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CHROMOSOME HETEROMORPHISMS IN THE JAPANESE
日本人における染色体の異形性

III. FREQUENCY OF C-BAND VARIANTS
III. C-バンド変異体の出現頻度

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SUMMARY
The type and frequency of chromosome variants detected by the C-staining method were ascertained in 1,857 individuals residing in Hiroshima. The most frequent heteromorphic variant was the total inversion of the C-band in chromosome 9 found in 27 individuals (1.45%). The total inversion of the C-band in chromosome 1 was not seen in this sample, but the partial inversion of the C-band in chromosome 1 was found in 18 persons (0.97%). Partial inversion was also detected in the C-band in chromosome 9 in 22 individuals (1.18%). In chromosome 16, neither total nor partial inversion of the C-band was observed in the present study. The frequencies of chromosomes 1, 9, and 16 with a very large C-band were 0.70%, 0.22%, and 0.54%, respectively. Aside from these (1, 9, & 16) a very large C-band was found occasionally in chromosomes 4, 5, 6, 11, 12, 14, and 15, and an unusual insertion of the Y chromosome was observed. A total of 128 C-band variants (6.89%) was found in the 1,857 Hiroshima residents.

INTRODUCTION
Recently developed chromosome banding techniques offer a new approach to the identification of human chromosome heteromorphisms. Some chromosome variants have been found to occur at a relatively high frequency in human populations. The C-staining method has proved quite useful for identifying variation in size and position of constitutive heterochromatin (C-band)

要 約
広島に在住する1,857人についてC-染色法を用いて変異染色体の種類と出現頻度を調べた．最も多く出現した変異染色体は9染色体のC-バンド逆位で，27例(1.45%)にみられた．1染色体にはC-バンド逆位はみられなかったが，C-バンドの部分逆位が18例(0.97%)に見いだされた．C-バンドの部分逆位は9染色体にもあり，22例(1.18%)にみられた．16染色体のC-バンドには全逆位及び部分逆位のいずれも認められなかった．非常に大きなC-バンドをもつ1，9，16染色体の出現頻度はそれぞれ0.70%，0.22%，0,54%であった．1，9，16染色体以外に，4，5，6，11，12，14，15染色体にも時折非常に大きなC-バンドをもつものがあり，更にY染色体の特異的な挿入が1例あった．全体として，1,857人の広島在住者に128例(6.89%)のC-バンド変異体が見いだされた．

緒 言
近年開発された染色体分染法は，ヒト染色体の異形性を確認する上で一つの新しい手掛かりとなっている．異形染色体のあるものはヒト集団に比較的高い頻度で見いだされることが確かめられている．着糸点部位における構成的異質染色質(C-バンド)の大きさ

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at the centromeric region. Considerable information about the frequency of C-band variants among various human populations has accumulated,[1-5] and some C-band variants showed significantly different frequencies in different human races.[6-8] The present report describes the type and frequency of chromosome variants detected by the C-staining method among 1,857 individuals residing in Hiroshima.

MATERIALS AND METHODS

The subjects studied were selected from participants in the RERF Adult Health Study (AHS) and the F_1 Mortality Study (F_1) samples in Hiroshima. The former comprises atomic bomb survivors and controls matched by sex and age, and the latter consists of the children born to the exposed parents and controls. The characteristics of these cohorts have been described elsewhere.[9,10] In the AHS sample, 700 blood specimens were prepared for the present study between 29 May 1973 and 27 April 1976 (culture H2801-H3500), of which C-band analysis was impossible for 119 cases, and 77 were duplicate samples (repeat examination). Thus, a total of 504 individuals (225 male and 279 female) were successfully studied for C-band analysis. In the F_1 sample 1,434 individuals examined between 6 June 1973 and 4 February 1977 were included in the present study (culture FH2001-FH3500, excluding 66 ineligible cases), and failure in C-band analysis was encountered in 81 cases, making a total of 1,353 successful cases (612 male and 741 female).

Chromosome preparations were made from whole blood cultures by the routine air-dry method and treated with the C-staining method of Sumner.[11] In each case, three to five metaphases were photographed and analyzed karyotypically, though four metaphases were examined in the majority of cases. For all variants detected by the C-staining method, the identification of variant chromosomes was confirmed by sequential staining of the same metaphase in combination with the Q- and C-staining methods. The Q-banding patterns in the chromosomes were derived from a slightly modified technique of Caspersson et al.[12]

RESULTS

Structural Rearrangements of the C-band

Usually, the C-band of chromosomes 1, 9, and 16

及び位置の変異を識別するには，C-分染法が極めて有用であることが立証されている．種々のヒト集団におけるC-バンド変異体の頻度に関する報告は年々増加しており，[1-5] C-バンド変異体のあるものは，その出現頻度が人種によって有意に異なることが認められている．[6-8] 本報告では，広島に在住する1,857人の対象者について，C-分染法によって識別された変異染色体の種類及び頻度について述べる．

材料及び方法

調査対象者は，広島放影研成人健康調査（AHS）及びF_1死亡調査（F_1）の集団から選択された．前者は原爆被爆者と，性別及び年齢別に組み合わせをした対照者とからなり，後者は被爆者の子供とその対照者である．これらの集団の特性については既にほかに記述されている．[9,10] AHS集団では，1973年5月29日から1976年4月27日まで（培養番号 H2801～H3500）の700例の血液標本について，今回調査したが，そのうち，119例はC-バンド分析が不可能であった．また，77例については二回にわたって検査を行った（反復調査）．したがって，合計504例（男性225例，女性279例）についてC-バンド分析が可能であった．F_1集団では，1973年6月6日から1977年2月4日までに調査した1,434例（培養番号 FH 2001～FH3500で，非該当のため培養番号のない66件は除く）を調査したが，81例がC-バンド分析が不可能であったため成功例数は合計1,353例（男性612例，女性741例）であった．

通常の空気乾燥法を用いて，全血培養により染色体標本を作成し，Sumner[11] のC-分染法に基づいて標本を処理した．各例ごとに，3～5個の中期分裂像を撮影し，核型分析を行ったが，大多数は4個の分裂像を対象とした．C-分染法によって見いだしたすべての変異体については，Q-及びC-分染法の併用による連続染色法に従って変異染色体の確認を行った．Q-分染パターンについては，若干の改変を加えたCaspersson ら[12] の方法を用いた．

