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Co-ordinated Interdisciplinary Efforts on Research in Animal Production and Health

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Houe H: Co-ordinated interdisciplinary efforts on research in animal production and health. Acta vet. scand. 2003. Suppl. 98, 51-64. – The objectives are to review results and experiences from interdisciplinary research projects in Research Centre for the Management of Animal Production and Health (CEPROS) concerning scientific content, organisation, and collaboration.

The Centre has been founded as a result of an agreement between four institutions: the Danish Institute of Agricultural Sciences (DIAS), the Danish Veterinary Laboratory (DVL), the Danish Veterinary Institute for Virus Research (DVIV) and The Royal Veterinary and Agricultural University (KVL). CEPROS is a "research centre without walls" and is physically located as an integrated part of the four institutions named above. The Centre has close collaboration with the industry.

The superior goals of the Centre are to co-ordinate fundamental and applied research and simultaneously integrate the veterinary and the production oriented livestock research within animal health and welfare, taking into consideration the production economics and reduced use of medication. The assignment of the Centre is to initiate and carry out research, aiming to investigate the influence of breeding and production systems on animal health and welfare as well as on production and product quality.

The Centre has since 1997 established 16 interdisciplinary research projects dealing with cattle, pigs, poultry, or mink. The scientific content can be divided into three research clusters: A. Management of animal production and health in production systems, B: Pathogenesis of production diseases, and C. Animal health economics. In Cluster A, the physical environments of production systems have been investigated, broader definitions of the concept health have been established and used in identification of risk factors. Cluster B has investigated physiological, immunological and genetic mechanisms behind development of production diseases and how to apply this knowledge in disease prevention. The cluster in animal health economics has developed decision support tools for disease control in swine and cattle herds.

The interdisciplinary research groups organised in a centre without walls are found very useful for dealing with complex issues. The initial phases in the projects may be long as it takes time for different researchers to define common goals and identify methods. The individual researcher must get some insight in other disciplines without loosing his/her own area of expertise. In order to reach a synthesis of the different parts of a project, it is important that the project is well organised and there is participation of researchers with both specialised insight and researchers with a more broad insight in the problems. It is also important that the integration process is balanced, and not too many research disciplines are included in the same project.

animal production and health; interdisciplinary research.

Introduction

In recent years there has been a higher emphasis towards subjects such as animal welfare and food quality and safety. In 1994, the Danish Government published the report: "Proposal for a national strategy for agricultural research" (report no. 1274, June 1994). The report proposed an orientation towards preventive health and welfare research. The committee behind the national strategy concluded that the traditional distinction between research in normal animals (animal science) on one hand and diseased animals (veterinary science) on the other hand was unsuitable for research and development within the areas of production and management systems for farm animals. To secure health in its broadest sense veterinary research should to a far greater extent be integrated in animal science. The establishment of the Research Centre for the Management of Animal Production and Health (CEPROS) was a result of recommendations in the report.

CEPROS was founded as an agreement between four institutions: the Danish Institute of Agricultural Sciences (DIAS), the Danish Veterinary Laboratory (DVL), the Danish Veterinary Institute for Virus Research (DVIV) and the Royal Veterinary and Agricultural University (KVL). CEPROS was founded on September 1st, 1996, for a period of five years. In the period CEPROS has initiated 16 research projects (Table 1). The objectives of this presenta-

