

Microorganisms. The microorganisms in the lesion were almost always of mixed species and in my own experience seldom included those with a reputation for high virulence. This contrasts with those published accounts which mention specific microorganisms. Staphylococcus were recovered twice but on both occasions were S. epidermatis, a relatively innocuous form more or less constantly found on human skin. Streptococcus faecalis was recovered twice but again, this is not a particularly malevolent bacterium. The most troublesom bacteria were members of the genus Escherichia, a coliform deriving from the feces of the bird. Whenever trouble dictated a new bacterial sample from the feet, these coliforms were almost certain to be present and usually were the dominant species. Two fungi were recovered, Aspergillus and Poecilomyces and in both cases it was not possible to determine whether or not they played an active role in

the infection. It is not improbable that either might on occasion produce a stubborn complication. Yeasts were a constant threat in the background and, in fact, produced some of the most alarming and damaging episodes in the course of the treatment. Whenever the bacterial populations were eliminated or sufficiently depressed, the yeasts came into their own, usually manifesting themselves within three to five days in swelling and obvious pain.

Drug therapy. The following table of drugs used is included to illustrate the range of the drug effort, and in some cases to indicate usefulness or apparent toxic effects. Antibiotics were almost always used in powder form.

Drugs and Other Substances Used in Treatment

<u>Drug</u>	<u>Topical</u>	<u>Oral</u>	<u>Remarks</u>
Penicillin G	X	X	
Procaine Penicillin G	X		toxic
Procaine Penicillin - streptomycin	X		toxic
Dihydro streptomycin	X		toxic
Penicillin V and sulfonimides		X	possibly toxic
Sulfasuxidine		X	possibly toxic
Ampicillin	X	X	
Neosporin	X		bactericidal in contrast to most antibiotics which are bacteriostatic
Chloramphenicol (aqueous, powdered)	X		(see text)
Sulfathiazole	X	X	potentially toxic
Madribon	X	X	potentially toxic
Tetrex-F	X	X	contains Nystatin as an antifungal agent as well as tetracycline. When applied topically in full strength this drug is evi- dently painful (see text)
Keraspray	X		
Albamycin	X	X	
Delta Albaplex	X	X	(see text)
Triburon	X		has been effective against yeasts

<u>Drug</u>	<u>Topical</u>	<u>Oral</u>	<u>Remarks</u>
Mycostatin)	X		(effective against yeasts (and fungi, applied as (powder
Fungizone (Ampho- teracin B))	X		
Furacin soluble dressing	X		
Aureomycin salve	X		
Chloramphenicol salve	X		
Betadine paint)	X		(Used as topical bacteri- (cides and for sanitation (of feet, legs, and perch (((((((
Betadine soap)	X		
2% aqueous Iodine)	X		
Gentian violet)	X		
Phisoex)	X		
Zephiran chloride)	X		
Castellani's paint)	X		
Hydrogen peroxide 6%)	X		
Upjohn product 17900	X		
Varidase)	X		
Elastase)			
Miscellaneous skin creams	X		
Ascorbic acid (vitamin C)		X	used in attempts to accel- erate healing
Upjohn super D (vitamin A and D)		X	
Miscellaneous vitamin preparations		X	

Drug therapy should be preceded by knowledge of what organisms are involved and of their drug sensitivities, but, in practice, the falconer is not apt to have ready access to either facilities or technical knowledge nor is he likely always to have time to search out the facilities or knowledge when he has a serious infection blowing up. While the course of the whole disease is relatively indolent in that it takes a long time to completely cripple the bird, an individual microbial flare-up can set one back a long time in just a day or two. Accordingly, one will often, in fact probably always, need a "shotgun" compound of drugs designed to kill or inhibit the growth of many species of microorganisms at once. I have contrived approximately thirty compounds of the various permutations and combinations of drugs in the table to fit particular situations. I believe firmly that no compound of drugs applied topically should omit an anti-yeast, anti-fungus component. The most generally effective compound I

have used has been composed of about equal parts of Tetrex-F, Neosporin, and Chloramphenicol. These are all used as powders. The continued use of Chloramphenicol may be inadvisable (though I have used it topically over extended periods) because of the possibility that it might produce pernicious anemias in birds as it is known to do in humans, and because of the effects it might have in inhibiting the synthesis of proteins responsible in large measure for healing. The latter point is doubtful since I have not been able to determine the effects it might have on bird tissues but it does achieve its anti-bacterial effects by preventing the bacterium from synthesizing proteins.