結　果

C-バンドの構造再配列

1，9及び16染色体のC-バンドは，通常長腕の基部

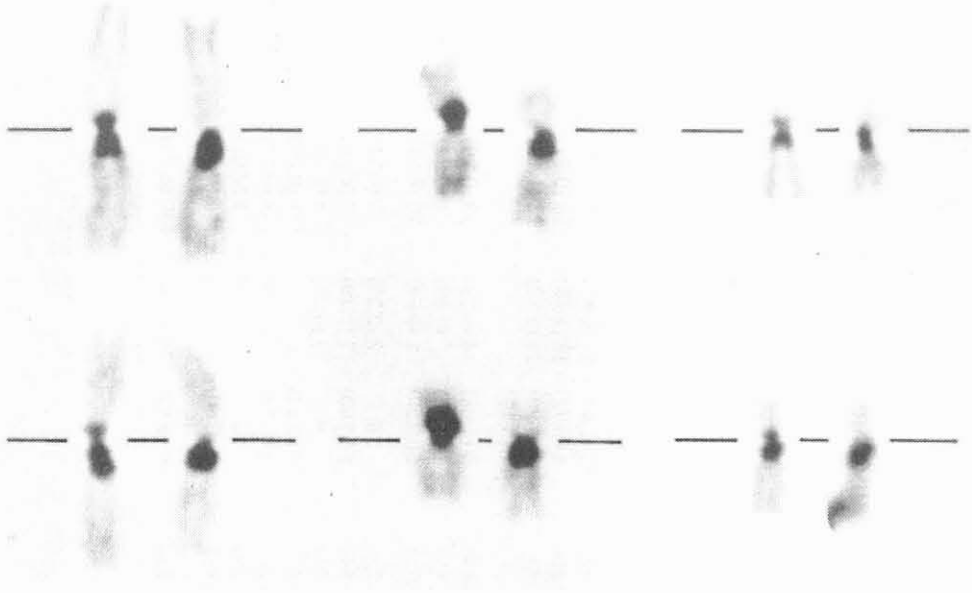

Figure 1. Two representative cases of variant chromosomes with partial inversion in chromosome 1 (left), total inversion in chromosome 9 (center), and partial inversion in chromosome 9 (right). The first of each pair is the variant chromosome.

図1　1染色体(左)の部分逆位，9染色体(中)の全逆位，及び9染色体(右)の部分逆位を示す変異染色体の代表的2例．各対の最初は変異染色体を示す．

can be seen at the proximal region of the long arm. However, all or part of the C-band appears occasionally on the short arm. When all the C-band material was on the short arm, it was recorded as a total inversion with respect to the C-band, and a partial inversion if a portion of the C-band was on the short arm (Figure 1).

The frequencies of total and partial inversions in chromosomes 1 and 9 found in the AHS and F_1 samples are shown in Table 1. No inversion was observed in chromosome 16. Total inversion in chromosome 9 was found in 7 (1.39%) individuals in the AHS sample and 20 (1.48%) in the F_1 sample, a total of 27 (1.45%) in the 1,857 Hiroshima residents. No difference was noted in the frequency of total inversion in chromosome 9 between males and females (Table 1).

The total inversion of the C-band in chromosome 1 was not seen in either sample. However, partial inversions of the C-band in chromosome 1 were found in both samples with almost identical frequency; 0.99% in the AHS and 0.96% in the F_1. Partial inversions were also detected in chromosome 9 with a slightly higher frequency in the

に位置している．しかし，ときにはC-バンドの全部又は一部が短腕に見られることがある．C-バンドのすべてが短腕上に位置した場合は，C-バンドの全逆位とし，またC-バンドの一部が短腕上にみられた場合は，部分逆位とした(図1)．

AHS集団及びF_1集団に認められた1及び9染色体におけるC-バンドの全逆位及び部分逆位の頻度を表1に示す．16染色体では逆位は認められなかった．広島在住の1,857人中，9染色体の全逆位は，AHS集団では7例(1.39%)，F_1集団では20例(1.48%)，合計27例(1.45%)であった．9染色体の全逆位の頻度には，男女差はみられなかった(表1)．

1染色体におけるC-バンドの全逆位は，いずれの集団にもみられなかったが，部分逆位は，両集団ともに認められ，その頻度はAHS集団では0.99%，F_1集団では0.96%と，ほぼ同じ値を示した．9染色体には部分逆位も認められ，その頻度はF_1集団(1.33%)

TABLE 1 NUMBER AND FREQUENCY (%) OF C-BAND VARIANTS IN THE HIROSHIMA AHS AND F_1 SAMPLES

表1　広島成人健康調査集団及びF_1集団におけるC-バンド変異体の数及び頻度(%)

