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Design of laboratory animal facilities must be functional. Accordingly, the designer should be aware of the complex nature of animal research and specifically the type of animal research which will be conducted in a new facility. The building of animal-care facilities in research institutions requires special knowledge in laboratory animal medicine, animal husbandry, biomedical research, and architecture. A major concern should be accessibility of the facility by investigators and reasonable proximity to laboratory areas. Six general floor plans for housing laboratory animals are discussed. (RH)

Laboratory Design Notes

Distributed in the interest of improved research laboratory design

Laboratory Animal Facilities

Albert M. Jonas, D.V.M.

Summary and Conclusions

Six general floor plans for housing laboratory animals for research are: (1) single-corridor system; (2) two- or three-corridor system; (3) two-corridor system associated with laboratories; (4) one-corridor system associated with laboratories; (5) tower arrangements; and (6) free-standing building attached to research buildings.

The building of animal-care facilities in research institutions requires special knowledge in laboratory animal medicine, animal husbandry, biomedical research, and architecture. The purpose of the animal facility is a means to an end—biological research. There are 3 main categories to which animals are assigned: research, quarantine, and production. A thorough knowledge of the requirements of each is essential for good design of facilities. A major concern should be accessibility of the facility by investigators and reasonable proximity to laboratory areas.

DESIGN of laboratory animal facilities must be functional. To be functional, the designer must be aware of the complex nature of animal research and specifically the type of animal research which will be conducted in the new facility.

The investigator, along with the experimental animals, must both be given full consideration.

Categories of Research Animals

The 3 main categories to which research animals may be assigned are research, quarantine, and production.

Research

Animals in this group may be allotted to 4 subgroups: (1) acute (nonsurvival), (2) acute (short-term survival), (3) long-term survival with constant observation, and (4) long-term survival with infrequent observation.

Requirements for animals in the 4 subgroups are as follows:

Acute (Nonsurvival).—Animals in this group are easiest to accommodate, since they are normal animals being brought into the research holding area, housed in proper cages for a minimum number of hours or days, and euthanatized after the experiment. The main problem in animal care, namely disease, is virtually eliminated. There is no time for communicable disease to affect these animals, even if the environment is contaminated. Elaborate control systems are therefore unnecessary, and the investigator has almost unlimited access to his animal rooms.

Acute (Short-Term Survival).—Here the disease factor is minor. Animals in this group are replaced rapidly. If reasonable controls for disease prevention and spread are instituted, only minimal problems should be expected. Here, too, the investigators have nearly unrestricted access to their animal rooms and they may, therefore, come and

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go with ease. The design of the facility must reflect this situation.

Long-Term Survival with Constant Observation.—Animals in this group require maximum disease-control measures, for as in subgroups 1 and 2, such animals should be in the main animal facility in close association with the research laboratories. Diseases among these animals are extremely costly in time, money, and frustration. Depending on the animal species, various degrees of control must be instituted and be available to house these animals free of disease. The investigator himself must be restricted in his movements, for each entry into the animal room presents a possibility of introducing infection. Because of longer survival required, there is greater chance of exposure and build-up of infectious agents. Sanitation procedures must be excellent and entry rules established and followed.

The greatest difficulty with these animals is encountered when taking the animal from the holding room to the testing room or special laboratory. By removing it from a protected environment, chance exposure to pathogens is potentially high. This can only be reduced by vigorous attention to disease control by the investigator. The testing laboratory should be as clean as possible, not a general supply center for the dissemination of disease.

Long term (Occasional Observation).—Animals in this group may be housed either at the main research building or at a facility located away from the institution in a low-value land area. Since only occasional observation is necessary, the investigator may go to the animal or it may be brought to him. If the animal is transported, rules must be established to insure freedom from exposure to infectious disease during transit. This critical nature of animals in this group is obvious, and it is paramount that all practical methods be utilized in order to reduce the possibility of developing intercurrent infection.