Case #2--Peregrine falcon

When incipient infections are caught early enough (not likely unless the falconer has once been burned and has developed very quick responses to subtle behavioral manifestations and inspects the feet in strong light at frequent and regular intervals) radical surgery may not be necessary. The second case with which I have had personal experience almost certainly was caused by talon puncture. The eyass bird had recently been entered to pigeons and when I took her up from the kill she was both keen and excited. I called her off from her kill with a partly eaten pigeon and a somewhat clumsy grappling on my fist ensued. When she settled down I noticed a small spot of blood on the plantar surface of the foot but believed that it was probably pigeon blood. This spot, on later examination, turned out to be located exactly at the point at which accidental puncture with the hind talon would have occurred. The same was the case with the larger initial lesions in the tiercel already described. The scab persisted for about three days and disappeared. About three weeks later I noticed a small dark spot at the same point accompanied by a barely detectable swelling of the pad of the foot. At this point I began the treatment which I believe offers considerable hope in early cases. I removed the spot which turned out to measure about $3/32$ inch in diameter and about $1/16$ inch deep. I would certainly have described this as a corn-like body had I not been aware of its history and would probably have thought its origin was due to the same series of events that cause corns in humans. The hole left from this operation narrowed to the bottom, and pink, relatively healthy looking tissue was visible with one small spot of rather suspicious white material. I washed the hole with betadine and packed it with the compound mentioned before of approximately equal parts of Tetrex-F, Neosporin, and chloramphenicol. It was then bandaged.

A systemic attack on the infection seems essential although dramatic improvements always seem most directly associated with topical treatment. In this case, I administered half a pill of Delta Albaplex (Upjohn) (as recommended by Beebe and Webster, North American Falconry and Hunting Hawks, 1964) every twelve

hours with the thought that the tetracycline ought to help in the infection and the cortisone might help to encourage healing. This regimen was continued for two weeks, allowed to lapse for a week and then resumed for two more weeks.

Examination, reapplication of drugs, and re-bandaging was done about every two days early in the treatment and later allowed to go for a week but with very close attention to any suspicious symptoms of heat in the foot, favoring, or palpable swelling. The swelling went down very soon (within three days), the hole apparently closed (about three days) and to all external casual examination all seemed well. However when the site was carefully examined, the material which closed the wound turned out not to be tissue at all and when removed showed the usual discouraging picture of a hole of at least the original size, ringed with dried tissue. This is very typical of plantar lesions and underscores perhaps the most discouraging and difficult aspect of the affliction, i.e., actual healing of the external aperture seems almost impossible when it is of any size. The formation of a ring or shallow cylinder of dead tissue may block any capacity that the dermis and epidermis may have to close the wound and is at least associated with it. The use of antibiotic salves to keep the area soft seems to do little good and in any event seems a very good way to accumulate resistant bacteria right at the site of the wound because of the stickiness of a salve.

After two months, the wound seemed to have gradually progressed to final stages of healing and I had concluded that granulation from below had actually occurred. Again, removal of an ambiguous surface layer showed not only the same hole but evidence of early infection. The wound was gently debrided, washed with betadine and bandaged in the usual manner. A balled piece of paper towel was then placed in the foot and the toes curled around it. The whole assembly was then bandaged providing for the hawk to support at least some of its weight on the curled-up toes. She tolerated the situation well and ultimately was able to balance on her balled foot even to the extent of raising the other into her breast feathers for long periods. Oral drug therapy with Delta Albaplex was continued as described earlier for the following three weeks during which time the foot-bandaging was maintained.