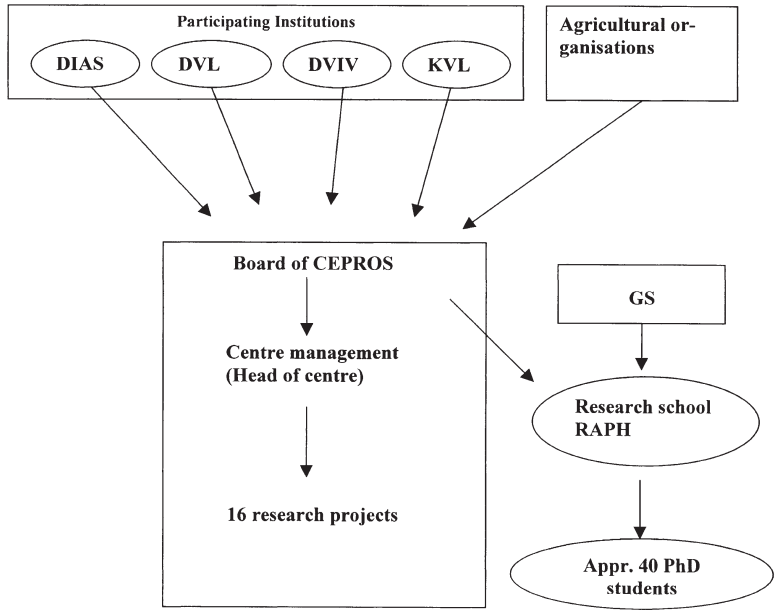

Figure 1. Organisation of CEPROS

CEPROS = Research Centre for the Management of Animal Production and Health. DIAS = Danish Institute of Agricultural Sciences. DVL = Danish Veterinary Laboratory. DVIV = Danish Veterinary Institute for Virus Research. KVL = The Royal Veterinary and Agricultural University. GS = The Graduate School for Veterinary and Agricultural Sciences in Denmark. RAPH = Research School for Animal Production and Health.

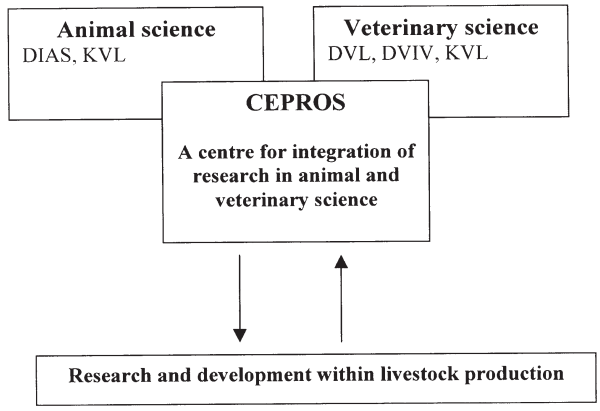

Figure 2. Scientific content of CEPROS
CEPROS = Research Centre for the Management of Animal Production and Health. DIAS = Danish Institute of Agricultural Sciences. DVL = Danish Veterinary Laboratory. DVIV = Danish Veterinary Institute for Virus Research. KVL = The Royal Veterinary and Agricultural University.

tion are to review results and experiences from interdisciplinary research projects in CEPROS.

Purpose assignment and organisation of the research centre

The purpose of the centre is to co-ordinate fundamental research with applied research and to integrate veterinary and production oriented animal research in such a way as to promote knowledge as to how profitable production of livestock can best be carried out with consideration for the health and welfare of livestock, as well as reducing the usage of medication.

The assignments of the centre are:

- to initiate and conduct research on the effect of breeding and production systems on health, welfare and production of livestock, and quality of the products
- to participate in training special and Ph.D. students in matters relating to the research projects
- to contribute to the further education of consultants in primary production

Originally, 50 mill. DDK were earmarked for the activities of the Centre. For the period 1998-2001 additionally 20 mill. DDK were allocated for strengthening research concerning immunity towards production diseases.

CEPROS is a "research centre without walls" and is physically located as an integrated part of the participating institutions. A board consisting of five members governs the centre. Four of these are from each of the participating institutions. The fifth member is selected by the livestock industry. The daily running of the centre is the responsibility of the Head of Centre. The organisation and scientific content of CEPROS is illustrated in Figure 1 and Figure 2.

Scientific content

An overall frame of the scientific content of CEPROS is illustrated in Figure 3, referring to the first assignment of studying the influence of breeding and production system on production, health, and welfare. The figure illustrates that the living conditions (or risk factors) for the animals include their genetic constitution, pres-

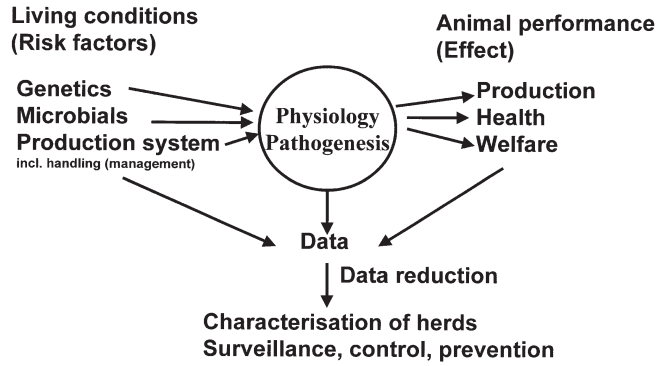

Figure 3. Frame for the scientific content of CEPROS

ence of contagious agents, and the quality of the production system including the use of the production system (handling of animals etc.). These living conditions will affect the biological mechanisms (physiological and pathological) some of which we try to measure in the animal performance including production, health and welfare. The figure also tries to illustrate that these elements are studied with focus on applied aspects such as characterisation of herds, surveillance, decision support systems, prophylaxis, and control. The figure has common validity in agricultural and veterinary science. But for the CEPROS projects there are increased focus on more holistic approaches and by increased integration among different researchers on the participating institutions.

