Journal of Invertebrate Pathology 131 (2015) 107–120

Contents lists available at ScienceDirect

Journal of Invertebrate Pathology

journal homepage: www.elsevier.com/locate/jip

Comparative pathology in bivalves: Aetiological agents and disease processes

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ARTICLE INFO

Article history:
Received 30 November 2014
Revised 22 July 2015
Accepted 23 July 2015
Available online 26 July 2015

Keywords:
Invertebrate pathology
Bivalve disease
Pathogenesis
Bivalve inflammation

ABSTRACT

Comparative pathology as a scientific discipline studies animal diseases in relation to their aetiology, pathogenesis and prognosis. Among the main aspects of this discipline, regressive changes, host defense responses with pathological implications and progressive changes, represent the majority of the possible responses of cells and tissues to pathogens and exposure to chemicals. One of the most persistent issues in the field of invertebrate pathology is the variability in terminology and definition, which has led to confusion in scientific communication. The aim of this paper is to provide an overview of the pathological basis of bivalve disease (defensive, regressive and progressive phenomena) and contribute to the standardised terminology for bivalve molluscan disease in the context of comparative pathology.

1. Comparative pathology: basic concepts

Disease, as a result of cell injury, mainly represents the "end-point" occurring when the adaptive response of an organism fails to accommodate environmental stressors (physical, chemical and/or biological). Studies of animal disease are largely approached from a medical and/or veterinary perspective; that is, for preventing or curing diseases (predominantly in individuals) that affect animal production, have zoonotic potential or as research models for human disease (Conn, 2013; De Vico and Carella, 2008; Lieschke and Currie, 2007; Grizel, 1989). Gradually, biologists have recognised the importance of diseases in the dynamics of animal populations, with an increased interest in the impact of aquatic animal diseases on animal biodiversity at both local and global scales (Longshaw et al., 2010; Kent et al., 2009; Lafferty et al., 2004; Daszak et al., 2000). Kinne (1983) characterizes disease as an ecological phenomenon which "may not only affect the relationship between agent and host, but also influence coexisting species, such as the host's prey, predators or competitors and, at the level of epidemic, may modify functions and structures of an ecosystem". The scientific discipline of comparative pathology studies animal diseases according to their aetiology, pathogenesis, progression and outcome (mortality, healing, chronicity) among animal groups (De Vico and Carella, 2012a; Robert, 2010; Montali, 1988). The discipline studies the biological basis of diseases in terms of elementary pathological processes (Pontieri et al., 2005), defined in this way not because of their simplicity, but in respect to their fundamental pathogenic role. In the context of comparative pathology, a disease can be defined as the "direct consequence of a structural and/or functional damage of cells, tissues and organs able to affect negatively on the overall economy of the organism" (Dianzani et al., 2005).

In this respect, although the most recent scientific approach to the knowledge of pathological processes places increasing emphasis on their molecular and biochemical aspects, the biological effects resulting from exposure of an organism to pathogens are always expressed at the cellular level (Simmons et al., 2009). Cells that have the ability to adapt to stimuli that challenge their survival (stressors/environmental pathogens), do so via finely regulated processes cellular stress responses, which maintain and restore homeostatic conditions and cellular integrity (Fulda et al., 2010; Monduzio et al., 2005). Extensive and/or chronic stress stimuli that exceed the capability of cell recovery, determine the different types of cellular damage that form the basis of all diseases (Trump et al., 1997; Trump and Berezesky, 1995) (Fig. 1).

Regressive changes, cell death, defensive changes with associated pathological implications and progressive changes, represent the majority of possible cell and tissue responses to pathogens of different nature (chemical, physical and biological) (Fig. 1). Molluscs constitute the second largest phylum in the animal kingdom, with bivalves representing the class showing the largest, distribution and habitat diversity (Gosling, 2008a). Bivalves are