The small amount of swelling went down within two days but the "balling" of the foot seemed to produce no dramatic improvements in healing. After three weeks "balling" of the foot was discontinued. Currently, about four and a half months after the initial surgical treatment, the foot has no swelling at all and is evidently free of infection. The surface of the skin, however, has not returned completely to normal and careful examination still discloses a lesion. Whether or not this case will ever really be cured is uncertain but the situation is hopeful. If

nothing else, close attention should permit it to be maintained as it is more or less indefinitely, i.e., fully functional and not malformed or disfigured.

Treatment of Foot Infections

The normal course of an untreated case leads to the development of an infection within the connective tissues of the foot. As I construct the usual course of events the opening to the surface of the skin, if plantar, becomes "plugged" with a dark corn-like structure, often adherent to and probably normally a part of a dense nodule which increases gradually in size within the substance of the foot. When a foot infection has reached this stage the chances of successful treatment have already diminished considerably. In such cases I would recommend immediate and drastic action similar to that outlined by Kost (in Woodford, M. H., 1960, A Manual of Falconry). I should emphasize, however, that I am recommending a treatment that has not successfully been employed by myself except in its component parts.

Anaesthetize the bird and remove all of the nodule and associated abnormal material within the hole. The pad of the foot (actually probably mostly in the dermis of the skin) contains an abundant circulatory supply which should be disturbed as little as possible both for the sake of the eventual recovery of the foot and because the surgical field will be flooded with blood which greatly hampers one's surgical technique and one's judgment of what is normal and what is abnormal material. A tourniquet and supply of sterile swabs will help in controlling blood leakage. If the surgery is performed by a professional, he will have additional materials and techniques with which to control blood flow.

The hole, once it is as clean as it is possible to get it, should be washed with topical bactericides such as betadine and then packed full of a very broad spectrum compound of drugs such as mentioned earlier, not omitting a component to suppress yeasts and fungi. The foot should then be bandaged very carefully. The best method I have devised is as follows. Cut a disc of foam padding with a concavity at the point where the wound will be and place it on a strip of surgical tape about four inches long. The pad is then centered on the wound and the ends of the tape passed across the foot, around and over the foot overlapping the ends, leaving the front toes uninvolved to this point. Then take two pieces of tape about three inches long, notched to fit between the front toes comfortably. Place one end of each of these on the tape over the top of the foot and pass the end all the way around the foot from front to back and then up again to the top to be stuck on where the piece began. When properly positioned these should close all substantial apertures toward the wound. Band aids stretch too much with time and I do not recommend them.

The bandages should be removed daily and the wound packed again (hawks develop an astonishing tolerance to this process when gently done and will stand and allow the foot to be lifted while the job is done) until the swelling has gone down and the wound is sterile. The wound should be cleaned of newly visible debris each time. Once the wound has checked out sterile, preferably by innoculating culture media, anaesthetize the hawk again and do one last, fanatically thorough job of debriding the wound. Cut away unhealthy tissue ringing the edges of the wound so that completely raw edges are exposed and pack the wound with the antibiotic compound. Then suture the edges together very carefully so that it is completely leak-tight. I have used a spray-on plastic "skin" to help keep bacteria away from the sutured wound but it is difficult to use and of dubious efficiency. The foot should then be bandaged again and not disturbed for about a week. If careful examination at this point shows no trouble, re-bandage for another week and then remove the sutures.

There are several possible problems with this approach. Absorbable sutures, in my experience, have not held long enough for the edges to heal properly. Silk holds very well and is easily removed but itself leaves small holes in the foot which may as easily as not furnish entrance to bacteria which can start the whole thing again. Removal of sutures, therefore should be accompanied by careful precautions against re-infection. An additional two weeks or possibly more should see the scab and/or dead cells loosening. Salves may help in this process. While I recommend this approach it should be made clear that the chances of a person succeeding without having had previous experience to condition his mental approach and to teach him the technical pitfalls do not seem good. There is a tendency to hope that the physiological processes of the bird will be able to take care of one's small failings in removing all infected materials or in really securing completely clean, raw tissue for suture. In my experience this will not happen and everything will be lost if even a single bacterium survives debriding and chemotherapy.

One ought to conduct the surgical approach with the feeling that this is the one and only chance. When unsuccessful the first time the chances of ultimate success seem poor indeed since one has, in fact, simply enlarged the lesion.