At the participating institutions in CEPROS,

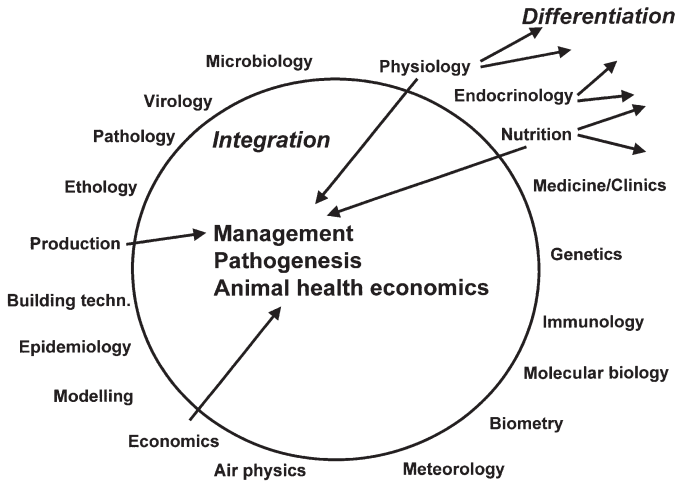

Figure 4. Research disciplines in CEPROS

Table 1. Full titles of initiated research projects in CEPROS

CEP97-1	Minimisation of the feeding health load by control of the calcium homeostasis and acid-base balance in dairy cattle
CEP97-2	Genetic improvement of health in swine (By 1999 incorporated in project CEP97-10)
CEP97-3	Health, welfare and production of swine in multi-site systems
CEP97-4	Operating Research Centre for Animal Production and Health
CEP97-5	Animal health economics - Decision support systems for disease control in pig and cattle herds
CEP97-6	Characterisation of the immune system in calves infected with bovine respiratory syncytial virus to improve the possibilities for prevention of disease
CEP97-7	Transfer of maternal immunity against Mycoplasma hyosynoviae to pigs and identification of immunity in swine herds with and without arthritis
CEP97-8	Influence of production systems on animal health and innate flock immunity in poultry
CEP97-9	Protective immunity to porcine reproductive and respiratory syndrome (PRRS): Towards a rational basis for PRRS control
CEP97-10	Genetic improvement of disease resistance in pigs
CEP97-11	The influence of production facilities, management strategies, and medication policy on health and antimicrobial resistance in dairy cattle herds
CEP97-12	Objective assessment of health status and use of medication in Danish mink production
CEP97-13	Objective evaluation of health status in Danish pig herds
CEP97-14	The influence of the farrowing environment on factors of importance for piglet health and survival
CEP97-15	*Escherichia coli* in Danish poultry production: Investigations on the role of management factors, with emphasis on production systems and feed composition, on the presence of potentially pathogenic clones of *E.coli* and colibacillosis
CEP97-16	Housing of growing pigs in large groups - principles and strategies and significance for animal welfare
CEP97-17	Airborne transmission of respiratory disease between pig units located at close range

several research disciplines are represented (physiology, genetics, virology, feeding, housing systems, epidemiology etc.) as shown in Figure 4. A lot of research in these areas can naturally be continued within each discipline. And often the natural driving force within each discipline is differentiation into more and more specialised areas indicated by arrows pointing out in Figure 4. However, when studying the complex association between production systems, health and welfare, a significant integration between disciplines is needed as indicated by arrows pointing inwards in Figure 4. In order to approach this integration, CEPROS has created a problem-orientated rather than a discipline-orientated profile. The problem-oriented research areas can be described in 3 research clusters that are also the priorities of the Research School of Animal Production and Health:

Cluster A: Management of animal production and health in production systems
Cluster B: Pathogenesis of production diseases
Cluster C: Animal health economics

In all research areas, the research has aimed at an application of the knowledge either at the strategic level (e.g. better genetic constitution or better housing systems) or at the tactical/operational level (e.g. decision support systems). Along with the distinction of three different clusters, there has been emphasis on integration between clusters also. In the following a very brief overview of the scientific content in each cluster and project will be given. A longer description of each project (listed in Table 1) is given in the annual report 2000 for CEPROS that also contains a reference list of publications from each project.