Variant	AHS			F_1			Total		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Cases	225	279	504	612	741	1353	837	1020	1857
Total inv (9)	4 (1.78)	3 (1.08)	7 (1.39)	8 (1.31)	12 (1.62)	20 (1.48)	12 (1.43)	15 (1.47)	27 (1.45)
Partial inv (1)	2 (0.89)	3 (1.08)	5 (0.99)	4 (0.65)	9 (1.21)	13 (0.96)	6 (0.72)	12 (1.18)	18 (0.97)
Partial inv (9)	3 (1.33)	1 (0.36)	4 (0.79)	5 (0.82)	13 (1.75)	18 (1.33)	8 (0.96)	14 (1.37)	22 (1.18)
Insertion (Y)	1 (0.44)	-	-	0	-	-	1 (0.12)	-	-
1qh+	5 (2.22)	2 (0.72)	7 (1.39)	4 (0.65)	2 (0.27)	6 (0.44)	9 (1.08)	4 (0.39)	13 (0.70)
9qh+	1 (0.44)	1 (0.36)	2 (0.40)	0	2 (0.27)	2 (0.15)	1 (0.12)	3 (0.29)	4 (0.22)
16qh+	2 (0.89)	1 (0.36)	3 (0.60)	3 (0.49)	4 (0.54)	7 (0.52)	5 (0.60)	5 (0.49)	10 (0.54)
4qh+	0	1 (0.36)	1 (0.20)	0	1 (0.13)	1 (0.07)	0	2 (0.20)	2 (0.11)
5ph+	1 (0.44)	0	1 (0.20)	4 (0.65)	2 (0.27)	6 (0.44)	5 (0.60)	2 (0.20)	7 (0.38)
6ph+	0	2 (0.72)	2 (0.40)	0	1 (0.13)	1 (0.07)	0	3 (0.29)	3 (0.16)
11ph+	0	0	0	1 (0.16)	0	1 (0.07)	1 (0.12)	0	1 (0.05)
12ph+	0	2 (0.72)	2 (0.40)	3 (0.49)	0	3 (0.22)	3 (0.36)	2 (0.20)	5 (0.27)
14ph+	0	0	0	0	1 (0.13)	1 (0.07)	0	1 (0.10)	1 (0.05)
15ph+	1 (0.44)	2 (0.72)	3 (0.60)	4 (0.65)	7 (0.94)	11 (0.81)	5 (0.60)	9 (0.88)	14 (0.75)
Total	20 (8.89)	18 (6.45)	38 (7.54)	36 (5.88)	54 (7.29)	90 (6.65)	56 (6.69)	72 (7.06)	128 (6.89)

F_1 sample (1.33%) than in the AHS (0.79%), though the difference is not statistically significant. A slight difference was also seen in the frequency of partial inversions in chromosomes 1 and 9 between males and females (Table 1), again with no statistical significance.

In the AHS sample, an unusual insertion of the Y chromosome was observed in a phenotypically normal male; a darkly stained C-band was located on the short arm and the proximal region of the long arm. By the conventional staining method, however, no specific morphological abnormality was detected. A detailed description of this insertion has been reported elsewhere.[13] So far, this type of aberration was found in only one individual (0.44%) out of 225 males of the AHS sample, and there was no such case in 612 males in the F_1 sample. The frequency of this insertion of the Y chromosome was 0.12% in the 837 males examined in the present study.

Size Variation of the C-band

The size variation of the C-band appeared to be a continuum, from very small to very large. Thus any division into discrete units is arbitrary. In the present report, only chromosomes with a very large C-band were scored as variant chromosomes.

Frequency of 1qh+, 9qh+, and 16qh+ (Figure 2). The frequencies of chromosomes 1, 9, and 16 with very large C-bands (referred to in the present study as 1qh+, 9qh+, and 16qh+) are shown in Table 1. Differences in the frequency of 1qh+ were found between the samples and between sexes; a higher frequency in the AHS (1.39%) than in the F_1 (0.44%), and a higher frequency in males (1.08%) than in females (0.39%). AHS males showed the highest frequency (2.22%), while the frequency in F_1 females was the lowest (0.27%). A total of 13 cases (0.70%) with 1qh+ was found in the 1,857 Hiroshima residents.

The frequency of 9qh+ was lower than that of 1qh+ and only four cases (0.22%) were found. A slightly higher frequency was seen in the AHS sample (0.40%) than in the F_1 sample (0.15%), and it was higher in females (0.29%) than in males (0.12%). However, the differences are not statistically significant.

The frequency of 16qh+ cases showing an intermediate value between 1qh+ and 9qh+ was

の方がAHS集団(0.79%)よりもやや高かったが，その差は統計的に有意ではなかった．1染色体と9染色体の部分逆位の頻度には，男女間でわずかな差が認められたが(表1)，これにも統計的有意差は認められなかった．

AHS集団では，正常表現型の男性1例のY染色体に特異的な挿入が認められた．短腕部及び長腕基部に濃染のC-バンドがみられたが，通常染色法では，形態学的異常は認められなかった．この挿入に関する詳細は，既に報告されている.[13] この異常は，AHS集団では男性225例中，わずか1例(0.44%)のみに認められ，F_1集団の男性612例中にはこの異常はみられなかった．このY染色体の挿入の頻度は，本調査の男性837例中，0.12%であった．

C-バンドの大きさの変異

C-バンドの大きさは，非常に小さいものから非常に大きいものまで連続的に変異している．したがって，その分類基準は任意なものとなる．本報では，非常に大きなC-バンドをもつ染色体のみを変異染色体とした．

1qh+，9qh+及び16qh+の頻度(図2)

非常に大きなC-バンドをもつ1，9，16染色体(1qh+，9qh+，及び16qh+と表す)の頻度を表1に示す．1qh+の頻度には両集団間並びに男女間に差が認められた．すなわち，AHS集団(1.39%)の頻度はF_1集団(0.44%)より高く，また男性(1.08%)の頻度は女性(0.39%)よりも高かった．AHS集団の男性の頻度は最も高く(2.22%)，F_1集団の女性は逆に最も低い頻度(0.27%)を示した．1qh+は広島在住の1,857人中，13例(0.70%)にみられた．

9qh+の頻度は1qh+の頻度よりも低く，わずか4例(0.22%)に認められたにすぎない．AHS集団の頻度(0.40%)はF_1集団(0.15%)よりもやや高く，女性(0.29%)が男性(0.12%)よりも高かったが，これらの差は統計的に有意ではなかった．

