Variants and Anomalies in Man, 32 interstitial deletions are known\(^1\) and Kucera and Polivkova\(^4\) found three cases with del(5)(q15q23), (q21q23), and (q15q22). The segment of the chromosome 5 that was lost in these three cases was different from the one in our patient. The clinical abnormalities of the patient of Pescia et al\(^3\) also differed from those of our patient.

Studies attempting to map genes on the fragment which was lost in our patient were inconclusive.

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**References**


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**Neurological and neuropathological findings in ring chromosome 4**

**SUMMARY** Despite the fact that mental retardation, microcephaly, seizures, and hyperactivity are common in patients with ring chromosome 4, little has been written about the underlying neuropathology. We describe a 6-year-old girl whose neuropathological findings included low brain weight, abnormal gyral development, and heterotopic neurons. The significance of these findings in regard to other retardation syndromes is discussed.

Microcephaly, mental retardation, seizures, and hyperactivity are frequently present in patients with

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FIG I
evaluation for malrotation of both also graphs she Although felt to grasp visual attention the midline. In addition, the Motor evaluation revealed normal distal neck, high arched palate, and micrognathia. In addition, she had short digits, medial deviation of the distal phalanx of the second toes, dislocated hips, and a deep sacral dimple. Chromosomal analysis showed a ring chromosome 4 (fig 1).

On neurological examination at 6 months of age, the child could not sit independently or roll over. Although she was extremely quiet, she had good visual attention and social smile. She followed past the midline. Oral secretions were handled poorly. Motor evaluation revealed normal tone and crude pincer grasp and transfer. At 18 months of age, evaluation for persistent vomiting confirmed a malrotation of both small and large bowel. Radiographs also showed spina bifida occulta.

Her subsequent neurological development was felt to be slow and at the age of 6 she functioned at the level of a 4-year-old child. She underwent tonsillectomy at the age of 6, but died of post-operative complications.

NEUROPATHOLOGICAL FINDINGS
The fresh brain was brachymicrocephalic, diffusely swollen, and weighed 800 g (normal, 1200 g). The gyral pattern was simplified and the left superior and middle frontal gyri were quite broad. The right superior temporal gyrus was poorly formed and did not fully extend posteriorly (fig 2). The temporal-occipital gyri were also poorly developed. A deep sulcus was present in the inferior right occipital lobe. The spinal cord, brainstem, and cerebellum appeared normal.

Multiple microscopical sections were stained with luxol fast blue, haematoxylin and eosin, and cresyl violet. A normally laminated six layer cortex was present. There appeared to be many heterotopic neurons in the white matter, most prominent at the crowns of the gyri (fig 3). The border between grey and white matter appeared indistinct. The neurons seemed sparse at the depths of the sulci. In the cerebellum, the Purkinje cells were indistinct in distribution. Sections of the brainstem and spinal cord were normal.

Discussion
Although exceptional cases of normal intellectual functioning have been reported, the majority of children with ring chromosome 4 are mentally retarded to a variable degree (table). Other evidence of neurological involvement includes seizures, epilepsy, perform electroencephalograms, and hyperactivity. Microcephaly is consistently found in patients with ring chromosome 4. While not of the extreme degree
TABLE Neurological and neuropathological findings in ring chromosome 4