Cluster A: Management of animal production and health in production systems

This cluster focuses on the production system, the handling of animals in these production systems and on how to obtain data for an evaluation of the production system. The following more specific areas have been identified in this cluster:

- Identification of risk factors in the production system that influences animal health, welfare, and production
- Identification of objective measurements of animal health and welfare
- Achievement of knowledge that can form the background for development of production systems that will improve animal health and welfare, reduce the need of medication, and secure animal product quality
- Development of methods for health surveillance
- Development and implementation of methods for control of animal health and immunity

Surveillance and control are relevant for all 3 clusters.

The management cluster is aiming at providing knowledge for the establishment of better production systems (i.e. long-term management), but also at providing better tools for the daily management of the production system and the animals.

One project investigates the possibilities of preventing transmission of infection in multi-site systems for pigs (CEP97-3, Table 1). Additionally, a health evaluation of these production systems is carried out, and tools for health monitoring and welfare evaluations are developed. It was possible to break the transmission chain for some agents, but not for others. Transportation and mixing was found to be stressful and may therefore have a negative influence on health and production. The necessary distance between buildings to prevent disease transmission is investigated in another project (CEP97-17). By placing pigs in two different mobile containers, the transmission over 20-100 m is investigated. Further the transmission is studied using computer simulation.

The influence of farrowing environment for piglet health and survival is investigated by giving sows different opportunities for nest building behaviour (CEP97-14). The lack of feedback from a completed nest had negative influence on the behaviour of the sow. Further there was a longer interval from birth to first suckling. Several blood parameters will be investigated. Especially the lack in physiological decline in plasma calcium around farrowing will be studied further and compared with the situation in cattle.

New regulations concerning the housing of growing pigs prescribe the provision of cooling facilities, rooting material, and partly solid floor. These improvements together with optimum utilisation of space is investigated in a project where the pigs are housed in larger groups based on dynamic introduction of pigs (CEP97-16).

Three projects attempt to find methods for a more accurate identification of the actual state of health in herds (CEP97-11; CEP97-12; CEP97-13) integrating several data on health measures. Medicine consumption is included in the total evaluation of the state of health of the livestock. Parallel with a more precise determination of the herd health, the effects of production conditions, including stables and design of these, climate and management factors, are investigated. In pig herds (CEP97-13), clinical recordings, meat inspection data, serological parameters on meat juice and blood, as well as antibiotic consumption are included. The project has developed ELISA tests for *Mycoplasma hyopneumoniae* and *Actinobacillus pleuropneumoniae* on meat juice. The project will identify risk factors for high antibiotic con-

sumption and assessment of the actual state of health in a larger number of herds.

In cattle herds the influence of production system, management routines, and medication policy on health and antimicrobial resistance is investigated (CEP97-11). Methods for a more comprehensive clinical characterisation of udder health giving a more true measure of udder health as compared to treated mastitis cases. Further, methods for characterising antibiotic resistance on herd level obtaining small screening samples are developed. The measures for antibiotic consumption, resistance, and udder health are combined in a model showing the interplay between risk factors, udder health, and production.

In mink farms, registration procedures for medication of mink, for description of the production system and management, for collection of reproduction data from breeding programmes, and for registration of growth, feeding routines as well as disease and necropsy recordings at farm level have been established and implemented (CEP97-12). This has been followed by a procedure for performing advisory activity in mink farms.

In poultry production, the presence of *E. coli* has been chosen to study the relation between production system, management, antibiotic resistance and characteristics of the agents (CEP97-15). A very heterogeneous population of *E. coli* isolates has been identified. *E. coli* isolated from cloaca and trachea, respectively have been found to be very different concerning serotypes and virulence.

Cluster B: Pathogenesis of production diseases

This cluster is aiming at understanding the basic mechanisms for development of production diseases. The cluster has emphasis on the genetic constitution and the physiological and immunological mechanisms as prerequisite for healthy and robust animals. The research is both aiming on how this knowledge can be used in the control of diseases and on how to strengthen prophylactic measures.

In cattle, it is investigated how feeding can be used to optimise calcium homeostasis and hence be used in the prophylaxis of milk fever (CEP97-1). Adding anions had a beneficial effect on calcium level. Further, steaming up with rolled barley induced a systemic acidification and hence a positive effect on blood calcium. Inspired by the project, the project group has continued studying the possibilities of improving calcium homeostasis around calving by adding calcium binders.