Quarantine

This is an important phase of laboratory animal care, for all the elaborate control systems are for naught if the animal is infected from the start. Fortunately, in various parts of the country, rats and mice are being produced under extremely refined conditions. In many instances, however, special strains may have to be purchased from suppliers with substandard facilities. Thus, provision must be made for quarantine.

The principle of animal quarantine is that each shipment of animals be quarantined separately. Separate shipments must not be mixed. If 2 or more shipments of animals are placed in a quarantine room at different time intervals, at the time of release of the 1st group, these animals may be incubating a disease brought in by the 2nd group. The room must be thoroughly cleaned between shipments, so it does not become a reservoir for disease that can be disseminated throughout the colonies.

The quarantine rooms may be located either in the animal buildings or at some more remotely located facility. Dogs and cats are ideally situated in a rural or suburban facility due to lower cost and added isolation factors.

Animal Production

There is little need to dwell on the problems of research institutions in obtaining specific-pathogen-free guinea pigs, hamsters, rabbits, dogs, or cats. These are generally not available for purchase. The investigator requiring "clean" animals must by necessity consider raising his own animals. Location, type of construction, cost of construction, type of animal species raised, and personnel to carry out the production scheme are major considerations.

Building Location

The first question which arises is accessibility of the animal quarters to the investigators. If the research laboratories are across a street from a laboratory, difficulties may be insurmountable. Most investigators desire the animal quarters as close as possible to their laboratories, and many will sacrifice control systems for this advantage. The two extremes in location of animal quarters is a free-standing animal building and individual animal quarters scattered throughout a re-

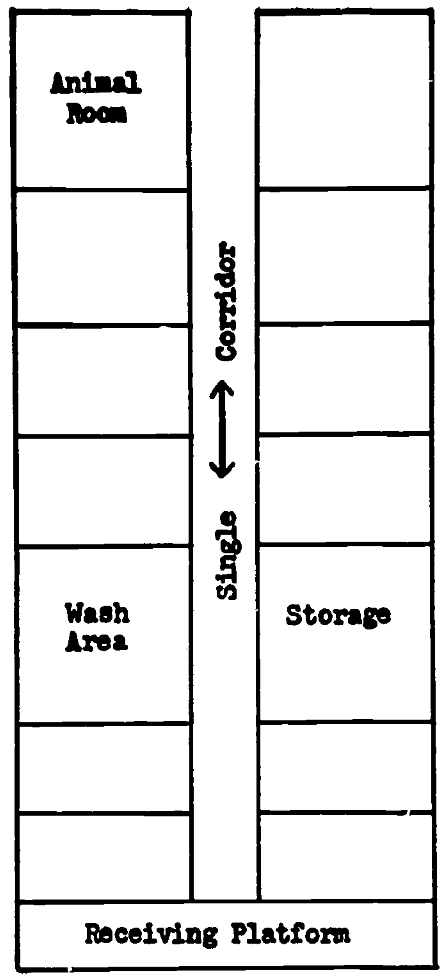

Fig. 1—The single-corridor system has economy of usable research space but a two-way traffic flow.

search building. The latter is generally untenable with the goals of modern animal care. A single, large free-standing animal building may also be undesirable from the standpoint of accessibility to the investigator, although the actual animal care could be excellent. There is a common ground which will preserve the excellence of animal care found in the free-standing building and still allow for easy accessibility—an animal building as an integral part of the research structure. If there are multiple research buildings, there should be multiple animal buildings or their equivalent. The advantages of good central animal care are still retained while still preserving the practical necessity of easy accessibility.

I make the assumption that the centralized animal-care facility does not have to be strongly defended. I also assume that scattered animal rooms throughout research institutions are undesirable. Going forward from these points, I will review various basic designs of animal floor plans for research institutions, considering sanitation problems as well as the use to which animals will be put in biologic experimentation.

Various Floor Plans for Animal Quarters

Single-Corridor System.—The standard floor plan for many years has been the single, double-door, loaded corridor (Fig. 1). This plan is the most efficient in conserving floor space but is the least flexible from the animal-care standpoint.