16qh+の頻度は，1qh+と9qh+との中間値を示す

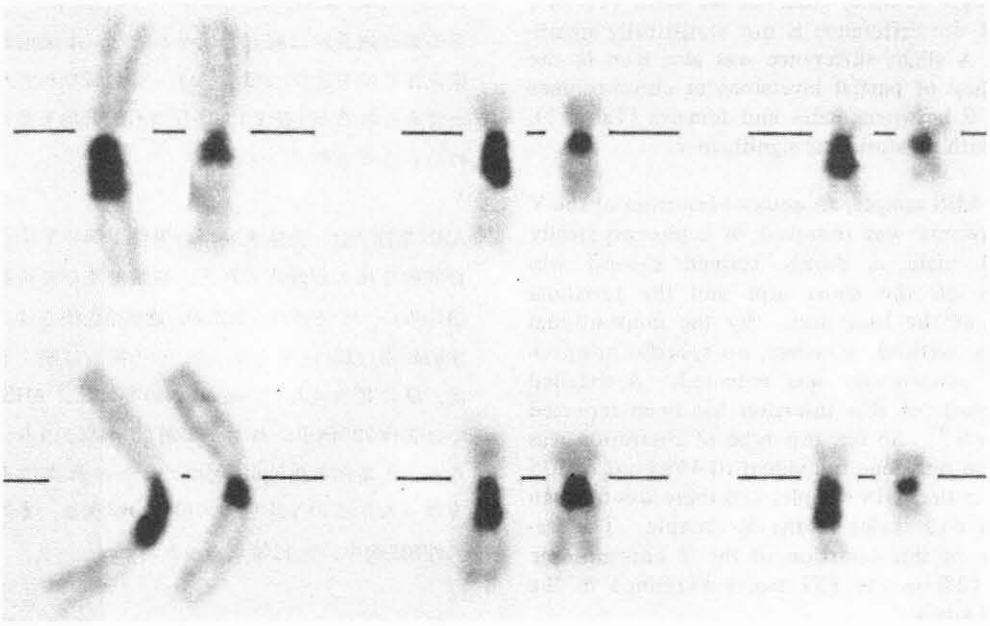

Figure 2. Two representative cases of variant chromosomes with 1qh+ (left), 9qh+ (center), and 16qh+ (right). The first of each pair is the variant chromosome.

図2　1qh＋(左)，9qh＋(中)，16qh＋(右)を示す変異染色体の代表的2例．各対の最初は変異染色体を示す．

0.54% (10/1857). No difference was observed in the frequency of 16qh+ between the samples or sexes; 0.60% in the AHS and 0.52% in the F_1, and 0.60% in males and 0.49% in females.

Frequency of Chromosomes with Very Large C-band Other Than 1qh+, 9qh+, and 16qh+. Aside from chromosomes 1, 9, and 16, very large C-bands were found occasionally in seven autosomes (4, 5, 6, 11, 12, 14, & 15). In these chromosomes, the C-band was located at the proximal region of the short arm, except for chromosome 4 in which the C-band was situated on the proximal region of the long arm. They were referred to as 4qh+, 5ph+, 6ph+, 11ph+, 12ph+, 14ph+, and 15ph+.

The frequency of 15ph+ was almost similar to that of 1qh+, 14 (0.75%) out of 1,857 with no significant differences between the samples or sexes (Figure 3 & Table 1). Six cases (0.44%) with 5ph+ were found among 1,353 F_1 individuals, while only one case (0.20%) was observed among 504 AHS cases (Figure 3 & Table 1).

A 12ph+ was seen in two AHS females and in three F_1 males, while three females (two AHS,

0.54％(10/1857)であった．16qh＋の頻度については，集団間又は男女間の差は認められなかった．すなわち，AHS集団で0.60％，F_1集団で0.52％であり，男性は0.60％，女性は0.49％であった．

1qh＋，9qh＋，16qh＋以外の非常に大きなC-バンドをもつ染色体の頻度

1，9，16染色体以外では，7個の常染色体(4，5，6，11，12，14及び15)において時折非常に大きなC-バンドが認められた．長腕基部に位置する4染色体を除外すれば，C-バンドは短腕基部に認められた．これらを，4qh＋，5ph＋，6ph＋，11ph＋，12ph＋，14ph＋及び15ph＋と表す．

15ph＋の頻度は，1qh＋の頻度とほぼ等しく，1,857人中の14例(0.75％)にみられ，集団間及び男女間に有意差は認められなかった(図3及び表1)．5ph＋は，$F_1$1,353例中に6例(0.44％)，AHS集団では504例中わずか1例(0.20％)にすぎなかった(図3及び表1)．

12ph＋はAHSの女性2例及びF_1の男性3例にみら

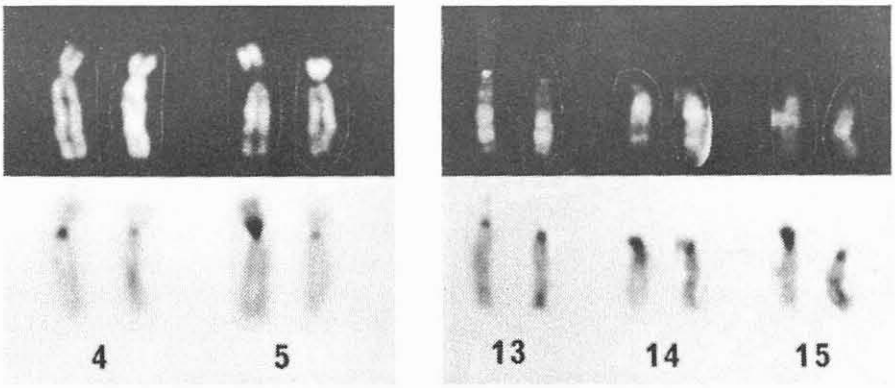

Figure 3. Partial karyotypes of B chromosomes from a case with 5ph+ (left) and of D chromosomes from a case with 15ph+ (right), prepared by successive staining of the same metaphase by Q- (upper row) and C- (lower row) staining methods. The first of each pair of chromosomes 5 and 15 is the variant chromosome.

図3　5ph＋(左)のB染色体及び15ph＋(右)のD染色体の部分核型で，Q-(上段)及びC-(下段)分染法による同一中期分裂像の連続染色に基づいて作成したもの．5及び15染色体の各対の最初は変異染色体を示す．

one F_1) were found to have the 6ph+ variant (Table 1). Detailed banding patterns of 6ph+ and 12ph+ have been described elsewhere.[14] In only two females 4qh+ (Figure 4) was observed (one each from both samples); and a male with 11ph+ (Figure 5) and a female with 14ph+ were found in the F_1 sample.

The frequency of major C-band variants in the F_1 sample was examined with respect to their parental A-bomb exposure. Subjects in the exposed group were born to either one or both parents with an estimate radiation dose of 1 rad or more. The parents of the controls were either non-exposed or received a dose of less than 1 rad. There was no significant difference between the control and exposed groups in the frequency of major C-band variants or of all types of variants (Table 2). In a comparison among the exposed groups (father exposed, mother exposed, and both parents exposed) there was also no significant difference in the frequency of C-band variants.