The possibilities of genetic improvement of disease resistance in pigs are studied by examining the genetic variation among immunological parameters and correlating these to disease resistance (CEP97-10). Among the examined immunological parameters a medium to high heritability has been found. Further, a moderate genetic variation in disease resistance as measured in relation to different treatment categories was found. There was a positive correlation between the resistance in different treatment categories. The results indicate that there is a potential for genetic improvement of disease resistance.

In poultry, the innate unspecific immune response, its genetic variation as well as the importance of production systems and feeding strategies for the immune response is investigated (CEP97-8). Two lines of chickens with either high or low unspecific immune response have been selected. It has been shown that certain additions to the feed reduced the unspecific immune response. Further, the time of infection was shown to have influence on the unspecific immune response. Thus, chickens infected in the morning when it was light had higher unspecific immune response than chickens infected in the evening when it was dark.

In three projects a closer investigation of the

Table 2. Research areas and research disciplines in CEPROS projects

Project No.	Title keyword (Research cluster)	Research areas	Research disciplines
CEP97-1	Calcium (B)	Basic mechanisms; Surveillance; Prophylaxis;	Physiology; Nutrition; Medicine;
CEP97-2	Genetics 1 (B)	Basic mechanisms; Surveillance; Prophylaxis;	Genetics; Immunology; Clinical diagnostics; Biometry
CEP97-3	Multi-site (A)	Risk factors; Welfare indicators; Surveillance; Control; Production system;	Microbiology; Clinical, serological, pathological diagnosis; Behaviour; Production; Epidemiology;
CEP97-5	Health economy (C)	Risk factor; Production system; Prophylaxis, control;	Medicine; Production; Epidemiology; Modelling; Economics;
CEP97-6	BRSV (B)	Basic mechanisms; Prophylaxis, control;	Virology; Immunology; Pathology; Molecular biology; (Epidemiology)
CEP97-7	Mycoplasma Hyosyn. (B)	Basic mechanisms; Surveillance; Prophylaxis; Control	Microbiology; Immunology; Pathology (Epidemiology)
CEP-97-8	Poultry immunity (B)	Basic mechanisms; Surveillance; Risk factors; Prophylaxis	Genetics; Immunology; Microbiology;
CEP97-9	PRRS (B)	Basic mechanisms; Prophylaxis, control;	Virology; Molecular biology; Immunology
CEP97-10	Genetics 2 (B)	Basic mechanisms; Surveillance; Prophylaxis;	Genetics; Immunology; Clinical diagnosis; Biometry
CEP97-11	Mastitis (A)	Risk factors; Production system Objective measurements Surveillance; Control	Microbiology; Clinical diagnostics; Medicine; Epidemiology
CEP97-12	Mink (A)	Objective measurements; Production system Surveillance; Control	Microbiology; Pathology; Clinical diagnostics; Ethology; Medicine; Production; Epidemiology
CEP97-13	Health, pigs (A)	Risk factors; Production system Objective measurements Surveillance	Microbiology; Clinical diagnostics; Medicine; Epidemiology
CEP97-14	Farrowing environment (A)	Basic mechanisms; Risk factors; Production system	Endocrinology; Immunology; Microbiology; Ethology; Reproduction
CEP97-15	E.coli, Poultry (A)	Basic mechanisms; Risk factors; Production system; Surveillance	Microbiology; Medicine; Epidemiology
CEP97-16	Flock size (A)	Objective measurements; production system;	Microbiology; immunology; Ethology; Production
CEP97-17	Airborne transm. (A)	Risk factors; Production system	Microbiology; Air Physics; Meteorology; Agricultural engineering;

immune response in relation to specific diseases is investigated (CEP97-6; CEP97-7; CEP97-9). One project examines the humoral and cellular immunity against bovine respiratory syncytial virus (BRSV) and the possibility of obtaining protection by vaccination (CEP97-6). Vaccinated calves did not show protective immunity in spite of marked IgG1 response. However, fewer of the vaccinated calves than of the unvaccinated calves excreted high levels of virus. On the contrary, clinical signs and pathological changes were markedly reduced in re-infected calves compared to calves infected with BRSV for the first time. It is expected that a comparison of the immune response seen in vaccinated calves with the response seen in re-infected calves will reveal factors important for the protective immunity to BRSV.

One project investigates the maternal and age specific immune response against *Mycoplasma hyosynoviae* and differences in immunological profiles in herds with and without clinical cases (CEP97-7). The study indicates that lymphoid cells are transferred with colostrum to the piglets. Pigs receiving both maternal antibodies and lymphoid cells were protected against spread of mycoplasma to the joints. There seemed not to be age-related insusceptibility. The T-cell responses tended to be stronger in non-lame pigs derived from herds without arthritis problems compared to the T cell responses in lame pigs derived from herds with arthritis.