Since there is 1 corridor, by necessity, all traffic uses this 1 throughway. Clean and dirty cages, healthy and sick animals, and food and personnel travel the same route, many times in direct contact. Animal technicians clean one room, and if the room is contaminated, have no way to make an assured sanitary exit and may contaminate the entire corridor. In a single-corridor system, if multistoried, a single elevator is employed. Because of space limitations, clean and dirty equipment may be in almost direct contact in the elevator. Dirty equipment is rolled to the washing area, washed, and immediately recontaminated in the same dirty area. The use of a barrier and two-door type equipment reduces the congestion on the dirty side but does not eliminate the problem, since a single elevator and corridor are the only way back to the animal room.

This single-corridor system, according to our previous discussion, is suitable for 2 of the 4 subgroups for animal research, *i.e.*, acute (nonsurvival) and acute (short-term survival). Because of the rapid animal turnover, the chance of an epizootic developing is low. If good sanitation procedures are employed, little difficulty with maximum accessibility by the investigators and animal technicians can be anticipated.

Intercurrent epizootics, however, are "built" into this system if subgroups 3 and 4 (chronic) are housed in facilities using this system. It is only with great difficulty that animals in subgroups 3 and 4 can be maintained under these conditions without developing intercurrent infection, since the potential of introducing infective agents into the environment is great.

Quarantine animals are poorly adaptable to a single-corridor system for the same reasons listed for long-term survival animals.

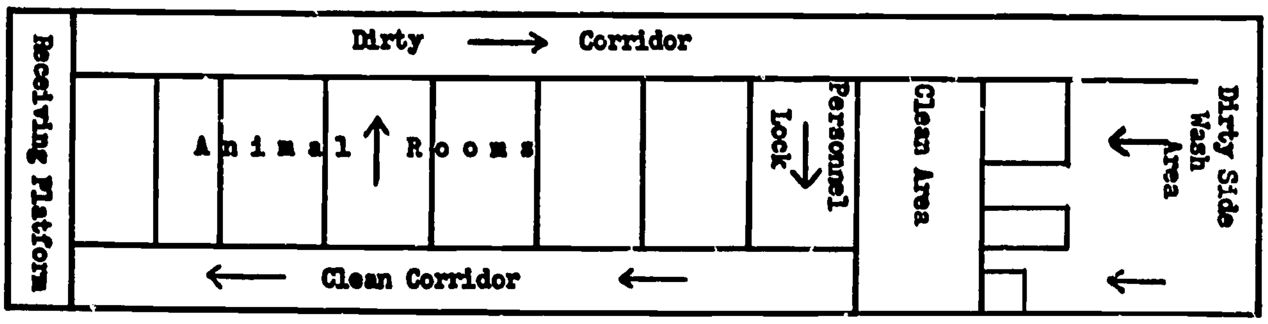

Fig. 2—The two-corridor system is designed for long, narrow buildings. Advantages of one-way traffic and reduced contamination may outweigh loss of research space.

Quarantine should be at least 2 weeks for most species and more ideally 4 weeks. During this time, repeated entries of personnel and equipment may introduce sufficient organisms to reach the Infective $Dose_{50}$ of a pathogen. This must be avoided.

A production unit designed to raise specific-pathogen-free animals is difficult, if not impossible, to obtain for protracted periods on this system. Repeated entries via a single corridor and movement of feeds, dirty and clean equipment, and healthy and sick animals raise the possibility of an epizootic occurring in a production colony. If the production colony is infected, constant dissemination of abnormal animals is the result.

In summary, the single-corridor system is satisfactory for acute nonsurvival and acute short-term survival experimental animals. Long-term survival animals are generally poorly accommodated. Animal production in a research animal building with a single-corridor system is fraught with potential major hazards.

Quarantine quarters may be satisfactorily arranged with such a system, but this would not be ideal.

Two-Corridor System.—This floor plan is wasteful of floor space and therefore more costly to install. It is, however, meeting with growing favor because it overcomes most of the problems found in a single-corridor system. If properly designed, it gives maximum flexibility of operation and use by both investigator and animal-care technicians. If the structure is multistoried, it should have 2 elevators (one designated "clean," the other "dirty") to protect the basic design and principles (Fig. 2).

