to be characteristic of the genus *Cavia*, since a somewhat similar one has also been reported in *C. porcellus*, *C. a. pamparum* and *C. fulgida*.

In *Galea spixii*, whose conventionally stained karyotype has already been described[11], we intend to report further observations on other specimens collected in distinct localities and on G-banded karyotype. 70 metaphases showed 2n = 64, FNa = 118, with an autosomal complement composed of 28 pairs of biarmed autosomes and 3 pairs of small acrocentrics. Large unstained segments in G-banded karyotypes, as found in *C. a. aperea*, were not observed in this species. Chromosome X is submetacentric – the biggest one in the complement – and Y is a small acrocentric (fig. 3). A submetacentric X is also the biggest element in *G. musteloides*[7]. In *Kerodon rupestris*, the analysis of 87 metaphases showed 2n = 52, FNa = 92 with 21 pairs of biarmed chromosomes and 4 pairs of small acrocentrics in the autosomal complement. X is metacentric and also the biggest one in the complement, and Y is a medium-sized acrocentric chromosome (fig. 4). C banding reveals that practically all constitutive heterochromatin in this genome is confined to the X chromosome, shaped as symmetrically-positioned large pericentromeric and telomeric blocks (fig. 5), a very distinctive pattern in comparison to those observed in species of genera *Cavia* and *Galea*.

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2 Manna, G.K., and Talukdar, M., Experientia *20* (1964) 324.
3 Makino, S., J. Fac. Sci., Hokkaido Univ., Ser. VI Zool. *9* (1947) 345.
4 Cohen, M., and Pinsky, L., Cytogenetics *5* (1966) 120.
5 Fernandez, R., and Spotorno, A.O., Archs Biol. Méd. exp. *5* (1968) 81.
6 Descailleaux, J.L., and Estrada, R., in: III Conq. Latinoamer. Genet., Montevideo 1977, p.222. Eds M.E. Drets, N. Brum-Zorrilla and G.A. Folle.
7 George, W., Weir, B., and Bedford, J., J. Zool., Lond. *168* (1972) 81.
8 Bianchi, N.O., and Ayres, J., Chromosoma *34* (1971) 254.
9 Popescu, N.C., Evans, C.H., and Dipaolo, J.A., Cancer Res. *36* (1976) 1404.
10 Pantaleão, E., Thesis Dept. Genet., Univ. Fed. R.G. Sul, Brazil 1978.
11 Maia, V., and Hulak, A., Rev. nord. Biol. *1* (1978) 119.
12 Alderete de Majo, A.M., Dulout, F.N., and de Adris, A.S., in: III Conq. Latinoamer. Genet., Montevideo 1977, p.222. Eds M.E. Drets, N. Brum-Zorrilla and G.A. Folle.
13 Ford, C.E., and Hamerton, J.L., Stain Technol. *31* (1956) 247.
14 Seabright, M., Lancet *2* (1971) 971.
15 Sumner, A.T., Expl Cell Res. *75* (1972) 304.

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## Differential sensitivity of *Drosophila melanogaster* and *Drosophila simulans* to chronic exposure to carbon dioxide during development[1]

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*Summary. Drosophila melanogaster* is less sensitive to low concentrations of $CO_2$ (2–20%) than *Drosophila simulans* with regard to egg-to-adult mortality, duration of development and adult size measured by wing length, thorax length and dry weight. This difference may be related to the better adaptation of *D. melanogaster* to alcoholic fermentation.

Effects of carbon dioxide upon *Drosophila* have been extensively studied. Besides narcosis, the most classical effects concern the sensitivity of adults which is either due to viral infection[2], or to genetic factors[3]. Other consequences in adults have been studied; reduction of longevity[4], and decrease of egg deposition for a few h after anesthesia[5]. Such exposure to pure $CO_2$ does not occur in the field, and we decided to examine the developmental effects of lower doses (2–20%) in *D. melanogaster* and *D. simulans*.

*Material and methods.* Stocks of *D. melanogaster* and *D. simulans* were founded from 2 sympatric Tunisian populations (Nasrallah) and kept in the laboratory by mass-breeding. Before the experiments, they were tested for their lack of sensitivity to short exposure to pure $CO_2$.

For the experiments, lots of 50 eggs were deposited each in 100 × 2.5 mm vials containing 20 g of corn-yeast medium[6] and closed with a wire netting allowing easy gas circulation.