Identical C-band variants were found in four pairs of brothers and/or sisters in the F_1 sample;

れたが，6ph＋は女性3例(AHS 2例，F_1 1例)に認められた(表1)．この6ph＋と12ph＋の分染パターンの詳細は，別に報告されている．[14] 4qh＋(図4)は，女性2例(両集団に各1例)にしか認められなかった．また，F_1集団では，11ph＋(図5)をもつ男性と14ph＋をもつ女性とが1例ずつ認められた．

F_1集団における主なC-バンド変異体の頻度については，その親の原爆被爆状況に基づいて検討した．被爆群は，両親の一方又は双方の推定被曝線量が1 rad以上であり，対照者では両親が非被爆者か又は1 rad未満の推定線量の被爆者である．主なC-バンド変異体及びすべての種類の変異体の頻度には，対照群と被爆群との間に有意な差はなかった(表2)．父親被爆，母親被爆及び両親が被爆した場合の各被爆群間においても，C-バンド変異体頻度に有意な差はみられなかった．

F_1集団のうち，4組の兄弟あるいは姉妹に，同じC-バンド変異体が認められた．すなわち，9染色体

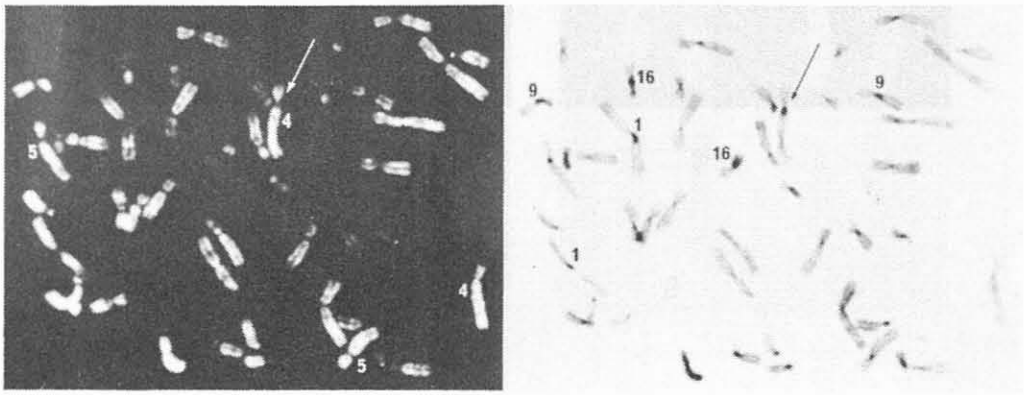

Figure 4. Representative metaphases obtained from a case with 4qh+, prepared by successive staining of the same metaphase by Q- (left) and C- (right) staining methods. Arrows indicate the variant chromosome.

図4　4 qh＋例から得た代表的な中期分裂像で，Q-（左）及びC-（右）分染法による同一中期分裂像の連続染色に基づいて作成したもの．矢印は変異染色体を示す．

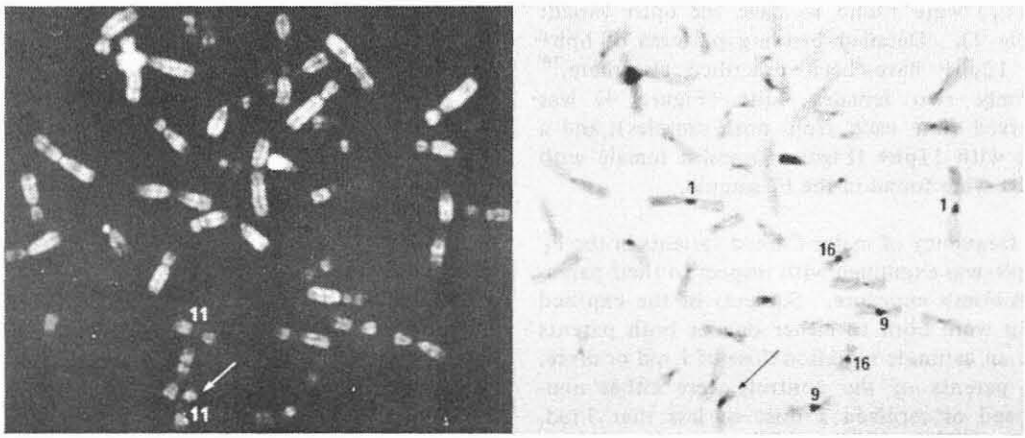

Figure 5. Representative metaphases obtained from a case with 11ph+, prepared by successive staining of the same metaphase by Q- (left) and C- (right) staining methods. Arrows indicate the variant chromosome.

図5　11ph＋例から得た代表的中期分裂像で，Q-（左）及びC-（右）分染法による同一中期分裂像の連続染色に基づいて作成したもの．矢印は変異染色体を示す．

TABLE 2 NUMBER AND FREQUENCY (%) OF C-BAND VARIANTS IN THE F_1 SAMPLE BY PARENTAL EXPOSURE STATUS

表2　F_1集団におけるC-バンド変異体の数及び頻度(%)，両親の被爆状況別

Variant	Control	Parental exposure status*			
		Father	Mother	Both	Total
Cases	445	238	481	186	905
Total inv (9)	8 (1.80)	2 (0.84)	7 (1.46)	3 (1.61)	12 (1.33)
Partial inv (1)	3 (0.67)	2 (0.84)	6 (1.25)	2 (1.08)	10 (1.10)
Partial inv (9)	7 (1.57)	3 (1.26)	7 (1.46)	1 (0.54)	11 (1.22)
1qh+	2 (0.45)	1 (0.42)	1 (0.21)	2 (1.08)	4 (0.44)
16qh+	2 (0.45)	3 (1.26)	0	2 (1.08)	5 (0.55)
5ph+	2 (0.45)	3 (1.26)	1 (0.21)	0	4 (0.44)
15ph+	3 (0.67)	4 (1.68)	4 (0.83)	0	8 (0.88)
Other**	1 (0.22)	0	6 (1.25)	2 (1.08)	8 (0.88)
Total	28 (6.29)	18 (7.56)	32 (6.65)	12 (6.45)	62 (6.85)

*Excludes 3 cases with parental dose unknown.
両親の線量が不明である3例は除く．

**Includes 4qh+, 6ph+, 9qh+, 11ph+, 12ph+, & 14ph+.
4qh＋，6ph＋，9qh＋，11ph＋，12ph＋及び14ph＋を含む．

one each of a total inversion in chromosome 9 in a brother and a sister, partial inversion in chromosome 9 in two brothers, 12ph+ in two brothers, and 16qh+ in two sisters. All other variants found in the F_1 as well as the AHS sample were in unrelated individuals.