The protective immunity against porcine reproductive and respiratory syndrome (PRRS) is studied (CEP97-9). Pigs are immunised against different virus proteins, and the protecting effect of the resulting immune response is investigated. Vaccination by the use of so-called "gene gun technology" is tested and optimised in the project. This method induces high antibody titers against PRRSV.

Cluster C: Animal health economics

The cluster investigates methods and tools that the decision-maker can use in the selection of control strategies. The methods include an integrated application of knowledge within veterinary science, animal science and economics.

In this cluster only one project has been initiated (CEP97-5). The project has focussed on developing decision support systems for selection of control strategies against milk fever and subclinical hypocalcaemia in cattle and against *Mycoplasma hyopneumoniae* in pigs. The models include knowledge of the risk factors for the specific diseases and the effect on health and production. Further, the effect and cost of specific control strategies are included. The results indicate that there is sufficient documentation of the selected diseases for the models to become operational. The economic effect of applying different control strategies is highly dependent of the individual herd, and it is therefore very important that herd specific data are used in the models. The models may in some herds indicate that it is not economically beneficial to introduce a control strategy. This may be disappointing from the view of the advisor. However, in these situations, the models can be used to put a price on welfare.

Characteristics of the interdisciplinary research projects

The research projects are characterised by the participation of several research disciplines. All 16 projects have more than one participating institution, and 11 of the projects have at least 3 participating institutions. In 15 of the projects there is participation of the livestock industry. The problem oriented research areas and research disciplines included in each project are listed in Table 2. Thus, the individual project participants have used time and effort to understand each own contribution in a larger context. Apart from covering different disciplines the

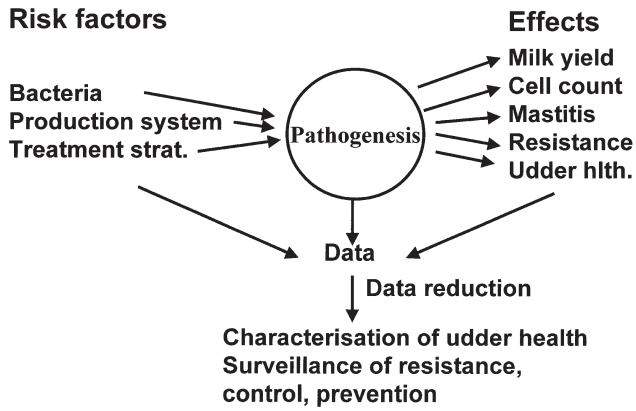

Figure 5. Example of scientific content in a CEPROS project (CEP97-11)

projects also often include different problem oriented areas and often include aspects of both production and health.

The integration process can be viewed both within and between research projects. In the following some general trends supplemented with a few examples will be given.

Integration within research projects

In the management cluster, several risk factors in the production system have been studied. Especially in pig production both risk factors concerning production system, transmission of pathogens and the daily handling of animals are included. The studies on production system include both studies of the total production system and selected areas such as farrowing environment and flock size. The effect of risk factors on health and welfare are studied in projects on different species using a very holistic study design using data on production system, health indicators and use of medication. Still, a lot of elaboration and systematic use of all these data seem necessary before this information can be used in practical tools for surveillance of animal health and welfare, and thus implementation of prophylactic measures.

This may be illustrated with the following example: In the project on udder health (CEP97-11), the purpose is to identify and describe which production and management factors, including drug use and strategies for medical treatment, that significantly affect the health status and antimicrobial resistance patterns in dairy herds. The content of the project is illustrated in Figure 5 as modified from Figure 3. Thus, the following measurement tools are developed in the project:

- The use of antibiotics
- Occurrence and patterns of antimicrobial resistance
- Housing facilities, disease parameters, and productivity
- Udder health measures
- Analyses of farmers' strategies

Digging one step further down, the udder health measures consist of approximately 20 parameters (shape, asymmetry, warts etc.) trying to give a full health characterisation of the udder. This characterisation is believed to give a more true measure of health than for example treatment rate that depends on the farmers' threshold

for calling the veterinarian. Qualitative interviews examining the farmers' choice of which cows to treat showed that it might depend on a lot of cow factors such as high yield. So when it looks like high yield causes mastitis it is actually the other way round that higher yielding cows are selected for mastitis treatment. And actually, the clinical udder health measures have shown a more consistent relationship with milk yield compared to traditionally applied measures such as treatment rate and cell count. In the project it is now attempted to include all aspects indicated in Figure 5. However, running a full model on the individual cow level including several herds may not even be possible with today's computer capacity. Thus, it may be necessary to do it stepwise for example first giving a herd a health character based on the clinical udder examinations. In doing so a clear health definition is necessary. Also the process may continuously create a high number of new hypotheses.