In the two-corridor system, clean items never contact dirty items, since the flow of traffic is one-way. When an entry into an animal room is made, the exit is via the dirty corridor. The standard sequence of animal-cage routing would be: (1) clean storage area, (2) clean corridor, (3) animal room, (4) dirty cages, dirty corridor, (5) dirty side of wash area, (6) clean side of wash area, (7) clean storage. By this system, dirty equipment can never contact the incoming clean equipment except in the actual animal room where the exchange occurs. All soiled materials exit via the dirty side and all personnel take the same route. Re-entry of personnel from the dirty side requires decontamination through a personnel lock.

Air pressure dictates air flow from the clean corridor, to animal room, to dirty corridor. A high rate of complete air exhaust further reduces airborne spread of infection.

Investigators may enter animal rooms (their own) either via the clean side (going through a personnel lock) or via the dirty corridor (avoiding the personnel lock) without fear of contaminating other animal rooms. Great flexibility can be built into such a system, since all degrees of control can be exercised in specific animal rooms without affecting other rooms.

Thus, for acute nonsurvival and acute short-term survival animals (subgroups 1 and 2), the investigator can maintain the easy access of a single-corridor system (using the dirty corridor).

A rigidly controlled entry and exit system may be employed for subgroups 3 and 4 (chronic) at his own option. He may still use the one-corridor system if he deems the extra precautions unnecessary in his own work. (This usually changes after the first major disease outbreak in his own animal room.)

Quarantine procedures are ideally suited for this system. By changing a sign, quarantine animals become supply animals and all rooms are interchangeable. The sequence for quarantine would be: (1) Bring the animals

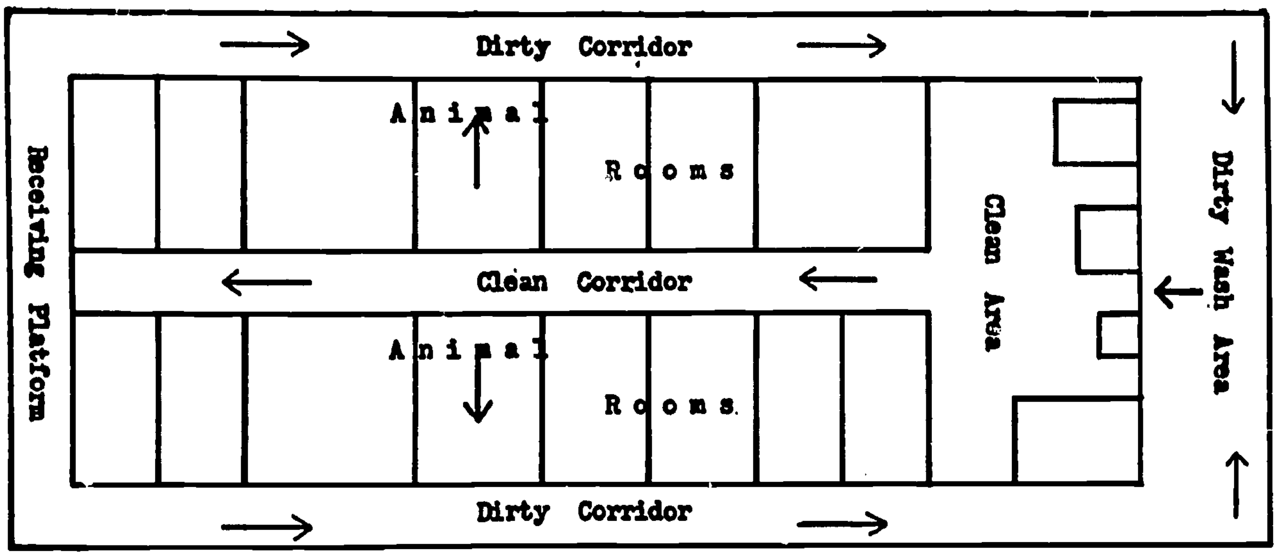

Fig. 3—The three-corridor system is best adapted to long, wide buildings. Advantages are one-way traffic patterns, reduced contamination, and flexibility of room usage.

in via the dirty corridor—protecting them as much as possible; (2) place them in a quarantine room; (3) service them via the clean corridor like all other animal rooms; (4) at the end of quarantine period, distribute them via the clean corridor to the appropriate animal rooms. Animal production is quite possible in this system with resultant specific-pathogen-free animals.

