|  |
| --- |
| La sperimentazione animale ai fini scientifici è disciplinata dal DL n. 26 del 2014 (attuazione della direttiva 2010/63/UE) e riguarda l’impiego e la protezione di vertebrati e cefalopodi.L’uso di modelli animali emergenti, ossia le specie per le quali, a oggi, si riconosce una minor complessità neurologica rispetto a quelle tutelate dalla normativa, è in continuo aumento e si configura sempre più come un valido esempio del “replacement” (Principio delle 3R).Per questo la Commissione didattica UZI ha ritenuto utile creare un database di specie di invertebrati già in utilizzo o potenzialmente utilizzabili in vari settori della ricerca biomedica riportando, ove possibile, la bibliografia di riferimento. |
| [PB1] | (Ricerca di Base) Oncologia | *Drosophila melanogaster*(Napoletano et al., 2017) |
| [PB2] | (Ricerca di base) Apparato cardiovascolare, sangue e sistema linfatico | *Drosophila melanogaster*(Ugur et al., 2016) *Pomacea canaliculata*  |
| [PB3] | (Ricerca di Base) Sistema Nervoso | *Drosophila melanogaster* (Napoletano et al., 2021)*Tenebrio molitor* (Breidbach, 1987)*Armadillidium gestroi* (Thompson et al., 1994)*Armadillidium nasatum* (Thompson et al., 1994)*Armadillidium pallasii* (Thompson et al., 1994)*Porcellionides pruinosus* (Thompson et al., 1994)*Hippolyte inermis* *Austropotamobius pallipes* *Cherax albidus* *Pomacea canaliculata* (Rivi et al., 2022)*Aplysia californica* (Mauelshagen et al., 1998) |
| [PB4] | (Ricerca di Base) Apparato Respiratorio | *Drosophila melanogaster* (Ehrhardt et al., 2022) |
| [PB5] | (Ricerca di Base) Apparato gastrointestinale, compreso il fegato | *Drosophila melanogaster*(Bertolio et al., 2019) |
| [PB6] | (Ricerca di Base) Sistema muscoloscheletrico | *Drosophila melanogaster* (Avellaneda et al., 2021)*Hippolyte inermis* *Austropotamobius pallipes* *Cherax albidus*  |
| [PB7] | (Ricerca di Base) Sistema Immunitario | *Drosophila melanogaster* (Buchon et al., 2014)*Tribolium castaneum**Tenebrio molitor* (Vommaro et al.,2021)*Hippolyte inermis* *Austropotamobius pallipes* *Cherax albidus* *Pomacea canaliculata* (Bergamini et al., 2023) |
| [PB8] | (Ricerca di Base) Apparato urogenitale/riproduttivo | *Drosophila melanogaster* (Napoletano et al., 2017)*Tribolium castaneum*(Vommaro et al., 2023)*Pterostichus melas* (Vommaro et al.,2022; Donato et al., 2021)*Hippolyte inermis* *Austropotamobius pallipes**Cherax albidus*  |
| [PB9] | (Ricerca di Base) Organi di senso (pelle, occhi e orecchie) | *Drosophila melanogaster*(Dourlen et al., 2012)*Tribolium castaneum* (Giglio et al., 2022)*Tenebrio molitor* (Giglio et al., 2022)*Pomacea canaliculata*  |
| [PB10] | (Ricerca di Base) Sistema endocrino/metabolismo | *Drosophila melanogaster*  (Bertolio et al., 2019)*Hippolyte inermis**Austropotamobius pallipes**Cherax albidus*  |
| [PB11] | (Ricerca di Base) Multiapparato | *Drosophila melanogaster* (Napoletano et al., 2021)*Pomacea canaliculata* (Davison and Neiman 2021)*Mytilus ssp*. (Schmidt et al., 2014)*Littorina littorea* (Larade and Storey, 2009) |
| [PB12] | (Ricerca di Base) Etologia / comportamento animale / Biologia animale | *Drosophila melanogaster* (Sokolowski, 2001)*Tenebrio molitor* (Carazo et al., 2012)*Neocaridina davidi* (Plichta et al., 2021)*Procambarus clarkii* (Dissegna et al., 2020)*Hippolyte inermis* *Austropotamobius pallipes* *Cherax albidus*  |
| [PB13] | (Ricerca di Base) Altra ricerca di base | Tardigradi (Giovannini, Boothby et al. 2022; Giovannini, Corsetto et al. 2022; Jönsson 2019; Kasianchuk et al, 2023; Schill et al., 2009) |
| [PB14] | (Ricerca di Base) Biologia dello sviluppo | *Drosophila melanogaster* (Napoletano et al., 2017)*Pomacea canaliculata* (Bergamini et al., 2023)*Hippolyte inermis**Austropotamobius pallipes**Cherax albidus*  |
| [PT21] | (Ricerca traslazionale e applicata) Tumori degli esseri umani | *Drosophila melanogaster*(Perrimon et al., 2016) |
| [PT24] | (Ricerca traslazionale e applicata) Disturbi nervosi e mentali degli esseri umani | *Drosophila melanogaster* (Narayanan and Rothenfluh, 2016) |
| [PT30] | (Ricerca traslazionale e applicata) Disturbi degli organi di senso degli esseri umani (pelle, occhi e orecchie) | *Drosophila melanogaster*(Nitta and Sugie, 2022) |
| [PT31] | (Ricerca traslazionale e applicata) Disturbi endocrini/metabolici degli esseri umani | *Drosophila melanogaster* (Moraes and Montagne, 2021)*Hippolyte inermis**Austropotamobius pallipes**Cherax albidus*  |
| [PT33] | (Ricerca traslazionale e applicata) Malattie e disturbi degli animali |  |
| [PT34] | (Ricerca traslazionale e applicata) Benessere degli animali | *Tenebrio molitor* *Neocaridina davidi* *Hippolyte inermis* *Austropotamobius pallipes* *Cherax albidus*  |
| [PT37] | (Ricerca traslazionale e applicata) Tossicologia ed ecotossicologia (studi non previsti dalla normativa) | *Pomacea canaliculata* *Littorina littorea* (Larade and Storey, 2009)*Tribolium castaneum**Tenebrio molitor* (Naccarato et al., 2023)*Pterostichus melas* (Giglio et al., 2021; Aiello et al., 2022) |
| [PT38] | (Ricerca traslazionale e applicata) Alimentazione animale | *Hippolyte inermis* |