The example illustrates that one of the challenges with the more holistic studies is the variability of the nature of data. Firstly there are data on several hierarchical levels: Individual quarters of the bovine udder, animal level, pen level, farm level, region level, national level. Further, there is a difference between so-called hard data and soft data. For example certain diseases can be categorised relatively precise with the presence or absence of micro-organisms or antibodies. In comparison, clinical evaluation of skin quality, foot conditions etc. underlie more subjective evaluations, and when it comes to the farmers' preferences for culling animals the research approach such as qualitative interview become very different from what is traditionally used in natural sciences. A statistical handling of the clinical and laboratory data as well as data on antibiotic consumption and production and management in an e.g. common index of health or welfare needs advanced statistical methods and also clarification of the concepts. In some projects, grouping of herds with certain characteristics using factor analyses is tried. After this grouping a closer examination of correlations with risk factors can be done.

Another challenge in the more holistic studies is that on some occasions it is difficult to give an overall assessment for example if certain production facilities have positive effect on health but negative effect on behaviour. How do we compare less respiratory disease rate with reduced accessibility to rooting material?

The projects in the pathogenesis cluster investigate basic mechanisms within physiology, genetics and immunology behind the development of production diseases. The physiological investigations of calcium-metabolism have directly implication for feeding related prophylaxis of milk fever. The possibilities for genetic improvement of disease resistance in swine also have direct implications for prophylaxis. The combined study of genetics and immunological indicator traits has also shown to be relevant. In poultry, the combined study of the innate immune system and the genetic variation have prophylactic perspectives. The projects on specific pathogens are aiming at prophylactic measures either by strategic immunisation or vaccination. These studies have started out with relatively basic studies, but still they have a practical aim that will end with recommendations for the industry concerning breeding programs and disease control.

The activities on animal health economy include milk fever and other metabolic diseases in cattle and *Mycoplasma hyopneumoniae* and related respiratory pathogens in swine. The diseases were selected to represent economic important diseases for the production economy. The spectrum of diseases was kept narrow in order to aim at practical implementable decision support systems. The activities have emphasised the integration of the biological nature

of diseases in the models of the decision support systems. The integration process in this project arises from the very different kind of data that are needed: Causes of diseases, risk factors in the production system, definition of disease states, defining prevalence and incidence of disease, effect of disease on production parameters, defining the actual production system and how it is used and finally the effect of control strategies under different production conditions. The challenge here is to combine data with very different nature and also to include the uncertainty of the data.

Integration between research projects

Although there has been most emphasis on integration within projects, there are several interdisciplinary aspects also between different projects. The studies on pathogenesis of milk fever in CEP97-1 have been important for the modelling approach for this disease in animal health economics (CEP97-5). The multi-site project (CEP97-3) has been important for the study design on airborne transmission of respiratory disease (CEP97-17). The establishment of a protocol for health based on clinical parameters in CEP97-13 will be utilised in the project of flock size (CEP97-16). Due to the relative large effort on an interdisciplinary interplay within the projects many common denominators have just started to emerge recently. For example, the 3 projects investigating objective measurements of health in cattle, swine, and fur animals using several different data certainly have overlap in the methodology of how to handle the data.

Assessment of collaboration and organisation

On some occasions it has taken a long time before the participants in a project group have reached common understanding of goals, necessary methodology, level of ambition and division of labour. It is like the natural force for the individual researcher is differentiation. It therefore continuously takes a lot of energy to maintain the integration process. The process of integration takes time and the experience is that it is important to find an appropriate level of integration, as there are limits as to how many angles of the problem that should be included at the same time. An increased focus on the integration process will be useful in order to analyse what border areas exist and need to be described further, e.g. what amount and kind of health data is it really realistic to include in a model. It is important in especially larger project groups to identify participants with professional competence within a broader field so that they can help keep the group together. For example they may have an overview of what kind of data really exist, how valid they are, and how expensive it will be to obtain other data asked for by the modellers. It is also important in the process of integration that the individual researcher in addition to try and understand the methodology, approach and relevance of other disciplines also present his or her own discipline in an open way in order to "let other researchers in". It is important relatively quickly and with reasonable time effort to get sufficient "insight" in the other disciplines. Of course researchers do not have time to get a deep understanding of several disciplines, but in a relative short time they may obtain sufficient principle understanding for other methods and their relevance in the whole context of the project. It takes will from the individual researchers and from both parties of two disciplines approaching each other. Another benefit of the process will often be that it will be easier for the individual researcher to communicate the results to the surrounding society.