A modification of the two-corridor system is the three-corridor system. This is basically the same as the two-corridor system but with one-way floor patterns. There is a central clean corridor and 2 exterior dirty corridors (Fig. 3) or 2 outside clean corridors with a central dirty corridor. Wide buildings can use this plan to better advantage. Notice that in both the two- and three-corridor systems, the corridor acts as insulation, since no animal room is situated against an outside wall. This supplements the air-conditioning program and compensates somewhat for the added cost of floor space.

In summary, the two-corridor system is more expensive initially but allows for good flexibility of operation for both the investigator and the animal-care program. Research, quarantine, and animal production can be accommodated immediately with this basic design, eliminating the anticipation of alterations if experimental requirements change.

Animal Research

Up to this point in this discussion of floor plans, we have discussed the holding of animals. The reason for existence of the animal facility is for animal research, not housing per se. Where then does the investigator use these animals? Experimentation is not al-

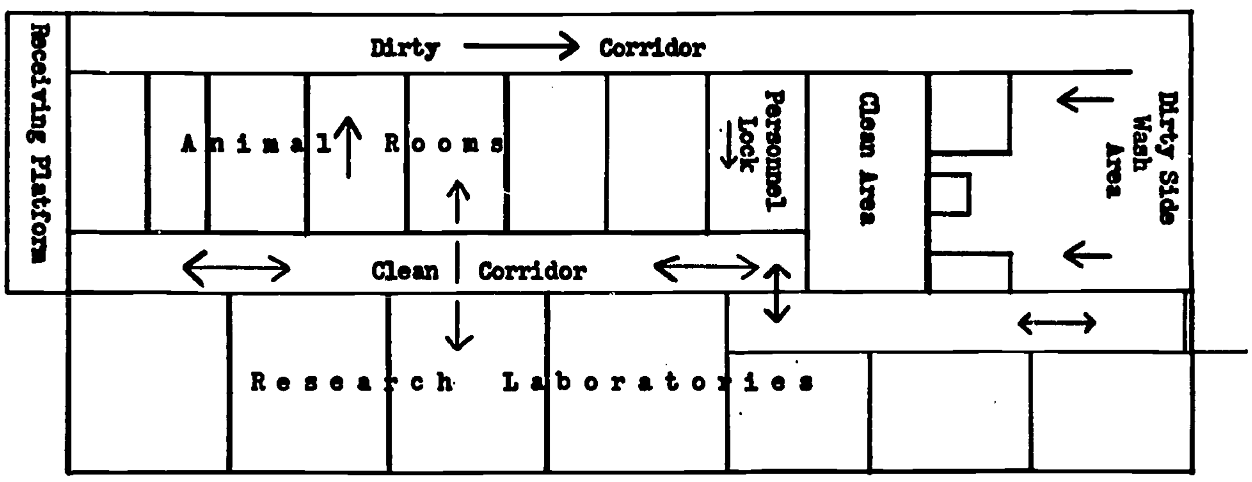

Fig. 4—This plan is a compromise which gives the research worker excellent access to animal quarters (two-way traffic) but allows only one-way traffic for animal-care personnel and equipment.

ways carried out in the animal facility itself but in the investigator's own laboratory.

If the animal must leave the comforts and protection of his holding room, be placed in a contaminated environment (laboratory), and then be brought back to infect his cagemates, why then all the elaborate animal house designs?

There are a few answers to this question. One is to give up and abandon all attempts to reduce the infective agents in all areas. A second is to attempt by various methods to reduce the risk in all areas while realizing the potential hazards of such a situation. A third solution exists in locating research laboratories in close association with the animal holding rooms. Conversely, one may strategically place holding facilities in a research building.