There were 6 individuals with two variant chromosomes; 2 cases in the AHS sample (total inversion of chromosome 9 & 16qh+; 12ph+ & 15ph+) and 4 in the F_1 sample (1qh+ & 16qh+; total inversion in chromosome 9 & 16qh+; partial inversions in chromosomes 1 & 9; 4qh+ & partial inversion in chromosome 9).

In 36 cases with C-band variants from the AHS sample, no physical or phenotypic abnormalities were observed in the clinical examinations at RERF. No clinical examination was performed for the F_1 children unless requested. However, in none of the 86 individuals with chromosome variants was an obviously unusual phenotype noted by trained nurses during a questionnaire interview dealing with the family and health history.

Since family studies have not yet been performed, there is no evidence to indicate whether the

の全逆位が男女各1人の同胞に，9染色体の部分逆位が男性の同胞2人に，12ph＋が男性の同胞2人に，そして16qh＋が女性の同胞2人にそれぞれ認められた．F_1集団並びにAHS集団に認められたその他のすべての変異体には，血縁関係は認められなかった．

二つの変異染色体を併せもつ者は6例あった．そのうち2例（9染色体の全逆位と16qh＋，12ph＋と15ph＋）はAHS集団に，4例（1qh＋と16qh＋；9染色体の全逆位と16qh＋；1染色体と9染色体の部分逆位；4qh＋と9染色体の部分逆位）はF_1集団に見いだされた．

AHS対象者でC-バンド変異体をもつ36例は，放影研における診察によれば身体的あるいは表現型の異常は認められなかった．F_1対象者に対しては，要望がなければ診察は行わなかった．熟練した看護婦が家族や病歴に関する質問票の記録のために面接を行ったが，異常と思われる表現型は変異染色体をもつ86例には認められなかった．

家族調査はまだ行われていないので，今回認められ

variant chromosomes observed here were inherited from their parents or were produced de novo in a parental gamete during meiosis. However, it seems likely that the identical variant chromosomes observed in four pairs of brothers and/or sisters in the F_1 sample may be an indication of heritable character.

Combining all types of C-band variants described, almost identical frequency values were observed in the AHS sample (7.54%) and the F_1 sample (6.65%), and also in males (6.69%) and females (7.06%). A total of 128 C-band variants (6.89%) was found in the 1,867 Hiroshima residents (Table 1).

DISCUSSION

The most frequent heteromorphic variant identified by the C-method in the present study was the total inversion of the C-band in chromosome 9. The frequency of this type of variant in different human populations reported so far is summarized in Table 3. Before the application of new banding techniques, the frequency of the total inversion in chromosome 9 was relatively low (under 0.3%) with the exception of the high frequency seen in two studies[6,18] (Table 3). Studies using the banding techniques show considerably higher frequencies of the total inversion in chromosome 9 (1.13%-1.50%) though the number of individuals examined was small. These findings are compatible with the frequency of the total inversion in chromosome 9 observed in 27 individuals (1.45%) in the present study; 7 (1.39%) in the AHS sample and 20 (1.48%) in the F_1 sample. In the early study of Lubs and Ruddle,[6] a racial difference in the frequency of the total inversion in chromosome 9 was observed among Caucasians and Negroes. Recently, Lubs et al[7] confirmed their previous report with the observation that the frequency of the total inversion in chromosome 9 was more prominent in Negroes (1.07%) than in Caucasians (0.13%). A racial difference in the frequency of the total inversion in chromosome 9 was also observed in a Hawaiian population;[8] the incidence was significantly greater among Orientals (5/190 or 2.63%, mainly Japanese) than non-Orientals (2/326 or 0.61%). However, the present results show that the frequency of total inversion in chromosome 9 among Japanese did not diverge from that of other populations (Table 3). The significance of the different frequencies for the total inversion in chromosome 9 among Japanese in Hiroshima

た変異染色体が両親から遺伝したものか，減数分裂の過程において親の配偶子に新たに形成されたのかは明らかでない．しかし，F_1集団の4組の兄弟ないし姉妹に同じ変異染色体が認められたことから，遺伝性のもののようである．

上述のすべてのC-バンド変異体についてみると，その出現頻度はAHS集団(7.54%)とF_1集団(6.65%)においても，また男性(6.69%)と女性(7.06%)においても，ほとんど同じ値を示した．つまり，広島在住者1,867人中に，合計128(6.89%)のC-バンド変異体が認められたことになる(表1)．

考　察

本調査においてC-法で確認された染色体変異で最も多かったのは，9染色体におけるC-バンドの全逆位である．これまで報告された種々のヒト集団におけるこの変異体の頻度を表3に要約して示す．新しい分染法を応用する前までは，高い頻度が認められた二つの調査[6,18]を除くと，9染色体の全逆位の頻度は比較的低かった(0.3%未満)(表3)．分染法を用いた調査では，調査例数は少ないが，9染色体の全逆位の頻度はかなり高い(1.13～1.50%)．この所見は，本調査の9染色体の全逆位の頻度，すなわち，AHS集団では7例(1.39%)，F_1集団で20例(1.48%)，合計27例(1.45%)という結果と一致している．Lubs及びRuddle[6]による初期の調査では，白人と黒人の間で，9染色体の全逆位の頻度に人種間の差が認められた．最近，Lubsら[7]は9染色体における全逆位の頻度は，黒人(1.07%)の方が白人(0.13%)より高く，彼らの以前の報告を確認した．9染色体全逆位の頻度についての人種差はHawaiiの集団[8]にも認められ，その頻度は，東洋系人種(主として日本人)の方が(5/190すなわち2.63%)，非東洋系人種(2/326すなわち0.61%)よりも有意に高かった．しかし，本調査の結果では，日本人の9染色体における全逆位の頻度は，ほかの集団と異ならなかった(表3)．広島とHawaiiの日本人の間にみられる9染色体全逆位頻度の差の有意性について