**References**

Aiello D., Giglio A., Talarico F., Vommaro M.L., Tagarelli A., Napoli A. Mass spectrometry-based peptide profiling of haemolymph from *Pterostichus melas* exposed to pendimethalin herbicide. *Molecules*, **2022**, 27(14):4645, <https://doi.org/10.3390/molecules27144645>

Avellaneda J., Rodier C., Daian F., Brouill, N., Rival T., Luis N.M., Schnorrer F. Myofibril and mitochondria morphogenesis are coordinated by a mechanical feedback mechanism in muscle. *Nat Commun*, **2021**, 12(1):2091, <https://doi.org/10.1038/s41467-021-22058-7>

Bergamini G., Sacchi S., Ferri A., Franchi N., Montanari M., Ahmad M., Losi C., Nasi M., Cocchi M., Malagoli D. Clodronate liposome-mediated phagocytic hemocyte depletion affects the regeneration of the cephalic tentacle of the invasive snail, *Pomacea canaliculata*. *Biology* (*Basel*), **2023**;12(7):992, <https://doi.org/10.3390/biology12070992>

Bertolio R., Napoletano F., Mano M., Maurer-Stroh S., Fantuz M., Zannini A., Bicciato S., Sorrentino G., Del Sal G. Sterol regulatory element binding protein 1 couples mechanical cues and lipid metabolism. *Nat Commun*, **2019,**10(1):1326, https://doi.org/10.1038/s41467-019-09152-7

Breidbach, O. Constancy of ascending projections in the metamorphosing brain of the meal-beetle *Tenebrio molitor* L. (Insecta: Coleoptera). *Roux's Arch Dev Biol* **196**, 450–459 (**1987**). <https://doi.org/10.1007/BF00399145>

Buchon N., Silverman N., Cherry S. Immunity in *Drosophila melanogaster* — from microbial recognition to whole- organism physiology. *Nat. Rev. Immunol*. **2014**, 14(12):796–810, https://doi.org/10.1038/nri3763

Buzzelli, C. Cue processing and spatial navigation in the terrestrial isopod [Doctoral dissertation, University of Akron]. OhioLINK Electronic Theses and Dissertations Center. **2017**. <http://rave.ohiolink.edu/etdc/view?acc_num=akron1492166083535544>

Carazo P., Fernández-Perea R., Font, E. Quantity estimation based on numerical cues in the mealworm beetle (*Tenebrio molitor*). *Frontiers in Psychology*, **2012**, *3*, 502