Research Laboratories Combined with Animal Rooms.—Such a combination system can be designed with single or double corridors. Its main advantage is the accessibility of animals by the research laboratory workers and investigators. There is much to recommend this system (Fig. 4). Investigators, once in the clean corridor, have access to their animal rooms without fear of contaminants. This is in fact a modified one-corridor system with the added features of a secondary dirty corridor with personnel locks. The laboratories are operated as clean rooms off the clean corridor. Thus, with only 1 entry through the personnel lock, the investigator is free to enter animal rooms at will and transfer animals from the animal room back to his laboratory. If an infection should occur, the animal rooms could be converted to a one-way traffic flow until the danger of contagion had been eliminated. Conservation of washing equipment is accomplished by using a central washing area utilizing 2 elevators—clean and dirty. A 3rd elevator for passenger use may be located in the front of the building. This system must be compared with one of individual washing units on each floor, eliminating 2 elevators.

All visitors must be carefully screened before entry and must pass through the personnel locks. For this system to work, reasonable controls must be employed.

With a one-corridor system (Fig. 5), utilizing some of the features of the previously

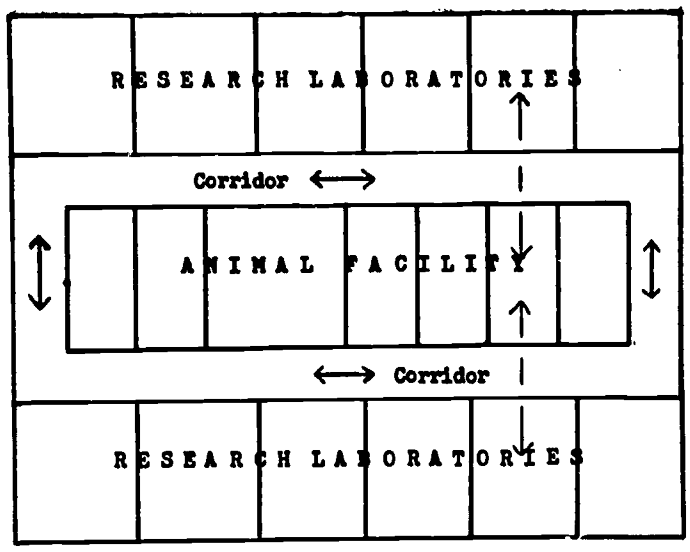

Fig. 5—One-corridor systems provide maximum access of research worker to animals. This system is best suited where there is rapid turnover of animals.

described system (Fig. 4), one can utilize central washing facilities on another level (basement) if desired. Rapid turnover groups of animals are well suited to this plan.

With the one-corridor system, the investigator has excellent access to his animal rooms and can shuttle animals back and forth from and to his laboratory with a minimum of difficulty. The disadvantages are: dirty equipment may be in regular corridors, potential contamination of equipment and animals, and increased odor and noise may occur.

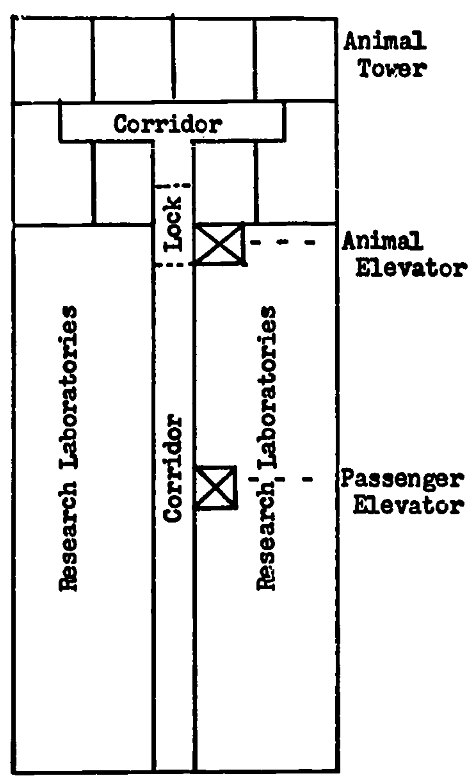

Fig. 6—A single floor of a multistoried research building. All floors are planned with the same research and animal locations (stacking). All services are vertical, but access is horizontal.