TABLE 3 NUMBER AND FREQUENCY (%) OF C-BAND TOTAL INVERSIONS IN CHROMOSOME 9 IN HUMAN POPULATIONS

表3　ヒト集団の9染色体におけるC-バンドの全逆位の数及び頻度(%)

Staining Method	Country	Sample	Total subjects	Number	%	Reference
Ordinary	USA	Newborn	3476[1]	2	0.06	6. Lubs and Ruddle (1971)
			807[2]	10	1.24	6. Lubs and Ruddle (1971)
Ordinary	USA	Newborn	11154	20	0.18	15. Walzer and Gerald (1972)
Ordinary (G,Q)	UK	Newborn	11680	2	0.02	16. Jacobs et al (1974)
Ordinary	USSR	Newborn	2500	-	-	17. Bochkov et al (1974)
Ordinary (Q)	UK	Adult	282	8	2.84	18. Madan and Bobrow (1974)
Ordinary (G,Q)	Canada	Newborn	13939	1	0.01	19. Hamerton et al (1975)
Ordinary (G,Q,C)	Denmark	Newborn	11148	-	-	20. Nielsen and Sillesen (1975)
Q,C	UK	Adult	200	3	1.50	21. Mutton and Daker (1973)
G,Q,C	Finland	Clin. ab.	631	9	1.43	22. De la Chapelle et al (1974)
Q,C	USA	Newborn	354	4	1.13	2. Müller et al (1975)
Q,C	USA	Newborn	77	1	1.30	3. McKenzie and Lubs (1975)
Q,C	UK	Newborn	717	9	1.26	4. Buckton et al (1976)
G,Q,C	Hawaii	Ment. ret.	326[3]	2	0.61	8. Mayer et al (1978)
			190[4]	5	2.63	8. Mayer et al (1978)
C(Q)	Japan	Adult	1857	27	1.45	Present study

Parentheses indicate banding methods used for ascertainment of variants by ordinary staining method.
括弧内は，通常の染色法によって見いだされた変異体を確認するための分染法．

Caucasian,[1] Negro,[2] Non-Oriental (Caucasian, Filipino, & Polynesian),[3] Oriental (mainly Japanese, but including Chinese & Korean).[4]
白人[1]，黒人[2]，東洋人以外の人種(白人，フィリピン人，及びポリネシア人)，[3] 東洋人(主として日本人であるが，中国人，韓国人をも含む)．[4]

and Hawaii remains to be explained, but may be related to the subjects selected for study; phenotypically normal individuals were studied in Hiroshima, while mentally retarded patients were examined in Hawaii; note also the relatively small sample size of the Hawaiian study. In general, the frequency of the total inversion in chromosome 9 in human populations examined using banding techniques seems to range from 1.0% to 1.5%.

The partial inversion of the C-band in chromosomes 1 and 9 was demonstrated by the application of banding techniques, and showed a relatively higher frequency with considerable differences among various populations (Table 4). This divergence may be ascribable to the use of different scoring criteria for partial inversion in different laboratories, since identification of the partial inversion, especially in chromosome 9, is more difficult than the total inversion. However, the possibility cannot be excluded that there is an ethnic difference in the frequency of the par-

は，これから解明されなければならないが，これは選定した調査対象者と関係があるかもしれない．すなわち，広島では，表現型の正常な者を調査したが，Hawaii では，知能遅滞者を調査している．更に，後者では，調査集団が比較的小規模であったことも注目される．分染法を用いて調べたヒト集団の9染色体における全逆位の頻度は，一般的には1.0%から1.5%までの範囲にあると思われる．

1及び9染色体のC-バンドの部分逆位は，分染法の応用によって識別されたもので，比較的高い頻度を示し，各種集団の間にかなりの差異がみられる(表4)．これらの差異は部分逆位，特に9染色体の部分逆位の識別が全逆位よりも難しいために各研究室における部分逆位の判定基準の違いに帰するかもしれない．しかし，1及び9染色体のC-バンドの部分逆位の

TABLE 4 NUMBER AND FREQUENCY (%) OF C-BAND PARTIAL INVERSIONS IN CHROMOSOMES 1 AND 9 IN HUMAN POPULATIONS

表4　ヒト集団の1及び9染色体におけるC-バンドの部分逆位の数及び頻度(%)

Country	Sample	Total subjects	Chromosome 1		Chromosome 9		Reference
			Number	%	Number	%	
UK	Newborn	467	13	2.78	35	7.49	4. Buckton et al (1976)
	Child	101	1	0.99	2	1.98	
	Adult	149	5	3.36	1	0.67	
	Total	717	19	2.65	38	5.30	
USA	Caucasian	3084	14	0.45	17	0.55	7. Lubs et al (1977)
	Negro	1780	1	0.06	8	0.45	
	Total	4864	15	0.31	25	0.51	
Hawaii	Oriental*	190	2	1.05	1	0.53	8. Mayer et al (1978)
	Non-Oriental*	326	2	0.61	1	0.31	
	Total	516	4	0.78	2	0.39	
Canada	Newborn	165	3	1.82	11	6.67	23. Wang & Hamerton (1979)
	Ment. ret.*	264	9	3.41	40	15.15	
	Total	429	12	2.80	51	11.89	
Japan	AHS	504	5	0.99	4	0.79	Present study
	F_1	1353	13	0.96	18	1.33	
	Total	1857	18	0.97	22	1.18	

*Mentally retarded　知能遅滞者.

tial inversion of the C-band in chromosomes 1 and 9.

The frequency of 1qh+, 9qh+, and 16qh+ in human populations is remarkably higher in the studies using banding techniques than in those using the conventional staining method (Table 5). This difference most likely results from more accurate identification of these variants by the banding techniques. Additional factors, such as differences in scoring criteria of the variants between the conventional and banding methods, and small sample size examined by the banding techniques, may also contribute to these divergent results.