On several occasions it has been possible to establish well-functioning research groups where the participation in larger interdisciplinary re-

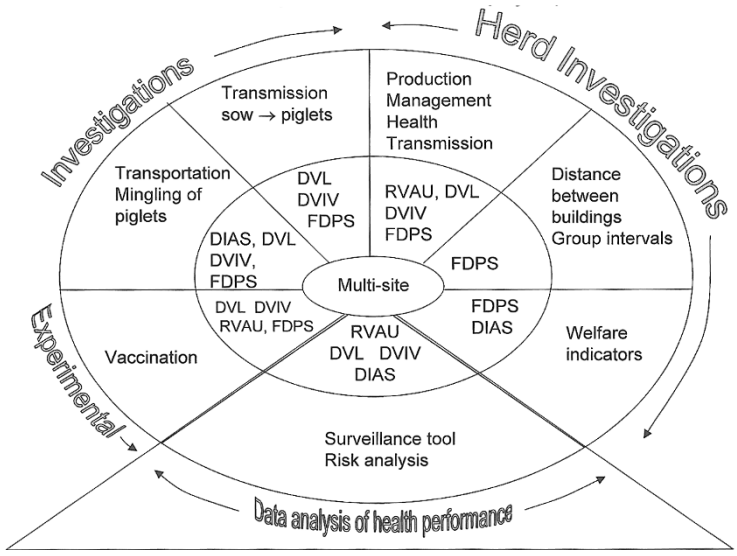

Figure 6. Example of project organisation in a CEPROS project (CEP97-3)

search groups has helped the individual researcher to get a different view on his or her own discipline. For example the joined effort of virologists, clinicians, epidemiologists and researchers in animal behaviour in the multi-site project (CEP97-3) has helped to see that they have common overall goals. And also that the results on for example behaviour need to be seen together with other areas such as health in order to make overall decisions on a production system. The understanding that some research issues need to be solved in a joint integrated effort has increased the respect among researchers working in different disciplines and also increased the interest for other disciplines. It has also been characteristic that the interdisciplinary research groups have found it necessary with more holistic evaluations of the production systems including more soft parameters.

The representation of each of the participating institutions and the livestock industry in the board of the Centre has ensured the relevance of research areas and participation of researchers with different disciplinary approaches in the projects. Further, it has increased the co-ordination of basic and more applied research. Thus, it has been emphasised already in the preparation phase of projects (i.e. workshops, formulations of tender packages) that only projects where a more joined effort was needed would be considered. The overall aims and will of the Centre have been efficiently communicated to researchers in the organisation. It has been possible to increase the emphasis on traditionally weak areas, i.e. areas where it will take some time before a group with high international level has been build up (e.g. animal health economy).

The time consuming process of integration may by some researchers be seen as merely waste of time. The Centre construction has helped (and in some cases been necessary) to establish and keep the necessary will and engagement among the involved researchers. Thus, the Centre has helped to emphasise that a reorientation of the

individual researcher that for him or her may be felt as an immediate drawback is actually a step forward for the whole project and the overall goals. Also, it has been more legal to cross traditional "territorial borders".

In the individual projects involving several institutions, it is of significant value to create overview for the whole group concerning overall goals and concepts and also project organisation. An example of a project organisation is shown in Figure 6. This will help the individual participant to see her or his own role in the project. It is very important that a well functioning project culture is established within the existing institutions and organisations including clarification of the competence of the project leader. As the project management go across the borders between departments and institutions a mutual respect between project leader and the established leaders within the institutions is necessary. A project leader shall feel free to maintain project plans for participants on other institutions and for participants with a higher position.

Conclusions

The idea behind integrated research is to perform research that the individual research disciplines could not perform alone. In order to create well-functioning integrated research groups, it is necessary that the project participants have some knowledge of other participating disciplines i.e. can look into the other disciplines without loosing the depth and expertise of their own disciplines. In doing so, they will gain respect for the other disciplines and understand the necessity of other disciplines for the whole project and feel responsible for the whole project. Some degree of concept clarification is often necessary. In such an environment new ideas and new ways of presenting the problems can come forward. A well functioning organisation is necessary to maintain the will and power of interdisciplinary research projects.

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