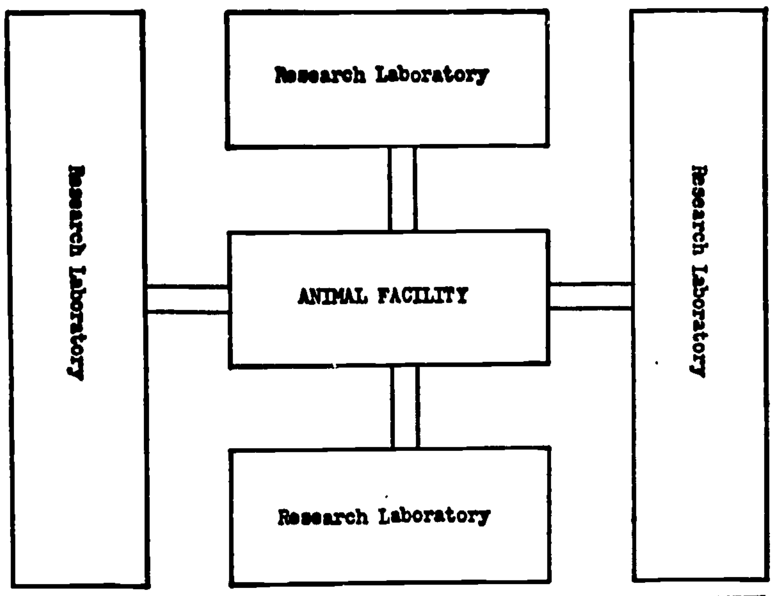

Fig. 7—Free-standing animal building attached to research laboratories.

Tower Arrangement.—The tower arrangement (Fig. 6) is an attempt to bring animal rooms close to investigators working on various floors. The ideal arrangement is for each floor at all times to have just the right number of investigators and just the right number of animals to properly use the animal rooms on that floor.

The criticisms of this concept apply to the 2 previously described systems (Fig. 4 and 5). The requirements of investigators may vary widely from year to year. Thus there will probably be either "feast or famine" in regard to animal space per floor. The result is that some investigators may have to travel to another floor, thus defeating the original object of convenience, or valuable space may not be utilized. Even with these disadvantages, the tower system may be acceptable providing that efficiency of design and flexibility of floor plans (two-corridor systems) exist in some other location to accommodate animals in subgroups 3 and 4. Two corridor systems per floor would probably be impractical because of expense and loss of actual animal research space.

The problem at many institutions is that experimental programs vary markedly from year to year. For example, a department may change from canine to rodent experimentation or may switch entirely from animal use to tissue-culture systems. A limited floor area per floor means limited flexibility. With changing requirements, for example, the need for a two-corridor system for housing of dogs or primates or a large rodent breeding colony, a limited floor plan would create serious difficulties.

Free-Standing Animal Building.—One other relationship of animal quarters to research buildings is a free-standing animal building utilizing a two- or three-corridor system and situated in the midst of a group of research buildings. This is most ideal from a cost-saving and animal-care point of view. It has the added advantage that it can grow with the actual needs of the institution without some of the problems associated with expansion (Fig. 7).

The concept of a free-standing structure linking up to surrounding buildings can in most cases only be utilized in initial building programs. Its construction in new facilities is indeed related to long-range planning and should be considered as 1 possible method to solve the animal housing problem.

Discussion

Basic floor plans should be designed to accommodate the 3 needs discussed: research, quarantine, and production. A decision must be made as to the desirability of having laboratories associated directly within animal quarters (Fig. 4 and 5), developing a tower arrangement (Fig. 6), or constructing animal quarters on a completely separate floor, with laboratory space available outside the facility (Fig. 1, 2, 3, and 7). Any one or a combination of these possibilities may be needed.

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