Treatment chambers were tightly closed clear plastic boxes (35 × 25 × 13 cm), each of which could receive 14 breeding vials (7 for *D. m.*, 7 for *D. s.*). The gaseous mixtures were delivered by gas-mixing pumps (Wösthoff). Pure $CO_2$ was mixed in the required ratio with atmospheric air previously filtered, dried over silica gel, cleared of $CO_2$ on KOH columns, then moistened again up to 60 ± 5% relative humidity by bubbling through a saline solution. Gaseous mixtures were conveyed to the treatment chambers; the gas flow rate was regulated up to 300 ml/min using flowmeters and needle valves. The insects were reared at 25 °C with a photophase (LD 12:12). The actual relative humidity inside the treatment chambers averaged 65%.

Emerging adults were counted and sexed twice a day. Egg-to-adult viability was calculated in each vial as the ratio of emerging flies to the initial number of eggs. Duration of development was measured in each vial separately for the 2 sexes. At each concentration, 25 males were randomly chosen in each species for individual measurement of their wing length, thorax length and dry weight. $CO_2$ tests were run simultaneously with 0% (control), 2%, 5%, 10% and 20% concentrations. Control tests were run on *D. melanogaster* in air enriched with 10% and 20% nitrogen.

*Results.* As shown in figure A, increasing $CO_2$ concentration reduced the overall viability. Analysis of variance shows a highly significant effect in both species ($p < 0.01$), the decrease being more striking in *D. simulans*. In this species, reduction of viability occurs for concentrations above 5% and reaches 43.4% at 20% $CO_2$. In *D. melanogaster* viability decreases linearly and reduction reaches only 11%. This mortality affects both sexes equally.

Mean developmental time for the sexes increases significantly with $CO_2$ concentration ($p < 0.01$) (fig. B). The lengthening is gradual and reaches 63.6 h (+28%) in *D. melanogaster*, 60.9 h (+27.8%) in *D. simulans*. Differences between sexes are not significant.

Wing length and thorax length decrease significantly ($p < 0.01$) and linearly (figs C and D). Curiously, the thorax length of controls (0%) is higher in *D. simulans*, which is rather un-

usual[10]. For both traits regression coefficients are higher in *D. simulans* ($p < 0.01$), which means that size of this species is more affected.

Dry weights of males vary significantly according to $CO_2$ concentration ($p < 0.01$) but with quite different features in the 2 species. In *D. simulans*, weight is not affected by low concentrations and decreases from 5% onwards. In *D. melanogaster*, weight increases significantly up to 5–10%, then decreases at 20% $CO_2$. This unexpected promoting effect of moderate concentrations on the weight of *D. melanogaster* confirms results from other experiments not presented here.

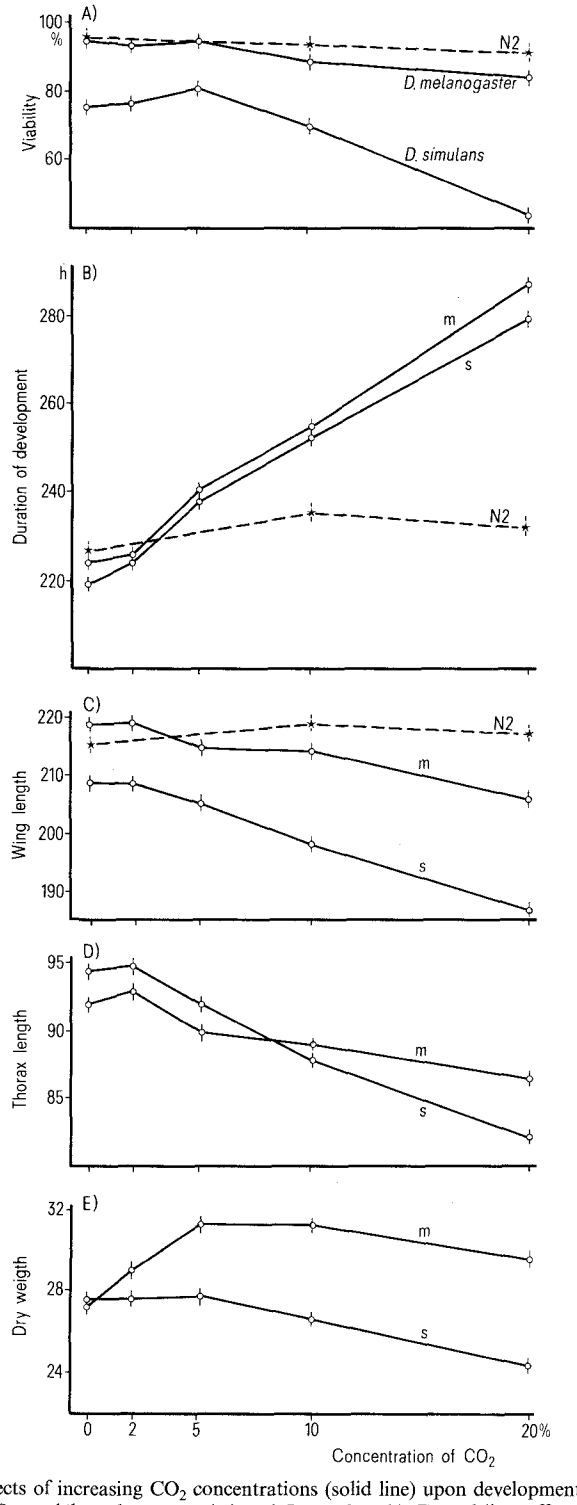
Exposing *D. melanogaster* to air enriched with 10% or 20% nitrogen gives quite different results; even at 20%, no significant variation could be detected in survival rate, rate of development or wing length, as shown in figures A, B and C.