Davison A., Neiman M. Mobilizing molluscan models and genomes in biology. *Philos Trans R Soc Lond B Biol Sci,* **2021**, 376(1825):20200163, https://doi.org/10.1098/rstb.2020.0163

Dissegna A., Caputi A., Chiandetti C. Long-lasting generalization triggered by a single trial event in the invasive crayfish *Procambarus clarkii*. *J Exp Biol* 15 November **2020**; 223 (22): jeb227827. doi: <https://doi.org/10.1242/jeb.227827>

Donato S., Vommaro M.L., Tromba G., Giglio A. Synchrotron X-ray phase contrast micro tomography to explore the morphology of abdominal organs in Pterostichus melas italicus Dejean, 1828 (Coleoptera, Carabidae). *Arthropod Struct Dev,* **2021**, 62:101044, https://doi.org/10.1016/j.asd.2021.101044

Dourlen P., Bertin B., Chatelain G., Robin M., Napoletano F., Roux M.J., Mollereau B. Drosophila fatty acid transport protein regulates rhodopsin-1 metabolism and is required for photoreceptor neuron survival. *PLoS genetics*, **2012**, 8(7):e1002833, https://doi.org/10.1371/journal.pgen.1002833

Ehrhardt B., El-Merhie N., Kovacevic D., Schramm J., Bossen J., Roeder T., Krauss-Etschmann S. Airway remodeling: The Drosophila model permits a purely epithelial perspective. *Front* *Allergy*, **2022**, 3:876673, https://doi.org/10.3389/falgy.2022.876673

Giglio A., Vommaro M.L., Gionechetti F., Pallavicini A. Gut microbial community response to herbicide exposure in a ground beetle. *J Appl Entomol*, **2021**, 145(10):986–1000, <https://doi.org/10.1111/jen.12919>

Giglio A., Vommaro M.L., Agostino R.G., Lo L.K., Donato S. Exploring compound eyes in adults of four coleopteran species using synchrotron X-ray phase-contrast microtomography (SR-PhC Micro-CT*). Life (Basel)*, **2022**, 12(5):741, https://doi.org/10.3390/life12050741

Giovannini I., Boothby T.C., Cesari M., Goldstein B., Guidetti R., Rebecchi L. Production of reactive oxygen species and involvement of bioprotectants during anhydrobiosis in the tardigrade *Paramacrobiotus spatialis*. *Sci Rep,* **2022**, 12(1):1938 https://doi.org/10.1038/s41598-022-05734-6

Giovannini I., Corsetto P. A., Altiero T., Montorfano G., Guidetti R., Rizzo A. M., Rebecchi L. Antioxidant response during the kinetics of anhydrobiosis in two eutardigrade species. *Life (Basel)*, **2022**, 12(6):817, https://doi.org/10.3390/life12060817

Jönsson K.I. Radiation tolerance in tardigrades: current knowledge and potential applications in medicine. *Cancers (Basel),* **2019**, 11(9):1333, https://doi.org/10.3390/cancers11091333

Kasianchuk N., Rzymski P., Kaczmarek Ł. The biomedical potential of tardigrade proteins: A review. *Biomed. Pharmacother*, **2023**, 158:114063, https://doi.org/10.1016/j.biopha.2022.114063

Larade K., Storey K.B. Living without oxygen: anoxia-responsive gene expression and regulation. *Curr Genomics*, **2009**, 10(2):76–85, https://doi.org/10.2174/138920209787847032

Mauelshagen J., Sherff C.M., Carew T.J. Differential induction of long-term synaptic facilitation by spaced and massed applications of serotonin at sensory neuron synapses of *Aplysia californica*. *Learn Mem*, **1998**, 5(3):246–256, https://doi.org/10.1101/lm.5.3.246

Moraes K.C.M., Montagne J. *Drosophila melanogaster*: A powerful tiny animal model for the study of metabolic hepatic diseases. *Front Physiol*, **2021**, 12:728407, https://doi.org/10.3389/fphys.2021.728407

Naccarato A., Vommaro M.L., Amico D., Sprovieri F., Pirrone N., Tagarelli A., Giglio A. Triazine herbicide and NPK fertilizer exposure: accumulation of heavy metals and rare earth elements, effects on cuticle melanization, and immunocompetence in the model species *Tenebrio molitor*. *Toxics,* **2023**, 11(6):499. https://doi.org/10.3390/toxics11060499