<table>
<thead>
<tr>
<th>Reference</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Head/skull</th>
<th>Seizures</th>
<th>Mental function</th>
<th>Neurpathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bofinger (Am J Dis Child 1973;125:135)</td>
<td>Infant</td>
<td>M</td>
<td>Dolichocephaly</td>
<td>30 cm</td>
<td></td>
<td>No external abnormalities seen</td>
</tr>
<tr>
<td>Carter (J Med Genet 1969;6:224)</td>
<td>Infant</td>
<td>M</td>
<td>Brachycephaly</td>
<td>30 cm</td>
<td></td>
<td>Brain 296 g, poor fissuring, poor neuronal differentiation</td>
</tr>
<tr>
<td>Faed (J Med Genet 1969;6:432)</td>
<td>Infant</td>
<td>M</td>
<td>Abnormal skull</td>
<td>3rd centile</td>
<td>Abnormal IQ 35</td>
<td>Hyperactive, mentally retarded</td>
</tr>
<tr>
<td>Pathak (Ann Hum Genet 1972;35:471)</td>
<td>1</td>
<td>M</td>
<td>46 cm</td>
<td></td>
<td></td>
<td>IQ 35</td>
</tr>
<tr>
<td>Hecht (Birth Defects 1969;5:106)</td>
<td>1</td>
<td>M</td>
<td>3rd centile</td>
<td></td>
<td></td>
<td>IQ 35</td>
</tr>
<tr>
<td>Bernstein (J Med Genet 1978;18:510)</td>
<td>3</td>
<td>M</td>
<td>40 cm</td>
<td></td>
<td></td>
<td>IQ 35</td>
</tr>
<tr>
<td>Bobrow (J Med Genet 1971;8:235)</td>
<td>4</td>
<td>M</td>
<td>43 cm</td>
<td></td>
<td></td>
<td>IQ 35</td>
</tr>
<tr>
<td>McDermott (J Med Genet 1977;14:228)</td>
<td>4</td>
<td>M</td>
<td>50 cm</td>
<td></td>
<td></td>
<td>IQ 35</td>
</tr>
<tr>
<td>Surana (J Med Genet 1971;8:517)</td>
<td>5</td>
<td>F</td>
<td>31 cm (at birth)</td>
<td></td>
<td></td>
<td>Mild-moderate retardation</td>
</tr>
<tr>
<td>Present case</td>
<td>6</td>
<td>F</td>
<td>31 cm (at birth)</td>
<td></td>
<td></td>
<td>Mild-moderate retardation</td>
</tr>
<tr>
<td>Fraisse (Ann Genet Paris 1977;20:101)</td>
<td>8</td>
<td>M</td>
<td>42 cm</td>
<td></td>
<td></td>
<td>Moderate retardation</td>
</tr>
<tr>
<td>Parker (Am J Dis Child 1974;128:371)</td>
<td>9</td>
<td>F</td>
<td>41 cm</td>
<td></td>
<td></td>
<td>IQ 27, hyperactive</td>
</tr>
<tr>
<td>Niss (Humangenetik 1975;28:9)</td>
<td>12</td>
<td>M</td>
<td>48 cm</td>
<td></td>
<td></td>
<td>IQ 40</td>
</tr>
<tr>
<td>Dallaire (Birth Defects 1969;5:114)</td>
<td>16</td>
<td>F</td>
<td>32 cm</td>
<td></td>
<td></td>
<td>IQ 100</td>
</tr>
</tbody>
</table>

It is important to interpret both microscopical and macroscopic findings cautiously. The brachycephaly and poor superior temporal gyral development seen in our patient are non-specific and may be present in 50% of patients with Down syndrome. Microscopical findings may similarly be non-specific or artefactual as a result of tangential sectioning. Heterotopic neurons have been reported in association with mental retardation syndromes as diverse as myotonic dystrophy or lissencephaly. It is impossible at present to correlate the degree of neurological involvement and the amount of chromosomal deletion. McDermott's patient had no more than the telomeres deleted, yet had an intelligence quotient of 50. In contrast, Surana's patient

FIG 3 A cluster of heterotopic neurons (arrow) can be seen within the white matter. (Cresyl violet, original magnification, × 160.)
had a short arm deletion, yet had normal intelligence (table). Finally, most patients with ring chromosomes are mosaics and may have a variety of ring shapes with differing amounts of chromatin. Patients may show an increase in the number of ring forms with advancing age.1

In summary, neurological and neuropathological abnormalities are frequently present in patients with ring chromosome 4. Because these abnormalities are non-specific, the mechanism of the mental deficiency will require further study.

We are grateful for the advice of Dr Lewis B Holmes. The patient's chromosomes were studied in the laboratory of Dr Leonard Atkins.

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References

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Corrections
On page 336 of the paper 'Medical genetics in China' by Bodmer and Clarke (JMG 1979;16:330-7), the Medical College in Cheng Chow should read Hunan Medical College, Changsha.

On page 310 of the paper 'Pericentric inversion (13) with two different recombinants in the same family' by Williamson et al (JMG 1980;17:309-12), the chromosomes in fig 3 were inadvertently printed upside down.