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http://dx.doi.org/10.1016/j.jip.2015.07.012
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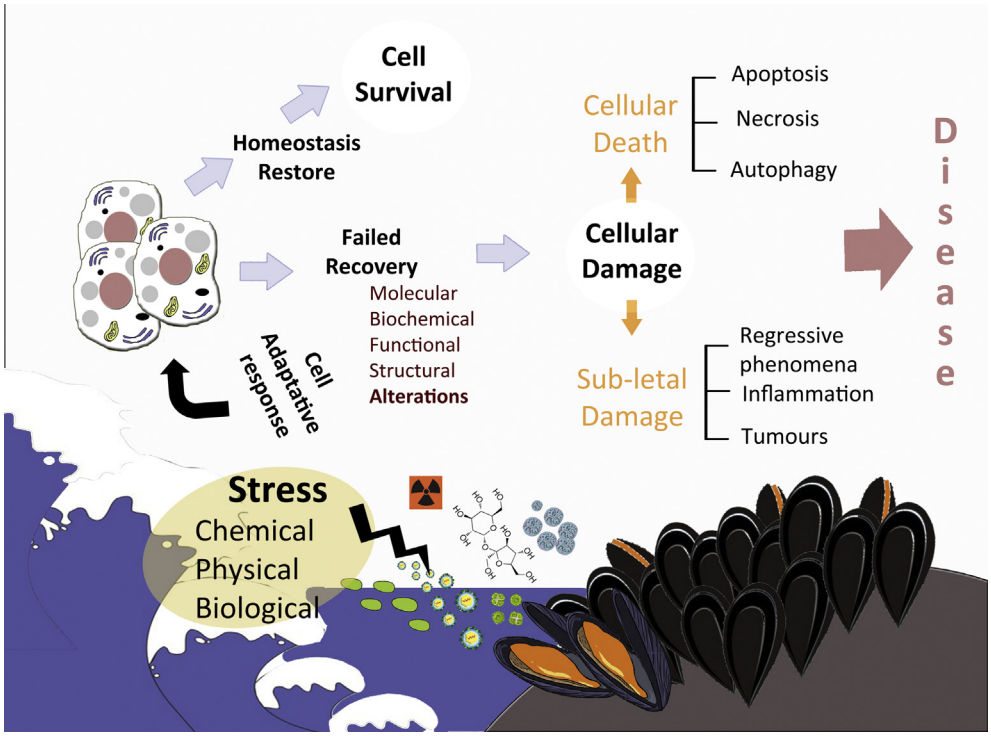

Fig. 1. Pathogenesis of the cellular damage. Lethal (cell death) and sub-lethal (defensive, regressive and progressive phenomena).

also an important economic resource internationally and demonstrate many characteristics that make them ideal as a sentinel organism for assessing environmental toxicity (Rittschof and McClellan-Green, 2005). The National Status and Trends Mussel Watch Program monitors contaminants of environmental concern used, as sentinel organisms, bivalves collected from sites distributed along the entire United States coastline. Results from the above program show that among the taxa, oysters (*Crassostrea virginica*, *C. rhizophorae*, *C. gigas*, and *Dendostrea sandvichensis*) were consistently more susceptible to parasites than mytilids (*M. edulis*, *M. galloprovincialis*, *M. trossulus* and *M. californianus*), but that this difference is also connected to toxin body burdens and to different geographic regions. Nevertheless, the data suggest innate differences between these taxa in their parasite communities (Kim and Powell, 2006, 2007).

The aim of this paper is to provide an overview of the pathological basis of bivalve diseases, taking into account comparative pathology in other animals in order to share terminology and definitions (De Vico and Carella, 2012a). Effective scientific communication is facilitated by a clearly defined terminology (Onstad et al., 2006; Shapiro-Ilan et al., 2005) and can contribute to an improved understanding of host/environment/pathogen interaction in the context of bivalve pathology.

2. Aetiology and pathogenesis

The aetiology of a disease is defined as any factor that can induce a quantifiable pathological effect linked to functional damage of cells, tissues and/or organs. Cause and effect can be *nonspecific* (the same effect/multiple causes) or *specific* (a given effect/a single cause). Furthermore many causes frequently cooperate to induce diseases (complex of causes) and some of them are *necessary* (their absence prevents the onset of the effect), while other are *predisposing* (preparing the ground to the action of the *necessary* cause). The causes of disease may be both *intrinsic* and *extrinsic* to the organisms. The former involve mutations at gene, chromosome and genome levels while the latter includes physical and chemical insults and pathogens. As is the case in other aquatic eukaryotic organisms, extreme environmental stressors (such as temperature, salinity and dissolved oxygen), contaminants (Morley, 2010) and physiological factors (such as reproductive condition) may prove sufficient to significantly compromise the natural defenses of the host (Table 1).

Some general aspects concerning the effect of physical and chemical environmental parameters on the mollusc immune

Table 1
Aetiologic agents of tissue injury.

External agents	
Physical	
Mechanical trauma	Compression, blow
Electric trauma	Lightning
Heat, cold	Freezing, cold shock
Radiant energy	
Pressure	Increased, decreased
Chemical	
Biologic toxins	Bacterial and fungal toxin, venoms
Water parameters	
Pesticides	Organophosphates, paraquat, 2,4D, dinitrophenols
Herbicides	
Dietary excesses	
Biological	
Acellular agents	Virus, prions
Prokaryotes	Bacteria (*Vibrio*, *Nocardia*, etc.)
Eukaryotes	Fungi, protozoa, algae (*Coccomyxa* sp., *Ostreopsis* sp.)
Metazoan parasites	Cestodes, nematodes, trematodes, crustaceans
External deficiencies	
Nutritional deficiency	Protein, vitamins, lipid
Environmental deficit	Water, oxygen, sunlight
Internal defects	
Immunologic genetic defect	