Napoletano F., Gibert B., Yacobi-Sharon K., Vincent S., Favrot C., Mehlen P., Girar V., Teil M., Chatelain G., Walter L., et al. p53-dependent programmed necrosis controls germ cell homeostasis during spermatogenesis. *PLOS Genet*, **2017**, 13(9):e1007024, https://doi.org/10.1371/journal.pgen.1007024

Napoletano F., Ferrari Bravo G., Voto I.A.P., Santin A., Celora L., Campaner E., Dezi C., Bertossi A., Valentino E., Santorsola M., et al. The prolyl-isomerase PIN1 is essential for nuclear Lamin-B structure and function and protects heterochromatin under mechanical stress. *Cell Rep*, **2021**, 36: 109694, <https://doi.org/10.1016/j.celrep.2021.109694>

Narayanan A.S., Rothenfluh A. I believe I can fly! Use of *Drosophila* as a model organism in neuropsychopharmacology research. *Neuropsychopharmacology*, **2016**, 41(6):1439–1446, https://doi.org/10.1038/npp.2015.322

Nitta Y., Sugie A. Studies of neurodegenerative diseases using *Drosophila* and the development of novel approaches for their analysis. *Fly (Austin),* **2022**, 16(1):275–298, https://doi.org/10.1080/19336934.2022.2087484

Perrimon N., Bonini N.M., Dhillon P. Fruit flies on the front line: the translational impact of *Drosophila*. *Dis Model Mech*, **2016**, 9(3):229–231, https://doi.org/10.1242/dmm.024810

Plichta, Z.; Kobak, J.; Maciaszek, R.; Kakareko, T. All Shades of Shrimp: Preferences of Colour Morphs of a Freshwater Shrimp *Neocaridina davidi* (Decapoda, Atyidae) for Substrata of Different Colouration. *Animals* **2021**, *11*, 1071. <https://doi.org/10.3390/ani11041071>

Rivi V., Batabyal A., Benatti C., Tascedda F., Blom J.M.C., Lukowiak K. Aspirin reverts lipopolysaccharide-induced learning and memory impairment: first evidence from an invertebrate model system. *Naunyn Schmiedebergs Arch Pharmacol*. **2022**, 395(12):1573–1585, https://doi.org/10.1007/s00210-022-02286-4

Schill R.O., Mali B., Dandekar T., Schnölzer M., Reuter D., Frohme M. Molecular mechanisms of tolerance in tardigrades: new perspectives for preservation and stabilization of biological material. *Biotechnol Adv*, **2009**, 27(4):348–52, <https://doi.org/10.1016/j.biotechadv.2009.01.011>

Schmidt W., Rainville L.C., McEneff G., Sheehan D., Quinn B. A proteomic evaluation of the effects of the pharmaceuticals diclofenac and gemfibrozil on marine mussels (Mytilus spp.): evidence for chronic sublethal effects on stress-response proteins. *Drug Test Anal*, **2014**, 6(3):210–219, https://doi.org/10.1002/dta.1463

Sokolowski M.B. *Drosophila*: Genetics meets behaviour. *Nat Rev Genet*, **2001**, 2(11):879–890. https://doi.org/10.1038/35098592

Thompson K.S., Zeidler M.P., Bacon, J. P. Comparative anatomy of serotonin‐like immunoreactive neurons in isopods: Putative homologues in several species. *Journal of Comparative Neurology*, **1994**, *347*(4), 553-569.

Ugur B., Chen K., Bellen H.J. *Drosophila* tools and assays for the study of human diseases. *Dis Model Mech*, **2016**, 9(3):235–244, https://doi.org/10.1242/dmm.023762

Vommaro M.L., Kurtz J., Giglio A. Morphological characterisation of haemocytes in the mealworm beetle *Tenebrio molitor* (Coleoptera, Tenebrionidae). *Insects*, **2021**, 12(5):423. <https://doi.org/10.3390/insects12050423>

Vommaro M.L., Donato S., Giglio A. Virtual sections and 3D reconstructions of female reproductive system in a carabid beetle using synchrotron X-ray phase-contrast microtomography. *Zool Anz*, **2022**, 298:123-130, https://doi.org/10.1016/j.jcz.2022.04.001

Vommaro M.L, Donato S., Lo L.K, Brandmayr P., Giglio A. Anatomical study of the red flour beetle using synchrotron radiation X-ray phase-contrast micro-tomography. *J Anat,* **2023**, 242(3):510–524, <https://doi.org/10.1111/joa.13796>

Database UZI “Specie alternative per la ricerca biomedica” del 10 settembre 2023

a cura di Maria Agnese Sabatini, Paola Zarattini e Adriana Canapa