Since 1qh+, 9qh+, and 16qh+ variants are characterized by a continuum in the amount of C-band material, quantitative measurement may be necessary to obtain more accurate frequency of these variants for comparison between different populations. Recently, quantitative analyses of

頻度に人種差のある可能性も否定できない.

ヒト集団における1qh＋，9qh＋及び16qh＋の頻度は，分染法による調査の方が，通常の染色法を用いた場合よりも著しく高い(表5)．これは，変異染色体の確認が分染法によってより正確にできたためであろう．また，通常染色法と分染法における変異体の判定基準の違いや，分染法による調査集団の規模が小さいことなどの要因も，両者間の差に関与しているかもしれない.

1，9，16，染色体のC-バンドの大きさは連続的変化を示すので，各集団間の比較のために1qh＋，9qh＋及び16qh＋変異染色体のより正確な頻度を得るには，定量的測定が必要であろう．最近，幾つかの研究

TABLE 5 NUMBER AND FREQUENCY (%) OF 1qh+, 9qh+, AND 16qh+ VARIANTS IN HUMAN POPULATIONS

表5　ヒト集団における1qh＋，9qh＋，及び16qh＋の数及び頻度（%）

Staining Method	Country	Sample	Total subjects	1qh+	9qh+	16qh+	Reference
Ordinary	USA	Newborn	4283	11 (0.26)	-	103 (2.40)	6. Lubs & Ruddle (1971)
Ordinary, Q	USSR	Adult	103		6 (5.83)	2 (1.94)	24. Mikelsaar et al (1973)
Ordinary	USSR	Newborn	2500	1 (0.04)	-	4 (0.16)	17. Bochkov et al (1974)
Ordinary (G)	UK	Adult	82		9 (10.98)		18. Madan & Bobrow (1974)
Ordinary, Q,C	USSR	Adult	208	4 (1.92)*			25. Tüür et al (1974)
Ordinary (G,Q)	Canada	Newborn	13939	5 (0.04)	1 (0.01)	14 (0.10)	19. Hamerton et al (1975)
Ordinary (G,Q,C)	Denmark	Newborn	11148	6 (0.05)	4 (0.04)	10 (0.09)	20. Nielsen & Sillesen (1975)
C	USA	Adult	20	1 (5.00)	2 (10.00)	-	1. Craig-Holmes et al (1973)
Q,C	USA	Newborn	355	11 (3.10)	6 (1.70)	10 (2.82)	2. Müller et al (1975)
Q,C	USA	Newborn	77	6 (7.79)	11 (14.29)	8 (10.39)	3. McKenzie & Lubs (1975)
C (Q)	Japan	Adult	1875	13 (0.07)	4 (0.02)	10 (0.05)	Present study

Parentheses indicate banding methods used for ascertainment of variants by ordinary staining method.

括弧内は，通常の染色法によって見いだされた変異体を確認するための分染法．

* Includes one case with inversion of chromosome 1.

1染色体の逆位を有する1例を含む．

the C-band material in chromosomes 1, 9, and16 were reported from several laboratories,[26-30] and we also examined quantitatively the C-band material based on area measurement of C-bands in 93 randomly selected Hiroshima residents.[31] Preliminary results indicated that there was considerable variation in the distribution of C-band material in chromosomes 1, 9, and 16 and the patterns all approximated the normal distribution, though the mean and standard deviation for each were quite different. Detailed results of the quantitative study of these variants will be reported elsewhere.

Gosden et al[32] recently described their studies on satellite DNA in human heteromorphic chromosomes by in situ hybridization methods, and concluded that the amount of hybridization was related to the size of the C-band on chromosome 1, whereas hybridization to other chromosomes (such as 9 and 16) was not related to the C-band size, although hybridization of total satellite DNA is proportional to the C-band size.

D and G chromosome variants, which are characterized by the enlargement or deletion of short arms and/or satellites, were rather frequently observed in human populations, and banding patterns of their enlarged areas by the Q- or C-method were found to be variable from case to case.[16,24,33-35] Since only the cases with an enlarged short arm characterized by very dark staining according to the C-method were described in the present study, it is difficult at present to compare the frequency of this specific D-variant among different populations.

Our previosuly reported 6ph+ and 12ph+ cases[14] were almost identical with those reported by several other investigators,[5,8,36] and a variant chromosome similar to 11ph+ described here was also reported by Simola et al.[37] Since the reported cases thus far are limited, in these instances it is premature to attempt a comparison of the frequency of these variants among different populations.

室[26-30]から，1，9，16染色体のC-バンドの定量的解析結果が報告されており，著者らも，広島在住者93例について，C-バンドの面積測定による定量的分析を行った.[31] 予備的な結果では，1，9，16染色体のC-バンドの分布にかなりの差異がみられ，その各々の平均値及び標準偏差も異なっていたが，その分布パターンはいずれも正規分布に近似していた．これらの変異体に関する定量的分析の詳細は別に報告する．

Gosden ら[32]は，最近，in situ 雑種形成法を用いて行ったヒト異形染色体におけるサテライト DNA の調査について報告し，雑種形成量は1染色体における C-バンドの大きさと関係があり，9，16などその他の染色体における雑種形成はC-バンドの大きさとは無関係であるが，全サテライト DNA の雑種形成は C-バンドの大きさに正比例すると結論している．

短腕あるいは付随体が増大又は欠失しているD及びG染色体は，ヒト集団において比較的多く認められ，増大部のQ-又はC-法による分染パターンは，各例で異なっている.[16,24,33-35] 本調査では，C-法によって濃染される大きい短腕例のみを対象としているので，この特異的なD-変異染色体の頻度に関する各集団間の比較は現時点において困難である．

著者らが以前に報告した6ph＋及び12ph＋[14]は，ほかの研究者[5,8,36]が報告したものとほとんど同じである．本報で述べた11ph＋と同様の変異染色体は，Simola ら[37]によっても報告されている．これまでの報告例はこのように限られているので，各種集団におけるこれら変異染色体の頻度を比較することはなお時機尚早である．

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