The real problem with foot infections seems to lie in the failure of the tissue to heal. I never saw the slightest evidence in the tiercel that any granulation leading to filling of the wound was occurring and I cannot see any hope whatever of the open foot healing even though bandaged and carefully tended every day. Constant pressure on the wound has seemed to be a major factor likely to hamper healing, as it is in human bed-sores, and the attempt to take the weight of the bird off of the foot via some such approach as "balling" the foot is

attractive. Dr. J. H. Enderson tried the same approach before I did but with the same ambiguous results.

If a technique is used which does give one access to the wound careful debriding is in order when accumulated dead cells and other material obstruct the healing process or deny access of drugs to the deeper regions. But it must be done gently. I have employed proteolytic enzymes such as Varidase and Elase in attempts to clean out the hole but with no success whatever in spite of very persistent applications. A gradual buildup of firm caseous material in a bad case of bumblefoot such as that of the tiercel seems relentlessly to occur and is a great problem. In his case I had simply to pick it out at intervals of about three weeks. It was invulnerable to proteolytic enzymes suggesting that this material and possibly the nodules which have been mentioned earlier as fairly typical of advanced cases of bumblefoot may well be accumulations of bacterial polysaccharide, not a tissue response of the hawk. This continuing re-accumulation of caseous material has not been emphasized by others and may have been more or less unique to my single experience with a serious case. It is possible that the caseous material may be traceable to the activity of acid-fast organisms (related to those causing tuberculosis in man). They are very difficult to grow up on culture media (taking as much as six to eight weeks) and nearly invulnerable to drug therapy apart from those now being used against human tuberculosis. Such organisms are known from birds.

Concomitant with topical treatment of either advanced or early cases, some systemic drug therapy should be used. As pointed out earlier, dramatic improvements seem to be most directly associated with topical treatments; in fact, I have never been sure that any oral drug was having any effect. It is also possible to kill the hawk by overdoing treatments which may eliminate the normal bacterial flora of the intestine, leaving the field to such organisms as yeasts. I very nearly lost the tiercel in this way and only my ready access to diagnostic techniques allowed me to save him with quick application of amphotericin B. I think it is wise to make sure that while oral drugs are being administered a constant input of "normal" microorganisms is being maintained by feeding natural food, so organized that the hawk eats some of the intestine. In this manner, a proper balance of microorganisms may be easier to maintain.

Some oral drugs may be outright toxic. Some of these are indicated in the list of drugs used but should not be regarded as definitive since at the slightest suspicion I discontinued use of the drug. It is well to remember, however, that the hawk's kidneys are vulnerable to sulfas in general. In any event, I never had the slightest hint that any of the sulfas I used did any good. Antibiotic sensitivities were low at

best for any organisms I recovered. A final point on toxicity: do not assume that topical use eliminates the issue of systemic poisoning. The circulation in the feet is quite capable of conveying a drug to the rest of the body in only a few minutes. This direct observation may bear on my tentative conclusions that oral drugs seem to have little significance in working improvements. The improvements seen with topical drugs (which were never abandoned in favor of solely oral treatment) may well have been accompanied by high blood levels of the topical drug diffusing from the locus in the foot. The possible effects of oral drugs would therefore tend to be masked.

An early case of a foot infection can be handled more easily and at the moment I have no better suggestion than to approach it as I did in Case #2. In this case I did not determine either the species of organisms involved nor their drug sensitivities, relying on what I felt from previous experience to be a predictably effective drug compound.

If an event is actually seen which is likely to lead to an infection it should be easy to head it off. When a cut, puncture, or other breach in the skin is known to have occurred an immediate oral dosing of a broad spectrum compound of antibiotics continued for at least a week may prevent infection and avoid the whole problem. I would couple this with a careful wash of the skin with Betadine Soap, application of Betadine paint, and a careful job of bandaging. Other topical bactericides would probably work equally well but it is hard to stress adequately how much preferable a little, or even a lot, of preventative or early treatment effort, is to a full blown foot infection.