On the whole, exposing larvae to increasing $CO_2$ concentrations results in a more and more abnormal development. Similar effects occur under any alteration of atmospheric composition, hyperoxia[7] as well as hypoxia[8]. The absence of any deleterious effect due to enriching air with nitrogen demonstrates the innocuousness of the slight hypoxia which does occur in our experiments, and the specificity of the $CO_2$ effects.

At high concentrations (10–20%) parallel variations of mortality, developmental rate and adult size reveal a overall harmful effect which could be due to physiological causes[9] or to a nervous antifeeding effect on larvae[10].

At lower concentrations (2–20%) effects on various traits are less well correlated and characters seem to behave independently. For example in *D. melanogaster*, wing length and thorax length decrease from 0 to 5% $CO_2$ though dry weight increases. This negative correlation is not surprising since body size is correlated either positively or negatively with dry weight according to the cause of variation: underfeeding[11], heat[12], or genetic differences[13]. It is likely that considering other imaginal traits would reinforce this observation of partly independent responses.

Another conclusion arises from a comparison between *D. melanogaster* and *D. simulans*. The better resistance of *D. melanogaster* to $CO_2$ is to be related to its better resistance to ethanol, which is interpreted as a better adaptation to alcoholic fermentation[14]. It can be assumed that species exploiting fermenting substrates are exposed to high atmospheric $CO_2$ concentrations all through preimaginal life. Variations of resistance to $CO_2$ among *Drosophila* species, which need further genetic studies, bring new aspects to the discussion of the ecological relationships of *Drosophila* with alcoholic fermentation.




Effects of increasing $CO_2$ concentrations (solid line) upon development of *Drosophila melanogaster* (m) and *D. simulans* (s). Dotted line: effects of enrichment with 0, 10% and 20% nitrogen on development of *D. melanogaster*. *A* Egg-to-adult viability; *B* duration of development (mean of sexes); *C* wing length of males (1/100 mm); *D* thorax length of males (1/100 mm); *E* dry weight of males (1/100 mg).

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2 Brun, G., and Plus, N., in: The Genetics and Biology of *Drosophila*, vol. 2. Eds M. Ashburner and T.R.F. Wright. Academic Press, New York 1978.
3 Matheson, A.C., and Parsons, P.A., Theor. appl. Genet. *43* (1973) 261.
4 David, J., and Huot, L., Can. J. Zool. *51* (1973) 811.
5 Sillans, D., Doctoral Thesis, No. 7828, Lyon 1978.
6 David, J., and Clavel, M.F., Bull. biol. Fr. Belg. *99* (1965) 369.
7 Philipott, D.E., Bensch, K.G., and Miquel, J., Aerospace Med. *45* (1974) 283.
8 Palos, L.A., and Blasko, G.Y., Aviat. Space envir. Med. *50* (1972) 411.
9 Woodring, J.P., Clifford, C.V., Roe, R.M., and Beckman, B.R., J. Insect Physiol. *24* (1978) 499.
10 Soderstrom, E.L., and Brandl, D.G., J. econ. Ent. *75* (1982) 704.
11 David, J., Fouillet, P., and Van Herrewege, J., Ann. Soc. Ent. Fr. *6* (1970) 367.
12 David, J., and Clavel, M.F., J. Insect Physiol. *13* (1967) 717.
13 David, J.R., Cohet, Y., Fouillet, P., and Arens, M.F., Egyptian J. Genet. Cytol. *9* (1980) 51.
14 David, J.R., and Van Herrewege, J., Comp. Biochem. Physiol. *74* (1983) 283.

0014-4754/84/060566-02$1.50 + 0.20/0