Padded perches during treatment are of course needed and added efforts at maintaining the sanitation of the area are not amiss. But the sanitation effort might as well be reasonable. At several times I attempted to maintain strict sanitation of temporarily sterile wounds in the tiercel with daily washes of the feet with Zephiran Chloride and/or PhisoHex and I daily removed a cloth cover of his perch and area of reach for sterilization. Even this sort of rigor did not insure that the lesion remained free of contamination. Perfect sanitation is impossible and one must be content with what is probably, after all, adequate as long as drug therapy continues.

Prevention

As mentioned earlier the use of the word bumblefoot seems unfortunate in that it implies a discrete disease and encourages the thought that there must be "a" cure and "a" means of prevention. I think simply referring to "foot infection" puts the matter in better perspective and one can then consider a general and broad category of activities designed to minimize the

possibilities of infections. While it may be true that dietary inadequacy, poor condition or other more or less obscure factors may contribute to the susceptibility of a bird to infections, the primary cause of foot infections must lie in the production of a breach in the skin. Obviously the physical properties of the substrate upon which the bird perches or may land from time to time can be important and abrasive, or splintery surfaces must be avoided. This is particularly true if the bird is not free in a mew and is allowed to bate against a leash which in turn swings the bird down hard on a surface. It seems possible that simply repeated bruising could readily open the defenses of the skin. I cannot be definitive on Beebe's analysis of a common cause based on polishing of the foot by a too-smooth surface and subsequent corn formation (Beebe and Webster, 1964), but my own observations would suggest that dark "corns" are actually a result of a breach in the skin predating the "corn," and while not precisely a "scab," resemble it.

I believe that Kost and Mavrogordato are correct in the opinion that foot infections are often caused by talon puncture. One of my cases is almost certainly attributable to this cause and I suspect the other, in the tiercel, to have been caused either in this way or by bating on a hard surface which may have done the initial damage by bruising. Blunting the talons is an easy and obvious way to prevent this probable cause. Some falconers have felt that stone blocks were helpful in preventing bumblefoot and it may well be that, so long as the bird cannot bate on such a surface, the talon-blunting effects of stone are helpful.

Falconers writing on the subject have not stated the time of the year in which the infections developed but one suspects that most often inception of the infection dates from periods in which the hawk was not being flown, i.e., during the molt or when flying had ceased after the hunting season. This is the likeliest time for relative inattention and poorer condition as well as the likeliest time for the food supply to shift toward more beef and less natural food. I doubt that the natural conclusions, i.e., that poor condition and/or poor food with inadequate vitamins, are actually causative are warranted. While it is possible that a predisposition might be caused, I think that with a reasonably competent falconer, such inadequacies are unlikely to be extreme enough to be an important factor.

My own falconry experience has been almost exclusively with accipiters and I am impressed with the relative clumsiness of a falcon's feet. Mavrogordato mentions the tendency of some hawks to perch with one or more toes clenched. I have wondered if this last trait plus the "clumsiness" of falcons might have a good deal to do with the relative susceptibility of falcons as compared with accipiters. For this reason it seems clear that perches ought to be designed so as to make the birds' toes and talons assume a non-dangerous position to minimize punctures.

Blocks typically permit the birds to perch with the talons or toes turned under, and for this reason seem less than perfect. A type of block which I have seen and used seems to answer this objection which is made of two inch wood stock. It is shaped like a triangle with the top side curved and the straight sides tapered down to the spike. The rounded perching surface can be covered as the individual wishes. In any event, there are pitfalls of many sorts when the bird is maintained tied up and the obvious advantages of liberty in a mews equipped with appropriate perches would tend to help a great deal.

The best type of perch must still be considered an open question. My two cases occurred, one with hard perches and the other with padded perches. I have not used stone or concrete. I do, however, feel padded perches to be the safer bet (see Enderson, 1967 Raptor Research News 1(3)43-45) and recommend a contour such as mentioned above, offering the hawk the option of more than one shape on a single perch.

But perhaps the falconer's single best weapon against foot infections is his own awareness of the extreme vulnerability of a hawk's feet. It might be well, and accurate, to regard the feet as almost devoid of the capacity to ward off infection on their own. I am inclined to believe that a wound virtually guarantees an infection.